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Super Science: Invisible natural science and visible social science are called Super Science. Positive apace, negative space, the invisible GLHUA sphere, and cloak are Super Science that will be in the next book. This book titled "Standard Space - Time Theory" by Shusheng Tan, is also Super Science.

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About the Author

Tan Shusheng, male, born in Liling City, Hunan Province, China, Professor of Dayuling Supercomputation Sciences Center, engaged in laser technology, basic theory of physics and philosophy research.

After more than 30 years of painstaking efforts, the author created Standard Space-time Theory. This is a rigorous logical system beyond Einstein's special theory of relativity, which is established by the author from the theory of Yuanqi in ancient China. Standard Space-time Theory takes the principle of the absolute reference frame and the principle of the constancy of the average circulation speed of light as the basic postulates, it allows the superluminal motion to exist without violating the law of causality, thus being compatible with the non-locality principle of quantum mechanics. Standard Space-time Theory has been highly praised by many famous scientists and scholars at home and abroad. In 2008, the monograph *From special theory of relativity to Standard Space-time Theory* was awarded the second "Three Hundred" Original Book Publishing Project Award by the State Press and Publication Administration of the People's Republic of China. In 2011, he published an English book on Standard Space-Time Theory.

In 2017, the author published the monograph *Meditation on Modern Materialist Philosophy*, which is the crystallization of the author's devotion to philosophical thinking, and is a philosophical work with creative ideas and important academic value.

Wave-Particle Mechanics is the quantum theory for complete description of microscopic systems, which is the original theoretical research achievement of the author. Wave-Particle Mechanics has given a deterministic description of single micro-system in the direction indicated by Einstein and de Broglie.

The author has founded Standard Space-time Theory and Wave-Particle Mechanics, hoping in this way to achieve the coordination and integration of space-time theory and quantum theory, so as to contribute to the breakthrough and development of modern physics.

The Brief Introduction of Content of This Book

Standard Space-time Theory is the original theoretical research result of the author of this book. It is a rigorous logical system established by the author starting from the concept of ancient Chinese Yuanqi Theory and based on the basic assumptions of the principle of absolute reference frame and the principle of the constancy of the average circuit speed of light. It allows superluminal motion to exist without violating the law of causality, so it is compatible with the principle of non-locality of quantum mechanics, and gives a unified description of subluminal and superluminal motion. It perfectly explains all the experimental results so far, including several kinds of experiments that cannot be explained by the special theory of relativity. Tan's Standard Space-time Theory is integrating and upgrading of Newton's and Einstein's concepts of space and time. Einstein's special theory of relativity is an approximation of Standard Space-time Theory in certain circumstances.

This book examines the cognitive history of Chinese and Western views of nature and views of space-time from ancient times to the present, the essence of space and time, the difficulties and challenges faced by the special theory of relativity, and shows a long historical picture of human exploration of the nature of space-time. This book gives the most systematic and complete exposition so far of the ideological origins, physical and mathematical structures of Standard Space-time Theory.

This book has clear physical concepts, rigorous logical analysis, detailed mathematical derivation and accurate and fluent language. This book is suitable for undergraduate and graduate students of related liberal arts and science as a teaching reference book, as well as for physicists and interested readers to learn and read.

Summary of Comments on Tan's Standard Space-time Theory

"In the special theory of relativity, space-time is flat, there is no matter inside, and therefore different coordinate systems are equivalent. In the actual space-time, there is some matter inside and space-time is thus curved. Naturally there is standard space-time, and different coordinate systems are not equivalent. In general theory of relativity, there is no equivalence between different coordinate systems."

"Overall, because space-time is not empty, Standard Space-time Theory holds true."

"Tan Shusheng's theory ...is a relative truth, not merely the words of one school."

"I suggest Comrade Tan Shusheng make some change to his paper, especially the 'introduction', stating the theory is a part of an integral theory, which has an applying domain, and is yet a very precise theory in such domains. This point of view is in accordance with Marxism philosophy, which explains why we are wiser than foreigners."

—Letter from the Famous Scientist Qian Xuesen(钱学森), February 16, 1984

"I think you have quite a nice point when you show that, by themselves, the experiments involving light travelling along some closed paths do not necessarily entail ordinary "special relativity" since they are compatible with a conception that is quite significantly different. This I did not know and, although the proof is simple, the (few) physicists with whom I discussed the matter were not aware of this fact either."

"I read the documents you sent me with great interest. If the publisher asks me my opinion about publishing them my answer will be a favorable one for I think your (very revolutionary) views are worth being known and discussed by genuine experts."

—Letters from the world-famous French Physicist B. d'Espagnat, Sept. 30, 1985 and Feb. 20, 2010

"Professor Tan Shusheng has been making more than 20 years of painstaking efforts to create Standard Space-time Theory. As a new self-consistent theoretical system, it succeeds and integrates the basic thoughts and achievements of Newtonian mechanics and Einstein's special theory of relativity. Both containing known things and having originality, this new system has eliminated the original paradox, and opens a new field of vision, which is of great significance to the development of physics. The publishing of this book "*From Special Theory of Relativity to Standard Space-time Theory*" will be beneficial to readers' study and applied modern physics."

—Preface written by Academician Song Jian (宋健), Honorary Chairman of the Presidium of the Chinese Academy of Engineering, for Professor Tan Shusheng's *From special theory of relativity to Standard Space-time Theory*，December，2007

"I can learn about this major theoretical innovation result in modern physics through your book. I would like to express my sincere admiration for your spirit that you are willing to sit on the cold bench, dare to challenge authority, decades of hard exploration. China needs so scientists like you who have devoted their lives to the pursuit of truth. And I sincerely congratulate on your scientific achievements.

"The establishment and acceptance of an essential original theory may need a very long time, decades or even longer. A real scientist must have this patience. Your decades of theoretical pursuit have fully demonstrated that you possess these excellent characteristics, which are extremely rare and really valuable. Whereas, I believe this day will finally come and we all can witness it."

—Letter from Academician Cheng Jinpei（程津培）, former Vice-Minister of the Ministry of Science and Technology, to Professor Tan Shusheng，January 14, 2009

"The violations of Bell's inequalities as experimental facts show that intrinsic dependences and correlations against Einstein's locality principle do exist among space-like-separated events. The kind of non-locality seems to call for an absolute simultaneity, which would pose a very real and ominous threat to the special theory of relativity, thus shaking the foundations of physics. In the past few years this worry finally allowed inside the house of serious thinking about physics and has become the centerpiece of debates that may finally dismantle or seed decay into the very foundations of physics. I think that the proposed book would make a contribution to reconstruction of the foundations of physics, if it is published."

"I do not know of any existing publications on this subject or manuscripts in preparation which are likely to compete with the book. I have not seen any existing publication which states a self-consistent and systemic theoretical system that can compete with Einstein's special theory of relativity."

—Comments by Academician Yijun Zhao (赵伊君)of the Laser technical specialist, August，2012

The article wrote: “In recent years, along with the advance of observation experiment level, and the constant improvement of theoretical thinking and mathematical means, more and more researchers have the question of relativity, and our country also emerged a group of relativity challenger, among which Professor Tan Shusheng is the physicist who makes great contribution.” “Professor Tan’s innovative spirit of questioning authority and scientific exploration is commendable in any society and era.”

—*Science and Technology Daily* (中国科技日报) published a long report entitled “Deepening the Foundation, challenging the authoritative—physicist Professor Tan Shusheng establishes Standard Space-time Theory”，On September 18, 2007

“Standard Space-time Theory is Tan’s original theoretical research results, ... It is a rigorous logic system beyond Einstein’s theory. The rationality and logic simplicity of basic postulates, and the logic consistency of the theory are superior to the special theory of relativity.”

“Challenge authority, challenge the inherent thinking, creative new theory, this is the way that only the brave and the unwilling to be lonely will choose. This is the way Einstein walked. Now, Professor Tan Shusheng is following the same path that few people follow.”

“A new point of view or a new theory is to become the truth, to reflect nature as it really is, not just by imagination or arbitrary fabrication. It is necessary to proceed from empirical facts to conduct rigorous theoretical research and accept the test of experiments.... the empirical facts are still the fair judges in the end. Professor Tan Shusheng has proposed an experiment that can be carried out under the existing technology, as a ruling experiment between the special theory of relativity and Standard Space-time theory.”

—*Science Times* （中国科学时报）published a long report titled “Standing on the Shoulders of Giants”, On March 14, 2011

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Introduction

Einstein was a great genius. His special theory of relativity has become one of the two main foundations of modern physics. The special theory of relativity fully reveals the relativity of the motion of matter which is not revealed by Newtonian's Mechanics, that is, the dependence of the space-time property of matter on the motion of matter. It explained many experimental facts that could not be explained by classical physics, and included the knowledge that physics has actually reached at the turn of the 19th and 20th centuries in his theoretical system and its understanding, so it has opened up the way for physics research. Einstein's work has done outstanding contributions to help shape the world in which we live today. In 1999, the American weekly Time named him "The Great Man of the Century", Einstein became the symbol of the highest human wisdom of the 20th century.

Nevertheless, science always moves forward and never stays at the same level. In the last half century, especially in the past 30 years, theoretical thinking and experimental tests have revealed the difficulties and challenges faced by the special theory of relativity. D. Bohm (He was an acknowledged world authority on quantum mechanics) said: "I don't think anybody can necessarily expect everything to turn out the way he expects it. Quite a few things turned out that way for Einstein, but he can't have everything right!" The discovery of cosmic background radiation confirms the existence of the absolute inertial reference frame. An experimental test of Bell's inequality found that "Einstein was wrong!" There is no doubt that there is a superluminal causal connection or influence between two entangled particles. It can be asserted that the non-locality must be an important feature of the microcosm. This opens up the way for the gestation, development and establishment of the new theory.

Einstein was sincere and humble about the special theory of relativity. Back in 1949, when Einstein was 70, he wrote to his friend M. Solovin, "I feel that there is no concept in my work that will stand up very firmly, nor am I sure that I am generally on the right track." In his later years, Einstein speculated many times that "The relativity may eventually need to give way to other theoretical systems."

Has modern physics reached a point where the special theory of relativity needs to give way to other theoretical systems? Has a more suitable theoretical system been produced? The answer is yes. This is the subject of this book.

Standard Space-time Theory is an original theoretical research results, and it is a rigorous logical system established beyond Einstein's theory. Standard Space-time Theory is the integrating and upgrading of Newton's and Einstein's space-time concepts. It describes the nature of space and time more accurately, and provides a more appropriate space-time framework for understanding and describing the physical world and even natural phenomena. Einstein's special theory of relativity is an approximation of Standard Space-time Theory under certain circumstances.

Physics is the foundation of the whole natural science. What is modern physics? Physics, based on Einstein's theory of relativity and quantum mechanics, is generally considered modern physics. In the *1998 World Science Report*, UNESCO stated that, "Einstein's theory of relativity and quantum mechanics are the two great academic achievements of the 20th century. Unfortunately, the two theories have so far proved to be opposed to each other. This becomes a serious obstacle." If we say that there are still 100 physics problems puzzling mankind, then, compared with the other 99 problems, the coordination of relativity and quantum mechanics is the root of all problems and the biggest problem in physics. Standard Space-time Theory is consistent with the time concept of quantum mechanics, which provides the correct foundation and starting point for solving the coordination problem between relativity theory and quantum mechanics. To be sure, Standard Space-time Theory is a more suitable theoretical system to replace the special theory of relativity. This involves a massive change in the concept of space and time that will drive the fourth breakthrough in modern physics.

This introduction will provide a clear and understandable explanation of the above assertions to help you understand this scientifically complex subject. The first three chapters of this book will guide you to appreciate the wisdom of eastern philosophy (Chinese Laozi's philosophy), and how Laozi's philosophy organically combines with western philosophy to solve the problems faced by Einstein's theory, and to make an accurate and in-depth understanding of the material world and the spiritual world. As you read the entire book, it will provide a systematic and detailed interpretation of the entire Standard Space-time Theory system. Even if you do not read the entire mathematical calculus, you will be familiar with the scientific evidence supporting Standard Space-time Theory and understand a series of important conclusions of Standard Space-time Theory.

Difficulties and Challenges Faced by Einstein's Special Theory of Relativity

In 1905, Einstein founded the special theory of relativity based on two assumptions, namely, the principle of relativity and the principle of the constancy of the light speed. The special theory of relativity is a logical system established by axiomatic method.

What is axiomatic method? Euclidean geometry is regarded as the first model of deductive mathematics system established by axiomatic method and the first successful example of human rational thinking. In proving geometric propositions, each proposition is always derived from one or more preceding propositions, which in turn are derived from even earlier ones. It is impossible to go back so infinitely, and there should be some propositions as a starting point. As the starting point of argumentation, the proposition that is self-explanatory and universally accepted is called axiom. In a theoretical system, a few axioms and a few concepts, unproved, should be selected as little as possible in advance, and taken as original assumptions, from which a series of propositions can be deduced by means of pure logical reasoning, and the whole theoretical system is built into a system of deduction. This method is called axiomatic method. The axiom system must satisfy the three requirements of independence, completeness and harmony (or consistency), that is, the axioms constituting the axiom system must be not many, not less and not contradictory.

With the development of the times, people gradually see that Euclid's *Elements of Geometry* is not perfect in a strict logical sense. Since ancient times, many mathematicians have made many attempts to improve the axiom system of Euclidean geometry. By the end of the 19th century, many works had been published on the foundations of geometry, the most important and complete of which was the work *The Foundations of Geometry* of the German mathematician Hilbert, Einstein's academic rival and friend.

Since the publication of Hilbert's work, a perfect and concise system of geometric axioms has been established. The research method of defining mathematical basic objects and their mutual relations with axioms system has become the axiomatic method of mathematics. Scholars espoused this approach formed the school of axioms. The effect extended to other areas of science. In physics, the mechanics, thermodynamics, relativity, electrodynamics, quantum mechanics and other subjects are in use of the axiomatic methods. Axiomatic method plays a very important role in the development of the whole science.

The special theory of relativity is a logical system established by axiomatic method. Its main logical elements are: two basic assumptions, that is, the relativity principle and the principle of the constancy of the light speed; three important logical conclusions, that is, the space-time properties of matter depend on the speed of matter motion, including the effects of length contraction, time delay and mass increase; an important logical corollary, that is the principle of the ultimate limitation of the light speed, or, more generally, that the speed of any matter motion or signal transmission must not exceed the speed of light in vacuum. Of course, it also contains many other rich contents, for example, the mass-energy relation.

The special theory of relativity reveals the dependence of the properties of space and time of matter on the motion of matter, and realizes a revolution and leap in physics. Nevertheless, further and fine theoretical thinking and experimental testing in modern physics have shown that these main logical elements of the special theory of relativity are questionable or certainly wrong. Before drawing any further conclusions, let us explain clearly the flaws and errors of each of these major logical elements.

First, astronomical observations confirm the existence of absolute frame of reference, which most physicists accept. It can be confirmed that the principle of relativity has been negated by astronomical observation.

As we all know, observing and describing the motion of an object requires a reference system; in order to quantitatively describe the motion of an object, it is necessary to establish a coordinate system on the reference system. The reference frame in which Newton's law of inertia holds true, i.e., the reference frame in which an object continues in a state of rest, or in motion with constant velocity, unless acted on by unbalanced forces, is called inertial frame of reference, or inertial frame for short.

According to Einstein's principle of relativity, all the laws of physics have the same form in all inertial systems; all inertial systems are equivalent or equal in rights. That is to say, there is no an inertial frame in which to describe the motion of matter, the laws of nature are the simplest than in any other inertial frame, and which can be used as a standard to determine whether every other inertial frame is stationary or moving, and how fast it is moving. The principle of relativity asserts that there is no and no need to introduce such a special, or superior, or standard, or absolute inertial frame of reference. The motion with respect to the absolute inertial frame of reference is called absolute motion. The principle of relativity can therefore be expressed as follows: there is no absolute motion, and all motion is relative.

The problem of inertial frame of reference, absolute motion and absolute inertial frame of reference actually involves a deep understanding of space-time. For this, the genius of Newton has done in-depth thinking and demonstration. Nevertheless, as long as willing to learn, do not refuse to think, ordinary people are completely understandable. This question is left in Chapter 2, especially in Sec. 2. 2 in it "Newton's absolute view of space and time" to give a detailed explanation.

We should make it clear that in the face of the achievements of modern cosmology, the above argument of Einstein's principle of relativity is no longer tenable.

1. The principle of relativity is in complete conflict with the principle of cosmology.

Currently accepted cosmological theories are based on the general theory of relativity and cosmological principles. Cosmological principles describe the kinematic characteristics of the evolving universe in large-scale space and time. The cosmological principle holds that the universe is spatially homogeneous and isotropic. This, of course, is not a detail of the universe, but only applies to the "smoothed" universe obtained after averaging of the regions with a diameter of 10^8 to 10^9 light-years, which is large enough to include many clusters of galaxies. The cosmological principle requires that there is a universal standard coordinate system to describe the evolution of the universe, the simultaneity relative to this time mark has essential significance in the meaning of the evolution of the universe; among them, the cosmic space is the cosmic background space. Typical galaxies or galaxy clusters are uniform and isotropic in the cosmic background space, while any observation in a reference frame moving at a certain speed relative to this background space will deviate from such uniformity and isotropy. The universal standard coordinate system is a superior space-time coordinate system, which in principle can measure the speed of the moving coordinate system (such as the earth) relative to the cosmic background space.

2. The cosmological principle is supported by a large number of observational facts; Astronomical observations confirm the existence of the absolute inertial frame of reference, and the relativity principle has been negated by astronomical observations.

In 1965, Penzies and Wilson in the United States discovered the cosmic microwave background radiation. Radiation is the emission and propagation of electromagnetic waves. In fact, every object emits radiation of various frequencies (and wavelengths), and radiation emitted by objects of different temperatures exhibits a different frequency spectrum (frequency-intensity) distribution. Further study confirmed that cosmic background radiation strictly isotropic case is only found in a certain inertial system that is not in the reference frame of reference of the sun or earth, relative to this inertial frame of reference, the microwave background radiation is very symmetrical, isotropic, showing the spectral distribution of the standard blackbody radiation, corresponding to the temperature of T_0 = 2.725K. The degree of anisotropy is expressed by temperature fluctuation, which is only one hundred-thousandth ($\delta T / T \sim 10^{-5}$). However, in any other inertial frame (such as the earth or solar reference frame) that moves with respect to this inertial frame, the directional change in radiant temperature is shown. This inertial reference frame is actually the cosmic background space or vacuum background field. Suppose that the moving frame of reference (such as the earth reference frame) in which the observer is located is moving at a speed $\boldsymbol{v}$ relative to the cosmic background space. Due to Doppler Effect, the radiation temperature is higher in the direction of motion and lower in the direction of backward motion. Like an oncoming train, the whistle is rising in pitch, while a speeding train the whistle is falling in pitch. Measuring the cosmic background radiation reaching the earth from all directions, it was found that the radiation temperature in one direction was the highest, exceeding the average value of 0.0035 degrees (3.5 mm-degrees), that is, over one thousandth (1‰) of the average value. This direction points to the brightest star in the constellation Leo (i.e., star α) at the usual celestial coordinate. The lowest temperature is in the direction of Aquarius, which is 180^0 different from the highest temperature zone. According to these calculations, the absolute velocity of the sun and earth through the cosmic background space is about 390 km/s. This is called “New Etheric Drift”.

Many famous physicists in the world have commented on the physical significance of the discovery of cosmic background radiation.

Bergmann, an eminent contemporary scholar of relativity, Einstein’s student and collaborator, has clearly pointed out that on the cosmic scale, the principle of relativity is destroyed; cosmic background radiation is isotropic only in a unique frame of reference, in the sense that that frame stands for “stillness”. Weisskopf believed that, in any case, the observed 2.7k radiation determines an isotropic absolute frame of reference; this meant that Michelson and Morley’s dream had become a reality, finding the absolute motion of our solar system. Many other famous physicists, such as Stapp, Rosen (who worked with Einstein on the EPR demonstration), Harken (the founder of synergetics), and Hu Ning (a Chinese relativistic physicist) have made similar claims.

In a 1979 report of the Princeton Congress to commemorate the 100th Anniversary of Einstein, Dirac said: “it can be said that the cosmic background radiation is symmetric only to one observer, and that this privileged observer is static in some absolute sense, perhaps even to the ether. This contradicts Einstein’s view.... In a sense, Lorenz was right and Einstein was wrong, because everything Einstein said was that it was impossible for physics to observe absolute zero velocity.... The only explanation, for why Michelson and Morley had zero results, and why they could not observe the absolute motion of the earth, was that their technology was not good. Today’s technology is much more advanced than it was about a hundred years ago. With modern technology, absolute motion exists.”

In short, the physical discovery of cosmic background radiation directly negates the basic assumption of the special theory of relativity, i.e., the principle of relativity.

Physicists are now on the investigation to the cosmic background radiation, mainly concerned about the temperature fluctuation of 1/100000 ($\delta T / T \sim 10^{-5}$) in every small area, which is used to study the non-uniform degree of the distribution of the matter in the big bang cosmology. The basic fact about the temperature difference of about 1/1000 (1 ‰) in the earth motion direction has been ignored, or been listen but not hear, turn a blind eye. This is not to avoid the weighty and catch the light, put the cart before the horse!

Second, the principle of the constancy of the light speed is an artificial stipulation and an excessive assumption without experimental basis.

1. The logical cycle between the one-way light speed measurement and the calibration of clocks at different places

The second basic assumption of the special theory of relativity is the principle of the constancy of the light speed, which assumes that in any inertial frame, the speed of light in any direction in vacuum is equal to the constant *c*. Has this principle been confirmed by experiments? No. The "speed of light" in Einstein's principle of the constancy of the light speed refers to the one-way speed of light, that is, the speed of propagation of a light signal in an arbitrarily determined direction. Einstein's principle of the constancy of the speed of light is actually the principle of the constancy of the one-way speed of light.

To measure the one-way speed of light between two separated points *A* and *B*, the distance and the time interval required for the light pulse emitted from point *A* to travel to point *B* must be determined. This time interval must be measured using two synchronized (i.e., calibrated) clocks placed at *A* and *B*, respectively. How do you calibrate the two clocks at different places? A signal can be sent from point *A* at time t_A, assuming the signal speed is *u*, and when it reaches point *B*, the clock reading at point *B* is t_B, if $t_B = t_A + AB/u$, it can be considered that the clocks at both places have been calibrated. This argumentation, of course, is examined in a strict and precise scientific sense. A conundrum arises: to measure one-way speeds, clocks at different places need to be calibrated; to calibrate clocks at different places, it is also necessary to know the one-way speed of a signal. This is the logical cycle between one-way velocity measurement and calibration of clocks at different places. In the special theory of relativity, this logical cycle is inevitable.

In his paper on the establishment of the special theory of relativity, Einstein said: A time common to *A* and *B* "can now be determined by establishing by definition that the 'time' needed for the light to travel from *A* to *B* is equal to the 'time' it needs to travel from *B* to *A*. For, suppose a ray of light leaves from *A* towards *B* at '*A* time' t_A, is reflected from *B* toward *A* at the '*B* time' t_B, and arrives back at A at the '*A* time' t'_A. The two clocks are synchronous by definition if $t_B - t_A = t'_A - t_B$." That is to say, the time it takes for light to travel from *A* to *B* is not necessarily the same as the time it takes for light to travel from *B* to *A*; Or, the speed of light from *A* to *B* is not necessarily the same as the speed of light from *B* to *A* in the opposite direction. Einstein calibrated the clocks of different places by specifying that the speed of light is independent of direction, that is, by specifying the constancy of the one-way speed of light to define the simultaneity of different locations, to calibrate the clocks at different places, and that's what happens in any direction and in any inertial system.

Thus, Einstein's principle of the constancy of the one-way speed of light is a completely artificial stipulation! As Einstein said: "That light requires the same time to traverse the path $A \to M$ as for the path $B \to M$ (Here *M* represents the midpoint of a line segment *AB*—my note). ...Only to arrive at a definition of simultaneity one of the terms I can make according to my own free will." Please pay attention to this paragraph! Generally speaking, unless the superluminal signal is discovered and used, or a new experimental method is found, it is impossible to measure the one-way speed of light by using the electromagnetic method, and it is impossible to test the principle of one-way speed of light.

2. The principle of the constancy of the speed of light is an artificial stipulation, an excessive assumption without experimental basis.

It is important to note that for the average two-way speed of light or the average circuit speed of light, which is sent out from point *A* and reflected back to point *A* after through a certain distance (or a circuit distance), it is not difficult to measure them by measuring distance and measuring time with only one clock placed at point *A*. There are no calibration of clocks of different places and synchronization of events of different places issues involved here. For more than one hundred years, a lot of measurement experiments of the speed of light have done under variety of different conditions, do all these experiments to prove that the average two-way speed of light or the average circuit speed of light has nothing to do with the speed of the light source, frequency and direction of light, and has indeed proved the average two-way speed of light or the average circuit speed of light are equal in all inertial system, equal to the constant *c*. For example, the analysis of the Michelson-Morley experiments and all the other experiments that examined the principle of the constancy of the speed of light shows that they proved only the constancy of the average two-way speed of light or the average circuit speed of light, not that the constancy of the one-way speed of light; All of these experiments can be explained by the constancy of the average two-way speed of light or the average circuit speed of light, rather than by the constancy of the one-way speed of light. However, the constancy of the average two-way speed of light or the average circuit speed of light is meaning that the one-way speed of light is variable. Therefore, the usual claim that the principle of the constancy of the one-way light speed has been experimentally verified does not hold true. This judgment has become a public opinion.

Therefore, Einstein's principle of the constancy of the light speed is actually an artificial stipulation and an excessive assumption without experimental basis. A theory based on this arbitrary assumption of "artificial stipulation", lacking (in fact, violating) the support of physical empirical facts, must eventually fall into all sorts of logical contradictions and absurdities.

Third, relativistic effects such as time delay, length contraction and mass increase are all measurement effects, and they are completely relative and reciprocal. The special theory of relativity falls into pure relativism.

Taking the relativity principle and the principle of the constancy of the speed of light as logical starting points, the time delay effect and length contraction effect can be directly derived. The effects of time delay and length contraction can be described as follows:

When the object is stationary relative to the inertial frame, the time interval to measure the physical process of the object is the shortest, that is, the proper time interval is the shortest. The time interval of the same physical process taking place when the object is in motion (let's its speed be v) measured in the same inertial frame is longer, and the delay is $\gamma = 1\big/\sqrt{1-v^2/c^2}$ times of the proper time interval. When a rigid rod is stationary relative to the inertial system, it has the longest length, i.e., the proper length is the longest. When the rigid rod is in motion relative to the inertial frame (let its speed be v), the length along its motion direction measured in the same inertial frame is shorter, which is shortened by $\sqrt{1-v^2/c^2}$ times of its proper length.

If you read the special theory of relativity carefully, you can understand that the time delay effect and length contraction effect of the special theory of relativity are measurement effects caused by the assumption of the constancy of the one-way light speed. They are the results observed by observers according to the constancy of the one-way light speed to calibrate the clocks at different place. This does not mean that matter and the process of motion of matter themselves truly what have changed. This is philosophically regarded as a subjective idealist view.

The special theory of relativity completely negates the absoluteness of the motion of matter. In the special theory of relativity, the time dilation effect and the length contraction effect are both relative and reciprocal. When observing in each inertial system, in any other inertial system which relative to it moves, their clock is slowed down and their ruler is shortened. Colloquially speaking, you and I are observers in relative motion. You see that my clock is slower than yours, and my ruler is shorter than yours, while I see that your clock is slower than mine, and your ruler is shorter than mine. You and I have the opposite judgments. However, your and my statements are valid in strict scientific sense at the same time, and besides that, there can be no other "objective" and "fair" judgment. No wonder someone exclaimed: according to this theory, science has no principles, science has no standards! Physics has fallen into relativism.

Fourth, the discovery of faster-than-light motion upended the special theory of relativity. The experimental results of Bell's inequality showed that Einstein was wrong. These findings shake the cornerstone of whole physics.

As is well known, the special theory of relativity asserts, as an important corollary, that the speed of light is the ultimate speed at which matter moves and signals travel. This is called the principle of the extreme limitation of the light speed in the special theory of relativity.

It is easy to see from Sec. 2.3 (especially Fig. 2.1) that, in the special theory of relativity, the principle of the constancy of the one-way light speed requires the abandonment of the absolute concept of simultaneity. Two events that occur at different places at the same time in one inertial frame, but are observed in another inertial frame moving relative to it do not occur at the same time. This is the relativity of simultaneity.

The special theory of relativity is further derived from the principle of the constancy of the one-way light speed and the principle of relativity: the statement of the time sequence of two pseudo-simultaneous events (also known as two space-like separation events) is also relative, which is related to the selection of the inertial frame, and has no absolute meaning. The so-called pseudo-simultaneous events mean that the space distance between two events is so large and the time interval between them is so small that the optical signal cannot travel such a large space distance in such short time interval. But here's the problem: if there is matter moving faster than the speed of light or a signal traveling faster than the speed of light, a causal link can be established between pseudo-simultaneous events. The salient feature of causality is that the cause always occurs before the result. Since the time sequence of two pseudo-simultaneous events is related to the selection of inertial frame, it can be reversed, which is bound to lead to the situation that "the result occurs before the cause" in some inertial frame of reference. It is absurd to violate the law of causation, so the special theory of relativity asserts that no matter can move faster or send a signal faster than the speed of light c in a vacuum.

The limitation of the speed of light is a famous argument of the special theory of relativity. Is the real situation of nature consistent with this?

In fact, matter can be divided into two different states, namely, aggregated state and dispersed state. Accordingly, the superluminal motion can be divided into two categories, namely, the superluminal motion of the aggregated-state matter (microscopic particles or macroscopic objects) and the superluminal motion of the dispersed-state matter, such as the superluminal propagation of energy or information in the vacuum background field. For the concepts of the aggregated state and the dispersed state, please read Chapter 1 (see Sec. 1.5) of this book carefully. It is doubtful that there is superluminal motion of the aggregated-state matter in nature. Perhaps there is no superluminal motion of the first kind matter (i.e., microscopic particles or macroscopic objects). The speed of light is still the ultimate speed of the whole motion of particles, their constituent macroscopic objects and celestial bodies. However, modern physical experiments have proved that the superluminal motion of the latter kind motion, that is, the dispersed-state matter (such as the vacuum background field) must exist. First, experimental tests of Bell's inequalities since the 1970s have shown that there are inherent dependencies and correlations between space-like separated events that violate Einstein's principle of locality (see the following paragraphs). Secondly, since the 1990s, using quantum tunneling effect to realize and observe superluminal phenomena has become a hot research topic. Experiments have confirmed that an electromagnetic pulse can pass through the potential barrier at superluminal speeds in short-wave, microwave and optical frequency bands.

Next, we will focus on the experimental test of Bell's inequality.

First, notice that in the concept of time, relativity and quantum mechanics have always been in conflict. Quantum mechanics uses the concept of time in an absolute sense, and simultaneity also has an absolute sense. Quantum mechanics allows superluminal (or even infinite) phenomena, which is the non-locality of quantum mechanics. All this is forbidden by relativity.

Einstein and Bohr hold completely different views on quantum mechanics, which has been debated for a long time. Einstein put forward the principle of localization: there is no signal transmitted by the speed faster than light and the instantaneous action at a distance; The actual states of the separated objects in space are independent of each other if there is no physical signal transmitted at a speed not greater than the light speed to establish a connection between the separated objects. We constantly hear or see the "EPR argument". The EPR argument is Einstein's attempt to deal a fatal blow to nonlocal quantum mechanics by using the principle of limitation of the speed of light or the principle of locality, which he fully believed in.

In order to conduct experimental research on the EPR demonstration, in the 1950s Bohm first transformed the EPR thought experiment into an experimental scheme for measuring the correlation between proton spin and photon polarization. Such experiments had been done earlier by Wu Jianxiong and others, and the results conform to the predictions of quantum mechanics.

In his famous paper "On EPR paradox" in 1964, on the basis of the analysis of EPR argumentation, starting from the theory of local implicit parameters and using the three basic assumptions of local realism, Bell proved an inequality, which was later called Bell's inequality.

The three basic assumptions of localized realism adopted by Bell are as follows: firstly, realism holds that the regularity of observed phenomena is caused by some physical object existing independently of the observer; Second, inductive reasoning, that you can freely use inductive reasoning to draw reasonable conclusions from consistent observations; Third, Einstein's principle of separability or Einstein's principle of locality. By the 1970s it was clear that the essence of Bell's inequality lay in Einstein's principle of locality.

Local Realism concluded that the experimental results satisfy Bell's inequality, and quantum mechanics predicts that the experimental results will violate this inequality. Until 1982 completed twelve experiments, in addition to the early two experiments with low precision and poor credibility, ten experiments (among them, in 1982 the European center for high energy physics, experiment done by A. Aspect is the most authoritative) are not the result of the fall in the vast area, meet the Bell inequality and just fall on the curve of quantum mechanics predictions. In the last decade, experiments to more accurately eliminate all kinds of possible loopholes (such as local loopholes and measurement loopholes) continue to be carried out, and results violating Bell's inequality have been obtained successively. At present, the vast majority of physicists accept the violation of Bell's inequality as an experimental fact, firmly believing that all experiments confirm that non-locality between quanta is a real existence. Although superluminal information cannot be transmitted by entangled particles at present, there is no doubt that there is a superluminal causal connection or influence between two entangled particles. It can be asserted that if quantum mechanics is the correct theory for describing the microcosm, the non-locality must be an important feature of the microcosm.

The Nobel Prize in Physics 2022 was awarded to A. Aspect, J. F. Clauser, and A. Zeilinger for their work on experiments with entangled photons, establishing violations of Bell's inequalities, and quantum information science. This shows that quantum entanglement has been recognized by the society.

The magazine *Scientific American* (2009， phase 3) published a long essay entitled *Was Einstein Wrong*, pointed out that since the 1970 s the Bell Inequality of experimental test has shown that the world is non-localized, the non-locality requires an absolute simultaneity, which constitute a serious threat to the special theory of relativity, shook the cornerstone of the whole physics. The article said: "In the past few years this old worry—has been finally allowed to step into the palace of physics —has become the subject of serious thinking and the centerpiece of debates that may finally disintegrate, distort, reimagine, solidify or seed decay into the very foundations of physics."

The confirmed fact that there is superluminal motion is of great significance. It overturns Einstein's special theory of relativity and shakes the cornerstone of modern physics. The whole theoretical system of physics may be reconstructed as a result, which would inevitably change our understanding of the universe. Therefore, the discovery of the phenomenon of superluminal motion shook the whole physics circle, and also aroused the wide attention of the scientific community and the public.

The above statement shows that: although the special theory of relativity fully reveals the relativity of the matter motion, get the important conclusion such as the relation of mass and energy, but, because one-sidedly negates the absoluteness of the matter motion, it is now clear that the main logical elements of the special theory of relativity are all wrong.

There have been three major breakthroughs in physics in the last 300 years. Every breakthrough brings revolutionary change and development to science and technology. The first was the establishment of Newtonian mechanics and the development of thermodynamics, which led to the invention of steam engine. Man entered the age of steam power and realized the first industrial revolution. The second was the establishment of Faraday-Maxwell's electromagnetic field theory, which led to the invention of generators and motors, the use of electrical appliances and electromagnetic waves, and the entry of mankind into the age of electrification. It also contributed to the development of telecommunications and the realization of the second industrial revolution. The third is the establishment of relativity and quantum mechanics, which led to the emergence and development of atomic energy, laser technology and electronic computer technology, realizing the third technological revolution.

In the 1960s, there was constant talk of the fourth great breakthrough in physics and the fourth industrial revolution. We waited for half a century and the things we expected didn't happen! Obviously, modern physics cannot be based on two opposing theories, or it is unlikely that modern physics can make great progress based on two opposing theories. This opposition between relativity and quantum mechanics shows that at least one of the two theories is wrong in its principal point of view.

As mentioned earlier, the special theory of relativity, based on the principle of relativity and the principle of the constancy of light speed, derives the effects of time delay, length contraction and mass increase. Although in the special theory of relativity, this is a kind of measurement effect, it is a completely relative and reciprocal effect, however, observations and experiments are always carried out in an inertial frame of reference, to verify these relativistic effects are not directly affected by the relative and inverse properties of these effects. In addition, the later study found (see Standard Space-time Theory described later), even if we proceed from the inverse proposition of relativity principle, that is, the absolute reference system principle, coupled with the principle of the constancy of the average circuit speed of light, the difference of the results derived in this way is only reflected in the correction of the factor $\alpha = 1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2$ (which is very close to 1) to replace 1, which is beyond the general experimental accuracy. Here, $\boldsymbol{u}, \boldsymbol{v}$ are respectively the velocity of the observed object and the inertial system of reference. So, it can be seen that the special theory of relativity has described the dependence of the temporal and spatial properties of matter on the motion of matter.

The important problem is that the special theory of relativity must make a wrong judgment on the nature of the world because of its concept of the void space with nothingness and the artificial assumption of the constancy of the one-way light speed. This is an error of the breadth of a single hair, can lead you a thousand of miles astray! The special theory of relativity must make the logical conclusion, that is, to deny the existence of the matter in dispersion state and the superluminal motion. This negates one of the two classes of matter (the aggregated state and the dispersed state) and one of the two classes of motion (subluminal and superluminal). This is not a question of the accuracy of the theoretical description, but a grand qualitative error. This is the result of the theory based on the concept of the void space with nothingness and the hypothesis of "artificial stipulation". Denying and discarding half country of the matter and its motion, and leaving them beyond theoretical description and investigation, inevitably blocks the way to the discovery of truth. At the advanced stage of the development of physics, the falsification of this theory is eventually bound to be confirmed by experiments. Obviously, only by breaking through the space-time concept of the special theory of relativity can we achieve a truly higher level of development.

At the turn of the 20—21st centuries, the discovery of superluminal motion and the negative conclusion of the test experiment of Bell's inequality were of profound scientific significance. It is considered by many prominent scientists as "the most important development of physics and the most far-reaching scientific discovery in physics". Like the historical negative results of the Michelson-Morley experiment, they are dark clouds in the clear sky of modern physics. Due to Einstein's great authority, this cloud has been floating for more than 30 years. However, the development of modern physics did come to the point where the special theory of relativity needed to give way to other systems of theory! If we do not turn the page of history, the development of physics will certainly remain stagnant. This is "the sadness of physics" that people are talking about!

The Basic Idea of Standard Space-time Theory

Has a more suitable theoretical system to replace the special theory of relativity been produced? This is the second question answered in the introduction.

In 1985, BBC radio 3 organized a programme featuring interviews by science journalist J. Brown with several leading scientists to find out what they had learned from the results of the Aspect experiment. After the program was broadcast, it aroused great interest from the public and gained full recognition from the public. The interview was edited and published in 1986 under the title *The Ghost in the Atom*, and became a bestseller. China Hunan Science and Technology Press published the Chinese translation.

J. S. Bell (1928—1990) is the excellent scientist at CERN, and the viewpoints he expressed in the interview was very clear especially. In *The Ghost in the Atom*, J. Bell said: "The cheapest solution is something like going back to relativity as it was before Einstein, when people like Lorenz and Poincare thought that there was an ether—a preferred frame of reference.... You can imagine that there is a preferred frame of reference, and in this preferred frame of reference things do go faster than light." "I find that there are lots of problems which are solved more easily by imagining the existence of the ether.... The reason I want to go the idea of the ether here is because in these EPR experiments there is the suggestion that behind the scenes something is going faster than light."

Popper, a famous philosopher of science, holds the same view.

I admire the persistence and sharpness of J. Bell and Popper's observations. The problem, however, Lorentz's efforts were realized with a series of revisions, supplements and additions of hypothesis to classical physics. His theories were not systematic and thorough. The Lorentz transformation is contradictory with his original idea of the ether theory. Lorentz did not set up a space-time theory in accordance with the principles of logical simplicity and logical self-consistency. Hence to return directly and simply to the Lorentz theory is not the most perfect resolving means.

Standard Space-time Theory, which will be expounded in this book, is an original theoretical research achievement, and is a new logical system beyond Einstein’s theory. It is starting from the thought of the ancient Chinese Yuanqi Theory, and systematizes and perfects the ether theory of Lorentz, and is a new space-time theory on two basic postulates, i.e. (1) the principle of the absolute reference frame and (2) the principle of the constancy of the average circuit speed of light.

The Principle of the Absolute Reference Frame is the converse proposition of the principle of relativity of the special theory of relativity. It is described as follows: there exists a preferred inertial reference frame called the “standard inertial frame” or “absolute inertial frame”, in which space appears to be isotropy. The length contraction of a body moving with respect to the absolute frame (if it exists) takes place only in the direction of the body motion and has its absolute meaning.

The “if it exists” in parentheses here is not an expression of uncertainty. It means length contraction is not assumed. In fact, the conclusion of Lorentz-FitzGerald length contraction can be derived from the existence of an absolute reference frame and the principle of the constancy of the average circuit speed of light.

In the book *The Evolution of Physics*, Einstein said, “What is the meaning of the sentence ‘there is not only relative uniform motion along a straight line but also absolute uniform motion along a straight line’? That is only to say, there is a coordinate system in which some natural laws are different from those in all other coordinate system. Hence this means that each observer can make comparisons among the laws effective in his coordinate system and those in the specific standard coordinate system so that he might judge whether his own system is in motion or at rest.” Of course, Einstein objected to the existence of this standard frame of reference. But Standard Space-time Theory does fit above description. Standard Space-time Theory holds that there exists an absolute reference frame, which is a superior inertial frame of reference that can be used as a standard. This is why it is called “Standard Space-time Theory”.

The principle of the constancy of the average circuit speed of light is stated as follows: In any inertial frame of reference, the average circuit speed of light signal propagating (in vacuum) over a closed path is always equal to a constant c, and is independent of position and motion of the light source, and the orientation of the space.

Next, I want to give a detailed explanation of two basic postulates.

As mentioned, the cosmic background radiation was discovered in 1965; later studies confirmed that the cosmic background radiation is strictly isotropic only in a unique inertial frame of reference that is not the terrestrial or solar reference frame. The observed cosmic background radiation determines an isotropic absolute frame of reference. This is the consensus of most physicists. This is the physical fact basis of the principle of the absolute reference frame of Standard Space-time Theory.

Einstein's special theory of relativity negates the existence of an absolute frame of reference and actually restores the image of vacuum as the empty space with nothingness. The special theory of relativity argues that the introduction of a special absolute frame of reference is superfluous, and the introduction of the ether as the material basis of the absolute reference frame is superfluous too. Light or electromagnetic wave is no longer a propagation process of electromagnetic oscillation in some medium namely ether; the electromagnetic field itself is no longer a state of a medium, i.e., the ether, but an independent substance. However, electromagnetic fields do not exist everywhere in space. Thus, as Einstein said: "A space not permeated by radiation and free of ponderable matter appears to be really empty."

Abundant physical experiments show that a vacuum is not void and void space with nothingness is not existed. The existence of the void space with nothingness is the view of an ancient Greek atomism (see Chapter 1). Another opposite image about absolute space is that the space is not empty, and the void space actually represents the extensiveness of a continuous dispersed medium. This is first shown in the ancient Chinese philosophy of Laozi, also it is the basic concept of the theory of Yuanqi in ancient China.

China's Laozi, born before Confucius (551 BC—479 BC), developed the first complete philosophical system. The Core of Laozi's philosophy system is "Tao". What is Tao? Laozi said, "There is such an integrated thing, it is born before heaven and earth, silent and invisible, exist alone, never change, cycling, never stop. It can be counted as the source of all things under heaven. I do not know its name, and it is called 'Tao'". Laozi made many descriptions about "Tao". "Tao" is intangible and no shape and no image, invisible forever, can't be heard and touched. But no seeing, no hearing, no touching doesn't mean the void space with nothingness; on the contrary, it is the source of all things.

Through thousands of years of historical development, Laozi's philosophy has formed the theory of Yuanqi in ancient China. Therefore, in China, there is the saying of "Laozi is the first in the world". The void space actually represents the extensiveness of a continuous dispersed medium, this is the basic idea of the theory of Yuanqi (which will be elaborated in Chapter 1 of this book), and later appeared in the 16th century French Cartesian philosophy. The Chinese called the medium "Yuanqi", and Descartes called it "Ether".

The theory of Yuanqi in ancient China holds that: "The intangible universe is invisible, the ontology of qi"; "Knowing the intangible universe that is of qi, then there is not nothing"; "All void space is full of qi"; "Yin and Yang two-qies are fully filled with the intangible universe, there is nothing else, also no gap"; "The intangible universe is not empty, fully occupied without surplus". Newton introduced the concept of absolute space to judge the motion state of everything in the universe. In fact, Newton's scientific thinking actually went further and thought that the absolute space filled by the continuous and dispersive medium, which naturally constitutes an absolute inertial frame of reference. Discovery of the cosmic microwave background radiation in the 1960s confirmed Newton's prediction of an absolute reference frame.

The cosmic background radiation is a physical process occurring in a vacuum background field. The vacuum background field with no shape and no image, which is called "The Qi of the intangible universe" in the theory of Yuanqi, forms the background and interaction mediation between the physical particles with shapes and images, and macroscopic objects and celestial bodies which is composed of the physical particles. Indeed, at the level of ultra-microscopic, background field also has a variety of forms and structures, with sharp fluctuations, ever-changing and rich colorful connotations. It cannot be uniform or stationary. On the macroscopic or cosmic scale, however, the field may be regarded as uniformly distributed. The vacuum background field is what we call an absolute reference frame. Relative to this reference frame, the cosmic microwave background radiation is uniform and isotropic, and can measure the speed of the earth or the solar system relative to this frame of reference.

Standard Space-time Theory takes the existence of absolute reference frame as the basic hypothesis. It is a logical system based on the ancient Chinese Yuanqi theory and according the guidance of the empirical facts. It is also the fundamental negation to the special theory of relativity's negation of the existence of absolute reference frame and absolute motion.。

Another basic postulate of Standard Space-time Theory is the constancy of the average circulation speed of light, and it is actually the summary of a large number of experimental facts. Einstein's principle of constancy of the one-way speed of light is actually an artificial stipulation and an excessive assumption without experimental basis. If Einstein's principle of the constancy of the one-way speed of light is true, then the principle of the constancy of the average circulation speed of light is also true; However, If the principle of the constancy of the average circulation speed of light is established, it does not lead to the conclusion that the principle of the constancy of the one-way speed of light is established.

As mentioned above, the basic postulates of Standard Space-time Theory have a solid experimental basis. The rationality of the basic postulates and the logic simplicity and logic consistency of the theory are better than that of the special theory of relativity. Therefore, different from the "artificial convention" of the special theory of relativity, Standard Space-time Theory adheres to the view of "objective realism" in the logical starting point. Starting from reliable basic postulates, and seriously and accurately carrying out logical reasoning and mathematical calculus, only such a theory can reflect the true nature.

Starting from the above two basic postulates strictly, the transformation of the space-time coordinates of the same event, between the standard inertial system and an ordinary inertial system moving at a constant speed $\boldsymbol{v}$ with respect to the standard inertial system is derived. The new space-time coordinate transformation is different from the Lorentz transformation, and is called Generalized Galilean Transformation (GGT). The kinematics, dynamics and electrodynamics of Standard Space-time Theory are further established.

Unlike the special theory of relativity, Standard Space-time Theory obtains absoluteness about simultaneity, that is, if two events occur simultaneously in one inertial frame of reference, then they occur simultaneously in any other inertial frame of reference. The time order of any two events has also absolute meaning, that is, the same judgment and conclusion will be drawn on the time order of any two events when observed in any inertial frame of reference. Thus, Standard Space-time Theory allows the superluminal motion to exist without violating the law of causality, which is compatible with the non-locality principle of quantum mechanics. Standard Space-time Theory further gives a unified description of subluminal motion and superluminal motion. Microscopic particles and their constituent macroscopic objects or celestial bodies do the motion of the subluminal velocity, the velocity of light is still the limit velocity of the whole motion of the aggregation state matter; and the superluminal motion is the process of motion in the dispersion state matter, such as the process of the superluminal propagation of energy or information in the vacuum background field. Within the scope of subluminal motion, Einstein's special theory of relativity is an approximation of Standard Space-time Theory under certain conditions (i.e., $\boldsymbol{u}\cdot\boldsymbol{v}/c^2 \ll 1$). Here, $\boldsymbol{u},\boldsymbol{v}$ are respectively the velocity of the observed object and the inertial system of reference.

Standard Space-time Theory proves that observation and experiment facts do not have to be explained by the special theory of relativity. Standard Space-time Theory derives the effects of time delay and length contraction, which clearly reflects the dependence of the space-time properties of matter on the motion of matter. In Standard Space-time Theory, the effect of time delay and length contraction is not a measurement effect, but a real change caused by the motion of matter relative to the absolute frame of reference, i.e., the vacuum background field.

For example, with respect to time delay, Standard Space-time Theory obtains the following results: When any object and clock is at a subluminal motion $(u_{\mathrm{a}} < c)$ relative to the standard inertial frame, the material motion process and the rate of the clock will really be dilated to $k_{1\mathrm{a}} = (1-u_{\mathrm{a}}^2/c^2)^{-1/2}$ times that at rest relative to the standard frame. If the actual time-delay effects of both the motion process of matter and the clock of the reference frame (the clock can only move at subluminal speed) are taken into account, the measurement of the time interval of the material motion process in any state of motion in any inertial frame can be predicted. In any inertial system, therefore, the measurement results of the time interval of the material motion process has its duality: on the one hand it has absoluteness, which reflects time change of the measured object due to its motion with respect to the standard frame, on the other hand, it has relativity, that is, the result of measurement is also related to the reference frame in which measurements are made, and this reflects the time dilation of the tools of measurement, i.e., the clock of the reference frame, due to their motion together with the reference frame relative to the standard frame. With respect to the length contraction effect, we can obtain similar results, and can make similar arguments.

Starting from the space-time coordinate transformation, that is, the Generalized Galilean Transformation, Standard Space-time Theory has derived the relations about the properties of the material space and time by the mathematical calculations. All of these relations, for example, Eqs. (5.29), (5.32) and (5.35), (5.36) in Sec. 5.2 of this book, reflect the above understanding, so that all of the relations can have a natural and clear physical understanding.

You can see that if an axiom system not only meets the requirements of independence, completeness and harmony (or consistency), and meet the requirements of the authenticity (or objectivity) which I put forward in particular, that is, each axiom conform to the objective reality, and they are a reflection and summary of the experimental facts, combined with the strict and correct logical reasoning and mathematical calculations, the theory based on such a axiomatic system will be able to reflect the essence of nature.

Standard Space-time Theory proves that all observation and experiment facts are consistent with the concepts of Standard Space-time Theory (such as absolute reference frame, absolute motion, etc.) that are very different in meaning from the special theory of relativity. If you read carefully Chap. 8 of this book, you can be sure that Standard Space-time Theory does give natural and satisfactory explanation for several experiments that have previously been considered to negate the existence of the absolute frame of reference (such as Michelson-Morley experiment, Cedarholm experiment, Trouton-Noble experiment, etc.). Standard Space-time Theory naturally and satisfactorily explains all previous experimental results, including several kinds of experimental facts that cannot be explained by the special theory of relativity, such as (1) the homopolar magnetic induction experiment; (2) the cosmic microwave background radiation; (3) superluminal motion experiment; (4) the experimental test of Bell's inequality.

Standard Space-time Theory has obtained some formulas similar to the special theory of relativity, such as the relation $\Delta E = c^2 \Delta m$ between mass and energy, and predicted many same observation effects. However, the space-time concepts of the two theories are quite different, and Standard Space-time Theory has the connotation of sharp conflict with the non-contractual elements of the special theory of relativity. This manifests itself in the principles, concepts, corollaries, formulas and equations that are so sharply opposed to the special theory of relativity. It is from these opposing principles, concepts, inferences, formulas and equations that Standard Space-time Theory explains the experimental results and observational facts that cannot be explained by the special theory of relativity, and predicts some observational effects which are different from those of the special theory of relativity.

Standard Space-time Theory is a new self-consistent theory system. The view of space-time of Standard Space-time Theory is a new space-time view, which is different from Newton's absolute view of space and time and Einstein's view of space and time of his relativity, and inherits and integrates the reasonable elements of them. Standard Space-time Theory leads to the conclusion that motion is both relative and absolute. All relations derived from the mathematical calculus of the properties of space-time in Standard Space-time Theory yield a natural and explicit physical understanding. Standard Space-time Theory reflects the objectivity, relativity and absoluteness of matter and motion, space and time. It reveals the close relation between space and time and the mutual dependence between space-time and material motion in a specific and rigorous theoretical form. Standard Space-time Theory provides a more suitable framework for understanding and describing physical world and even natural phenomena. Such a new theory certainly represents a progress in man's understanding of nature.

What is the more appropriate space-time framework offered by Standard Space-time Theory?

As is well known, in the 16th century (1543), the Copernicus sun center theory came into being, which replaced Ptolemy's earth center theory. It was a symbol of the independence of modern natural science and became a milestone in the history of human thought. Although there is little difference between the geocentric and heliocentric interpretations of the everyday visual effects of the sun rising in the east and setting in the west, we now understand that only the sun center theory reflects the truth of nature; Without the sun center theory, it is impossible to produce Newton's law of universal gravitation and Newton's mechanical system, and it is impossible to have the subsequent development of natural science and enter the space navigation times. Later scientific developments showed that the sun is actually just a star in the Milky Way, not the center of the universe. All stars, galaxies, even clusters of galaxies, are moving in relative motion. This is now the center of the research of astronomy and cosmology.

Summing up the development of modern science, Standard Space-time Theory provides a further picture of the space-time frame as follows: Matter is divided into two different forms, namely, aggregation state and dispersion state; all stars, galaxies, and even clusters of galaxies move in a cosmic vacuum background field. On the macroscopic or cosmic scale, the vacuum background field can be regarded as uniformly distributed, which constitutes what we call the absolute reference frame. Only with respect to this absolute frame of reference, the cosmic background radiation and the propagation of light waves are uniform and isotropic. In principle, the velocity of a celestial body such as the earth or the sun relative to this absolute reference frame can be determined. All this immediately brings us to the starting point of many practical applications (described in detail in Chapter 11).

As long as any space-time theory admits and accepts the basic experimental facts of the existence of an absolute reference frame and the constancy of the average circuit speed of light, its main characteristics will be consistent with Standard Space-time Theory. Therefore, to be honest, Standard Space-time Theory is a more appropriate theoretical system to replace the special theory of relativity.

Recall the sharp opposition between the special theory of relativity and quantum mechanics. As far back as 1946, in his *Autobiography*, Einstein pointed out: “So far, all the efforts to merge together the quantum theory with relativity have met with resistance.” In 1970, Dirac pointed out in a lecture: “This contradiction has been a major problem in physics for the last forty years. The major efforts of physicists have revolved around the problem of reconciling relativity and quantum mechanics. A lot of work has been done on this subject, but no solution is in sight.” In 1981, the famous American physicist Wheeler said, “We often say that the biggest problem in physics is to reconcile quantum theory with relativity. I now say more clearly: quantum theory and relativity are simply impossible to reconcile.” Many scientists believe that there is a deep, sharp contradiction between quantum theory and relativity, and they may have to wait for a more powerful theory to conquer the both theories and achieve a “deeper integration”, their fundamental differences can be resolved. Properly solving the problem between quantum theory and space-time theory contains a scientific revolution.

If we look at Standard Space-time Theory again, we can understand it as follows: the concept of time in Standard Space-time Theory is qualitatively close to the concept of time in quantum mechanics, that is, the simultaneity and time order of any two events is absolute, and all inertial reference frames will get the same judgment and result; Qualitatively, it is close to the concept of time delay in the special theory of relativity, that is, the properties of space and time of matter and their measurements are related to the state of matter’s motion. It is, however, a real delay, not completely relative and reciprocal as described in the special theory of relativity. Are not these logical conclusions derived from two basic postulates in Standard Space-time Theory exactly what the development of modern physics should be? Is not this the perfect integration of the truth elements of quantum mechanics and the special theory of relativity?

As for the significance, status and future development of quantum mechanics, the views of Einstein School and Copenhagen School are diametrically opposed, and there has been a long and unprecedented debate between them. Einstein and Bohr are two of the most outstanding figures in the last century. The question is which of them is right? What direction does quantum mechanics go?

Although the experimental test of Bell's inequality denies Einstein's principle of locality, it is consistent with the prediction of time concept and non-locality of quantum mechanics; this shows that the special theory of relativity must give way to other theoretical systems, which is the goal of Standard Space-time Theory. However, that doesn't mean Einstein was completely wrong. On the contrary, I think Einstein's argumentation that quantum mechanics should return to determinism indicate the right direction. In fact, quantum mechanics itself is not a mature theory, it also needs a real breakthrough and development.

Base on that the aggregated-dispersed states natural images and the theoretical results of Standard Space-time Theory, the physical picture of a single microscopic object can be provide, and the physical basis of quantum mechanics can be established. The superposition of superluminal waves in the vacuum background field form stable wave-packets; and the stable wave-packet is the true representation of the micro-system as the center of extensive wave phenomena. This is the deep physical origin behind the non-locality of quantum phenomena. According to these concepts, it is possible to provide a correct knowledge of quantum ensembles and a complete and deterministic description of individual microscopic systems (see Chapter 11 for details). I will strive to make real progress in quantum theory.

The most important thing is the upgrading in the understanding of the view of nature. Space is not empty. The aggregated-dispersed states natural images described in Chapter 1 of this book is the basis of the natural view of Standard Space-time Theory (its concentrated expression, see Sec. 1.5.3 of this book), and it is also an accurate and in-depth understanding and summary of the natural image of today's scientific development. In the future development of physics, I think the most important problem is that, in the view of nature, people can't just remember particles, particles, particles. In fact, if there is no dispersed-state matter between particles, which is far more extensive than particles, all particles will be scattered sand. Therefore, today we should not only remember the atom of the ancient Greece, but also remember the concept of "Tao" of Laozi in China. That is to say, we not only need to study particles and the interaction between them, but also need to study the dispersed-state field, and then study the mutual transformation and interaction between particles and the dispersed-state field. This is the real meaning of the aggregated-dispersed states natural images proposed by myself. Remember that we understand Newton's absolute space as a space composed of an invisible and continuous dispersion medium (Ether or Plenum). According to this view, we can understand the wave function ψ of quantum mechanics, the entangled particles and so on, and everything will become clear and understandable. Starting from the aggregated-dispersed states natural images, we can achieve a real breakthrough and development of quantum th and physics as a whole. It can be considered that Standard

Space-time Theory is consistent with the time concept of quantum mechanics, which can achieve “deeper integration” and provide a correct basis and starting point for the reconstruction of the foundation of modern physics. This involves a great change in the concept of time and space, which will promote the realization of the fourth breakthrough in physics.

Acknowledgment

Standard Space-time Theory has begun in gestation since 1979 and has been founded in 1983. The related papers “Standard Space-time Theory” were submitted in September 1983 and published in *Journal of National University of Defense Technology* (1st issue, 1984) (page 151—202). Then subsequent relative articles have been published in domestic journals such as *Nature Journal* and *Studies in Dialectics of Nature* and other journals, and monograph were published in 1992. Since 2005, I have focused on all aspects of Standard Space-time Theory to make full research and demonstration, clean up any possible doubts, greatly enhance the competitiveness of this theory. In December 2007, Hunan Science & Technology Press published the book *From special theory of relativity to Standard Space-time Theory* (457 pages), elaborating on the complete theoretical system of this theory. This book won The First Hunan Publishing Government Award, and the Second China Original Book Award issued by the State Administration of Press and Publication in 2008.

In December 2011, the English work *Standard Space-time Theory—a new self-consistent theoretical system* published. It systematically elaborated the complete theoretical system of Standard Space-time Theory in English.

In particular, I would like to thank the famous Chinese scientist Qian Xuesen (钱学森) for his care and support for me and my research. As early as the Spring Festival of 1984, Qian Xuesen read my paper and wrote to point out that “Standard Space-time Theory is valid”, which “is the relative truth, not just statements of a school”. He suggested that I should rewrite the introduction to say that this is “part of a complete theory, which has a scope of adaptation, and within its scope of adaptation, it is very accurate. This view is in line with Marxist philosophy, and is also our superior to foreigners.” In the more than 15 years since then, he has written more than 30 letters to me, face-to-face talk to me three times, and several times proposed to the relevant leaders, and asking them to support my work. He recommended my papers on publication to the journals. He paid tribute to my “dedication to theoretical work” and encouraged me to “fear nothing and triumph will come!” “Things in China always move forward step by step, and next year will be better than this year,” he wrote. “Please believe that things will get better!” Qian Xuesen’s care and support is the most important external support for me to sharpen a sword for more than 30 years.

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I would like to pay special tribute and thanks to the internationally renowned physicists J. Bell and B. d’Espagnat. In 1985, after perusing my paper or work, two physicists wrote to me with high comments quickly. Suggestions for guidance (see appendix). Unfortunately, J. Bell died young. In 2010, B. d’Espagnat, who was still poring over my English book at the age of nearly 90, wrote back: “Your very revolutionary views and insights deserve to be familiar and discussed by real experts.... You are dealing with many very fine subjects, and it will take me too long to arrive at a complete and definite understanding.” B. d’Espagnat is now dead. I salute the two predecessors of physics!

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Standard Space-time Theory as an original innovation theory, after publication, also received high degree of evaluations from many domestic famous academician, well-known professors, experts and researchers, such as He Zuoxiu, Fei Wei-yang, Bai Mingfu, Kuang Huisun, Dong Guangbi, Tian Kunyu, Ge Xuchu, Liu Rangsu, Yan Ye, Liu Gong, Chen Dayou, Chen Yiwen, Huang Xinwei and well received the praise of the vast number of readers. More than 20 newspapers, books and magazines editorial departments gave publicity reports and highly evaluation. I express my sincere gratitude to the related media and my friends for their support and friendship.

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Chapter 1

The Aggregated-Dispersed States Natural Images

Human's understanding on space and time is inseparable from the understanding of natural nature, i.e., from the view of nature. What is the view of nature? Nature in its broad sense refers to the forms of existence and movement of all materials with infinite varieties between heaven and earth, including human beings. In this sense, the concept of nature corresponds to the concept of the world. The view of nature is people's fundamental view about nature, including the fundamental understandings of the origin of the world and the law of world evolution.

The view of nature of any age is formed under certain historical and cultural backgrounds, which is related to the development level of natural science in that era. Ancient Chinese view of nature of Yuanqi Theory and ancient Greek view of nature of Atom Theory are two main forms of ancient simple materialist view of nature, which have or will have an important impact on the development of ancient, modern and contemporary philosophies and natural sciences. The development of modern science (first of all, modern physics) provides people with more and more accurate, more and more rich understanding of nature. The picture of the material world revealed by the modern physics shows the trend of the confluence of the Yuanqi theory of ancient China and the atom theory of ancient Greece, and forms a new natural view, which I call the View of Nature of Atom-Yuanqi Theory, which depicts the aggregated-dispersed states natural images of the material world.

1. 1. Ancient Chinese Yuanqi Theory

The concept of Yuanqi was gradually formed, tempered and perfected by ancient wise and able Chinese people in the process of discussing the problem of the origin of the world for thousands of years. The Yuanqi Theory is the basic theory of Chinese ancient materialism philosophy, and also the basis of traditional Chinese Medicine Theory and Qigong Theory.

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and able Chinese people in the process of discussing the problem of the origin of the world for thousands of years. The Yuanqi Theory is the basic theory of Chinese ancient materialism philosophy, and also the basis of traditional Chinese Medicine Theory and Qigong Theory.

The View of Nature of Yuanqi Theory was born in pre-Qin Dynasty, formed in the Han Dynasty, and highly developed in the Song, Ming and Qing dynasties. This section first gives a brief description of the history of germination, formation and development of ancient Chinese Yuanqi Theory. Then, on the basis of Zhang Zai in Song Dynasty and Wang Fuzhi in late Ming and early Qing dynasties, this section analyzes the nature of Yuanqi in details and expounds the main points of Yuanqi theory in mature form.

1. 1. 1. The Germination, Formation and Development of Yuanqi Theory

In the Western Zhou Dynasty of China (11th century BC — 771 BC), Qi, as a clear philosophical category, has emerged. For example, in the year of the accession of Zhou Xuan King (827 BC), Guo Wengong advised Zhou Xuan King that the imbalance of Yin Qi and Yang Qi was used as the cause of the earthquake, instead of being attributed to the supernatural force, which could be regarded as the germination of a simple materialist view.

Later, the theory of Taiji Yin and Yang appeared, which began in Chinese ancient book *Zhou Yi*, believing that Taiji and the resulting Yin (qi)-Yang (qi) are the origin of all things in the world. It is the rudiment of Yuanqi Theory, which has an important influence on the generation and development of Yuanqi Theory.

About the origin of the world, Laozi put forward the first complete philosophical system. Most researchers believe that Laozi was the Laodan who was the historian of Zhou, and born before Confucius (551 BC—479 BC). The book *Laozi* [1], also known as *Tao Te Ching*, was the record and expression of Lao Dan's Theory, and was set up after Laozi, the book was completed in the mid-period of the Warring States.

The Core of Laozi's philosophy system is "Tao". What is Tao? Laozi wrote (in Chap. 25 of *Laozi*): There is such a one integrated thing, it is born before heaven and earth, silent and invisible, exist alone, never change, cycling in motion, never stop. It can be counted as the source of all things under heaven. I do not know its name, and it is called "Tao", reluctantly called "big". It is the primitive origin. Laozi's Tao is the object that exists objectively, it is one integrated thing. It is the original materials to form all things. It is the origin of all things.

Tao is an invisible thing without shape and image, so Laozi's Tao is also called "nothing". "The nameless, is the beginning of heaven and earth." (Chap. 1) "All things of heaven and earth are born of being (existence), and all beings are born of nothing" (Chap. 40). In general, there are two interpretations of the "nothing": The first is the nothing of "nothing at all", nothing of the nothingness, the absolute nothingness, this is that "all beings are born from nothing", which is one kind of idealism philosophy; The second is integrated and no shape and no image of a material existing, "beings are born of nothing" is a materialist explanation.

What does Laozi mean by “nothing”? Laozi’s “nothing” does not mean nothingness. It is just invisible and no shape and no image. It can never be seen or touched. Because of this, it is not subject to the conditions of space and time, nor is it obstructed at all, it is everywhere and all the time, but it has become a great dominion over all. Laozi’s nothing is another expression of Tao. It is by no means an absolute nothingness with nothing, but an objective existence that is integrated and immaterial, and it is the raw materials that constitute all things with form and image.

Laozi’s philosophy is free of God’s Theology to look for the unity of the world. It is sure that all things in the world have common origin and general laws. This is Laozi’s great theoretical contribution and a great leap in human knowledge.

Laozi’s philosophy is ambiguous in some places. The confusion of concept and meaning is a problem of traditional Chinese philosophy. Historically, the understanding of Laozi has been divided into two groups: materialism and idealism. Play in the opposite direction.

Guanzi is an important work in the Spring and Autumn Period and Warring States Period. It is the first time to put forward the Jingqi (Essence) Theory in the four chapters of *Guanzi*, such as *Minds*. According to the Jingqi Theory, Jingqi is the source of all things. The Jingqi Theory really established the monism of ancient Chinese view of nature of Qi. It is the connecting link between Laozi and Xunzi, which laid the theoretical foundation for the philosophy tradition of the Yuanqi theory in ancient China. The Jingqi theory is also the original Taoist theory of health preservation, which is the germ of TCM theory.

Zhuangzi of the Warring States Period (369 BC — 286 BC) inherited and developed Laozi’s thought. Xun Kuang, the master of Pre-Qin Philosophy, was a thorough materialist thinker. He believes that the Qi of materiality is the source of all things.

He Guanzi, written by the Taoist school in the end of the Warring States Period, first used the concept of “Yuanqi” and the word “Yuanqi”, saying that Yuanqi is the beginning of heaven and earth and the mother of all things. In ancient Chinese philosophy, “Yuan” refers to the origin. To compound “Yuan” and “Qi” means to take Qi as the origin of all things.

In the Han Dynasty, Wang Chong clearly took Yuanqi as the origin of all things, formed his own philosophical system, and established and formed the view of nature of Yuanqi theory. This was the first transition of Materialist Philosophy after the Pre-Qin Period. Wang Chong’s Yuanqi Theory is the most important milestone in the development history of Yuanqi Theory in the Han Dynasty.

The Northern Song Dynasty was an important period for the development of the Yuanqi Theory. Zhang Zai (1020 — 1077) was the master of Yuanqi Theory and established a relatively complete philosophy system of Yuanqi Theory.

Wang Fuzhi (1619—1692, the late Ming and early Qing Dynasties, Hengyang, Hunan) systematically summarized the ancient simple materialism, which made great development in the view of nature, epistemology, dialectics and the view of history. He inherited Zhang Zai's materialist thought and developed the theory of Yuanqi into a mature and complete form through the liquidation and criticism of idealism since Song and Ming dynasties. Wang Fuzhi's philosophy is the peak of Chinese ancient simple materialism dialectics.

1. 1. 2. The Main Viewpoints of the Yuanqi Theory of Mature Form

Zhang Zai and Wang Fuzhi are two monuments in the development of Yuanqi Theory. Based on the discourses of Zhang Zai and Wang Fuzhi [2, 3], this section analyzes the character of Yuanqi in details and expounds the main viewpoints of Yuanqi Theory of mature form.

First, Qi is a continuous general material existence that fills the entire universe. There is no void space without matter.

Zhang Zai believed that all existence is qi. "The intangible universe is invisible, and its ontology is qi." "Where there is a shape, there is a being; where there is a being, there is an image; where there is an image, and there is qi." That is to say that all can be expressed is beings, all beings are the visible images, and all the visible images are qi.

Zhang Zai also said: "The intangible universe can't be without qi", "the meeting and parting of qi is in the intangible universe, like ice condensing and releasing in water."

Wang Fuzhi affirmed that qi is the only entity: "The holding of the heaven and human is only the qi." "Where there is a void space, there is qi." "Yin qi and Yang qi fill the universe, in addition to qi there is nothing else, nor gap." "The intangible universe is not empty, fully occupied without surplus." In Wang Fuzhi's view, qi is a material existence with universality, infinity and continuity, and there is no void space without any matter.

Second, as material general, qi is eternal and cannot be destroyed, and it is in constant and regular motion and change.

Zhang Zai believed that although qi has meeting and parting, but it does not have birth and death. Therefore, he said: "qi cannot but become the objects with gathering together, and all objects cannot but become the intangible universe with dispersion." "It's gathering and dispersing depends on the objective conditions." Zhang Zai believed that qi is in perpetual motion and change, and this motion and change is regular. He said: "qi moves in the universe, rise and float, never cease." Zhang Zai thought: "It is also in order to produce all things from heaven and earth, and the things are both in shape and in rank." That is to say, the qi changes in motion constantly and has its own laws of motion changes.

Wang Fuzhi inherited and developed Zhang Zai's theory.

Wang Fuzhi said: "Qi changes of meeting and parting, and its ontology is not for the profit and loss." "Qi is parting to going to the universe, and recover its ontology of movement changes, not destroy." Wang Fuzhi stipulated the eternal indestructibility of qi, and he actually clarified the Law of Indestructibility of Matter.

Wang Fuzhi believed that matter and motion are inseparable, and everything in the world is in motion and changes. Wang Fuzhi believed that motion is absolute while stillness is relative. "A quiet thing is always moving, not unmoving." "Motionless contains motion, moving not giving-up static." "Nonsense silence is not there." There is no absolute silence. "Movement and motionless both are moving." Wang Fuzhi thought further, motion changes are regular. "The qi's orderliness, mood, rhythm and its principle are visible." However, he said that as the principle of the law of motion changes cannot leave qi. "Outside of qi, there is no principle which is virtual and isolated." "Qi is that the principle is relies on."

Later, the materialist enlightenment thinker Dai Zhen (1724—1777) proposed that "Qi is keeping change, and producing new things and never ends", which made a good summary of Qi Theory. That is to say, the material world is in perpetual motion and change, constantly produce new things and never stop. This expresses the essence of viewpoint of Qi change in the Yuanqi theory.

Third, the fundamental reason for the movements and changes of qi lies in its internal contradictions. Qi is a unity containing the two opposites of Yin and Yang.

Why can qi move and change? Zhang Zai put forward the category of "one or two" and gave a profound discussion on the internal contradictions of qi. He thinks, the qi of the intangible universe, there are two in one. "One thing contains two aspects, which is qi." The qi containing the unity of Yin and Yang is called Taihe. "Taihe", as the unity of Yin and Yang, Yang floating, rising and moving, while Yin sinking, falling and static, the two interact with each other, and they make the changes of infiltrating and pushing each other, this wins and that loses, or bend and stretch.

Zhang Zai said: "The qi of the intangible universe is invisible, being born from feeling and forming the image because of the gathering. Pairs produce from the images and each pair must consist of the contrary, the contrary cause hatred, and the hatred must be reconciled to get the solution." That is to say that the hatred must be solved by the "He" (reconcilement). Zhang Zai expounded that ancient Chinese dialectic thought paid attention to the unity of Yin and Yang, discussed the proposition of "He" (harmony), and put forward "Taihe so-called Tao", "hatred must be reconciled and solved". The wisdom of *Zhouyi* lies in harmony. Harmony has been the consistent philosophy of the Chinese nation for five thousand years.

As mentioned above, Zhang Zai realized that qi was divided into two parts, which contained the opposition of Yin and Yang, thus forming a movement. This unity of simple materialism and simple dialectics is Zhang Zai's great contribution.

Wang Fuzhi developed Zhang Zai's viewpoint of "one thing with two aspects" and "moving is not from outside", insisting on the theory of internal cause and opposing the theory of external cause. He said: "within a qi, two ends already not peace, rubbing of swing, and with infinite changes." And he said, "The world changes, but it must come to both ends."

What are the two ends? The two ends are the two opposites of Yin and Yang. “There is no qi that has Yin without Yang, or has Yang without Yin.” On the one hand, the two ends of Yin and Yang are integrated and cannot be separated. On the other hand, Yin and Yang “stand up against each other”. In a word, Yin and Yang with opposite ends, rubbing of swing, cause the movement and changes of qi. This is the source of movement and change of everything. Yin and Yang are always together and transform each other. All these show that Wang Fuzhi expounded more clearly and profoundly that the unity of opposites of Yin and Yang was the source of movement changes than Zhang Zai.

Fourth, the qi condenses and becomes tangible objects, and the qi disperses and back to the intangible universe. Qi is the origin of all things.

Zhang Zai believed that all existence is qi. “The intangible universe is invisible, and its ontology is qi; its gathering and dispersing depend on the objective conditions.” The invisible qi of the intangible universe is the original state of qi, condensing and dissipating is only the temporary form of the movement and changes of qi. “The intangible universe cannot be without qi, and qi has to be aggregated into all things, and all things have to be dispersed into the intangible universe.”

Wang Fuzhi developed Zhang Zai’s thought that all existence is qi and all creation is made up of qi. He said, “Every void space is full of qi. If gathering it, qi will have a show, human will say it is being; if qi is scattering, it is invisible, human will say nothing.” “Gathering is to have shape, and scattering is to back to the intangible universe.”

In the view of Zhang Zai and Wang Fuzhi, there are three basic forms of physical existence: the invisible qi in the intangible universe, the free qi in rising and floating and the tangible objects. Or gathering or scattering, tangible and intangible, is only the result of Yuanqi movement and changes.

Fifth, qi not only constitutes all tangible objects, but also fully fills them. The ungathering qi not only transforms and interacts with objects, but also to be the intermediary of the interactions between these objects. Qi connects the universe into a whole.

Zhang Zai called the qi not gathering in the intangible universe “clear qi”, and the result of the qi gathering “turbid qi”. In this regard, Wang Fuzhi added: “before the qi is gathering in the intangible universe, it is thin and small and invisible, so it is clear; because of the clear, all things with shape and image can enter it. .... It is heavy and turbid when the qi gathering in the universe, then the things cannot enter it, neither the qi enter the things”. That is to say, the qi not gathering in the intangible universe, is accessible for the tangible things to enter into, but vice versa the qi can enter into the tangible things. The things formed by condensation of the qi have mutual inaccessibility.

So how do interactions between objects occur? Wang Fuzhi said: “Each of the things is a thing, and the qi is to and from the void space between all things.” It is considered that the interaction between objects is not an action at a distance, but through the Yuanqi (field). The relationship not only between inanimate objects, but also between various parts of the human body is conducted through the medium of qi. Finally, the connection between people and the outside world is mediated by qi. Wang Fuzhi said: "Qi, it is the connector between my body and the world." He said again, "if a sage wants to manage the world, it is only able to make good use of his qi."

Qi is the medium of interaction between all things. Therefore, qi connects all the things of the universe as a whole. Zhang Zai said, "The sage does his best, not to shackle his heart with seeing and hearing, his seeing on the world, nothing is not me." The nature of all things has the ability to sense each other, so all things from "nature" link-up into one, but only the "to the best of nature" of the sage can realize, for the sage, "nothing is not me".

The above, according to Zhang Zai and Wang Fuzhi, expounded the nature of Yuanqi and the main points of view of Yuanqi Theory. If further generalized, it can be said that the ancient Chinese Yuanqi theory has four basic characteristics, i.e., the continuous material origin, qi's change in prevalence to produce new things and never ends, the unity of opposites of Yin and Yang, and the overall view of organic connection. These views reflect the Oriental wisdom and the characteristics of Chinese philosophy, which more profoundly reflects the dialectics of nature itself.

Like all things and doctrines, Zhang Zai's philosophy and Wang Fuzhi's philosophy are bound to have shortcomings and historical limitations. On Zhang Zai's philosophy, there are still big differences in academic circles.

Zhang Zai philosophy and Wang Fuzhi philosophy are what a broad and profound theoretical system! Wang Fuzhi's philosophy, in particular, reached the theoretical height that could be reached at that time and it is of epoch-making significance. It is a brilliant pearl in the history of Chinese thoughts and even the history of the world thoughts. To this day it is still radiating eternal glory. Inheriting this precious legacy, we should make greater contributions to the development of science.

1. 2. Ancient Greek Atomic Theory

In the development of the ancient Greek atomic theory, the following three stages can be determined: The perceptual and intuitive concept of world origin from Miletus' school and Heraclitus; The Seed Theory of Anaxagoras and the Theory of Four Roots of Empedocles; The Atomic theory of Leucippus and Democritus, Epicurus and Lucretius.

Thales (about 624 BC—547 BC) of Miletus' school of ancient Greece is regarded as the ancestor of western philosophy. In the west, Thales was the first to put forward a philosophical proposition: water is the beginning of all things. *) [4] (p.3)

Water is a concrete sensible object, which contradicts the universality of the material concept as the origin of all things. Thus Anaximander (about 611 BC—546 BC), the second of the Milesian philosophers, argued that the beginning of all things was not the water of Thales, nor any other concrete matter as we know it, but infinite, eternal, and endless, in perpetual motion. "From which all things come out, all things perish and return back to it." [4] (p.7) Anaximander, unable to specify its name, grudgingly called it infinity.

What exactly does "infinity" mean? The third of the three philosophers of Miletus school, Anaximenēs (about 588 BC—525 BC), believed that the infinity is air. According to him, the beginning of all things is the infinite air, which forms various entities through concentration and dilution. When it is thin, it forms fire. When it is concentrated, it forms wind, water, earth and stone. Everything in the world is produced by the concentration and dilution of air. [4] (p.11)

Heraclitus (540 BC—480 BC), who was at the same time as Miletus school, believed that "the fire is the foundation of all things; All things are born of fire, and perish, and return back to the fire." He said, "The world is the same with all beings. It is not created by any God, nor by any man; its past, present and future are always a group of eternal living fire, burning in a certain size, and extinguished in a certain size." [4] (p.21) He believes that all things are in perpetual motion and changes, "Everything flows and nothing stays." [4] (p.17) He compared all things to a stream and asserted that "a person cannot step into the same river twice." [4] (p. 27)

We see, about the origin of the world, the Chinese and western ancient materialist philosophers' the initial understanding and answer, what a striking resemblance. It is considered that the origin of all things is a unique continuous entity, and the continuous air (or water or fire) without fixed shape is regarded as the origin of all things, which reflects a correct conception of the materiality, unity and continuity of the world. However, western philosophy and Chinese philosophy did not continue along the same path. First came the Seed Theory of Anaxagoras and the Four Roots Theory of Empedocles, and then came Leucippus and Democritus who proposed the concept of Multiple Structural Atom, laying the foundation of Atomic Theory. This transformation has determined the different historical process of Chinese and western philosophy for two thousand years.

Anaxagoras (about 500 BC—428 BC) proposed that the matter particle is the beginning of all existence, this particle is the "seed" of all things. Seeds are "infinitely numerous,

*) In ancient China, Guan Zhong (about 723 BC—645 BC) was the first to put forward the idea of "water is the origin of all things", and demonstrated in detail how he reached this conclusion(see《Guanzi ·Water and Land》). Guan zhong was about a century older than Thales.

infinitely small" and come in all shapes, colors and smells. The infinite variety of concrete things in the world are made of such seeds, and their creation and destruction are merely "mixtures or separations from what is already there." [4] (p.68-72)

Empedocles (490BC — 435 BC) attributed the diversity of matter to four sources (elements), namely, fire, water, earth and air. Everything in the world (including human beings) is composed of these four elements, and proposed that "love" is the driving force for the combination of elements, while "hatred" is the cause of their separation. [4] (p.74)

Empedocles (about 490 BC—435 BC) attributed the diversity of matters to four roots (elements), i.e., fire, water, earth and air. Everything in the world (including human beings) are composed of these four elements, and proposed that "love" is the driving force for the combination of elements, and "hate" is the reason for their separation. [4] (p.74) It is obvious that the theory of four roots is only a simple synthesis of the aforementioned theories that take water, air and fire as the origin of all things.

Both the Seed Theory and the Theory of Four Roots follow the idea of continuity of matter. According to Anaxagoras, although the number of seeds is infinite, their size is infinitesimal, and they are particulate, but seeds are not isolated from each other. "Nothing is absolutely separate from everything else," he said. Lucretius said, "He does not agree that there are gaps in an object, or that there is a limit to divide an object." [4] (p.68-71) Empedocles also believed that "there is neither emptiness nor excess in the whole"; Water, fire, earth, air, "these elements have no emptiness." [4] (p.81-83) Moreover, the seed and the four roots are still the primitive (not structural) concepts of matter. Nevertheless, the theory of seeds and the theory of four roots led to a fundamental change in the concept of matter: from a single concept of matter to a pluralistic concept of matter. At this point they have come very close to the conception of atomic theory, with the property of passing from the concept of the primitive matter to that of structural matter. This was the germ of atomism ideas.

The formation of the concept of multiple structural matter is marked by the atomism proposed by Leucippus and Democritus. Leucippus (unknown life) and Democritus (460 BC —370 BC) believed that everything is composed of the smallest, irreducible particles—atoms. The atom is eternal, indivisible, indestructible, and in perpetual motion. There are an infinite number of atoms and an infinite number of species. There are differences between atoms in shape, size, order and position. From this comes a great variety of things. What's in the space between the atoms? There is nothing with emptiness, a void space. They believe that the atom is existence, the void space is non-existence, non-existence is not nonexistence, and it is also a kind of existence. "Being is not more real than nonexistence", because "emptiness is not more real than reality", both the atoms and the void space have the objective reality. Thus "the beginning of all things is the atom and the void space" [4] (p.96), the atom moves in the void space. Atoms gather and collide with each other, to form vortex motion. "These atoms move about in the void space at will, and by their sharp, untidy motion they collide with each other, and, when they collide with each other, they collude with each other because of their various shapes. In this way, the world and its things are formed, or rather countless worlds." [4] (p.99) All things come into being and perish only because of the combination and separation of atoms. The human soul is also made up of the most mobile and delicate atoms. In short, everything in the world is made up of atoms according to certain rules.

Democritus wrote a large number of books, as many as the quantities of the volume, the breadth of the contents, contemporaries are unparalleled with him, and he was comparable to the later Aristotle. According to the ancient scholars, the writing of Democritus is beautiful, poetic, chic and strict in BC logic, eloquent and persuasive. In the long Middle Ages atomic theory was banned. The Christian worshippers burned a great deal of the atomism. By the end of the 6th century, the book of Democritus has been lost. This is the misfortune in the history of philosophy.

The ancient Greek atomism, founded by Leucippus and systematized by Democritus, formed the first systematic and typical materialist school in the west. Note that atoms and void space are not one or two concrete material forms, but rather concept of pluralistic, structural general matter.

By the third stage of ancient Greek philosophy, Epicurus (about 341 BC—270) further developed the atomism. Lucretius (98 BC—53 BC), an ancient Roman poet and philosopher, inherited and developed Epicurus' theory. In his famous philosophical poem *De rerum natura* [5] (On the nature of things) (a total of six volumes), he made the most comprehensive and systematic exposition of ancient Greek atomism. Lucretius' Atomic Theory is the peak of the development of materialism philosophy in ancient Greece and Rome.

1. 3. The Emergence, Decline and Revival of Ether Theory

In the development of modern science in the West, in addition to the theory of atomism, there is another theory, which is opposed to atomism and competes with atomism, and is similar to Yuanqi theory, and takes continuous matter as the origin of the world. It has gone through a long history, and also played a very important role in the development of modern science. This theory is called Ether Theory. To understand the themes discussed in this book, we should understand the ether theory and its historical development. The paper [6] systematically introduces the historical development of the ether theory.

1. 3. 1. Ether of Ancient Greece

Ether is a time-honored concept. The word "ether", first appeared in an ancient Greek myth: the dark god Ilypos combined with the night god Nikas to give birth to a spirit of the god of Zeus, this is ether. At that time, ether was the spirit of the elves that pervaded the whole universe.

The ether became a philosophical concept among Greek philosophers. [4] (p.17, 68) According to Aristotle, there is no void space, but all space is fully filled with continuous matter everywhere. He believed that objects on earth contained four elements: i.e., earth, fire, air and water. To this is added the fifth element, the substance from heaven. He said, "The heaven is different from earth, fire, water and air. It is what the ancient called ether." [7] (p.330) Aristotle, however, did not regard the ether as the sole source of the continuous physical world.

1. 3. 2. Descartes Ether Theory

The Ether Theory was first proposed by Descartes of France (1596—1650). Descartes is a philosopher who has great influence on scientific thought and is regarded as the ancestor of modern western philosophy. In 1644, he first introduced ether into science and put forward the "Ether Vortex Theory" [8]. He believed that: matter is continuous, in such a material world, there is no action at a distance, and all the force between objects must be transmitted through some intermediary; Therefore, the void space does not exist. The whole space is filled with an invisible original material, which is ether. The ether was in constant and violent motion, its parts interacting to create vortices of varying sizes, speeds, and densities. Gaseous, liquid, and solid materials are made up of ether, the primitive element, which is rotated, rubbed, and finally aggregated. He said there was a huge vortex around the sun, and its whirling motion forced earth and other planets around the sun. Each planet is at the center of a gravitational phenomenon.

This is an overview of Cartesian's Ether Theory and Ether Vortex Theory. How similar Descartes' theory of Ether is to Zhang Zai's theory of Yuanqi (1020—1077), the former is simply a translation of the latter! Among them, the word "Yuanqi" is translated into "Ether", which, as mentioned above, is a spirit that pervades the whole universe. In terms of etymology and semantics, this translation is very appropriate! Descartes' Theory of Ether Vortex is exactly the same as Zhang Zai's Theory of the Intangible Universe Vortex. German Leibniz (1646—1716) came into contact with and studied ancient Chinese philosophy and put forward the view that the Yuanqi is ether [9]. Ding Weiliang (1827—1916), an American missionary, compared Zhang Zai's Theory of Yuanqi and Cartesian's Ether Theory, put forward that the Cartesian's Ether Theory may come from Zhang Zai [10]. Ding Weiliang pointed out that Zhang Zai's Theory of Yuanqi must be from the country's oldest sacred book *Yi Jing*. "Couldn't some fragments of Chinese philosophy translated by Jesuit missionaries have fallen into the hands of Descartes, a student of Lafleur College?" "If this is confirmed," Ding wrote, "we may have to admit that the first impetus for the philosophical movement that began in France and swept through Europe came from 11th-century Chinese thinkers."

The speculation that Descartes Ether Theory may be from the ancient Chinese Yuanqi Theory is very likely to be true, although this speculation needs to be confirmed by further conclusive evidence. If examined from the thought relations, the ancient Chinese Yuanqi Theory is indeed the forerunner of the Ether Theory of the modern science.

1. 3. 3. Huygens and Hooke's Wave Theory and Newton's Ambivalen Attitude to the Ether

Huygens (1629—1695) of the Netherlands and Hooker (1635—1703) of England were the believers in the Ether Theory of Descartes. Hooke first proposed the wave theory of light, considering that the light is a propagation process in the ether of uniform dispersive medium by the rapid vibration of small amplitude of luminous particles. He first put forward the idea that light waves are transverse waves. Huygens believed in the theory of Ether Vortex. Light, he argues, is the "state wave" of the ether medium: the ether medium as a whole is immobile, only its individual parts vibrate. The vibration state propagates in all directions through the ether. He proposed Huygens's principle and developed the wave theory of light in an all-round way. Huygens discovered the polarization phenomenon of light.

Newton (1642—1727) proposed the particle theory of light as opposed to the wave theory. Newton believed that light is a stream of particles moving according to the laws of mechanics and emitted from a light source. Newton is an atomist, who accepted atomism that the beginning of all things is the atom and the void space, which formed his absolute view of space and time. Newtonian's mechanics was the first negation of ether theory. But Newton's attitude to the ether was very contradictory and wavering. In his 1678 letter to Boyle, he gave a detailed account of the specific ideas for the ether, and expressed his belief that at last the action of some matter must be found to account for the phenomenon of gravity. After 1687, Newton easily explained the phenomena such as gravity, chemical affinity, cohesion, refraction and reflection of light particles by using the view of the attraction and exclusion of the action at a distance, so he was step by step closer to the view of the action at a distance. The recognition of action at a distance certainly negates the existence of the ether. However, Newton always had some reservations about action at a distance. In his 1692 letter to Bentley wrote: "That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws; but whether this agent be material or immaterial, I have left open to the consideration of my readers."

1. 3. 4. The Decline of Ether theory in the 18th Century and the Revival and Development of Ether theory in 19th Century

The 18th century was the century of the decline of ether theory. After Newton, there was a heated debate between the viewpoint of action at a distance based on the premise of existence of void space and the viewpoint of contact action based on the premise of existence of ether. Since the law of gravity that has explained the motion of celestial bodies in the solar system has achieved great success, the idea of action at a distance gradually prevails. In optics area, because of Newton's immense prestige, and because of his followers' idolization and abuse of his authority, the particle theory of light prevailed, and the wave theory was suppressed, which made little progress for a century and a half.

By the end of the 18th century, the French completely abandoned the French Descartes' theory of ether theory and believed in the English Newton school's mechanics of action at a distance. However, at the same time, the English inherited the Ether Theory of Descartes in France, mainly because of the British research work, and the ether theory was revived and developed in the 19th century.

Thomas Young (1773 — 1829), an Englishman, carried out a double-slit interference experiment and discovered the interference of light. He was the first to show the wave properties of light. The French Fresnel (1788—1827) supplemented Huygens principle with the principle of light interference, proposed Huygens-Fresnel Principle, and perfected the theory of light diffraction. Fresnel accepted Young's idea about transverse wave of light, and explained the interference of polarized light with this hypothesis, proved the transverse wave property of light, and put the wave theory of light into a new period.

Foucault's 1850 accurate measurements of the speed of light in air and water confirmed the wave theory prediction, delivering the final blow to the particle theory. Wave theory won what at the time seemed an undisputed victory. After repeated contests, wave theory finally established its position in physics, and ether as a carrier of light waves became the object of physics research.

1. 3. 5. 19th Century Mechanical Model of Ether and Maxwell's Electromagnetic Ether

The problem did not end there. The light wave was then understood to be a mechanical wave and, as Young and Fresnel discovered, it is a transverse wave. Elastic transverse waves can only travel through solids. The ether should be an elastic solid. This dealt a heavy blow to “ethereal fluidity”.

After Newton’s success, there was a trend of thought that all natural phenomena could be explained by laws of mechanics and ideas of mechanical motion. The defect of the ether theory in the 19th century is to understand and discuss the ether purely from the concept of mechanical movement. Physicists were racking their brains to build all sorts of mechanical models of the ether. Many additional assumptions and boundary conditions about the density and elasticity and others about the nature of ether were introduced by various ether theories with the aim of explaining various optical phenomena according to the laws of mechanics. However, it is always difficult to understand the ether from a purely mechanical point of view.

Electromagnetism, as a science, began to emerge after the middle of the 18th century. The earliest electromagnetic theory was also the theory of action at a distance, leaving no space for ether theory. The French Coulombs (1736—1806) and Amperes (1775—1836) followed Newton’ line, imitated the theoretical system of Newtonian mechanics, and established the law of the interaction between two stationary point charges or between current to current on the basis of their own experiments.

British scientists Faraday (1791—1867) and Maxwell (1831—1879) developed the electromagnetic field theory of short-range action or contact action, in contrast to the action at a distance theory in continental Europe.

Maxwell systematically summarized the previous achievements, put forward the hypothesis of vortex electric field and displacement current, and obtained a set of differential equations, which is Maxwell’s equations, to describe the general law of electromagnetic field. According to Maxwell’s equations, the theory of electromagnetic field is different from the theory of action at a distance. It is a theory of action at close range, or a theory of contact action, the electromagnetic action between objects is the propagating from a point in space to another point at infinitesimally small distance. In 1873, his great work *General Theory of Electromagnetism* published, it is a classic of systematic summary of all the research results of electromagnetic phenomena that so far human has done, including his own great contribution, it marks the establishment of complete electromagnetic theory, its scientific value can compare favorably with Newton’s *Mathematical Principles of Natural Philosophy* and Darwin’s *On the Origin of Species*.

Maxwell’s equations predicted the existence of electromagnetic waves that propagating at the light speed. In 1888, nine years after Maxwell’s death, the German Hertz (1857—1894) experiment confirmed the existence of electromagnetic wave and the identity of electromagnetic wave and light wave. This completely overturns the theory of action at a distance of electromagnetic. Faraday- Maxwell’s theory of electromagnetic fields won a decisive victory.

The announcement of the Hertz Experiment sent shock-waves through the scientific community. Today we are content to regard the Hertz experiment as the proof of Maxwell's theory, but at that time, the academic circles saw it as evidence that the ether really existed. This reasoning is not very different from what we infer today from the cloud chamber track about the existence of a new particle. For physicists at the end of the 19th century, the ether was already a reality.

Descartes regarded the ether as the origin of the material world, from which all materials were generated and developed. However, later westerners generally understood ether as a continuous medium permeating space in a narrow sense, and light or electromagnetic wave is a wave process in this ether medium. In order to describe and explain the propagation of light or electromagnetic fields in the ether, western physicists in the 19th century imagined various ethereal mechanical models, which were regarded as the medium of pure mechanical motion. In this way, the analysis of some important ideas in ancient China, for example, Yuanqi contains the unity of opposites between Yin and Yang, and qi condenses into tangible objects, qi scatters to the void space, this view of qi connects all the things in the universe to become a whole, is not involved or didn't get fully reflect in ether theory. It is always difficult to understand the ether from a purely mechanical point of view. With the creation of the special theory of relativity, the mechanical theory of the ether died out.

1. 4. The Comparison of Yuanqi Theory and Atom Theory

1. 4. 1. Ancient Civilizations of China and Greece

In the long process from barbarism age to civilization age, various nations in the world have produced their ancient civilizations in the natural geographical environment, social political and cultural environment in different parts of the world. They have experienced long labor practices in different environments, contacted nature closely, observed nature directly, and made speculative guesses about the nature, thus forming the Yuanqi Theory view of nature and Atomic Theory view of nature with both generalities and differences.

Ancient China was obviously in a closed natural geographical environment. Cold Siberia lies to the north, mountains to the west and southwest, and oceans to the south and southeast. Once a primitive human being lives here, it is difficult to leave. The great migrations of peoples that lasted in Europe for centuries, but it did not and could not have taken place in ancient China. It takes hundreds of years, thousands of years or even longer for a family name to flourish in a village. The ancient Chinese society was based on the family, and it was closely organized by the family property, family rules, family tree, clan hall, and a set of ethical norms of clan, and established the clan rule characterized by "family world". On the basis of fathers' legal system, a centralized state in an autocratic society was formed. In this social and political environment, the emphasis is on the concept of unity. "All over the world, there is no land not belongs to the emperor." Individuals can only dissolve in the clan, dissolve in the whole society. Chinese pre-Qin learning was humanist, with strong political and ethical color. It originated from the era of great changes in the late Zhou Dynasty, paid attention to the study of the relationship between people, always put the governance of society, the standard of family relations as their main subject.

The history of ancient Greek civilization began with the Aegean civilization. The so-called Aegean civilization refers to the civilization of the Aegean region. The region of Aegean Sea, including the Greek peninsula, the Aegean Sea and many islands in the sea and the western coastal area of Asia Minor peninsula, this is the geographical scope of ancient Greece. In the coastal regions of Greece and Asia Minor there were no fertile river basins or vast plains (the natural conditions of which were necessary for the establishment of centralized imperial organizations such as those of ancient India and China), only continuous mountains dividing the land into many small pieces. The Aegean Sea is dotted with more than 480 large and small islands, among which Crete in the south is the largest. Aegean Sea likes a "thousand island lake", where the sea and land are crisscrossed, and boat transport is convenient, the scenery of the mountains and water, the opening people to think.

The earliest slavery countries appeared on Crete Island in 2000 BC, and the ancient country existed for about 800 years in the Aegean region. After Homer's era, the early Greek city-state of slavery formation period, the Greeks, which is based on the Aegean region of natural geographical environment, established more than 200 slavery cities-state, every city in a city-state was as the center, including several nearby villages, land was no more than 100 miles, and population was no more than tens of thousands, political and economic independence, typical of a small country with small population. City-state pursued the democratic system of sovereignty in the people, and citizens directly participate in the governance of the city-state. Each city-state strengthened the political and military connection through the alliance way, and takes the bigger city-state as the alliance leader. The ancient Greek society was composed of city-states, each of which was composed of monogamous families, and the whole society could be said to be a loose group of individuals, just as the Aegean Sea was composed of many islands. In the sociopolitical realm, the idea of the individual prevails. The Greeks loved independence and freedom. Each person has an independent personality. Society was formed by the collection of individual free will, just as atoms form matter. The core of the ancient Greek worldview and morality was individuality. Greek learning was naturalistic, which originates from the activities of free thinking of observing and thinking about nature with curiosity and calmness. It pays attention to the study of natural laws, and always regards the exploration of natural mysteries and the pursuit of universal principles of nature as major independent subjects. It was in such a geographical environment and human social environment that the ancient Greek atomism came into being.

1. 4. 2. Two Materialist Views of Nature

The Yuanqi Theory and the Atomic Theory are two main forms of the natural view of simple materialism in ancient times. Both Yuanqi Theory and Atomism deny that the world is created by God and admit its objectivity and materiality, acknowledging the immortality of matter and the infinity of the universe; acknowledging that matter is in the process of eternal and regular movement. These both theories have the characteristics of intuitiveness, speculation and conjecture.

Chinese ancient simple materialism tried to find the unity of the material world from some unformed materials, and finally thought that the continuous Yuanqi is the origin of the world. The simple materialism of ancient Greece tried to find the unity of the material world from the materials with a fixed form, and finally thought that everything was composed of discontinuous atoms, which moved in the void space. The beginning of all things is atoms and void spaces with emptiness. Yuanqi and atom are not concrete material forms, but material concepts of the abstract thinking, which are the highest categories of each of the two philosophies respectively.

Obviously, the Yuanqi theory and the atom theory are two theoretical forms with significant differences, which are mainly manifested in the following aspects. (1) Wholeness and individuality: Yuanqi are a wholeness material that is omnipresent, all-embracing and boundless that pervades the universe. Atom is the smallest unit of an object, an indivisible individual or particle. (2) Continuity and discontinuity: the yuanqi of Yuanqi Theory is the material form of continuity; Atoms exist in the void space, atoms move in the void space, and each atom is separated by the void space. (3) Invisibility and visibility: yuanqi are the material existence without image and intangible, from which the qi without image and intangible produces all things in the world with image and tangible. Atoms have different shapes, sizes, sequences, positions, weights, etc. (4) Function and structure: the Yuanqi Theory emphasizes the function of yuanqi. The movement and changes of the world are caused by the movement and changes of yuanqi, as to how the invisible yuanqi produces various things, the Yuanqi Theory seldom talks about; Atomic Theory emphasizes the structure of the world. It holds that everything in the world is made up of atoms, the atoms with different shapes, orders, positions and weights combine into all kinds of different things. (5) Internal cause theory and external cause theory: the Yuanqi Theory holds that the fundamental reason for the movement and changes of qi lies in its internal contradiction, and qi is a unity containing the two opposites of Yin and Yang; Atomic Theory regards atoms as absolutely substantial and inseparable primitive particles, canceling the inherent contradiction of atoms. Atoms make pure mechanical displacement movement in the void space, which is caused by the collision between atoms and comes from external causes. These differences determine the different processes of the development of Chinese and Western philosophy and even natural science.

1. 4. 3. The Strengths and Weaknesses of Atomic Theory and Yuanqi Theory

The strength of ancient Greek Atomic Theory lies in its structural concept of matter, which holds that everything is composed of atoms with different shapes, orders, positions and weights, and mechanically fit together to form various things, thus resulting in differences in their properties. This speculation has gone beyond the simple understanding and perceptual intuition of the natural attributes of things, rising to the rational analysis of the structural elements and internal structure of things. Atomic Theory, as the theory of material structure, provides an excellent theoretical model for revealing the hierarchy and characteristics of material system. This is beyond the reach of the ancient Yuanqi Theory in China.

The ancient Greek atomism promoted people's research on the analysis of the material world and formed the rational analysis method in western science. It is evident that only through the analysis of its parts and its elements, then people can understand the whole nature of the world to a higher level. Therefore, ancient Greek atomic theory played an important historical role in promoting the development of modern science.

In fact, Yuanqi theory philosophy can admit the existence of microscopic particles in its own theoretical framework, thus accommodating the concept of microscopic particle structure of matter. To this end, as long as the particle could be understood as a kind of structure formed by the yuanqi condensed. However, it is a pity that although there are such thoughts in the ancient history of Chinese philosophy, it has not been able to form a clear point of view. The Yuanqi Theory failed to accommodate the structural concept of the tangible matter is a structure of microscopic particles, and thus Yuanqi theory does nothing to discuss the structure and nature of matter.

The Yuanqi theory stays in generally and roughly understanding and guessing of things as a whole, although the thinking of this understanding is generally correct. But it is impossible to know the essence of things in depth by neglecting the detailed anatomy and analysis of the details, structures, characteristics, mechanisms and causal links of specific things. The thought inertia of yuanqi theory neglects the application of analytical method, and it is difficult to promote the scientific breakthrough.

The associated with analytical method is the scientific experimental methods. People artificially control conditions according to predetermined purposes by means of instruments and equipment and other physical means, so that natural processes emerge in a pure form in a specific environment free from the interference of accidental, secondary and irrelevant factors, so as to conduct fine observation on them to obtain scientific facts and conclusions. That's the science experiment. Francis Bacon, the ancestor of modern British materialism, regarded scientific experiment as the basic method of understanding nature. The scientific experiments gradually occupy an important position in Europe, and promoting the progress and development of science. However, the ancient Chinese Yuanqi Theory stayed on to explain all kinds of natural phenomena in general and vaguely by using the concepts of yin and yang opposition, which gave people a kind of spiritual satisfaction. In fact, they did not say and answer any questions, resulting in a habit and inertia of being lazy in the experiment. Despising experiments and not being good at them is a common problem in Chinese academia for a long time. Until the Ming and Qing dynasties in China, scientific experimental methods were still in childbirth. This is also one of the important reasons why modern science and technology cannot come into being in China.

While atomic theory has made great achievements, its limitations are gradually and obviously exposed. The view of nature of the Atomic Theory contains isolated static views, such as (1) the existence of absolute void space; (2) absolute discontinuities between atoms; (3) exogenous theory of atomic motion; (4) the inseparability and immutability of atoms. Those seriously hinder the development of natural science. On each of these points, the Yuanqi theory is far superior to the atomic theory. Compared with the atomic theory, the Yuanqi theory reflects the dialectics of nature itself more profoundly.

The atomism acknowledges the existence of the void space with emptiness. What is the void space with emptiness? "That is a space, in which nothing can be touched." [5] (p.18) The void space of the Atomic Theory is a space where there is nothing at all. This is the way, for the ancient Greek atomists, as well as others such as Aristotle and Hegel, to understand it. Does the void space have to exist? According to atomism, "if there is no space, place, that we call void space, then the objects have nowhere to go and cannot move at all." [5] (p.23) The objects can move because there is void space between them. The void space is an essential condition of the atoms motion. Since the atoms are in motion, the void space with emptiness as a necessary condition for motion is also real.

As far back as ancient Greek times, Aristotle (384 BC—322 BC) rejected the atomism, especially the existence of void space with emptiness. Aristotle is the most important representative of ancient Greek civilization. He was a great man who collected all the knowledge of ancient Greece. Aristotle said, "There can be change in the fullness of space, and even if there is no void space between objects to separate them, they can change places with each other." "In the void space," he added, "the motion is canceled, and in the void space there is only a universal stillness." [7] (320-321)

Different from atomism, Yuanqi Theory put forward the viewpoint that "the void space is qi" or "the intangible universe is qi".

According to the atomic theory, the inside of an atom is absolutely full, absolutely continuous, and indivisible, while around it there is nothing, an absolute void space. In this way, the atom is completely disconnected from the outside world and has no connection whatsoever. It is a unit of matter isolated existence. The natural view of Atomic Theory disconnects the continuity and discontinuity of matter and inevitably meets great theoretical difficulties.

According to the Yuanqi theory, the invisible continuous qi (the universe's qi, floating qi) and the tangible discontinuous objects exist simultaneously. The tangible objects can enter into the invisible qi, and the qi is full of the objects. In the continuity there are discontinuities, in the discontinuities there are continuities, the two are in motion and changes and mutual transformation, and the whole material world constitutes an organic whole. The view of nature of the Yuanqi Theory reflects the unity of opposites between material continuity and discontinuity.

Atomism holds that the atom is in motion and changes, but that the atom itself is an indivisible and unchangeable object that lost its inner source of motion; All the motion and changes refer only to the displacement of atoms and their union and separation; Atoms move because they collide with each other. This is the externalism of atomic motion and the invariance of atoms. It can be assumed that if the atoms collide inelastic, then the momentum of their motion will be gradually lost, and the result, as Aristotle put it, will be "a universal stillness in the void space."

Different from the atomism, the yuanqi theory holds that the whole material world is the qi always moving and changing, and both invisible qi and tangible objects are moving and changing and constantly changing their forms of existence.

The Yuanqi Theory, with its basic characteristics of continuous material origin, qi's change in prevalence to produce new things and never stop, the unity of opposites of Yin and Yang and the holistic view of organic connection, gives a complete picture of the material motion changes and its interaction, which reflects the dialectics of nature itself more profoundly than the atomism of ancient Greece. Glory Contribution

He Zuoxiu, who first pointed out the importance of ancient Chinese theory of yuanqi in modern science, said it was a glorious contribution of ancient Chinese thinkers, "the study of the general motion of the universe, or the study of certain details, Yuanqi is beyond the reach of ancient Greek atomism." [11] Perhaps because of this, it can only be seen at a higher stage of scientific development.

It is very clear that it is very wrong to totally affirm or deny Chinese or western traditional culture. The attitude we should take is to stand at the new height of historical development, make a concrete analysis of various traditional cultures, absorb the essence, eliminate the dross, foster strengths and circumvent weaknesses, learn from each other, integrate Chinese and Western cultures, and strive to create a more excellent human culture. Involving our topic, we absorb the theoretical wisdom and philosophical enlightenment of ancient Chinese natural view of Yuanqi theory and ancient Greek natural view of Atomic Theory, avoid their limitations and defects, and establish a new scientific view of nature based on the rich research results of modern natural science. This is a great new synthesis. This is the task before today's scientists and thinkers.

1. 5. The View of Nature of Atom-Yuanqi Theory and The Aggregated-Dispersed States Natural Images

The form of matter is varied and infinitely diverse, from micro-particles to huge celestial bodies, from inorganic to organic, from single-celled organisms to human beings, all of which are concrete forms of matter. They have rich and colorful connotations. In this section, we first put forward and demonstrated that the dispersed state and the aggregated state are the two most basic forms of matter. Finally, we expound a new scientific view of nature, i.e., the Natural View of Atom-Yuanqi Theory, which depicts the aggregated-dispersed states natural images of the material world.

1. 5. 1. Amazing Scientific Facts

In order to demonstrate the most basic forms of matter, let us briefly state some facts that modern science has established.

Generally speaking, macroscopic objects are composed of atoms and molecules, and atoms and molecules are composed of elementary particles. Such words are written in various textbooks. It is both right and wrong, or at least inaccurate and incomplete.

Take the simplest atom, the hydrogen atom as an example. The first Bohr orbit of the hydrogen atom has a radius of 0.529×10^{-8} cm as measured by modern physics experiments, and its component, i.e., the proton, has a scale of about 1 Fermi $=10^{-13}$ cm, and the electron has a scale of less than 1×10^{-16} cm. According to Bohr's atomic theory, in a stable hydrogen atom, an electron goes around the nucleus i.e., the proton, at the radius of its first Bohr orbit; According to quantum mechanics, the distribution of electrons outside the nucleus is described by probability clouds, and the radius of the first Bohr orbital corresponds to the position where the electron distribution has the highest probability density. If the above data are magnified to 10^{13} times, it can be likened to: the electron is like a small dust less than 1 micron, the proton is like a glass ball with a diameter of 1 centimeter, and the electron rotates around the proton with a diameter of about 1 kilometer. Between the proton and the electron, there is a wide dispersion state matter, under the action of the two charged particles, i.e., the proton and the electron, which present the state of electric field. Without the intermediation of these dispersion substances, it is impossible for electrons and protons to combine into hydrogen atoms. Indeed, the size of the particles that make up the hydrogen atom (that is, electrons and protons) is so small as to be almost negligible compared with the distance between the particles or the scale of the hydrogen atom. The resting mass of proton, electron and hydrogen atom (according to the data in 2006) was respectively $Mp=1.672621637\times10^{-24}$ grams, $Me= 9.10938215\times10^{-28}$ grams, and $M_H = 1.673532831\times10^{-24}$ grams. From the mass of the hydrogen atom minus the sum of the mass of the proton and the electron, we see that the mass of the dispersion state matter is almost negligible.

Other atoms have nothing more than a few more nucleons inside and a few more electrons outside. There has been no fundamental change.

Neutron mass $Mn=1.674927211\times10^{-24}$ grams, which is close to proton mass. Proton and neutron have a mass density of about 10^{15} grams of cm^{-3}, or a billion tons per cubic centimeter, which is the equivalent to the density of compressing the entire Himalayas (on average 0.7 kilometers high, 100 kilometers wide, 1,500 kilometers long, and 3 tons per cubic meter) into a small food box (about 1 cubic meter in size). That's the nuclear density.

Look at the atmosphere around the earth. At one atmosphere pressure and room temperature (such as 25^0C), the air molecular density is about 3.5×10^{19} cm^{-3}. With the best vacuum technology, the best vacuum available is usually 10^{-8} torr (1 torr is 1/760 of one atmospheric pressure) and the molecular density is about $3.3\times 10^9 cm^{-3}$. That is to say, there are also 3.3 billion air molecules per cubic centimeter.

The vast expanse of interstellar space has a much lower molecular density and is almost completely empty. In fact, there are also physical particles and radiation. The interstellar medium is primarily hydrogen and helium (hydrogen being the highest, helium the closest), with a relative mass of more than 95 percent and a few heavy elements (less than a few percent). Very low particle density, about one particle per cubic centimeter or less; The radiation field is highly diluted, with an average density of 1 electron volt per cubic centimeter, (converted to photon) or less than 1 photon per cubic centimeter. The temperature of the interstellar medium is very low, close to absolute zero, a few degrees kelvin.

Small perturbations in density produce interstellar aerial clouds due to gravity. The mean number density of atoms in the nebula is roughly 10 cm^{-3}. Individual gas clouds can reach thousands of atoms per cubic centimeter, or even more. When the number density is more than 100 cm^{-3} and the motion temperature is low, hydrogen atoms combine to form hydrogen molecules. Stars are formed in molecular clouds. The mass and scale of a molecular cloud are large. The mass is measured by the mass of the sun, and the scale is measured by light year. The temperature is about 10 K. Molecular cloud due to the gravity contraction, gravitational potential energy translates into kinetic energy and heat energy, its density increasing, the temperature rising, plus a variety of complex physical processes, such as convection, rotation, radiation, magnetic field, after millions of years or longer of gravitational contraction and bipolar mass outflow process, finally evolved into a star.

After the nuclear fuel burns out and experiences an outer layer explosion, it collapses towards the center under the strong gravity. The collapsed celestial body has a density of up to 10^{15} grams cm^{-3}, the nuclear density described above. This is a neutron star. Pulsars are neutron stars that spin rapidly and have a strong magnetic field.

1. 5. 2. Aggregated State and Dispersed State

Although the material forms in nature are infinitely diverse and each material form has its own particularity, many different material forms have commonalities in some basic characteristics. On the basis of in-depth consideration of modern scientific achievements and in accordance with modern materialist philosophy, I believe that all material forms in nature can be summed up into two basic forms, i.e., dispersion state and aggregation state.

First, discuss the problem of "vacuum is not empty".

The void space of atomic theory in ancient Greece was a void space of nothing. Newton accepted the idea that all things were based on atoms and void space, forming his absolute view of space and time. However, whether the spaces between atoms or objects and celestial bodies are void spaces with nothing, or is ether extensiveness, Newton's attitude is very contradictory and wavering.

Modern physics in the 20th century proved conclusively that there is no absolute void space; and vacuum is not empty, vacuum has complex properties and rich connotations, it is actually a form of material existence. Many articles elaborate on the idea that a vacuum is not empty. A vacuum is no shape and no image, low energy density and continuous material existence. Vacuum is equivalent to the qi in the intangible universe of Yuanqi theory, which is also equivalent of Laozi's Tao.

Secondly, discuss the problem of field.

Newton did not propose the concept of gravitational field, and he thought that gravitational interaction is a kind of action at a distance. Faraday and Maxwell developed and established the theory of electromagnetic field by describing the interaction between charged bodies with electric fields and magnetic fields. The electromagnetic wave experiment done by Hertz in 1888 proves the correctness of the electromagnetic field theory. The development of modern physics reveals the objective reality of electromagnetic field.

In modern physics, there are various fields, electric field, magnetic field and gravitational field. In quantum field theory, a kind of particle has a corresponding field, and the particle is the excited state of the corresponding field. For example, the photon is an excited state of an electromagnetic field, and the meson is an excited state of a meson field, and so on. At any point in space, you can have all kinds of fields at the same time. All the fields are considered to be mutually accessible substances.

According to the ancient Chinese Yuanqi Theory, meanwhile, according to the principle of thinking unity and the principle of logical simplicity, various fields should be regarded as the different manifestation forms and the different attributes of the unified field matter (called the dispersed-state matter). This is a very natural understanding. To this day, this view has not been popularized among the public. But, in fact, Maxwell held this view from the beginning, and he thought that the electromagnetic field was just an excited state of the moving ether. Later, the progress of physics shows that，comparing the view that there are all kinds of fields and that all kinds of fields are mutually accessible， the view of unified field is closer to depicting the true face of nature.

Einstein believed in a unified field. Einstein's unified field is the common origin and common basis of all known fields (first of all, gravitational field and electromagnetic field), continuously fills the whole space, and all known fields are only its different manifestations and different attributes. Not only that, Einstein took a big step forward, believing that physical particles could be "seen as particularly strong regions of field in the space." [12]

Einstein's point of view above is nothing but a modern expression of the idea of Yuanqi Theory "qi condenses into a tangible object". We can see that, going back to the source and comparing the thought of unified field theory with the thought of ancient Chinese Yuanqi Theory, we can assert that: The unified field theory is the manifestation form of the natural view of Yuanqi Theory in modern physics; Yuanqi is equivalent to the unified field. The view of nature of Yuanqi theory is the thought forerunner of modern unified field theory.

If Yuanqi Theory regards particles as a structure formed by the condensation of the yuanqi, and regards particles as self-organization phenomenon or energy condensation area of the yuanqi or the unified field, thus, it will allow existence of micro-particles to be recognized in its own theoretical framework. To establish this point of view is to set a bridge between the natural view of primordial qi theory and the natural view of atomic theory.

According to the point of view of the thorough unified field theory, continuous dispersion matter is widely extended as the whole space, which is the common origin and common basis of various known fields. All known fields, first of all gravitational fields and electromagnetic fields, only are the different manifestations and different attributes of a unified field. The AB and AC effects provide theoretical and experimental support for this idea (The description of these two effects is abbreviated).

1. 5. 3. The Aggregated-Dispersed States Natural Images

The development of modern science, first of all, modern physics, provides people with more and more accurate and rich understanding of nature, which reveals the picture of the material world and shows the confluence trend of ancient Chinese Yuanqi Theory and ancient Greek Atomic Theory. Our task is to base on the abundant materials provided by the development of modern science, to combine the natural views of ancient Chinese Yuanqi Theory and ancient Greek atomic theory, and to form a new View of Nature of Atomic-Yuanqi Theory, which depicts the aggregated-dispersed states natural images of the material world.

From 1990 to 1993, I successively published several papers to illustrate this understanding. [13, 14, 15] The two monographs [16, 17] also expound this new view of nature. This new natural image of modern science is summarized here.

> The world is a continuous material world, and the Yuanqi field (equivalent to the unified field) is the origin of the continuous material world, which exists in two different forms, i.e., the dispersed state and the aggregated state. The dispersed state is the natural state that the Yuanqi field is dispersed without gathering, unformed quality, invisible and intangible, and low energy density, while the aggregated state is the excited state or energy condensation zone in which the Yuanqi field gathers to have forms, visible and tangible and with high energy density.
>
> Compared with the vacuum created on the earth by humans (more than 3.3 billion air molecules per cubic centimeter volume) an interstellar space has a much lower molecular density or radiation density. It is a complete vacuum. The word "vacuum" is easily taken literally to mean a void space with nothing, but in fact there is no void space with nothing. Interstellar space is primarily dispersed-state matter, a particular form of material motion with the lowest energy density.
>
> There is also a dispersed-state matter that is the field associated with particles (association field), in general, it is always with particles together, and at the same time to produce and disappear, can be regarded as epitaxial part of micro-particle. The aggregated-state particles aggregate most of the mass and energy.
>
> In the microcosm and macrocosm composed of atoms and molecules, to compare with the aggregated-state matter, the dispersed-state matter disperses and extends to most of the space, and the size of the aggregated-state particles is as small as almost negligible. To compare with the dispersed-state matter, the aggregated-state particles gather most of the mass and energy, and the mass and energy of the dispersed-state matter are as small as almost negligible. For the vast expanse of interstellar space and the universe as a whole, not only is the size of the matter in the aggregated state more negligible, but the mass and energy of the dispersed-state matter may account for a greater proportion than that of the aggregated-state matter.
>
> Physical particles are mainly aggregated-state matter. As a whole, the particle itself is not a uniform and single organization, it is separable, and it is a unity of the

dispersed-state and aggregated-state matter on a smaller scale. Therefore, the microscopic particles are self-organizing phenomenon of the yuanqi field in the super-microscopic world.

In the structure of matter of different levels and scales, the dispersed-state matter is the medium of interaction and interrelation between the aggregated-state matters of different levels. Atoms and molecules are a unity of the dispersed-state matter and the aggregated-state particles (i.e., electrons, protons, neutrons, etc.). Ordinary the macroscopic objects are nothing more than a unity of the dispersed-stat field and the aggregated-state particle. Only through the intermediate contact of the dispersed-state field, the atoms and molecules can only form macroscopic objects and then form various celestial systems.

Super-dense states (such as black holes, neutron stars, pseudo-vacuum states, etc.) are another type of matter in aggregated state. They are characterized by the extremely great density of matter, whose atomic structure is destroyed by the huge gravitational force. Neutron stars have densities of more than 10^{15} grams per cubic centimeter, or more than the nuclear density. A black hole, if confirmed to exist, is denser, and its massive gravitational squeezing has stripped it of all information about the structure of matter (internal structure, the number of leptons, the number of baryons), leaving only three observable measurements, i.e., mass, charge and angular momentum. Super-dense states exist in the space and are the product at a certain stage of the evolution of stars or universe.

As the dispersed-state matters in the background space, they can be called the vacuum background field or yuanqi background field. The vacuum background field is by no means of a homogeneous single, it is not fixed and stationary. At the level of ultra-microscopic, the background field also has a variety of forms and structures, with sharp fluctuations, ever-changing and rich and colorful connotations. Its complexity is no less than that of micro-particles and their complexes.

The dispersed-state matter is like an ocean, and it is the medium of the interaction and the interrelation with each other of the aggregated-state particles that scatter and present in this ocean. At the same time, it is the background of the occurrence of all material processes. All material processes do not occur outside this background, but within this background. For example, electromagnetic fields and gravitational fields are only one form or one attribute of this dispersion state matter. The continuous dispersion state matter is the qi of the intangible universe in the ancient Chinese yuanqi theory. Going back further, it is Laozi’s “tao” or “nothing”, which is a kind of integrated existence of matter without shape and image.

Relative to the space-time scale of the universe, the static and local investigations are made. Due to the antagonism between the two poles of exclusion and attraction, the dispersed-state matters and aggregated-state matters interact and transform each other violently. The background field of the yuanqi fluctuates sharply to form virtual particles, which absorb a certain amount of energy and turn into real particles. The positive and negative particles annihilate and change into a vacuum dispersion state; the spin motion and overall motion of particles are closely related to the motion of the association field and background field, and interact with and influence each other. The aggregated-state particles are energy energy exciters or energy condensers in the ocean of the dispersed-state matter. The dispersed-state matter connects everything in the world into a whole.

The above statements is the view of nature of the atom-yuanqi theory, and it depicts the aggregated-dispersed states natural images. It is the clear and systematic expression of the new natural view revealed by the development of modern science. This perspective will significantly deepen our understanding of the material world.

The most important problem is that one cannot just remember particles, particles, particles. In fact, if among the particles there were not the dispersed-state matter, which extensiveness is much greater than the particles', all the particles would be like a plate of scattered sand.

According to Aristotle's definition, the origin of the world is an ultimate being distinct from any concrete physical form, a primitive non-creation, and the initial limit of all motions and changes, and it is the elements of the foundation of everything, the original matter or the brick of the universe. What is the origin of the world? From ancient times to the present, many philosophers and scientists have made long, extensive and in-depth explorations. There are many answers to the question. This is a big subject of different opinions.

According to ancient Chinese yuanqi theory, continuous yuanqi is the origin of all things in the world. If modern science develops further and the unified field theory becomes a complete success, it means that the world has a unique origin: "The Yuanqi field exists in two different forms, i.e., dispersed state and aggregated state. The Yuanqi Field (equivalent to the uniform field) is the only origin of the world."

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Chapter 2

What is Space? What is Time?
—The essence of space and time

What is space? What is time? This is the simplest but also the most important problem we face. A work on space-time theory must answer this question.

What is space? Aristotle, the learned and versatile scholar of ancient Greece, said [1] (p.103): "Just as a container is a space that can be moved, so space is a container that cannot be moved." Is that the right answer? If something is wrong, where is the mistake?

What is time? Franklin and Lu Xun said, "Time is life." Balzac said, "Time is wealth." As businessmen say, "Time is money." These statements are clearly only literary descriptions of the phenomena that occur at a given time. What is time? 1600 years ago, the Roman theologian Saint Augustine gave a sly but helpless answer. He said: "When no one asks me that question, I know the answer, but once I try to explain, I don't know."

For many serious modern physicists, "what is space and time?" is thought to be a question that humans have asked millions of times but haven't yet to answer. To many philosophers, "what is space and time" is always spoken that it is clear and confident, but if somebody does not feel there is nothing wrong with the saying that "matter can only move within time and space" (Lenin's statement), he must have a vague understanding of it in his heart.

To mark the centenary of Einstein's special theory of relativity, the United Nations has designated 2005 as the world year of physics. In 2005, a commemorative paper in the Chinese journal *Physics* was entitled "Hourglass of Time", and its conclusion said: "Time is a concept that I understand that I don't understand, but I wish I could explain what I don't understand." [2]

This chapter describes the historical development of the concept of space and time, from the early human concept of space and time, Newton's absolute concept of space and time, to Einstein's concept of space and time of relativity, we expect and strive to finally give a clear and definite answer to the philosophical and scientific question "what space is and what time is" and give a clear introduction to the space-time concept of Standard Space-time Theory.

2. 1. Early Human's Concept of Space and Time

Human is the product and the highest stage of the long-term development of nature. Through productive labor, human produces the material means of livelihood necessary for his own survival. In the process of understanding and transforming the world, we have formed our views on nature. The so-called view of nature refers to people's fundamental views on nature, including the fundamental understanding of the origin of the world and the law of world evolution. People's concept of space and time is an important part of the view of nature.

In ancient China, the Period of Warring States, Shi Jiao said: "The four directions, up and down called Yu, since ancient to now called Zhou." The book *Changes* is the oldest classic in China. Its basic contents were completed in the early years of the Western Zhou Dynasty (about 1100 BC). Confucius (551 BC—479 BC) compiled the six classics, ranking the *Changes* as the first of them. The Book *Changes*, as a classic book on "variation", first affirms that all things in the universe are moving and changing. "Confucius looked at the river on the bank and said: time is like this rushing river, no matter day or night, it goes on and on."

The first chapter has stated that Laozi put forward the first complete philosophical system about the origin of the world [3]. The Core of Laozi's philosophy is "Tao". Laozi's Tao is the object that exists objectively, it is one integrated thing. It is the original materials to form all things. It is the origin of all things.

Laozi described "Tao" a lot. "Tao" cannot be seen, heard, or touched: "Those who cannot see are called yi, those who cannot hear are called xi, and those who cannot touch are called wei." "It is not shiny above and it is not dark underneath, and boundless and indescribable, return to invisibility." (In Chapter 14 of *Laozi*). The Tao, as a matter, is in a state of trance, but in a trance, it has an image, and produces all things; in a trance, it contains a very subtle spirit. Since ancient times, its name cannot be removed, according to it, to understand the creation of all things.

Tao is an invisible thing without shape and image, so Laozi's Tao is also called "wu (nothing)". "Nameless, is the beginning of heaven and earth." Laozi's "nothing" does not mean the absolute nothingness. It is just no shape and no image. It can never be seen or touched. Because of this, it is not restricted by the conditions of space and time, nor is it obstructed at all, and it presents at all times, it presents everywhere. It has become a great dominion over everything. Laozi's nothing is another expression of Tao. It is by no means an absolute nothingness with nothing, but an objective existence that is integrated and no shape and no image. It is the original materials to form all things of heaven and earth.

The above quoted Laozi's discussion is just a wonderful description of dispersion state matter and its mutual transformation with aggregation state matter. Of course, things should be explained according to the true order of history: the view of nature of atom-yuanqi theory and the natural image of aggregation state-dispersion state expounded in the first chapter is the inheritance and development of Laozi's thought.

Laozi did not make a direct discussion about space and time. However, according to Laozi's thought, space is naturally the extensiveness and coexistence of "Tao" and time is the motion and change of "Tao", i.e., "the cycling in motion, and never stop" of "Tao". According to Laozi's thought, of course, the existence of the absolute void space with nothingness is completely rejected.

Heraclitus (540 BC—480 BC) of ancient Greece believed that all things are in perpetual motion and change, "everything flows and nothing stays" [4] (p.17). Like his contemporary Confucius, he likened everything to a great river and declared that "one cannot step into the same river twice." [4] (p.27)

The ancient Greek atomism, founded by Leucippus (about 500 BC — 440 BC) and systematized by Democritus (about 460 BC — 370 BC), formed the first systematic and typical materialist school in the west. As stated in chapter 1, atomism holds that everything is made up of the smallest, indivisible particles known as atoms. What's in the space between the atoms? There is nothing with emptiness, a void space. Thus, "all things are based on atom and void space." [4] (p.96) Atoms move in void space, forming atomistic concepts of space and time.

Another idea about space and time, as opposed to the ancient Greek atomism, is that space is not void and the void space actually represents the extensiveness of a continuous dispersion medium. This is the basic concept of ancient Chinese Yuanqi Theory, also appeared in the 16th century French Descartes philosophy. The Chinese call this medium as "Yuanqi". Descartes calls it as "Ether". According to the ancient Chinese Yuanqi Theory: "The intangible universe is invisible, and its ontology is qi"; "Knowing the intangible universe that is qi, then there is not nothing"; "All void space is full of qi"; "Yin and Yang two-qies are fully filled with the universe, there is nothing else, also no gap"; "the intangible universe is not empty, fully occupied without surplus".

According to the ancient Chinese theory of yuanqi, qi, as a general material, is eternal and will not disappear and in constant and regular motion. The movement and change of qi are called "qihua". "Qi's changing everywhere all the time, and producing new things never stop", and that has made the very good summary to the "Qihua" viewpoint.

Wang Fuzhi at the end of Ming Dynasty and the beginning of Qing Dynasty developed the ancient Chinese yuanqi theory into a mature and complete form.

For the first time in human history, Aristotle (384 BC—322 BC) systematically studied and elaborated the problems of space and time, reaching a very high level, which was a milestone in the history of human cognition.

Aristotle is the most important representative of ancient Greek civilization. He was a polymath and encyclopedic scholar of ancient Greece. He was a great man who collected the knowledge of ancient Greece and was the greatest thinker, philosopher and scientist in ancient times. He was the founder of logic, physics, biology, politics, economics and ethics. In the hundreds and thousands of years since his death, no one has had such a systematic and comprehensive knowledge. Hegel said, "If there is such a thing as a so-called human teacher, Aristotle should be thought of as such a man."

In order to focus on the main points, Aristotle's understandings of space and time are summarized. Aristotle said: "Space is the immediate enveloping of a thing, and not its part." [1] (p.100) "just as a container is space that can be moved, space is a container that cannot be moved." [1] (p. 103) "Time cannot be separated from motion and changes." "Time is reflected through movement." What is exactly time? "Time is not motion, but making motion countable." [1] (p. 104, 125)

Aristotle rejected atomism, especially against the existence of void space with nothing. In the fourth chapter of his work *Physics* [1], he made a detailed study of space and time. According to Aristotle, things cannot leave space, while space can exist without things. What exactly is space? He gave the above answer. So, in fact, he believed that space and matter are separated from each other, space is like an immovable container, it is the place where objects exist and move.

Aristotle believed that time is not motion and change themselves. "Time is everywhere and everything equally. Second, change is always fast or slow, and time is not." But "time cannot be separated from motion and change." "All change and all movement are in time." [1] (p.135) "Time is not motion, but making motion countable." "Judge the amount of movement by time. Therefor time is a number." [1] (p. 125)

Aristotle put forward the concept of "now", revealing the continuity and discontinuity of time. He said: "The time is divided into 'before' and 'after' by 'now'." "Time is continuous because of 'now' and divided because of 'now'." "The 'now' is a link between the past time and the future time. It is also a limit of time: the beginning of the future time and the end of the past time.... Moreover the 'now', which separates time, is different from each other, and the 'now', which connects time, is always the same." "Obviously, there is no 'now' without time, and also there is no time without 'now'." "Just as the movement goes on and on, so does time."

In human history, for the first time, Aristotle made a systematic study and detailed exposition of the philosophy of space and time, which reached a quite high level and was a milestone in the history of human cognition. Historical limitations are inevitable and obvious. It can be said that it is a simple understanding of space and time obtained by human beings from the initial intuitive investigation, and it is a materialist absolute view of space and time that separates space and time from matter and its movement.

In contrast to materialism, idealism denies the objective reality of space and time. Objective idealists, such as Plato, regard space and time as derivatives of absolute ideas. Subjective idealists regard space and time as subjective forms or inner experiences of human perceptual intuition. To this, this book does not elaborate.

2. 2. Newton's Absolute View of Space and Time

Through two thousand years of time, Newton inherited the ideas of ancient Greece Democritus and Aristotle, and put forward the concept of absolute space and absolute time.

Newton in *Mathematical Principles of Natural Philosophy* [5] (hereinafter referred to as *Principles*, at the outset extremely refined language put forward a series of definitions, such as the quantity of matter (i.e., mass), the quantity of motion (i.e., momentum), inertia and outside force, etc. that "the terms unknown" at that time, and then puts forward the three laws of motion in the form of axioms, to the back of the narrative laid the foundation logic.

Newtonian mechanics discusses the motion state of an object and the change of its motion state, this description is inseparable from the reference frame. Newton's law of motion does not apply to all reference frame, the reference frame that Newton's law of motion applies to is called inertial reference frame by later generations. But what frame of reference is the inertial frame of reference that Newton's laws hold? The theoretical framework of Newtonian mechanics did not by itself provide a definitive answer. Newton was fully aware of this weak link in his theory. His solution was to introduce an objective criterion—absolute space and absolute time—to determine whether the state of things in the universe was static, uniform, straight, or accelerated.

In *Principles*, following eight definitions, Newton wrote his ideas about space, time, place, and motion in "Scholium". Newton wrote [5]:

> "I do not define time, space, place, and motion, as being well known to all. Only I must observe, that the common people conceive those quantities under no other

notions but from the relation they bear to sensible objects. And thence arise certain prejudices, for the removing of which it will be convenient to distinguish them into absolute and relative, true and apparent, mathematical and common."

"Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration; relative, apparent, and common time, is some sensible and external (whether accurate or uneven) measure of duration by the means of motion, which is commonly used instead of true time; such as an hour, a day, a month, a year."

"Absolute space, in its own nature, without relation to anything external, remains always similar and immovable. Relative space is some movable dimension or measure of the absolute spaces; which our senses determine by its position to bodies; and which is commonly taken for immovable space; such is the dimension of a subterraneous, an aerial or celestial space, determined by its position in respect of the earth. Absolute and relative spaces are the same in figure and magnitude; but they do not remain always numerically the same. For if the earth, for instance, moves, a space of our air, which relatively and in respect of the earth remains always the same, will at one time be one part of the absolute space into which the air passes; at another time it will be another part of the same, and so, absolutely understood, it will be continually changed."

"Place is a part of space which a body takes up, and is according to the space, either absolute or relative."

"Absolute motion is the translation of a body from one absolute place into another; and relative motion, the translation from one relative place into another."

"The real, absolute rest is the continuance of the body in the same part of that immovable space."

This is Newton's absolute view of space and time. In modern language, Newton's absolute view of space and time can be divided into the following three elements:

(1) The objective reality of space and time: Newton recognized the objective reality of space and time, and admitted that space and time are the existence forms of moving matter.

(2) The concept of absolute time and absolute space: absolute time is a continuous and uniform passage of itself, and absolute space is uniform everywhere and never moves.

(3) The irrelevance between space and time and the movement of matter: absolute space and time have nothing to do with anything outside, and there is no connection of the passage of time and the nature of space with the movement of matter.

What exactly are absolute space and absolute time? The genius Newton, who was born more than 300 years ago, could not have said more.

As mentioned above (see chap.1, there has been an image of absolute space since ancient times, that is, the extensiveness of a continuous dispersion medium. This is the basic concept of ancient Chinese yuanqi theory, which also appeared in the "etheric vortex theory" of Descartes in the 16th century. In the view of Zhang Zai and Wang Fuzhi of China, (1) qi in the intangible universe, (2) floating qi with rising and floating in the sky, and (3) tangible objects with shape and image, are the three basic forms of physical existence, but the aggregation or dispersion, or tangible or intangible are only the results of qi's movements and changes. The dispersion state vacuum background field of no shape and no image, which is called "qi in the intangible universe" in the theory of yuanqi, constitutes the motion background and interaction medium of the tangible objects and macroscopic objects and celestial bodies. This is the picture of the absolute space.

Is Newtonian absolute space a void space with nothingness or a space filled with a continuous dispersion medium? Newton, in *Principle*, gave no definitive answer.

Newton was an ardent atomist, who accepted the atomism thought that everything was based on atoms and the void space, forming his absolute view of space and time. Newtonian mechanics was the first negation of ether theory. But Newton's attitude to the ether, as described in chapter one, was ambivalent and vacillating. Newton said, "That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it."

Why was Newton so ambivalent and vacillating about the ether? That's easy to understand. Newton was a genius with great powers of thought and was heavily influenced by Aristotle. As mentioned earlier, atomism holds that the void space is an essential condition for atomic motion. Aristotle pointed out that there is no void space; and in the void space there is only a general stillness; Space is full of continuous matter everywhere. He said objects on the ground contain four elements: earth, fire, air and water. To this is added a fifth element, the heavenly substance. "Heaven is different from earth, fire, water and air. It is what the ancient called ether." Newton could not and was not able to ignore the great Aristotelian view.

Einstein commented, "Newton was most strongly opposed to the idea of a force that could transmit itself through void space. Newton wanted to use the Ether to attribute the action at a distance to the contact force."

Newton emphasized in *Principle* that absolute space is "real space", absolute time is "real time" and absolute motion is "real motion". Speaking of the "absolute place", Newton said, "But because the parts of (absolute) space cannot be seen, or distinguished from one another by our senses, therefore in their stead we use sensible measures of them.... But in philosophical disquisitions, we ought to abstract from our senses, and consider things themselves, distinct from what are only sensible measures of them." He believes that relative time, space and motion are only a "representation". In short, in Newton's view, absolute space, time and motion are all real things and real existence. However, we cannot directly perceive it through our senses, but can only understand and grasp it through the "representation" of relative time, space and motion perceived by our senses.

Newton introduced the concept of absolute space to judge the state of motion of the all things in Universe. The reference frame stationary with respect to the absolute space is the absolute inertial reference frame in which Newton's laws of motion hold true. Newton laid a solid foundation for his theory. But at the same time, it also meant that Newton's scientific thought actually went further, i. e, the absolute space filled by a continuous dispersive medium is taken for granted as the absolute reference frame.

It is safe to assume that Newton, in constructing his theory, had in his mind an idea of absolute space composed of the Ether or Plenum of no shape and no image, continuous dispersion medium. If we read Newton's *Principle* treatise on absolute space, time and motion, and relative space, time and motion written in the form of " Scholium" [5] (p.10-17), according to this view, everything becomes suddenly clear and understandable. Note my statement: according to Newton, the absolute space is an absolute inertial frame of reference, or absolute frame of reference for short. The discovery of cosmic microwave background radiation in the 1960s merely confirmed Newton's prediction of the absolute space and the absolute reference system.

Newton believed that rotation with respect to absolute space (i.e., absolute rotation) is observable. Newton proposed the famous rotating bucket experiment (Fig. 2.1) to observe and understand absolute rotation.

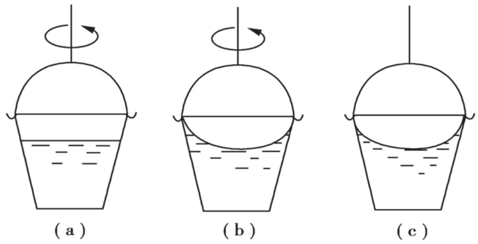

Fig. 2.1

The bucket of water is suspended from a long, twisted rope, and then let go. It is observed in turn: (a) at first the bucket rotates rapidly, but the water is almost stationary. The surface of the water is flat, exactly as it was before the bucket was turned, until enough time has passed for the viscous force to cause the water to rotate as well; (b) the surface of the water becomes concave paraboloid as it rotates with the bucket; (c) stop the bucket from rotating, but the water inside the bucket is still rotating, and the surface of the water remains a concave paraboloid. In stages (a) and (c), the water and the bucket move relative to each other, but the water surface of the (a) is horizontal while the water surface of the (c) is concave; In stages (b) and (c), the (b) water and the bucket have no relative motion, while the (c) water and the bucket have relative motion, but the water surface of the both is a concave paraboloid. Water moves away from its center and up the bucket wall to form a concave paraboloid, indicating the tendency of water to move away from the axis of rotation; Newton concluded from the above analysis that the relative motion of the water and the bucket was not the cause of the depression; The concave surface of the water shows the true absolute (that is, relative to the absolute space) rotational motion of water. "The difference between the effect of absolute motion and that of relative motion is the force that flies off the axis of rotation." This is the off-axis inclination force caused by the circular motion. Newton believed that absolute rotation could be determined.

Absolute rotation is observable; Observing absolute rotation can reveal the existence of absolute space. This is an important idea of Newton. It is of great value not only in mechanics but also in other fields of physics such as electromagnetism. The phenomenon of monopole magnetic induction shows the existence of background space through the rotation of axisymmetric cylindrical permanent magnet. We will discuss this in Chap. 9.

The above discussion indicates that the main parts of Newton's view of space and time, i.e., the basic concepts of its first and second element, are all correct, although in today's view it needs further deepening and more accurate expression. As time progresses and scientific experiments become more sophisticated, it can be confirmed that ideas must be abandoned and changed is its third element, that is, the irrelevance of space and time to the movement of matter.

In fact, Newton did a series of experiments (such as the pendulum experiment) to discover the effect of absolute space (or ether) on the motion of matter. We now know that this effect is as small as to the order of u^2/c^2 magnitude, where u is the speed of motion, and c is the speed of light. Given the technology of three hundred years ago, Newton must have had zero results. Newton learned from his experiments that if the ether existed, it would have a negligible effect on the movement of physical matter. Ether, as an invisible dispersion substance with different properties, is not a common object, but constitutes the background of all material movements, and is also the medium of various interactions. But Newton's experiments failed to discover its effect on the movement of tangible matter.

Since it cannot be found that the ether as absolute space has any effect on the movement of physical matter, so Newton in his *Principle*, and then after the three laws of motion, corollary Ⅴ is given:

> The motions of bodies included in a given space are the same among themselves, whether that space is at rest, or moves uniformly forwards in a right line without any circular motion.

Newton wrote, “A clear proof of this we have from the experiment of a ship; where all motions happen after the same manner, whether the ship is at rest, or is carried uniformly forwards in a right line.” [5] This is Galileo’s principle of mechanical relativity.

In Newtonian mechanics, according to Newton’s absolute view of space and time and the principle of mechanical relativity, the Galileo transformation formula is obtained:

$$\left.\begin{aligned} x' &= x - vt, \\ y' &= y,\ z' = z, \\ t' &= t; \end{aligned}\right\} \tag{2.1}$$

$$\boldsymbol{u}' = \boldsymbol{u} - \boldsymbol{v},\ \ \boldsymbol{u}' = \boldsymbol{u} + \boldsymbol{v}\ . \tag{2.2}$$

Here (x, y, z, t) and (x', y', z', t') represent the space-time coordinates of an event in two inertial systems S and S' moving in a uniform straight line with relative to each other, and $\boldsymbol{v}$ represents the relative speed of the systems S to S' moving in the positive direction of their common x-axis. $\boldsymbol{u}, \boldsymbol{u}'$, represent the speed of a particle measured by systems S and S' respectively.

According to Newton’s absolute view of space and time and the corresponding Galileo transformation formula, the simultaneity of two events, the measurement results of the time interval of the motion process and the length of the object are all independent of the selection of the inertial reference frame. The same results are obtained in different inertial systems. This is the so-called the absolute nature of the measurement of time and space.

Newton put forward the concepts of “absolute time and absolute space” and “relative time and relative space”, which originally left a place for the relativity of space and time. However, Newton derived the principle of relativity from the third element of his concept of space and time， i.e., the irrelevance of space and time with the motion of matter, through the principle of relativity but to the pure absoluteness, forming his absolute concept of space and time.

It is natural to raise such a question: How can Newton’s absolute view of space-time be compatible with the principle of relativity? Now there is an answer to the question: although absolute time and absolute space are assumed to exist, the results of Newton’s experiments more than 300 years ago failed to find any effect of absolute space on the motion of tangible matter. In this case, Newton assumed that the laws of mechanics would have the same form in different inertial frames of uniform rectilinear motion.

As mentioned earlier, the observer of each inertial frame uses his own ruler and clock at rest with respect to the inertial coordinate system, to measure and determine the coordinates of the object's position and the time interval that has gone through by its motion and changes. The rulers and clocks used in different inertial systems are in different uniform and linear states of motion in relative the absolute space. In different inertial systems, relative space and relative time should be different as the different "representations" of absolute space and absolute time. However, since it has not been found that absolute space has any effect on the movement of tangible matter, according to the third element of Newton's absolute view of space and time, there is no connection of relative space and relative time with the movement of matter. Thus, as long as the rulers and clocks used in each inertial coordinate system have the same structure and the same accuracy (which, of course, can always be theoretically assumed), the measurement will not be affected in any way by the different uniform and linear states of motion in which the measurement is carried out. That is to say, the same results will be obtained regardless of the inertial frame. This is the absoluteness of the length measurement and the absoluteness of the time measurement.

It can be assumed that if Newton's experiments found that the absolute space (i.e., dispersion background space, or ether) had an impact on the movement of tangible matter, the natural result would surely be that the greater the speed of absolute movement of tangible matter, the greater the impact of the absolute space (i.e., dispersion background space, or ether) on it. Therefore, first of all, the laws of mechanics will not have the same form in different inertial frames of uniform and linear motion; Secondly, the absoluteness of length measurement and time measurement are not valid.

Now it seems that, strictly speaking, the principle of relativity, and the absoluteness of the measurement of length and the absoluteness of the measurement of time do not hold. The opposite conclusion is only a physical conclusion derived from the experimental results under the technical conditions at that time. The third element of Newton's space-time view reflects that it is impossible to discover the weak influence of absolute space-time on the movement of matter in the early stage of the development of science and technology, which results in the limitations of the times of scientific knowledge. This should not be exacted from predecessors.

The main part of Newton's view of space and time, i.e., its first and second elements of the basic concept are correct, still guide the path of scientific exploration. Theories of space and time that violate these two elements are bound to collapse. The development of scientific experiments (again Michelson-Morley experiment should be mentioned first) has revealed that the absoluteness of length measurement and time measurement couldn't be maintained. Lorenz etc. explained these new experimental facts with the length contraction hypothesis and the time delay hypothesis. It was on the right track. However, Lorentz's ether theory was not a systematic, thorough and mature theory, and violated the requirements of logical simplicity and logical self-coincidence principle. Einstein seized the weaknesses and opportunities, through the negative absolute space, actually recovered the images of the void space with nothingness, making the "principle of relativity" promotion to the extreme, and together with his hypothesis of artificial determinism, i.e., the principle of the constancy of the one-way speed of light, he included the knowledge of physics at the turn of the 19th-20th century in his interpretation and understanding, and created the relativistic theory of space and time, i.e., the special theory of relativity.

2. 3. The Idea of Space and Time in Special Theory of Relativity

Einstein founded his special theory of relativity from the principle of relativity and the principle of the constancy of the light speed.

In its modern general form, the principle of relativity can be stated as follows: the laws of physics have the same form in all inertial systems. In other words, all inertial systems are equivalent to the laws of physics that describe motion; there is no special superior inertial frame of reference, that is, the absolute frame of reference.

In its modern general form, the principle of the constancy of the light speed can be stated as follows: the speed of light in a vacuum equals a constant c in all inertial systems, independent of the orientation of space and the state of motion of the light source.

The special theory of relativity, founded by these two basic assumptions, fully reveals the relativity of the motion of matter, that is, the dependence between the space-time property of matter and the motion of matter, which is not revealed by Newtonian mechanics system, and is used to explain many experimental facts that cannot be explained by classical physics. Later, the special theory of relativity and quantum mechanics became the cornerstones of modern physics as a whole.

Einstein's relativity principle is the extension of the relativity principle of mechanics to the whole field of physics, while the principle of the constancy of the light speed is completely contrary to the Galileo's velocity transformation, so it is in complete conflict with Newton's mechanics. This shows that the classical Galileo transformation must be abandoned in the special theory of relativity, and the absolute space and time view of Newtonian mechanics must be changed.

It is easy to prove that this fundamental change is necessary to accept the principle of the constancy of the light speed. Consider a simple example and you can see this immediately.

Fig. 2.2 depicts an observing the propagation of spherical light waves in two inertial systems. Considering the two inertial systems S and S' (see Fig. 3.1), take the origin O and O' coincidence time of the two systems as the starting point of the two-system clock timing, i.e., $t_0 = t_0' = 0$. At the moment $t_0 = t_0' = 0$, the light source flashes at the origin of the two systems. Suppose the light travels along the positive direction of the axis Ox , at the moment t_1 in the propagation process, reaches the receiver p_1 located at $x_1 (x_1 > 0)$ in the S system. In the S' system, the observer records at the time t_1' and location $x_1' (x_1' > 0)$ of the event. According the principle of the constancy of the speed of light, in the S system, there is $x_1 / t_1 = c,\ t_1 = x_1 / c$; in S' system, there is $x_1' / t_1' = c,\ t_1' = x_1' / c$. Because the origin O' of S' system has moved some distance relative to the system S , there must be $x_1' < x_1$, $t_1' < t_1$ So, according to the special theory of relativity, time can't be absolute, and it can't be $t_1' = t_1$. The intuitive notion of absolute time $t' = t$ must be abandoned.

In the system S observation, at the moment t_1 of time, the light wave reaches the sphere of radius ct_1 , at this time some receivers such as p_1, p_2, p_3, p_4 located on the sphere receive the light signal at the same time. How does an observer in the system S' describe the above physical phenomena? Suppose that the optical signal recorded by the system S' observer reaches the receiver p_1 at the moment t_1' of time, where the coordinate is x_1' . When the optical signal is received p_1 , the origin O' of the S' system is closer to p_1 and farther apart p_3 . However, according to the principle of the constancy of the speed of light in all directions in the system S' is still c. Therefore, the observer of the system S' must assume that the light wave arrives p_1 earlier than it arrive p_3 . Thus, two simultaneous events observed in the system S (p_1 and p_3 received optical signals), do not appear to be simultaneous in the system S'. This means that the observer of the system S and the system S' see different spherical wave-fronts. This tells us directly that the absolute concept of simultaneity must be abandoned. that the observer of the system S and the system S' see different spherical wave-fronts.

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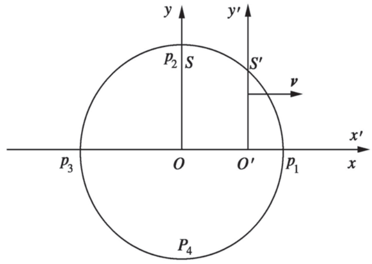

Fig. 2. 2

Each inertial reference frame should have its own measuring instrument, i.e., its own ruler and clock, and at least at the time of measurement, its own measuring ruler and clock should be in a static state relative to that inertial frame. The spatial length of an object is equal to the difference between the coordinate readings of the two end points of the object measured at the same time. Therefore, the measurement of spatial length also involves the concept of simultaneity. The principle of the constancy of the light speed leads to great changes in the concepts of time and simultaneity, and inevitably leads to the significant difference between the measurement of space scale and the whole concept of space.

In the special theory of relativity, according to the principles of relativity and the constancy of the speed of light, the measure of the time and space are not absolute, the simultaneity, time sequence, time interval and space length measurement, depending on which inertial reference frame the measurement is made in, different results will be obtained in different inertial reference frame.

In the special theory of relativity, starting from the principles of relativity and the constancy of the speed of light, consider the theory must satisfy (1) homogeneity assumption of space and time, and (2) the requirements of the correspondence principle, derived the transformation formula, i.e., in the two inertial system S and S' of relative uniform linear motion, the space and time coordinates of the same event must satisfy the Lorentz transformation

$$x' = \gamma(x - vt), \quad y' = y, \quad z' = z, \quad t' = \gamma(t - vx/c^2) \tag{2.3}$$

where $\boldsymbol{v}$ represents the motion velocity of the system S' relative to the system S along the positive direction of their common axis Ox , and

$$\beta = v/c, \quad \gamma = 1/\sqrt{1 - v^2/c^2} = 1/\sqrt{1 - \beta^2} \ . \tag{2.4}$$

According to the special theory of relativity, from Lorentz transformation formula can be obtained:

(1) The simultaneity is not absolute, but relative. That is to say, if two events occur simultaneously in the S system, the observer in the S' system measures that the two events do not generally occur simultaneously; the concept of simultaneity changes with the choice of inertial systems. This is the relativity of simultaneity.

(2) If the space-time coordinates of two events satisfy

$$(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2(t_2 - t_1)^2 > 0 \ . \tag{2.5}$$

Such two events are called events with a space-like interval; the time sequence of such events is relative, that is, its time sequence is related to the selection of inertial system, which can be reversed, and does not have absolute significance.

(3) When the object is stationary relative to the inertial system, the time interval of measuring the physical process of the object is the shortest, that is, the proper time is the shortest. The time interval of the same physical process measuring when an object moves in

the same inertial system is longer, the delay is γ times as long as the proper time. This is the relativity of the measure of time.

(4) A rigid rod is the longest when it is stationary in the inertial system, i.e. the proper length L_0 is the longest; when measuring the rod in motion in the same inertial system, the length L along its motion direction is shorter, which is shortened to γ^{-1} of the proper length L_0 .This is the relativity of the measurement of length. This means that the space-time properties of matter are dependent on the motion of matter. For example, the moving clock slows down as the moving speed increases, the length of the moving ruler decreases as the moving speed increases, and so on.

The time delay effect can be derived directly from the fundamental assumption, i.e., the principle of the constancy of the speed of light. The relativity of simultaneity and the effect of time delay are derived from the principle of the constancy of the speed of light.

To measure the length of a moving object in an inertial system, the coordinates of the two ends of the object must be measured at the same time. This simultaneity depends on the principle of the constancy of the speed of light to judge, so the length contraction effect is also the direct result of the relativity of simultaneity, and therefore the conclusion derived from the constancy of the speed of light hypothesis. In the special theory of relativity, the length contraction effect is a measurement effect derived from the assumption that the speed of light remains constant.

The analysis above in this section is clearly explained in literature [6].

The Sec. 3.3 of this book will make it clear that the assumption of the constancy of the light speed is an artificial convention and an excessive and counter-intuitive assumption. The effects of time delay and length contraction of the special theory of relativity are all based on the measurement effects caused by the assumption of the constancy of the light speed, and it does not mean that something has really happened to matter and to the process of its movement. What's more, the time-delay and the length-contraction effects of the special theory of relativity are relative and inverse effects. The special theory of relativity falls into complete, pure relativism!

It is impossible to do so without paying a price. The costs include the denial of the existence of absolute reference frames, the concept of the void space with nothingness, the limit of the light speed and Einstein's locality, all of which have been negated by experiments. This is outlined in the introduction to this book. This will be discussed in detail in Chapter 3.

Note that in Newtonian mechanics, Galileo's principle of relativity, coupled with the assumption of absolute reference frame, moves towards the pure absoluteness, forming Newton's absolute view of space and time. The real reason is that today we know that absolute space (i.e., dispersion background space, or ether) has a small effect as small as the magnitude of u^2/c^2 on the motion of objects. This means that the Galilean principle of relativity does not actually hold, that the laws of mechanics take different forms in different inertial systems, but the differences are extremely small to the level of the magnitude u^2/c^2. Given the level of technology three hundred years ago, such a difference would be impossible to detect and enter into theoretical discussions and practical applications.

The principal flaw in the special theory of relativity is the principle of relativity. In the theory of the special theory of relativity, the ether hypothesis is further abandoned and the relativity principle is raised to negate the existence of absolute reference system. Thus, the space without physical particles, without electromagnetic fields, becomes a void space with nothing. As will be described in Sec.3.3, all analyses show that all test experiments prove only that the constancy of the average circuit light speed, not the constancy of the one-way light speed. The problem is that by adding the principle of relativity to the principle of the constancy of the circuit average speed of light, it is possible to derive the conclusion that the one-way speed of light is invariable, thus returning to the special theory of relativity. So, the relativity principle is the key element of the theory.

In the special theory of relativity, of course, Einstein's principles of relativity (which include the negation of the existence of absolute reference frames and ether), plus the principle that the constancy of the one-way speed of light, constitute the special theory of relativity that falls into total and pure relativism. So, in the special theory of relativity, the constancy of the light speed is also indispensable.

Einstein's relativity principle negates the existence of the absolute reference frame and returns to the concept of void space with nothing, which completely violates the basic understanding of modern physics. The principle of the constancy of light speed is an artificial stipulation and excessive, contrary to common sense assumption. Due to the lack of (actually violate) support from physical empirical facts, the theory set up from this arbitrary "artificial stipulation theory" is bound to fall into various logical contradictions and absurdities.

Before introducing the system of Standard Space-time Theory, it is necessary to expound the understanding of space and time from the height of modern science and natural philosophy. Only in this way we can stand higher and see farther.

2. 4. The Accurate Understanding of the Concepts of Space and Time

What exactly is space? What is time? Since ancient times, there have been a variety of answers, most of which sound reasonable at first. My book *Meditations on Modern*

Materialist Philosophy [7] (about 680,000 words) covers a wide range of contemporary philosophical issues, including a detailed discussion on space and time. This section will briefly describe my views on space and time.

What is space? The material world has extension and co-existence. Every object has certain extension. There are certain positional or coexisting relationships between different objects. Unlike Democritus, Aristotle or Newton thought to be, space is a motionless container from which moving matter can be separated, as if matter were moving in it. In fact, Space refers to the extensiveness and coexistence of motion materials. This is a very clear concept, and we must carry this understanding through to the end. It should be clearly realized that the atmosphere around the earth is the extensiveness of existence of the atmosphere or of air. Running in the air is like swimming in a lake, and it is only that the relative position changes between the body and the fluid (gas or liquid).

How to understand the earth’s outer background space? The world is a continuous material world. As stated in the view of nature of atom-yuanqi theory, matter exists in two different forms, i.e., dispersion state and aggregation state. Vacuum is mainly a dispersion state matter, which is a special state of matter motion with the lowest energy. Generally speaking, dispersion state matter is not only the medium of the interaction and interrelation of the aggregate state particles, but also the background of all the motion process of tangible matter. As the background space, the dispersion state matter is called vacuum background field. Macroscopic objects and celestial bodies move relative to the background space, which is the confluence and unification of macroscopic objects, celestial bodies and the dispersion matter as background space. The space concept in people mind refers to the background space. In the vast expanse of interstellar space, the density of clustered particles is extremely low, equal to or less than one particle per cubic centimeter. Background space is the extensiveness of continuous dispersion matter. When we talk about the motion of matter in space, we're really saying that the matter we're looking at is moving relative to the background space, i.e., relative to this dispersion state of matter that's the background field. Note: the background space is not nothingness, and it is the dispersion background field!

Therefore, I think:

(1) Space refers to the extensiveness and coexistence of moving matter. It is not that matter occupy, fill, place, or extend into space; on the contrary, space is the extensiveness and coexistence themself of matter.

(2) In the strict sense, it is not proper to say that matter moves in space; the movement of matter in space, in fact, in essence, refers to a change in the relative positions of the various parts of the material world (dispersion matter and aggregation matter).

It is true that on the ultra-microscopic level, the dispersed-state vacuum background field pulsates rapidly, which cannot be uniform and static. However, on the macroscopic or cosmic scale, the background field is uniform and isotropic, and because of its very weak interaction with heavy objects, it is indeed, as Newton said, “Its own characteristics have nothing to do with all external things, it is uniform everywhere, and it never moves”. The dispersion vacuum background field is what Newton called absolute space. The cosmic microwave background radiation is uniform and isotropic relative to this reference frame, which can measure the speed of the earth or the solar system relative to this reference frame.

What is time? Motion, said Engels, in its most general sense, as understood as the mode of existence of matter, the inherent properties of matter, cover all the changes and processes that take place in the universe, from simple position changes to thinking. A certain difference that the internal nature of a thing (such as its elements, structure, quantity, scale, state, form of motion, etc.) and its external connection produce from the original, called change. The internal nature of a thing (such as its elements, structure, quantity, scale, state, form of motion, etc.) and its external connection produce from the original, called change. Time is the continuity and sequence of the motion and changes of matter. Notice that all things do not move and change in time. On the contrary, Time is the motion change itself of matter. This statement will become clearer after the measurement of time is described below. If there were no motion changes in the physical world, time would not exist. But, as we have said, matter without motion and motion without matter are both nonexistent and inconceivable.

To define change, to say that is “Some difference from the original”, the word “original” here can also mean “before” or “previous”. This implies that the concept of sequence is implicit in the predicate of the definition “Time is the motion-change of matter itself”. There is no need to be too fastidious about this. In fact, people as observers, even without any formal education, produce subjective experience of time. First, there will be “present”, “past” and “future” ideas. When you read the word “ideas” here, you would think that right now—present—is reading the word “ideas”; Of course, when you finish reading it, the moment when you read “ideas” is no longer “right now”, it’s “past”. “Now” is always refreshing itself, it is constantly passing. “Confucius looked at the river on the bank and said: time is like this rushing river.” (*The Analects of Confucius*) We all have a deep-seated intuition that the “past” cannot be changed, the “now” is an instant in a twinkling of an eye, and the “future” is uncertain. Second, as a subjective experience, there is a sense of order. When you blink twice in a row, you instinctively discriminate between first and second. You instinctively judge that fire comes first and burn later; Aim first, hit second; Marriage and union come first, offspring later; And so on. Third, by observing the various external processes of change, you will instinctively compare the short or long duration of two continuous processes (for example, the burning of a match and the burning of a pile of wood, the writing of a word and the writing of an article).

Does this mean that the concept of time is entirely or purely the result of man’s subjective experience as an observer of the movement and change of external things? Is it just a product of our feelings, just people’s illusions? No.

The material world is always in motion. The objective material world consists of an infinite number of parts, each undergoing its own course of motion and change. The motion changes of all parts are interrelated, affect and restrict each other. Such correlation, mutual influence and mutual restriction are subject to a law, i.e., the law of causation. Causality is a basic and universally applicable law in nature, and one of the manifestations of universal connection and mutual restriction in the objective material world. The occurrence of any natural phenomenon is caused by another or some other phenomenon (cause), and any natural phenomenon is bound to cause another or some other phenomenon (result). This causation and occurrence are the causal connection between things. The salient feature of the causal connection is that the cause always precedes the effect. It is impossible to reverse the sequence of two causal events. For example, the claim that a mother is born before her son is born, observed in any frame of reference, it must be true. For example, aiming at shooting, firing shells, after a period of time to hit the target, in any reference frame observation, hit the target is unlikely to happen before aiming at shooting.

In short, the persistence and sequence of the motion change of matter and the concept of time is the person as an observer for a subjective experience of time, it is also a manifestation of the causal law that all the motion-changing events are related to each other and affect each other in the process of their respective motion changes in the objective material world.

Thus, I realized:

(1) Time is the persistence and sequence of the motion changes of matter. It is not that things are move and change in time. On the contrary, time is the motion change itself of matter. In detail, the persistence and sequence themselves of material motion and change are time.

(2) The law of causality orders the events of all the changes in motion in the material world (in order), and since any process of change can be thought of as consisting of many successive sub-processes, it also determinedly compares the transience or permanence of any two continuous processes of change.

People’s subjective state (such as age, health, mood, inner expectation, etc.) does affect the spatial scale of objective objects (such as height, length, width, area, etc.) and the subjective perception of time speed and delay. However, this does not negate the existence of objective measures of space and time.

Space is measured in terms of the motion of certain substances in time. For example, the distance traveled by light in a vacuum over a specified period of time serves as a bench mark for measuring length. The speed of light c = 299792458 m/s has been accepted by the scientific community as an accurate value (note that this is the circuit average speed of light, not a one-way speed of light), and the bench mark unit of length 1 m is defined as the distance that light travels in a fraction of a second of 1/299792458. Obviously, the measurement of space and the concept of space are related and different.

Time is measured in terms of the motion of certain substances in space. People use different moments to indicate the sequence of different events, and time intervals to describe the duration of the process of motion change. The measurement of time is a kind of activity that human beings deal with the objective object of time subjectively. It is formed and improved step by step by defining, dividing and comparing the movement and change process of things on the basis of understanding things. Generally, a specific material motion process is selected as a reference, and the motion process of other materials is compared with this reference process, so as to identify and arrange the sequence of events, as well as the time when the event occurs and the time interval experienced by the motion change process. Obviously, the measurement of time and the concept of time are both related and different.

The material motion changes of the objective world are so rich and colorful, and it is different and varied, and it is impossible to say that the real changes are "passing by themselves evenly". In fact, some things move periodically, and some things don't move obviously periodically, or not at all periodically. It is impossible to choose any process of material movement as the standard for measuring time. Things with obvious periodic changes in motion, such as the rotation and revolution of the earth, the motion of a pendulum, the oscillation of an atom, and so on, are often used as the standard for measuring time.

> The motion changes themselves of matter are time. We select the monotonous, regular, repetitive, i.e., periodic cyclical motion process of "passing itself evenly" of the particular matter, to give a universal measurement of time for all things in the world.

Through the scientific measurement of time and space, human has been able to carry out a detailed study of the laws of motion of matter. It can be said that the measurement of space and time is the basis of all scientific research.

People often know space and time through the measurement of space and time. But whether or not there is a human being, whether or not there is an observer measuring space and time, space and time, which reflect the nature of matter, are objective objects.

To sum up, matter is a being that to have extensiveness and in perpetual motion; the extensiveness and coexistence themselves of matter are space; the motion changes themselves of matter are time. Therefore, it is saying “the existence and development of anything must occupy a certain space and experience a certain amount of time”, or, as Lenin said, “the matter in motion can only move in time and space”, such statements imply the idea of the separation of space and time from moving matter, and thus are not an accurate statement. They do not reveal the essence of space and time, but, on the contrary, lead to a wrong understanding of the essence of space and time.

This section, I think, has provided a clear, unambiguous answer to the philosophical and scientific question “what is time, what is space”.

2. 5. Moving to Standard Space-time Theory

Einstein’s relativistic view of space and time of pure relativism have obtained partial knowledge of truth, but only partial truth. Rooted in the development of modern physics, history has come to a new era, requires us to pass some kind of specific theoretical form, to integrate reasonable factors in Newton and Einstein’s concept of space and time, and to promote, and avoid their one-sidedness, forming a new system of space-time theory with unified, rigorous, self-contained specialty. This is the study of Standard Space-time Theory.

To provide a more suitable space-time frame for understanding and describing the physical world, the space-time view of Standard Space-time Theory should reach a higher level. I must go further for this purpose. Here, with a page close to one page, is a collection of previous systematic discussions on matter and its existence and change, space and time, dispersion state and aggregation state, the absolute space and the absolute reference system. Standard Space-time Theory should reflect these objective truths.

According to dialectical materialism, the world is the world of matter. What is matter? Traditional philosophy textbooks give the following definition: “matter is a philosophical category that marks objective reality, which is perceived by human beings through their senses. It does not depend on our feelings, and is copied, photographed and reflected by our feelings.” However, there are many defects in this definition.

Monograph [7] (p.76) makes a detailed analysis of this, and gives the definition of the accurate and universal definition of matter as follows:

> Matter is an existence, which is in an eternal motion and with extensiveness. The sum of this existence is the basis and origin of the world, and within the scope of

reach of people's observation its concrete form can be reflected by people's feeling and thinking.

Here, the properties of time and space of matter are taken as the basis for the definition of matter. What is space? What is time? As described in the previous section:

The space refers to the extensiveness and coexistence of moving materials. Not that matter occupies, fills, places, or extends into space; on the contrary, space is the extensiveness and coexistence themself of matter. Time is the persistence and sequence of the motion changes of matter. All things are not move and change in time. On the contrary, Time is the motion change itself of matter. In detail, the persistence and sequence themselves of material motion changes are time.

To select the monotonous, regular, repetitive, i.e., periodic cyclical motion process of "passing itself evenly" of the particular matter, to give a universal measurement of time for all things in the world. The distance traveled by light in a specified period of time in a vacuum is used as bench mark for the measurement of length, giving a general measure of the spatial extensiveness of all concrete physical systems in the world. The measurement of space and time is related to and different from the concept of space and time.

In Chapter 1, according to the development results of modern science, the natural view of ancient Chinese yuanqi theory and ancient Greek atomism theory are combined to put forward the natural view of atom-yuanqi theory, which depicts the aggregated-dispersed states natural images. The main ideas are simply restated as follows:

> The world is a continuous material world, and the Yuanqi field (equivalent to a unified field) is the origin of the continuous material world, which exists in two different forms, i.e., dispersed state and aggregated state. The dispersed state is a natural state that the Yuanqi field is dispersed without gathering, unformed quality, invisible and intangible, and with low energy density, while the aggregated state is excited state or energy condensation zone in which the Yuanqi field gathers to have forms, visible and tangible and with high energy density. In the microcosm and macrocosm, to compare with the aggregated-state matter, the dispersed-state matter disperses and extends to most of the space, and the size of the aggregated-state particles is as small as almost negligible. To compare with the dispersed-state matter, the aggregated-state particles gather most of mass and energy, and the mass and energy of the dispersed-state matter are as small as almost negligible.
>
> The void space of nothingness does not exist. The interstellar space is primarily dispersed-state matter, a particular form of material motion with the lowest energy density. The dispersed-state vacuum background field, which is called "qi of the

intangible universal” in the yuanqi theory, is the background and interaction medium between the physical particles with shapes and images, and macroscopic objects and celestial bodies which is composed of the physical particles. This is the picture of the absolute space and absolute frame of reference.

From what has been said above, we can confirm that, at least at the present level of modern scientific development, a new system of space-time theory must meet the following requirements simultaneously.

(1) The objective reality of space and time: the world is the material world; the extensiveness and coexistences themselves of matter are space; the motion changes themselves of matter are time.

(2) The concept of the absolute space and absolute reference system: The dispersed-state vacuum background field is the absolute space and absolute reference system, which is the medium of the background and interaction between the physical particles with shapes and images, and macroscopic objects and celestial bodies which are composed of the physical particles. The motion of aggregated-state matter relative to absolute space is absolute motion.

(3) The correlation between the space-time properties of matter and the motion of matter: The physical particles, as well as macroscopic objects and celestial bodies move in the absolute space, they must be affected by the dispersed-state vacuum background field. The natural result is that the higher the velocity of the aggregated-state matter, the more its space-time properties are affected by the dispersed-state vacuum background field.

(4) The principle of relativity is not valid. Different inertial systems move at different uniform and straight speeds relative to the absolute space and are affected differently by the dispersed-state vacuum background field, and the length of their rulers vary and the speed of their clocks vary differently. Therefore, the laws describing the motion of matter are different in different inertial systems. The laws governing the motion changes of a physical system are related to the inertial systems by which these changes are described.

The motion of different aggregated-state matters with each other, or the motion of a certain aggregated-state matter relative to a general inertial system, is the relative motion.

(5) The world is the phenomena and changing processes of all things with infinite diversity and complexity between heaven and earth, or the sum of all the phenomena and changing processes of all things [7] (p.3). The causality ranks (sequence) all the events that move and change in the physical world. Thus, simultaneity and time order should be absolute, that is, the simultaneity and time order of two or more events should be true for all observers of different inertial systems.

(6) From the perspective of optical level, the dispersion state vacuum background field pulsates rapidly and cannot be uniform. However, within a certain range (such as the

macroscopic scale or the cosmic scale), the field can be regarded as uniformly distributed. The velocity of light wave propagating in absolute reference frame is constant c with isotropic. However, the anisotropy of the speed of light is measured in a general inertial system moving in relative absolute space. Einstein's one-way constant speed of light principle does not hold.

Of course, in absolute space itself, since there is not aggregated-state matter, it is impossible to measure the speed of light directly. However, in a general inertial system, the absolute velocity of the inertial system can be determined by measuring the degree and direction of the anisotropy of the speed of light. If the anisotropy disappears and becomes isotropic of the speed of light, then it can be judged that the inertial frame is stationary relative to the absolute reference frame.

(7) The measurement of space and time is related to and different from the concept of space and time. The measuring stick and the clock, as instruments of measurement, are also in motion.

As a fine reflection, we have to examine the impact of this statement on major theoretical issues. I will discuss and develop this in detail in future books.

With these important understandings, how to construct a new theory of space-time? According to axiomatic law, we should start from the simplest possible, the least number of reliable assumptions, to build a logical rigorous theoretical system.

Introduction (see page 1) already mentioned, as original theory research results, the standard space and time theory is starting from the view of nature of Atom-Yuanqi Theory, to make Lorentz's theory of ether more perfect and systematic, taking the principle of the absolute reference frame and the principle of circuit average speed of light as the basic assumptions to establish a rigorous logic system beyond Einstein's theory. The introduction has given a complete description of the two basic assumptions. From these two basic assumptions, the establishment of the entire theoretical system of standard time and space theory is the content of chapter four to chapter eight.

Standard Space-time Theory is a new self-consistent theoretical system. It does reflect the objective knowledge of truth about matter and its motion, space and time, dispersed state and aggregated state, absolute space and the absolute frame of reference described earlier in this section. The view of space and time of Standard Space-time Theory is a new view of space and time which is different from Newton's absolute view of space and time and Einstein's relativistic view of space and time, and inherits and synthesizes the reasonable elements of the two. Standard Space-time Theory leads to the conclusion that motion is both relative and absolute. Standard Space-time Theory reveals the close relationship between space and time, as well as the mutual dependence between space, time and material movement in a concrete and rigorous theoretical form, and profoundly reflects the objectivity, relativity and absoluteness of matter and movement, space and time. It provides a more suitable space-time framework for understanding and describing the physical world and even natural phenomena. Such a new theory certainly represents the progress in human understanding of nature.

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Chapter 3

Difficulties and Challenges Faced by the Special Theory of Relativity

Einstein was the greatest physicist of the 20th century. His special theory of relativity has become one of the foundations of modern physics. Einstein has become a symbol of the greatest wisdom of the 20th century. This is evidenced that he won the American magazine *Time* selected him as "The Great Man of the Century". Nevertheless, science always moves forward and never stays on the same level. There is no ultimate truth. Experiments and theoretical thinking always reveal the difficulties and defects of the original theory and open up the way for the breeding and development of new theory.

Einstein was modest about the special theory of relativity. Back in 1949, when Einstein was 70, he wrote to his friend M. Solovin: "I feel that there is no concept in my work that will stand up very firmly, nor am I sure that I am generally on the right track." [1] (p. 485) In his later years, Einstein speculated many times that "relativity may eventually need to give way to other theoretical systems."

This chapter describes the difficulties and challenges faced by Einstein's special theory of relativity: introduces experimental facts that the principle of relativity is not strictly valid; explains that the principle of the constancy of the light speed is an artificial agreement and excessive and unnatural assumption which lacks experimental basis; introduces the challenges faced by Einstein's principle of the limitation of the light speed .

3. 1. Einstein on the Ether and the Unified Field

3. 1. 1. The Special Theory of Relativity Has Restored the Image of a Vacuum as Void Space with Nothingness

Einstein founded his special theory of relativity on the basis of two assumption, i.e., the principle of relativity and the principle of the constancy of the light speed. The principle of relativity holds that the laws of physics have the same form in all inertial systems; all inertial systems are equivalent to the laws of physics that describe motion. This means that the quotation of the particular superior absolute frame of reference is redundant. Thus, light or electromagnetic wave is no longer a propagation process of electromagnetic oscillation in some medium, i.e., the ether; the electromagnetic field itself is no longer a state of some kind of medium, that is, the ether, it becomes a kind of independent existence matter. However, electromagnetic fields do not exist everywhere in space. In this way, as Einstein said: "A space not permeated by radiation and free of ponderable matter appears to be really empty."

In his *On the Electrodynamics of Moving Objects* (1905) (see *The Collected Papers of Albert Einstein* (English) ([2], Volume 2, pp.140~170), Einstein wrote: "The introduction of a 'light ether' will prove to be superfluous inasmuch as the view here to be developed will not require a light ether 'absolutely stationary space' provided with special properties, nor assign a velocity-vector to a point of the empty space in which electromagnetic processes take place."

In *On the Relativity Principle and the Conclusions Drawn from it* (1907) ([2], Volume 2, pp. 252~311), Einstein wrote: "only the conception of a luminiferous ether as the carrier of electric and magnetic forces does not fit into the theory described here; for electromagnetic forces appear not as states of some substance, but rather as independently existing things that are similar to ponderable matter and share with it the feature of inertia."

In *On the Development of Our Views Concerning the Nature and Constitution of Radiation* (1909) ([2], Volume 2, pp.379—394), Einstein gave a clearer account: "Taking as a basis the ether hypothesis, the experiment led to the supposition that the ether is immobile. In that case the principle of relativity states that all laws of nature referred to a coordinate system K' that is in uniform motion relative to the ether must be identical with the corresponding laws referred to a coordinate system K that is at rest relative to it. But if this is so, then we have a just as much reason to imagine the ether at rest relative to K', as at rest relative to K. Hence it is totally unnatural to single out one of the two coordinate sstem K, K' by introducing an ether that is at rest relative to it. From this it follows that one can obtain a satisfying theory only if one drops the ether hypothesis. In that case the electromagnetic fields that constitute the light will no longer appear to be states of a hypothetical medium, but rather independent entities emitted by the sources of light, exactly as in the Newtonian emission theory of light. Exactly as according to the latter theory, a space not permeated by radiation and free of ponderable matter appears to be really empty."

These statements show that the special theory of relativity, which uses the principle of relativity as its basic hypothesis, unquestionably abandons the special absolute reference frame and negates the existence of ether as the absolute reference frame. Not only that, but in the early days of the special theory of relativity, Einstein tended to abandon and deny the concept and hypothesis of ether in general. The special theory of relativity does not contain the physical quantities that describe the ether, and it leaves no territory for the ether; the electromagnetic field is not a state of the ether medium, but an independent substance. However, the electromagnetic field cannot exist everywhere in space, so the space without radiation passing through, that is, the intensity of the electromagnetic field is zero, and there is no heavy matter, is truly void with nothingness. The special theory of relativity actually restores that the vacuum is the image of the void with nothingness, and the concept of the void with nothingness is certainly confusing and inconceivable.

3. 1. 2. Einstein on the Ether and the Unified Field

The Ether Theory regards ether as the only source of the material world, and the essence of the ether concept is to deny the existence of void and over-range action. According to the ether theory, the space is not empty. In the space without visible objects, the ether exists as a universal dispersion, omnipresent, and continuous material state. In this basic sense, ether is the Yuanqi field, which cannot be denied. Einstein realized this. Things changed in 1915 when Einstein developed his theory of general relativity. In *Ether and the Theory of Relativity* (1920) ([2], Volume 7, pp. 160~182), Einstein elaborated on his ideas of the ether.

First, Einstein said: “Certainly, from the standpoint of the special theory of relativity, the ether hypothesis appears at first to be an empty hypothesis.” But, “To deny the ether is ultimately to assume that empty space has no physical qualities whatever. The fundamental facts of mechanics do not harmonize with this view.” “More careful reflection teaches us, however, that the special theory of relativity does not compel as to deny ether. We may assume the existence of ether; only we must give up ascribing a definite state of motion to it, i.e., we must by abstraction take from it the last mechanical characteristic which Lorentz had still left it.” “The special theory of relativity forbids us to assume the ether to consist of particles observable through time, but the hypothesis of ether in itself is not in conflict with the special theory of relativity. Only we must be on our guard against ascribing a state of motion to the ether.”

It is not allowed to assume that the ether is made up of particles, which is completely correct and in line with the thought of ancient Chinese Yuanqi Theory. If not, suppose that the Ether-Yuanqi consists of particles, what is between the particles? Either answer (“a void space” or “full of yuanqi or ether”) would violate the basic idea of Yuanqi Theory. According to the Yuanqi theory, Yuanqi is the only primitive of the continuous material world, the particles are nothing more than the condensation of the yuanqi.

Einstein believed that the physical space of general theory of relativity has acted as the ether. “According to the general theory of relativity a space is endowed with physical qualities; in this sense, therefore, there exists ether. According to general theory of relativity, space without ether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in any physical sense. But this ether may not be thought of as endowed with the quality characteristic of ponderable media, as consisting of part which tracked through time. The idea of motion may not be applied to it." "According to this theory (i.e., the general theory of relativity) the metrical qualities of the continuum of space-time differ in the environment of different points of space-time, and are partly conditioned by the matter existing outside of the territory consideration.… The recognition of the fact that 'empty space' in its physical relation is neither homogeneous nor isotropic, compelling us to describe its state by ten functions (the gravitational potential $g_{\mu\nu}$), has, I think, finally disposed of the view that space is physically empty. But there with the conception of the ether has again acquired an intelligible content, although this content differs widely from that of the ether of the mechanical undulatory theory of light. The ether of the general theory of relativity is a medium, which is itself devoid of all mechanical or kinematical qualities, but helps to determine mechanical (and electromagnetic) events."

Einstein wrote: "As for the role this new ether is destined to play in the future world picture of physics, we are not clear yet. We know that it determines the metrical relations in the space-time continuum, e.g., the configurative possibilities of solid bodies as well as the gravitational fields; but we do not know whether it has an essential share in the structure of the electrical elementary particles constitute matter." Although there is no clear relationship between the new ether and particles, the "new ether" without the purely mechanical characteristics is undoubtedly closer to the concept of ancient Chinese Yuanqi theory.

The above ideas of Einstein were inherited, supplemented and developed in the later research of unified field theory. Since general relativity has achieved great success in describing gravitational field by Riemann geometry, can it create a new geometry to describe both gravitational field and electromagnetic field? This was the earliest idea of the unified field theory proposed by Weil (1885—1955) in 1918. Einstein was initially unsympathetic to the idea. But a few years later, he changed his tune and became a central figure in the creation of a unified field theory. For 32 years, from 1923 until his death in 1955, he devoted almost all his energy to the creation of a unified field theory.

In previous physical theories, gravitational fields, electromagnetic fields and physical particles were the three major elements that make up the physical world. Einstein firmly believed in the unity of nature and the principle of logical simplicity. Einstein's unified field, is known to all, the first is the gravitational field and electromagnetic field) of the common origin and common basis, continuously full of whole space, a variety of known field is its different forms and different properties, and physical particles can be regarded "as some areas of space where the unified field particularly strong" [3], that is, the energy condensation region of the unified field.

Dialectical materialism holds that the unity of the world lies in its materiality. In the unified field theory, the unity of the world is not unified in general in matter, but in the concrete continuous form of matter, the unified field. Therefore, unified field theory is not only in line with dialectical materialism about the unity of the world, but also a scientific theory.

Einstein believed that the success of unified field theory would be a great step forward, "Then, for the first time the epoch of theoretical physics founded by Faraday and Maxwell would a satisfactory conclusion. The contrast between ether and matter would fade away." ([2], Volume 7, p.180) It is true that the mechanical view of the ether was denied in Einstein's mind, but the ether itself (the spirit that permeates the whole universe) was not denied.

If we abandon the mechanical model imposed on the ether, and consider only its basic meaning as dispersed, omnipresent, continuous origin of the matter, then it is clear that the unified field theory is the resurrection and development of the theory of ether under modern conditions. We know that "ether" is only the western translation of the word "Yuanqi". By comparing the unified field theory with the ancient Chinese yuanqi theory, we can further assert that the unified field theory is the manifestation form of the view of nature of Yuanqi theory in modern physics. Yuanqi is equivalent to the unified field in modern physics. The view of nature of Yuanqi theory is the forerunner of modern unified field theory.

He Zuoxiu [4] first pointed out the important position of Yuanqi Theory in modern science. He zuoxiu believes that "in modern natural sciences, the material that is really similar to the Yuanqi is not the ether as the medium of transmission interaction in natural sciences, but the fields that are constantly changing and developing, such as electric field, magnetic field, gravitational field and so on." And he said: "The yuanqi theory is the beginning of modern quantum field theory." The analogy with yuanqi is the field or quantum field in modern science, which, I do not think, is considered a very accurate statement. Why is that? There are all kinds of fields, electric fields, magnetic fields, gravitational fields, and in quantum field theory, there is a corresponding field for a class of particles, and the particle is the excited state of the corresponding field. For example, photon is excited state of the electromagnetic field, electron is excited state of the electron field, and meson is excited state of the meson field, and so on. According to the five main ideas of the yuanqi theory of mature form (see Sec.1.1), Yuanqi is the only origin of all things in the world. Therefore, the accurate statement is: yuanqi is equivalent to the unified field in modern physics; the view of nature of Yuanqi theory is the forerunner of modern unified field theory.

Return to the main line of this section—Einstein's unified field theory. According to the basic idea of unified field theory, light or electromagnetic field is no longer an independent substance as asserted by the special theory of relativity, but a form, a process or an attribute of the continuous unified field. From this point of view, it certainly leads to the logical negation of the assertion of the special theory of relativity about acknowledging the void space with nothingness and denying the concept of ether. This is a negative of a negative! At the same time, it will inevitably lead to the logical negation of the two basic assumptions of the special theory of relativity, i.e., the principle of relativity and the principle of the constancy of the light speed. In this regard, the following is a clear description.

3. 1. 3. Einstein's Concept of Unified Field Denies the Basic Assumptions of Special Theory of Relativity

Einstein's unified field is the common origin and common basis of all known fields, which continuously fills the whole space. All known fields are just their different manifestations and properties. Physical particles are the energy condensing region of the unified field. Therefore, the unified field presents in two forms, i.e., aggregated state and dispersed state. Light or electromagnetic field is no longer an independent substance as asserted by the special theory of relativity, but as an attribute of the dispersed-state unified field and a propagation process of a state of electromagnetic oscillation in the dispersion state unified field. Both experimental facts and theoretical assumptions confirm that the propagation of light in the dispersion uniform field is uniform and isotropic, so the dispersed state uniform field shows uniformity and isotropy at least at the macroscopic level. It forms the background of all physical processes. If all particles are left out, the dispersed-state unified field is the cosmic vacuum background field described in Sec.1.5. It forms an absolute frame of reference. Therefore, Einstein's idea of a unified field is a potential but substantial negation of the principle of relativity.

The idea of a unified field must also lead to a denial of the principle of the constancy of light speed. As shown in Fig. 3.1, there are two inertial reference frames S and S', wherein, the frame S is an inertial frame of motionless with a relatively dispersed-state background field, and the frame S' is an inertial frame with a general motion, which moves along the common axial Ox positive direction of the two frames with a velocity $\boldsymbol{v}$ relative to the frame S . The moment of coincidence of the origin points of the two frames O and O' are taken as the starting point of the timing of the two frames.

At this moment $t_1 = t_1' = 0$, the light wave is emitted from the origin O of the system S and propagates along the positive direction of the axis Ox . At the moment of time $t_2(t_2')$, reaching the reflector M fixed in the system S'. According to both ether theory and the special theory of relativity, the speed of light is uniform and isotropic, equal to constant c, in the system S, i.e., dispersion state background field. With that as a starting point, let's figure out the speed of light in the system S' .

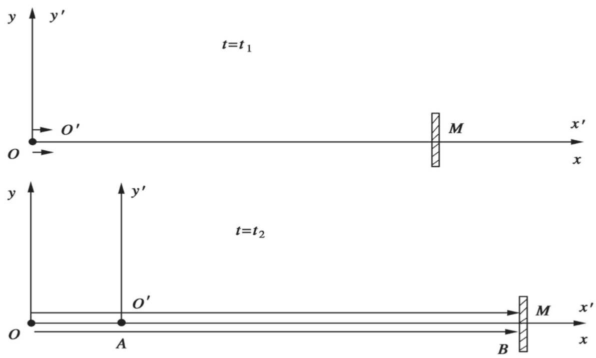

Fig. 3.1

For comparison, Einstein's idea of a unified field is set aside for the moment, and to consider according to the void space of the special theory of relativity and Lorentz's transformation formula. The emission and arrival of the above light waves are regarded as two events (event 1 and event 2), and their respective space-time coordinates in the system S and the system S' are

$$(x_1, t_1) \text{ and } (x_2, t_2), \qquad (x_1', t_1') \text{ and } (x_2', t_2')$$

Among them: $x_1 = 0,\ t_1 = 0;\ x_1' = 0,\ t_1' = 0.$ And

$$x_2 - x_1 = c(t_2 - t_1). \tag{3.1}$$

By Lorentz transformation, there is

$$\Delta x' = x_2' - x_1' = \gamma[(x_2 - x_1) - v(t_2 - t_1)] = \gamma(c - v)(t_2 - t_1), \tag{3.2}$$

$$\Delta t' = t_2' - t_1' = \gamma[(t_2 - t_1) - v(x_2 - x_1)/c^2] = \gamma(1 - v/c)(t_2 - t_1). \tag{3.3}$$

So, relative to the system S', there is

$$c' = \frac{\Delta x'}{\Delta t'} = \frac{x_2' - x_1'}{t_2' - t_1'} = c\ . \tag{3.4}$$

This is naturally consistent with Einstein's basic assumption that the speed of light does not change. In fact, the Lorentz transformation is derived from the principle of relativity and the principle of the constancy of the light speed.

Considering the above process according to Einstein's unified field concept, different results will be obtained. According to the unified field concept, the coordinate system S' and its fixed reflector M is taken as a macroscopic reference body moving in the unified field. The light is the process of propagation of the electromagnetic oscillation in dispersed-state background field. At the moment of time $t_1(t_1')$, the light source is emitted from the point O of the background field. At this moment, the origin O' of the system S' coincides with the point O. At time $t_2(t_2')$, the origin O' reaches the point A of the unified field, and the light wave and reflector M reach the point B in the background field. The O, A, B are the three points with determinate position in the system S (i.e., in the background field). According to the relative system S, there is

$$OA = v(t_2 - t_1),\ OB = c(t_2 - t_1),$$
$$AB = OB - OA = x_B - x_A = (c - v)(t_2 - t_1).$$

To the origin O' of the system S', measuring by the observer in the system S' during the period of $t_2' - t_1'$, the relative position of the wave-front of the light wave changes from zero at time t_1' into $(AB)'$ at time t_2'.

How to calculate $(AB)'$ and $t_2' - t_1'$, and to calculate the speed of light in the system S'?

In the first method, according to the ether theory, that is, according to the FitzGerald-Lorentz length contraction effect, the ruler of S' system is shortened to γ^{-1} of the length in rest; according to the Lodge-Lorentz time delay effect, the clock running period of the system S' is delayed to the period of its absolute rest. Therefore, relative to the system S', the change $\Delta x' = (AB)'$ of the relative position (that is, the position relative to the point O') of the light wave front and the time interval $\Delta t' = t_2' - t_1'$ between the emission of the light wave from the origin O' to reflector M respectively

$$\left.\begin{aligned}\Delta x' = \gamma(x_B - x_A) = \gamma(c - v)(t_2 - t_1) = (c - v)(t_2 - t_1)\Big/\sqrt{1 - v^2/c^2},\\ \Delta t' = t_2' - t_1' = \gamma^{-1}(t_2 - t_1) = \sqrt{1 - v^2/c^2}\,(t_2 - t_1).\end{aligned}\right\} \tag{3.5}$$

Thus, relative to the system S', the speed of light is obtained

$$c' = \frac{\Delta x'}{\Delta t'} = \frac{x_2' - x_1'}{t_2' - t_1'} = \frac{c}{1 + v/c}. \tag{3.6}$$

In the second approach, according to the point of view of the special theory of relativity, what is the situation? As long as we accept the concept of unified field, it is noted that light is the propagation process of electromagnetic oscillation in the background field of dispersed state, and A, B are the two points with determinate position in the system S. From the point of view of the system S', they are in the motion of relative velocity $-\boldsymbol{v}$ (that is, along the negative direction of the common axis Ox of the two systems). So, according to the Einstein length contract effect in the special theory of relativity, can be obtained

$$\Delta x' = (x_B - x_A)\sqrt{1 - v^2/c^2} = (c - v)(t_2 - t_1)\sqrt{1 - v^2/c^2} = \gamma^{-1}(c - v)(t_2 - t_1). \tag{3.7}$$

In addition, considering the measurement of time, the emission and arrival of the above light waves are the two events that occur neither at rest in the system S nor at rest in the system S'. According to the point of view of the special theory of relativity, it is still calculated $\Delta t' = t_2' - t_1'$ by formula (3.3). So, we get

$$c' = \frac{\Delta x'}{\Delta t'} = \frac{\gamma^{-1}(c-v)(t_2-t_1)}{\gamma(1-v/c)(t_2-t_1)} = c(1-v^2/c^2). \tag{3.8}$$

What has been said above is enough to show that as long as the unified field concept is introduced, it is considered that light waves are the propagation process of electromagnetic oscillations in the background field of dispersed state, then whether from the point of view of ether theory or the special theory of relativity, we can get the conclusion that the speed of light is related to the inertial reference system. Einstein's unified field view must lead to the denial of the principle of the constancy of the light speed. In Sec. 3.3.3, I will proceed from this point to further clarify that the principle of the constancy of the light speed is a counterintuitive assumption.

The judgment and arguments in this section are independently discovered and proposed by me. I have not seen this argument anywhere else. But perhaps, I suspect, Einstein was aware of this in his mind. He wrote to his best friend, M. Solow, when he was seventy in March 1949: "You must imagine that I must look back on the achievements of my life at this very moment with satisfaction. But, on closer examination, it is not at all the same. I feel that no concept would stand firm in my work, and I am not sure that I am generally on the right track.... it is only natural that there should be a feeling of discontent in my own heart, so long as one is honest and critical." ([1], p.485) I can understand Einstein's mood.

3. 2. The Cosmic Background Radiation and Absolute Reference Frame

3. 2. 1. The Contradiction between Principle of Relativity and Modern Cosmology

Although Einstein later did not deny the existence of ether, he used the physical space of general relativity as the role of ether, and he developed the concept of unified field as the original of the world, there is no doubt that neither his ether nor unified field could constitute the absolute reference frame in Einstein's view. This is because the special theory of relativity is based on the principle of relativity as the basic assumption that all inertial systems are completely equivalent, there can be no special absolute reference system. In this section, we will explain that in the face of the achievements of modern cosmology, Einstein's these claims are no longer valid. The principle of relativity is in complete conflict with modern cosmology.

The currently accepted cosmological theories are based on general relativity and cosmological principles (see literature [5]). The field equation of general relativity is the dynamic basis of connecting the matter distribution of the universe and the geometric properties of the universe at large scale. Cosmological principles describe the kinematics of the evolving universe over large scales of space and time. The cosmological principle (also known as the Copernican principle) holds that the universe is uniform and isotropic in space. This is not for the details of the universe, of course, but only for “smoothed” universe obtained after averaging of the regions with a diameter of 10^8 to 10^9 light-years, which is large enough to include many clusters of galaxies. The cosmological principle requires that there is a universal standard coordinate system to describe the evolution of the universe, the simultaneity relative to this time mark has essential significance in the meaning of the evolution of the universe; among them, the cosmic space is the cosmic background space. Typical galaxies or galaxy clusters are uniform and isotropic in the cosmic background space, while those observed in the reference frame moving at a certain speed relative to the background space will deviate from such uniformity and isotropy. The universal standard coordinate system is a superior space-time coordinate system, which in principle can measure the speed of the moving coordinate system (such as the earth) relative to the cosmic background space.

The special theory of relativity denies absolute time and absolute space, and denies the absoluteness of simultaneity. Although the universal standard time scale and cosmic background space are not Newtonian absolute time and absolute space, and the simultaneity relative to the evolution of the universe is not Newtonian’s simultaneity; However, in the physical meaning of the concept, the two are comparable. Large-scale space-time is not Minkowski’s space-time of the special theory of relativity at all, but the cosmic standard time scale and cosmic background space satisfying the cosmological principle. It is clear, therefore, that the space-time concept of the special theory of relativity and the principle of relativity itself are no longer valid on a cosmic scale.

3. 2. 2. Cosmic Background Radiation

The cosmological principle is supported by a large number of observational facts. 1965, the Americans Penzias and Wilson discovered the cosmic microwave background radiation. It is the most important discovery in cosmology since Hubble's discovery of the redshift of galaxy spectral lines. Later, further studies confirmed [6] that the strict isotropy of background radiation only exists in an inertial system. Compared with this inertial reference system, the microwave background radiation presents an excellent black body spectrum, and the corresponding temperature is T_0 = 2.725K, which is extremely uniform in all directions, and the degree of anisotropy expressed by temperature fluctuation is only $\delta T / T \sim 10^{-5}$. However, changes in the direction of the radiant temperature are shown in any other inertial system moving relative to this inertial system. It can be considered that the cosmic background space where the cosmic background radiation occurs is the best physical representation of the standard coordinate system of the universe. Suppose the reference frame of the observer moves at a speed $\boldsymbol{v}$ relative to the cosmic background space. Due to the Doppler Effect, the radiation temperature is higher in the direction of motion, but lower in the direction of backward motion. The radiation temperature in different directions changes as follows:

$$T(\theta)=\frac{\sqrt{1-v^2/c^2}}{1-v\cos\theta/c}T_0, \tag{3.9}$$

where θ represents the included angle between $\boldsymbol{v}$ and observation direction. Measuring the cosmic background radiation reaching earth from all directions, gets the highest temperature above the average of 0.0035 degrees (3.5 milli-degrees), in the direction of the brightest star (α star) of Leo at the usual celestial coordinates of right ascension (11 degrees), latitude (6 degrees) or southeast (15 degrees), and the lowest temperature is in the direction of Aquarius, which differs 180^0 from the highest temperature zone. Based on these calculations, the absolute speed at which the sun and earth move through the cosmic background space is about 390 km/s.

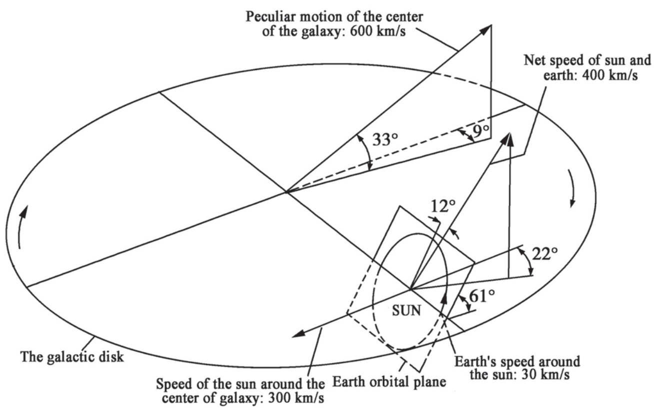

Fig. 3. 2

Fig. 3.2, taken from Ref. [6], depicts the absolute velocity of the earth's motion as determined by measuring small deviations in the temperature of the cosmic background radiation reaching the earth from all directions. The earth moves around the sun in its own orbit at 30km/s for a period of one year. The sun orbits the Milky Way's center at a speed of 220 km/s for a period of 2.46×10^8 years (known as a cosmic year). Earth's absolute velocity vector is represented by a directed line segment starting from the sun, which is in the plane of the earth's orbit around the sun and tilts at an angle of 12° upwards (northward) from the plane leaving the Milky Way galaxy, at 390 km/s. That's not much different than the speed at which the sun orbits the center of the Milky Way at 220 kilometers per second, but in different directions. According to the vector relationship of velocity synthesis, the calculation shows that the Milky Way must move with a (absolute) velocity of about 600 km/s relative to the cosmic background space.

Many of the world's leading physicists have commented on the physical significance of the discovery of the cosmic background radiation.

Bergmann [7], an eminent contemporary scholar of relativity, Einstein's student and collaborator, clearly points out that on the cosmic scale, the principle of relativity is destroyed; the cosmic background radiation is only in a unique frame of reference isotropy, in that sense, that frame of reference stands for stillness. Weisskopf [8] believed that, in any case, the observed 2.7k radiation determined an isotropic absolute reference system; this meant that Michelson and Morley's dream had become a reality, finding the absolute motion of our solar system. According to Stapp [9], the 2.7k background radiation defines a superior reference frame, which can be used to determine the absolute sequence of events. Rosen [10] (the physicist who developed the EPR argument with Einstein) even argues that the latest cosmological findings call for a return to the idea of absolute space.

The founder of Synergetics Harken [11] said at "the physical thought in the 1980s' conference in France: "The special theory of relativity denies the existence of a special frame of reference, but in a way, general relativity sort of reintroduces it, in 1965, the 3K cosmic background radiation (a remnant of the initial explosion 10 to 20 billion years ago) replaced the usual statistical system, the galaxy, as the absolute reference frame. In a sense, this new absolute space leads to an interesting concept of time. In the special theory of relativity, different observers in random motion cannot find a common time, while the cosmic observer experiences a universal time or common time."

Hu Ning [12], a Chinese relativistic physicist, in an article commemorating Einstein's centenary, wrote: "There is no contradiction between Michelson's results and the ether model." "The experiment has measured that there is a radiation distribution of 3K in the whole space, and you can find a coordinate system in which the radiation distribution of 3K is isotropic. The experiment measured the speed of the solar system relative to this coordinates system is 400 kilometers per second. This coordinate can be thought of as the centroid coordinate for the entire distribution of matter, or it can be thought of as the stationary coordinate system for a vacuum. In a sense, the velocity given above can be thought of as Michelson's measure of the velocity of the solar system relative to the ether.... We conclude that there must be a limit to the applicability of the relativity principle and the generalized covariance."

Finally, let's take a look at the comments made by the famous physicist Dirac (1902—1984). As early as 1970, he pointed out: "the idea of the ether is not dead, it is merely an idea whose use has not yet been discovered, and as long as the fundamental problem remains unsolved, it must be remembered that there is a possibility here." In a 1979 report of the Princeton Congress to commemorate the 100th Anniversary of Einstein, Dirac [13] further said: "it can be said that the cosmic background radiation is symmetric only to one observer, and that this privileged observer is static in some absolute sense, perhaps even to the ether. This contradicts Einstein's view.... In a sense, Lorenz was right and Einstein was wrong, because everything Einstein said was that it was impossible for physics to observe absolute zero velocity.... The only explanation, for why Michelson and Morley had zero results, and why they could not observe the absolute motion of the earth, was that their technology was not good. Today's technology is much more advanced than it was about a hundred years ago. With modern technology, absolute motion exists."

3. 2. 3. What is the Ether Absolute Frame of Reference?

Although the westerners generally think of ether only in a narrow sense as a uniform and continuous medium dispersing in the space, and light is a propagation process of the electromagnetic oscillation in this ether medium, but according to Descartes' ether theory, the ether in the west is what ancient Chinese called the Yuanqi, which is the origin of the material world. What is the origin? When discussing simple materialism in ancient Greece, Engels [14] quoted a passage from Aristotle:

> "There is something, of which all things are made, from which all things first came, and which at last return to it, as substance, it always the same, changing only in its own regulations, this is the element and the origin of all things."

Since, according to the ether theory, the ether is the origin of all things in the world, one of my papers "A new exploration of the special theory of relativity" [15], is subtitled "Where is the ether？ Where there is not the ether?" According to the theory of ancient Chinese Yuanqi, in the view of Zhang Zai and Wang Fuzhi, (1) the invisible qi in intangible universe, (2) the floating qi rising and floating, and (3) the objects with tangible and image are the three basic forms of physical existence, but, aggregation or dispersion, or tangible or intangible, they are the results of the motion and changes of qi. As the origin of the physical world, the ether, as Descartes calls it, also exists in these three basic forms. In this sense, it is clear that the ether is not the same thing as the ether absolute frame of reference. Then what exactly is the ether absolute frame of reference?

To answer this question, we first need to recall the natural image of modern science as described in Sec.1.5, i.e., the view of nature of atom-yuanqi theory. The yuanqi field (or unified field) is the origin of the continuous material world. It exists in two different states, that is aggregated state and dispersed state. The aggregated state is the excited state or energy condensation zone in which the Yuanqi field gathers to have forms, visible and tangible and with high energy density. The dispersed state is the natural state that the Yuanqi field is dispersed without gathering, unformed quality, invisible and intangible, and the energy density is low. The vacuum mainly contains the dispersed-state matter, which is the background of all material processes. All material processes do not occur outside this background, but within and within it. The word “vacuum” is easily taken literally to mean the void of nothingness, but modern science has proved beyond doubt that the void of nothing doesn’t exist. Therefore, the vacuum as the background space is better called the vacuum background field, or background field for short.

The dispersed-state vacuum background field without shape and image, i.e., the yuanqi theory calls it “qi of the intangible universe”, constitutes the background of motion of material objects and the macroscopic objects with shape and image and celestial bodies and interaction medium. At the level of ultra-microscopic, background field also has a variety of forms and structures, with sharp fluctuations, ever-changing and rich colorful connotations. At an optical level, the field pulsates rapidly and cannot be uniform. However, within a certain range (such as the macroscopic scale or the cosmic scale), the field can be regarded as uniformly distributed. Cosmic background radiation is a process that occurs in the cosmic vacuum background field. The dispersed-state cosmic vacuum background field is what we call the ether absolute reference frame. The CMB radiation is uniform and isotropic relative to this reference frame, and the velocity of the earth or solar system relative to this reference frame can be measured.

3. 3. The Principle of the Constancy of the Light Speed is an Artificial Stipulation, and Excessive and Counterintuitive Assumption

3. 3. 1. Logical Cycle between the One-way Light Speed Measurement and the Calibration of Clocks at Different Places. Principle of the Constancy of Light Speed Is an Artificial Stipulation

The second basic assumption of the special theory of relativity is the principle of the constancy of the light speed, i.e., suppose that in any inertial frame of reference, the speed of light in a vacuum is the same, equal to a constant *c*, independent of the orientation of space and motion state of the light source. Has this principle been experimentally proven? No.

The "speed of light" in Einstein's principle of the constancy of light speed refers to the one-way light speed, that is, the propagation speed of light signal along any given direction. In some cases, we also call it the principle of the constancy of the one-way light speed.

To measure the one-way speed of light between two points of separation *A* and *B*, it is necessary to determine the distance and the time interval required for the propagation of light pulses from the point *A* to the point *B*. The measurement of this time interval must use two synchronized (calibrated) clocks placed at *A* and at *B* respectively. The synchronization (calibration) of the clocks of different places is essentially a question of determining the simultaneity of different locations.

How do you calibrate two locally-placed *A* and locally-placed *B* clocks? We can send a signal from the point *A* at the moment of time t_A, assuming the signal speed is *u*, and the clock reading t_B at the moment when the signal reach the point B, if $t_B = t_A + AB/u$, we can assume that the clocks at both places have been calibrated.

A conundrum arises here: in order to measure one-way speeds, clocks at different places need to be calibrated; In order to calibrate the clocks at different places, you also need to know the one-way speed of the signal. This is the logical cycle between one-way velocity measurement and calibration of clocks at different places. In the system of the special theory of relativity, this logic cycle is inevitable. Einstein himself acknowledged this earlier [16], although he later (1946) actually denied it. [1] (p. 25)

How did Einstein solve this problem? Einstein, in his 1905 paper on the creation of the special theory of relativity ([2], Volume 2, p.140~171), said: "But it is not possible to compare the time of an event at *A* with one at *B* without a further stipulation; thus far we have defined only an '*A* time' and a '*B* time' but not defined a 'time' common to *A* and *B*. The latter can now be determined by establishing by definition that the 'time' needed for the light to travel from *A* to *B* is equal to the 'time' it needs to travel from *B* to *A*. For, suppose a ray of light leaves from *A* towards *B* at '*A* time' t_A, is reflected from *B* toward *A* at the '*B* time' t_B, and arrives back at *A* at the '*A* time' t'_A. The two clocks are synchronous by definition if $t_B - t_A = t'_A - t_B$."

It can be seen that Einstein's principle of the constancy of the one-way light speed is a completely artificial stipulation ah! Or, as Einstein said ([2], volume 6, p.272, or see[16]): "That light requires the same time to traverse the path $A \to M$ as for the path $B \to M$ (Here *M* represents the midpoint of a line segment *AB*—my note) is in reality neither a supposition nor a hypothesis about the physical nature of light, but a stipulation which I can make of my own freewill in order arrive at a definition of simultaneity." In general, it is impossible to measure the one-way speed of light, or to test Einstein's principle of the constancy of the one-way light speed, unless a superluminal signal is discovered and used (its existence is contrary to the special theory of relativity), or a novel experimental method is found.

3. 3. 2. The Principle of the Constancy of Light Speed is an Artificial and Excessive Assumption

The results of the Michelson-Morley experiment can be easily explained by relying on the principle of the constancy of the one-way light speed. But, in fact, the analysis of the Michelson-Morley experiment, and all the other experiments that examined the principle of the constancy of the light speed, have shown [17] that all these experiments proved only the constancy of the average circuit speed of light, not that the constancy of the one-way speed of light; All of these experiments can be explained by the constancy of the average circuit speed of light, rather than by the constancy of the one-way speed of light. Therefore, the usual claim that the principle of the constancy of the one-way light speed has been experimentally verified does not hold true. The principle of the constancy of the one-way light speed is an artificial assumption.

It is important to note that to measure the average speed of light of a circuit from a point O through a distance back to the point O, is not difficult to do so by measuring the distance and measuring the time with only a clock placed at the point O. The calibration of clocks at different places and the synchronization of events at different places are not involved here. For more than one hundred years, a lot of measurement experiments of the light speed have done under variety of different conditions (see literature [17]), all these experiments have proved that the average two-way speed of light or the average circuit speed of light have nothing to do with the speed of light source, frequency and direction of light, and indeed proved the average two-way speed of light or the average circuit speed of light in all inertial system were equal to the constant c. However, the constancy of the average two-way or average circuit speed of light is meaning that the speed of light in one way is variable. Thus, the principle of the constancy of the one-way light speed is an excessive assumption.

In the 1960s and 1970s, Edward [18] and Winey [19] etc. substituted Einstein's the principle of the constancy of the one-way light speed with the principle of the constancy of the average circuit speed of light, and derived the generalized Lorenz Transformation or ε -Lorenz Transformation. Their papers are entitled *The special theory of relativity in Anisotropic Space* and *The special theory of relativity without the Assumption of Unidirectional Light Speed*. They aim to show that the special theory of relativity with the principle of the constancy of the average circuit light speed predicts the same observable effects as Einstein's special theory of relativity.

Actually, it's easy to understand. On the basis of the principle of the constancy of the average circuit light speed and the principle of relativity, the conclusion of the constancy of the one-way light speed can be derived, so as to return to the special theory of relativity. So, here the relativity principle is the key element of the theory.

3. 3. 2. The Principle of the Constancy of the Light Speed is a Counterintuitive Assumption

In the inertial syste S, light propagates along the positive direction of the axis Ox with a speed of c. According to Einstein's principle of the constancy of the one-way light speed, for the reference frame S_1' with relative system S moving in the positive direction of the axis at the speed of +0.9c, and the reference frame S_2' with relative system S moving in the negative direction of the axis at the speed of –0.9c, the propagation speed of this beam of light is equal to constant c (see Fig. 3.3).This is against common sense.

What is the speed? The concept of speed involves both the change in the spatial position of the object under investigation and the time that such a change takes place, and the spatial position and its changes are meaningful only with respect to the specified reference object (or observer), In other words, speed is the rate of time change of the spatial position of the object under investigation based on the reference body (or observer). The object under investigation generally involves a large spatial range, and the motion state (spatial position and its rate of change) of each part varies. You have to describe the parts before you can grasp the whole. The object under investigation may be a material entity or a certain state of matter. Because of these reasons, physics abstract particle velocity, signal velocity, phase velocity and other concepts.

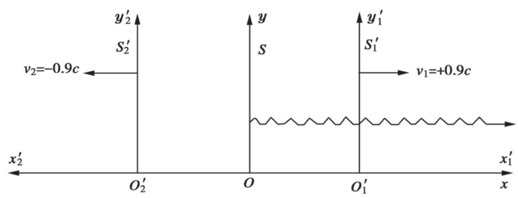

Fig. 3. 3

The speed of light in vacuum refers to the phase velocity of light waves (including monochromatic light and polychromatic light) in vacuum, that is, the time rate of change of the position of a certain equipotential phase plane of light waves relative to the coordinate system (and its origin) established on the selected reference object (or observer). In this case, the speed of light should depend on the choice of reference frame. A series of light waves propagate in vacuum. According to Einstein's special theory of relativity, the electromagnetic field moves in a void space with nothingness at all as an independent matter (that is, a beam of photons). According to Einstein's unified field concept, this is the propagation process of electromagnetic oscillation in the unified field. If we think in terms of Einstein's unified field, we are immediately in contradiction.

Let a series of light waves propagate in the vacuum background field (Fig. 3.3). For the reference frame S_1' with a relative speed of +0.9 *c* to follow and go after the movement of the light wave, and reference frame S_2' with a relative speed of –0.9 *c* to back away from the wave movement within the same time movement, within movement, within the same time (refers to the general time), the changes in the position (i.e., relative to the origins o_1' and o_2' of the two reference frames) of a selected equal-phase surface in the light wave are obviously different, and the location change relative to the frame S_2' obviously bigger than the location change relative to frame S_1' . Therefore, the speed of light in a vacuum naturally depends on the frame of reference. This is common sense.

Einstein first took this common sense into account. He was puzzled. After years of thinking, he finally found a "solution" to the problem. He said: "The answer to this question comes from the analysis of time, it is impossible to determine time absolutely, and there is an inextricable link between time and signal speed. With this new concept, I solved the problem thoroughly for the first time." Indeed, it is difficult to judge whether two events at different places are happening at the same time. I will return to this question in later chapters and suggest a reasonable solution. At first glance, the only way to determine the simultaneity of distant events is to see if the two events can establish a causal link through some interaction (such as signaling). However, as mentioned earlier, there is a logical circulation between the measurement of the speed of the one-way signal and the calibration of clocks at different places. If no reasonable solution can be proposed, this leaves a certain degree of "arbitrariness" for the simultaneity of events at different places. Einstein was take advantage of this, and disregarding the common sense, first put forward the hypothesis of the constancy of the one-way light speed, asserted in any inertial system, even if the inertial system at a speed of 0.9 *c* goes after or reverse moves away from the light wave, the one-way speed of light is equal, is equal to the constant c, and improve the hypothesis to the height of the axiom, on this basis to achieve the calibration of clocks at different places, and establish the whole system of the special theory of relativity. This may be a helpless choice, but also domineering and unreasonable choice.

Taking the principle of the constancy of the one-way light speed (plus the relativity principle) as the starting point of logic, Einstein deduced the relativity of simultaneity and time-delay effect. Considering that the measurement of the length of a moving object requires to read the position coordinates of both ends of the object at the same time, the length contraction effect becomes a direct result of the relativity of simultaneity, and therefore it is also a conclusion derived from the principle of the constancy of the one-way light speed.

Therefore, according to the special theory of relativity, the time delay effect and the length contraction effect are all measurement effects caused by the hypothesis of the constancy of the one-way light speed. These effects are the results observed by the observer who calibrates the clock in different places according to the hypothesis of the constancy of the one-way light speed, and they do not represent any real changes in matter and the process of matter motion itself. In philosophy, this is considered to be a subjective idealist view.

In the special theory of relativity, the time dilation effect and the length contraction effect derived from the principle of the constancy of the light speed are both relative and inverse. When observing in each inertial system, the clock is slowed down and the ruler is shortened in any other inertial system that is in relative motion to. Colloquially speaking, you and I are observers in relative motion. You see that my clock is slower than yours, my ruler is shorter than yours, and I see that your clock is slower than mine, your ruler is shorter than mine. Your and my judgments are diametrically opposed, but your and my statements are scientifically valid at the same time, and there can be no other "objective and fair" judgment. No wonder someone exclaimed: according to this theory, science has no principles, science has no standards! Physics has fallen into relativism.

Although some of the conclusions are counterintuitive, it should be admitted that the above conclusions of the special theory of relativity are logically consistent. Now the question is: does the special theory of relativity cause some real logical contradiction? Or is there a strict logical paradox in the special theory of relativity? As stated earlier, it is now established that the relativity principle has been negated by the discovery of the cosmic background radiation, and that the principle of the constancy of the light speed is actually an artificial convention and an excessive, counterintuitive assumption. Due to the lack of (actually violated) support from physical empirical facts, the theory established from this arbitrary "artificial contract theory" is bound to fall into various logical contradictions and absurdities. In Chapter 8 I propose a strict logical paradox, the sliding paradox of the special theory of relativity. At the same time, we know that special theory of relativity's assertion of the limit of the speed of light is fundamentally opposed to time idea of quantum mechanics. This is a big and serious problem in modern physics.

"Einstein's theory of relativity and quantum mechanics are two of the great academic achievements of the 20th century," UNESCO said in its *World Science Report 1998*. "Unfortunately, the two theories have so far proved to be contradictory to each other. This becomes a serious barrier."

Einstein tried to deal a fatal blow to non-local quantum mechanics by using his firm belief in the principle of the limitation of the light speed or the principle of locality. It was here that Einstein met his Waterloo. We will discuss this in more detail in the next section.

3. 4. Faster-than-light Speed issue and Distant-Correlation Experiments in Quantum Mechanics

Before the birth of the special theory of relativity, J. J. Thomson, O. Heaviside, and A. Sommerfeld etc., talked about faster-than-light speed issue. After the special theory of relativity, the seriously work on faster-than-light issue began in the 1960s. In 1962, O. M. P. Bilaniuk etc. published an article [20], trying to establish the theory of superluminal speed on the basis of the special theory of relativity. Then, in 1967, G. Feinberg [21] published a long paper on the classical theory and quantum theory of faster-than-light particles, marking a new historical period for the study of faster-than-light, leading to a series of theoretical research, astronomical observation and experimental research on faster-than-light over the next 40 years.

3. 4. 1. The Main Reason for the Special Theory of Relativity about the Limitation of the Speed of Light

The special theory of relativity asserts that no object can move or signal can travel faster than the speed of light c in a vacuum. Arguments about the limitation of the speed of light include:

First, the root type $\sqrt{1-v^2/c^2}$ appears in the Lorentz transformation， From the space-time coordinates must be a real number, "it can be inferred that the velocity of matter beyond the speed of light is impossible." [22]

Second, according to Einstein's formula for length contraction, when a body moves at a speed $v = c$, everything shrinks flat. "For superluminal velocities our considerations become meaningless." ([2], Volume 2, p. 152)

Third, according to relativity, the speed transformation formula

$$u' = \frac{u - v}{1 - uv / c^2}. \tag{3.10}$$

It can be deduced that it is impossible to make an object move faster than the speed of light by means of kinematics (coordinate transformation).

Fourth, by relativistic mechanical equation

$$\boldsymbol{F} = \frac{\mathrm{d}}{\mathrm{d}t}\frac{m_0\boldsymbol{u}}{\sqrt{1-u^2/c^2}}. \tag{3.11}$$

It can be concluded that it is impossible to make an object move faster than the speed of light by means of dynamics (applying constant force).

Fifth, according to the kinetic energy formula of particles

$$T = m_0 c^2 \left(\frac{1}{\sqrt{1-u^2/c^2}} - 1 \right). \tag{3.12}$$

"Thus, the kinetic energy becomes infinitely large when $u = c$. As in our previous results, superluminal velocities have no possibility of existence." ([2], Volume 2, p. 170)

Sixth, if there is a faster-than-light object or a faster-than-light signal, a causal link can be established between two pseudo-simultaneous events. This is bound to lead to the violation of the law of causality in some inertial reference frames where the effect occurs before the cause. Therefore, "there cannot exist an effect that can be used for arbitrary signaling and that is propagated faster than light in vacuum." ([2], Volume 2, p. 265)

In short, the special theory of relativity asserts that the speed of motion of any object, or the speed of signal transmission, can't exceed the speed of light in a vacuum. In the logic system of the special theory of relativity, the existence of faster-than-light motion inevitably destructs the law of causality. So does faster-than-light motion actually exist? This needs to be answered by observed and experimental facts.

3. 4. 2. Advances in Experimental Research on Faster-than-light Speed

Contrary to the assertions of the special theory of relativity, experimental studies of modern physics since the 1970s have established that faster-than-light motion exists.

First, since 1970, radio astronomy has discovered the faster-than-light expansion of dozens of quasars [23-25]. Observations show that these quasars may contain multiple sub-sources, and the distances between these sub-sources increase rapidly over time at an expansion rate of several times or even tens of times the speed of light. In 1994, two superluminal expansion sources were observed in the Milky Way galaxy. They appear within the stars and their distance is determined by trigonometric parallax method. Cao Shenglin, in his book *Theory of Relativity and Cosmology in Fensler's Space-time* [26], introduced in detail the observed facts of celestial bodies' faster-than-light expansion (see §8.2 in this book), indicating that a total of 111 faster-than-light expansion sources of 64 celestial bodies have been observed so far. After ruling out some possible explanations, he pointed out that this is the true faster-than-light motion of celestial bodies.

Secondly, since the 1990s, using quantum tunneling effect to realize and observe faster-than-light phenomena has become a research hot-spot. Experiments have confirmed that a single photon or electromagnetic pulse can travel across a barrier at faster-than-light speeds in short-wave, microwave and optical frequencies. Huang Zhixun's *Theory and Experiments on Faster-than-Light Research* [27] makes detailed introduction and discussion on this. With reference to Huang Zhixun's narration, several typical tunneling effect faster-than-light experiments are introduced below.

In 1993, American scientists A. M. Steinbeig, P. G. Kwait and R. Y. Chiao [28] reported a faster- than-light experiment of two-photon races using quantum tunneling effect. By laser irradiation on reducible crystal that produces two photons, and then try to make the two photons emitted at the same time through the different paths, one through the air, another through by dielectric barrier—coating of titanium dioxide (TiO_2) on the silica (SiO_2) substrate, (λ indicating laser wavelength), finally using high sensitivity (10^{-9} s) coincidence counter to compare the time they reach the same terminal. The result is that the photon travels across the barrier at a speed of $v = 1.7c\left(\pm 0.2c\right)$.

In 1994, Ch. Spielman etc. [29] reported an experiment using the double-pulse race of quantum tunneling effect to exceed the speed of light. A femtosecond laser is used to generate a 12-femtosecond pulse, which is divided into two channels by a splitter, one through air, the other through a multilayer medium acting as a potential barrier, and finally the time to reach the terminal detector is compared. Experiments have shown that laser pulses travel across the barrier at faster-than-light group speeds.

1992, the team of G. Nimtz [30] published a faster-than-light of microwave pulses experiment using a cutoff wave-guide as a potential barrier. The wave-guide usually used as a microwave transmission line, and is no longer a transmission wave under the state below the cut-off frequency, but a vanishing field whose intensity decreases according to the exponential function with the increase of penetration depth. This can be likened to the disappearing waves of the tunnel effect, creating the premise that the wave-guide acts as a potential barrier. The G. Nimtz team's experiment divided the microwave pulses into two channels, one through a cutoff wave-guide of about 12 centimeters in length, which acts as a potential barrier, and the other through a transmission line of equal length at the speed of light c. The group velocity $v_g = 4.7c$ of microwave pulses passing through the barrier is obtained by measuring the time difference between them. In 1997, the G. Nimtz group [31] published a new experimental result, group speed $v_g = 4.34c$.

In these experiments, can the information be confirmed to have been transmitted faster than the speed of light? Because of the distortion caused by the pulse passing through the barrier, it is generally believed that the existing experiments of faster-than-light crossing the quantum barrier cannot prove that useful information can be transmitted faster than the speed of light. But there are scientists who take a completely different view. For example, the Nimtz group's experiment implemented a coded transmission using the microwave input modulated by the music of Mozart's 40th symphony, and the music was clearly discernible after decoding at the receiving end. This, G. Nimtz insists, shows that information can travel faster than light.

As stated in the previous section, if experiments do find faster-than-light motions or signals, the special theory of relativity should and will surely be superseded by new theories of space-time that are consistent with experimental results.

3. 4. 3. The Time View of Quantum Mechanics and Distant-correlation Experiments

Relativity and quantum theory, two pillars of modern physics, have always been in conflict. Quantum mechanics uses the concept of time in the absolute sense, and simultaneity also has the absolute sense. Quantum mechanics allows for phenomena that exceed the speed of light (or even the speed of infinity), which is known as the non-locality of quantum mechanics. All of these are not allowed by relativity. As Dirac said in 1975: "Here we have a great difficulty at the beginning.... This conflict has been a major problem in physics for the last four decades. It can be said that the main efforts of physicists revolve around the issue of coordinated relativity and quantum mechanics. A lot of work has been done on this subject, but there is no solution yet."

We know that Einstein and Bohr had very different ideas about quantum mechanics, and there was a long debate about that. Einstein did not deny that quantum mechanics had made great progress in physics, but he believed that quantum mechanics was only an incomplete description of the actual state of a single system. The motion of a particle must be explained in terms of probability simply because some parameters that determine its motion have not been found; if you know the values of these hypothetical "hidden parameters", you can define and completely determine the particle's trajectory.

In order to demonstrate the incompleteness of quantum mechanics, Einstein, together with B. Podolsky and N. Rosen [1] (p. 328 ~ 335) proposed a hypothetical experiment (called EPR demonstration) as early as 1935. They considered two particles A and B with spin $\pm 1/2$ to compose the system with total spin zero. Let's set up that within a period before the time t_0 the two particles interact with each other, and then they are separated by means that do not affect the spin of each particle, when $t > t_0$, they are so far apart in space that they no longer interact. According to Einstein's principle of localization, any interaction in nature can only be transmitted at a speed less than the speed of light. Systems separated by space should be localized, in which case, the measurement of particle *A* should not have any immediate effect on particle *B*. But quantum mechanics predicts that if you measure a component of the spin of *A*, you immediately know the value of the same component of the spin of *B*. According to the theory of quantum mechanics, microscopic objects are generally not in a certain eigenstate before measurement. The measurement operation can get the component value of the *A* particle's spin in a certain direction, and the particle *A* itself will immediately enter the eigenstate of the value of the spin component. But how a distant particle *B*, which neither interacts with a particle *A* nor with an instrument, can cause its spin to take opposite values immediately in the same direction? The problem becomes more serious when considering that the above statement holds true for any direction of the spin measurement, that is, the direction of the instrument measurement can be arbitrarily changed. This means that the event in which the *A* spin is measured by the instrument has an effect on the particle *B*, and that effect is instantaneous beyond the speed of light. This was unacceptable to Einstein.

The limitation of the speed of light is an important consequence of the special theory of relativity. Combining Einstein's view of physical reality with the limitation of the speed of light, we can get Einstein's principle of separability or principle of locality, which can be expressed as: There is no superluminal interaction and instantaneous action at a distance; If there are no the physical signals transmitted at a speed not greater than the speed of light to establish a connection, the real states of the objects separated in the space are independent of each other.

The so-called EPR demonstration was Einstein's attempt to deal a fatal blow to non-local quantum mechanics by using his own firm belief in the principle of the limitation of the speed of light or the principle of locality.

To eliminate the paradox, Einstein said, one can only be certain of one of two assertions: "Either quantum mechanics is incomplete or it must assume action at a distance." We know that Einstein emphatically upheld the principle of locality and denied the completeness of quantum mechanics.

In order to conduct experimental research on the demonstration of EPR, Bohm first changed the EPR thought experiment into an experimental scheme to measure the correlation between proton spin and photon polarization in the 1950s. The experiments of this kind were done earlier by Wu Jianxiong and others, and the results have been consistent with predictions of quantum mechanics.

In 1964, Bell, in his famous paper "On the EPR paradox" [32], on the basis of analyzing the demonstration of EPR, started from the theory of localized hidden parameters, and adopted three basic assumptions of localized realism (see below) to prove an inequality:

$$\left|P(\boldsymbol{a}, \boldsymbol{b})-P(\boldsymbol{a}, \boldsymbol{c})\right| \leq 1+P(\boldsymbol{b}, \boldsymbol{c}), \tag{3.13}$$

where $P(\boldsymbol{a},\boldsymbol{b}), P(\boldsymbol{a},\boldsymbol{c})$ and $P(\boldsymbol{b},\boldsymbol{c})$ respectively represent: the product A_aB_b, A_aB_c, A_bB_c of the mean value of the spin projection of the particle *A* and *B* measured in (1) $\boldsymbol{a}$ and $\boldsymbol{b}$ direction; (2) $\boldsymbol{a}$ and $\boldsymbol{c}$ direction; (3) $\boldsymbol{b}$ and $\boldsymbol{c}$ direction respectively. This relation is called Bell's inequality.

Let angle θ represents the included angle between the direction $\boldsymbol{a}$ and the direction $\boldsymbol{b}$ (take the value of less than π), since the three-dimensional space isotropy, denoted by $P(\boldsymbol{a},\boldsymbol{b})=P(\theta)$, can be further obtained

$$\left|P\left(30^0\right)\right| \le 2/3, \quad \left|P\left(45^0\right)\right| \le 1/2, \quad \left|P\left(60^0\right)\right| \le 1/3 . \tag{3.14}$$

Bell adopted three basic assumptions of local realism: First, realism, holds that the regularity of observed phenomena is caused by some physical object that exists independently of the observer; Second, inductive inference method, that is rational conclusion can be drawn from the consistent observations by using the inductive reasoning method; Third, Einstein’s principle of separability or Einstein’s principle of locality.

By the 1970s, after the simplified derivation of Wigner etc., especially the work of Stapp and B. d’Espagnat etc., it became clear that the essence of Bell’s inequality laid in Einstein’s principle of localization, and had nothing to do with the specific introduction of implicit parameters. That is to say, Bell’s inequality can be derived by introducing quantum mechanical observable measurements according to the three assumptions of local realism.

According to the theory of quantum mechanics, the following equation can be obtained, that is

$$P(\boldsymbol{a},\boldsymbol{b}) = P(\theta) = -\cos\theta. \tag{3.15}$$

That is to say, the local reality asserts that the experimental results satisfy Bell’s inequality, whereas quantum mechanics predicts that the experimental results will violate this inequality. Until 1982, completed twelve experiments, in addition to the early years (1973—1974) two low accuracy, poor reliability experiments, the results of ten experiments, the most authoritative of which were carried out by A. Aspect [33-35] of the European Center for High Energy Physics in 1982, did not fall on the vast region satisfying the Bell inequality, but just down on the curve predicted by quantum mechanics. In 1998, a new experiment was published [36], which was conducted with two-photon with wavelength of 7020 angstrom (A) at a space distance of 400 meters. The result also violated Bell’s inequality and supported quantum mechanics. For more than 30 years, starting in 1982, many experiments have been carried out with entangled twin photons, whose distance is more than 100 kilometers. The experimental results all support the quantum mechanics non-locality and violate Bell’s inequality. In 2008 experiments and calculations by Swiss scientists showed that the speed at which two photons in entangled states, 18 kilometers apart, interact with each other, is not infinite, but it is faster-than-light, that can be reached（104—107）c. The results were published in the prestigious journal *Nature*.[37]

In recent years, experiments to more accurately eliminate possible loophole (such as local loophole and measurement loophole), are continuing. At present, physicists have generally accepted the violation of Bell’s inequality as an experimental fact. All experiments confirm that the non-locality between quanta is a real existence. Although it is not possible to use entangled particles to transmit faster-than-light information at present, there is no doubt that there is a faster-than-light causal link or effect between two entangled particles.

Thus, local realism seems untenable, and at least one of the three basic assumptions that underlie it is wrong. The first deals with materialism, the second with methodology, and the third with relativity. What's the problem? Comparing these three assumptions, especially in view of Einstein's initial statements, the vast majority of physicists tend to believe that the experimental test of Bell's inequality is, in fact, a test of Einstein's principle of locality, and that experimental facts that violate Bell's inequality can be explained only by abandoning this principle. Experiments to test Bell's inequality are also known as distant-correlation experiments.

Commenting on the test results of Bell's inequality, physicists have come up with many new ideas.

Bohm believed that [38], there exists a new field in the objective world, in which the nonlocal relation is a more basic and real relation. Bohm explained this kind of nonlocal relation by means of the quantum potential of universal correlation or wholeness correlation. He believes that the current development of physics is indicating the existence of this new ontology or essence. Stapp [9] argues that the spatial separate parts of the world do not exist independently, but must relate to each other in a way that transcends the familiar causal connection that can only be transmitted to the anterior light cone; this is a "faster-than-light connection" between individual events. According to B. d'Espagnat [39], the experimental test of Bell's inequality shows that Einstein's principle of localization is broken, which means that there is a faster-than-light causal link or effect between multiple independent systems or within a single extended system. Experimental facts that violate Bell's inequality can only be explained by abandoning Einstein's principle of locality.

According to Bohm, Stapp, and B. d'Espagnat, distant-correlation experiments reveal a faster-than-light connection or influence between microscopic objects, but this does not mean that controllable faster-than-light interactions convey macroscopic information, and therefore do not imply the existence of faster-than-light signals.

In my view, however, the experimental test of the Bell inequality reveals that there is a nonlocal correlation or faster-than-light correlation between microscopic objects, which should be understood as a faster-than-light interaction transmitted by matter moving at a deeper level of the faster than light. If so, isn't that a challenge to the "light-cone specification" of the special theory of relativity? The results of distant-correlation experiments show that Einstein's principle of locality gives an artificial and erroneous description of the nature, and scientists must pursue and explore a new space-time theory compatible with the principle of non-locality, which allows the existence of superluminal interactions and mutual influences, and even accepts the concept of superluminal signals. This was the view expressed by me in my 1983 paper "Standard Space-time Theory".

Professor Lu Hefu thinks: "The theory of quantum is essentially a non-locality, involving space-like contact or associated, which involves faster-than-light signals transmission." [40]

Nobel prize-winner British physicist B.D. Josephson points out that the interactions in the EPR process are instantaneous and, of course, faster-than-light. Einstein thought this could not happen, but Bell (in 1965) and later Stapp proved that these faster-than-light effects were predictable, using equations generally accepted in quantum mechanics.

Popper, a famous philosopher of science, said that the possibility of existence of the action at a distance should be considered after the publication of the Aspect experiment. If there is action at a distance, it will oppose Einstein's interpretation of the formal system of the special theory of relativity and support the Lorentz interpretation, or even Newton’s concept of absolute space. Therefore, the Aspector experiment can be regarded as a decisive experiment between the Lorentz theory and the special theory of relativity.

In 1985 BBC radio 3 ran a feature programme in which science journalist J. Brown recorded interviews with leading scientists to see what they learned from the results of the Aspect’s experiment. After the program was broadcast, it aroused great interest of the public and gained full recognition from the public. These interview contents were compiled and published in 1986 [41], among which the translation version *The Ghost in the Atom* by Hunan Science and Technology Press. To conclude this section, the following excerpts are some important questions and answers from the interviews of the three scientists directly related to the experiment (Aspect, Bohm, Bell). In the following excerpts, the omitted sentences and paragraphs are omitted without ellipsis in order to achieve coherence and save space, but the content expressed is absolutely faithful to the original text.

Let’s start with a partial Q & A from the reporter and Aspect

Q: And so, having performed this experiment, what conclusions do you draw from the results?

A: We can say that the results violate Bell’s inequalities, which means that we cannot keep a simple picture of the world, retaining with Einstein’s idea of separability.

Q: Do you believe that it’s possible that there is some sort of faster-than-light signaling taking place between the separated regions?

A: What these experiments have shown is first that they violate Bell’s inequalities, and on the other hand, that these results are in very good agreements with the prediction of quantum mechanics. Even in this kind of experiment it is not possible to send any messages or useful information faster than light. However, if you mean that in some picture of the world that you want to construct, you can include some kind of faster than light mathematical object.

Part of the reporter’s Q & A with Bohm follows

Q: Now, as I understand it, given Aspect’s results we have to relinquish either what we might call objective reality—the external world existing independently of our observations—or locality—the idea that different regions of the universe can’t signal to each other faster than light, crudely speaking. Which of these two are you prepared to relinquish?

A: I would be quite ready to relinquish locality; I think it’s an arbitrary assumption. I mean in the last few hundred years it has been given tremendous weight. If you went back 1000 or 2000years, almost everybody was thinking non-locally.

Q: Then you want to abandon the special theory of relativity?

A: I don’t say abandon relativity theory. I'm saying it’s going to be an approximation to a much broader point of view, just as Newtonian mechanics is an approximation to relativity.

Q: But you must certainly entertain the idea of faster-than-light signaling.

A: Yes, I have a view which would entertain that and yet not contradict any experiments which have been performed.

Q: It seems a little ironical that you are, if not contradicting Einstein’s special theory, at least drastically modifying it, perhaps against the spirit of the original theory. What do you think Einstein would make of this?

A: Yes, well I don’t think anybody can necessarily expect everything to turn out the way he expects it. Quite a few things turned out that way for Einstein, but he can't have everything right!

Finally, we quote some of the reporter’s Q & A with Bell in a bit more detail

Q: Einstein made the famous remark that God does not play dice with the universe. Would you say that after this experiment, and after your work, you’re convinced that God does indeed play dice with the universe?

A: No, no, by no means. But I would also like to qualify a little bit this “God does not play dice” business. This is something which is often quoted Einstein did say rather early in his early career, but afterwards he was more concerned with other aspects of quantum mechanics than with the question of indeterminism. And indeed, Aspect’s particular experiment tests rather those other aspects, specifically the question of no action at a distance.

Q: Do you think this experiment does’t tell us anything about determinism, or indeterminism, or the physical world?

A. I think that it’s a whole world view which is tested by an experiment. To be sure, this experiment shows that Einstein’s world view is untenable.

Q: Bell’s inequality is, as I understand it, rooted in two assumptions: the first is what we might call objective reality—the reality of the external world, independent of our observations; the second is locality, or non-separability, or no faster-than-light signaling. Now, Aspect’s experiment appears to indicate that one of these two has to go. Which of the two would you like to hang on to?

A: I think it's a deep dilemma. But I would say that the cheapest solution is something like going back to relativity as it was before Einstein, when people like Lorenz and Poincare thought that there was an ether—a preferred frame of reference. You can imagine that there is a preferred frame of reference, and in this preferred frame of reference things do go faster than light. That is certainly the cheapest solution. Behind the apparent Lorentz invariance of the phenomena, there is a deeper level which is not Lorentz invariant.

Q: Of course, the theory of relativity has a tremendous amount of experimental support, and it's hard to imagine that we can go back to a pre-Einstein position without contradicting some of the results of this experimental support. Do you think it's actually possible?

A: Well, what is not sufficiently emphasized in textbooks, in my opinion, is that the pre-Einstein position of Lorenz and Poincare, Larmor and Fitzgerald was perfectly coherent, and is not inconsistent with relativity theory. The idea that there is an ether, and the Fitzgerald contraction and Larmor dilations occur, and that as a result the instrument do not detect motion through the ether—that is perfectly coherent point of view.

Q: And it was abandoned on grounds of elegance?

A: Well, on the grounds of philosophy; that what is unobservable does not exist. And also, on grounds of simplicity, because Einstein found that the theory was both more elegant and simpler when we left out the idea of the ether. I think that the idea of the ether should be taught to students, because I find that there are lots of problems which are solved more easily by imagining the existence of the ether. The reason I want to go back to the idea of the ether here is because in these EPR experiments there is the suggestion that behind the scenes something is going faster than light.

Q: To sum up then, you would prefer to remain the notion of objective reality and throw away one of the tenets of relativity: that signals cannot travel faster than the speed of light?

A: Yes. One wants to be able to take a realistic view of the world in order, to talk about the world as if it is if it really there, even when it is not being observed. I certainly believe in a world that was here before me, and will be here after me, and I believe you are part of it! And I believe that most physicists take this point of view when they are being pushed into a corner by philosophers.

Q: You believe that the present formulation of quantum theory, which has been so tremendously successful over the last 50 years, is still only tentative, and will be replaced at some stage in the future by a better theory?

A: I'm quite convinced that: quantum theory is only a temporary expedient.

J. S. Bell (1928—1990) was a prominent scientist at CERN, but he died a little early. The point of view he stated in the interview was so clear that it would be cumbersome for me to outline it further. I completely agree with Bell on these points.

Some may be uneasy about abandoning or going beyond the special theory of relativity. Two things must be kept very clear when discussing innovation. First, the earth is four or five billion years old, the human race is four or five million years old, and our science and technology are only three or four hundred years old, if we count the emergence of modern science and technology. Tsiolkovski said, "The earth is the cradle of mankind, but mankind cannot live in the cradle forever." It is a proud achievement that man, with his existing science and technology, has the ability to escape the earth's gravity. However, if we take a longer view, we can assert that the development of human science and technology has only passed its "cradle period" so far. It is very childish and superficial to leave this judgment, and to think that the knowledge has already existed has exhausted the truth, and to reject as false or no, or to turn a blind eye, to any theory or empirical fact which contradicts the original system of theory. Second, a new point of view, a new theory, should become the truth and reflect nature as it really is, not just by imagination or arbitrary fabrication. What is needed is to proceed from empirical facts, carry out rigorous and realistic theoretical research, and accept the test of experiment. Although the new theory may be conceptually different from the original, as Bohm said, the original theory, which has been proved correct to a certain extent, is still an approximation of the new theory under certain circumstances. New theories must have this capacity for inclusion. The above two points are two aspects of the same problem, the lack of which aspect has one-sidedness.

In short, Einstein's special theory of relativity has major flaws. Or, as he himself speculated, the special theory of relativity would eventually need to give way to other theoretical systems. Otherwise, we can only exclaim: the feast of physics has passed! Human science is bound to stagnate. This will be the "sadness of physics"! In the next chapter we move away from the special theory of relativity, and return to the nature images of the aggregation state-dispersion state to see what new things will be opened up.

Before moving on to the next chapter, I feel compelled to make two important explanations here.

First, quantum mechanics itself is not a mature theory.

The narrative of this section seems to indicate that people seem to think that the experimental judgments of the special theory of relativity and quantum mechanics end with the complete victory of quantum mechanics. Is that the case? I think that it can only to say that the results of the distance correlation experiments confirm the correctness of non-locality of quantum mechanics (that is, the presence of connections, influences that allow faster-than-light transmission) and that the special theory of relativity needs to give way to other theoretical systems. However, quantum mechanics itself is not a mature theory. In this regard, a more detailed discussion will be given in Chapter 10.

Secondly, Bell said, the cheapest solution is to go back to pre-Einstein's theory of relativity, i. e. the Lorentz's ether theory. But Lorentz's efforts, as described in the introduction, are accomplished by adding a series of additional assumptions, corrections, and additions to classical physics. Lorentz's ether theory is not systematic and thorough. Lorentz did not establish a theory of space and time consistent with the principles of logical simplicity and logical self-chastity. And the Lorentz transformation goes against the original ideas of ether. So simply returning to Lorentz's ether theory is not the best solution.

In the next chapter, we will leave the special theory of relativity, which is based on void space with nothingness, and follow the nature images of the aggregation-dispersion state of the material world set in Chap. 1, and objective realism, logical simplicity and logical self-coincidence principles, enter into the subject of this book—the construction and study of the system of Standard Space-time Theory.

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Chapter 4

Basic Postulates and Coordinate Transformation of Standard Space-time Theory

4. 1. Introduction

The concepts described in the introduction and the first three chapters lay the theoretical foundation of epistemology for the establishment of the new space-time theory.

Newton's absolute space-time theory and Einstein's special theory of relativity are two major basic scientific achievements in human history. They have laid the basic theoretical foundation for the progress of human civilization. However, the development of modern science clearly shows that we must continue to move forward and realize integrating and upgrading of Newton's and Einstein's concept of time and space.

How to move forward? The basic theory of basic science must focus on the understanding of the nature of the world.

Modern science, first of all, the development of modern physics, has provided people with a more accurate and richer understanding of nature, and the picture of the material world revealed by it shows the trend of the confluence of the ancient Chinese yuanqi theory and ancient Greek atomism theory. The aggregated-dispersed states natural images is a clear and systematic expression of the new view of nature revealed by the frontier development of modern science.

We have already known that in the macroscopic or cosmic scale, the dispersed-state vacuum background can be regarded as a uniform distribution, which constitutes the background and the medium of the interaction between the physical particles and the macroscopic objects and celestial bodies composed of them. The cosmic background radiation is a process that occurs in the vacuum background field.

The dispersed-state vacuum background field is the absolute reference frame we are looking for.

It is on the basis of the aforementioned concepts and the abundant materials provided by the development of modern science that we first accurately understand the experimental fact of the constancy of the average circuit speed of light, and secondly recognize that the vacuum background field constitutes the absolute frame of reference for the motion of matter. Starting from this, we will establish a new space-time theory to realize integrating and upgrading of Newton's and Einstein's space-time concepts.

This chapter advances two postulates about the properties of space-time: (1) the principle of the absolute reference frame and (2) the principle of the constancy of the average circuit speed of light. Obviously, these two postulates are different from those of Einstein's Special Theory of Relativity (SR). They are the fundamental postulates for constructing a new space-time theory, here called "Standard Space-time Theory" (SST). Strictly from the above two postulates, this chapter derives the space-time coordinates transformation between an ordinary inertial reference frame and the standard inertial reference frame, i.e., Generalized Galilean Transformation (GGT)

4. 2. Basic Postulates

Since many famous physicists have put forward the proposal of restoring the ether hypothesis and admitting existence of absolute reference frame, to investigate that what results can be logically gained from the postulate of the absolute reference frame is undoubtedly meaningful works. However, the results gained purely from this postulate are very limited. Please notice that the postulate of the constancy of the average circuit speed of light has firmer experimental bases and is nothing but summation of great deal of experimental facts. Hence, in my view, the following two basic postulates can be taken as the logical starting point for construct a new space-time theory.

Postulate 1: The principle of the absolute reference frame

There exists a preferred inertial reference frame called the "standard inertial frame" or "absolute inertial frame", in which space appears to be isotropic. The length contraction of a body moving with respect to the standard frame (if it exists) takes place only at the direction of the body motion and has its absolute meaning. A reference frame that moves uniformly in a straight line with respect to the standard inertial frame is also an inertial reference frame.

Postulate 2: The principle of the constancy of the average circuit speed of light

In any inertial reference frame, the average circuit speed of light signal propagated (in vacuum) over a closed path is always a constant c, and is independent of the light source position and motion and space direction.

Apart from the above two postulates, new space-time theory must satisfy the following three requirements as the special theory of relativity does:

(1) For two events between which there could be a causal connection, event as “cause” occurs always prior to event as “result”. (The causality)

(2) The all points in space and time are equivalent. (The assumption of uniformity of space-time)

(3) The new space-time transformations in the range of low speed ($v \ll c$) should be returned to the classical transformations. (The correspondence principle).

Whatever is the absolute reference frame? The invisible and imageless vacuum background field to spread all over the place, i.e., “Tai Xu Zhi Qi” (“The Qi of the intangible universe”) of ancient Chinese theory of ‘Qi’ (vitality), forms the background of motions of visible substantial matter, macroscopic bodies and celestial bodies and the intermediary medium of their interactions. The vacuum background field is the above-mentioned absolute reference frame, relative to which the cosmic background radiation is uniform and isotropic, and relative to which the motion velocity of our Earth or solar system can be measured.

As to Postulate 1, since the existence of the absolute frame is admitted, the length contraction is naturally considered as the result of interaction of the moving body with the matter constituting the absolute frame, and is a dynamic effect and has the absolute meaning. Notice that a body is a structure of substantial particles and fields, and the dimension of a particle is much smaller than the distance between particles. For example, according to the experimental results of modern physics, dimension of a hydrogen atom is 1×10^{-10} m, while that of its components, i.e. nucleus and electron are 1×10^{-15} m and less 1×10^{-18} m, respectively. Then the length contraction of the moving body occurs only at the direction of its motion. Then the First Postulate is natural and consistent in logic.

As to Postulate 2, if the constancy of one-way light speed holds, then we can infer the constancy of the average circuit speed of light. But the constancy of the one-way speed of light cannot be inferred from the constancy of the average circuit speed of light. As mentioned above, the constancy of one-way light speed is only a convention, and cannot be tested by experiments. Only the constancy of the average circuit speed of light has solid experimental basis. Then the Second Postulate is more reasonable and trustworthy than the postulate of the special theory of relativity.

Following to axiomatic methodology, I hope to start from the above two basic postulates, not to add other postulates, but to use mathematical tools and logical inference to dig out and explain as best I can the plentiful physical contents contained in the basic postulates, and finally compare the theoretical results with experimental facts. All these efforts develop a new space-time theory, which I call Standard Space-time Theory.

4. 3. Derivation of the Transformation of Space-time Coordinates

According to Postulate 1, there exists standard inertial frame Σ_a. Now we derive the space-time coordinates transformation between an ordinary inertial frame Σ and the standard inertial frame Σ_a.

(1) The limitation of causality to the one-way speed of light in an arbitrary direction

The average two-way speed of light pulse (a special case of the average circuit speed of light), traveling from point *A* to *B* and reflecting back to *A*, is an observable quantity which does not depend upon the definition of simultaneity. Obviously, the related time interval satisfies the relation

$$t_{ABA} = t_{AB} + t_{BA}\,, \tag{4.1}$$

where the subscripts represent the path of the light signal, the first and the last subscripts represent the clocks that are read when the light signal starts and arrives, respectively. According to Principle 2, we have

$$\frac{2x}{c} = \frac{x}{c_{AB}} + \frac{x}{c_{BA}}, \quad \text{or} \quad \frac{2}{c} = \frac{1}{c_{AB}} + \frac{1}{c_{BA}}, \tag{4.2}$$

where *x* represents the distance between *A* and *B*.

We can't conclude that $c_{AB} = c_{BA} = c$ as Einstein's principle of the constancy of the speed of light requires. But causality requires $t_{AB} > 0$, $t_{BA} > 0$. Hence from (4.2) we know that $c_{AB} > c/2$, $c_{BA} > c/2$. This statement holds true to speed of light $c(\alpha, \beta, \gamma)$ at any direction (α, β, γ denote direction angles), so

$$c/2 < c(\alpha, \beta, \gamma) < \infty. \tag{4.3}$$

Obviously, the determination of one-way speed of light and the synchronization of clocks at different places are interchangeable matters. Formula (4.3) has manifested that if only the principle of constant of average circuit speed of light is considered, the determination of one-way speed of light and the synchronization of clocks at different places have both certain arbitrariness.

(2) Relation between the speed of light in any direction and that along three mutual perpendicular coordinate axes

Suppose a light signal emanates from point *O* and reflects from some appropriately placed mirrors and forms circuit *OABCO* (Fig.1). We write the identity

$$t_{OABCO} = t_{OA} + t_{AB} + t_{BC} + t_{CO}\,. \tag{4.4}$$

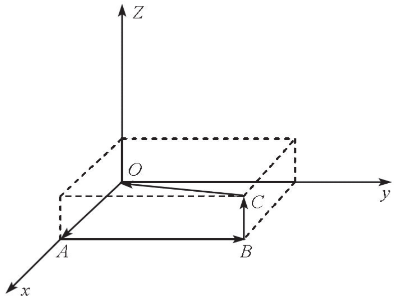

Fig.4.1

According to Postulate 2 we have from Eq. (4.4) that in any inertial frame (Σ_a or Σ)

$$\frac{x+y+z+(x^2+y^2+z^2)^{1/2}}{c}=\frac{x}{c_x}+\frac{y}{c_y}+\frac{z}{c_z}+\frac{(x^2+y^2+z^2)^{1/2}}{c(-\alpha,-\beta,-\gamma)}, \tag{4.5}$$

where c_x, c_v, c_z represent speed of light along positive x, y, z axes and $c(-\alpha,-\beta,-\gamma)$ represents the speed of light in the direction of the negative radius vector from the origin *CO*. But, from (4.2), the speed of light $c(\alpha,\beta,\gamma)$ along vector *CO* can be written as

$$\frac{1}{c(\alpha,\beta,\gamma)}=\frac{2}{c}-\frac{1}{c(-\alpha,-\beta,-\gamma)} \quad \text{or} \quad \frac{1}{c(-\alpha,-\beta,-\gamma)}-\frac{1}{c}=\frac{1}{c}-\frac{1}{c(\alpha,\beta,\gamma)}.$$

Substituting it into Eq. (4.5) we have

$$1-\frac{c}{c(\alpha,\beta,\gamma)}=\left(1-\frac{c}{c_x}\right)\cos\alpha+\left(1-\frac{c}{c_y}\right)\cos\beta+\left(1+\frac{c}{c_z}\right)\cos\gamma . \tag{4.6}$$

Now we introduce the following light speed parameters

$$X=1-\frac{c}{c_x},\ \ Y=1-\frac{c}{c_y},\ Z=1-\frac{c}{c_z},\ \ R=1-\frac{c}{c(\alpha,\beta,\gamma)}, \tag{4.7}$$

or

$$c_x=\frac{c}{1-X},\ \ c_y=\frac{c}{1-Y},\ \ c_z=\frac{c}{1-Z},\ \ c(\alpha,\beta,\gamma)=\frac{c}{1-R} . \tag{4.8a}$$

From Eqs. (4.2) and (4.7) we can get the speed of light along negative coordinate axes and along negative vector *CO*:

$$c_{-x}=\frac{c}{1+X},\ \ c_{-y}=\frac{c}{1+Y},\ \ c_{-z}=\frac{c}{1+Z},\ \ c(-\alpha,-\beta,-\gamma)=\frac{c}{1+R}. \tag{4.8b}$$

Besides, from the restriction condition (4.3) we have

$$-1<X,Y,Z,R<+1 . \tag{4.9}$$

Substituting Eq. (4.7) into Eq. (4.6) we have

$$R(\alpha,\beta,\gamma)=X\cos\alpha+Y\cos\beta+Z\cos\gamma . \tag{4.10}$$

This result shows that the speed of light along any direction is determined when the speed of light along x, y, z axes are given.

(3) Wave-front equation of a point light source

The wave-front equation of a point light source located at the origin is

$$r = c(\alpha, \beta, \gamma)t\,. \tag{4.11}$$

Substituting the last equation of Eqs. (4.8) and Eq. (4.10) into Eq. (4.11), we get

$$r = ct + Xx + Yy + Zz\,, \tag{4.12}$$

$$x^2 + y^2 + z^2 = (ct + Xx + Yy + Zz)^2\,. \tag{4.13}$$

The discussions of the above (1), (2) and (3) are all hold true for any inertial frame.

(4) Simplified case

Consider the simple case of taking the two inertial frames $\Sigma_{\rm a}$ and Σ in a special configuration, where the ordinary frame Σ with respect to the standard inertial frame $\Sigma_{\rm a}$ moves at a constant velocity $\boldsymbol{v}$ along positive $x_{\rm a}$ axis of $\Sigma_{\rm a}$. Here $\boldsymbol{v}$ is relative to $\Sigma_{\rm a}$ and is measured in $\Sigma_{\rm a}$. The x axes of the two reference frames are taken along the same direction (Fig.4.2) and at the instant the origins of the two frames coincide, we let the clocks there read $t_{\rm a} = 0$ and $t = 0$. In the above case, symmetry relative to x axis exists in frame Σ; hence $Y = Z = 0$, $c_v = c_{-v} = c$, $c_z = c_{-z} = c$ but $X \neq 0$, $c_{\pm x} = c/(1 \mp X) \neq c$. The speed of light in frame $\Sigma_{\rm a}$ is isotropic, hence $X_{\rm a} = Y_{\rm a} = Z_{\rm a} = 0$. In frame $\Sigma_{\rm a}$ and frame Σ, the wave-front equation can be written as

$$x_{\rm a}^2 + y_{\rm a}^2 + z_{\rm a}^2 = c^2 t_{\rm a}^2\,, \tag{4.14}$$

$$x^2 + y^2 + z^2 = (ct + Xx)^2\,. \tag{4.15}$$

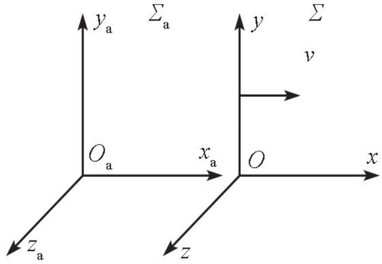

Fig. 4.2

(5) Linear transformation

According to Postulate 1, if a body is in uniform rectilinear motion in frame $\Sigma_{\rm a}$, and the equation of motion is described by the linear relation between $x_{\rm a}$ and $t_{\rm a}$, then its equation of motion in frame Σ should also be described by a linear relation between x and t. Also, from the assumption of uniformity of space and time, the finite value of space-time coordinates in frame $\Sigma_{\rm a}$ must remain finite in frame Σ. Hence, the space-time transformations between two inertial frames must be linear. We can generally write them in the form

$$\begin{pmatrix} x \\ y \\ z \\ t \end{pmatrix} = \begin{pmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & \alpha_{34} \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} \end{pmatrix} \begin{pmatrix} x_a \\ y_a \\ z_a \\ t_a \end{pmatrix} . \tag{4.16}$$

In such arrangement of the coordinate systems, each point which is at rest relative to frame Σ moves at a constant velocity $\boldsymbol{v}$ along the positive x_a axis with respect to frame Σ_a. Hence, the first equation in Eq. (4.16) should be taken the following form

$$x = \alpha_{11}(x_a - vt_a) . \tag{4.17}$$

The x axes of two coordinate systems are all along the direction of $\boldsymbol{v}$. Plane $o_a x_a z_a$ coincides with plane oxz, and plane $o_a x_a z_a$ coincides with plane oxy forever. That is to say, when $y_a = 0$, we have $y = 0$; when $z_a = 0$, we have $z = 0$. Hence

$$\alpha_{21} = \alpha_{23} = \alpha_{24} = 0, \quad y = \alpha_{22} y_a , \tag{4.18}$$

$$\alpha_{31} = \alpha_{32} = \alpha_{34} = 0, \quad z = \alpha_{33} z_a . \tag{4.19}$$

Besides, owing to the existence of symmetry relative to the x axis, t should be independent to y_a and z_a, otherwise the clocks in plane $o_a y_a z_a$ placed symmetrically to the x axis would show different readings to an observer in frame Σ. Hence

$$t = \alpha_{41} x_a + \alpha_{44} t_a . \tag{4.20}$$

(6) Define $\alpha_{11}, \alpha_{22}, \alpha_{33}, \alpha_{41}$ and α_{44}

Substituting Eqs. (4.17)—(4.20) into the wave-front Eq. (4.15) gives

$$\begin{aligned} &\left[\alpha_{11}^2 - (c\alpha_{41} + X\alpha_{11})^2\right] x_a^2 + \alpha_{22}^2 y_a^2 + \alpha_{33}^2 z_a^2 \\ &= \left[(c\alpha_{44} - Xv\alpha_{11})^2 - v^2\alpha_{11}^2\right] t_a^2 + 2\left[(c\alpha_{41} + X\alpha_{11})(c\alpha_{44} - X v\alpha_{11}) + v\alpha_{11}^2\right] x_a t_a . \end{aligned}$$

This equation shows the same thing as Eq. (4.14) does. Comparing the coefficients of the two equations we have

$$\left.\begin{aligned} &\alpha_{11}^2 - (c\alpha_{41} + X\alpha_{11})^2 = 1, \\ &\alpha_{22}^2 = 1, \ \alpha_{33}^2 = 1, \\ &(c\alpha_{44} - Xv\alpha_{11})^2 - v^2\alpha_{11}^2 = c^2, \\ &(c\alpha_{41} + X\alpha_{11})(c\alpha_{44} - Xv\alpha_{11}) + v\alpha_{11}^2 = 0. \end{aligned}\right\} \tag{4.21}$$

Solving these equations, we obtain

$$\alpha_{11} = \gamma, \tag{4.22}$$

$$\alpha_{22} = \alpha_{33} = 1, \tag{4.23}$$

$$\alpha_{41} = -\gamma c^{-1}(\beta + X), \tag{4.24}$$

$$\alpha_{44} = \gamma(1 + \beta X), \tag{4.25}$$

where $\beta = v/c, \ \gamma = (1 - v^2/c^2)^{-1/2}$. From Eq. (4.22) we can see that for real α_{11} we must have $v < c$ or $\beta = v/c < 1$. That is to say, inertial frames can only be put onto subluminal matter. Besides, from Eq. (4.21) we should get $\alpha_{11} = \pm\gamma$, $\alpha_{22} = \alpha_{33} = \pm 1$, etc., but here we only take positive sign in order to satisfy the requirement of the correspondence principle.

Up to now, we have obtained the transformation form as follows

$$x = \gamma(x_{\mathrm{a}} - vt_{\mathrm{a}}), \tag{4.26}$$

$$y = y_{\mathrm{a}},\ z = z_{\mathrm{a}}, \tag{4.27}$$

$$t = \gamma(1+\beta X)t_{\mathrm{a}} - \gamma c^{-1}(\beta + X)x_{\mathrm{a}}. \tag{4.28}$$

(7) Define X

The remained problem is to define X. We shall show that evaluation of X can be decided from the principle of the absolute reference frame.

Suppose the space-time coordinates of two events 1 and 2 in frames Σ_{a} and Σ (for simplicity, coordinates y and z are neglected) are separately $(x_{\mathrm{a1}}, t_{\mathrm{a1}})$ and $(x_{\mathrm{a2}}, t_{\mathrm{a2}})$, (x_1, t_1) and (x_2, t_2). Let

$$\Delta x_{\mathrm{a}} = x_{\mathrm{a2}} - x_{\mathrm{a1}}, \quad \Delta t_{\mathrm{a}} = t_{\mathrm{a2}} - t_{\mathrm{a1}};$$

$$\Delta x = x_2 - x_1, \quad \Delta t = t_2 - t_1.$$

According to Eqs. (4.26)—(4.28) we have

$$\Delta x = \gamma(\Delta x_{\mathrm{a}} - v\Delta t_{\mathrm{a}}), \tag{4.29}$$

$$\Delta t = \gamma(1+\beta X)\Delta t_{\mathrm{a}} - \gamma c^{-1}(\beta + X)\Delta x_{\mathrm{a}}. \tag{4.30}$$

First, suppose a rigid rod is placed along x axis and at rest relative to Σ, and so it is in motion relative to Σ_{a} with a velocity $\boldsymbol{v}$, with which the frame Σ moves along the common x axes with respect to Σ_{a}. The length of the rod relative to Σ is its proper length L_0, namely $\Delta x = L_0$, which should not depend on whether the readings of the two ends of the rod are read simultaneously or not. But the length of the rod relative to Σ_{a} is $\Delta x_{\mathrm{a}} = L_{\mathrm{a}}$. Here the readings x_{a2} and x_{a1} of the two ends should be read simultaneously ($\Delta t_{\mathrm{a}} = 0$). Substituting the condition $\Delta t_{\mathrm{a}} = 0$ into Eq. (4.29) gives

$$\Delta x_{\mathrm{a}} = \gamma^{-1}\Delta x \quad \text{or} \quad L_{\mathrm{a}} = \gamma^{-1}L_0 = \sqrt{1-\beta^2}\,L_0, \tag{4.31}$$

where L_0 also represent the rest length of the rod relative to frame Σ_{a}, because of that we can reasonably consider that a rod and a ruler in the same motion state will have the same changes of length per unit length, so in any inertial frame the measure of the length of the same rod at rest relative to this frame will gain the same result. From Eq. (4.31) we can assert that in the view of the observer in the absolute frame Σ_{a}, the length of a rigid rod or ruler moving at velocity v relative to Σ_{a} is contracted in the direction of motion than its length at rest to by the factor $\sqrt{1-\beta^2}$. This is Fitzgerald-Lorentz length contraction effect. Here this is not hypothesis but a conclusion derived from the postulate of the absolute reference frame and the postulate of the constancy of the average circuit speed of light.

Next, we consider the length of a rod placed along x_{a} axis and at rest relative to Σ_{a}. In this case the length of the rod measured in Σ_a is not depended on whether the readings of the two ends of the rod are read simultaneously or not. But measuring the length of the rod in Σ, one should read the readings of the two ends simultaneously ($\Delta t = 0$). From Eq. (4.30) $\Delta t = 0$ means that

$$\Delta t_a = (\beta + X)c^{-1}(1+\beta X)^{-1}\Delta x_a .$$

Substituting the above equation into Eq. (4.29), we obtain

$$\Delta x = (1+\beta X)^{-1}\gamma^{-1}\Delta x_a, \quad \text{or} \quad L = (1+\beta X)^{-1}\gamma^{-1}L_a . \tag{4.32}$$

But we have naturally obtained the relation (4.31) of the length contraction of a rod or a ruler. According to the postulate of the absolute reference frame, this length contraction of the ruler in frame Σ has absolute meaning. This is original implication of the length contraction hypothesis put forward by Fitzgerald and Lorentz from the ether concept. Thus, the length of the rod at rest relative to Σ_a, as measured by the observer in Σ with contracted ruler, should be

$$L = \gamma L_a = L_a / \sqrt{1-\beta^2} . \tag{4.33}$$

Noticing Eq. (4.32), we must accept

$$X = -\beta . \tag{4.34}$$

Finally, we obtain the transformation of the space-time coordinates between an ordinary inertial reference frame Σ and the standard inertial frame Σ_a

$$\left.\begin{aligned} x &= \gamma(x_a - vt_a), \\ y &= y_a,\ z = z_a, \\ t &= \gamma^{-1}t_a. \end{aligned}\right\} \tag{4.35}$$

This is called generalized Galilean Transformation (GGT).

It is easy to obtain the inverse transformation

$$\left.\begin{aligned} x_a &= \gamma^{-1}x + \gamma v t, \\ y_a &= y,\ z_a = z, \\ t_a &= \gamma t. \end{aligned}\right\} \tag{4.36}$$

The space-time coordinates transformation between two general inertial frames Σ_1 and Σ_2 can also be derived from GGT

$$\left.\begin{aligned} x_2 &= (\gamma_2/\gamma_1)x_1 + (v_2 - v_1)\gamma_1\gamma_2 t_1, \\ y_2 &= y_1,\ \ z_2 = z_1, \\ t_2 &= (\gamma_2/\gamma_1)t_1. \end{aligned}\right\} \tag{4.37}$$

where $\gamma_1 = (1 - v_1^2/c^2)^{-1/2}$, $\gamma_2 = (1 - v_2^2/c^2)^{-1/2}$, v_1 and v_2 represent speeds of Σ_1 and Σ_2 with respect to Σ_a, respectively, and are measured in Σ_a.

The coordinate transformations between general inertial frames are absolutely symmetry relative to space-time coordinates of two inertial frames. We can prove that the space-time coordinate transformations between general inertial frames constitute a group.

Obviously, if the principle of relativity is remained, then the length contraction has relative meaning and the physical laws have the same form in all inertial reference frames. Therefore, we should have

$$L = \gamma^{-1} L = \sqrt{1-\beta^{-2}} L_{\mathrm{a}} \tag{4.38}$$

instead of Eq. (4.33). So, we must take on

$$X = 0, \tag{4.39}$$

instead of Eq. (4.34) and return the Lorentz transformation.

4. 4. Derivation of GGT from Lorentz Three Hypotheses

In the late 19th century Fitzgerald[1]、Lodge[2, 3] 、Lorentz[4] and other physicists put forward the length contraction hypothesis and the time dilation hypothesis to explain the results of the Michelson- Morley experiment on the base of classical physics. The Lorentz's and others' length contraction hypothesis and time dilation hypothesis are built on the base of the existence of the ether absolute reference frame, so the following three hypotheses (they are referred to as Lorentz three hypotheses) are essentially contained:

First, the hypothesis of the ether absolute reference frame: There exists an ether absolute reference frame, in which space appears to be isotropic. A reference frame that moves uniformly in a straight line with respect to the ether absolute reference frame is also an inertial reference frame.

Second, the length contraction hypothesis: For anybody moving with the velocity $\boldsymbol{v}$ relative to the ether reference frame, its length L along the direction of the motion will really be contracted to $(1-\beta^2)^{1/2}$ times the length L_0 at absolute rest.

Third, the time dilation hypothesis: For any motion process of the matter moving with the velocity v relative to the ether reference frame, its time interval τ of the motion process will really be dilated to $\gamma = (1-\beta^2)^{-1/2}$ times the time interval τ_0 at absolute rest.

Starting from the Lorentz three hypotheses and additional two requirements, i.e., the assumption of space-time uniformity and correspondence principle, we can derive the space-time coordinate transformation which is not the Lorentz transformation but the generalized Galilean transformation, i.e., Eq. (4.35).

We carry out our discussions to an ordinary inertial frame Σ and the standard inertial frame Σ_{a} in the simple case (Fig. 4.2) all the same. Repeating just the same proofs as Eq. (4.5) linear transformation, from the hypothesis of the ether absolute reference frame and the assumption of uniformity of space and time we gain that the space-time transformations between the two inertial frames must be linear, i.e., Eq. (4.16) holds true, and in the above arrangement of the coordinate systems we should have

$$x = \alpha_{11}(x_a - vt_a), \tag{4.40}$$

$$y = y_a, z = z_a, \tag{4.41}$$

$$t = \alpha_{41}x_a + \alpha_{44}t_a. \tag{4.42}$$

First define α_{41} and α_{44} .Suppose the space-time coordinates of two arbitrary events 1 and 2 in frames Σ_a and Σ (for simplicity, coordinates y and z are neglected) are respectively (x_{a1}, t_{a1}) and (x_{a2}, t_{a2}), (x_1, t_1) and (x_2, t_2). Substituting them into Eq. (4.42) gives

$$t_1 = \alpha_{41}x_{a1} + \alpha_{44}t_{a1},$$

$$t_2 = \alpha_{41}x_{a2} + \alpha_{44}t_{a2}.$$

Respectively subtracting the lefts and rights of the above two equations from each other and letting

$$\Delta x_a = x_{a2} - x_{a1},\ \Delta t_a = t_{a2} - t_{a1},$$

$$\Delta x = x_2 - x_1,\ \Delta t = t_2 - t_1.$$

We obtain

$$\Delta t = \alpha_{41}\Delta x_a + \alpha_{44}\Delta t_a. \tag{4.43}$$

According to the time dilation hypothesis, the period of the clock in Σ ,owing its motion relative to Σ_a with a velocity v, will really be dilated to $\gamma = (1-\beta^2)^{-1/2}$ times its period at absolute rest. So, we should have

$$\Delta t = \Delta t_a\sqrt{1-\beta^2}. \tag{4.44}$$

From the assumption of uniformity of space-time we can deduce that the above formula should hold true, whatever the values of the location coordinates of the events 1 and 2. Comparing Eq. (4.44) and Eq. (4.43) we obtain

$$\alpha_{41} = 0,\ \alpha_{44} = \sqrt{1-\beta^2},$$

$$t = t_a\sqrt{1-\beta^2}. \tag{4.45}$$

The above two inertial frames Σ and Σ_a in the simple case have the common origin of time, so the probable constant in the right of Eq. (4.45) is taken as zero.

Next define α_{11}. From Eq. (4.45) we obtain the absolute simultaneity, so the simultaneity of reading the coordinates of the two ends of the rod when its length is measured will hold true simultaneously to Σ_a and Σ . Suppose the rod (whatever its motion state) is paralleled with the x axis, and the coordinates of its two ends simultaneously measured in Σ_a and Σ are x_{a1}, x_{a2} and x_1, x_2 . From Eq. (4.40) we have

$$x_2 - x_1 = \alpha_{11}(x_{a2} - x_{a1}), \quad \text{or} \quad \Delta x = \alpha_{11}\Delta x_a. \tag{4.46}$$

According to the length contraction hypothesis the length of the ruler in Σ, owing its motion relative to Σ_a with a velocity $\boldsymbol{v}$, will really be contracted to $(1-\beta^2)^{1/2}$ times the length at absolute rest, so we should have

$$\Delta x = \gamma \, \Delta x_a. \tag{4.47}$$

Comparing Eqs. (4.47) and (4.46) gives

$$\alpha_{11} = \frac{1}{\sqrt{1-v^2/c^2}} = \frac{1}{\sqrt{1-\beta^2}} = \gamma .$$

Similarly, there are not the length contraction effects on the directions of y and z axes perpendicular to the x axis, so we have

$$y = y_a, \ z = z_a .$$

Up to now we have also derived the generalized Galilean transformation (GGT) (4.35), i. e.,

$$\left.\begin{aligned} &x = (x_a - vt_a)\big/\sqrt{1-\beta^2}, \\ &y = y_a, \ z = z_a, \\ &t = t_a\sqrt{1-\beta^2}. \end{aligned}\right\} \tag{4.48}$$

The above derivations are very explicit and strict. After about one century has passed, we have affirmed that the transformation of the space-time coordinates consistent logically with the Lorentz three hypotheses about ether is not the Lorentz transformation but GGT.

The Lorentz's and others' works are realized by way of serial revisions and supplements and additions of hypotheses to classical physics. Their theories are not systematic and thorough. Particularly the Lorentz transformation is not in accord with the original idea of the ether theory. They have not set up a space-time theory in accord with the principle of logical simplicity and principle of logical self-consistency. Just because of this, the Lorentz ether theory is finally replaced by the Einstein's special theory of relativity.

In Standard Space-time Theory, we prefer the principle of the absolute reference frame and the principle of constant of average circuit speed of light rather than the Lorentz three hypotheses as basic postulates i.e., the logical starting point of the theory. Fundamental reasons lie in that the postulate of constancy of average circuit speed of light have firmer experimental bases and is nothing but summation of great deal of experimental facts.

It is easily proved that the conclusions of the Fitzgerald-Lorentz length contraction and the Lodge-Lorentz time dilation can be derived from GGT. So, these two hypotheses, as a part of the logical inferences of the two basic postulates of Standard Space-time Theory, are contained in Standard Space-time Theory.

4. 5. Lorentz Transformations (LT) and Generalized Galilean Transformation (GGT)

We can now clear up the essence of LT and GGT. LT and GGT both satisfy the principle the constancy of the average circuit speed of light. Frames Σ_a and Σ in GGT are corresponded with S and S' in LT. If the speed of light is isotropic in any inertial reference frame and the principle of relativity holds true, we must take $X_r = X'_r = 0$ and gain LT. If we consider the speed of light is isotropic only in one (standard) inertial frame and the principle of the absolute reference frame holds true, we must take $X_a = 0$, $X = -\beta$ and gain GGT.

Different basic postulates lead to different definition of simultaneity and different method of the synchronization of clocks at different places.

Under the postulate of the constancy of the average circuit speed of light, the time of light propagating along a non-closed path AB is

$$t_B - t_A = \int_A^B \frac{\mathrm{d}r}{c(\alpha,\beta,\gamma)} . \tag{4.49}$$

Using Eqs. (4.7) and (4.10) and noticing that according to the assumption of uniformity of space and time, X, Y, Z and R should be independent of space coordinates, we obtain from Eq. (4.49) that

$$t_B - t_A = [t_{rB} - (Xx_B + Yy_B + Zz_B)/c] - [t_{rA} - (Xx_A + Yy_A + Zz_A)/c] , \tag{4.50}$$

where subscript r denotes relativistic quantity, $t_{rB} - t_{rA} = L/c$ and L is the length of the path AB. From this we obtain the relation between the time t under the postulate of the constancy of the average circuit speed of light and the relativistic t_r

$$t = t_r - (Xx + Yy + Zz)/c . \tag{4.51}$$

The frames Σ_a and Σ in GGT are corresponded with S and S' in LT. Applying (4.51) respectively to frame Σ_a and S, and Σ and S', and noticing the space coordinates under two assumptions are the same, we can obtain

$$\left.\begin{aligned} &x_a = x_r, y_a = y_r, z_a = z_r, t_a = t_r; v = v_r, \\ &x = x_r, y = y_r, z = z_r, t = t_r + (v/c^2)x_r. \end{aligned}\right\} \tag{4.52}$$

The only difference is given by the above last equation which shows the difference in time coordinates introduced from the different basic postulates and different synchronization method of clocks at different places deduced from these basic postulates. Using Eq. (4.52), LT and GGT can be deduced mutually.

Tangherlini [5] once wrote the two-dimensional form of GGT as the middle step in the deducing of LT. Zhang Cao [6] proposed to study the problem of superluminal velocity using GGT in a short article. The work done in this book is that the two basic postulates about the properties of the space-time are presented based upon the up-to-date experimental facts and theoretical thinking results in modern physics, and GGT have been deduced strictly from these two postulates. Then it has been shown that GGT is the inevitable logic result of the two postulates.

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Chapter 5

Mechanics of Standard Space-time Theory

In this chapter, the kinematics and dynamics of subluminal particle and superluminal matter are uniformly and systematically studied from GGT.

5. 1. Velocity Transformation and Synchronization of Clocks at Different Places

5. 1. 1. Velocity Transformation

In Chapter 4 the transformation of space-time coordinates between an ordinary inertial frame Σ and the standard inertial frame Σ_a, i.e.,GGT, derived strictly from two basic postulates as follows:

$$\left.\begin{aligned} x &= \gamma(x_a - vt_a), \\ y &= y_a,\ z = z_a, \\ t &= \gamma^{-1} t_a. \end{aligned}\right\} \tag{5.1}$$

where $\gamma = (1-\beta^2)^{-1/2}$, $\beta = v/c$ and the meanings of the other symbols are the same as in Chapter 4. The last equation states the absolute simultaneity. so it permits the existence of superluminal motion and action. In this present chapter, we will deal with the kinematical and dynamical problems of both subluminal and superluminal motion, strictly from GGT. These derivations construct the mechanics of Standard Space-time Theory.

From GGT, by differentiation, we easily obtain the transformation equations

$$\left.\begin{aligned} \mathrm{d}x &= \gamma(\mathrm{d}x_a - v\mathrm{d}t_a), \\ \mathrm{d}y &= \mathrm{d}y_a,\ \mathrm{d}z = \mathrm{d}z_a, \\ \mathrm{d}t &= \gamma^{-1}\mathrm{d}t_a. \end{aligned}\right\} \tag{5.2}$$

Further we can obtain the velocity transformation equations and their inverse equations:

$$u_x = \gamma^2 (u_{\mathrm{ax}} - v),\ u_y = \gamma\, u_{\mathrm{ay}},\ u_z = \gamma\, u_{\mathrm{az}}, \tag{5.3}$$

$$u^2 = \gamma^2 [\gamma^2 (u_{\mathrm{ax}} - v)^2 + (u_{\mathrm{ay}}^2 + u_{\mathrm{az}}^2)], \tag{5.4}$$

$$u_{\mathrm{ax}} = \gamma^{-2} u_x + v,\ u_{\mathrm{ay}} = \gamma^{-1} u_y,\ u_{\mathrm{az}} = \gamma^{-1} u_z, \tag{5.5}$$

$$u_{\mathrm{a}}^2 = (\gamma^2 u_x + v)^2 + \gamma^{-2} (u_y^2 + u_z^2). \tag{5.6}$$

When $v << c$, these transformations are consistent with those of classical mechanics.

When the velocity $\boldsymbol{u}$ of the motion of matter is along the direction of the common x-axes of the frames Σ_{a} and Σ , the velocity transformations can be written

$$u = \gamma^2 (u_{\mathrm{a}} - v),\ u_{\mathrm{a}} = \gamma^{-2} u + v. \tag{5.7}$$

In the above formulas, $\gamma = (1-\beta^2)^{-1/2}, \beta = v/c$. v represents the relative velocity of the frame Σ relative to frame Σ_{a}

5. 1. 2. The one-way speed of light in vacuum

How to get the one-way speed of light in every inertial reference frame?

Einstein's special theory of relativity artificially stipulates that the one-way speed of light is constant in any inertial reference frame. Standard Space-time Theory derives generalized Galilean transformations from the two basic postulates based on experimental facts. From the generalized Galilean transformation, the expression of the one-way speed of light in any inertial reference frame can be derived.

Next we directly use some formulas and results obtained in the process of deriving the generalized Galilean transformation(GGT). As discussed in Sec. 4.3, consider the simple case of taking the two inertial frames Σ_{a} and Σ in a special configuration, where the ordinary frame Σ with respect to the standard inertial frame Σ_{a} moves at a constant velocity $\boldsymbol{v}$ along positive x_{a} axis of Σ_{a} (See Fig. 4.2). In the absolute reference frame Σ_{a} space exhibits isotropy, and therefore the light speed is isotropy and is equal to the constant c, that is,

$$X_{\mathrm{a}} = Y_{\mathrm{a}} = Z_{\mathrm{a}} = 0,\ R_{\mathrm{a}} = 0, \quad c_{\mathrm{a}}(\alpha, \beta, \gamma) = c. \tag{5.8}$$

In a general inertial frame Σ,

$$X = -\beta = -v/c,\ Y = Z = 0,\ R = X\cos\alpha = -\beta\cos\alpha = -(v/c)\cos\alpha.$$

From Eq.(4.8), we have

$$c_{+x} = \frac{c}{1+(v/c)}, \quad c_{-x} = \frac{c}{1-(v/c)}, \quad c_{\pm y} = c,\ c_{\pm z} = c,$$

$$c(\alpha, \beta, \gamma) = \frac{c}{1+(v\cos\alpha / c)} = \frac{c}{1+\boldsymbol{n}\cdot\boldsymbol{v}/c}, \tag{5.9}$$

where $\boldsymbol{n}$ represents the unit vector of the light propagation direction in the frame Σ, α represents the angle between $\boldsymbol{n}$ and the positive direction of the x axis, and $\boldsymbol{v}$ represents the relative velocity of the frame Σ relative to frame Σ_a

If the inertial coordinate system of the general configuration of frames Σ_a and Σ is selected (see Sec. 6.3 and Fig. 6.1), each coordinate axis of the two frames still keeps parallel, but $\boldsymbol{v}$ is not in the directions of the *x*-, *y*-, or *z*-axis, and the angles between $\boldsymbol{v}$ and the *x*-, *y*-, *z*-axes are represented respectively by α, β, γ. In this arrangement, it is easy to get

$$c_{\pm x} = \frac{c}{1 \pm \beta_x}, \ c_{\pm y} = \frac{c}{1 \pm \beta_y}, \ c_{\pm z} = \frac{c}{1 \pm \beta_z} \tag{5.10}$$

$$c(\alpha, \beta, \gamma) = \frac{c}{1 + (\beta_x \cos\alpha + \beta_y \cos\beta + \beta_z \cos\gamma)} = \frac{c}{1 + \boldsymbol{n} \cdot \boldsymbol{v} / c} \tag{5.11}$$

where $\beta_x = v_x / c, \beta_v = v_v / c, \beta_z = v_z / c$, and α, β, γ represent the angle between $\boldsymbol{n}$ and the positive direction of the x, y, z axis, and $\boldsymbol{v}$ represents the speed of the frame Σ relative to frame Σ_a.

Eqs. (5.9) and (5.11) are the expressions for the one-way speed of light in vacuum of any reference frame Σ. The above formulas is also applicable to frame Σ_a, in which case $v = 0$.

From the discussion about the role of the speed of light in velocity transformation by using the velocity transformation equations and the light speed expression, we can obtain such conclusion: If the speed of a body in a certain inertial reference frame and a certain direction is less than (or equal to, or larger than) the speed of light in this reference frame and this direction, then its speed in any inertial frame is less than (or equal to, or larger than) the speed of light in the corresponding reference frame and the corresponding direction. That is to say, the classification of subluminal, luminal and superluminal speeds cannot be transformed into each other through the choice of inertial reference frames. The following research shows that the form and nature of superluminal matter (if exists) are not the same with those of macroscopic or subluminal "particles". However, for simplicity, we sometimes call the superluminal matter as "superluminal particles" .

5. 1. 3. Synchronization of Clocks at Different Places

Starting from the assumption of the constancy of the (one-way) light speed, the special theory of relativity gives the methods of calibrating of clocks at different places and judging the simultaneity of two events in different places(see Sec.3.3).

In Standard Space-time Theory, although simultaneity is absolute, there is still the problem of calibration of clocks at different places for each inertial reference frame. How can Standard Space-time Theory achieve this problem?

Obviously,, The time interval of the light propagation along a rectilinear path of a certain direction is inversely proportional to its propagation speed in this direction. Hence, according to the expression (5.11) of the one-way light speed of Standard Space-time Theory, the method of the synchronization of clocks at different places is follows.

As discussed in Sec. 4.3, consider the simple case of taking the two inertial frames Σ_a and Σ in the special configuration. Suppose two identical clocks are respectively placed at arbitrary two points A and B in Σ . A light signal starts out from A at t_A of "A time" to B, and is reflected by a mirror at B at t_B of "B time" from B to A, and arrives back to A at t'_A of "A time". If

$$(t_B - t_A)c_{+\boldsymbol{n}} = (t'_A - t_B)c_{-\boldsymbol{n}},$$

or

$$\frac{t_B - t_A}{t'_A - t_B} = \frac{c + v\cos\alpha}{c - v\cos\alpha}, \tag{5.12}$$

the two clocks at different places are synchronized, where $\boldsymbol{n}$ represents the unit vector along the direction $\boldsymbol{AB}$ of light propagation, α represents the angle between $\boldsymbol{n}$ and the positive direction of the x axis. The methods to judge simultaneity and sequence of two events to happen at different places can be given similarly.

In general, we can first calibrate the clocks at any two points A and B in the direction parallel to the x axis, at which time, $\cos\alpha = 1$, Eq.(5.9) becomes

$$\frac{t_B - t_A}{t'_A - t_B} = \frac{c + v}{c - v} \tag{5.13}$$

When light propagates between two points A and B in the direction parallel to the x axis, as long as the readings of the clocks at A and B satisfy the above formula, the clocks at A and B are synchronized. Then, considering that $c_{\pm v} = c$, $c_{\pm z} = c$, the clocks at any two points in the direction perpendicular to the x axis can be synchronized by taking $v = 0$ according to the above formula, namely

$$t_B - t_A = t'_A - t_B \tag{5.14}$$

That is, as long as the readings of the clocks at A and B satisfy the above formula, the clocks at A and B are synchronized.

If the direction of the velocity $\boldsymbol{v}$ of the inertial frame Σ is not known exactly, we can also find the method of calibration of clocks at different places of Standard Space-time Theory from the above discussion. For a detailed description, please refer to book [1]. Omit here.

Therefore, based on the principle of the constancy of the one-way speed of light, the calibration of clocks at different places and the discrimination of simultaneity of events in different places in the special theory of relativity are lack of experimental basis and contrary to common sense.

Here I would like to emphasize that, as stated in Sec.3.3, Einstein's principle of the constancy of one-way light speed is a logical convention, and it is an untestable, artificial, excessive, and counterintuitive assumption. Thus, in the special theory of relativity, based on the principle of the constancy of the one-way speed of light, the calibration of clocks at different places and the discrimination of simultaneity of events in different places are lack of experimental basis and contrary to common sense. On the contrary, according to Standard

Space-time Theory, the one-way light speed expression (5.11) is a logical conclusion derived from the principle of the constancy of average circuit speed of light and the principle of the absolute reference frame, in which the average circuit speed of light can be measured experimentally, and the principle of the constancy of average circuit speed of light is the expression of a large number of experimental facts, which has a solid experimental basis. The combination of the two principles must lead to the generalized Galilean transformation (4.35), which must lead to the expression (5.11) for the one-way speed of light. All these, together with the calibration of clocks at different places and the discrimination of simultaneity and sequence of events in different places described in this section, are the inevitable logical results derived from the experimental facts expressed by these two principles, which are reasonable, understandable and easy to understand.

5. 1. 4. Acceleration Transformation

The acceleration $\boldsymbol{a}$ of a particle is defined as the time rate of change of the particle velocity. It is a vector. In the inertial frame Σ_{a} and Σ , the components of the acceleration are

$$\begin{cases} \boldsymbol{a}_{\mathrm{a}} = \dfrac{\mathrm{d}\boldsymbol{u}_{\mathrm{a}}}{\mathrm{d}t_{\mathrm{a}}}; \quad a_{\mathrm{a}x} = \dfrac{\mathrm{d}u_{\mathrm{a}x}}{\mathrm{d}t_{\mathrm{a}}}, \quad a_{\mathrm{a}y} = \dfrac{\mathrm{d}u_{\mathrm{a}y}}{\mathrm{d}t_{\mathrm{a}}}, \quad a_{\mathrm{a}z} = \dfrac{\mathrm{d}u_{\mathrm{a}z}}{\mathrm{d}t_{\mathrm{a}}} \\ \boldsymbol{a} = \dfrac{\mathrm{d}\boldsymbol{u}}{\mathrm{d}t}; \quad a_x = \dfrac{\mathrm{d}u_x}{\mathrm{d}t}, \quad a_y = \dfrac{\mathrm{d}u_y}{\mathrm{d}t}, \quad a_z = \dfrac{\mathrm{d}u_z}{dt} \end{cases} \tag{5.14}$$

Using the velocity transformations (5.3) and their inverse transformations (5.5), and $t_{\mathrm{a}} = \gamma t$, the following acceleration transformations and their inverse transformations can be easily obtained

$$\begin{aligned} a_x &= \gamma^3 a_{\mathrm{a}x}, \quad a_y = \gamma^2 a_{\mathrm{a}y}, \quad a_z = \gamma^2 a_{\mathrm{a}z} \\ a_{\mathrm{a}x} &= \gamma^{-3} a_x, \quad a_{\mathrm{a}y} = \gamma^{-2} a_y, \quad a_{\mathrm{a}z} = \gamma^{-2} a_z \end{aligned} \tag{5.15}$$

According to the FitzGerald-Lorentz length contraction effect and the Lodge-Lorentz time retardation effect (see Sec. 5. 3), the physical origin of these formulas is easy to understand. Obviously, compared with the corresponding formulas of the special theory of relativity, the acceleration transformation formula and its inverse transformation formula of Standard Space-time Theory are much more concise.

5. 1. 5. An Important Transformation

Using the velocity transformations (5.3)—(5.7), an important transformation which will be used frequently in the future can be proved:

$$\gamma k = k_{\mathrm{a}}, \tag{5.15}$$

where $$k_{\mathrm{a}} = k_{1\mathrm{a}} = (1 - u_{\mathrm{a}}^2 / c^2)^{-1/2},$$

$$k = k_1 = [(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - u^2/c^2]^{-1/2}, \tag{5.16a}$$

for subluminal motion $(u_a < c)$; and

$$k_a = k_{2a} = (u_a^2/c^2 - 1)^{-1/2},$$
$$k = k_2 = [u^2/c^2 - (1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2]^{-1/2}, \tag{5.16b}$$

for superluminal motion $(u_a > c)$.

Here u_a and u represent speeds of the matter motion measured in frames Σ_a and Σ, respectively. It can be proved that those quantities in formulas (5.15)—(5.16), i.e. γ, k_{1a}, k_{2a}, k_1 and k_2 take positive real values.

Besides, we shall sometimes use the notations which are suitable to any inertial frame Σ_i $(i = \text{a}, 1, 2, \cdots)$:

$$\left.\begin{aligned} k = k_1 &= [(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - u^2/c^2]^{-1/2}, \quad \text{for subluminal motion;} \\ k = k_2 &= [u^2/c^2 - (1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2]^{-1/2}, \quad \text{for superluminal motion.} \end{aligned}\right\} \tag{5.17}$$

where $\boldsymbol{u}$ represents the speed of the matter motion measured in frame Σ_i; $\boldsymbol{v}$ is the speed of frame Σ_i with respect to Σ_a measured in frame Σ_a, For $i = \text{a}$, i.e., frame Σ_a, we should take $v = 0$, and hence $k_1 = k_{1a}$ and $k_2 = k_{2a}$.

For the later applications, the formula (5.15) is written in a more obvious form as follows

$$\frac{\sqrt{1-u_a^2/c^2}}{\sqrt{1-v^2/c^2}} = \sqrt{(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - u^2/c^2}, \quad \text{for subluminal motion}, \tag{5.18a}$$

$$\frac{\sqrt{u_a^2/c^2 - 1}}{\sqrt{1-v^2/c^2}} = \sqrt{u^2/c^2 - (1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2}, \quad \text{for superluminal motion}. \tag{5.18b}$$

There is another problem which should be pointed out: the speed $\boldsymbol{v}$ of Σ with respect to Σ_a measured in Σ_a is not equal to the negative $\boldsymbol{v}_a$ where $\boldsymbol{v}_a$ is the speed of Σ_a with respect to Σ measured in Σ, i.e., $\boldsymbol{v} \neq -\boldsymbol{v}_a$. This is obviously different from the conclusion of the special theory of relativity. Using the reasoning of Sec. 4.3, we can obtain

$$\boldsymbol{v}_a = -\gamma^2\boldsymbol{v}. \tag{5.19}$$

5. 2. The Length Contraction and Time Dilation Formulas

Given two events, whose space-time coordinates in the inertial frame Σ_a and the inertial frame Σ are respectively (x_a, y_a, z_a, t_a) and $(x_a + \Delta x_a, y_a + \Delta y_a, z_a + \Delta z_a, t_a + \Delta t_a)$, and (x, y, z, t) and $(x + \Delta x, y + \Delta y, z + \Delta z, t + \Delta t)$. From GGT and its inverse form we obtain

$$\left.\begin{array}{l}\Delta x=\gamma(\Delta x_{\mathrm{a}}-v\Delta t_{\mathrm{a}}),\ \Delta x_{\mathrm{a}}=\gamma^{-1}\Delta x+\gamma\, v\Delta t, \\ \Delta y=\Delta y_{\mathrm{a}}, \qquad \Delta z=\Delta z_{\mathrm{a}}, \\ \Delta t=\gamma^{-1}\Delta t_{\mathrm{a}},\ \ \Delta t_{\mathrm{a}}=\gamma\Delta t,\end{array}\right\} \tag{5.20}$$

where $\gamma=(1-\beta^2)^{-1/2}, \beta=v/c.$

Now we derive the length contraction and time dilation formulas from the above formulas. First, we discuss length contraction. For simplicity, we only discuss the case in which a rigid rod moving along the direction of its own length.

First, we discuss some examples. In the discussion of the following five examples, we use the L_{ar} and L_{r} to denote the length of the rod at rest with respect to Σ_{a} and measured in frame Σ_{a} and frame Σ respectively; and use the $L_{\mathrm{a}u}$ and L_u to denote the length of the rod in motion with respect to Σ_{a} (for the case in motion, its speed is u_{a}, and $u_{\mathrm{a}}<c$) and measured in frame Σ_{a} and frame Σ respectively.

Example 1. Suppose a rod is in motion with respect to Σ_{a} and at rest with respect to Σ. An observer in Σ_{a} measure its length $L_{\mathrm{a}v}$ and another observer in Σ measure its length L_v. The result measured in Σ is $\Delta x=L_v=L_0$ (the proper length), and that should not depend on whether the readings of the two ends of the rod are read simultaneously or not. The result measured in Σ_{a} is $\Delta x_{\mathrm{a}}=L_{\mathrm{a}v}$, here $\Delta t_{\mathrm{a}}=0$ should be satisfied. Substituting these conditions into the first equation of (5.21) we obtain

$$L_v=\gamma L_{\mathrm{a}v}. \tag{5.21}$$

That is to say, when the rod is at motion with respect to frame Σ_{a} and at rest with respect to frame Σ, the length of the rod measured in frame Σ is longer than that measured in frame Σ_{a} by the factor γ.

Example 2. Let us in frames Σ_{a} and Σ respectively measure the length L_{ar} and L_{r} of the rod at rest with respect to Σ_{a}. With the similar discussion above we can obtain

$$L_{\mathrm{r}}=\gamma L_{\mathrm{ar}}. \tag{5.22}$$

That is to say, when the rod is at rest with respect to frame Σ_{a}, the length of the rod measured in frame Σ will also be longer than that measured in frame Σ_{a} by the factor γ.. This conclusion is contrary to that in the special theory of relativity.

Example 3. Because $\Delta t_{\mathrm{a}}=0$ and $\Delta t=0$ should hold true simultaneously, for any body or material system at subluminal, luminous or superluminal motion, we can obtain by combining equation (5.21) that the length L measured in frame Σ will all be longer that L_{a} measured in frame Σ_{a} by the factor γ, or

$$L=L_{\mathrm{a}}\Big/\sqrt{1-\beta^2}=\gamma L_{\mathrm{a}}. \tag{5.23}$$

Example 4. The observer in frame Σ_{a} measures the length L_{ar} and $L_{\mathrm{a}u}$ of the same rod at rest or in motion ($u_{\mathrm{a}}<c$)with respect to Σ_{a}. When the rod is at rest to Σ_{a},

$$\Delta x_{\mathrm{a}} = L_{\mathrm{ar}} = L_0 \text{ . (The proper length)} \tag{5.24}$$

When the rod moves with a velocity $\boldsymbol{u}_{\mathrm{a}}$ relative to Σ_{a}, it will be at rest relative to such a frame Σ of which the velocity relative to frame Σ_{a} is $\boldsymbol{v} = \boldsymbol{u}_{\mathrm{a}}$. According to Example 1, the length of the rod $L_{\mathrm{a}u}$ measured in frame Σ_{a} and $L_{u=v}$ measured in frame Σ satisfy the equation

$$L_{u=v} = L_{\mathrm{a}u} \Big/ \sqrt{1-u_{\mathrm{a}}^2/c^2} = k_{1\mathrm{a}} L_{\mathrm{a}u} . \tag{5.25}$$

We can reasonably consider that the rigid rod and ruler in the same state of motion have the same change in length per unit length. Hence, the same result will be obtained if we measure in any inertial frames the length of the same rigid rod at rest with respect to this frame. That is called the proper length and denoted by L_0. Therefore, for the above frame Σ,

$$L_{u=v} = L_{\mathrm{ar}} = L_0 .$$

Substituting it into Eq. (5.25) we obtain

$$L_{\mathrm{a}u} = L_{\mathrm{ar}} \sqrt{1-u_{\mathrm{a}}^2/c^2} = k_{1\mathrm{a}}^{-1} L_0 . \tag{5.26}$$

That is to say, when observer measures in frame Σ_{a} , the length of the rod in motion with respect to Σ_{a} is shorter than the length of the same rod at rest with respect to Σ_{a} by the factor $(1-u_{\mathrm{a}}^2/c^2)^{1/2}$.

Example 5. The observer in frame Σ measures the length L_{r} of the rigid rod at rest with respect to Σ_{a}, or the length L_v of the same rigid rod in motion ($u_{\mathrm{a}} = v < c$) with respect to Σ_{a} and at rest with respect to Σ. Similar to the discussion of the above example we can obtain

$$L_v = L_{\mathrm{r}} \sqrt{1-\beta^2} = \gamma^{-1} L_{\mathrm{r}} . \tag{5.27}$$

That is to say, when observers measure in frame Σ, the length L_v of the rod at rest to Σ and in motion relative to Σ_{a} will be contracted than the length L_{r} of the same rod at rest to Σ_{a} and in motion relative to Σ by the factor $\sqrt{1-\beta^2}$. This conclusion is contrary to that in the special theory of relativity.

On the basis of the above discussion of various specific examples, we can now find the general expression for the length of a body in subluminal motion or a material system in superluminal motion measured in any inertial frame $\Sigma_i (i = \mathrm{a}, 1, 2, \cdots)$. For simplicity, we use the above-derived formulas directly.

First discuss subluminal motion. Substituting Eq. (5.26) into Eq. (5.23) and using Eq. (5.16) we obtain

$$L_u = \frac{L_{\mathrm{a}u}}{\sqrt{1-\beta^2}} = L_0 \frac{\sqrt{1-u_{\mathrm{a}}/c^2}}{\sqrt{1-\beta^2}} . \tag{5.28}$$

Using the notation (5.17) we can write the above equation in a common form suitable to any inertial frame Σ_i

$$L = k_{1\mathrm{a}}^{-1} \gamma L_0 = k_1^{-1} L_0 , \tag{5.29a}$$

or
$$L = L_0 \frac{\sqrt{1-u_a^2/c^2}}{\sqrt{1-v^2/c^2}} = L_0\sqrt{(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - u^2/c^2}, \tag{5.29b}$$

where u_a and u represent the velocity of the body in subluminal motion measured in frame Σ_a and Σ, respectively.

Next, we discuss the superluminal motion. According to discussion of Example 3, the equation (5.23) holds true yet. Using Eqs. (5.15)—(5.17), from Eq. (5.23) we obtain

$$L = k_2^{-1}k_{2a}L_a = L_a\sqrt{u^2/c^2 - (1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2} \,/\, \sqrt{u_a^2/c^2 - 1}\,. \tag{5.30}$$

The above equation holds true to any inertial frame $\Sigma_i\,(i = \mathrm{a},1,2,\cdots)$, so

$$\frac{L_1}{\sqrt{u_1^2/c^2-\alpha_1^2}} = \frac{L_2}{\sqrt{u_2^2/c^2-\alpha_2^2}} = \cdots\cdots = \frac{L_a}{\sqrt{u_a^2/c^2-1}} = L_0,$$

where $\alpha_i = 1-\boldsymbol{u}_i\cdot\boldsymbol{v}_i/c^2$, $\boldsymbol{v}_i$, $\boldsymbol{u}_i$ and L_i represent the characteristic velocity of Σ_i, the motion velocity and the length of superluminal matter measured in frame Σ_i respectively. Since the relevant quantities satisfied with the above proportional relation to any inertial frame, so we can let it equal to a constant L_0. Hence from the above relation we obtain

$$L = L_0\sqrt{u^2/c^2-\alpha^2}, \tag{5.31}$$

where $\alpha = 1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2$. Using the Eqs. (5.15)—(5.17), we have

$$L = \gamma k_{2a}^{-1}L_0 = k_2^{-1}L_0, \tag{5.32a}$$

or
$$L = L_0\frac{\sqrt{u_a^2/c^2-1}}{\sqrt{1-v^2/c^2}} = L_0\sqrt{u^2/c^2-\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)^2}, \tag{5.32b}$$

where u_a and u represent the velocity of superluminal matter measured in frame Σ_a and Σ respectively.

What is the meaning of the constant L_0 of Eqs. (5.31)—(5.32)? For the superluminal motion, the proper length L_0 as the "rest length" has lost its significance. From Eq. (5.31) we can see that L_0 denote the length of the superluminal system when it moves with a speed $u_a = \sqrt{2}c$ in frame Σ_a and is called "$\sqrt{2}c$ length". It should noticed that because there exists symmetry relative to the direction $\boldsymbol{v}$ in space, for the same material system in superluminal motion, the length measured in any frame Σ_i of the system moving with $u_i = \sqrt{2}c$ perpendicular to the characteristic velocity v_i of Σ_i are all equal to each other and are all equal to the length L_0 measured in frame Σ_a of the system moving with $u_a = \sqrt{2}c$ (no matter to which direction) i.e. $L_{0i} = L_0$. Hence, defining the L_0 of a superluminal system as "$\sqrt{2}c$ length" has general significance. Only in general inertial frame Σ, $\boldsymbol{u}$ should be perpendicular to the characteristic velocity $\boldsymbol{v}$ of frame Σ.

Eqs. (5.29) and (5.32) are the general expressions about the length contraction or the length elongation effect of Standard Space-time Theory, and are suited to subluminal and superluminal motions respectively.

Now we deduce the general expression of time dilation. First, we discuss the time dilation of subluminal motion. From Eq. (4.37) of two inertial frames Σ_1 and Σ_2, we obtain

$$\Delta t_2 = (\gamma_1 / \gamma_2)\Delta t_1, \qquad (5.33)$$

where

$$\gamma_1 = (1-\beta_1^2)^{-1/2}, \ \ \beta_1 = v_1 / c;$$
$$\gamma_2 = (1-\beta_2^2)^{-1/2}, \ \ \beta_2 = v_2 / c.$$

Suppose that a body observed moves together with frame Σ_1, its speed measured in frame Σ_a is $u_a = v_1$, or $\gamma_1 = k_{1a}$. Take the frame Σ_2 as the frame Σ, its speed of motion v_2 relative to the frame Σ_a is represented by v, or $\gamma_2 = \gamma$. From Eq. (5.33) we get the time interval of a process occurring on this body measured in frame Σ is

$$\tau = k_{1a}\gamma^{-1}\tau_0, \qquad (5.34)$$

where τ_0 is the time interval of the process measured in the reference frame at rest relative to the moving body. For the same reason we can take the view that the matter process and clock vibration at the same motion state have the same time dilation per unit time interval. Hence, τ_0 is also equal to the time interval measured in Σ_a of the same process of this body at rest relative to Σ_a, and we can call it the proper time interval.

Substituting Eq. (5.15) into Eq. (5.34) and write the result as a common form suitable to any inertial frame Σ_i

$$\tau = k_{1a}\gamma^{-1}\tau_0 = k_1\tau_0, \qquad (5.35a)$$

or

$$\tau = \tau_0 \frac{\sqrt{1-v^2/c^2}}{\sqrt{1-u_a^2/c^2}} = \frac{\tau_0}{\sqrt{(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - u^2/c^2}}. \qquad (5.35b)$$

Next, we discuss the time change problem of the superluminal system ($u_a > c$). That is similar to the discussion about the length change problem of superluminal system.

Using the Eqs. (5.15)—(5.17), from Eq.(5.20) we obtain

$$\Delta t = \gamma^{-1}\Delta t_a = \Delta t_a\sqrt{1-\beta^2} \quad \text{and} \quad \Delta t = \Delta t_a \frac{\sqrt{u_a^2/c^2-1}}{\sqrt{u^2/c^2-(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2}}.$$

The above equation holds true to any inertial frame $\Sigma_i (i = \mathrm{a}, 1, 2, \cdots)$, so

$$\Delta t_1\sqrt{u_1^2/c^2-\alpha_1^2} = \Delta t_2\sqrt{u_2^2/c^2-\alpha_2^2} = \cdots = \Delta t_a\sqrt{u_a^2/c^2-1} = \tau_0,$$

where $\alpha_i = 1-\boldsymbol{u}_i\cdot\boldsymbol{v}_i/c^2$, $\boldsymbol{v}_i, \boldsymbol{u}_i$ and Δt_i represent the characteristic velocity of Σ_i, the motion velocity and the time interval of the process of superluminal matter measured in frame Σ_i. Since the relevant quantities satisfied with the above proportional relation to any inertial frame, so we can let it equal to a constant τ_0. Hence, using Eqs. (5.15)—(5.17) and τ denoting Δt, from these relation we obtain

$$\tau = k_{2a}\gamma^{-1}\tau_0 = k_2\tau_0, \qquad (5.36a)$$

or
$$\tau=\tau_0\frac{\sqrt{1-v^2/c^2}}{\sqrt{u_a^2/c^2-1}}=\frac{\tau_0}{\sqrt{u^2/c^2-\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)^2}},\tag{5.36b}$$

where u_a and u represent the velocity of superluminal matter measured in frame Σ_a and Σ respectively.

What is the meaning of the constant τ_0 of Eq. (5.36)? For superluminal motion, τ_0 as the proper time interval has lost its significance. We define τ_0 under superluminal case as "$\sqrt{2}c$ time interval" or the time interval of the process occurring when the system moves with a speed $u_a=\sqrt{2}c$ relative to Σ_a and measured in Σ_a. The same way, all the time intervals τ_{0i} measured in any frame Σ_i of the process occurring when the superluminal system moves with $u_i=\sqrt{2}c$ perpendicular to the characteristic velocity $\boldsymbol{v}$ of Σ_i are all equal to the above "$\sqrt{2}c$ time interval", or $\tau_{0i}=\tau_0$.

Eqs. (5.35) and (5.36) are the general expressions of the time dilation or time shortening effect of Standard Space-time Theory and are suitable to the subluminal and superluminal motion respectively.

Based on the previous analysis of the examples and the general expressions obtained, we can obtain the substantive understanding of Standard Space-time Theory about the length contraction or length elongation effect and the time delay or time shortening effect.

(1) Any rigid rod or ruler moving with subluminal speed $(u_a<c)$ relative to the standard frame Σ_a will show real length contraction along its motion direction by the factor $k_{1a}^{-1}=(1-u_a^2/c^2)^{1/2}$ from the proper length. Any material system moving with superluminal speed $(u_a>c)$ relative to the standard frame Σ_a will have real length elongation along its motion direction, and the lengthened length is $k_{2a}^{-1}=(u_a^2/c^2-1)^{1/2}$ times the "$\sqrt{2}c$ length". The space length will lengthen to infinity if the speed of motion u_a tends to infinity and this kind of material system should spread all over space.

(2) To any subluminal, luminous or superluminal material system, if observers measure the length along its motion direction, the length measured in the standard frame is the minimum, and the length measured in an ordinary frame is γ times the former one. This is due to the result of the length contraction of the ruler in the ordinary inertial frame caused by its motion relative to the standard frame.

(3) The ruler and body at rest relative to any inertial frame are both in the same motion state relative to the standard frame and have the same length contraction per unit length, so an observer of an inertial frame cannot perceive the length contraction effect of the body at rest relative to this frame. The length contraction effect at the motion direction of the body at rest relative to a frame can be observed by an observer in the standard frame or in the ordinary frames which have the same direction of absolute motion and the speed smaller than that of former frame. By the same reasoning, an observer in an ordinary frame, owing to the length contraction at the motion direction of its ruler, will observe the lengthened length along the motion direction of the body at rest relative to the standard frame or the ordinary frames which have the same direction of absolute motion and the smaller speed as compared with that of former frame.

(4) If we consider simultaneously the real length change of the moving matter and the ruler of the reference frame (the ruler can only move subluminally with the reference frame), we can predict the measuring result of the spatial length of material system for any motion state in any inertial frame. According to such understanding, we can directly explain the above conclusions about various examples of the length contraction or elongation and the general expression of the length contraction or elongation.

(5) When any body and clock is at a subluminal motion ($u_{\mathrm{a}} < c$) , their motion process and the rate of the clock will really be dilated to $k_{1\mathrm{a}} = (1 - u_{\mathrm{a}}^2 / c^2)^{-1/2}$ times that at rest relative to the standard frame. When any material systems is at a superluminal motion $(u_{\mathrm{a}} > c)$, with increase of the speed, its motion process will really be shortened relative to the "$\sqrt{2}c$ time interval" by a factor $k_{2\mathrm{a}} = (u_{\mathrm{a}}^2 / c^2 - 1)^{-1/2}$.

(6) For any subluminal, luminous or superluminal motion process, its time interval measured in the standard frame is the longest, and the time interval measured in an ordinary inertial frame is shortened relative to that measured in the standard inertial frame by a factor γ^{-1}. This is due to the result of the time dilation of the clock in the ordinary inertial frame caused by its motion relative to the standard inertial frame.

(7) The clock and the motion process of material system at rest relative to any inertial frame are both in the same motion state relative to the standard frame and have the same time dilation effect, so an observer of a frame cannot perceive the time dilation effect of the material system at rest relative to this frame. The time dilation effect of the motion process of the material system at rest relative to an inertial frame can be observed by an observer in the standard frame or in the ordinary frames which have the absolute motion speed smaller than that of the former frame. By the same reasoning, an observer in an ordinary frame, owing to the time dilation of its clock, will observe the time shortening effect of a motion process of the material system at rest relative to the standard frame or the ordinary frames which haves the absolute speed smaller than that of the former frame.

(8) If we consider simultaneously the real time dilatation or shortening effect of the material process of motion and the clock in a reference frame (the clock can only move subluminally with the reference frame), we can predict the result of measuring the time interval of a process of the matter in subluminal, luminous or superluminal motion.

Therefore, the result of measuring the spatial length of moving matter and the time interval of the material process of motion in any inertial frame has its duality: on the one hand it has absoluteness which reflects real length or time change of the measured object due to its motion with respect to the standard frame; on the other hand, it has relativity, or in other words, the result of measurement is related to the reference frame in which measurements are made, and this reflects the length contraction and the time dilation of the tools of measurement, i.e., the ruler and the clock of the reference frame, due to their motion together with the reference frame relative to the standard frame.

From above we can see that the motion state and the static state with respect to the standard frame have particular significance. Standard Space-time Theory admits the existence of absolute motion and absolute static state, and considers the motion or static state relative to the standard inertial frame to be absolute motion or absolute static state. Besides, the previous study indicates that the FitzGerald-Lorentz length contraction and the Larmor-Lorentz time dilation hypothesis, as a part of the logical inferences of the two basic postulates of Standard Space-time Theory, are contained in Standard Space-time Theory.

5. 3. Interval between Events

5. 3. 1. General definition of Interval between Events

Given the space-time coordinates of two events in frames Σ_a and Σ are (x_a, y_a, z_a, t_a) and $(x_a + dx_a, y_a + dy_a, z_a + dz_a, t_a + dt_a)$, and (x, y, z, t) and $(x + dx, y + dy, z + dz, t + dt)$, separately. If the two events are connected by light, from Eq. (4.13) we can get

$$\begin{aligned}&\left(dx_a^2 + dy_a^2 + dz_a^2\right) - (c dt_a + X_a dx_a + Y_a dy_a + Z_a dz_a)^2 \\ &\qquad = (dx^2 + dy^2 + dz^2) - (c dt + X dx + Y dy + Z dz)^2\end{aligned} \tag{5.37}$$

and its left and right sides are identically equal to zero. For GGT, $X_a = Y_a = Z_a = 0$, $X = -\beta$, $Y = Z = 0$, using Eqs. (5.2) we can easily prove that Eq. (5.37) is true for any two events connected by subluminal or superluminal action, although the two sides are no longer equal to zero. Hence, we can write the expression

$$ds^2 = (dz^2 + dy^2 + dz^2) - (c dt - \beta dx)^2, \tag{5.38}$$

where (x, y, z, t), etc. represent quantities belonging to frame $\Sigma_i\,(i = a, 1, 2, \cdots)$. For $i = a$, i.e., frame Σ_a, $\beta = 0$. ds^2 is an invariant under GGT.

It can be proved that ds^2 of two events connected by subluminal action, luminous action and superluminal action has different signs, i.e.,

$$ds^2 \begin{cases} < 0, & \text{subluminal action,} \\ = 0, & \text{luminous action,} \\ > 0, & \text{superluminal action.} \end{cases} \tag{5.39}$$

The above equation can be proved to be true to any frame Σ_i, but it is the easiest to prove to frame Σ_a. Just note that, for frame Σ_a, $\beta = 0$. It is also possible to prove (5.39) for general inertial frames Σ_i, for example, for two events linked by subluminal signal,

$$\sqrt{\mathrm{d}x_i^2 + \mathrm{d}y_i^2 + \mathrm{d}z_i^2} < c_i(\alpha, \beta, \gamma)\mathrm{d}t_i. \qquad (5.40)$$

However, by Eqs.(4.8) and (4.10), and noting $X_i = -\beta_i, Y_i = Z_i = 0$, we can get

$$c_i(\alpha,\beta,\gamma)\mathrm{d}t_i = \frac{c\mathrm{d}t_i}{1 - R_i(\alpha,\beta,\gamma)} = \frac{c\mathrm{d}t_i}{1 + \beta_i \mathrm{d}x_i / \sqrt{\mathrm{d}x_i^2 + \mathrm{d}y_i^2 + \mathrm{d}z_i^2}}.$$

Substituting the above equation into (5.40) yields

$$\sqrt{\mathrm{d}x_i^2 + \mathrm{d}y_i^2 + \mathrm{d}z_i^2} + \beta_i \mathrm{d}x < c\mathrm{d}t_i, \quad \mathrm{d}x_i^2 + \mathrm{d}y_i^2 + \mathrm{d}z_i^2 < (c\mathrm{d}t_i - \beta_i \mathrm{d}x_i)^2.$$

Because $\mathrm{d}s^2$ is an invariant,we have proved

$$\mathrm{d}s^2 = (\mathrm{d}x^2 + \mathrm{d}y^2 + \mathrm{d}z^2) - (c\mathrm{d}t - \beta \mathrm{d}x)^2 < 0.$$

Similarly, it can be proved that $\mathrm{d}s^2 = 0$ for light signals,; $\mathrm{d}s^2 > 0$ for superluminal signals.

From Eq, (5.39) we can obtain the following conclusions:

(1) For two events connected by subluminal action, there always exists such a reference frame observed from which the two events occur at the same place; but, observing in any other reference frame, the two events do not occur at the same place.

Suppose that in frame Σ, $\mathrm{d}s^2 = \mathrm{d}l^2 - (c\mathrm{d}t - \beta\mathrm{d}x)^2 < 0$ and $\mathrm{d}l \neq 0$. Then an frame Σ^* can always be found, which satisfies $-c^2\mathrm{d}t^{*2} = \mathrm{d}l^2 - (c\mathrm{d}t - \beta\mathrm{d}x)^2 < 0$, therefore, $\mathrm{d}l^* = 0$, that is the two events occur at the same place in frame Σ^*. According to the space-time coordinate transformation formula (6.71) between two general inertial frames derived from the generalized Galilean transformation (see § 6.4) , we can obtain

$$\mathrm{d}x = \sqrt{\frac{1-\beta^{*2}}{1-\beta^2}}\mathrm{d}x^* + \frac{(v^* - v)}{\sqrt{(1-\beta^{*2})(1-\beta^2)}}\mathrm{d}t^* = \frac{(v^* - v)}{\sqrt{(1-\beta^{*2})(1-\beta^2)}}\mathrm{d}t^* \neq 0.$$

That is in any other inertial frame Σ , the two events do not occur at the same place in space.

(2) Two events connected by superluminal action cannot occur at the same place observing in any frames, because for two events occurring at the same place in space there must be $\mathrm{d}s^2 < 0$.

(3) For two events connected by subluminal action or limited superluminal action, it is not possible for them to occur simultaneously. Only those two events connected by instantaneous action or two mutually independent events can occur simultaneously.

5. 3. 2. Time-like Interval and Space-like Interval

For two events connected by subluminal action, we define time-like interval $\mathrm{d}\tau_1$ which satisfies

$$\mathrm{d}s^2 = (\mathrm{d}x^2 + \mathrm{d}y^2 + \mathrm{d}z^2) - (c\mathrm{d}t - \beta\, \mathrm{d}x)^2 = -c\mathrm{d}\tau_1^2. \qquad (5.40)$$

Let $|\mathrm{d}s| = (\mathrm{d}s^2)^{-1/2}$, then

$$\begin{aligned} \mathrm{d}\tau_1 &= |\mathrm{d}s|/c = \sqrt{(c\mathrm{d}t - \beta\mathrm{d}x)^2 - (\mathrm{d}x^2 + \mathrm{d}y^2 + \mathrm{d}z^2)}/c \\ &= \sqrt{(1 - \boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - u^2/c^2}\,\mathrm{d}t = k_1^{-1}\mathrm{d}t, \end{aligned} \tag{5.41}$$

where $\boldsymbol{u}$ is the propagation velocity of the subluminal action connecting the two events measured in frame Σ_i, and $\boldsymbol{v}$ is the velocity of the frame Σ_i relative to frame Σ_a measured by frame Σ_a.

The meaning of $\mathrm{d}\tau_1$ is: It is just the time interval of the two events measured in the frame in which the two events occur at the same place.

To two events connected by superluminal action, we define space-like interval $\mathrm{d}\tau_2$ which satisfies

$$\mathrm{d}s^2 = (\mathrm{d}x^2 + \mathrm{d}y^2 + \mathrm{d}z^2) - (c\mathrm{d}t - \beta\,\mathrm{d}x)^2 = c^2\mathrm{d}\tau_2^2. \tag{5.42}$$

Let $|\mathrm{d}s| = (\mathrm{d}s^2)^{-1/2}$, then

$$\begin{aligned} \mathrm{d}\tau_2 &= |\mathrm{d}s|/c = \sqrt{(\mathrm{d}x^2 + \mathrm{d}y^2 + \mathrm{d}z^2) - (c\mathrm{d}t - \beta\mathrm{d}x)^2}/c \\ &= \sqrt{u^2/c^2 - (1 - \boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2}\,\mathrm{d}t = k_2^{-1}\mathrm{d}t, \end{aligned} \tag{5.43}$$

where $\boldsymbol{u}$ represents the propagation velocity of the superluminal action connecting the two events measured in frame Σ_i.

To consider the meaning of $\mathrm{d}\tau_2$, we choose such a reference frame that its velocity $\boldsymbol{v}$ relative to frame Σ_a be consistent with the direction of the superluminal velocity $\boldsymbol{u}$, and $v = c^2/u < c$, i.e., $1 - \boldsymbol{u}\cdot\boldsymbol{v}/c^2 = 0$, in which we can obtain

$$\mathrm{d}\tau_2 = |\mathrm{d}s|/c = u\mathrm{d}t/c = \sqrt{\mathrm{d}x^2 + \mathrm{d}y^2 + \mathrm{d}x^2}/c\,. \tag{5.44}$$

Therefore, the meaning of the space-like interval $\mathrm{d}\tau_2$ can be stated as the spatial interval (divided by the average speed of light c) of the two events measured in the frame moving along the superluminal propagation direction with a speed $v = c^2/u < c$ with respect to the frame Σ_a, or in other words, it is the time required to go through the spatial interval of the two events with the average speed of light c measured in the above frame. Obviously, this is longer than the spatial interval of the two events measured in any other frame.

5. 4. Mass of Moving Particle and Mass Increase Effect

In this section we discuss the mass of a subluminal particle and superluminal material system and the mass increase effect on the basis of the kinematics of Standard Space-time Theory. The basic presupposition is to assume the conservation law of momentum hold true in any inertial reference frame.

We start our discussion from the ideal experiment introduced by Lewis and Tolman [2].

Suppose an observer in the standard frame Σ_{a} and an observer in an ordinary frame Σ observe the elastic collision of two identical balls (Fig.5.1). Ball A is thrown out by the observer in Σ_{a} along $-y_{\mathrm{a}}$ direction with a velocity V (as measured in Σ_{a}). Ball B is thrown out by the observer in Σ along $+y$ direction with a velocity V (as measured in Σ). When the collision occurs, the line connecting the centers of the two balls is perpendicular to x axis (x_{a} or x). The velocity components of the two balls before and after their collision observed in frames Σ_{a} and Σ are listed in the following table:

Before collision		
Ball A	$u_{axA}=0,\ u_{ayA}=-V$ $u_{aA}=V$	$u_{xA}=-\gamma^2 v, u_{yA}=-\gamma V$ $u_A^2=\gamma^4 v^2+\gamma^2 V^2$
Ball B	$u_{axB}=v,\ u_{ayB}=\gamma^{-1}V$ $u^2_{aB}=v^2+\gamma^{-2}V^2$	$u_{xB}=0,\ u_{yB}=V$ $u_B=V$

After collision		
Ball A	$\bar{u}_{axA}=0,\ \bar{u}_{ayA}=\bar{V}$ $\bar{u}_{aA}=\bar{V}$	$\bar{u}_{xA}=-\gamma^2 v,\ \bar{u}_{yA}=\gamma\bar{V}$ $\bar{u}_A^2=\gamma^4 v^2+\gamma^2\bar{V}^2$
Ball B	$\bar{u}_{axB}=v, \bar{u}_{ayB}=-\gamma^{-1}\bar{V}$ $\bar{u}^2_{aB}=v^2+\gamma^{-2}\bar{V}^2$	$\bar{u}_{xB}=0,\ \bar{u}_{yB}=-\bar{V}$ $\bar{u}_B=\bar{V}$

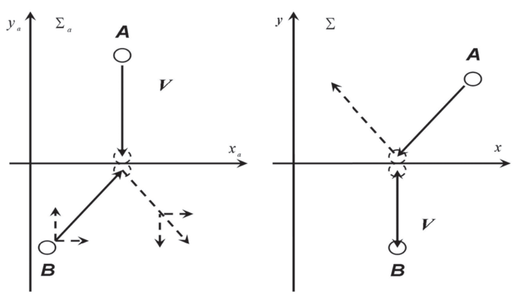

Fig. 5.1

In this table, the directions of the velocity components are represented by plus and minus signs, the letters $V, \bar{V}$ and $u_{\mathrm{a}A}, \bar{u}_{\mathrm{a}A}, u_A, \bar{u}_A$, etc., only represent the scalar value of the velocities; besides, velocities before collision $u_{\mathrm{a}A}$, $u_{\mathrm{ax}A}$, $u_{\mathrm{av}A}$ of ball A in Σ_{a} and velocities before collision u_B, u_{xB}, u_{vB} of ball B in Σ are given certain in the ideal experiment, while the velocities u_A, u_{xA}, u_{yA} before collision of ball A in Σ and velocities before collision u_{aB}, u_{axB}, u_{ayB} of ball B in Σ_a are obtained from the transformations (5.7) — (5.10). Besides, V represents the value of velocity before collision, $\bar{V}$ represents the value of velocity after collision. The relation between V and $\bar{V}$ is awaited to be found. $\gamma = (1 - v^2/c^2)^{-1/2}$, $\boldsymbol{v}$ represents the motion velocity of frame Σ along the x_a axis of frame Σ_a with respect to Σ_a.

Denote the masses of balls A and B before and after collision in the two frames as

$$\text{Frame } \Sigma_a : m_{aA}, \bar{m}_{aA}, m_{aB}, \bar{m}_{aB},$$
$$\text{Frame } \Sigma : m_A, \bar{m}_A, m_B, \bar{m}_B.$$

First, we discuss the mass expression in frame Σ_a.

From the conservation of momentum along the x_a axis direction of Σ_a, $\bar{m}_{aB} v = m_{aB} v$, we have

$$\bar{m}_{aB} = m_{aB}. \tag{5.45}$$

From the conservation of momentum along the y_a axis direction of Σ_a we have

$$-m_{aA} V + m_{aB} \gamma^{-1} V = \bar{m}_{aA} \bar{V} - m_{aB} \gamma^{-1} \bar{V}. \tag{5.46}$$

If we assume the masses of the two balls to be invariant, from above we get

$$(V + \bar{V})(1 - \gamma^{-1}) = 0.$$

Because we have already assumed $V, \bar{V}$ and v to be not zero, this above relation cannot be satisfied. Hence, the mass of a moving particle or material system cannot be invariant; it necessarily depends on the velocity of the particle. Since it is so, Eq. (5.45) means that

$$\bar{u}_{aB} = u_{aB}, \quad \text{or} \quad v^2 + \gamma^{-2} \bar{V}^2 = v^2 + \gamma^{-2} V^2.$$

Hence

$$\bar{V} = V, \quad \bar{u}_{aA} = u_{aA}. \tag{5.47}$$

Identical balls at the same motion state in an inertial frame (note that the velocity is along the $\pm y$ axis directions perpendicular to $\boldsymbol{v}$) should have the same masses, so

$$\bar{m}_{aA} = m_{aA}. \tag{5.48}$$

Substituting Eqs. (5.45), (5.47) and (5.48) into Eq. (5.46), we finally obtain

$$m_{aA} = \gamma^{-1} m_{aB} \tag{5.49}$$

Apply Eqs. (5.15) and (5.16) to ball B, i.e., in Eq. (5.16), according to the velocity values in the above Table, let $u_a = u_{aB}$, $u_x = u_{aB} = 0$, $u = u_B = V = u_{aA}$. Substituting them into Eq. (5.15), then by using its result we express γ^{-1} in Eq. (5.49) and finally obtain

$$\frac{m_{aA}}{m_{aB}} = \begin{cases} \sqrt{1 - u_{aB}^2 / c^2} \Big/ \sqrt{1 - u_{aA}^2 / c^2}, & u_{aA}, u_{aB} < c, \\ \sqrt{u_{aB}^2 / c^2 - 1} \Big/ \sqrt{u_{aA}^2 / c^2 - 1}, & u_{aA}, u_{aB} > c. \end{cases}$$

To make sure that the above equation be true all along, we can only make the following definition: the mass of a moving particle or material system in Σ_a is

$$m_{\mathrm{a}}=\begin{cases}\dfrac{m_0}{\sqrt{1-u_{\mathrm{a}}^2/c^2}}, & \text{for subluminal particle;}\\[2ex] \dfrac{m_0}{\sqrt{u_{\mathrm{a}}^2/c^2-1}}, & \text{for superluminal system}.\end{cases}$$

or
$$m_{\mathrm{a}}=k_{\mathrm{a}}m_0, \tag{5.50}$$
where for subluminal particles, $k_{\mathrm{a}}=k_{1\mathrm{a}}$, m_0 represents the rest mass of the particle in frame Σ_{a}; for superluminal material system, $k_{\mathrm{a}}=k_{2\mathrm{a}}$, m_0 represents the mass of the matter when $u_{\mathrm{a}}=\sqrt{2}c$.

Apart from our unified treatment to subluminal particle and superluminal material system, the process and results of the above discussion are completely similar to the corresponding discussion and results in the special theory of relativity. But it is so only in the standard inertial frame; for ordinary inertial frames, serious difference with the special theory of relativity will occur. Now we discuss the mass expression in frame Σ.

From the conservation of momentum along the x axis direction of Σ we have
$$\overline{m}_A=m_A. \tag{5.51}$$
Besides, from Eq. (5.47) we have $\overline{u}_B=u_B$, so
$$\overline{m}_B=m_B. \tag{5.52}$$

From the conservation of momentum along the y axis direction of Σ we have
$$-m_A\gamma V+m_BV=\overline{m}_A\gamma\overline{V}-\overline{m}_B\overline{V}.$$
Substituting Eqs. (5.47), (5.51) and (5.52) into the above equation we obtain
$$m_A=\gamma^{-1}m_B. \tag{5.53}$$
The same, using Eqs. (5.15) and (5.16), but to express γ^{-1} in the above equation by quantities in Σ, we must apply them to ball A, i.e., in Eq. (5.16) we let $u=u_A$, $u_x=u_{xA}$, $u_{\mathrm{a}}=u_{\mathrm{a}A}$, from the velocity values in the above Table can easily prove that
$$\left.\begin{aligned}\sqrt{1-u_{\mathrm{a}A}^2/c^2}&=\sqrt{(1-\boldsymbol{u}_B\cdot\boldsymbol{v}/c^2)^2-u_B^2/c^2},\\ \sqrt{u_{\mathrm{a}A}^2/c^2-1}&=\sqrt{u_B^2/c^2-(1-\boldsymbol{u}_B\cdot\boldsymbol{v}/c^2)^2}.\end{aligned}\right\}$$
Substituting these equations into Eqs. (5.16) and (5.15), and using its result we express γ^{-1} in (5.53), finally obtain
$$\frac{m_A}{m_B}=\begin{cases}\dfrac{\sqrt{(1-\boldsymbol{u}_B\cdot\boldsymbol{v}/c)^2-u_B^2/c^2}}{\sqrt{(1-\boldsymbol{u}_A\cdot\boldsymbol{v}/c^2)^2-u_A^2/c^2}}, & \text{for subluminal particle;}\\[2ex] \dfrac{\sqrt{u_B^2/c^2(1-\boldsymbol{u}_B\cdot\boldsymbol{v}/c^2)^2}}{\sqrt{u_A^2/c^2-(1-\boldsymbol{u}_A\cdot\boldsymbol{v}/c^2)^2}}, & \text{for superluminal system.}\end{cases}$$

To make sure that the above equation be satisfied all along, we have to define the mass of a moving particle or material system in frame Σ to be

$$m = k\,m_0, \tag{5.54}$$

where for subluminal particle,

$$k = k_1 = [(1 - \boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - u^2/c^2]^{-1/2},$$

and m_0 represents its rest mass in Σ ; for superluminal material system,

$$k = k_2 = [u^2/c^2 - (1 - \boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2]^{-1/2},$$

and m_0 represents its mass when it moves perpendicularly to $\boldsymbol{v}$ with a velocity $u = \sqrt{2}c$ in the frame Σ.

Similarly, we can reasonably consider the matter or the weights as standards of mass at the same motion state will have the same mass change per unit mass. Hence, to the same subluminal particle, its rest masses m_{0i} measured in any frame Σ_i are the same, and are equal just the rest mass m_0 measured in Σ_a. The same, to the same superluminal system, noticing that there exists symmetry relative to $\boldsymbol{v}$ direction in space-time, its masses m_{0i} measured in any frame Σ_i when it moves perpendicularly to characteristic velocity $\boldsymbol{v}$ with $u_i = \sqrt{2}c$ are all equal to the mass m_0 measured in Σ_a when it moves (to any direction) with the speed $u_a = \sqrt{2}c$. Hence, Eqs. (5.50) and (5.54) can be combined to the common form to any frame

$$m = k_a \gamma^{-1} m_0 = k m_0, \tag{5.55a}$$

$$m = \begin{cases} \dfrac{\sqrt{1 - v^2/c^2}}{\sqrt{1 - u_a^2/c^2}} m_0 = \dfrac{m_0}{\sqrt{(1 - \boldsymbol{u}\cdot\boldsymbol{v})/c^2)^2 - u^2/c^2}}, & \text{for subluminal particle;} \\[2ex] \dfrac{\sqrt{1 - v^2/c^2}}{\sqrt{u_a^2/c^2 - 1}} m_0 = \dfrac{m_0}{\sqrt{u^2/c^2 - (1 - \boldsymbol{u}\cdot\boldsymbol{v})/c^2)^2}}, & \text{for superluminal system,} \end{cases} \tag{5.55b}$$

where we used Eq. (5.17). For a subluminal particle, m_0 represents the rest mass of the particle; for superluminal system, m_0 represents the $\sqrt{2}c$ mass of the system.

Formula (5.55) is obtained by applying the law of momentum conservation. If the law of mass conservation is also applied at the same time to discuss the complete elastic collision of two balls (see reference [3]), the same conclusion will be obtained.

Similarly to the statements on the length contraction effect and time dilation effect, we can get the substantive understanding about the "mass increase effect" from the above discussions and formula (5.55): the mass of any body and weight as the mass standard of the reference frame will really increase relative to the rest mass by a factor $\sqrt{1 - u_a^2/c^2}$ when they are at subluminal motion ($u_a < c$). The mass of any material system will really decrease relative to the " $\sqrt{2}c$ mass" when it is at superluminal motion ($u_a > c$). If we consider simultaneously the real change in mass of the moving matter and weights of reference frame (notice that the weights can only move at subluminal speed with respect to the reference frame), we can predict the results of measurement in any frame for the masses of any matter in subluminal, luminous or superluminal motion. Obviously, this result of measurement has also the nature of duality, i.e., absoluteness and relativity.

5. 5. Dynamical Equations

Using the mass expression obtained in the last Section, we can naturally define the momentum of a subluminal particle or superluminal material system

$$\boldsymbol{p} = m\boldsymbol{u} = km_0\boldsymbol{u}, \tag{5.56a}$$

or

$$\boldsymbol{p} = m\boldsymbol{u} = \begin{cases} \dfrac{m_0\boldsymbol{u}}{\sqrt{(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - u^2/c^2}}, & \text{for subluminal particle;} \\ \dfrac{m_0\boldsymbol{u}}{\sqrt{u^2/c^2 - (1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2}}, & \text{for superluminal system.} \end{cases} \tag{5.56b}$$

For subluminal particle, $k = k_1, m_0$ is the rest mass; for superluminal system $k = k_2, m_0$ is the "$\sqrt{2}c$ mass".

Force is defined as the rate of change of the momentum under the action of this force, i.e.

$$\boldsymbol{f} = \frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t} = \frac{\mathrm{d}}{\mathrm{d}t}(m\boldsymbol{u}) = \frac{\mathrm{d}}{\mathrm{d}t}(km_0\boldsymbol{u}), \tag{5.57a}$$

or

$$\boldsymbol{f} = \frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t} = \begin{cases} \dfrac{\mathrm{d}}{\mathrm{d}t}\dfrac{m_0\boldsymbol{u}}{\sqrt{(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - u^2/c^2}}, & \text{for subluminal motion;} \\ \dfrac{\mathrm{d}}{\mathrm{d}t}\dfrac{m_0\boldsymbol{u}}{\sqrt{u^2/c^2 - (1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2}}, & \text{for superluminal motion.} \end{cases} \tag{5.57b}$$

This is the dynamic equations of Standard Space-time Theory, which is valid for any inertial reference frame $\Sigma_i (i = \mathrm{a}; 1, 2, \cdots)$. When it is applied to frame Σ_i, the forces $\boldsymbol{f}$ and $\boldsymbol{u}$, u_x etc. are the quantities measured by the frame Σ_i. $\boldsymbol{v}$ is speed of motion of the frame Σ_i relative to frame Σ_a measured in frame Σ_a.

For $i = \mathrm{a}$, i. e. frame Σ_a, , one should take $\boldsymbol{v} = 0$, and Eq. (5.57b) becomes

$$\boldsymbol{f} = \frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t} = \begin{cases} \dfrac{\mathrm{d}}{\mathrm{d}t}\dfrac{m_0\boldsymbol{u}_\mathrm{a}}{\sqrt{1-u_\mathrm{a}^2/c^2}}, & \text{for subluminal motion;} \\ \dfrac{\mathrm{d}}{\mathrm{d}t}\dfrac{m_0\boldsymbol{u}_\mathrm{a}}{\sqrt{u_\mathrm{a}^2/c^2 - 1}}, & \text{for superluminal motion.} \end{cases} \tag{5.57c}$$

To clarify the relation between the force and the acceleration we research the dynamical equation (5.57). It gives

$$\boldsymbol{f}=\frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t}=\frac{\mathrm{d}}{\mathrm{d}t}(m\boldsymbol{u})=m\frac{\mathrm{d}\boldsymbol{u}}{\mathrm{d}t}+\boldsymbol{u}\frac{\mathrm{d}m}{\mathrm{d}t}.$$

Considering the normal and tangential component (represented respectively by the subscripts n and t), the above formula can be written as

$$\boldsymbol{f}=\boldsymbol{f}_n+\boldsymbol{f}_t=m\left(\frac{\mathrm{d}\boldsymbol{u}}{\mathrm{d}t}\right)_n+m\left(\frac{\mathrm{d}\boldsymbol{u}}{\mathrm{d}t}\right)_t+\boldsymbol{u}\frac{\mathrm{d}m}{\mathrm{d}t}=m\boldsymbol{a}_n+m\boldsymbol{a}_t+\boldsymbol{u}\frac{\mathrm{d}m}{\mathrm{d}t}.$$

From the above formula and noting to

$$a_t=\frac{\mathrm{d}u}{\mathrm{d}t},\qquad \boldsymbol{u}\frac{\mathrm{d}m}{\mathrm{d}t}\parallel\boldsymbol{u},$$

we can obtain

$$f_n=ma_n=\begin{cases}\dfrac{m_0}{\sqrt{\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)^2-u^2/c^2}}a_n, & \text{for subluminal motion;}\\[2ex] \dfrac{m_0}{\sqrt{u^2/c^2-\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)^2}}a_n, & \text{for superluminal motion,}\end{cases}\tag{5.58a}$$

$$f_t=ma_t+u\frac{\mathrm{d}m}{\mathrm{d}t}=m\frac{\mathrm{d}u}{\mathrm{d}t}+u\frac{\mathrm{d}m}{\mathrm{d}t}=\frac{\mathrm{d}}{\mathrm{d}t}(mu),$$

i.e.,

$$f_t=\frac{\mathrm{d}}{\mathrm{d}t}(mu)=\begin{cases}\dfrac{\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)m_0}{\left[\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)^2-u^2/c^2\right]^{3/2}}a_t, & \text{for subluminal motion;}\\[2ex] \dfrac{-\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)m_0}{\left[u^2/c^2-\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)^2\right]^{3/2}}a_t, & \text{for superluminal motion.}\end{cases}\tag{5.58b}$$

From Eqs. (5.58a) and (5.58b) we see that in the case of high-speed motion of a particle, the force acting on the particle is not equal to the product of its test mass and its acceleration in numerical value, furthermore for the different factors of a_n and a_t in the rights of the two equations the direction of the force is different from the direction of the acceleration.

From Eq. (5.58b) we can see that for a superluminal material system, when its speed $\boldsymbol{u}$ is close to the speed of light, which satisfies $1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2>0$, then the force on it is the opposite to the direction of its acceleration a_t. That is to say, to slow it down, the force must be applied in the same direction of its speed. This is completely opposite to the subluminal case.

From the dynamical equation we can derive the law of conservation of momentum of Standard Space-time Theory, that is, when the external force $\boldsymbol{f}=0$,

$$\boldsymbol{p}=m\boldsymbol{u}=\text{constant}.\tag{5.59}$$

To a material system which consists of several parts without mutual interaction, if no external forces are applied, the total momentum

$$\sum_j \boldsymbol{p}_j = \sum_j \boldsymbol{p}_j^* = \text{constant}$$

where $\boldsymbol{p}_i$ and $\boldsymbol{p}_i^*$ respectively represent the momentums of the jth part at any two moments t and t^*. If there exists interaction between each part of the material system during a certain time interval, although the system is not acted upon by an external force, Eq. (5.59) is only suitable before or after the interactions, but not during the interactions. In the equation, $\boldsymbol{p}_i$ and $\boldsymbol{p}_i^*$ represent the momentum of the jth part before the interaction (at time t) and after the interaction (at time t^*) respectively.

5. 6. Mass-Energy Relations

In this Section we find the mass-energy relation for Standard Space-time Theory. For this, we have to find out the expression of kinetic energy.

As in Newtonian mechanics, we define work done by a force to be proportional to the product of the applied force and the displacement along the direction of the force: $dw \propto \boldsymbol{f} \cdot d\boldsymbol{r}$. If all these works are used to increase the kinetic energy T, we have

$$\mathrm{d}T = \mathrm{d}w \propto \boldsymbol{f} \cdot \mathrm{d}\boldsymbol{r},$$

$$\frac{\mathrm{d}T}{\mathrm{d}t} \infty \boldsymbol{f} \cdot \frac{\mathrm{d}\boldsymbol{r}}{\mathrm{d}t} = \boldsymbol{f} \cdot \boldsymbol{u} = \boldsymbol{u} \cdot \frac{\mathrm{d}}{\mathrm{d}t}(m\boldsymbol{u}). \tag{5.60}$$

Substituting the mass formula (5.55) into the above equation, we can obtain the expression of kinetic energy. For subluminal particles, we take $k = k_1$, and we get

$$\mathrm{d}T \infty P_1 \mathrm{d}u_x + Q_1 \mathrm{d}u_y + R_1 \mathrm{d}u_z. \tag{5.61}$$

where

$$\left.\begin{aligned} P_1 &= k_1^3 m_0 (1 - u_x v / c^2)[u_x + (u_y^2 + u_z^2) v / c^2], \\ Q_1 &= k_1^3 m_0 (1 - u_x v / c^2)^2 u_y, \\ R_1 &= k_1^3 m_0 (1 - u_x v / c^2)^2 u_z. \end{aligned}\right\} \tag{5.62}$$

It is easy to show that the right side of Eq. (5.61) satisfies the complete integrable condition:

$$P_1\left(\frac{\partial Q_1}{\partial u_z} - \frac{\partial R_1}{\partial u_y}\right) + Q_1\left(\frac{\partial R_1}{\partial u_x} - \frac{\partial P_1}{\partial u_z}\right) + R_1\left(\frac{\partial P_1}{\partial u_y} - \frac{\partial Q_1}{\partial u_x}\right) = 0\,.$$

Hence, there must be an integral factor μ such that $\mu(P_1 du_x + Q_1 du_v + R_1 du_z)$ is the total differential of a certain function. If we neglect difference of a constant factor, from Eq. (5.61) we can write

$$\mathrm{d}T = \mu(P_1\mathrm{d}u_x + Q_1\mathrm{d}u_y + R_1\mathrm{d}u_z) . \tag{5.63}$$

Solving for this integral factor we can get

$$\mu = \left|1 - u_x v / c^2\right|^{-1}, \text{or} \quad \mu = \left|1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2\right|^{-1}, \tag{5.64}$$

where the absolute sign is obtained naturally from the solution process. But for a subluminal particle, $u_x < c_{+x} < c^2 / v$, $1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2 > 0$, so the absolute sign can be taken away.

Substituting Eq. (5.64) into (5.63), we can easily get

$$T = k_1 m_0 c^2 (1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2) + C .$$

Because the kinetic energy of a subluminal particle increases as the velocity increase, we can assume the kinetic energy to be zero as the velocity of the particle is zero, so $C = m_0 c^2$. Therefore, we get the expression of the kinetic energy of the subluminal particle as follows:

$$T = k_1 m_0 c^2 (1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2) + C, \tag{5.65}$$

where $k_1 = [(1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2)^2 - u^2 / c^2]^{-1/2}$. Using Eqs. (5.55) and (5.56) we can write the expression of kinetic energy as other forms

$$T = mc^2 (1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2) - m_0 c^2 ; \quad T = mc^2 - m_0 c^2 - \boldsymbol{p} \cdot \boldsymbol{v} . \tag{5.66}$$

The total energy of a subluminal free particle is $E = T + m_0 c^2$, here $m_0 c^2$ represents the rest mass energy of the free particle. From the expressions of kinetic energy (5.65) and (5.66) we get its corresponding energy expression to be

$$\left.\begin{aligned} &E = m_0 c^2 k_1 (1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2), \\ &E = mc^2 (1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2), \\ &E = mc^2 - \boldsymbol{p} \cdot \boldsymbol{v}. \end{aligned}\right\} \tag{5.67}$$

From this we see that the energy of a subluminal particle increases as its speed increase. When the speed reaches that of light, as Eq. (5.11) shows, k_1 and the corresponding energy becomes infinity. Hence, it is impossible to accelerate the speed of a subluminal particle to that of light.

It is easy to show that the following equations hold true to subluminal particle:

$$E^2 = p^2 c^2 + m_0^2 c^4, \quad \text{or} \quad E = c\sqrt{p^2 + m_0^2 c^2} \tag{5.68}$$

and

$$\frac{\mathrm{d}E}{\mathrm{d}p} = \frac{Pc^2}{E} = \frac{u}{1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2}. \tag{5.69}$$

Besides, by examining the interaction process between particles of a particle system and noticing the conservation of total momentum before and after the interaction (see the last Section), we can obtain from the energy expression that

$$\Delta E = c^2 \Delta m, \tag{5.70}$$

where ΔE and Δm represent the change in total energy and total mass of the particle system before and after the interaction.

Now we find for the expression equations of the kinetic energy and total energy of a superluminal material system. Taking $k = k_2$ in Eq. (55) and substituting into Eq. (5.60) we get

$$\mathrm{d}T \ \infty \ P_2\mathrm{d}u_x + Q_2\mathrm{d}u_y + R_2\mathrm{d}u_z, \tag{5.71}$$

where

$$\left.\begin{aligned} P_2 &= -k_2^3 m_0 (1 - u_x v / c^2)[u_x + (u_y^2 + u_2^2) v / c^2], \\ Q_2 &= -k_2^3 m_0 (1 - u_x v / c^2)^2 u_y, \\ R_2 &= -k_2^3 m_0 (1 - u_x v / c^2)^2 u_z. \end{aligned}\right\} \tag{5.72}$$

Similarly, we can prove that the right side of Eq. (5.71) satisfies complete integrable condition. Hence the integral factor μ exists, which makes

$$\mathrm{d}T = \mu(P_2\mathrm{d}u_x + Q_2\mathrm{d}u_y + R_2\mathrm{d}u_z) . \tag{5.73}$$

It is easy to find that this integral factor is the same as that in the subluminal case, and is show as in Eq. (5.64). However, to superluminal material system, $1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2$ can be positive or negative; hence the absolute sign must be maintained.

Substituting the expression of μ into Eq. (5.73), it is not difficult to find that

$$T = k_2 m_0 c^2 \left|1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2\right| + C, \tag{5.74}$$

where $k_2 = [u^2 / c^2 - (1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2)^2]^{-1/2}$.

We can let the kinetic energy of a superluminal material system be $m_0 c^2$ when its velocity $\boldsymbol{u} \perp \boldsymbol{v}$, $u = \sqrt{2}c$. Substituting into the above equation we obtain $C = 0$. So, we get the expressions for kinetic energy and total energy of the superluminal material system. Using Eqs. (5.55) and (5.56), we can write this expression as other forms:

$$E = T = k_2 m_0 c^2 \left|1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2\right| = mc^2 \left|1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2\right| = \left|mc^2 - \boldsymbol{p} \cdot \boldsymbol{v}\right|. \tag{5.75}$$

The absolute sign is naturally obtained, so here the negative-energy difficulty does not occur. From the above equation we can see that the energy of the superluminal material system increases as its speed decreases when $1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2 > 0$, for example, $\boldsymbol{u} \parallel \boldsymbol{v}$, $u < c^2 / v$ (to frame Σ_a, it is $u_\mathrm{a} < \infty$). The superluminal system has infinitive energy when the speed decreases to that of light (as show in Eq. (5.11). Therefore, in order to decrease the speed of a superluminal system, we must provide energy from outside. To decrease it to the speed of light, we must provide infinitive energy. This indicates that it is impossible to decrease the speed of superluminal material system to that of light.

It is easy to show that the following equation holds true to superluminal material system:

$$E^2 = P^2 c^2 - m_0^2 c^4, \ \ or \ \ E = c\sqrt{P^2 - m_0^2 c^2}, \tag{5.76}$$

and we have

$$\frac{\mathrm{d}E}{\mathrm{d}P} = \frac{Pc^2}{E} = \frac{u}{1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2}. \tag{5.77}$$

To the interaction process between each part of a superluminal system, the relation of the total energy change ΔE and total mass change Δm before and after the interaction may show different cases because $(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)$ or $(mc^2-\boldsymbol{p}\cdot\boldsymbol{v})$ may be positive or negative to each part. However, if to each part we have $(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)>0$ (for example, the speed of each part $u<c^2/v$ can satisfy this condition), we can still get from the law of conservation of momentum (5.59) and the expression for energy (5.74) that

$$\Delta E = c^2 \Delta m \, . \tag{5.78}$$

Another point should be emphasized here. According to above statements, there exists a "light barrier" between subluminal particle and superluminal material system, they cannot transform into each other directly. However, the same inference that a substantial particle need infinite energy to be accelerated to the speed of light also holds true in the special theory of relativity, and this does not hinder quantum mechanics and quantum electrodynamics to discuss the problem of the interaction and mutual transformation between light and matter (substantial particle).So we can start from Standard Space-time Theory to establish similarly and symmetrically the theory of interaction and mutual transformation between the photon and the subluminal particle as well as the photon and the superluminal material system. Hence, we can affirm now that the subluminal particle and the superluminal material system can mutually interact and transform indirectly (take photons to be the medium) through their interactions and transformations with the photon respectively.

5. 7. Transformation Equations for Mass, Momentum, Energy and Force

Suppose m_{a} is the mass of a subluminal particle or a superluminal system when it moves with respect to frame Σ_{a} with speed u_{a}, and m and u are its mass and speed with respect to frame Σ. From Eqs. (5.50) and (5.54) we get the transformation of the mass

$$m = \gamma^{-1} m_{\mathrm{a}} \, . \tag{5.79}$$

From the definition of momentum (5.56), by using the velocity transformation (5.17) and mass transformation (5.79) we can easily obtain

$$p_x = m u_x = \gamma m_{\mathrm{a}} (u_{\mathrm{a}x} - v),$$

or

$$p_x = \gamma (p_{\mathrm{a}x} - \beta E_{\mathrm{a}} / c), \tag{5.80}$$

$$p_y = p_{\mathrm{a}y}, \;\; p_z = p_{\mathrm{a}z}. \tag{5.81}$$

Equations (5.80) and (5.81) are the transformation equations of the momentum.

Using Eqs. (5.79) and (5.7) we can find the transformation equation of energy as follows:

$$E\Big/\left|1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right| = \gamma^{-1}E_{\mathrm{a}}, \tag{5.82}$$

or

$$E = \gamma\left|E_{\mathrm{a}} - \boldsymbol{p}\cdot\boldsymbol{v}\right|. \tag{5.83}$$

Using Eqs. (80)—(82) and formula $E_{\mathrm{a}} = m_{\mathrm{a}}c^2$ can easily show that

$$p^2c^2 - E^2 = p_{\mathrm{a}}^2c^2 - E_{\mathrm{a}}^2, \tag{5.84}$$

i.e., $p^2c^2 - E^2$ is an invariant. From Eqs. (5.68) and (5.76) we know that it equals $-m_0^4c^4$ for a subluminal particle and equals for $+m_0^4c^4$ for a superluminal system.

Using Eqs. (5.68) and (5.76) we can easily prove the formula

$$\frac{\mathrm{d}E_{\mathrm{a}}}{\mathrm{d}t_{\mathrm{a}}} = \boldsymbol{f}_{\mathrm{a}}\cdot\boldsymbol{u}_{\mathrm{a}}, \tag{5.85}$$

which holds true for a subluminal particle and a superluminal system. Its physical meaning is: power done by a force equals to the rate of change of energy in the standard inertial frame.

Using the transformation equation of energy (5.83) and Eq. (5.6) and let $\alpha = \mu^{-1} = \left|1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right|$, we can show that

$$\frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{E}{\alpha}\right) = \frac{\mathrm{d}E_{\mathrm{a}}}{\mathrm{d}t_{\mathrm{a}}} = \boldsymbol{f}_{\mathrm{a}}\cdot\boldsymbol{u}_{\mathrm{a}}. \tag{5.86}$$

The physical meaning of this equation can be studied further.

Starting from the dynamical equation (5.57) and using Eqs. (5.80), (5.81), (5.85) and (5.6), we can find

$$\left.\begin{aligned} f_x &= \gamma^2(f_{\mathrm{a}x} - \beta\,\boldsymbol{f}_{\mathrm{a}}\cdot\boldsymbol{u}_{\mathrm{a}}/c),\\ f_y &= \gamma f_{\mathrm{a}y},\\ f_z &= \gamma f_{\mathrm{a}z}. \end{aligned}\right\} \tag{5.87}$$

This is the transformation equation of force.

5. 8. Simplified forms of Equations of Standard Space-time Theory Mechanics

In the preceding sections of this chapter, the mechanics of Standard Space-time Theory were established. Starting from the basic assumptions of Standard Space-time Theory, the mechanical problems of both subluminal particles (or macroscopic objects) and superluminal material systems are dealt with in a unified way, including (1) velocity and acceleration transformations; (2) length contraction or elongation effects, time dilation or shortening effects; (3) mass increase or decrease effects; (4) expressions for momentum, energy, and dynamic equations; (5) mass-energy relations; (6) transformations of mass, momentum, energy, and force. For all these mechanical problems, general expressions for subluminal motion and superluminal motion were provided uniformly but separately.

Things can be made even simpler. This is the simplified forms of the equations of Standard Space-time Theory mechanics discussed and expressed in preceding sections of this chapter. In short, the physical quantities and their equations (or formulas and expressions) related to the superluminal system in the standard space-time mechanics can be properly reformed to obtain the equations (or formulas and expressions) with the same form for subluminal particles (or macroscopic objects) and superluminal systems, thereby simplifying the equations of the standard space-time mechanics.

To simplify the equations of Standard Space-time Theory mechanics, it is only necessary to uniformly express the mass of subluminal particles (or macroscopic objects) and superluminal systems. As mentioned earlier, the mass of a moving matter varies with the velocity of the matter, and its functional relations is given in equations (5.50) and (5.55), where m_0 represents the rest mass or $\sqrt{2}c$ mass. In detail, for a subluminal particle (or macroscopic object), the masses $m_{0i}(i=1,2,3,\cdots)$ of the particle (or object) at rest relative to any general inertial frame Σ_i measured by this inertial frame Σ_i is all equal, and is equal to the mass m_0 of the particle (or object) at rest relative to the inertial frame Σ_a measured by this inertial frame Σ_a. Similarly, for a superluminal systems, the masses $m_{0i}(i=1,2,3,\cdots)$ of the systems moving with velocity $u_i=\sqrt{2}c$ in the direction perpendicular to the characteristic velocity $\boldsymbol{v}$ and measured by this inertial frame Σ_i is all equal, and is equal to the mass m_0 of the systems moving with velocity $u_\text{a}=\sqrt{2}c$ (regardless of direction) relative to the standard inertial frame Σ_a and measured by this inertial frame Σ_a.

To obtain equations, formulas, or expressions identical in form, we replace the rest mass m_0 (for subluminal motion) and $\sqrt{2}c$ mass m_0 (for superluminal motion) in all equations of Standard Space-time Theory mechanics with a same symbol m_s, which satisfies the following formula

$$m_\text{s}=\begin{cases} m_0, & \text{for the subluminal motion;} \\ \text{i}m_0, & \text{for the superluminal motion.} \end{cases} \tag{5.88}$$

Here, the subscript s of m_s is used to distinguish it from the mass of the special theory of relativity. Using s as the subscript, this can be understood as the characteristic mass value associated with the rest mass m_0 (for subluminal motion) or $\sqrt{2}c$ mass m_0 (for superluminal motion) in Standard Space-time Theory. Note: For subluminal motion we have $m_\text{s}=m_0$, so m_0 and m_s take the same real value; for superluminal motion, we have $m_\text{s}=-\text{i}m_0$, $\sqrt{2}c$ mass m_0 takes a real value, while m_s takes the corresponding imaginary value.

According to this discussion and convention, first of all, the mass and momentum formulas (5.50), (5.55) and (5.56) for subluminal particles (or macroscopic objects) and superluminal matter systems are transformed into the following unified forms:

$$m_{\mathrm{a}} = \frac{m_{\mathrm{s}}}{\sqrt{1-u_{\mathrm{a}}^2/c^2}}, \qquad (5.89)$$

$$m = \frac{\sqrt{1-v^2/c^2}}{\sqrt{1-u_{\mathrm{a}}^2/c^2}} m_{\mathrm{s}} = \frac{m_{\mathrm{s}}}{\sqrt{\alpha^2-u^2/c^2}}, \qquad (5.90)$$

$$\boldsymbol{p} = m\boldsymbol{u} = \frac{m_{\mathrm{s}}\boldsymbol{u}}{\sqrt{\alpha^2-u^2/c^2}}, \qquad (5.91)$$

where $\alpha = 1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2$, the meaning of $\boldsymbol{u}, \boldsymbol{v}$ is as before. For standard inertial frames Σ_{a}, we have $v=0,\ \alpha=1, u=u_{\mathrm{a}}$, the above equations concerning the subluminal motion revert to the corresponding equations of the special theory of relativity.

It is important to note that for superluminal material systems, the m_{s} in the above three equations takes imaginary values. However, because $u_{\mathrm{a}} > c$, it can be easily proved by the velocity transformation equation (5.18b) that $u^2/c^2 > \alpha^2$, or $u^2/c^2 > (1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2$. The denominators of the above three equations all take imaginary values. Therefore, in spite of the introduction of imaginary number i, the mass m and momentum $\boldsymbol{p}$ of the superluminal matter systems are still taken as real values. Imaginary number i is introduced only to simplify the equations, formulas or expressions of subluminal particles (or macroscopic objects) and superluminal matter systems into exactly the same form.

Correspondingly, the dynamic equation (5.57) of Standard Space-time Theory is replaced by:

$$\boldsymbol{f} = \frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t} = \frac{\mathrm{d}}{\mathrm{d}t}(m\boldsymbol{u}) = \frac{\mathrm{d}}{\mathrm{d}t}\frac{m_{\mathrm{s}}\boldsymbol{u}}{\sqrt{\alpha^2-u^2/c^2}}. \qquad (5.92)$$

This dynamic equation also applies to subluminal particles (or macroscopic objects) and superluminal material systems.

Next, let's study the expressions of energy and the mass-energy relationship. The energy representation formulas (5.67) and (5.75) for subluminal particles (or macroscopic objects) and superluminal material systems obtained in Sec.5.6 and the mass-energy relationship formulas (5.68) and (5.76) can be respectively replaced by the following concise forms:

$$E = \frac{m_{\mathrm{s}}|\alpha|c^2}{\sqrt{\alpha^2-u^2/c^2}} = m|\alpha|c^2, \qquad (5.93)$$

$$E^2 = p^2c^2 + m_{\mathrm{s}}^2c^4, \quad \text{or} \quad E = c\sqrt{p^2+m_{\mathrm{s}}^2c^2}. \qquad (5.94)$$

where $\alpha = 1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2$. For a superluminal matter system, $u^2/c^2 > \alpha^2$, it is easy to prove that $p^2+m_{\mathrm{s}}^2c^2 = p^2-m_0^2c^2$. Therefore, the energy obtained from the second expression in (5.94) is also taken as a real value. For the standard inertial frame, $v=0,\ \alpha=1,\ u=u_{\mathrm{a}}$, the Eq. (5.93) reverts to the mass-energy relation of the special theory of relativity.

Considering interaction processes in closed systems, it is noted that the total momentum is conserved before and after interaction. From the energy expression (5.93), we also obtain:

$$\Delta E = c^2 \Delta m. \tag{5.95}$$

As explained in detail in Sec. 5.5—5.7, the energy of subluminal particles increases as their velocity increases, and when the velocity reaches the speed of light, their energy becomes infinite. Therefore, it is impossible to accelerate subluminal particles to the speed of light. The energy of superluminal material systems increases as their speed decreases, and when the speed decreases to the speed of light, their energy becomes infinite accordingly. Therefore, it is impossible to slow down the superluminal matter system to the speed of light. This implies that there is a "light barrier" between subluminal particles and superluminal material systems, and it is impossible for them to directly convert and interact with each other. However, subluminal particles and superluminal matter systems can achieve mutual conversion and interaction indirectly (with light as the intermediate medium) through their mutual conversion and interaction with light (light quantum).

From this, it can be seen that subluminal particles (or macroscopic objects) and superluminal material systems are two different modes of material existence and motion, which cannot be directly converted and interacted with each other. Starting from Standard Space-time Theory, similar and symmetric theories can be established for the interaction and conversion between light and subluminal particles, as well as light and superluminal material systems.

References

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3. W. G. V. Rosser, An Introduction to the Theory of Relativity, Butterworths, London, 1971, Appendix 3.

Chapter 6

Standard Space-time Theory Formulated in Four-dimensional Form and in General Coordinate System

The present chapter continues with discussions based on the previous chapter 4 and 5. The four-dimensional form of Standard Space-time Theory is established, and its dynamical equation is shown to meet the requirement of covariance of equations. The formulas of Standard Space-time Theory in a general coordinate system are obtained, in which any coordinate axis is not consistent with the direction of the characteristic velocity of the ordinary reference frame.

6. 1. Non-Orthogonal Transformations in the Four-Dimensional Pseudo- Euclidean Space

From what we discussed in the previous chapter 4 and 5, we can see that space and time are closely connected and indivisible. Space and time coordinate mutually connect when the inertial reference frame changes. Three-dimensional space and one-dimensional time constitute a unified four-dimensional space-time.

Usually, we can let

$$\left.\begin{aligned} x_{\mathrm{a}}^{1} = x_{\mathrm{a}}\,,\ x_{\mathrm{a}}^{2} = y_{\mathrm{a}}\,,\ x_{\mathrm{a}}^{3} = z_{\mathrm{a}}\,,\ x_{\mathrm{a}}^{4} = ct_{\mathrm{a}}\,, \\ x^{1} = x,\quad x^{2} = y,\quad x^{3} = z,\quad x^{4} = ct. \end{aligned}\right\} \tag{6.1}$$

So, GGT can be written as

$$x^{1} = \gamma(x_{\mathrm{a}}^{1} - \beta\, x_{\mathrm{a}}^{4}),\ \ x^{2} = x_{\mathrm{a}}^{2},\ \ x^{3} = x_{\mathrm{a}}^{3},\ \ x^{4} = \gamma^{-1} x_{\mathrm{a}}^{4}. \tag{6.2}$$

This transformation and its transformation matrix can be written as

$$\boldsymbol{X} = \boldsymbol{T}\boldsymbol{X}_{\mathrm{a}}\,, \quad \text{or} \quad x^{\mu} = t_{\nu}^{\mu} x_{\mathrm{a}}^{\nu}\,,\ \ \mu,\nu = 1,2,3,4$$

where

$$\boldsymbol{T}=(t^{\mu}_{\nu})=\begin{bmatrix}\gamma & 0 & 0 & -\gamma\beta\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & \gamma^{-1}\end{bmatrix}. \tag{6.3}$$

According to the discussion of the chapter 5, we know that the square of the radius vector OA from the origin to the point $A=(x, y, z, t)$ representing event A in four-dimensional space-time is an invariant

$$A^2=(x^2+y^2+z^2)-(ct-\beta x)^2, \tag{6.4}$$

or

$$A^2=(x^1)^2+(x^2)^2+(x^3)^2-(x^4-\beta x^1)^2. \tag{6.5}$$

A moving point generally forms a curve line. The square of the line element is

$$\mathrm{d}s^2=(\mathrm{d}x^1)^2+(\mathrm{d}x^2)^2+(\mathrm{d}x^3)^2-(\mathrm{d}x^4-\beta\,\mathrm{d}x^1)^2, \tag{6.6}$$

which is also an invariant.

According to the above equation, from the general expression $\mathrm{d}s^2=g_{\mu\nu}\mathrm{d}x^{\mu}\mathrm{d}x^{\nu}$, we get the metric tensor

$$(g_{\mu\nu})=\begin{pmatrix}1-\beta^2 & 0 & 0 & \beta\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ \beta & 0 & 0 & -1\end{pmatrix}. \tag{6.7}$$

Hence, to any inertial frame Σ_i, each element of this tensor is a constant, i.e.

$$g_{\mu\nu}(x^1,x^2,x^3,x^4)=\text{constant}. \tag{6.8}$$

Obviously, the four-dimensional space-time manifold given such a metric tensor constitutes a flat four-dimensional pseudo-Euclidean space.

The above (x^1,x^2,x^3,x^4) represent quantities measured in any inertial frame Σ_i. To frame Σ_{a}, $\beta=0$, Eqs. (6.5)—(6.7) become:

$$A^2=(x_{\mathrm{a}}^1)^2+(x_{\mathrm{a}}^2)^2+(x_{\mathrm{a}}^3)^2-(x_{\mathrm{a}}^4)^2, \tag{6.9}$$

$$\mathrm{d}s^2=(\mathrm{d}x_{\mathrm{a}}^1)^2+(\mathrm{d}x_{\mathrm{a}}^2)^2+(\mathrm{d}x_{\mathrm{a}}^3)^2-(\mathrm{d}x_{\mathrm{a}}^4)^2, \tag{6.10}$$

$$(g_{\mu\nu})=\begin{pmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & -1\end{pmatrix}. \tag{6.11}$$

We know that the Lorentz transformation of the special theory of relativity can be considered as an orthogonal transformation from one orthogonal frame to another in a four-dimensional pseudo- Euclidean space.

Now we examine the corresponding case of GGT. From Eq. (6.3) and simple computation we get $\det\left|t^{\mu}_{\nu}\right| = 1$, but

$$T^{-1} \neq \tilde{T}, \tag{6.12}$$

i.e.

$$t^{\mu}_{\lambda} t^{\nu}_{\mu} = \delta_{\lambda\nu} = \begin{cases} 1 & \text{for } \lambda = \nu, \\ 0 & \text{for } \lambda \neq \nu. \end{cases}$$

does not hold true to all the λ, μ, ν. Hence, although GGT can be regarded as a coordinate transformation with a non-zero determinant in the four-dimensional pseudo-Euclidean space, it is not an orthogonal coordinate transformation from one orthonormal frame to another.

Note that to frame Σ_{a}, Eq. (6.11) holds true, i.e., $g_{\mu\nu} = \pm\delta_{\mu\nu}$, Eqs. (6.9) and (6.10) are just the expression for its radius vector and line element. Hence, the standard inertial frame Σ_{a} can be regarded as an orthonormal frame in this four-dimensional pseudo-Euclidean space. However, Eqs. (6.9) and (6.10) do not hold true for other ordinary inertial frames Σ_i $(i \neq \mathrm{a}, i = 1, 2, \cdots)$. They are not orthonormal frames but rather inclination frames of this space.

Therefore, we can obtain the following conclusion: the transformation of the space-time coordinates from the standard inertial frame to one ordinary inertial frame (i.e., GGT) can be regarded as a non-orthogonal transformation from the orthonormal frame to an inclination frame in the four-dimensional pseudo-Euclidean space.

6. 2. Four-Dimensional Velocity, Momentum, Dynamical Equations

Physical quantities can be classified according to their transformation properties under the coordinate transformation in the four-dimensional pseudo-Euclidean space, that is, the GGT. Physical quantities that are invariant under GGT are called scalars or invariants, such as the interval $\mathrm{d}s^2$ between two events, the time-like interval $\mathrm{d}\tau_1$ and the space-like interval $\mathrm{d}\tau_2$.

A physical quantity consisting of four components V^{μ}, whose components satisfy the same transformation relations as the coordinate transformations (6.2)—(6.3) under the GGT (6.2), namely

$$V^{\mu} = \frac{\partial x^{\mu}}{\partial x^{\nu}_{a}} V_{a}^{\ \nu} = t^{\mu}_{\nu} V_{a}^{\ \nu}, \qquad \mu, \nu = 1, 2, 3, 4,$$

Then it is called a four-dimensional contravariant tensor of first rank (i.e., a four-dimensional contravariant vector).

For example, the differentiation of the coordinates under the GGT (6.2), one has

$$\mathrm{d}x^{\mu} = \frac{\partial x^{\mu}}{\partial x_{\mathrm{a}}^{\nu}} \mathrm{d}x_{\mathrm{a}}^{\nu} = t_{\mathrm{a}}^{\mu} x_{\mathrm{a}}^{\nu}$$

So it's a four-dimensional contravariant vector.

The four-dimensional contravariant tensor of each rank can be defined similarly.

A physical quantity consisting of four components V_u , whose components satisfy the same transformation relations as the inverse transformation relations (6.4)—(6.5) under the GGT (6.2), namely

$$V_{\mu} = \frac{\partial x_{\mathrm{a}}^{\nu}}{\partial x^{\mu}} V_{\mathrm{a}\nu} = t_{\mu}^{\nu} V_{\mathrm{a}\nu}$$

Then it is called a four-dimensional covariant tensor of first rank (i.e., a four-dimensional covariant vector).

In the above description, by convention, the indices of a contravariant tensor are marked with a superscript, and the indices of a covariant tensor are marked with a subscript for notational distinction.

One can similarly define four-dimensional covariant tensors of all rank, and mixed tensors with both contravariant and covariant indices. No further description will be given here. For a detailed and comprehensive treatment of the basic theory of tensors, the reader is referred to the relevant specialized books (e. g. Ref. [1]).

Finally I want to make a note. In the special theory of relativity, the four-dimensional contravariant tensor and four-dimensional covariant tensor under the LT can be similarly defined, but the LT is a representation of an orthogonal linear transformation satisfying the principle of one-way invariance of the speed of light

$$x'^2 + '^2 + z'^2 - c^2 t'^2 = x^2 + y^2 + z^2 - c^2 t^2 \quad \text{or} \quad x'_u x'_u = x_v x_v$$

The matrix of the transformation satisfies the condition (6.14), that is, the inverse transform matrix A^{-1} is equal to the transpose matrix $\tilde{A}$ of A . In this case, the difference between the contravariant tensor and the covariant tensor vanishes. In this case, the difference between the contravariant tensor and covariant tensor vanishes. Therefore, in the special theory of relativity, there is no need to consider the distinction between contravariant and covariant indices. However, in Standard Space-time Theory, the principle of one-way invariance of the speed of light is no longer valid. As mentioned above, the GGT can be regarded as a non-orthogonal linear transformation from an orthonormal frame to an oblique frame in four-dimensional pseudo-Euclidean space. From Eqs. (6.3) and (6.5), we see that, therefore, we must pay attention to distinguish between four-dimensional contravariant tensors and four-dimensional covariant tensors.

Now we can make classification of physical quantities according to their nature under the generalized Galilean transformation (GGT) in a four-dimensional pseudo-Euclidean space. The physical quantities which do not vary under the generalized Galilean transformation

(GGT) such as the interval ds^2 between two events, the time-like interval $d\tau_1$ and the space-like interval $d\tau_2$ (to deal with subluminal and superluminal motions unitedly, sometimes we do not distinguish $d\tau_1$ and $d\tau_2$ but denote them as $d\tau$) are called "scalars" or "invariant". Now we study the expressions for two four-dimensional contravariant tensors of the first rank, i. e. the four-dimensional velocity and four-dimensional momentum.

Note that the displacement vector dx^μ is a four-dimensional vector, while the time-like interval or space-like interval $d\tau$ is an invariant, so

$$U^\mu = \frac{dx^\mu}{d\tau}, \quad \text{or} \quad U = \left(\frac{dx^1}{d\tau}, \frac{dx^2}{d\tau}, \frac{dx^3}{d\tau}, \frac{dx^4}{d\tau}\right) \tag{6.13}$$

is a four-dimensional contravariant vector and we call it a "four-dimensional velocity vector". For the subluminal or superluminal motion, from Eq. (6.13) we separately get

$$\boldsymbol{U} = k(u_x, u_v, u_z, c), \tag{6.14}$$

where u_x, u_v, u_z represent the velocity components of three-dimensional (subluminal motion or superluminal motion) velocity; $k = dt/d\tau$ can be obtained from Eqs. (5. 41) and (5.43), and the result is also shown in Eq. (5.17). Starting from Eq. (5.14) and using the velocity transformations (5.3) and Eq. (5.15), we can show that each component of four-dimensional velocity vector transforms according to the law of coordinates transformation; i.e.

$$U^1 = \gamma(U^1_{\mathrm{a}} - \beta U^4_{\mathrm{a}}),\ U^2 = U^2_{\mathrm{a}},\ U^3 = U^3_{\mathrm{a}},\ U^4 = \gamma^{-1} U^4_{\mathrm{a}}. \tag{6.15}$$

Multiplying the four-dimensional velocity vector by invariant m_o, we get the four-dimensional momentum

$$P^\mu = m_0 U^\mu = m_0 (dx^\mu / d\tau), \tag{6.16}$$

$$\boldsymbol{P} = m_0 \boldsymbol{U} = (p_x, p_y, p_z, mc) = (\boldsymbol{p}, mc), \tag{6.17}$$

where $\boldsymbol{p} = m\boldsymbol{u}, p_x = mv_x$, etc. represent the three-dimensional momentum and its components. The above two equations hold true for subluminal particles or superluminal material system, only m and $\boldsymbol{p}$ should take corresponding expressions.

Using the Eqs. (5.67) and (5.75) and letting $\alpha = |1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2|$, and substituting it into Eq. (6.17) we get

$$\boldsymbol{P} = (p_x, p_y, p_z, E/\alpha c) = (\boldsymbol{p}, E/\alpha c), \tag{6.18}$$

$$P^4 = mc = E/(\alpha c). \tag{6.19}$$

The transformation of the components of the four-dimensional momentum is

$$p_x = \gamma(p_{\mathrm{a}x} - \beta E_{\mathrm{a}}/c),\ p_y = p_{\mathrm{a}y},\ p_z = p_{\mathrm{a}z},\ E/(\alpha c) = \gamma^{-1} E_{\mathrm{a}}/c, \tag{6.20}$$

These are the momentum transformations (80) and (81) and energy transformation (5.82).

From Eq. (6.17) we know that $d\boldsymbol{P} = (d\boldsymbol{p}, d(E/\alpha c))$ is a four-dimensional contravariant vector. Dividing it by invariant $d\tau$, we get the four-dimensional force vector

$$K^\mu = dP^\mu / d\tau, \tag{6.21}$$

or
$$\boldsymbol{K}=\left(\frac{\mathrm{d}p_x}{\mathrm{d}\tau},\frac{\mathrm{d}p_y}{\mathrm{d}\tau},\frac{\mathrm{d}p_z}{\mathrm{d}\tau},\frac{\mathrm{d}}{\mathrm{d}\tau}\frac{E}{\alpha c}\right)=\left(\frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}\tau},\frac{\mathrm{d}}{\mathrm{d}\tau}\frac{E}{\alpha c}\right). \tag{6.22}$$

This is the basic dynamical equation of Standard Space-time Theory in the four-dimensional form.

Let us discuss first the three components of the four-dimensional force. For subluminal particles and superluminal system, when $\mu=1,2,3$ (correspond to $v=x,y,z$), using Eqs. (5.41) and (5.43) and three-dimensional dynamical equation (5.57), we get

$$K^{\mu}=\frac{\mathrm{d}p^{\mu}}{\mathrm{d}\tau}=\frac{\mathrm{d}p^{\mu}}{\mathrm{d}t}\frac{\mathrm{d}t}{\mathrm{d}\tau}=\begin{cases}k_1F_{\mu}, & \text{for subluminal particle;}\\ k_2F_{\mu}, & \text{for superluminal system,}\end{cases} \tag{6.23}$$

where k_1 and k_2 are shown in Eq. (5.17). Hence, the first three components of the dynamical equation in four-dimensional form can be written as

$$\boldsymbol{K}=\frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}\tau},\qquad \text{or}\qquad \boldsymbol{f}=\frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t}. \tag{6.24}$$

This is the three-dimensional dynamical equation of Standard Space-time Theory derived in Chap. 5.

The fourth component of the four-dimensional force vector ***K*** is

$$K^4=\frac{\mathrm{d}}{\mathrm{d}\tau}\left(\frac{E}{\alpha c}\right)=\frac{1}{c}\frac{\mathrm{d}}{\mathrm{d}\tau}\left(\frac{E}{\alpha}\right). \tag{6.25}$$

For frame Σ_{a}, $\alpha=1$, we have

$$K_{\mathrm{a}}^4=\frac{1}{c}\frac{\mathrm{d}E_{\mathrm{a}}}{\mathrm{d}\tau}. \tag{6.26}$$

Using the energy transformation (5.82) it is easy to get

$$\frac{\mathrm{d}}{\mathrm{d}\tau}\left(\frac{E}{\alpha}\right)=\gamma^{-1}\frac{\mathrm{d}E_{\mathrm{a}}}{\mathrm{d}\tau}. \tag{6.27}$$

Then using formulas (5.15) and (5.85), the above equation (6.27) gives

$$\frac{\mathrm{d}}{\mathrm{d}\tau}\left(\frac{E}{\alpha}\right)=\frac{\mathrm{d}E_{\mathrm{a}}}{\mathrm{d}t_{\mathrm{a}}}=\boldsymbol{f}_{\mathrm{a}}\cdot\boldsymbol{u}_{\mathrm{a}}. \tag{6.28}$$

Using Eq. (6.25) above for force, and transformation (5.86), and (5.15), we can show that each component of the four-dimensional force vector transforms according to the law of the coordinate transformation; i.e.

$$K^1=\gamma(K_{\mathrm{a}}^1-\beta K_{\mathrm{a}}^4),\ K^2=K_{\mathrm{a}}^2,\ K^3=K_{\mathrm{a}}^3,\ K^4=\gamma^{-1}K_{\mathrm{a}}^4. \tag{6.29}$$

So, we have proved that the both sides of the dynamical equation in four-dimensional form belong to the same kind of tensor (contravariant tensor of the first rank). They transform according to the same law (i.e., the law of the coordinate transformation) when the reference frame transforms. Hence the form of the equations keeps invariant. So, the four-dimensional form of Standard Space-time Theory satisfies the requirement of covariance of equations.

6. 3. GGT under Inertial Coordinate Systems in General Configuration

According to the present physical experiment, we do not yet have precise understanding for the characteristic velocity of an ordinary inertial frame Σ (for example, Solar or Earth frame) or its velocity with respect to the standard frame Σ_a. Hence, it is necessary for us to study the formulas of Standard Space-time Theory in the general case in which coordinate axes (such as *x*-axis) do not coincide with the characteristic velocity $\boldsymbol{v}$.

Suppose the coordinate system of Σ_a and Σ are as shown in Fig. 6.1. Each coordinate axis of the two frames still keeps parallel but $\boldsymbol{v}$ is not in the directions of *x*-, *y*-, or *z*-axis. The angles between $\boldsymbol{v}$ and *x*-, *y*-, *z*-axes are represented respectively by α, β, γ. Such a coordinate system is called the general coordinate system of frames Σ_a and Σ.

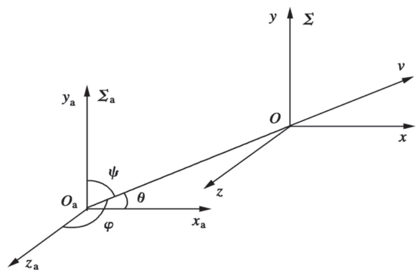

Fig. 6.1

There are many methods to deduce the space-time coordinates transformation for the general coordinate system. We can consider still from two basic postulates in Chapter 4, but such approach is quite overlabored. We can regard the general coordinates system of Σ_a and Σ as obtained by the coordinate rotation transformation of the original coordinates system of Σ_a and Σ. In GGT, Eq. (4.35), replacing the coordinate variables of the original system by the coordinates of the rotational transformations of coordinates and solving the linear equations thereby obtained, we get the required coordinate transformations. However, the following method is the simplest one.

Assume $\boldsymbol{r}_a$ represent the position vector from the origin of Σ_a to the event occurred at time t_a and position (x_a, y_a, z_a), $\boldsymbol{r}$ represent the position vector from the origin of Σ to the same event occurred at time t and position (x, y, z). Resolve $\boldsymbol{r}_a$ and $\boldsymbol{r}$ into components parallel to $\boldsymbol{v}$ and those perpendicular to $\boldsymbol{v}$; i.e.

$$\boldsymbol{r}_{\mathrm{a}}=\boldsymbol{r}_{\mathrm{a}\|}+\boldsymbol{r}_{\mathrm{a}\perp}, \qquad \boldsymbol{r}=\boldsymbol{r}_{\|}+\boldsymbol{r}_{\perp}. \tag{6.30}$$

From Eq. (4.35), we get

$$\boldsymbol{r}_{\|}=\gamma(\boldsymbol{r}_{\mathrm{a}\|}-\boldsymbol{v}t_{\mathrm{a}}), \quad \boldsymbol{r}_{\perp}=\boldsymbol{r}_{\mathrm{a}\perp}, \quad t=\gamma^{-1}t_{\mathrm{a}}, \tag{6.31}$$

or

$$\boldsymbol{r}=\boldsymbol{r}_{\mathrm{a}}+[(\gamma-1)(\boldsymbol{r}_{\mathrm{a}}\cdot\boldsymbol{v})/v^2-\gamma t_{\mathrm{a}}]\boldsymbol{v}, \quad t=\gamma^{-1}t_{\mathrm{a}}. \tag{6.32}$$

Writing the first formula of Eqs. (6.32) in the form of coordinate components, we have

$$\left.\begin{aligned} x&=x_{\mathrm{a}}+[(\gamma-1)(x_{\mathrm{a}}v_x+y_{\mathrm{a}}v_y+z_{\mathrm{a}}v_z)/v^2-\gamma t_{\mathrm{a}}]v_x,\\ y&=y_{\mathrm{a}}+[(\gamma-1)(x_{\mathrm{a}}v_x+y_{\mathrm{a}}v_y+z_{\mathrm{a}}v_z)/v^2-\gamma t_{\mathrm{a}}]v_y,\\ z&=z_{\mathrm{a}}+[(\gamma-1)(x_{\mathrm{a}}v_x+y_{\mathrm{a}}v_y+z_{\mathrm{a}}v_z)/v^2-\gamma t_{\mathrm{a}}]v_z. \end{aligned}\right\} \tag{6.33}$$

If let

$$\hat{T}=I+[(\gamma-1)/v^2]\,\boldsymbol{v}\boldsymbol{v}\bullet=I+(\gamma-1)\,\boldsymbol{v}_0\boldsymbol{v}_0\bullet \tag{6.34}$$

where $\boldsymbol{v}_0$ represents the unit vector in the direction of the characteristic velocity $\boldsymbol{v}$, I represents the unit transformation, then Eq. (6.32) can be written as succinct form:

$$\boldsymbol{r}=\hat{T}(\boldsymbol{r}_{\mathrm{a}}-\boldsymbol{v}t_{\mathrm{a}}), \quad t=\gamma^{-1}t_{\mathrm{a}}. \tag{6.35}$$

Equations (6.31)—(6.33) and (6.35) are GGT in the general coordinate system.

Similarly, we can get the inverse GGT for the general coordinate system from the inverse GGT (4.36):

$$\boldsymbol{r}_{\mathrm{a}\|}=\gamma^{-1}\boldsymbol{r}_{\|}+\gamma\boldsymbol{v}t, \quad \boldsymbol{r}_{\mathrm{a}\perp}=\boldsymbol{r}_{\perp}, \quad t_{\mathrm{a}}=\gamma t, \tag{6.36}$$

or

$$\boldsymbol{r}_{\mathrm{a}}=\boldsymbol{r}+[(\gamma^{-1}-1)(\boldsymbol{r}\cdot\boldsymbol{v})/v^2+\gamma t]\boldsymbol{v}, \quad t_{\mathrm{a}}=\gamma t. \tag{6.37}$$

Writing the first formula of Eqs. (6.37) in the form of coordinate components, we have

$$\begin{aligned} x_{\mathrm{a}}&=x+[(\gamma^{-1}-1)(xv_x+yv_z+zv_z)/v^2+\gamma t]v_x,\\ y_{\mathrm{a}}&=y+[(\gamma^{-1}-1)(xv_x+yv_y+zv_z)/v^2+\gamma t]v_y,\\ z_{\mathrm{a}}&=z+[(\gamma^{-1}-1)(xv_x+yv_y+zv_z)/v^2+\gamma t]v_z. \end{aligned} \tag{6.38}$$

If let

$$\hat{T}^{-1}=I+[(\gamma^{-1}-1)/v^2]\,\boldsymbol{v}\boldsymbol{v}\bullet=I+(\gamma^{-1}-1)\boldsymbol{v}_0\boldsymbol{v}_0\bullet \tag{6.39}$$

Equation (6.37) can be written as succinct form:

$$\boldsymbol{r}_{\mathrm{a}}=\hat{T}^{-1}\boldsymbol{r}+\gamma t\boldsymbol{v}, \quad t_{\mathrm{a}}=\gamma t. \tag{6.40}$$

Equations (6.36), (6.37), (6.38) and (6.40) are the inverse GGT under the general coordinate system.

All the above equations return to original ones under the simple case in which x-axis coincides with $\boldsymbol{v}$.

It is easy to prove that the following equation holds true

$$\hat{T}^{-1}\hat{T}=\hat{T}\hat{T}^{-1}=I. \tag{6.41}$$

6.4. Formulas of Standard Space-time Theory under Inertial Coordinate Systems in General Configuration

From the transformations and their inverse ones in the above section we can get velocity transformations. From the definition of the velocity and the GGT (6.32), we have

$$\boldsymbol{u}=\frac{\mathrm{d}\boldsymbol{r}}{\mathrm{d}t}=\frac{\mathrm{d}\boldsymbol{r}}{\mathrm{d}t_{\mathrm{a}}}\frac{\mathrm{d}t_{\mathrm{a}}}{\mathrm{d}t}=\gamma\left[I+(\gamma-1)\boldsymbol{v}_0\boldsymbol{v}_0\bullet\right]\left(\frac{\mathrm{d}\boldsymbol{r}_{\mathrm{a}}}{\mathrm{d}t_{\mathrm{a}}}-\boldsymbol{v}\right) \tag{6.42}$$

and

$$\boldsymbol{u}=\gamma\hat{T}(\boldsymbol{u}_{\mathrm{a}}-\boldsymbol{v})=\gamma\left\{\boldsymbol{u}_{\mathrm{a}}+[(\gamma-1)(\boldsymbol{u}_{\mathrm{a}}\cdot\boldsymbol{v})/v^2-\gamma]\boldsymbol{v}\right\}. \tag{6.43}$$

This velocity transformation can be written as the form of coordinate components:

$$\begin{aligned}u_x&=\gamma u_{\mathrm{a}x}+[(\gamma^2-\gamma)(\boldsymbol{u}_{\mathrm{a}}\cdot\boldsymbol{v})/v^2-\gamma^2]v_x,\\ u_y&=\gamma u_{\mathrm{a}y}+[(\gamma^2-\gamma)(\boldsymbol{u}_{\mathrm{a}}\cdot\boldsymbol{v})/v^2-\gamma^2]v_y,\\ u_z&=\gamma u_{\mathrm{a}z}+[(\gamma^2-\gamma)(\boldsymbol{u}_{\mathrm{a}}\cdot\boldsymbol{v})/v^2-\gamma^2]v_z.\end{aligned} \tag{6.44}$$

Letting $\boldsymbol{u}_{\mathrm{a}}=0$, from the above equations it can be proved that Eq. (5.18) holds true also under the general coordinate system, i.e.

$$\boldsymbol{v}_{\mathrm{a}}=-\gamma^2\boldsymbol{v}=-\boldsymbol{v}/(1-\beta^2). \tag{6.45}$$

From the definition of the velocity and the inverse GGT (6.37), we have

$$\boldsymbol{u}_{\mathrm{a}}=\frac{\mathrm{d}\boldsymbol{r}_{\mathrm{a}}}{\mathrm{d}t_{\mathrm{a}}}=\frac{\mathrm{d}\boldsymbol{r}_{\mathrm{a}}}{\mathrm{d}t}\frac{\mathrm{d}t}{\mathrm{d}t_{\mathrm{a}}}=\gamma^{-1}\left[I+(\gamma^{-1}-1)\boldsymbol{v}_0\boldsymbol{v}_0\bullet\right]\frac{\mathrm{d}\boldsymbol{r}}{\mathrm{d}t}+\boldsymbol{v}$$

and get

$$\boldsymbol{u}_{\mathrm{a}}=\gamma^{-1}\hat{T}^{-1}\boldsymbol{u}+\boldsymbol{v}=\gamma^{-1}\left\{\boldsymbol{u}+[(\gamma^{-1}-1)(\boldsymbol{u}\cdot\boldsymbol{v})/v^2]\boldsymbol{v}\right\}+\boldsymbol{v}. \tag{6.46}$$

Besides, we can still get

$$\left.\begin{aligned}u^2&=\gamma^4(u_{\mathrm{a}}\cos\theta-v)^2+\gamma^2u_{\mathrm{a}}^2(1-\cos^2\theta),\\ u_{\mathrm{a}}^2&=(\gamma^{-2}u\cos\theta+v)^2+\gamma^{-2}u^2(1-\cos^2\theta).\end{aligned}\right\} \tag{6.47}$$

Starting from the definition of the acceleration

$$\boldsymbol{a}=\frac{\mathrm{d}\boldsymbol{u}}{\mathrm{d}t},\qquad \boldsymbol{a}_{\mathrm{a}}=\frac{\mathrm{d}\boldsymbol{u}_{\mathrm{a}}}{\mathrm{d}t_{\mathrm{a}}}$$

and using the velocity transformation (6.42) and $\mathrm{d}t=\gamma^{-1}\mathrm{d}t_{\mathrm{a}}$, we obtain the acceleration transformation

$$\boldsymbol{a} = \gamma^2 \hat{T} \boldsymbol{a}_{\text{a}}, \quad \boldsymbol{a}_{\text{a}} = \gamma^{-2} \hat{T}^{-1} \boldsymbol{a} \tag{6.48}$$

Besides, we can show that Eq. (5.15) also holds true in the general coordinate system, i.e.

$$\left.\begin{aligned} &\frac{\sqrt{1-u_{\text{a}}^2/c^2}}{\sqrt{1-v^2/c^2}} = \sqrt{(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - u^2/c^2}, && \text{for subluminal particle;} \\ &\frac{\sqrt{u_{\text{a}}^2/c^2-1}}{\sqrt{1-v^2/c^2}} = \sqrt{u^2/c^2-(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2}, && \text{for superluminal system.} \end{aligned}\right\} \tag{6.49}$$

and we can show that also holds true in the general coordinate system

$$1-\frac{\boldsymbol{u}\cdot\boldsymbol{v}}{c^2} = \frac{1-\boldsymbol{u}_{\text{a}}\cdot\boldsymbol{v}/c^2}{1-\beta^2}. \tag{6.50}$$

From the mass transformation (5.79) and the velocity transformation (6.42) we can get the energy transformation and the momentum transformation

$$E = \gamma\left|E_{\text{a}} - \boldsymbol{p}_{\text{a}}\cdot\boldsymbol{v}\right|, \tag{6.51}$$

$$\boldsymbol{p} = m\boldsymbol{u} = \hat{T}(\boldsymbol{p}_{\text{a}} - m_{\text{a}}\boldsymbol{v}) = \hat{T}(\boldsymbol{p}_{\text{a}} - \boldsymbol{v}E_{\text{a}}/c^2). \tag{6.52}$$

Eq. (6.52) is written in greater detail as

$$\boldsymbol{p} = \boldsymbol{p}_{\text{a}} + [(\gamma-1)/v^2](\boldsymbol{p}_{\text{a}}\cdot\boldsymbol{v})\boldsymbol{v} - \gamma(E_{\text{a}}/c^2)\boldsymbol{v}. \tag{6.53}$$

Finally, from the transformations of the space-time coordinates (6.33) and (6.38) we can obtain the transformations between the operators ∇_{a} and ∇ , the operators $\partial/\partial t_{\text{a}}$ and $\partial/\partial t$. In practice,

$$\begin{aligned} \nabla = \boldsymbol{i}\frac{\partial}{\partial x} + \boldsymbol{j}\frac{\partial}{\partial y} + \boldsymbol{k}\frac{\partial}{\partial z} &= \boldsymbol{i}\left(\frac{\partial}{\partial x_{\text{a}}}\frac{\partial x_{\text{a}}}{\partial x} + \frac{\partial}{\partial y_{\text{a}}}\frac{\partial y_{\text{a}}}{\partial x} + \frac{\partial}{\partial z_{\text{a}}}\frac{\partial z_{\text{a}}}{\partial x}\right) \\ &+ \boldsymbol{j}\left(\frac{\partial}{\partial x_{\text{a}}}\frac{\partial x_{\text{a}}}{\partial y} + \frac{\partial}{\partial y_{\text{a}}}\frac{\partial y_{\text{a}}}{\partial y} + \frac{\partial}{\partial z_{\text{a}}}\frac{\partial z_{\text{a}}}{\partial y}\right) + \boldsymbol{k}\left(\frac{\partial}{\partial x_{\text{a}}}\frac{\partial x_{\text{a}}}{\partial z} + \frac{\partial}{\partial y_{\text{a}}}\frac{\partial y_{\text{a}}}{\partial z} + \frac{\partial}{\partial z_{\text{a}}}\frac{\partial z_{\text{a}}}{\partial z}\right). \end{aligned} \tag{6.54}$$

Substituting Eq. (6.38) into Eq. (6.54) and operating we have

$$\nabla = \left[I + (\gamma^{-1}-1)\boldsymbol{v}_0\,\boldsymbol{v}_0\,\bullet\right]\left(\boldsymbol{i}\frac{\partial}{\partial x_{\text{a}}} + \boldsymbol{j}\frac{\partial}{\partial y_{\text{a}}} + \boldsymbol{k}\frac{\partial}{\partial z_{\text{a}}}\right), \text{ or } \nabla = \hat{T}^{-1}\nabla_{\text{a}}. \tag{6.55}$$

By the same reasoning, from Eq. (6.33) we obtain

$$\nabla_{\text{a}} = \boldsymbol{i}\frac{\partial}{\partial x_{\text{a}}} + \boldsymbol{j}\frac{\partial}{\partial y_{\text{a}}} + \boldsymbol{k}\frac{\partial}{\partial z_{\text{a}}} = \left[I + (\gamma-1)\boldsymbol{v}_0\,\boldsymbol{v}_0\,\bullet\right]\left(\boldsymbol{i}\frac{\partial}{\partial x} + \boldsymbol{j}\frac{\partial}{\partial y} + \boldsymbol{k}\frac{\partial}{\partial z}\right),$$

or

$$\nabla_{\text{a}} = \hat{T}\nabla. \tag{6.56}$$

Similarly, from Eqs. (6.33) and (6.38) we obtain

$$\frac{\partial}{\partial t} = \frac{\partial}{\partial t_{\text{a}}}\frac{\partial t_{\text{a}}}{\partial t} + \frac{\partial}{\partial x_{\text{a}}}\frac{\partial x_{\text{a}}}{\partial t} + \frac{\partial}{\partial y_{\text{a}}}\frac{\partial y_{\text{a}}}{\partial t} + \frac{\partial}{\partial z_{\text{a}}}\frac{\partial z_{\text{a}}}{\partial t} = \gamma\left(\frac{\partial}{\partial t_{\text{a}}} + v_x\frac{\partial}{\partial x_{\text{a}}} + v_y\frac{\partial}{\partial y_{\text{a}}} + v_z\frac{\partial}{\partial z_{\text{a}}}\right)$$

And therefore, we have

$$\frac{\partial}{\partial t}=\gamma\left(\frac{\partial}{\partial t_{\mathrm{a}}}+\boldsymbol{v}\cdot\nabla_{\mathrm{a}}\right). \tag{6.57}$$

By the same reasoning, we have

$$\frac{\partial}{\partial t_{\mathrm{a}}}=\gamma^{-1}\frac{\partial}{\partial t}-\gamma\,\boldsymbol{v}\cdot\nabla. \tag{6.58}$$

Now we particularly discuss intervals between events in the general coordinate system and the expression of the speed of light.

According to the above, the interval expression (5.38) between two events in the general coordinate system should be written as

$$\mathrm{d}s^2=(\mathrm{d}x^2+\mathrm{d}y^2+\mathrm{d}z^2)-(c\mathrm{d}t-\beta_x\mathrm{d}x-\beta_y\mathrm{d}y-\beta_z\mathrm{d}z)^2, \tag{6.59}$$

where

$$\beta_x=v_x/c,\beta_y=v_y/c,\beta_z=v_z/c. \tag{6.60}$$

To frame Σ_{a} they are taken to be zero. Eq. (5.58) is the general expression of interval between events in the general coordinate system.

According to Eq. (5.37), the invariant $\mathrm{d}s^2$ in any inertial frame derived from the postulate of the constancy of circulation average speed of light can be written as

$$\mathrm{d}s^2=(\mathrm{d}x^2+\mathrm{d}y^2+\mathrm{d}z^2)-(c\mathrm{d}t+X\mathrm{d}x+Y\mathrm{d}y+Z\mathrm{d}z)^2. \tag{6.61}$$

Comparing Eqs. (6.59) and (6.61) we can get that to the general coordinate system, we should take the velocity variables as

$$X=-\beta_x,\ \ Y=-\beta_y,\ \ Z=-\beta_z. \tag{6.62}$$

Such notation is suitable to any inertial frame Σ_i, but to frame Σ_{a} we should take $v=0$, $\beta_x=\beta_y=\beta_z=0$.

From Eq. (4.8) we get the speed of light along the coordinate axes direction and an arbitrary direction in any inertial frame Σ_i

$$c_{\pm x}=c/(1\pm\beta_x),\ \ c_{\pm y}=c/(1\pm\beta_y),\ \ c_{\pm z}=c/(1\pm\beta_z), \tag{6.63}$$

$$c(\alpha,\beta,\gamma)=\frac{c}{1+(\beta_x\cos\alpha+\beta_y\cos\beta+\beta_z\cos\gamma)}=\frac{c}{1+\boldsymbol{n}\cdot\boldsymbol{v}/c}. \tag{6.64}$$

where $\boldsymbol{n}$ represents the unit vector along the direction of the propagation of light. The same, to frame Σ_{a}, we should take $v=0$, $\beta_x=\beta_v=\beta_z=0$.

The discussion of the four-dimensional form of Standard Space-time Theory in the general coordinate system has also been made. Considering that such discussion is more complex only in computation and results, but does not contain new physical thoughts, we neglect them here.

6. 5. Coordinate Transformation between Two General Inertial Frames

Every general inertial frame moves relative to the absolute inertial reference frame Σ_a, at a defined characteristic speed. For any two general inertial frames Σ_1 and Σ_2, their characteristic velocities $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$ may be parallel to each other, or more likely (or in more cases) not.

6. 5. 1. Simple cases: $\boldsymbol{v}_1 \parallel \boldsymbol{v}_2$

Start with the simple case: $\boldsymbol{v}_1 \parallel \boldsymbol{v}_2$. In this case, the coordinate systems with cial configuration can be established for the frames Σ_a and Σ_1, and the frames Σ_a and Σ_2, respectively, so that two general inertial coordinate systems with special configuration can also be formed for the frames Σ_1 and Σ_2, where the frames Σ_1 and Σ_2 move in the positive direction of the x_a axis of the frame Σ_a at the speed $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$, respectively, and the directions of the coordinate axes of the three inertial coordinate systems are parallel to each other. The time when the coordinate origins of the three inertial coordinate systems coincide is taken as the zero point of the three frames timing. When $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$ are in the same direction, the $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$ are taken along the positive direction of the x_a axis of the frame Σ_a ($\boldsymbol{v}_1$ and $\boldsymbol{v}_2$ both are positive); when $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$ are in the opposite direction, the $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$ are taken along the positive and negative directions of the axis of the frame Σ_a, respectively (in $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$, one is positive and the other is negative). This is shown in Fig. 6.2. In this case, the generalized Galilean transformation (4.37) holds between the space-time coordinates of the frames Σ_a and Σ_1, and between the space-time coordinates of the frames Σ_a and Σ_2.

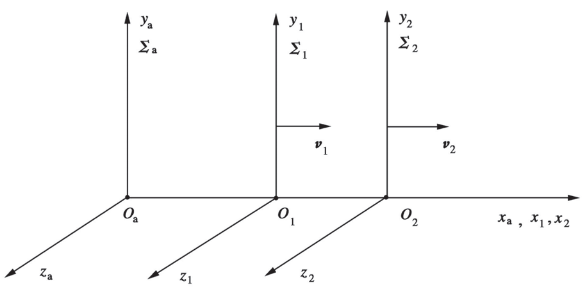

Fig. 6.2

The space-time coordinate transformation between two general inertial frames and can be obtained from the generalized Galilean transformation (4.37).

$$\begin{aligned} x_2 &= (\gamma_2 / \gamma_1)x_1 - (v_2 - v_1)\gamma_1\gamma_2 t_1, \\ y_2 &= y_1, z_2 = z_1, \quad t_2 = (\gamma_1 / \gamma_2)t_1. \end{aligned} \tag{6.65}$$

Or write the above formula as

$$x_2 = \sqrt{\frac{1-\beta_1^2}{1-\beta_2^2}}\left(x_1 - \frac{v_2 - v_1}{1-\beta_1^2}t_1\right), \; y_2 = y_1, \quad z_2 = z_1, \; t_2 = \sqrt{\frac{1-\beta_2^2}{1-\beta_1^2}}t_1. \tag{6.66}$$

where

$$\gamma_1 = \frac{1}{\sqrt{1-\beta_1^2}}, \; \beta_1 = \frac{v_1}{c}; \; \gamma_2 = \frac{1}{\sqrt{1-\beta_2^2}}, \; \beta_2 = \frac{v_2}{c}. \tag{6.67}$$

The coordinate transformation (6.65) or (6.66) can be further simplified. From the velocity transformation equation (5.6), the velocity v_{21} of the frame Σ_2 observed by the frame Σ_1 (that is, the velocity of the frame Σ_2 relative to the frame Σ_1) and the velocity v_{12} of the frame Σ_1 observed by the frame Σ_2 (that is, the velocity of the frame Σ_1 relative to the frame Σ_2) can be easily obtained

$$v_{21} = \frac{v_2 - v_1}{1-\beta_1^2}, \quad v_{12} = \frac{v_1 - v_2}{1-\beta_2^2} \tag{6.68}$$

And we have

$$v_{21} = -v_{12}\frac{1-\beta_2^2}{1-\beta_1^2} = -v_{12}\left(\frac{\gamma_1}{\gamma_2}\right)^2 \tag{6.69}$$

or

$$\frac{1-\beta_1^2}{1-\beta_2^2} = -\frac{v_{21}}{v_{12}}. \tag{6.70}$$

Using the above formula, the coordinate transformation between two general inertial frames Σ_1 and Σ_2 can be written as

$$x_2 = \sqrt{\frac{1-\beta_1^2}{1-\beta_2^2}}(x_1 - v_{21}t_1), \; y_2 = y_1, \; z_2 = z_1, \; t_2 = \sqrt{\frac{1-\beta_2^2}{1-\beta_1^2}}t_1. \tag{6.71}$$

Put

$$\gamma_{21} = \gamma_2/\gamma_1 = \sqrt{\frac{1-\beta_1^2}{1-\beta_2^2}}, \quad \gamma_{12} = \gamma_1/\gamma_2 = \sqrt{\frac{1-\beta_2^2}{1-\beta_1^2}} = \gamma_{21}^{-1}. \tag{6.72}$$

Then we have

$$\left.\begin{aligned} x_2 &= \gamma_{21}(x_1 - v_{21}t_1), \quad y_2 = y_1, \quad z_2 = z_1, \quad t_2 = \gamma_{21}^{-1}t_1 \\ x_1 &= \gamma_{12}(x_2 - v_{12}t_2), \quad y_1 = y_2, \quad z_1 = z_2, \quad t_1 = \gamma_{12}^{-1}t_2 \end{aligned}\right\} \tag{6. 73}$$

This is the space-time coordinate transformation between two general inertial frames Σ_1 and Σ_2 under the special configuration.

6. 5. 2. General cases: $\boldsymbol{v}_1$ not parallel to $\boldsymbol{v}_2$

In the general case where the characteristic velocities $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$ are not parallel to each other, only the coordinate systems of general configuration can be established for the frames Σ_a and Σ_1, or the frames Σ_a and Σ_2. In order to make a general adaptive treatment, the coordinate systems of general configuration are established for both the frames Σ_a and Σ_1, as well as for the frames Σ_a and Σ_2. The coordinate systems thus established (generally) also constitute two coordinate systems in general configuration for the frames Σ_1 and Σ_2. The origin O_1 of the first frame Σ_1 and the origin O_2 of the second frames Σ_2 are selected to be located at the coincidence with the origin O_a of the frames Σ_a at a certain time, and the time when the three origins coincide is taken as the zero point of the three-system timing. This is shown in Fig. 6.3.

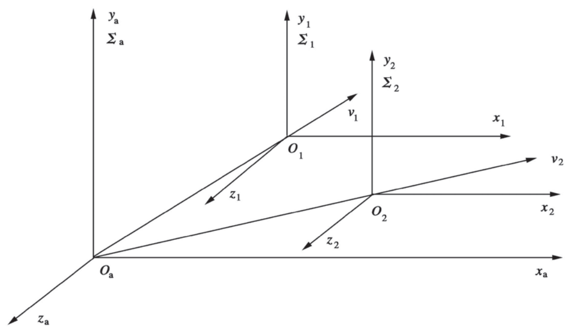

Fig. 6.3

According to the space-time coordinates transformation formula (6.43) between the frame Σ_a and the frame Σ in the coordinate system with general configuration, there are

$$\left.\begin{aligned} \boldsymbol{r}_1 &= \hat{T}_1(\boldsymbol{r}_a - \boldsymbol{v}_1 t_a), \quad t_1 = \gamma_1^{-1} t_a \\ \boldsymbol{r}_2 &= \hat{T}_2(\boldsymbol{r}_a - \boldsymbol{v}_2 t_a), \quad t_2 = \gamma_2^{-1} t_a \end{aligned}\right\} \tag{6. 74}$$

$$\left.\begin{aligned} \boldsymbol{r}_a &= \hat{T}_1^{-1}\boldsymbol{r}_1 + \gamma_1 t_1 \boldsymbol{v}_1, \quad t_a = \gamma_1 t_1 \\ \boldsymbol{r}_a &= \hat{T}_2^{-1}\boldsymbol{r}_2 + \gamma_2 t_2 \boldsymbol{v}_2, \quad t_a = \gamma_2 t_2 \end{aligned}\right\} \tag{6. 75}$$

where

$$\gamma_1 = \frac{1}{\sqrt{1-\beta_1^2}}, \beta_1 = \frac{v_1}{c}; \quad \gamma_2 = \frac{1}{\sqrt{1-\beta_2^2}}, \beta_2 = \frac{v_2}{c}. \tag{6.76}$$

From the second expression of each row of formula (6.75), we obtain the transformation with respect to the time of the two frames

$$\gamma_2 t_2 = \gamma_1 t_1 \text{ , or } t_2 = (\gamma_1/\gamma_2) t_1 = \gamma_{21}^{-1} t_1 \text{ ,} \tag{6.77}$$

where

$$\gamma_{21} = \gamma_2/\gamma_1 = \sqrt{\frac{1-\beta_1^2}{1-\beta_2^2}} \text{ .} \tag{6.78}$$

From the first expression of each row of Eqs. (6.75) and using Eq. (6.77), we obtain

$$\hat{T}_2^{-1}\boldsymbol{r}_2 + \gamma_2 t_2 \boldsymbol{v}_2 = \hat{T}_1^{-1}\boldsymbol{r}_1 + \gamma_1 t_1 \boldsymbol{v}_1, \quad \hat{T}_2^{-1}\boldsymbol{r}_2 - \hat{T}_1^{-1}\boldsymbol{r}_1 + \gamma_1 t_1 (\boldsymbol{v}_2 - \boldsymbol{v}_1) = 0 \text{ .} \tag{6.79}$$

For the operators acting on both sides of the above equation, using Eq. (6.41), the transformation of the position vector from the frame Σ_1 to frame Σ_2 to is obtained, which is written together with the time transformation as follows:

$$\left.\begin{aligned} \boldsymbol{r}_2 &= \hat{T}_2 \hat{T}_1^{-1}\boldsymbol{r}_1 - \gamma_1 \hat{T}_2 (\boldsymbol{v}_2 - \boldsymbol{v}_1) t_1, \\ t_2 &= (\gamma_1/\gamma_2) t_1 = \gamma_{21}^{-1} t_1. \end{aligned}\right\} \tag{6.80}$$

This is the space-time coordinate transformation between two general inertial frames and under the general configuration of the coordinate system.

In the specific calculation, the first expression of Eq. (6.80) can be calculated as follows

$$\begin{aligned} \boldsymbol{r}_2 &= \hat{T}_2\left[\boldsymbol{r}_1 + (\gamma_1^{-1} - 1)(\boldsymbol{r}_1 \cdot \boldsymbol{v}_{10})\boldsymbol{v}_{10}\right] - \gamma_1 t_1 \left[\gamma_2 \boldsymbol{v}_2 - \boldsymbol{v}_1 - (\gamma_2 - 1)(\boldsymbol{v}_1 \cdot \boldsymbol{v}_{20})\boldsymbol{v}_{20}\right] \\ &= \boldsymbol{r}_1 + (\gamma_1^{-1} - 1)(\boldsymbol{r}_1 \cdot \boldsymbol{v}_{10})\boldsymbol{v}_{10} + (\gamma_2 - 1)(\boldsymbol{r}_1 \cdot \boldsymbol{v}_{20})\boldsymbol{v}_{20} \\ &\quad + (\gamma_1^{-1} - 1)(\gamma_2 - 1)(\boldsymbol{r}_1 \cdot \boldsymbol{v}_{10})(\boldsymbol{v}_{10} \cdot \boldsymbol{v}_{20})\boldsymbol{v}_{20} - \gamma_1 t_1 \left[\gamma_2 \boldsymbol{v}_2 - \boldsymbol{v}_1 - (\gamma_2 - 1)(\boldsymbol{v}_1 \cdot \boldsymbol{v}_{20})\boldsymbol{v}_{20}\right] \end{aligned} \tag{6.81}$$

The physical meaning and operational rules of operator $\hat{\boldsymbol{T}}$ is discussed in detail in Sec.7.1.

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Chapter 7

Electrodynamics of Standard Space-time Theory

7. 1. Basic Postulates and Operator $\hat{T}$

7. 1. 1. Introduction

Human beings live in electromagnetic phenomena, and all kinds of life itself contain electromagnetic processes. Whatever the objective laws do the electromagnetic phenomena obey? The Maxwell equations and the Lorentz force formula have given answers to this question. These are now recognized as the correct electromagnetism theory. According to Maxwell's and Lorentz's idea, the law of electromagnetic field does not obey the principle of relativity, and the ether constitutes the absolute frame of reference for the motion of all objects; the ether is carrier of the electromagnetic fields, and electromagnetic waves are wave processes propagating the electromagnetic turbulence in the ether; the Maxwell equations and the Lorentz force formula hold true only in the ether absolute frame; but in an ordinary inertial frame at a uniform rectilinear motion to the ether absolute frame, the laws of the electromagnetic fields will manifest definite deviations from the Maxwell equations and the Lorentz force formula. Then, what on earth concrete forms are the laws of the electromagnetic fields in an ordinary inertial frames taken? Maxwell and Lorentz have not given a last and definite answer.

In contrast with Maxwell's and Lorentz's ideas, Einstein's special theory of relativity negates the existence of the ether absolute reference frame. He uses the principle of relativity as the basic assumption that the laws of physics have the same form in all inertial frames. The electromagnetic equations should be applied to all inertial reference frames. When from one inertial system S to another S', the space-time coordinates satisfy the Lorentz transformation, and the laws of electromagnetic fields such as Maxwell's equations and Lorentz's force remain unchanged in their form. This is called the Lorentz covariance of the electrodynamics equation.

When we accept the view of nature of the Atom-Yuanqi Theory, which maintains that the vacuum is not empty, and the void space with nothingness does not exist, these assertions of the special theory of relativity become unacceptable. Note that the Maxwell's equations and the Lorentz's force formula are the results obtained by experiments in the case of the field-source charge and the electromagnetic medium at motion of low speed or stationary state. Now according to the special theory of relativity it is found that the Maxwell's equations and the Lorentz's formula are always correct with absolute accuracy, even when they are at high speed (even close to the speed of light). This is certainly strange and astounding. It is inconceivable that the field-source charge and the medium pass through the vacuum background field at high speed (even close to the speed of light) without any effect on the motion and changes of the electromagnetic field, and the situation is exactly the same as when they're at rest relative to the vacuum background.

Standard Space-time Theory has followed the aggregated-dispersed states natural images, and admitted that the dispersed state vacuum background field is the background generating all matter processes, it constitutes the absolute inertial reference frame. The vacuum background field is carrier of the electromagnetic fields; and the electromagnetic fields are not an independent matter form, but a description of the local motion state of the vacuum background field. These have returned to Maxwell's and Lorentz's idea. Hence, Standard Space-time Theory considers that in any ordinary inertial frame the laws of the electromagnetic fields have the forms different from that in the absolute frame.

Starting from the basic postulates of Standard Space-time Theory, this chapter will discover and express the electromagnetic field law in the ordinary inertial system, establish the transformation between the electromagnetic quantities in the absolute inertial system and the electromagnetic quantities in the ordinary inertial system, and use them to explain and predict various experimental electromagnetic phenomena, thus establishing the complete electrodynamics of Standard Space-time Theory. This is the goal and task of this chapter.

When I basically finished this research, I felt deeply that the study of natural science is not a factitious arbitrary fabrication, but a careful listening to the voice of nature and calmly meditating on the pulse of nature according to the revelation of the experiments, then using the power of logical thinking to discover the objective laws of nature, which must be simple and graceful essentially.

7. 1. 2. Basic Postulates

The following basic postulates are the logical starting point for the electrodynamics of Standard Space-time Theory：

(1) Maxwell's equations and the Lorentz force formula hold true in the absolute inertial frame;

(2) The transformations of the space-time coordinate, and the velocity and the force of

Standard Space-time Theory;

(3) The principle of the constancy of charge, i.e., the total amount of the charge in a closed charged system is independent of its motion state and remains unchanged;

(4) Coulomb's law for the force between two point-charges at rest with respect to the chosen inertial frame.

Besides these, we will follow the definitions of the elementary electromagnetic quantities in the classical electromagnetism, especially the definitions of the electric field intensity $\boldsymbol{E}$ and the magnetic induction intensity $\boldsymbol{B}$.

According to the first postulate, the electromagnetic field equations in vacuum with respect to the absolute frame Σ_{a} and the Lorentz force are written as

$$\left.\begin{aligned}
&\nabla_{\mathrm{a}} \times \boldsymbol{E}_{\mathrm{a}} = -\frac{\partial \boldsymbol{B}_{\mathrm{a}}}{\partial t_{\mathrm{a}}},\\
&\nabla_{\mathrm{a}} \times \boldsymbol{B}_{\mathrm{a}} = \mu_0 \boldsymbol{j}_{\mathrm{a}} + \varepsilon_0 \mu_0 \frac{\partial \boldsymbol{E}_{\mathrm{a}}}{\partial t_{\mathrm{a}}},\\
&\nabla_{\mathrm{a}} \cdot \boldsymbol{E}_{\mathrm{a}} = \rho_{\mathrm{a}} / \varepsilon_0,\\
&\nabla_{\mathrm{a}} \cdot \boldsymbol{B}_{\mathrm{a}} = 0,
\end{aligned}\right\} \tag{7.1}$$

$$\boldsymbol{f}_{\mathrm{a}} = q\boldsymbol{E}_{\mathrm{a}} + q\boldsymbol{u}_{\mathrm{a}} \times \boldsymbol{B}_{\mathrm{a}}. \tag{7.2}$$

These are Maxwell's equations and the Lorentz force formula, where $\boldsymbol{E}_{\mathrm{a}}$ and $\boldsymbol{B}_{\mathrm{a}}$ represent respectively the macroscopic electric field intensity and magnetic induction intensity in the absolute frame Σ_{a}, ε_0 and μ_0 are respectively the permittivity of free space and the permeability of free space, ρ_{a} and $\boldsymbol{j}_{\mathrm{a}}$ are respectively the macroscopic charge density and the current density in frame Σ_{a}, $\boldsymbol{u}_{\mathrm{a}}$ represents the velocity of the moving charge with respect to frame Σ_{a}. $\boldsymbol{f}_{\mathrm{a}}$ represents the force exerted by the electromagnetic field on an electric charge q moving with velocity $\boldsymbol{u}_{\mathrm{a}}$ in the absolute frame Σ_{a}.

The electric displacement $\boldsymbol{D}_{\mathrm{a}}$ and magnetic field intensity $\boldsymbol{H}_{\mathrm{a}}$ in material are defined as follows:

$$\boldsymbol{D}_{\mathrm{a}} = \varepsilon_0 \boldsymbol{E}_{\mathrm{a}} + \boldsymbol{P}_{\mathrm{a}}, \tag{7.3}$$

$$\boldsymbol{B}_{\mathrm{a}} = \mu_0 (\boldsymbol{H}_{\mathrm{a}} + \boldsymbol{M}_{\mathrm{a}}), \tag{7.4}$$

where $\boldsymbol{P}_{\mathrm{a}}$ and $\boldsymbol{M}_{\mathrm{a}}$ represent respectively the polarization intensity vector and magnetization intensity vector of the material with respect to frame Σ_{a}.

Maxwell has proved: in the absolute inertial frame the propagation speeds of electromagnetic wave in vacuum is isotropy, and are all equal the constant c in any direction, and

$$c = 1\big/\sqrt{\varepsilon_0 \mu_0}, \quad \text{or} \quad c^{-2} = \varepsilon_0 \mu_0. \tag{7.5}$$

The Maxwell equations in media with respect to frame Σ_{a} are written as

$$\left.\begin{aligned}&\nabla_{\mathrm{a}}\times\boldsymbol{E}_{\mathrm{a}}=-\frac{\partial\boldsymbol{B}_{\mathrm{a}}}{\partial t_{\mathrm{a}}},\\&\nabla_{\mathrm{a}}\times\boldsymbol{H}_{\mathrm{a}}=\boldsymbol{j}_{\mathrm{fa}}+\frac{\partial\boldsymbol{D}_{\mathrm{a}}}{\partial t_{\mathrm{a}}}\\&\nabla_{\mathrm{a}}\cdot\boldsymbol{D}_{\mathrm{a}}=\rho_{\mathrm{fa}},\\&\nabla_{\mathrm{a}}\cdot\boldsymbol{B}_{\mathrm{a}}=0,\end{aligned}\right\}\tag{7.6}$$

where ρ_{fa} and $\boldsymbol{j}_{\mathrm{fa}}$ are respectively the free charge density and the free current density with respect to frame Σ_{a}.

The electromagnetic field equations and the formula of electromagnetic force in the general inertial frame will be different from Maxwell's equations and Lorentz force formula, otherwise, we will inevitably return to Lorentz's transformation, which is not allowed by Standard Space-time Theory. But the difference is only to add a number of terms related to the characteristic velocity $\boldsymbol{v}$ of the inertial system, and when $\boldsymbol{v}=0$, it must be reduced to Maxwell's equations and Lorentz force formula.

According to the electrodynamics of Standard Space-time Theory, the below mentioned Maxwell's equations are just the equations of electromagnetic field in vacuum or in material with respect to the absolute frame Σ_{a}, and the below mentioned the Lorentz force formula is just the force exerted by the electromagnetic field on the moving charge with respect to the absolute frame Σ_{a}.

As to the second postulate, we will discuss in the formulas of Standard Space-time Theory under the general case in which coordinate axes (such as x-axis) do not coincide with the characteristic velocity $\boldsymbol{v}$ of the ordinary inertial frame. The results obtained in these ways have catholicity. For convenience of citation, we assemble these results as follows.

To the generally collocated the absolute frame Σ_{a} and an ordinary inertial frame Σ, the generalized Galilean transformation (GGT)

$$\left.\begin{aligned}&\boldsymbol{r}_{\mathrm{a}\parallel}=\gamma^{-1}\boldsymbol{r}_{\parallel}+\gamma t\boldsymbol{v},\quad \boldsymbol{r}_{\mathrm{a}\perp}=\boldsymbol{r}_{\perp},\\&t_{\mathrm{a}}=\gamma t,\end{aligned}\right\}$$

or

$$\left.\begin{aligned}&\boldsymbol{r}=\boldsymbol{r}_{\mathrm{a}}+[(\gamma-1)(\boldsymbol{r}_{\mathrm{a}}\cdot\boldsymbol{v})/v^2-\gamma t_{\mathrm{a}}]\boldsymbol{v},\\&t=\gamma^{-1}t_{\mathrm{a}}.\end{aligned}\right\}\tag{7.7}$$

Let

$$\hat{T}=I+[(\gamma-1)/v^2]\boldsymbol{v}\boldsymbol{v}\cdot=I+(\gamma-1)\boldsymbol{v}_0\boldsymbol{v}_0\cdot\tag{7.8}$$

we have

$$\left.\begin{aligned}&\boldsymbol{r}=\hat{T}\left(\boldsymbol{r}_{\mathrm{a}}-\boldsymbol{v}t_{\mathrm{a}}\right),\\&t=\gamma^{-1}t_{\mathrm{a}}.\end{aligned}\right\}\tag{7.9}$$

where $\boldsymbol{v}$ represents the velocity of the frame Σ relative to the frame Σ_a, $\boldsymbol{v}_0$ represents the unit vector in the direction of $\boldsymbol{v}$; $\gamma = (1 - v^2/c^2)^{-1/2}$.

The inverse ones of GGT

$$\left.\begin{aligned} &\boldsymbol{r}_{a\parallel} = \gamma^{-1}\boldsymbol{r}_{\parallel} + \gamma t\boldsymbol{v}, \quad \boldsymbol{r}_{a\perp} = \boldsymbol{r}_{\perp}, \\ &t_a = \gamma t, \end{aligned}\right\}$$

or

$$\left.\begin{aligned} &\boldsymbol{r}_a = \boldsymbol{r} + [(\gamma^{-1} - 1)(\boldsymbol{r}\cdot\boldsymbol{v})/v^2 + \gamma t]\boldsymbol{v}, \\ &t_a = \gamma t. \end{aligned}\right\} \tag{7.10}$$

Let

$$\hat{T}^{-1} = I + [\gamma^{-1} - 1)/v^2]\boldsymbol{v}\boldsymbol{v}\cdot = I + \left(\gamma^{-1} - 1\right)\boldsymbol{v}_0\boldsymbol{v}_0\cdot \tag{7.11}$$

we have

$$\boldsymbol{r}_a = \hat{T}^{-1}\boldsymbol{r} + \gamma t\boldsymbol{v}, \quad t_a = \gamma t. \tag{7.12}$$

The velocity transformation equations and their inverse equations are as follows:

$$\boldsymbol{u} = \gamma\hat{T}\left(\boldsymbol{u}_a - \boldsymbol{v}\right), \tag{7.13}$$

$$\boldsymbol{u}_a = \gamma^{-1}\hat{T}^{-1}\boldsymbol{u} + \boldsymbol{v}. \tag{7.14}$$

The transformation equation of force and their inverse equations

$$\boldsymbol{f} = \gamma\hat{T}\boldsymbol{f}_a - \gamma^2\left(\boldsymbol{f}_a\cdot\boldsymbol{u}_a\right)\boldsymbol{v}/c^2, \tag{7.15}$$

$$\boldsymbol{f}_a = \gamma^{-1}\hat{T}\boldsymbol{f} + \left(\boldsymbol{f}\cdot\boldsymbol{u}\right)\frac{\boldsymbol{v}/c^2}{1 - \boldsymbol{u}\cdot\boldsymbol{v}/c^2}. \tag{7.16}$$

Where u_a and u represent respectively the velocity of a particle acted by a force relative to the frames Σ_a and Σ.

7. 1. 3. Operator $\hat{T}$

The operator $\hat{T}$ is introduced in Chap. 6. In the present chapter all discussions are made in general coordinate system of frames, so one need a great deal of operation relate to the operator $\hat{T}$ and operator $\hat{T}^n$. The operation formula on the operator $\hat{T}$ and operator $\hat{T}^n$ are my independent innovation, the readers should know well and grip them so as to comprehend the electrodynamics of Standard Space-time Theory.

The definition of the operator $\hat{T}$ is follows: suppose $\boldsymbol{A}$ is an arbitrary vector,

$$\hat{T} = I + \left(\gamma - 1\right)\boldsymbol{v}_0\boldsymbol{v}_0\cdot, \qquad \hat{T}\boldsymbol{A} = \boldsymbol{A} + \left(\gamma - 1\right)\boldsymbol{A}_{\parallel} = \boldsymbol{A}_{\perp} + \gamma\boldsymbol{A}_{\parallel}. \tag{7.17}$$

That is to say that $\hat{T}\boldsymbol{A}$ represents that the operator $\hat{T}$ acts on the vector $\boldsymbol{A}$ so that one obtains a new vector, of which the perpendicular component is equal to that of the original vector, the parallel component is equal to γ times that of the original vector. Here "parallel" and "perpendicular" are correlative with the characteristic velocity $\boldsymbol{v}$ of the inertial frame Σ, and

$\boldsymbol{v}_0$ represents the unit vector in the direction of velocity $\boldsymbol{v}$.

The definitions of the operator $\hat{T}^{-1}$ and the general operator $\hat{T}^{n}$ are follows: suppose $\boldsymbol{A}$ is an arbitrary vector,

$$T^{-1}=I+\left(\gamma^{-1}-1\right)\boldsymbol{v}_0\boldsymbol{v}_0\cdot\ ,\quad \hat{T}^{-1}\boldsymbol{A}=\boldsymbol{A}+\left(\gamma^{-1}-1\right)\boldsymbol{A}_{\parallel}=\boldsymbol{A}_{\perp}+\gamma^{-1}\boldsymbol{A}_{\parallel}, \tag{7.18}$$

$$\hat{T}^{n}=I+\left(\gamma^{n}-1\right)\boldsymbol{v}_0\boldsymbol{v}_0\cdot\ ,\quad \hat{T}^{n}\boldsymbol{A}=\boldsymbol{A}+\left(\gamma^{n}-1\right)\boldsymbol{A}_{\parallel}=\boldsymbol{A}_{\perp}+\gamma^{n}\boldsymbol{A}_{\parallel}. \tag{7.19}$$

where, n is an arbitrary positive or negative integer. $\hat{T}^{-1}\boldsymbol{A}$ (or $\hat{T}^{n}\boldsymbol{A}$) represents that the operator $\hat{T}^{-1}$ (or $\hat{T}^{n}$) acts on the vector $\boldsymbol{A}$ so that one obtains a new vector, of which the perpendicular component is equal to that of the original vector, the parallel component is equal to γ^{-1} (or γ^{n}) times that of the original vector. In the same way, here "parallel" and "perpendicular" are correlative with the characteristic velocity $\boldsymbol{v}$ of the inertial frame Σ.

For convenience of discussions in below sections, the present section will give a series of operation formulas on the operator $\hat{T}^{n}$. These formulas are based on the formulas of vector analysis and the definitions of the operator $\hat{T}^{n}$.

In the present section we use constant vector $\boldsymbol{v}$ to represent the characteristic velocity of the inertial frame Σ, φ to represent an arbitrary potential field, $\boldsymbol{A}$ or $\boldsymbol{B}$ to represent an arbitrary vector field.

Here we give the formulas commonly used in vector analysis as follows:

$$\nabla=\boldsymbol{i}\frac{\partial}{\partial \boldsymbol{x}}+\boldsymbol{j}\frac{\partial}{\partial y}+\boldsymbol{k}\frac{\partial}{\partial z}, \tag{7.20}$$

$$\nabla\cdot\left(\varphi\boldsymbol{A}\right)=\left(\nabla\varphi\right)\cdot\boldsymbol{A}+\varphi\left(\nabla\cdot\boldsymbol{A}\right), \tag{7.21}$$

$$\nabla\times\left(\varphi\boldsymbol{A}\right)=\left(\nabla\varphi\right)\times\boldsymbol{A}+\varphi\left(\nabla\times\boldsymbol{A}\right), \tag{7.22}$$

$$\nabla\cdot\left(\boldsymbol{A}\times\boldsymbol{B}\right)=\left(\nabla\times\boldsymbol{A}\right)\cdot\boldsymbol{B}-\boldsymbol{A}\cdot\left(\nabla\times\boldsymbol{B}\right), \tag{7.23}$$

$$\nabla\times\left(\boldsymbol{A}\times\boldsymbol{B}\right)=\left(\boldsymbol{B}\cdot\nabla\right)\boldsymbol{A}+\left(\nabla\cdot\boldsymbol{B}\right)\boldsymbol{A}-\left(\boldsymbol{A}\cdot\nabla\right)\boldsymbol{B}-\left(\nabla\cdot\boldsymbol{A}\right)\boldsymbol{B}, \tag{7.24}$$

$$\nabla\left(\boldsymbol{A}\cdot\boldsymbol{B}\right)=\boldsymbol{A}\times\left(\nabla\times\boldsymbol{B}\right)+\left(\boldsymbol{A}\cdot\nabla\right)\boldsymbol{B}+\boldsymbol{B}\times\left(\nabla\times\boldsymbol{A}\right)+\left(\boldsymbol{B}\cdot\nabla\right)\boldsymbol{A}, \tag{7.25}$$

$$\nabla\times\left(\nabla\times\boldsymbol{A}\right)=\nabla\left(\nabla\cdot\boldsymbol{A}\right)-\left(\nabla\cdot\nabla\right)\boldsymbol{A}=\nabla\left(\nabla\cdot\boldsymbol{A}\right)-\nabla^{2}\boldsymbol{A}. \tag{7.26}$$

When constant vector $\boldsymbol{v}$ enters the above formulas, we have

$$\nabla\cdot\left(\varphi\boldsymbol{v}\right)=\left(\nabla\varphi\right)\cdot\boldsymbol{v}, \tag{7.27}$$

$$\nabla\times\left(\varphi\boldsymbol{v}\right)=\left(\nabla\varphi\right)\times\boldsymbol{v}, \tag{7.28}$$

$$\nabla\cdot\left(\boldsymbol{v}\times\boldsymbol{A}\right)=-\boldsymbol{v}\cdot\left(\nabla\times\boldsymbol{A}\right), \tag{7.29}$$

$$\nabla\times\left(\boldsymbol{v}\times\boldsymbol{A}\right)=\left(\nabla\cdot\boldsymbol{A}\right)\boldsymbol{v}-\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{A}, \tag{7.30}$$

$$\nabla\left(\boldsymbol{v}\cdot\boldsymbol{A}\right)=\boldsymbol{v}\times\left(\nabla\times\boldsymbol{A}\right)+\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{A}. \tag{7.31}$$

The triple vector product is also often used:

$$\boldsymbol{A}\times\left(\boldsymbol{B}\times\boldsymbol{C}\right)=\left(\boldsymbol{A}\cdot\boldsymbol{C}\right)\boldsymbol{B}-\left(\boldsymbol{A}\cdot\boldsymbol{B}\right)\boldsymbol{C}. \tag{7.32}$$

We have proved the following formulas to hold true (cf. Chapter 6)

$$\nabla = \hat{T}^{-1}\nabla_{\mathrm{a}} \ , \quad \nabla_{\mathrm{a}} = \hat{T}\nabla \ , \tag{7.33}$$

$$\frac{\partial}{\partial t} = \gamma \frac{\partial}{\partial t_{\mathrm{a}}} + \gamma \boldsymbol{v}\cdot\nabla_{\mathrm{a}} \ , \quad \frac{\partial}{\partial t_{\mathrm{a}}} = \gamma^{-1}\frac{\partial}{\partial t} - \gamma \boldsymbol{v}\cdot\nabla. \tag{7.34}$$

From the definitions of the operator $\hat{T}^n$ (7.17)—(7.19) one easily proves that

$$\hat{T}\boldsymbol{v} = \gamma\boldsymbol{v}, \ \hat{T}^{-1}\boldsymbol{v} = \gamma^{-1}\boldsymbol{v}, \ \hat{T}^{n}\boldsymbol{v} = \gamma^{n}\boldsymbol{v}, \tag{7.35}$$

$$\hat{T}\left(\boldsymbol{v}\times\boldsymbol{A}\right) = \hat{T}^{-1}\left(\boldsymbol{v}\times\boldsymbol{A}\right) = \hat{T}^{n}\left(\boldsymbol{v}\times\boldsymbol{A}\right) = \boldsymbol{v}\times\boldsymbol{A}. \tag{7.36}$$

This is because that $\boldsymbol{v}$ is, of course, in the direction parallel to $\boldsymbol{v}$, while $\boldsymbol{v}\times\boldsymbol{A}$ is in the direction perpendicular to $\boldsymbol{v}$.

From the definitions of the operator $\hat{T}^n$ (7.17)—(7.19) we also prove that

$$\hat{T}\ \hat{T}^{-1} = I, \tag{7.37}$$

$$\hat{T}\ \hat{T} = \hat{T}^{2}, \tag{7.38}$$

$$\hat{T}^{-1}\hat{T}^{-1} = \hat{T}^{-2}, \tag{7.39}$$

$$\hat{T}^{m}\,\hat{T}^{n} = \hat{T}^{(m+n)}. \tag{7.40}$$

Here we will prove only the last formula. From the definitions of the operator $\hat{T}^n$

$$\hat{T}^{n}\boldsymbol{A} = \boldsymbol{A}_{\perp} + \gamma^{n}\boldsymbol{A}_{\parallel} \ , \quad \hat{T}^{m}\boldsymbol{B} = \boldsymbol{B}_{\perp} + \gamma^{m}\boldsymbol{B}_{\parallel},$$

we have

$$\hat{T}^{m}\hat{T}^{n}\boldsymbol{A} = \hat{T}^{m}\left(\hat{T}^{n}\boldsymbol{A}\right) = \hat{T}^{m}\left(\boldsymbol{A}_{\perp} + \gamma^{n}\boldsymbol{A}_{\parallel}\right)$$

$$= \boldsymbol{A}_{\perp} + \gamma^{m}\left(\gamma^{n}\boldsymbol{A}_{\parallel}\right) = \boldsymbol{A}_{\perp} + \gamma^{(m+n)}\boldsymbol{A}_{\parallel} = \hat{T}^{(m+n)}\boldsymbol{A}.$$

Then Eq. (7.40) holds true. Thus, Eqs. (7.37)—(7.39), of course, also hold true.

From the definitions of the operator $\hat{T}^n$ (7.17)—(7.19) we can proves that

$$\left(\hat{T}\boldsymbol{A}\right)\times\left(\hat{T}\boldsymbol{B}\right) = \gamma\hat{T}^{-1}\left(\boldsymbol{A}\times\boldsymbol{B}\right), \tag{7.41}$$

$$\left(\hat{T}^{-1}\boldsymbol{A}\right)\times\left(\hat{T}^{-1}\boldsymbol{B}\right) = \gamma^{-1}\hat{T}\left(\boldsymbol{A}\times\boldsymbol{B}\right), \tag{7.42}$$

$$\left(\hat{T}^{m}\boldsymbol{A}\right)\cdot\left(\hat{T}^{n}\boldsymbol{B}\right) = \boldsymbol{A}\cdot\left[\hat{T}^{(m+n)}\boldsymbol{B}\right] = \left[\hat{T}^{(m+n)}\boldsymbol{A}\right]\cdot\boldsymbol{B}. \tag{7.43}$$

In fact, according to the definition of the operator $\hat{T}$, we have

$$\left(\hat{T}\boldsymbol{A}\right)\times\left(\hat{T}\boldsymbol{B}\right) = \left(\boldsymbol{A}_{\perp} + \gamma\boldsymbol{A}_{\parallel}\right)\times\left(\boldsymbol{B}_{\perp} + \gamma\boldsymbol{B}_{\parallel}\right) == \gamma\left(\boldsymbol{A}_{\perp}\times\boldsymbol{B}_{\parallel} + \boldsymbol{A}_{\parallel}\times\boldsymbol{B}_{\perp}\right) + \boldsymbol{A}_{\perp}\times\boldsymbol{B}_{\perp}$$

$$= \gamma\left[\left(\boldsymbol{A}\times\boldsymbol{B}\right)_{\perp} + \gamma^{-1}\left(\boldsymbol{A}\times\boldsymbol{B}\right)_{\parallel}\right] = \gamma\hat{T}^{-1}\left(\boldsymbol{A}\times\boldsymbol{B}\right).$$

Here one should notice that in despite of $\boldsymbol{A}_{\parallel}\times\boldsymbol{B}_{\parallel} = 0$, yet $\boldsymbol{A}_{\perp}\times\boldsymbol{B}_{\perp}$ is generally not equal to zero. This is because that the two vectors $\boldsymbol{A}_{\perp}$ and $\boldsymbol{B}_{\perp}$ perpendicular to the characteristic velocity $\boldsymbol{v}$ are generally not in the same direction. But $\boldsymbol{A}_{\perp}\times\boldsymbol{B}_{\perp}$ is definitely in the direction of $\boldsymbol{v}$, and is equal to $\left(\boldsymbol{A}\times\boldsymbol{B}\right)_{\parallel}$.

Similarly, one can prove Eq. (7.42) holds true.

The first sign of equality of Eq. (7.43) can be proved as follows:

$$\left(\hat{T}^m \boldsymbol{A}\right)\cdot\left(\hat{T}^n \boldsymbol{B}\right)=\left(\boldsymbol{A}_\perp+\gamma^m \boldsymbol{A}_{\parallel}\right)\cdot\left(\boldsymbol{B}_\perp+\gamma^n \boldsymbol{B}_{\parallel}\right)$$
$$=\boldsymbol{A}_\perp\cdot\boldsymbol{B}_\perp+\gamma^{(m+n)}\left(\boldsymbol{A}_{\parallel}\cdot\boldsymbol{B}_{\parallel}\right)=\boldsymbol{A}\cdot\boldsymbol{B}-\boldsymbol{A}_{\parallel}\cdot\boldsymbol{B}_{\parallel}+\gamma^{(m+n)}\left(\boldsymbol{A}_{\parallel}\cdot\boldsymbol{B}_{\parallel}\right)$$
$$=\boldsymbol{A}\cdot\boldsymbol{B}-\boldsymbol{A}\cdot\boldsymbol{B}_{\parallel}+\boldsymbol{A}\cdot\gamma^{(m+n)}\boldsymbol{B}_{\parallel}=\boldsymbol{A}\cdot\left[\boldsymbol{B}+\left(\gamma^{(m+n)}-1\right)\boldsymbol{B}_{\parallel}\right]=\boldsymbol{A}\cdot\left[\hat{T}^{(m+n)}\boldsymbol{B}\right].$$

Similarly, we can prove that the second sign of equality of Eq. (7.43) holds true.

We can generally prove that the following equations hold true:

$$\left[\boldsymbol{v}\left(\boldsymbol{v}\cdot\nabla\right)\right]\cdot\boldsymbol{A}=\nabla\cdot\left[\boldsymbol{v}\left(\boldsymbol{v}\cdot\boldsymbol{A}\right)\right]=\boldsymbol{v}\cdot\left[\nabla\left(\boldsymbol{v}\cdot\boldsymbol{A}\right)\right], \tag{7.44}$$

$$\left(\hat{T}\nabla\right)\cdot\boldsymbol{A}=\nabla\cdot\left(\hat{T}\boldsymbol{A}\right), \tag{7.45}$$

$$\left(\hat{T}^n\nabla\right)\cdot\boldsymbol{A}=\nabla\cdot\left(\hat{T}^n\boldsymbol{A}\right). \tag{7.46}$$

First, we prove Eq. (7.44). In fact, using the formulas (7.20) and (7.21) we have

$$\left[\boldsymbol{v}\left(\boldsymbol{v}\cdot\nabla\right)\right]\cdot\boldsymbol{A}=\left[\left(\boldsymbol{i}v_x+\boldsymbol{j}v_y+\boldsymbol{k}v_z\right)\left(v_x\frac{\partial}{\partial x}+v_y\frac{\partial}{\partial y}+v_z\frac{\partial}{\partial z}\right)\right]\cdot\boldsymbol{A}$$
$$=\left(v_x\frac{\partial}{\partial x}+v_y\frac{\partial}{\partial y}+v_z\frac{\partial}{\partial z}\right)\left(v_xA_x+v_yA_y+v_zA_z\right)$$
$$=\frac{\partial}{\partial x}v_x\left(\boldsymbol{v}\cdot\boldsymbol{A}\right)+\frac{\partial}{\partial y}v_y\left(\boldsymbol{v}\cdot\boldsymbol{A}\right)+\frac{\partial}{\partial z}v_z\left(\boldsymbol{v}\cdot\boldsymbol{A}\right)=\nabla\cdot\left[\boldsymbol{v}\left(\boldsymbol{v}\cdot\boldsymbol{A}\right)\right]=\boldsymbol{v}\cdot\left[\nabla\left(\boldsymbol{v}\cdot\boldsymbol{A}\right)\right]$$

From the definitions of the operator $\hat{T}^n$, by Eq. (7.44) we have

$$\left(\hat{T}^n\nabla\right)\cdot\boldsymbol{A}=\left[\nabla+\left(\gamma^n-1\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\nabla\right)\right]\cdot\boldsymbol{A}=\nabla\cdot\boldsymbol{A}+\left(\gamma^n-1\right)\nabla\cdot\left[\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\boldsymbol{A}_0\right)\right]$$
$$=\nabla\cdot\left[\boldsymbol{A}+\left(\gamma^n-1\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\boldsymbol{A}\right)\right]=\nabla\cdot\left(\hat{T}^n\boldsymbol{A}\right),$$

where $\boldsymbol{v}_0$ represents a unit vector in the direction of $\boldsymbol{v}$. Substituting $\boldsymbol{v}$ in Eq. (7.44) by $\boldsymbol{v}_0$, the obtained formula is still valid, so that we have proved Eq. (7.46). When $n=1$, one gets Eq. (7.45).

Finally, we prove generally that the following a set of formula holds true:

$$\left[\boldsymbol{v}\left(\boldsymbol{v}\cdot\nabla\right)\right]\times\boldsymbol{A}=\left(\boldsymbol{v}\cdot\nabla\right)\left(\boldsymbol{v}\times\boldsymbol{A}\right)=\boldsymbol{v}\times\left[\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{A}\right], \tag{7.47}$$

$$\left[\boldsymbol{v}\left(\boldsymbol{v}\cdot\nabla\right)\right]\times\boldsymbol{A}=v^2\left(\nabla\times\boldsymbol{A}\right)-\boldsymbol{v}\left[\boldsymbol{v}\cdot\left(\nabla\times\boldsymbol{A}\right)\right]+\boldsymbol{v}\times\left[\nabla\left(\boldsymbol{v}\cdot\boldsymbol{A}\right)\right], \tag{7.48}$$

$$\left(\hat{T}^n\nabla\right)\times\boldsymbol{A}=\gamma^n\hat{T}^{-n}\left(\nabla\times\boldsymbol{A}\right)+\left(\gamma^n-1\right)\boldsymbol{v}_0\times\left[\nabla\left(\boldsymbol{v}_0\cdot\boldsymbol{A}\right)\right], \tag{7.49}$$

$$\hat{T}^{-n}\left(\nabla\times\boldsymbol{A}\right)=\gamma^{-n}\left(\hat{T}^n\nabla\right)\times\boldsymbol{A}+\left(\gamma^{-n}-1\right)\boldsymbol{v}_0\times\left[\nabla\left(\boldsymbol{v}_0\cdot\boldsymbol{A}\right)\right]. \tag{7.50}$$

where, n is an arbitrary positive or negative integer.

We prove Eq. (7.47). In fact,

$$\left[\boldsymbol{v}\left(\boldsymbol{v}\cdot\nabla\right)\right]\times\boldsymbol{A}=\left[\left(\boldsymbol{i}v_x+\boldsymbol{j}v_y+\boldsymbol{k}v_z\right)\left(v_x\frac{\partial}{\partial x}+v_y\frac{\partial}{\partial y}+v_z\frac{\partial}{\partial z}\right)\right]\times\boldsymbol{A}$$

$$=\left(v_x\frac{\partial}{\partial x}+v_y\frac{\partial}{\partial y}+v_z\frac{\partial}{\partial z}\right)\left(\boldsymbol{v}\times\boldsymbol{A}\right)=\boldsymbol{v}\times\left[\left(v_x\frac{\partial}{\partial x}+v_y\frac{\partial}{\partial}+v_z\frac{\partial}{\partial z}\right)\boldsymbol{A}\right]$$

$$=\left(\boldsymbol{v}\cdot\nabla\right)\left(\boldsymbol{v}\times\boldsymbol{A}\right)=\boldsymbol{v}\times\left[\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{A}\right].$$

Then we have proved Eq.(7.47). From this equation, by the formula (7.31) of vector analysis and formula (7.32) we get

$$\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{A}=\nabla\left(\boldsymbol{v}\cdot\boldsymbol{A}\right)-\boldsymbol{v}\times\left(\nabla\times\boldsymbol{A}\right),$$

$$\left[\boldsymbol{v}\left(\boldsymbol{v}\cdot\nabla\right)\right]\times\boldsymbol{A}=-\boldsymbol{v}\times\boldsymbol{v}\times\left(\nabla\times\boldsymbol{A}\right)+\boldsymbol{v}\times\left[\nabla\left(\boldsymbol{v}\cdot\boldsymbol{A}\right)\right]$$

$$=v^2\left(\nabla\times\boldsymbol{A}\right)-\boldsymbol{v}\left[\boldsymbol{v}\cdot\left(\nabla\times\boldsymbol{A}\right)\right]+\boldsymbol{v}\times\left[\nabla\left(\boldsymbol{v}\cdot\boldsymbol{A}\right)\right].$$

Then we have proved Eq. (7.48).

Substituting $\boldsymbol{v}$ in Eq. (7.48) by the unit vector $\boldsymbol{v}_0$ in the direction of $\boldsymbol{v}$, using the obtained formula and the definition (7.19) of the operator $\hat{T}^n$, we obtain

$$\left(\hat{T}^n\nabla\right)\times\boldsymbol{A}=\left[\nabla+\left(\gamma^n-1\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\nabla\right)\right]\times\boldsymbol{A}=\nabla\times\boldsymbol{A}+\left(\gamma^n-1\right)\left[\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\nabla\right)\right]\times\boldsymbol{A}$$

$$=\gamma^n\nabla\times\boldsymbol{A}-\left(\gamma^n-1\right)\boldsymbol{v}_0\left[\boldsymbol{v}_0\cdot\left(\nabla\times\boldsymbol{A}\right)\right]+\left(\gamma^n-1\right)\boldsymbol{v}_0\times\left[\nabla\left(\boldsymbol{v}_0\cdot\boldsymbol{A}\right)\right]$$

$$=\gamma^n\left[\nabla\times\boldsymbol{A}+\left(\gamma^{-n}-1\right)\boldsymbol{v}_0\boldsymbol{v}_0\cdot\left(\nabla\times\boldsymbol{A}\right)\right]+\left(\gamma^n-1\right)\boldsymbol{v}_0\times\left[\nabla\left(\boldsymbol{v}_0\cdot\boldsymbol{A}\right)\right]$$

$$=\gamma^n\hat{T}^{-n}\left(\nabla\times\boldsymbol{A}\right)+\left(\gamma^n-1\right)\boldsymbol{v}_0\times\left[\nabla\left(\boldsymbol{v}_0\cdot\boldsymbol{A}\right)\right]$$

That is Eq. (7.49). Multiply separately the two sides of Eq.(49) by γ^{-n} and re-arranging, we obtain Eq. (7.50).

In Eqs. (7.49) and (7.50) taking $n=+1$ or $n=-1$, one can get four formulas on $\left(\hat{T}\nabla\right)\times\boldsymbol{A}$, $\hat{T}\left(\nabla\times\boldsymbol{A}\right)$; $\left(\hat{T}^{-1}\nabla\right)\times\boldsymbol{A}$, $\hat{T}^{-1}\left(\nabla\times\boldsymbol{A}\right)$. For saving the page space they are not written out here.

7. 2. The Transformation of Charge and Current Densities. The Law of Charge Conservation

7. 2. 1. The Transformation of Charge and Current Densities

The motions of a large number of discrete charged particles form current. Consider a unit volume at a point (x_a, y_a, z_a) at a time t in the absolute inertial frame Σ_a. Let it contain many sorts of charged particle, in which the number of the particle with charge q_i and velocity $\boldsymbol{u}_{ai}$ is n_{ai}. In general, n is called "number density" for short. The charge and current densities at this point can be given by

$$\rho_a = \Sigma n_{ai} q_i \tag{7.51}$$

$$\boldsymbol{j}_a = \Sigma n_{ai} q_i \boldsymbol{u}_{ai} \tag{7.52}$$

where that is summing over all possible values of the velocity $\boldsymbol{u}_{ai}$, also over all charged particles.

In an ordinary inertial frame Σ moving with uniform velocity $\boldsymbol{v}$ relative to frame Σ_a, the same charge and current densities can be represented as

$$\rho_a = \Sigma n_{ai} q_i \tag{7.53}$$

$$\boldsymbol{j} = \Sigma n_i q_i \boldsymbol{u}_i \tag{7.54}$$

where $\boldsymbol{u}_i$ and n_i represent the velocity and the number density of charged particles relative to frame Σ. According to the principle of conservation of charge, the total amount of the charge in a closed charged system is independent of its motion state and remains unchanged, so is independent of the choice of inertial reference frame. Therefore, in the latter two equations it is used the same charge value q_i with that in the previous two equations.

The motion of charge is a variation of the spatial position of charged particle, i.e., charge. In any inertial reference frame (frame Σ_a or any ordinary frame Σ) one can describe the position coordinates of charged particles and their variations with time. These are Eqs. (7.51)—(7.52) and (7.53)—(7.54). These descriptions can transform each other by the formulas derived from the generalized Galilean transformation (GGT).

Consider a physically infinitesimal volume ΔV_{ai}, which moves along with charged particle having charge q_i and velocity $\boldsymbol{u}_{ai}$ and number density n_{ai} with respect to frame Σ_a; for frame Σ this physically infinitesimal volume is ΔV_i, in which the charge of the particle is also q_i and velocity of the particle is $\boldsymbol{u}_i$, number density is n_i. According to the principle of the constancy of electric charge, the total amount of the charge in this volume is independent of the choice of inertial reference frame, so we have

$$n_i q_i \left(\Delta V_i\right) = n_{ai} q_i \left(\Delta V_{ai}\right) \tag{7.55}$$

By the FitzGerald-Lorentz length contraction of the ruler in frame Σ in the direction of the characteristic velocity $\boldsymbol{v}$ of frame Σ in Chapter 5, we have

$$\Delta V_i = \gamma \left(\Delta V_{ai}\right)$$

where $\gamma = \left(1 - v^2 / c^2\right)^{-1/2}$. Substituting the above formula into Eq. (7.55), we get the transformation of the number density

$$n_i = \gamma^{-1} n_{ai}, \quad \text{or} \quad n_{ai} = \gamma n_i. \tag{7.56}$$

Substituting the above formula into Eq. (53) or (51), we get the transformation of charge density as follows:

$$\rho = \gamma^{-1}\rho_{\text{a}} \ , \quad \text{or} \quad \rho_{\text{a}} = \gamma\,\rho. \tag{7.57}$$

Using the transformation of the number density (7.56) and the velocity transformation (7.13) and Eq. (7.35), starting from Eq. (7.54) we obtain

$$\boldsymbol{j} = \Sigma\gamma^{-1}n_{\text{a}i}q_i\gamma\hat{T}\left(\boldsymbol{u}_{\text{a}i} - \boldsymbol{v}\right) = \hat{T}\Sigma n_{\text{a}i}q_i\boldsymbol{u}_{\text{a}i} - \gamma\left(\Sigma n_{\text{a}i}q_i\right)\boldsymbol{v}$$

Using Eqs. (7.51) and (7.52), we further obtain the transformation of current density as follows

$$\boldsymbol{j}_{\text{a}} = \hat{T}^{-1}\boldsymbol{j} + \gamma\rho\boldsymbol{v}. \tag{7.58}$$

Applying the operator $\hat{T}^{-1}$ to act on the two sides of the above equation, and using Eqs. (7.35), (7.37) and (7.57), we obtain the reverse transformation of current density as follows

$$\boldsymbol{j}_{\text{a}} = \hat{T}^{-1}\boldsymbol{j} + \gamma\rho\boldsymbol{v}. \tag{7.59}$$

Collect the transformations of charge and current density and reverse transformations as follows

$$\begin{cases} \rho = \gamma^{-1}\rho_{\text{a}}, \quad \boldsymbol{j} = \hat{T}\boldsymbol{j}_{\text{a}} - \gamma\rho_{\text{a}}\boldsymbol{v} \\ \rho_{\text{a}} = \gamma\rho, \quad \boldsymbol{j}_{\text{a}} = \hat{T}^{-1}\boldsymbol{j} + \gamma\rho\,\boldsymbol{v} \end{cases} \tag{7.60a}$$

By the components of parallel and perpendicular to $\boldsymbol{v}$, Eq.(60a) can be re-written as

$$\begin{cases} \boldsymbol{j}_{\|} = \gamma\left(\boldsymbol{j}_{\text{a}\|} - \rho_{\text{a}}\boldsymbol{v}\right), \quad \boldsymbol{j}_{\perp} = \boldsymbol{j}_{\text{a}\perp} \\ \boldsymbol{j}_{\text{a}\|} = \gamma^{-1}\boldsymbol{j}_{\|} + \gamma\rho\boldsymbol{v} \ , \quad \boldsymbol{j}_{\text{a}\perp} = j_{\perp} \end{cases} \tag{7.60b}$$

where $\boldsymbol{j}_{\text{a}}$ and ρ_{a} are the values at point $\left(x_{\text{a}}, y_{\text{a}}, z_{\text{a}}\right)$ at time t_{a} in frame Σ_{a}, $\boldsymbol{j}$ and ρ are the values at point (x, y, z) at time t in frame Σ; the space-time coordinates in frame Σ_{a} and Σ are related according to GGT.

7. 2. 2. The Physical Explanation of the Transformations of Charge Density and Current Density

The physical meaning of the transformations of charge and current density is very clear.

First, the transformations (7.57) of charge density can be understood easily. Suppose a volume element is ΔV_{a} relative to frame Σ_{a} and is ΔV relative to frame Σ. According to the principle of the constancy of electric charge, the total amount of the charge in this volume element is independent of the choice of inertial reference frame, so can be represented by Δq. But no matter how this volume element moves along with charge, considering the FitzGerald-Lorentz length contraction of the ruler in frame Σ, one necessarily has

$$\Delta V = \gamma\left(\Delta V_{\text{a}}\right) \tag{7.61}$$

Hence, starting from the definition of charge density

$$\rho_{\text{a}} = \lim_{\Delta V_{\text{a}}\to 0}\frac{\Delta q}{\Delta V_{\text{a}}}, \quad \rho = \lim_{\Delta V\to 0}\frac{\Delta q}{\Delta V}, \tag{7.62}$$

we get

$$\rho_{\mathrm{a}} = \lim_{\Delta V_a \to 0} \frac{\Delta q}{\Delta V_{\mathrm{a}}} = \left(\lim_{\Delta V \to 0} \frac{\Delta q}{\Delta V} \right) \frac{\Delta V}{\Delta V_{\mathrm{a}}} = \gamma \rho$$

i.e., Eq. (7.57) holds true.

Second, we discuss the transformations (7.58) and (7.59) of charge and current density. For example, according to Eq. (7.59), if in frame Σ, $\boldsymbol{j} = 0$ but $\rho \neq 0$, then in frame Σ, besides $\rho_{\mathrm{a}} = \gamma \rho$, we also have

$$\boldsymbol{j}_{\mathrm{a}} = \gamma \rho \boldsymbol{v}.$$

This is because the charge which density is ρ moves with the characteristic velocity $\boldsymbol{v}$ of frame Σ relative to frame $u(x,t)$, so in frame Σ_{a} produce current density $\boldsymbol{j}_{\mathrm{a}} = \rho_{\mathrm{a}} \boldsymbol{v} = \gamma \rho \boldsymbol{v}$.

It is necessary to points especially the difference between the transformation (7.60) of Standard Space-time Theory and the corresponding transformation of the special theory of relativity.

First, the special theory of relativity negates the existence of the absolute reference frame, its transformations are on that of charge and current density of two arbitrary inertial frames S and S'. Standard Space-time Theory admits the existence of the absolute inertial frame, and its transformations describe the transformations of relative electromagnetic quantities in the absolute inertial frame Σ_{a} and an ordinary inertial frame Σ.

Second, the important difference also manifests in the transformation of charge density and the reverse transformation. For comparison, they are written out all together as follows

$$\rho_{\mathrm{r}}' = \gamma\left(\rho_{\mathrm{r}} - \boldsymbol{v} \cdot \boldsymbol{j}_{\mathrm{r}} / c^2\right), \quad \rho_{\mathrm{r}} = \gamma\left(\rho_{\mathrm{r}}' + \boldsymbol{v} \cdot \boldsymbol{j}_{\mathrm{r}}' / c^2\right),$$

$$\rho_{\mathrm{s}} = \gamma^{-1} \rho_{\mathrm{as}} , \qquad \rho_{\mathrm{as}} = \gamma \rho_{\mathrm{s}},$$

where the subscript r represents the quantity of the special theory of relativity, the subscript s represents the quantity of Standard Space-time Theory. The above equations indicate that according to the special theory of relativity, if in an inertial frame S', $\rho_{\mathrm{r}}' = 0$, but $\boldsymbol{j}_{\mathrm{r}}' \neq 0$, then in another inertial frame S there is charge density $\rho_{\mathrm{r}} = \gamma \boldsymbol{v} \cdot \boldsymbol{j}_{\mathrm{r}}' / c^2$. That is to say, an electrically neutral conductor carrying current at rest relative to an inertial frame have charge density with respect to another inertial frame. According to Standard Space-time Theory, this inference of the special theory of relativity does not hold true, the charge density must simultaneously be zero, or simultaneously is not zero in frame Σ_{a} and in frame Σ.

The above inference of the special theory of relativity is produced by relativity of simultaneity, while relativity of simultaneity is from the postulate of the constancy of one-way light speed. Hence the above inference of the special theory of relativity is a measured effect produced by the postulate of the constancy of one-way light speed. According Standard Space-time Theory, simultaneity is absolute, while relativity of simultaneity is a visionary inference derived from un-examinable, artificial and excessive postulate, i.e., the principle of the constancy of the one-way speed of light, so the measured effect derived from relativity of simultaneity is not a natural result.

7. 2. 3. The Law of Charge Conservation

Suppose a closed surface encloses charged material in an inertial frame, if no net charges cross the surface, then, the algebraic sum of the positive and negative charges enclosed in the closed surface remains unchanged. This is called the law of conservation of charge. Below we will prove by the basic postulates (1), (2) and (3) of the electrodynamics of Standard Space-time Theory, the law of conservation of charge holds true in any inertial frames.

Based on the first postulate, Maxwell's equations hold true in the absolute inertial frame Σ_{a}. Taking the divergence of the two sides of the second equation of (1), we obtain

$$\nabla_{\mathrm{a}} \cdot \left(\nabla_{\mathrm{a}} \times \boldsymbol{B}_{\mathrm{a}}\right) = \mu_0 \nabla_{\mathrm{a}} \cdot \boldsymbol{j}_{\mathrm{a}} + \frac{1}{c^2} \frac{\partial}{\partial t_{\mathrm{a}}} \nabla_{\mathrm{a}} \cdot \boldsymbol{E}_{\mathrm{a}}$$

But the divergence of the curl of any vector is zero, and using the third equation of (7.1) and Eq. (7.5), we obtain

$$\nabla_{\mathrm{a}} \cdot \boldsymbol{j}_{\mathrm{a}} + \frac{\partial \rho_{\mathrm{a}}}{\partial t_{\mathrm{a}}} = 0 \tag{7.63}$$

This is the equation of continuity in frame Σ_{a}. Integrating Eq. (7.63) over a spatial volume V_{a} and applying Gauss' theorem, we obtain

$$\frac{\partial}{\partial t_{\mathrm{a}}} \int_{V_{\mathrm{a}}} \rho_{\mathrm{a}} \mathrm{d}V_{\mathrm{a}} = -\oint_{S_{\mathrm{a}}} \boldsymbol{j}_{\mathrm{a}} \cdot \mathrm{d}\boldsymbol{s}_{\mathrm{a}} \ , \tag{7.64}$$

where S_{a} is the closed surface enclosing the volume V_{a}. The above equation indicates that, observing in frame $u(x,t)$, any variation processes of the motion state of a charged system in any volume are unable to produce the generation and annihilation of charges, and the increase rate of charges is equal to only the charges influent through the closed surface in a unit time. This is the law of conservation of charge in frame Σ_{a}.

If the closed surface enclosing the charged system is far away from all the charges, so that no charges cross the surface, then we have

$$\frac{\partial}{\partial t_{\mathrm{a}}} \int_{V_{\mathrm{a}}} \rho_{\mathrm{a}} \mathrm{d}V_{\mathrm{a}} = 0. \tag{7.65}$$

This means that no matter how the motion state of charged system change, the total amount of the charge in the charged system remains unchanged. This is the constancy of charge in frame Σ_{a}.

So far, we have derived the law of conservation of charge and the principle of the constancy of charge in frame Σ_{a} from the first postulate. Although we derived from Maxwell's equations in vacuum, yet consider the physical picture of material is only that there is distribution of moving charges (charged particles) in vacuum background field, so the results obtained here have general meaning, ρ_{a} and $\boldsymbol{j}_{\mathrm{a}}$ should be comprehended as all distribution of charges and currents in frame Σ_{a}.

To an ordinary inertial frame Σ do the law of conservation of charge and the principle of the constancy of charge hold true? The answer is affirmative.

Starting from Eq. (7.63), using Eqs. (7.33) and (7.34) and the transformations (7.60) of charge and current density, transforming to an ordinary inertial frame Σ, we obtain

$$\left(\hat{T}\nabla\right)\cdot\left(\hat{T}^{-1}\boldsymbol{j}+\gamma\rho\boldsymbol{v}\right)+\gamma^{-1}\frac{\partial}{\partial t}(\gamma\rho)-\gamma\left(\boldsymbol{v}\cdot\nabla\right)(\gamma\rho)=0.$$

Using Eqs. (7.45), (7.37), (7.35) and (7.27), we have

$$\left(\hat{T}\nabla\right)\cdot\left(\hat{T}^{-1}\boldsymbol{j}\right)=\nabla\cdot\left[\left(\hat{T}\hat{T}^{-1}\right)\boldsymbol{j}\right]=\nabla\cdot\boldsymbol{j},$$

$$\left(\hat{T}\nabla\right)\cdot(\gamma\rho\boldsymbol{v})=\gamma\nabla\cdot\left[\hat{T}\left(\rho\boldsymbol{v}\right)\right]=\gamma^{2}\nabla\cdot(\rho\boldsymbol{v})=\gamma^{2}\boldsymbol{v}\cdot(\nabla\rho)=\gamma^{2}(\boldsymbol{v}\cdot\nabla)\rho=\gamma(\boldsymbol{v}\cdot\nabla)(\gamma\rho).$$

Then to an ordinary inertial frame Σ, we have

$$\nabla\cdot\boldsymbol{j}+\frac{\partial\rho}{\partial t}=0. \tag{7.66}$$

From Eq. (7.66) we further obtain

$$\frac{\partial}{\partial t}\int_{V}\rho\mathrm{d}V=-\oint_{S}\boldsymbol{j}\cdot\mathrm{d}\boldsymbol{s}, \tag{7.67}$$

where S is the closed surface enclosing the volume V. If the closed surface is far away from all the charges, so that no charges cross the surface, then we have

$$\frac{\partial}{\partial t}\int_{V}\rho\mathrm{d}V=0. \tag{7.68}$$

Equations (7.66)~(7.68) mean that in ordinary frames the law of conservation of charge and the principle of the constancy of charge also hold true.

Now that the law of conservation of charge and the principle of the constancy of charge hold true all to the absolute inertial frame Σ_{a} and any ordinary inertial frame Σ, whether is the third postulate in the basic postulates of the electrodynamics of Standard Space-time Theory permitted to cancel? Cannot. This is because that in the above derivations it is necessary to use the transformations (60) of charge and current density for derivation of Eq. (7.66) from Eq. (7.63), while in the derivation of the transformations (60) we already used the principle of constant charge.

The reasoning of the present section indicates that the third postulate is logically consistent with the first and the second postulate; it is proved by the first, the second and the third postulate that the law of conservation of charge holds true for any inertial frame.

7. 3. Coulomb Law and Maxwell's Equations

The fourth postulate of the electrodynamics of Standard Space-time Theory is Coulomb's law, i.e., observing in any frame, the force of interaction between two point-charges at rest in vacuum is directly proportional to the product of magnitudes of the two charges, and is inversely proportional to the square of the distance between them, and is along the direction joining the two charges. Here Coulomb's law holds true not only to the absolute inertial frame, but also to any inertial frame, as long as the two point-charges are at rest relative to the chosen frame. If Coulomb's law holds true only to the absolute inertial frame, it is not necessary to put forward it as a basic postulate, because from Maxwell's equations and the uniformity and symmetry of space-time of frame Σ_a we can derive it.

In present section, first, starting from Coulomb's law and the Lorentz force formula and using the second and the third postulate, we will find the expression of the electric field and magnetic field produced by moving charges in the absolute frame; second, we will explain that thus obtained electric field and magnetic field obeys Maxwell's equations, so that prove the fourth postulate (i.e. Coulomb's law which holds true all with respect to any the chosen inertial frame) is logically consistent with other three postulates.

7. 3. 1. The Electric Field and Magnetic Field Produced by Moving Charges in the Absolute Frame

Consider general coordinate systems of frames Σ_a and Σ, in which the ordinary inertial frame Σ moves with a uniform velocity v relative to the absolute frame Σ_a. Suppose a source charge Q and test charge q both are at rest relative to frame Σ, and are respectively located at the origin O and the point $p(x,y,z)$ of frame Σ (as shown in Fig.7.1). According Coulomb's law, observing in frame Σ, the force acting on the test charge q is

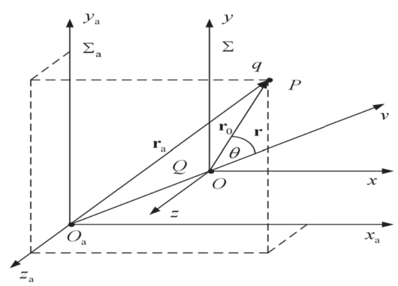


Fig.7.1

$$\boldsymbol{f} = \frac{qQ\boldsymbol{r}}{4\pi\varepsilon_0 r^3} \tag{7.69}$$

where $\boldsymbol{r}$ is the radius vector from the origin O to point P measured in frame Σ.

Using the reverse transformation (7.16) of force of Standard Space-time Theory, from Eq. (7.69) we can find the expression of force acting on the test charge q in frame $\Sigma_{\rm a}$. According to Eq. (7.16), we have

$$\boldsymbol{f}_{\rm a} = \gamma^{-1}\hat{T}\boldsymbol{f} + (\boldsymbol{f}\cdot\boldsymbol{u})\frac{\boldsymbol{v}/c^2}{1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2},$$

where $\gamma = (1-v^2/c^2)^{-1/2}$, $\boldsymbol{u}$ is the velocity of the particle acted on by force with respect to frame Σ. Here $\boldsymbol{u}$ is just the velocity of the charge q relative to frame Σ, but the charge q is at rest relative to frame Σ, that is $\boldsymbol{u} = 0$, so one has

$$\boldsymbol{f}_{\rm a} = \gamma^{-1}\hat{T}\boldsymbol{f} = \frac{qQ}{4\pi\varepsilon_0\gamma r^3}\hat{T}\boldsymbol{r}. \tag{7.70}$$

Denoting $\boldsymbol{r}$ and r^3 by the corresponding quantities in frame $\Sigma_{\rm a}$, we have

$$\boldsymbol{r} = \hat{T}(r_{\rm a} - \boldsymbol{v}t_{\rm a}) = \hat{T}(\boldsymbol{r}_0), \tag{7.71}$$

where

$$\boldsymbol{r}_0 = \boldsymbol{r}_{\rm a} - \boldsymbol{v}t_{\rm a} = (\boldsymbol{op})_{\rm a}, \tag{7.72}$$

i.e., $\boldsymbol{r}_0$ represents the radius vector from the origin O to point P measured in frame $\Sigma_{\rm a}$. Using the definition (7.19) of the operator $\hat{T}$ and Eq. (7.38), we obtain

$$\begin{aligned}\hat{T}\boldsymbol{r} &= \hat{T}(\hat{T}\boldsymbol{r}_0) = \hat{T}^2\boldsymbol{r}_0 = \boldsymbol{r}_{0\|} + \gamma^2\boldsymbol{r}_{0\|} = \gamma^2(\gamma^{-2}\boldsymbol{r}_{0\|} + \boldsymbol{r}_{0\|}) \\ &= \gamma^2\left[\left(1-\frac{v^2}{c^2}\right)\boldsymbol{r}_{0\perp} + \boldsymbol{r}_{0\|}\right] = \gamma^2\left(\boldsymbol{r}_0 - \frac{v^2}{c^2}\boldsymbol{r}_{0\perp}\right),\end{aligned} \tag{7.73}$$

$$\begin{aligned}r^3 &= (r^2)^{3/2} = (r_\perp^2 + r_\|^2)^{3/2} = (r_{0\perp}^2 + r^2 r_{0\|}^2)^{3/2} = (r_0^2\sin^2\theta + \gamma^2 r_0^2\cos^2\theta)^{3/2} \\ &= \gamma^3\left[(1-\beta^2)r_0^2\sin^2\theta + r_0^2\cos^2\theta\right]^{3/2} = \gamma^3 r_0^3(1-\beta^2\sin^2\theta)^{3/2},\end{aligned} \tag{7.74}$$

where θ is the angle between the radius vector $\boldsymbol{r}_0$ and the direction of the velocity $\boldsymbol{v}$ of the charge Q. Substituting the above two equations into Eq. (7.70), we obtain

$$\boldsymbol{f}_{\rm a} = \frac{qQ}{4\pi\varepsilon_0\gamma^2 r_0^3(1-\beta^2\sin^2\theta)^{3/2}}\left(\boldsymbol{r}_0 - \frac{v^2}{c^2}\boldsymbol{r}_{0\perp}\right).$$

Using the formula (7.32) of the triple vector product, we have

$$\boldsymbol{v}\times(\boldsymbol{v}\times\boldsymbol{r}_0) = (\boldsymbol{v}\cdot\boldsymbol{r}_0)\boldsymbol{v} - v^2\boldsymbol{r}_0 = v^2(\boldsymbol{r}_{0\|} - \boldsymbol{r}_0) = -v^2\boldsymbol{r}_{0\perp}. \tag{7.75}$$

Substituting Eq. (7.75) into the preceding formula, last, we obtain

$$\boldsymbol{f}_{\mathrm{a}}=\frac{qQ\left(1-\beta^2\right)}{4\pi\varepsilon_0 r_0^3\left(1-\beta^2\sin^2\theta\right)^{3/2}}\left[\boldsymbol{r}_0+\frac{1}{c^2}\boldsymbol{v}\times\left(\boldsymbol{v}\times\boldsymbol{r}_0\right)\right]. \tag{7.76}$$

In frame Σ_{a} two charges Q and q move with the velocity $\boldsymbol{v}$. Eq. (7.76) is the expression of the force acting on charge q by the electromagnetic field produced due to another charge Q. It is obtained from Coulomb's law in frame Σ and through the reverse transformation of force in Standard Space-time Theory. But, on the other hand, the Lorentz force formula (7.2) has given the force acting on a moving charge in frame Σ_{a} by electromagnetic field

$$\boldsymbol{f}_{\mathrm{a}}=q\left(\boldsymbol{E}_{\mathrm{a}}+\boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}\right). \tag{7.77}$$

Comparing Eqs. (7.76) and (7.77), we obtain

$$\boldsymbol{E}_{\mathrm{a}}=\frac{Q\left(1-\beta^2\right)\boldsymbol{r}_0}{4\pi\varepsilon_0 r_0^3\left(1-\beta^2\sin^2\theta\right)^{3/2}}, \tag{7.78}$$

$$\boldsymbol{B}_{\mathrm{a}}=\frac{\mu_0 Q\left(1-\beta^2\right)\boldsymbol{v}\times\boldsymbol{r}_0}{4\pi r_0^3\left(1-\beta^2\sin^2\theta\right)^{3/2}}=\frac{1}{c^2}\boldsymbol{v}\times\boldsymbol{E}_{\mathrm{a}}. \tag{7.79}$$

These are the expression of the electric field intensity and magnetic induction intensity produced by moving source charge Q at an arbitrary spatial point P in frame Σ_{a}.

7. 3. 2. General Case: Multi Source Charges

According to the general viewpoint of electromagnetism, the electromagnetic field at a spatial point is produced by all charges and motions of charges in the environmental space, and the variation of the electromagnetic field in the neighborhood. The environmental space can extend to very large as to infinite range. If the electromagnetic field which can propagate in space (i.e., electromagnetic wave) does not form, then the farther away a charge is from the observed point, the less the influences to the electromagnetic field at the observed point is. If electromagnetic wave is formed to propagate in space, then charges and motions of charges in far-off position are able to have influence (even very great influence) over the electromagnetic field at the observed point. But this later influence can come to the variation of the electric field and magnetic field in the neighborhood with time. Hence it can be said that the electromagnetic field at a spatial point dependent on the charges and the motions of charges in the neighborhood of the point, and variation of the electric field and magnetic field in the neighborhood with time.

We first consider source charges in the neighborhood of a point and their motions.

Suppose the electromagnetic field $\boldsymbol{E}_{\mathrm{a}}$ and $\boldsymbol{B}_{\mathrm{a}}$ are produced by multi source charges Q_i $\left(i=1,2,3,\cdots\right)$, which are respectively located at $O_i\left(i=1,2,3,\cdots\right)$, and move respectively with velocity $\boldsymbol{v}_i\left(i=1,2,3,\cdots\right)$ relative to frame Σ_{a}. Under the circumstances, the electric field and magnetic field at the observed point P produced by Q_i

$$\boldsymbol{E}_{\mathrm{a}i}=\frac{Q_i\left(1-\beta_i^2\right)\boldsymbol{r}_{0i}}{4\pi\varepsilon_0 r_{0i}^3\left(1-\beta_i^2\sin^2\theta_i\right)^{3/2}},\quad \boldsymbol{B}_{\mathrm{a}i}=\frac{\mu_0 Q_i\left(1-\beta_i^2\right)\boldsymbol{v}_i\times\boldsymbol{r}_{0i}}{4\pi r_{0i}^3\left(1-\beta_i^2\sin^2\theta_i\right)^{3/2}}=\frac{1}{c^2}\boldsymbol{v}_i\times\boldsymbol{E}_{\mathrm{a}i},$$

where $\boldsymbol{r}_{0i}$ is the radius vector from O_i to point P measured in frame Σ_{a}, θ_i is the angle between the vector radius $\boldsymbol{r}_{0i}$ and the direction of the velocity $\boldsymbol{v}_i$ of the charge Q_i measured in frame Σ_{a}, and $\beta_i=v_i/c$.

According to the superposition principle of field intensity, the total field intensity

$$\boldsymbol{E}_{\mathrm{a}}=\sum_i\boldsymbol{E}_{\mathrm{a}i}=\sum_i\frac{Q_i\left(1-\beta_i^2\right)\boldsymbol{r}_{0i}}{4\pi\varepsilon_0 r_{0i}^3\left(1-\beta_i^2\sin^2\theta_i\right)^{3/2}},\tag{7.80}$$

$$\boldsymbol{B}_{\mathrm{a}}=\sum_i\boldsymbol{B}_{\mathrm{a}i}=\sum_i\frac{\mu_0 Q_i\left(1-\beta_i^2\right)\boldsymbol{v}_i\times\boldsymbol{r}_{0i}}{4\pi r_{0i}^3\left(1-\beta_i^2\sin^2\theta_i\right)^{3/2}}=\sum_i\frac{1}{c^2}\boldsymbol{v}_i\times\boldsymbol{E}_{\mathrm{a}i}.\tag{7.81}$$

And we still have

$$\boldsymbol{f}_{\mathrm{a}}=q\left(\boldsymbol{E}_{\mathrm{a}}+\boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{B}_{\mathrm{a}}\right),$$

where $\boldsymbol{u}_{\mathrm{a}}$ is the moving velocity of the test charge q relative to frame Σ_{a}.

7. 3. 3. Consistency between Coulomb's Law and the Front Three Postulates

Are Coulomb's law which holds true to any inertial frame (the fourth postulate) consistent with the front three postulates (especially Maxwell's equations)? This is a problem to need to discuss. Starting from Coulomb's law and the Lorentz force formula and using the second and the third postulate, we have found the expressions (7.78) and (7.79) of the electric field and magnetic field produced by moving charges in the absolute frame; and further have obtained the expressions (7.80) and (7.81) of the electric field and magnetic field produced by multi moving source charges. Next, we prove that thus obtained electric field and magnetic field satisfy Maxwell's equations.

First, we demonstrate and calculate for the case of a single source charge. For that, we use the space-time coordinates $\left(x_{\mathrm{a}},y_{\mathrm{a}},z_{\mathrm{a}},t_{\mathrm{a}}\right)$ of frame Σ_{a} to denote Eqs. (7.78) and (7.79). For simplicity, choose two specific inertial coordinates systems Σ_{a} and Σ, ,frame Σ with respect to Σ_{a} moves at a constant velocity $\boldsymbol{v}$ along positive x_{a} axis of the frame Σ_{a} (Fig.7.2). In this case, we have

$$\boldsymbol{r}_0=\left(x_{\mathrm{a}}-vt_{\mathrm{a}}\right)\boldsymbol{i}+y_{\mathrm{a}}\boldsymbol{j}+z_{\mathrm{a}}\boldsymbol{k}.\tag{7.82}$$

By Eq. (7.74)

$$\begin{aligned}r_0^3\left(1-\beta^2\sin^2\theta\right)^{3/2}&=\gamma^{-3}\left(r_0^2\sin^2\theta+\gamma^2 r_0^2\sin^2\theta\right)^{3/2}\\&=\gamma^{-3}\left[\gamma^2\left(x_{\mathrm{a}}-vt_{\mathrm{a}}\right)^2+y_{\mathrm{a}}+z_{\mathrm{a}}^2\right]^{3/2}.\end{aligned}\tag{7.83}$$

Substituting the above two formulas into Eq. (7.78) or (7.79), we obtain

$$\boldsymbol{E}_{\mathrm{a}}=\frac{Q\gamma\left[\left(x_{\mathrm{a}}-vt_{\mathrm{a}}\right)\boldsymbol{i}+y_{\mathrm{a}}\boldsymbol{j}+z_{\mathrm{a}}\boldsymbol{k}\right]}{4\pi\varepsilon_0\left[\gamma^2\left(x_{\mathrm{a}}-vt_{\mathrm{a}}\right)^2+y_{\mathrm{a}}^2+z_{\mathrm{a}}^2\right]^{3/2}},\tag{7.84}$$

$$\boldsymbol{B}_{\mathrm{a}}=\frac{1}{c^2}\boldsymbol{v}\times\boldsymbol{E}_{\mathrm{a}}=\frac{\mu_0 Q\gamma\left[-z_{\mathrm{a}}\boldsymbol{j}+y_{\mathrm{a}}\boldsymbol{k}\right]}{4\pi\left[\gamma^2\left(x_{\mathrm{a}}-vt_{\mathrm{a}}\right)^2+y_{\mathrm{a}}^2+z_{\mathrm{a}}^2\right]^{3/2}}.\tag{7.85}$$

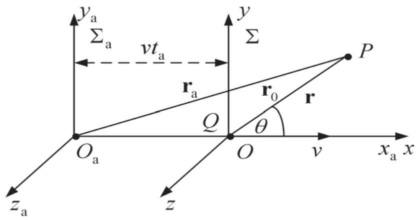


Fig. 7.2

Starting from the above two formulas, calculating $\nabla_{\mathrm{a}}\times\boldsymbol{E}_{\mathrm{a}}, \nabla_{\mathrm{a}}\times\boldsymbol{B}_{\mathrm{a}}, \nabla_{\mathrm{a}}\cdot\boldsymbol{B}_{\mathrm{a}}$ according to the expressions of the curl and divergence of vector, and calculating by differentiation $\partial\boldsymbol{B}_{\mathrm{a}}/\partial t_{\mathrm{a}}$ and $\partial\boldsymbol{E}_{\mathrm{a}}/\partial t_{\mathrm{a}}$, it is to prove easily that

$$\nabla_{\mathrm{a}}\times\boldsymbol{E}_{\mathrm{a}}=-\frac{\partial\boldsymbol{B}_{\mathrm{a}}}{\partial t_{\mathrm{a}}},\tag{7.86}$$

$$\nabla_{\mathrm{a}}\cdot\boldsymbol{B}_{\mathrm{a}}=0,\tag{7.87}$$

i.e., $\boldsymbol{E}_{\mathrm{a}}$ and $\boldsymbol{B}_{\mathrm{a}}$ satisfy the first equation and the fourth equation of Maxwell's equations.

On the curl and divergence of $\boldsymbol{B}_{\mathrm{a}}$, by the above calculation we obtain

$$\nabla_{\mathrm{a}}\times\boldsymbol{B}_{\mathrm{a}}=\varepsilon_0\mu_0\frac{\partial\boldsymbol{E}_{\mathrm{a}}}{\partial t_{\mathrm{a}}}.\tag{7.88}$$

Compared with Eq. (7.1), in the right of Eq. (7.88) there is no term $\mu_0\boldsymbol{j}_{\mathrm{a}}$. This is because that the problem here is related only to the source charge rather than electric current. For this the probable disproval is that the moving charges or the motion of charges are just electric current. Yes. But the moving charges create magnetic field, in practice, in the final analysis this is should that the moving charges create a changing electric field, while the changing electric field create magnetic field. So, if in the right of the second equation of Maxwell's equations one has wrote down the term of changing electric field, then one cannot any longer write down the term of moving charges. Hence the obtained Eq. (7.88) is not contradictory with the second equation of Maxwell's equations (7.1).

Equations (7.86) —(7.88) all hold true to the electric field $\boldsymbol{E}_{\mathrm{a}i}$ and magnetic field $\boldsymbol{B}_{\mathrm{a}i}$ produced by every source charge $Q_i\left(i=1, 2, 3,\cdots\right)$, so the lefts and the rights of these equations are respectively summed over all source charges, then we have

$$\left.\begin{aligned}
&\nabla_{\mathrm{a}}\times\Sigma\boldsymbol{E}_{\mathrm{a}i}=-\frac{\partial\Sigma\boldsymbol{B}_{\mathrm{a}i}}{\partial t_{\mathrm{a}}}, &&\text{or}\quad \nabla_{\mathrm{a}}\times\boldsymbol{E}_{\mathrm{a}}=-\frac{\partial\boldsymbol{B}_{\mathrm{a}}}{\partial t_{\mathrm{a}}},\\
&\nabla_{\mathrm{a}}\cdot\Sigma\boldsymbol{B}_{\mathrm{a}i}=0, &&\text{or}\quad \nabla_{\mathrm{a}}\cdot\boldsymbol{B}_{\mathrm{a}}=0,\\
&\nabla_{\mathrm{a}}\times\Sigma\boldsymbol{B}_{\mathrm{a}i}=\varepsilon_0\mu_0\frac{\partial\Sigma\boldsymbol{E}_{\mathrm{a}i}}{\partial t_{\mathrm{a}}}, &&\text{or}\quad \nabla_{\mathrm{a}}\times\boldsymbol{B}_{\mathrm{a}}=\varepsilon_0\mu_0\frac{\partial\boldsymbol{E}_{\mathrm{a}}}{\partial t_{\mathrm{a}}}.
\end{aligned}\right\}\qquad(7.89)$$

where $\boldsymbol{E}_{\mathrm{a}}$ and $\boldsymbol{B}_{\mathrm{a}}$ in the right equations are shown as Eqs. (7.80) and (7.81). These just prove that in the case of multi-source charge $\boldsymbol{E}_{\mathrm{a}}$ and $\boldsymbol{B}_{\mathrm{a}}$ satisfy the first equation, the second equation and the fourth equation of Maxwell's equations.

Finally, we find the divergence of the electric field $\boldsymbol{E}_{\mathrm{a}}$. The calculation of $\nabla_{\mathrm{a}}\cdot\boldsymbol{E}_{\mathrm{a}}$ starting from Eq. (7.84) is related to the operation of δ function. We prefer that directly starting from Eq. (7.78) to calculate the integral of $\boldsymbol{E}_{\mathrm{a}}$ over an arbitrary closed surface S

$$\oint_s \boldsymbol{E}_{\mathrm{a}}\cdot\mathrm{d}\boldsymbol{s}_{\mathrm{a}}=\frac{Q}{4\pi\varepsilon_0}\oint\frac{\left(1-\beta^2\right)\boldsymbol{r}_0\cdot\mathrm{d}\boldsymbol{s}_{\mathrm{a}}}{r_0^3\left(1-\beta^2\sin^2\theta\right)^{3/2}}.\qquad(7.90)$$

If Q is inside the closed surface S, as shown in Fig.7.3, then the solid angle of $\mathrm{d}\boldsymbol{s}_{\mathrm{a}}$ to the point charge Q

$$\mathrm{d}\Omega=\frac{\boldsymbol{r}\cdot\mathrm{d}\boldsymbol{s}_{\mathrm{a}}}{r^3}=\frac{\mathrm{d}s_{\mathrm{a}0}}{1},\qquad(7.91)$$

$$\oint_s\frac{\left(1-\beta^2\right)r\cdot\mathrm{d}s_{\mathrm{a}}}{r^3\left(1-\beta^2\sin^2\theta\right)^{3/2}}=\oint_{s_0}\frac{\left(1-\beta^2\right)\mathrm{d}s_{\mathrm{a}0}}{\left(1-\beta^2\sin^2\theta\right)^{3/2}}$$

$$=\int_0^{2\pi}\int_0^{\pi}\frac{\left(1-\beta^2\right)\sin\theta\,\mathrm{d}\varphi\,\mathrm{d}\theta}{\left[1-\beta^2\left(1-\cos^2\theta\right)\right]^{3/2}}=\int_0^{\pi}\frac{-2\pi\left(1-\beta^2\right)\mathrm{d}\left(\beta cos\theta\right)}{\beta\left[\left(1-\beta^2\right)+\beta^2\cos^2\theta\right]^{3/2}}.$$

Let $x=\beta\cos\theta$, we have

$$\oint\frac{\left(1-\beta^2\right)\boldsymbol{r}\cdot\mathrm{d}\boldsymbol{s}_{\mathrm{a}}}{r^3\left(1-\beta^2\sin^2\theta\right)^{3/2}}=-\frac{2\pi\left(1-\beta^2\right)}{\beta}\int_{\beta}^{-\beta}\frac{\mathrm{d}x}{\left[\left(1-\beta^2\right)+x^2\right]^{3/2}}$$

$$=-\frac{2\pi\left(1-\beta^2\right)}{\beta}\left[\frac{x}{\left(1-\beta^2\right)\left(1-\beta^2+x^2\right)^{1/2}}\right]_{\beta}^{-\beta}=4\pi.$$

Substituting the above equation into Eq. (7.90), we obtain

$$\oint_s\boldsymbol{E}_{\mathrm{a}}\cdot\mathrm{d}\boldsymbol{s}_{\mathrm{a}}=Q/\varepsilon_0\quad(Q\text{ is inside }S)$$

If Q is not inside the closed surface S, as shown in Fig.7.3, then the solid angle of the closed surface S to the point charge Q is zero, and we easily obtain

$$\oint\boldsymbol{E}_{\mathrm{a}}\cdot\mathrm{d}\boldsymbol{s}_{\mathrm{a}}=0.\quad(Q\text{ is outside }S)$$

If consider the general case of the multi-source charges $Q_i\left(i=1,2,3,\cdots\right)$, then we first

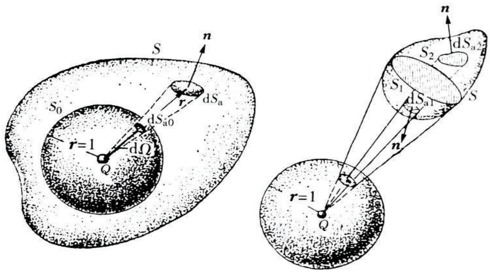


Fig. 7.3

apply the above two equations to every source charge Q_i, afterward according to the superposition principle of field intensity, that is $\boldsymbol{E}_{\mathrm{a}} = \Sigma \boldsymbol{E}_{\mathrm{a}i}$, we obtain

$$\oint_s \boldsymbol{E}_{\mathrm{a}} \cdot \mathrm{d}\boldsymbol{s}_{\mathrm{a}} = \frac{1}{\varepsilon_0}\Sigma Q_i = \frac{1}{\varepsilon_0}\int_v \rho_{\mathrm{a}} \mathrm{d}V_{\mathrm{a}}, \qquad (7.92)$$

where S represents an arbitrary closed surface in frame Σ_{a}, V represents a volume enclosed by S, ΣQ_i represents the algebraic sum of the charges enclosed by the surface S.

Applying Gauss' theorem, from Eq. (7.92) we at once obtain that $\boldsymbol{E}_{\mathrm{a}}$ satisfy Maxwell's equation

$$\nabla_{\mathrm{a}} \cdot \boldsymbol{E}_{\mathrm{a}} = \rho_{\mathrm{a}} / \varepsilon_0. \qquad (7.93)$$

So far, we have completely proved that starting from Coulomb's law and the Lorentz force formula and using the second and the third postulate, thus obtained electric field and magnetic field produced by source charges satisfy Maxwell's equations. Hence Coulomb's law which holds true to any inertial frame is logically consistent with the front three basic postulates.

7. 4. The Force on Moving Charge by Electromagnetic Field in Ordinary Inertial Frame. The Transformations of *E* and *B*

7. 4. 1. The Force on Moving Charge by Electromagnetic Field in Ordinary Inertial Frame

Consider two general inertial coordinates systems Σ_{a} and Σ, frame Σ moves at a constant velocity $\boldsymbol{v}$ with respect to frame Σ_{a}. Suppose at a certain time a source charge Q is located at the origin of frame Σ and a test charge q is located at a point P, it's moving velocities relative to frame Σ_{a} and frame Σ are respectively $\boldsymbol{u}_{\mathrm{a}}$ and $\boldsymbol{u}$ (cf. Fig.7.1, but here the charge q is moving with respect to frame Σ_{a} and frame Σ).

If $\boldsymbol{u}_{\mathrm{a}} = \boldsymbol{v}$, then the source charge Q and test charge q both are at rest relative to each other and relative to frame Σ. This is the case discussed in the above section. According Coulomb's law, observing in frame Σ, the force acting on the test charge q at rest is (to attach subscript r to denote the rest to distinguish the force acting on the moving test charge)

$$\boldsymbol{f}_{\mathrm{r}} = \frac{qQ\boldsymbol{r}}{4\pi\varepsilon_0 r^3},$$

where $\boldsymbol{r}$ is the radius vector from the charge Q and to test charge measured in frame Σ. According to electromagnetism, the electric field intensity at given point in frame Σ is defined to be the force per unit positive charge when the charge is placed at that point and is at rest relative to frame Σ, that is

$$\boldsymbol{E} = \frac{\boldsymbol{f}_{\mathrm{r}}}{q} = \frac{Q\boldsymbol{r}}{4\pi\varepsilon_0 r^3}, \tag{7.94}$$

$$\boldsymbol{f}_{\mathrm{r}} = q\boldsymbol{E}. \tag{7.95}$$

If $\boldsymbol{u}_{\mathrm{a}} \neq \boldsymbol{v}$, then there is the relative motion between the charges Q and q. This is general case. Observing in frame Σ, is the force acting on the moving test charge different from that at rest? We do not answer for the moment, and write the force acting on the moving test charge in this case as

$$\boldsymbol{f}_{\mathrm{e}} = a(\boldsymbol{v},\boldsymbol{u})\frac{qQ\boldsymbol{r}}{4\pi\varepsilon_0 r^3}. \tag{7.96}$$

This is means that when $\boldsymbol{u}_{\mathrm{a}} = \boldsymbol{v}$, we definitely have $a(\boldsymbol{v},\boldsymbol{u}) = 1$; when $\boldsymbol{u}_{\mathrm{a}} \neq \boldsymbol{v}$, then $a(\boldsymbol{v},\boldsymbol{u}) = 1$ is not probably equal to 1. Even if when $\boldsymbol{u}_{\mathrm{a}} \neq \boldsymbol{v}$, $a(\boldsymbol{v},\boldsymbol{u})$ is not equal to 1, this is contradictory with the definition (7.94) of the electric field intensity $\boldsymbol{E}$. But, from Eqs. (7.94) and (7.96), the force acting on the moving test charge will become

$$\boldsymbol{f}_{\mathrm{e}} = a(\boldsymbol{v},\boldsymbol{u})q\boldsymbol{E}. \tag{7.97}$$

How do we determine the factor a ? By the inverse transformation equation (7.16) of force, we transform the expression (7.96) the force acting on the moving test charge q in frame Σ into the expression of the force acting on the moving test charge q in frame Σ_{a}; and substitute the obtained expression into the expression (7.78) and (7.79) of the electric field intensity and magnetic induction intensity produced by moving source charge Q in frame Σ_{a}, then compare them with the Lorentz force formula, last can find the factor a.

Substituting Eq. (7.96) into the transformation equation (7.16) of force, we obtain

$$\boldsymbol{f}_{\mathrm{a}} = \frac{aqQ\gamma}{4\pi\varepsilon_0 r^3\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)}\left[\frac{1}{\gamma^2}\left(1-\frac{\boldsymbol{u}\cdot\boldsymbol{v}}{c^2}\right)\hat{T}\boldsymbol{r} + \frac{1}{\gamma c^2}(\boldsymbol{u}\cdot\boldsymbol{r})\boldsymbol{v}\right]. \tag{7.98}$$

Using Eqs. (7.73), (7.74) and (6.59), namely

$$\hat{T}\boldsymbol{r} = \gamma^2\left[\boldsymbol{r}_0 - \left(v^2/c^2\right)\boldsymbol{r}_{0\perp}\right], \qquad r^3 = \gamma^3 r_0^3\left(1-\beta^2\sin^2\theta\right)^{3/2},$$

$$1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2=\gamma^2\left(1-\boldsymbol{u}_{\rm a}\cdot\boldsymbol{v}/c^2\right), \tag{7.99}$$

and

$$\frac{\gamma^2}{c^2}=\frac{\gamma^2-1}{v^2}, \quad \frac{\gamma^2}{c^2}v^2=\gamma^2-1, \tag{7.100}$$

and the transformations (7.13)、(7.71) of $\boldsymbol{u}$ and $\boldsymbol{r}$, we obtain

$$\frac{1}{\gamma^2}\left(1-\frac{\boldsymbol{u}\cdot\boldsymbol{v}}{c^2}\right)\hat{T}\boldsymbol{r}=\gamma^2\left(1-\frac{\boldsymbol{u}_{\rm a}\cdot\boldsymbol{v}}{c^2}\right)\left(\boldsymbol{r}_0-\frac{v^2}{c^2}\boldsymbol{r}_{0\perp}\right)$$

$$=\gamma^2\boldsymbol{r}_0-\gamma^2\frac{v^2}{c^2}\boldsymbol{r}_{0\perp}-\frac{\gamma^2}{c^2}(\boldsymbol{u}_{\rm a}\cdot\boldsymbol{v})\boldsymbol{r}_0+\gamma^2\frac{v^2}{c^4}(\boldsymbol{u}_{\rm a}\cdot\boldsymbol{v})\boldsymbol{r}_{0\perp}$$

$$=\gamma^2\boldsymbol{r}_0-\left(\gamma^2-1\right)\boldsymbol{r}_{0\perp}-\frac{\gamma^2}{c^2}(\boldsymbol{u}_{\rm a}\cdot\boldsymbol{v})\boldsymbol{r}_0+\frac{\gamma^2-1}{c^2}(\boldsymbol{u}_{\rm a}\cdot\boldsymbol{v})\boldsymbol{r}_{0\perp}$$

$$=\gamma^2\boldsymbol{r}_{0\parallel}+\boldsymbol{r}_{0\perp}-\frac{\gamma^2}{c^2}(\boldsymbol{u}_{\rm a}\cdot\boldsymbol{v})\boldsymbol{r}_{0\parallel}-\frac{1}{c^2}(\boldsymbol{u}_{\rm a}\cdot\boldsymbol{v})\boldsymbol{r}_{0\perp},$$

$$\frac{1}{\gamma c^2}(\boldsymbol{u}\cdot\boldsymbol{r})\boldsymbol{v}=\frac{1}{c^2}\boldsymbol{v}\left[\hat{T}(\boldsymbol{u}_{\rm a}-\boldsymbol{v})\right]\cdot\left(\hat{T}\boldsymbol{r}_0\right)=\frac{1}{c^2}\boldsymbol{v}\left[\hat{T}(\boldsymbol{u}_{\rm a}-\boldsymbol{v})\cdot\left(\hat{T}^2\boldsymbol{r}_0\right)\right]$$

$$=c^{-2}\boldsymbol{v}\left\{(\boldsymbol{u}_{\rm a}-\boldsymbol{v})\cdot\left[\boldsymbol{r}_0+\left(\gamma^2-1\right)\boldsymbol{r}_{0\parallel}\right]\right\}$$

$$=c^{-2}(\boldsymbol{u}_{\rm a}\cdot\boldsymbol{r}_0)\boldsymbol{v}-\frac{v^2}{c^2}\boldsymbol{r}_{0\parallel}+c^{-2}\left(\gamma^2-1\right)(\boldsymbol{u}_{\rm a}\cdot v)\boldsymbol{r}_{0\parallel}-c^{-2}v^2\left(\gamma^2-1\right)\boldsymbol{r}_{0\parallel}$$

$$=c^{-2}v^2(\boldsymbol{u}_{\rm a}\cdot\boldsymbol{r}_0)\boldsymbol{v}+\left(1-\gamma^2\right)\boldsymbol{r}_{0\parallel}+c^{-2}v^2\left(\gamma^2-1\right)(\boldsymbol{u}_{\rm a}\cdot v)\boldsymbol{r}_{0\parallel}$$

$$=c^{-2}v^2(\boldsymbol{u}_{\rm a}\cdot\boldsymbol{r}_0)\boldsymbol{v}-\frac{v^2}{c^2}\boldsymbol{r}_{0\parallel}+c^{-2}v^2\left(\gamma^2-1\right)(\boldsymbol{u}_{\rm a}\cdot v)\boldsymbol{r}_{0\parallel}-c^{-2}v^2\left(\gamma^2-1\right)\boldsymbol{r}_{0\parallel}$$

$$=\frac{1}{c^2}(\boldsymbol{u}_{\rm a}\cdot\boldsymbol{r}_0)\boldsymbol{v}+\left(1-\gamma^2\right)\boldsymbol{r}_{0\parallel}+\frac{1}{c^2}\left(\gamma^2-1\right)(\boldsymbol{u}_{\rm a}\cdot v)\boldsymbol{r}_{0\parallel}.$$

Substituting Eqs. (7.74), (7.99) and the above two equations into Eq. (7.98) we obtain

$$\boldsymbol{f}_{\rm a}=\frac{aqQ\left(1-\beta^2\right)^2}{4\pi\varepsilon_0 r_0^3\left(1-\beta^2\sin^2\theta\right)^{3/2}\left(1-\boldsymbol{u}_{\rm a}\cdot\boldsymbol{v}/c^2\right)}\left\{\boldsymbol{r}_0+\frac{1}{c^2}\left[(\boldsymbol{u}_{\rm a}\cdot\boldsymbol{r}_0)\boldsymbol{v}-(\boldsymbol{u}_{\rm a}\cdot\boldsymbol{v})\boldsymbol{r}_0\right]\right\}$$

$$=\frac{aqQ\left(1-\beta^2\right)^2}{4\pi\varepsilon_0 r_0^3\left(1-\beta^2\sin^2\theta\right)^{3/2}\left(1-\boldsymbol{u}_{\rm a}\cdot\boldsymbol{v}/c^2\right)}\left[\boldsymbol{r}_0+\frac{1}{c^2}u_{\rm a}\times(\boldsymbol{v}\times\boldsymbol{r}_0)\right],$$

where the derivation of the second sign of equality has applied the formula (7.32) of triple vector product.

Substituting the expression (7.78) and (7.79) of the electric field intensity and magnetic induction intensity produced by moving source charge Q in frame $\Sigma_{\rm a}$ into the above equation, we obtain

$$\boldsymbol{f}_{\mathrm{a}}=\frac{a\left(1-\beta^{2}\right)}{1-\boldsymbol{u}_{\mathrm{a}}\cdot\boldsymbol{v}/c^{2}}q\left(\boldsymbol{E}_{\mathrm{a}}+\boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{B}_{\mathrm{a}}\right). \qquad (7.101)$$

Comparing Eq. (7.101) with the Lorentz force (7.2), and using (6.49), we finally obtain

$$a\left(\boldsymbol{v}\cdot\boldsymbol{u}_{\mathrm{a}}\right)=\frac{1-\boldsymbol{u}_{\mathrm{a}}\cdot\boldsymbol{v}/c^{2}}{1-\beta^{2}}=1-\boldsymbol{u}\cdot\boldsymbol{v}/c^{2}. \qquad (7.102)$$

Substituting the above equation into Eq. (7.97), we obtain the force on a moving charge by electromagnetic field in any ordinary inertial frame

$$\boldsymbol{f}_{\mathrm{e}}=qa\boldsymbol{E}=q\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^{2}\right)\boldsymbol{E}. \qquad (7.103)$$

Obviously, when the velocity of the moving charge $\boldsymbol{u}=0$, i.e. it is at rest relative to frame Σ and to the source charge, we obtain $a=1$, $\boldsymbol{f}_{\mathrm{e}}=\boldsymbol{f}_{\mathrm{r}}=q\boldsymbol{E}$, and return to Eq. (7.95).

In relativistic electromagnetism, the force acting on the moving charge by electrostatic field is the same with the force acting on the rest charge by electrostatic field, all are determined by the same formula, in other words, the force acting on a charge due to electrostatic field is independent of the velocity of this charge. It was generally thought that this conclusion was validated by the experiment of electron-beam deflection through the electrostatic field in the middle of the two rest and parallel charged plates of oscilloscope.

Obviously, Eq. (7.103) of Standard Space-time Theory indicates that the above conclusion is valid only to the absolute reference frame $(\boldsymbol{v}=0)$, while in ordinary inertial frames the force acting on a charge due to electrostatic field is related with the characteristic velocity $\boldsymbol{v}$ of the inertial frame and the velocity $\boldsymbol{u}$ of this charge. As to this, it is necessary to give following two explanations. First, the difference $-\boldsymbol{u}\cdot\boldsymbol{v}/c^{2}$ between the factor a of $\boldsymbol{f}_{\mathrm{a}}$ and 1 is so infinitely small that exceed out of the limits of precision of the present experiments. Second, the time interval, velocity, acceleration and force measured by synchronizing clocks at different places according to the method described by Standard Space-time Theory are necessarily different from the results measured according to the postulate of the constancy of the one-way speed of light of the special theory of relativity. It is able prove that the differences between Standard Space-time Theory and the special theory of relativity denoted by Eq. (7.103) are inevitable, otherwise it is not comprehensible.

We derived Eq. (7.103) in the case of a static electric field generated by a single rest source charge. It is easy to prove that the electrostatic field generated by multiple rest source charges also obeys the same law. Moreover, Eq. (7.103) can be generalized to general electric fields, that is, it is generally true. What is the basis for this promotion? Here we quote a passage from E.M. Purcell's book [1]:

"That is all very well for the particularly simple arrangement of charges here pictured; do our conclusions have more general validity? This question takes us to the heart of the meaning of field. If the electric field $\boldsymbol{E}$ at a point in space-time is to have a unique meaning, then the way $\boldsymbol{E}$ appears in other frames of reference, in the same space-time neighborhood, cannot depend on the nature of the sources, wherever they may be, that produced $\boldsymbol{E}$. In other words, the observer in F having measured the field in his neighborhood at some time, ought to be able to predict from these measurements alone what observers in other frames of reference would measure at the same space-time point. Where this not true, field would be a useless concept."

It is follows to discuss the force acting on moving charge due to magnetic field $\boldsymbol{B}$. The answer of this problem still needs to follow the definition of $\boldsymbol{B}$ given by electromagnetism. According to electromagnetism, in any inertial reference frame the magnetic induction intensity $\boldsymbol{B}$ is defined by

$$\boldsymbol{f}_{\mathrm{m}} = q\boldsymbol{u}\times\boldsymbol{B}, \tag{7.104}$$

where $\boldsymbol{u}$ is the velocity of the test charge q. We should not change this definition. Otherwise, we have not a definite object to discuss.

Combining Eq. (7.103) and Eq. (7.104), we obtain the force acting on a moving charge by electromagnetic field in an ordinary inertial frame

$$\boldsymbol{f} = \boldsymbol{f}_{\mathrm{e}} + \boldsymbol{f}_{\mathrm{m}} = q\left[\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)\boldsymbol{E} + \boldsymbol{u}\times\boldsymbol{B}\right]. \tag{7..105}$$

This is a formula obviously different from the Lorentz force formula.

7. 4. 2. The transformations of *E* and *B*

Once the Lorentz force formulas and the force on charge by electromagnetic field in an ordinary inertial frame have be determined, then the transformations of the electric field and magnetic field in frame Σ_{a} and in an ordinary inertial frame Σ are determined.

Suppose a charge q acted on by electromagnetic field is at rest relative to frame Σ, which moves at velocity $\boldsymbol{v}$ relative to frame Σ_{a}. According to the definition of the electric field intensity $\boldsymbol{E}$ given by electromagnetism, we obtain

$$\boldsymbol{E} = \boldsymbol{f}_{\mathrm{r}}/q\ ,\quad \boldsymbol{f}_{\mathrm{r}} = q\boldsymbol{E}, \tag{7.106}$$

where $\boldsymbol{f}$ to attach subscript r denotes the force acting on the rest charge.

According to the transformation (7.15) of force and the Lorentz force formula (7.2), noticing $\boldsymbol{u}_{\mathrm{a}}$ in them represents the velocity of charge acted on by electromagnetic field relative to frame Σ_{a}, here $\boldsymbol{u}_{\mathrm{a}} = \boldsymbol{v}$, we obtain

$$\boldsymbol{f}_{\mathrm{r}} = \gamma\hat{T}\boldsymbol{f}_{\mathrm{a}} - \gamma^2\left(\boldsymbol{f}_{\mathrm{a}}\cdot\boldsymbol{v}\right)\boldsymbol{v}/c^2 = \gamma\hat{T}\left[q\left(\boldsymbol{E}_{\mathrm{a}} + \boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}\right)\right] - \left(\gamma^2/c^2\right)q\boldsymbol{v}\left[\boldsymbol{v}\cdot\left(\boldsymbol{E}_{\mathrm{a}} + \boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}\right)\right].$$

Using the definition (7.17) of the operator $\hat{T}$ and Eq. (7.36), we can find

$$\boldsymbol{f}_{\mathrm{r}} = q\gamma\left[\boldsymbol{E}_{\mathrm{a}} + (\gamma-1)\boldsymbol{E}_{\mathrm{a}\parallel} - \gamma\left(v^2/c^2\right)\boldsymbol{E}_{\mathrm{a}\parallel} + \boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}\right] = q\gamma\left[\boldsymbol{E}_{\mathrm{a}} + \left(\gamma-1\right)\boldsymbol{E}_{\mathrm{a}\parallel} + \boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}\right],$$

i.e.

$$\boldsymbol{f}_{\mathrm{r}} = q\left(\gamma\hat{T}^{-1}\boldsymbol{E}_{\mathrm{a}} + \gamma\boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}\right). \tag{7.107}$$

Comparing the above equation with Eq. (106), we obtain the transformation of the electric field intensity $\boldsymbol{E}$ as follows

$$\boldsymbol{E}=\gamma\left(\hat{T}^{-1}\boldsymbol{E}_{\mathrm{a}}+\boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}\right). \tag{7.108}$$

To find the inverse transformation of $\boldsymbol{E}$, it is necessary to find the transformation of $\boldsymbol{B}$. In fact, once that the formulas of the force acted on a moving charge by electromagnetic field in the frame Σ_{a} and in the ordinary frame Σ, i.e. the Lorentz force formula (7.2) and our formula (7.105) have be determined, then we can find the transformation of $\boldsymbol{B}$ from the transformation of force.

The first, from Eq. (7.105) we obtain

$$\boldsymbol{u}\times\boldsymbol{B}=\left(\boldsymbol{f}/q\right)-\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^{2}\right)\boldsymbol{E}. \tag{7.109}$$

From the transformation (7.15) of force, the Lorentz force formula (7.2) and the inverse velocity transformation equation (7.14), we obtain

$$\begin{aligned}\boldsymbol{f}/q&=\left[\gamma\hat{T}\boldsymbol{f}_{\mathrm{a}}-\gamma^{2}\left(\boldsymbol{f}_{\mathrm{a}}\cdot\boldsymbol{u}_{\mathrm{a}}\right)\boldsymbol{v}/c^{2}\right]/q=\gamma\hat{T}\left(\boldsymbol{E}_{\mathrm{a}}+\boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{B}_{\mathrm{a}}\right)-\gamma^{2}\left(\boldsymbol{E}_{\mathrm{a}}\cdot\boldsymbol{u}_{\mathrm{a}}\right)\boldsymbol{v}/c^{2}\\&=\gamma\hat{T}\boldsymbol{E}_{\mathrm{a}}+\hat{T}\left[\left(\hat{T}^{-1}\boldsymbol{u}\right)\times\boldsymbol{B}_{\mathrm{a}}\right]+\gamma\boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}-\gamma\left[\boldsymbol{E}_{\mathrm{a}}\cdot\left(\hat{T}^{-1}\boldsymbol{u}\right)\right]\boldsymbol{v}/c^{2}-\gamma^{2}\boldsymbol{v}\left(\boldsymbol{v}\cdot\boldsymbol{E}_{\mathrm{a}}\right)/c^{2}.\end{aligned}$$

Noticing Eq. (7.100) and the definitions of the operators $\hat{T}$ and $\hat{T}^{-1}$, we obtain

$$\boldsymbol{f}/q=\gamma\hat{T}^{-1}\boldsymbol{E}_{\mathrm{a}}+\hat{T}\left[\left(\hat{T}^{-1}\boldsymbol{u}\right)\times\boldsymbol{B}_{\mathrm{a}}\right]+\gamma\boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}-\gamma\left[\boldsymbol{E}_{\mathrm{a}}\cdot\left(\hat{T}^{-1}\boldsymbol{u}\right)\right]\boldsymbol{v}/c^{2}.$$

Using the transformation (7.108) of the electric field intensity $\boldsymbol{E}$ we obtain

$$\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^{2}\right)\boldsymbol{E}=\gamma\hat{T}^{-1}\boldsymbol{E}_{\mathrm{a}}+\gamma\boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}-\left(\boldsymbol{u}\cdot\boldsymbol{v}\right)\left(\gamma\hat{T}^{-1}\boldsymbol{E}_{\mathrm{a}}+\gamma\boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}\right)/c^{2}.$$

Substituting the above two equations into Eq. (7.109), and using the definitions of the operators $\hat{T}$ and $\hat{T}^{-1}$, and the formula (7.32) of the triple vector product, we obtain

$$\begin{aligned}\boldsymbol{u}\times\boldsymbol{B}&=\hat{T}\left[\left(\hat{T}^{-1}\boldsymbol{u}\right)\times\boldsymbol{B}_{\mathrm{a}}\right]-\gamma\left[\boldsymbol{E}_{a}\cdot\left(\hat{T}^{-1}\boldsymbol{u}\right)\right]\boldsymbol{v}/c^{2}\\&\quad+\gamma\left(\boldsymbol{u}\cdot\boldsymbol{v}\right)\left(\hat{T}^{-1}\boldsymbol{E}_{\mathrm{a}}\right)/c^{2}+\gamma\left(\boldsymbol{u}\cdot\boldsymbol{v}\right)\left(\boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}\right)/c^{2}\\&=\hat{T}\left(\boldsymbol{u}\times\boldsymbol{B}_{\mathrm{a}}\right)+\left(\gamma^{-1}-1\right)\left(\boldsymbol{u}_{\|}\times\boldsymbol{B}_{\mathrm{a}}\right)-\gamma\left(\boldsymbol{E}_{\mathrm{a}}\cdot\boldsymbol{u}\right)\boldsymbol{v}/c^{2}+\left(\gamma-1\right)\left(\boldsymbol{E}_{\mathrm{a}}\cdot\boldsymbol{u}_{\|}\right)\boldsymbol{v}/c^{2}\\&\quad+\gamma\left(\boldsymbol{u}\cdot\boldsymbol{v}\right)\boldsymbol{E}_{\mathrm{a}}/c^{2}+\gamma\left(\gamma^{-1}-1\right)\left(\boldsymbol{E}_{\mathrm{a}}\cdot\boldsymbol{u}_{\|}\right)\boldsymbol{v}/c^{2}+\gamma v^{2}\left(\boldsymbol{u}_{\|}\times\boldsymbol{B}_{\mathrm{a}}\right)/c^{2}\\&=\boldsymbol{u}_{\perp}\times\boldsymbol{B}_{\mathrm{a}\perp}+\boldsymbol{u}_{\|}\times\boldsymbol{B}_{\mathrm{a}\perp}+\boldsymbol{u}_{\perp}\times\boldsymbol{B}_{\mathrm{a}\|}+\left(\gamma-1\right)\left(\boldsymbol{u}_{\perp}\times\boldsymbol{B}_{\mathrm{a}\perp}\right)\\&\quad+\left(\gamma^{-1}-1+\gamma v^{2}/c^{2}\right)\left(\boldsymbol{u}_{\|}\times\boldsymbol{B}_{\mathrm{a}\perp}\right)-\gamma\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{E}_{\mathrm{a}}\right)/c^{2}\\&=\gamma\left(\boldsymbol{u}_{\perp}\times\boldsymbol{B}_{\mathrm{a}\perp}\right)+\gamma\left(\boldsymbol{u}_{\|}\times\boldsymbol{B}_{\mathrm{a}\perp}\right)+\boldsymbol{u}_{\perp}\times\boldsymbol{B}_{\mathrm{a}\|}-\gamma\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{E}_{\mathrm{a}}\right)/c^{2}\\&=\boldsymbol{u}\times\left[\gamma\hat{T}^{-1}\boldsymbol{B}_{\mathrm{a}}-\gamma\left(\boldsymbol{v}\times\boldsymbol{E}_{\mathrm{a}}\right)/c^{2}\right],\end{aligned}$$

where the third and the last sign of equality also applied respectively the following formulas

$$\boldsymbol{u}_{\|} \times \boldsymbol{B}_{\mathrm{a}} = \boldsymbol{u}_{\|} \times \left(\boldsymbol{B}_{\mathrm{a}\perp} + \boldsymbol{B}_{\mathrm{a}\|}\right) = \boldsymbol{u}_{\|} \times \boldsymbol{B}_{\mathrm{a}\perp}, \tag{7.110}$$

$$\boldsymbol{u}_{\perp} \times \boldsymbol{B}_{\mathrm{a}\|} = \left(\boldsymbol{u}_{\perp} + \boldsymbol{u}_{\|}\right) \times \boldsymbol{B}_{\mathrm{a}\|} = \boldsymbol{u} \times \boldsymbol{B}_{\mathrm{a}\|}. \tag{7.111}$$

Thus, we obtain the transformation of magnetic induction intensity $\boldsymbol{B}$ as follows

$$\boldsymbol{B} = \gamma\left(\hat{T}^{-1}\boldsymbol{B}_{\mathrm{a}} - \boldsymbol{v} \times \boldsymbol{E}_{\mathrm{a}} / c^2\right). \tag{7.112}$$

Acting on the two sides of the transformations (7.108) and (7.112) respectively by the operator $\gamma^{-1}\hat{T}$, and using Eqs. (7.36) and (7.37), we obtain

$$\boldsymbol{E}_{\mathrm{a}} = \gamma^{-1}\hat{T}\boldsymbol{E} - \boldsymbol{v} \times \boldsymbol{B}_{\mathrm{a}}, \quad \boldsymbol{B}_{\mathrm{a}} = \gamma^{-1}\hat{T}\boldsymbol{B} + \boldsymbol{v} \times \boldsymbol{E}_{\mathrm{a}} / c^2.$$

Substituting the above second equation into the above first equation, and using the formula (7.32) of the triple vector product, we obtain

$$\begin{aligned}\boldsymbol{E}_{\mathrm{a}} &= \gamma^{-1}\hat{T}\boldsymbol{E} - \boldsymbol{v} \times \left(\gamma^{-1}\hat{T}\boldsymbol{B}\right) - \boldsymbol{v} \times \left(\boldsymbol{v} \times \boldsymbol{E}_{\mathrm{a}}\right) / c^2 \\ &= \gamma^{-1}\hat{T}\boldsymbol{E} - \gamma^{-1}\boldsymbol{v} \times \boldsymbol{B} - \boldsymbol{v}\left(\boldsymbol{v} \cdot \boldsymbol{E}_{\mathrm{a}}\right) / c^2 + v^2\boldsymbol{E}_{\mathrm{a}} / c^2.\end{aligned}$$

Remove the terms relate to $\boldsymbol{E}_{\mathrm{a}}$ in the right to the left

$$\gamma^{-2}\boldsymbol{E}_{\mathrm{a}} + \left(v^2 / c^2\right)\boldsymbol{E}_{\mathrm{a}\|} = \gamma^{-1}\hat{T}\boldsymbol{E} - \gamma^{-1}\boldsymbol{v} \times \boldsymbol{B}.$$

Multiplying the two sides of the above equation by γ^2, and using Eq. (7.99) and the definition (7.19) of the operator $\hat{T}^n$, we obtain

$$\hat{T}^2\boldsymbol{E}_{\mathrm{a}} = \gamma\left(\hat{T}\boldsymbol{E} - \boldsymbol{v} \times \boldsymbol{B}\right).$$

Acting on the two sides of the above equation by the operator $\hat{T}^{-2}$, and using formulas (7.36) and (7.40), we obtain

$$\boldsymbol{E}_{\mathrm{a}} = \gamma\left(\hat{T}^{-1}\boldsymbol{E} - \boldsymbol{v} \times \boldsymbol{B}\right), \tag{7.113}$$

and find similarly

$$\boldsymbol{B}_{\mathrm{a}} = \gamma\left(\hat{T}^{-1}\boldsymbol{B} + \boldsymbol{v} \times \boldsymbol{E} / c^2\right). \tag{7.114}$$

We collect the transformations of the electric field intensity $\boldsymbol{E}$ and magnetic induction intensity $\boldsymbol{B}$ and the reverse transformations as follows

$$\left.\begin{aligned}\boldsymbol{E} &= \gamma\left(\hat{T}^{-1}\boldsymbol{E}_{\mathrm{a}} + \boldsymbol{v} \times \boldsymbol{B}_{\mathrm{a}}\right), \quad \boldsymbol{B} = \gamma\left(\hat{T}^{-1}\boldsymbol{B}_{\mathrm{a}} - \boldsymbol{v} \times \boldsymbol{E}_{\mathrm{a}} / c^2\right), \\ \boldsymbol{E}_{\mathrm{a}} &= \gamma\left(\hat{T}^{-1}\boldsymbol{E} - \boldsymbol{v} \times \boldsymbol{B}\right), \quad \boldsymbol{B}_{\mathrm{a}} = \gamma\left(\hat{T}^{-1}\boldsymbol{B} + \boldsymbol{v} \times \boldsymbol{E} / c^2\right),\end{aligned}\right\} \tag{7.115a}$$

or by the components of parallel and perpendicular to $\boldsymbol{v}$, Eq. (7.115a) can be re-written as

$$\left.\begin{aligned}&\boldsymbol{E}_{\|} = \boldsymbol{E}_{\mathrm{a}\|}, && \boldsymbol{B}_{\|} = \boldsymbol{B}_{\mathrm{a}\|}, \\ &\boldsymbol{E}_{\perp} = \gamma\left(\boldsymbol{E}_{\mathrm{a}\perp} + \boldsymbol{v} \times \boldsymbol{B}_{\mathrm{a}}\right), && \boldsymbol{B}_{\perp} = \gamma\left(\boldsymbol{B}_{\mathrm{a}\perp} - \boldsymbol{v} \times \boldsymbol{E}_{\mathrm{a}} / c^2\right), \\ &\boldsymbol{E}_{\mathrm{a}\|} = \boldsymbol{E}_{\|}, && \boldsymbol{B}_{\mathrm{a}\|} = \boldsymbol{B}_{\|}, \\ &\boldsymbol{E}_{\mathrm{a}\perp} = \gamma\left(\boldsymbol{E}_{\perp} - \boldsymbol{v} \times \boldsymbol{B}\right), && \boldsymbol{B}_{\mathrm{a}\perp} = \gamma\left(\boldsymbol{B}_{\perp} + \boldsymbol{v} \times \boldsymbol{E} / c^2\right).\end{aligned}\right\} \tag{7.115b}$$

We see that these transformations and reverse transformations are the same completely with the that of the special theory of relativity. But the transformations of Standard Space-time Theory describe the transformation of the relative quantities in the absolute inertial frame Σ_a and an ordinary inertial frame Σ; the special theory of relativity does not admit the existence of the absolute inertial frame, its transformations describe the transformations of the relative quantities in two arbitrary inertial frames S and S'.

7. 5. The Electromagnetic Field Equations in Vacuum in an Ordinary Inertial Frame

Starting from Maxwell's equations (7.1), the transformations (7.115) of $\boldsymbol{E}$ and $\boldsymbol{B}$, and the transformations (7.60) of charge and current density, and using the transformations (7.33) of the operator ∇ and transformations (7.34) of the operator $\partial/\partial t$, we can find the equations of electromagnetic field in an ordinary inertial frame.

7. 5. 1. The Relation between $\nabla\cdot\boldsymbol{E}$ and $\nabla\times\boldsymbol{B}$. The Relation between $\nabla\cdot\boldsymbol{B}$ and $\nabla\times\boldsymbol{E}$

Starting from the transformation (7.113), and using in turn Eqs. (7.33), (7.45), (7.37) and (7.39), we easily obtain

$$\begin{aligned}\nabla_a\cdot\boldsymbol{E}_a&=\gamma\nabla_a\cdot\left(\hat{T}^{-1}\boldsymbol{E}\right)-\gamma\nabla_a\cdot\left(\boldsymbol{v}\times\boldsymbol{B}\right)=\gamma\left(\hat{T}\nabla\right)\cdot\left(\hat{T}^{-1}\boldsymbol{E}\right)-\gamma\left(\hat{T}\nabla\right)\cdot\left(\boldsymbol{v}\times\boldsymbol{B}\right)\\&=\gamma\nabla\cdot\boldsymbol{E}-\gamma\nabla\cdot\left(\boldsymbol{v}\times\boldsymbol{B}\right)=\gamma\nabla\cdot\boldsymbol{E}+\gamma\boldsymbol{v}\cdot\left(\nabla\times\boldsymbol{B}\right).\end{aligned}$$

According to Eq. (7.60), $\rho_a=\gamma\rho$. Substituting the third equation of Maxwell's equations (7.1)

$$\nabla_a\cdot\boldsymbol{E}_a=\rho_a/\varepsilon_0=\gamma\rho/\varepsilon_0 \tag{7.116}$$

into the front equation, we find

$$\nabla\cdot\boldsymbol{E}=\left(\rho/\varepsilon_0\right)-\boldsymbol{v}\cdot\left(\nabla\times\boldsymbol{B}\right). \tag{7.117}$$

Starting from the transformation (7.114), similarly, we can obtain

$$\begin{aligned}\nabla_a\cdot\boldsymbol{B}_a&=\gamma\nabla_a\cdot\left(\hat{T}^{-1}\boldsymbol{B}\right)+\gamma\nabla_a\cdot\left(\boldsymbol{v}\times\boldsymbol{E}/c^2\right)=\gamma\left(\hat{T}\nabla\right)\cdot\left(\hat{T}^{-1}\boldsymbol{B}\right)+\gamma\left(\hat{T}\nabla\right)\cdot\left(\boldsymbol{v}\times\boldsymbol{E}/c^2\right)\\&=\gamma\nabla\cdot\boldsymbol{B}+\gamma\nabla\cdot\left(\boldsymbol{v}\times\boldsymbol{E}/c^2\right)=\gamma\nabla\cdot\boldsymbol{B}-\gamma\boldsymbol{v}\cdot\left(\nabla\times\boldsymbol{E}\right)/c^2.\end{aligned}$$

Substituting the fourth equation of Eqs. (7.1) into the above equation, we find

$$\nabla\cdot\boldsymbol{B}=\frac{1}{c^2}\boldsymbol{v}\cdot\left(\nabla\times\boldsymbol{E}\right). \tag{7.118}$$

After finding out $\nabla\times\boldsymbol{B}$ and $\nabla\times\boldsymbol{E}$ we can find the last expression of $\nabla\cdot\boldsymbol{E}$ and $\nabla\cdot\boldsymbol{B}$.

7. 5. 2. The Equations of the Curl of Electric Field Intensity and the Divergence of Magnetic Induction Intensity

Substituting the reverse transformations (7.113) and (7.114) of the electric field $\boldsymbol{E}$ and magnetic induction intensity $\boldsymbol{B}$ into the first equation of Maxwell's equations (7.1), that is

$$\nabla_{\mathrm{a}}\times\boldsymbol{E}_{\mathrm{a}}=-\frac{\partial\boldsymbol{B}_{\mathrm{a}}}{\partial t_{\mathrm{a}}}$$

and in turn using Eqs. (7.18), (7.28), (7.30)—(7.34), (7.47) , (7.49) and (7.100), we obtain

$$\begin{aligned}
\nabla_{\mathrm{a}}\times\boldsymbol{E}_{\mathrm{a}}&=\gamma\left(\hat{T}\nabla\right)\times\left(\hat{T}^{-1}\boldsymbol{E}-\boldsymbol{v}\times\boldsymbol{B}\right)=\gamma\left(\hat{T}\nabla\right)\times\left(\hat{T}^{-1}\boldsymbol{E}\right)-\gamma\left(\hat{T}\nabla\right)\times\left(\boldsymbol{v}\times\boldsymbol{B}\right)\\
&=\gamma^{2}\hat{T}^{-1}\left[\nabla\times\left(\hat{T}^{-1}\boldsymbol{E}\right)\right]+\gamma\left(\gamma-1\right)\boldsymbol{v}_{0}\times\nabla\left[\boldsymbol{v}_{0}\cdot\left(\hat{T}^{-1}\boldsymbol{E}\right)\right]-\gamma^{2}\hat{T}^{-1}\left[\nabla\times\left(\boldsymbol{v}\times\boldsymbol{B}\right)\right]\\
&=\gamma^{2}\hat{T}^{-1}\left(\nabla\times\boldsymbol{E}\right)+\left(\gamma-\gamma^{2}\right)\hat{T}^{-1}\left\{\nabla\times\left[\boldsymbol{v}_{0}\left(\boldsymbol{v}_{0}\cdot\boldsymbol{E}\right)\right]\right\}+\left(\gamma-1\right)\boldsymbol{v}_{0}\times\left[\nabla\left(\boldsymbol{v}_{0}\cdot\boldsymbol{E}\right)\right]\\
&\qquad-\gamma^{2}\hat{T}^{-1}\left[\left(\nabla\cdot\boldsymbol{B}\right)\boldsymbol{v}-\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{B}\right]\\
&=\gamma^{2}\nabla\times\boldsymbol{E}+\left(\gamma-\gamma^{2}\right)\boldsymbol{v}_{0}\left[\boldsymbol{v}_{0}\cdot\left(\nabla\times\boldsymbol{E}\right)\right]-\left(\gamma-\gamma^{2}\right)\hat{T}^{-1}\left\{\boldsymbol{v}_{0}\times\left[\nabla\left(\boldsymbol{v}_{0}\cdot\boldsymbol{E}\right)\right]\right\}\\
&\qquad+\left(\gamma-1\right)\boldsymbol{v}_{0}\times\left[\nabla\left(\boldsymbol{v}_{0}\cdot\boldsymbol{E}\right)\right]-\gamma\left(\nabla\cdot\boldsymbol{B}\right)\boldsymbol{v}+\gamma^{2}\hat{T}^{-1}\left[\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{B}\right]\\
&=\gamma^{2}\nabla\times\boldsymbol{E}+\left(\gamma-\gamma^{2}\right)\boldsymbol{v}_{0}\left[\boldsymbol{v}_{0}\cdot\left(\nabla\times\boldsymbol{E}\right)\right]+\left(\gamma^{2}-1\right)\boldsymbol{v}_{0}\times\left[\nabla\left(\boldsymbol{v}_{0}\cdot\boldsymbol{E}\right)\right]\\
&\qquad-\gamma\left(\nabla\cdot\boldsymbol{B}\right)\boldsymbol{v}+\gamma^{2}\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{B}+\left(\gamma-\gamma^{2}\right)\boldsymbol{v}_{0}\left[\boldsymbol{v}_{0}\cdot\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{B}\right]\\
&=\gamma^{2}\nabla\times\boldsymbol{E}+\left(\gamma-\gamma^{2}\right)\boldsymbol{v}_{0}\left[\boldsymbol{v}_{0}\cdot\left(\nabla\times\boldsymbol{E}\right)\right]+\left(\gamma^{2}-1\right)\boldsymbol{v}_{0}\times\left[\boldsymbol{v}_{0}\times\left(\nabla\times\boldsymbol{E}\right)\right]-\gamma\left(\nabla\cdot\boldsymbol{B}\right)\boldsymbol{v}\\
&\qquad+\left(\gamma^{2}-1\right)\boldsymbol{v}_{0}\times\left[\left(\boldsymbol{v}_{0}\cdot\nabla\right)\boldsymbol{E}\right]+\gamma^{2}\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{B}+\left(\gamma-\gamma^{2}\right)\boldsymbol{v}_{0}\left[\boldsymbol{v}_{0}\cdot\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{B}\right]\\
&=\nabla\times\boldsymbol{E}+\left(\gamma-1\right)\boldsymbol{v}_{0}\left[\boldsymbol{v}_{0}\cdot\left(\nabla\times\boldsymbol{E}\right)\right]+\left(\gamma^{2}-1\right)\boldsymbol{v}_{0}\times\left[\left(\boldsymbol{v}_{0}\cdot\nabla\right)\boldsymbol{E}\right]-\gamma\left(\nabla\cdot\boldsymbol{B}\right)\boldsymbol{v}\\
&\qquad+\gamma^{2}\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{B}+\left(\gamma-\gamma^{2}\right)\left(\boldsymbol{v}\cdot\nabla\right)\left[\boldsymbol{v}_{0}\left(\boldsymbol{v}_{0}\cdot\boldsymbol{B}\right)\right],
\end{aligned}$$

$$\begin{aligned}
-\frac{\partial\boldsymbol{B}_{\mathrm{a}}}{\partial t_{\mathrm{a}}}&=\left[-\gamma^{-1}\frac{\partial}{\partial t}+\gamma\left(\boldsymbol{v}\cdot\nabla\right)\right]\left(\gamma\hat{T}^{-1}\boldsymbol{B}+\gamma\boldsymbol{v}\times\boldsymbol{E}/c^{2}\right)\\
&=-\frac{\partial}{\partial t}\left(\hat{T}^{-1}\boldsymbol{B}\right)+\gamma^{2}\left(\boldsymbol{v}\cdot\nabla\right)\left(\hat{T}^{-1}\boldsymbol{B}\right)-\frac{1}{c^{2}}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}+\gamma^{2}\frac{v^{2}}{c^{2}}\left(\boldsymbol{v}_{0}\cdot\nabla\right)\left(\boldsymbol{v}_{0}\times\boldsymbol{E}\right)\\
&=-\frac{\partial\boldsymbol{B}}{\partial t}-\left(\gamma^{-1}-1\right)\boldsymbol{v}_{0}\left[\boldsymbol{v}_{0}\cdot\frac{\partial\boldsymbol{B}}{\partial t}\right]+\gamma^{2}\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{B}+\left(\gamma-\gamma^{2}\right)\left(\boldsymbol{v}\cdot\nabla\right)\left[\boldsymbol{v}_{0}\left(\boldsymbol{v}_{0}\cdot\boldsymbol{B}\right)\right]\\
&\qquad-\frac{1}{c^{2}}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}+\left(\gamma^{2}-1\right)\boldsymbol{v}_{0}\times\left[\left(\boldsymbol{v}_{0}\cdot\nabla\right)\boldsymbol{E}\right].
\end{aligned}$$

Substituting the above two equations into the first equation of Maxwell's equations (7.1), and eliminating the same terms in the two sides of the given equation and rearranging, we obtain

$$\hat{T}\left(\nabla\times\boldsymbol{E}\right)-\gamma\left(\nabla\cdot\boldsymbol{B}\right)\boldsymbol{v}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}=-\hat{T}^{-1}\frac{\partial\boldsymbol{B}}{\partial t}.$$

Acting on the two sides of the above equation by the operator $\hat{T}^{-1}$, and using Eqs.(7.35), (7.36), (7.37) and (7.39), we obtain

$$\nabla\times\boldsymbol{E}-\left(\nabla\cdot\boldsymbol{B}\right)\boldsymbol{v}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}=-\hat{T}^{-2}\frac{\partial\boldsymbol{B}}{\partial t}. \tag{7.119}$$

Dot multiplying the two sides of the above equation by $\boldsymbol{v}/c^2$, and using Eqs. (7.118) and (7.119), we obtain

$$\left(1-\frac{v^2}{c^2}\right)\left(\nabla\cdot\boldsymbol{B}\right)=-\frac{1}{c^2}\left(1-\frac{v^2}{c^2}\right)\boldsymbol{v}\cdot\frac{\partial\boldsymbol{B}}{\partial t}.$$

That is

$$\nabla\cdot\boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{B}}{\partial t}=0. \tag{7.120}$$

Substituting Eq. (7.120) into Eq. (7.119) we obtain

$$\nabla\times\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}=-\hat{T}^{-2}\frac{\partial\boldsymbol{B}}{\partial t}-\frac{1}{c^2}\boldsymbol{v}\left(\boldsymbol{v}\cdot\frac{\partial\boldsymbol{B}}{\partial t}\right).$$

Using Eqs. (7.19) and (7.100) to the right of the above equation, we further obtain

$$\nabla\times\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}=-\frac{\partial\boldsymbol{B}}{\partial t}. \tag{7.121}$$

Thus, we have found the equations of the divergence of magnetic induction intensity and the curl of the electric field intensity.

7. 5. 3. The Equations of the Curl of Magnetic Induction Intensity and the Divergence of Electric Field Intensity

Similarly with the above discussion, substituting the reverse transformations (7.113) and (7.114) of the electric field intensity $\boldsymbol{E}$ and magnetic induction intensity $\boldsymbol{B}$ and the reverse transformation (7.59) of current density $\boldsymbol{j}$ into the second equation of Maxwell's equations (7.1), that is

$$\nabla_{\mathrm{a}}\times\boldsymbol{B}_{\mathrm{a}}=\mu_0\boldsymbol{j}_{\mathrm{a}}+\varepsilon_0\mu_0\frac{\partial\boldsymbol{E}_{\mathrm{a}}}{\partial t_{\mathrm{a}}}$$

and similarly in turn using Eqs. (7.18), (7.28), (7.30)—(7.34), (7.47) , (7.49) and (7.100), we obtain

$$
\begin{aligned}
\nabla_{\mathrm{a}} \times \boldsymbol{B}_{\mathrm{a}} &= \gamma\left(\hat{T}\nabla\right)\times\left(\hat{T}^{-1}\boldsymbol{B}+\boldsymbol{v}\times\boldsymbol{E}/c^2\right)\\
&= \gamma^2\hat{T}^{-1}\left[\nabla\times\left(\hat{T}^{-1}\boldsymbol{B}\right)\right]+\gamma\left(\gamma-1\right)\boldsymbol{v}_0\times\nabla\left[\boldsymbol{v}_0\cdot\left(\hat{T}^{-1}\boldsymbol{B}\right)\right]+\gamma^2\hat{T}^{-1}\left[\nabla\times\left(\boldsymbol{v}\times\boldsymbol{E}\right)\right]/c^2\\
&= \gamma^2\hat{T}^{-1}\left(\nabla\times\boldsymbol{B}\right)+\left(\gamma-\gamma^2\right)\hat{T}^{-1}\left\{\nabla\times\left[\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\boldsymbol{B}\right)\right]\right\}+\left(\gamma-1\right)\boldsymbol{v}_0\times\left[\nabla\left(\boldsymbol{v}_0\cdot\boldsymbol{B}\right)\right]\\
&\qquad+\gamma^2\hat{T}^{-1}\left[\left(\nabla\cdot\boldsymbol{E}\right)\boldsymbol{v}-\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{E}\right]/c^2\\
&= \gamma^2\nabla\times\boldsymbol{B}+\left(\gamma-\gamma^2\right)\boldsymbol{v}_0\left[\boldsymbol{v}_0\cdot\left(\nabla\times\boldsymbol{B}\right)\right]+\left(\gamma^2-1\right)\boldsymbol{v}_0\times\left[\nabla\left(\boldsymbol{v}_0\cdot\boldsymbol{B}\right)\right]\\
&\qquad+\gamma\left(\nabla\cdot\boldsymbol{E}\right)\boldsymbol{v}/c^2-\left(\gamma^2/c^2\right)\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{E}+\left(\gamma^2-\gamma\right)\left(\boldsymbol{v}\cdot\nabla\right)\left[\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\boldsymbol{E}\right)\right]/c^2\\
&= \gamma^2\nabla\times\boldsymbol{B}+\left(\gamma-\gamma^2\right)\boldsymbol{v}_0\left[\boldsymbol{v}_0\cdot\left(\nabla\times\boldsymbol{B}\right)\right]+\left(\gamma^2-1\right)\boldsymbol{v}_0\times\left[\boldsymbol{v}_0\times\left(\nabla\times\boldsymbol{B}\right)\right]\\
&\qquad+\left(\gamma^2-1\right)\boldsymbol{v}_0\times\left[\left(\boldsymbol{v}_0\cdot\nabla\right)\boldsymbol{B}\right]+\gamma\left(\nabla\cdot\boldsymbol{E}\right)\boldsymbol{v}-\left(\gamma^2/c^2\right)\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{E}\\
&\qquad+\left(\gamma^2-\gamma\right)\left(\boldsymbol{v}\cdot\nabla\right)\left[\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\boldsymbol{E}\right)\right]/c^2\\
&= \nabla\times\boldsymbol{B}+\left(\gamma-1\right)\boldsymbol{v}_0\left[\boldsymbol{v}_0\cdot\left(\nabla\times\boldsymbol{B}\right)\right]+\left(\gamma^2-1\right)\boldsymbol{v}_0\times\left[\left(\boldsymbol{v}_0\cdot\nabla\right)\boldsymbol{B}\right]\\
&\qquad+\gamma\left(\nabla\cdot\boldsymbol{E}\right)\boldsymbol{v}/c^2-\left(\gamma^2/c^2\right)\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{E}+\left(\gamma^2-\gamma\right)\left(\boldsymbol{v}\cdot\nabla\right)\left[\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\boldsymbol{E}\right)\right]/c^2,
\end{aligned}
$$

$$
\mu_0\boldsymbol{j}_{\mathrm{a}}=\mu_0\hat{T}^{-1}\boldsymbol{j}+\mu_0\gamma\rho\boldsymbol{v},
$$

$$
\begin{aligned}
\varepsilon_0\mu_0\frac{\partial\boldsymbol{E}_{\mathrm{a}}}{\partial t_{\mathrm{a}}}&=\frac{\gamma}{c^2}\left[\gamma^{-1}\frac{\partial}{\partial t}-\gamma\left(\boldsymbol{v}\cdot\nabla\right)\right]\left(\hat{T}^{-1}\boldsymbol{E}-\boldsymbol{v}\times\boldsymbol{B}\right)=\frac{1}{c^2}\frac{\partial\boldsymbol{E}}{\partial t}+\frac{1}{c^2}\left(\gamma^{-1}-1\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\frac{\partial\boldsymbol{E}}{\partial t}\right)\\
&-\frac{\gamma^2}{c^2}\left(\boldsymbol{v}\cdot\nabla\right)\boldsymbol{E}+\left(\gamma^2-\gamma\right)\left(\boldsymbol{v}\cdot\nabla\right)\left[\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\boldsymbol{E}\right)\right]/c^2-\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{B}}{\partial t}+\left(\gamma^2-1\right)\boldsymbol{v}_0\times\left[\left(\boldsymbol{v}_0\cdot\nabla\right)\boldsymbol{B}\right].
\end{aligned}
$$

Substituting the above three equations into the second equation of Maxwell's equations (7.1), and eliminating the same terms in the sides of the obtained equation and rearranging, we obtain

$$
\hat{T}\left(\nabla\times\boldsymbol{B}\right)+\frac{\gamma}{c^2}\left(\nabla\cdot\boldsymbol{E}\right)\boldsymbol{v}=\mu_0\hat{T}^{-1}\boldsymbol{j}+\mu_0\gamma\rho\boldsymbol{v}+\frac{1}{c^2}\hat{T}^{-1}\left(\frac{\partial\boldsymbol{E}}{\partial t}\right)-\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{B}}{\partial t}.
$$

The operator $\hat{T}^{-1}$ acts on both sides of the above equation, using (9.35)—(9.39), we get

$$
\nabla\times\boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{B}}{\partial t}+\frac{1}{c^2}\left(\nabla\cdot\boldsymbol{E}\right)\boldsymbol{v}=\mu_0\hat{T}^{-2}\boldsymbol{j}+\mu_0\rho\boldsymbol{v}+\frac{1}{c^2}\hat{T}^{-2}\left(\frac{\partial\boldsymbol{E}}{\partial t}\right).
$$

Substituting Eq. (7.117) into the above equation we obtain

$$
\nabla\times\boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{B}}{\partial t}-\frac{1}{c^2}\boldsymbol{v}\left[\boldsymbol{v}\cdot\left(\nabla\times\boldsymbol{B}\right)\right]=\mu_0\hat{T}^{-2}\boldsymbol{j}+\frac{1}{c^2}\hat{T}^{-2}\left(\frac{\partial\boldsymbol{E}}{\partial t}\right). \qquad (7.122)
$$

Dot Multiply both sides of the above equation by $\boldsymbol{v}$ and divide the result by γ^{-2}, we obtain

$$
\boldsymbol{v}\cdot\left(\nabla\times\boldsymbol{B}\right)=\mu_0\boldsymbol{v}\cdot\boldsymbol{j}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{E}}{\partial t}. \qquad (7.123)
$$

Substituting the above equation into Eqs. (7.117) and (7.122) and noticing

$$\gamma^{-2} - 1 = -v^2 / c^2 . \tag{7.124}$$

We last obtain

$$\nabla \cdot \boldsymbol{E} + \frac{1}{c^2}\boldsymbol{v} \cdot \frac{\partial \boldsymbol{E}}{\partial t} = \frac{\rho}{\varepsilon_0} - \mu_0 \boldsymbol{v} \cdot \boldsymbol{j}, \tag{7.125}$$

$$\nabla \times \boldsymbol{B} + \frac{1}{c^2}\boldsymbol{v} \times \frac{\partial \boldsymbol{B}}{\partial t} = \mu_0 \boldsymbol{j} + \frac{1}{c^2}\frac{\partial \boldsymbol{E}}{\partial t}. \tag{7.126}$$

In this way, we have found the equations of the divergence of the electric field intensity $\boldsymbol{E}$ and the curl of the magnetic induction intensity $\boldsymbol{B}$.

7. 5. 4. The Electromagnetic Field Equations in Vacuum in an Ordinary Inertial Frame

Collecting the above obtained the electromagnetic field equations in vacuum in an ordinary inertial frame as follows

$$\left.\begin{aligned}
&\nabla \times \boldsymbol{E} + \frac{1}{c^2}\boldsymbol{v} \times \frac{\partial \boldsymbol{E}}{\partial t} = -\frac{\partial \boldsymbol{B}}{\partial t}, \\
&\nabla \times \boldsymbol{B} + \frac{1}{c^2}\boldsymbol{v} \times \frac{\partial \boldsymbol{B}}{\partial t} = \mu_0 \boldsymbol{j} + \varepsilon_0 \mu_0 \frac{\partial \boldsymbol{E}}{\partial t}, \\
&\nabla \cdot \boldsymbol{E} + \frac{1}{c^2}\boldsymbol{v} \cdot \frac{\partial \boldsymbol{E}}{\partial t} = \frac{\rho}{\varepsilon_0} - \mu_0 \boldsymbol{v} \cdot \boldsymbol{j}, \\
&\nabla \cdot \boldsymbol{B} + \frac{1}{c^2}\boldsymbol{v} \cdot \frac{\partial \boldsymbol{B}}{\partial t} = 0.
\end{aligned}\right\} \tag{7.127a}$$

Applying Stokes' theorem and Gauss' theorem we can rewrite Eq. (7.127a) in the corresponding integral form

$$\left.\begin{aligned}
&\oint_L \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{l} = -\frac{\mathrm{d}}{\mathrm{d}t}\int_s \left(\boldsymbol{B} + \frac{1}{c^2}\boldsymbol{v} \times \boldsymbol{E}\right) \cdot \mathrm{d}\boldsymbol{s}, \\
&\oint_L \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{l} = \mu_0 \int_s \boldsymbol{j} \cdot d\boldsymbol{s} + \frac{1}{c^2}\frac{\mathrm{d}}{\mathrm{d}t}\int_s \left(\boldsymbol{E} - \boldsymbol{v} \times \boldsymbol{B}\right) \cdot \mathrm{d}\boldsymbol{s}, \\
&\oint_s \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{s} = \frac{1}{\varepsilon_0}\int_v \left(\rho - \frac{1}{c^2}\boldsymbol{v} \cdot \boldsymbol{j}\right) \mathrm{d}V - \frac{1}{c^2}\frac{\mathrm{d}}{\mathrm{d}t}\int \left(\boldsymbol{v} \cdot \boldsymbol{E}\right) \mathrm{d}V, \\
&\oint_s \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{s} = -\frac{1}{c^2}\frac{\mathrm{d}}{\mathrm{d}t}\int_v \left(\boldsymbol{v} \cdot \boldsymbol{B}\right) \mathrm{d}V.
\end{aligned}\right\} \tag{7.127b}$$

In the first equation and second equation L represents an arbitrary closed curve, S represents a surface around bounded by L; in the third equation and the fourth equation S represents an arbitrary closed surface, V represents a volume enclosed by S .

The equations (7.127) are the electromagnetic field equations in vacuum in an ordinary inertial frame in the differential form and integral form. Obviously, taking $\boldsymbol{v}=0$ in Eqs. (7.127) then they return to or revert to Maxwell's equations which describe the law of the electromagnetic field motion in vacuum relative to the absolute reference frame.

Notice that the third equation of the equations (7.127a) can also rewrite as

$$\nabla\cdot\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{E}}{\partial t}=\frac{1}{\varepsilon_0}\left(\rho-\frac{1}{c^2}\boldsymbol{v}\cdot\boldsymbol{j}\right). \quad (7.128)$$

Comparing the equations (7.127) with Maxwell's equations, we can see that the differences are only additions of one or two terms coefficient of which is $\left(v/c^2\right)$. Notice it is not $\left(v/c\right)$, is not $\left(v/c\right)^2$ either, but $\left(v/c^2\right)$. These differences are so infinitely small that exceed out of the limits of precision of the present experiments.

7. 6. The Electromagnetic Field Equations in Media in an Ordinary Inertial Frame

7. 6. 1. The Motion Forms of Charges in Media

As we study the electromagnetic properties of materials, we call them as electromagnetic media. According to the properties of "conduct electricity" of materials, the electromagnetic media can classify as conductors, semiconductors and dielectric. We can say that the summation of the extensions of the three conceptions, i.e., conductors, semiconductors and dielectric, is the whole extension of the media. But the magnetic material is not the paratactic conception with conductors, semiconductors or dielectric. All matters which can be magnetized under action of external magnetic field and inversely affect and produce magnetic field are call as magnetic material. In fact, all matters more or less can be magnetized under action of external magnetic field and inversely affect and produce magnetic field, so all matters can be call as magnetic material.

To found the equations of electromagnetic field in media, it is necessary first to classify suitably the charges and currents in media. The charges in media are classified as free charge and bound charge; the currents in media are classified as free current and bound current.

The free charges are classified as two sorts: a sort of free charges is these charges which can remove a macroscopic distance under the action of electric field, such as free moving electrons in metal and vacuum, ions in gas and electrolytic solution and so on; another sort of free charges is these charges which are brought to the surface of dielectric so to destroy the electric neutrality of the dielectric. The charges, which cannot be divorced from the range of the atom or molecule and freely remove and which are the component parts of the atom or molecule, are called bound charge. If the medium is dielectric, almost all of the positive and negative charges are bound in atomic nucleus and around it; if the medium is conductor, a majority of the positive and negative charges are bound in atomic nucleus and around it, while another part is free charges, i.e., free electrons.

The macroscopic and directional motions of the free electrons in metal and ions in electrolytic solution form conduction current. The macroscopic removes of the charged body form convection current. The conduction current and convection current are all together call free current. The motions of the bound charges of medium form bound current.

When dielectric media are in external electric field, the non-polar molecules take place displacement polarization, the polar molecules take place turn polarization (there are also displacement polarization but which is much weaker than turn polarization), so that the vector summation of all the molecular electric dipoles in any volume element is not equal to zero. Introduce polarization intensity vector $\boldsymbol{P}$ to describe the polarization degree of dielectric, it is defined as the ratio of the vector summation of all the molecular electric dipoles $\boldsymbol{p}_i$ in physically infinitesimal volume element ΔV to this volume ΔV, namely

$$\boldsymbol{P} = \frac{\Sigma \boldsymbol{p}_i}{\Delta V}, \qquad (7.129)$$

where $\boldsymbol{p}_i$ represents the electric dipole of the ith molecule. As the result of polarization, the surface of the dielectric and even inside the dielectric there appears macroscopic distribution of polarization charges. The polarization charges of dielectric are macroscopic effects produced by minute displacement of the bound charges in dielectric. The polarization charges density is the macroscopic average value of bound charges intensity in physically infinitesimal volume. Electromagnetism has proved that the polarization charges density

$$\rho_{\mathrm{p}} = -\nabla \cdot \boldsymbol{P}. \qquad (7.130)$$

When electric fields change, the polarization intensity vector $\boldsymbol{P}$ of dielectric takes place changes. These changes are substantively macroscopic average effects produced by position displacement of the bound charges in dielectric, and produce another current which is call the polarization current. The polarization current intensity

$$\boldsymbol{j}_{\mathrm{p}} = \frac{\partial \boldsymbol{P}}{\partial t}. \qquad (7.131)$$

Media in magnetic fields will magnetize. Introduce magnetization intensity vector $\boldsymbol{M}$ to describe the magnetization degree of magnetic material, it is defined as the ratio of the vector summation of all the molecular magnetic moment $\boldsymbol{m}_i$ in physically infinitesimal volume element ΔV to this volume ΔV, namely

$$\boldsymbol{M} = \frac{\Sigma \boldsymbol{m}_i}{\Delta V}, \qquad (7.132)$$

where $\boldsymbol{m}_i$ represents the magnetic moment of the ith molecule in volume element ΔV. The magnetization currents in magnetic material are macroscopic average effects produced by regular turns of the molecular currents in external magnetic field. The magnetization current intensity is macroscopic average value of the molecular currents in physically infinitesimal volume. Electromagnetism has proved that the magnetization current density

$$\boldsymbol{j}_{\mathrm{m}} = \nabla \times \boldsymbol{M}. \tag{7.133}$$

7. 6. 2. Maxwell's Equations in Media

According to the aggregated-dispersed states natural images, the macroscopic material world is but unity of the dispersed state background field and the aggregated-state particles. The microscopic particles in aggregated state include the electrons of negative charge and nuclei of positive charge, that are swimming and moving in vacuum background field. In the normal cases the electrons move around nucleus, just like the earth turns around the sun. These electrons are call bound electrons. But there are the other electrons which broke away from bondage of nucleus, just like comet passes through space between different stars. They are call free electrons. These are microscopic picture of media: in vacuum background field there are moving charged particles, namely distribution of moving charges.

The Lorentz electron theory generalizes the macroscopic Maxwell's equations in vacuum to microscopic domain, and he assumed that Maxwell's equations (7.1) were valid on a microscopic scale in the absolute reference frame Σ_{a} :

$$\left.\begin{aligned} &\nabla_{\mathrm{a}} \times \boldsymbol{E}_{\mathrm{mic,a}} = -\frac{\partial \boldsymbol{B}_{\mathrm{mic,a}}}{\partial t_{\mathrm{a}}}, \quad \nabla_{\mathrm{a}} \times \boldsymbol{B}_{\mathrm{mic,a}} = \mu_0 \, j_{\mathrm{mic,a}} + \varepsilon_0 \mu_0 \frac{\partial \boldsymbol{E}_{\mathrm{mic,a}}}{\partial t_{\mathrm{a}}}, \\ &\nabla_{\mathrm{a}} \cdot \boldsymbol{E}_{\mathrm{mic,a}} = \rho_{\mathrm{mic,a}} / \varepsilon_0, \quad \nabla_{\mathrm{a}} \cdot \boldsymbol{B}_{\mathrm{mic,a}} = 0, \end{aligned}\right\} \tag{7.134}$$

where the subscript "mic" denotes microscopic quantities. This means that these equations are correct regardless of the motion of the microscopic elementary charges and, therefore, regardless of the motion of the medium of which they are composed.

Lorentz regarded the macroscopic electromagnetic field quantities as average values of the corresponding microscopic electromagnetic field quantities in equations (7.134) in physically infinitesimal volume. We evaluate the average values of the electromagnetic field quantities in Eqs. (7.134) to a physically infinitesimal volume, and gain a set of equations on macroscopic quantities of electromagnetic field, which forms are the same completely with Maxwell's equations (7.1) in vacuum, but here

$$\boldsymbol{E}_{\mathrm{a}} = \overline{\boldsymbol{E}}_{\mathrm{mic,a}}, \quad \boldsymbol{B}_{\mathrm{a}} = \overline{\boldsymbol{B}}_{\mathrm{mic,a}}, \tag{7.135}$$

$$\rho_{\mathrm{a}} = \overline{\rho}_{\mathrm{mic,a}} = \rho_{\mathrm{f\,a}} + \rho_{\mathrm{p\,a}}, \tag{7.136}$$

$$\boldsymbol{j}_{\mathrm{a}} = \overline{\boldsymbol{j}}_{\mathrm{mic,a}} = \boldsymbol{j}_{\mathrm{f\,a}} + \boldsymbol{j}_{\mathrm{pa}} + \boldsymbol{j}_{\mathrm{m\,a}}, \tag{7.137}$$

where

$$\rho_{\mathrm{pa}} = -\nabla_{\mathrm{a}} \cdot \boldsymbol{P}_{\mathrm{a}}\,,\quad \boldsymbol{j}_{\mathrm{pa}} = \frac{\partial \boldsymbol{P}_{\mathrm{a}}}{\partial t_{\mathrm{a}}}\,,\quad \boldsymbol{j}_{\mathrm{ma}} = \nabla_{\mathrm{a}} \times \boldsymbol{M}_{\mathrm{a}}. \qquad (7.138)$$

The signs of the average values in the above equations represent to evaluate the average values to a physically infinitesimal volume. Equations (7.135)—(7.137) also use the results in the above section, but to add the subscripts "a" to denote that apply these formulas to the absolute reference frame, where $\rho_{\mathrm{f\,a}}$ is the free charge density, $\rho_{\mathrm{p\,a}}$ is the polarization charge density, $\boldsymbol{j}_{\mathrm{f\,a}}$, $\boldsymbol{j}_{\mathrm{pa}}$ and $\boldsymbol{j}_{\mathrm{m\,a}}$ are respectively the free current intensity, polarization current intensity and magnetization current density. Eq. (7.138) is gained by applying Eqs. (7.130), (7.131) and (7.133) to frame Σ_{a}, but whether the media are at rest or move, these equations are all valid, namely they are regarded as definitions of $\boldsymbol{P}_{\mathrm{a}}$ and $\boldsymbol{M}_{\mathrm{a}}$.

Substituting Eqs. (7.136)—(7.138) to the equation which form is same completely with Eq. (7.1), and defining the electric displacement $\boldsymbol{D}_{\mathrm{a}}$ and magnetic field intensity $\boldsymbol{H}_{\mathrm{a}}$ in frame Σ_{a} as follows

$$\boldsymbol{D}_{\mathrm{a}} = \varepsilon_0 \boldsymbol{E}_{\mathrm{a}} + \boldsymbol{P}_{\mathrm{a}}\,,\quad \boldsymbol{H}_{\mathrm{a}} = \frac{\boldsymbol{B}_{\mathrm{a}}}{\mu_0} - \boldsymbol{M}_{\mathrm{a}}\,, \qquad (7.139)$$

we obtain

$$\left.\begin{aligned} &\nabla_{\mathrm{a}} \times \boldsymbol{E}_{\mathrm{a}} = -\frac{\partial \boldsymbol{B}_{\mathrm{a}}}{\partial t_{\mathrm{a}}}, \quad \nabla_{\mathrm{a}} \times \boldsymbol{H}_{\mathrm{a}} = \boldsymbol{j}_{\mathrm{f\,a}} + \frac{\partial \boldsymbol{D}_{\mathrm{a}}}{\partial t_{\mathrm{a}}}, \\ &\nabla_{\mathrm{a}} \cdot \boldsymbol{D}_{\mathrm{a}} = \rho_{\mathrm{f\,a}}, \qquad \nabla_{\mathrm{a}} \cdot \boldsymbol{B}_{\mathrm{a}} = 0. \end{aligned}\right\}$$

These are the macroscopic electromagnetic field equations in media in the absolute reference frame Σ_{a}. Whether the media are at rest or move, Maxwell's equations (7.6) in media are all valid. The difference is only that the constitutive relations of moving media take the different form more complex than that of rest media (see Sec. 7.7).

7. 6. 3. Several relations

To discuss further, in present section several relations on free charge density and the free current intensity, average bound charge density and average bound current density are derived.

The discussions of Sec. 7.2 indicate that, according to Standard Space-time Theory, the law of conservation of charge holds true for any inertial frame, as shown by Eqs. (7.63) and (7.66), i. e.

$$\nabla_{\mathrm{a}} \cdot \boldsymbol{j}_{\mathrm{a}} + \frac{\partial \rho_{\mathrm{a}}}{\partial t_{\mathrm{a}}} = 0\,,\quad \nabla \cdot \boldsymbol{j} + \frac{\partial \rho}{\partial t} = 0.$$

The law of conservation of charge is essentially correlative with microscopic charge and current, i.e., for the absolute reference frame Σ_{a} and any ordinary inertial frame Σ, we have

$$\nabla_{\mathrm{a}} \cdot \boldsymbol{j}_{\mathrm{mic,a}} + \frac{\partial \rho_{\mathrm{mic,a}}}{\partial t_{\mathrm{a}}} = 0, \quad \nabla \cdot \boldsymbol{j}_{\mathrm{mic}} + \frac{\partial \rho_{\mathrm{mic}}}{\partial t} = 0.$$

To evaluate the average values of the quantities in the above equations to a physically infinitesimal volume, and regard the macroscopic electromagnetic field quantities as average values of the corresponding microscopic electromagnetic field quantities to physically infinitesimal volume, we obtain Eqs. (7.63) and (7.66), where

$$\rho_{\mathrm{a}} = \bar{\rho}_{\mathrm{mic,a}}, \quad \boldsymbol{j}_{\mathrm{a}} = \bar{\boldsymbol{j}}_{\mathrm{mic,a}}, \tag{7.140}$$

$$\rho = \bar{\rho}_{\mathrm{mic}}, \quad \boldsymbol{j} = \bar{\boldsymbol{j}}_{\mathrm{mic}}. \tag{7.141}$$

By the previous discussion,

$$\rho_{\mathrm{a}} = \rho_{\mathrm{fa}} + \rho_{\mathrm{pa}}, \quad \boldsymbol{j}_{\mathrm{a}} = \boldsymbol{j}_{\mathrm{fa}} + \boldsymbol{j}_{\mathrm{pa}} + \boldsymbol{j}_{\mathrm{ma}}, \tag{7.142}$$

$$\rho = \rho_{\mathrm{f}} + \rho_{\mathrm{p}}, \quad \boldsymbol{j} = \boldsymbol{j}_{\mathrm{f}} + \boldsymbol{j}_{\mathrm{p}} + \boldsymbol{j}_{\mathrm{m}}. \tag{7.143}$$

Substituting the above equations into Eqs. (7.63)—(7.66), we obtain

$$\nabla_{\mathrm{a}} \cdot \left(\boldsymbol{j}_{\mathrm{fa}} + \boldsymbol{j}_{\mathrm{pa}} + \boldsymbol{j}_{\mathrm{ma}}\right) + \frac{\partial}{\partial t_{\mathrm{a}}}\left(\rho_{\mathrm{fa}} + \rho_{\mathrm{pa}}\right) = 0, \ \nabla \cdot \left(\boldsymbol{j}_{\mathrm{f}} + \boldsymbol{j}_{\mathrm{p}} + \boldsymbol{j}_{\mathrm{m}}\right) + \frac{\partial}{\partial t}\left(\rho_{\mathrm{f}} + \rho_{\mathrm{p}}\right) = 0.$$

If in point of macroscopic average effect there are not mutual transformation between the free charge and bound charge, and the free current and bound current (for example, there are not the phenomena of dielectric breakdown), then we have

$$\nabla_{\mathrm{a}} \cdot \boldsymbol{j}_{\mathrm{fa}} + \frac{\partial \rho_{\mathrm{fa}}}{\partial t_{\mathrm{a}}} = 0, \quad \nabla_{\mathrm{a}} \cdot \left(\boldsymbol{j}_{\mathrm{pa}} + \boldsymbol{j}_{\mathrm{ma}}\right) + \frac{\partial \rho_{\mathrm{p}}}{\partial t_{\mathrm{a}}} = 0, \tag{7.144}$$

$$\nabla \cdot \boldsymbol{j}_{\mathrm{f}} + \frac{\partial \rho_{\mathrm{f}}}{\partial t} = 0, \quad \nabla \cdot \left(\boldsymbol{j}_{\mathrm{p}} + \boldsymbol{j}_{\mathrm{m}}\right) + \frac{\partial \rho_{\mathrm{p}}}{\partial t} = 0. \tag{7.145}$$

That is to say that to any inertial frame, the free charge and free current, and the bound charge and bound current will respectively satisfy the law of conservation of charge.

The similar reasoning can apply to the transformations of charge density and current density. Substituting Eqs. (7.142) and (7.143) into Eq. (7.60a), we obtain

$$\rho_{\mathrm{f}} + \rho_{\mathrm{p}} = \gamma^{-1}\left(\rho_{\mathrm{fa}} + \rho_{\mathrm{pa}}\right), \quad \boldsymbol{j}_{\mathrm{f}} + \boldsymbol{j}_{\mathrm{p}} + \boldsymbol{j}_{\mathrm{m}} = \hat{T}\left(\boldsymbol{j}_{\mathrm{fa}} + \boldsymbol{j}_{\mathrm{pa}} + \boldsymbol{j}_{\mathrm{ma}}\right) - \gamma\left(\rho_{\mathrm{fa}} + \rho_{\mathrm{pa}}\right)\boldsymbol{v}.$$

If we apply the same postulate: in point of macroscopic average effect there are not mutual transition between the free charge and bound charge, and the free current and bound current, then we have

$$\rho_{\mathrm{f}} = \gamma^{-1}\rho_{\mathrm{fa}}, \quad \boldsymbol{j}_{\mathrm{f}} = \hat{T}\boldsymbol{j}_{\mathrm{fa}} - \gamma\rho_{\mathrm{fa}}\boldsymbol{v}, \tag{7.146}$$

$$\rho_{\mathrm{p}} = \gamma^{-1}\rho_{\mathrm{pa}}, \quad \boldsymbol{j}_{\mathrm{p}} + \boldsymbol{j}_{\mathrm{m}} = \hat{T}\left(\boldsymbol{j}_{\mathrm{pa}} + \boldsymbol{j}_{\mathrm{ma}}\right) - \gamma\rho_{\mathrm{pa}}\boldsymbol{v}. \tag{7.147}$$

By the above two equations we can obtain reverse transformations as follows

$$\rho_{\mathrm{fa}} = \gamma\rho_{\mathrm{f}}, \quad \boldsymbol{j}_{\mathrm{fa}} = \hat{T}^{-1}\boldsymbol{j}_{\mathrm{f}} + \gamma\rho_{\mathrm{f}}\boldsymbol{v}, \tag{7.148}$$

$$\rho_{\mathrm{pa}} = \gamma \rho_{\mathrm{p}}, \quad \boldsymbol{j}_{\mathrm{pa}} + \boldsymbol{j}_{\mathrm{m\,a}} = \hat{T}^{-1}\left(\boldsymbol{j}_{\mathrm{p}} + \boldsymbol{j}_{m}\right) + \gamma \rho_{\mathrm{p}} \boldsymbol{v}. \qquad (7.149)$$

7. 6. 4. The Electromagnetic Field Equations in Media in an Ordinary Inertial Frame

By the similar method to that in Sec. 7.6.2 we can find the electromagnetic field equations in material in an ordinary inertial frame. First, we generalize the electromagnetic field equations in vacuum in an ordinary inertial frame (7.127a) to microscopic domain. Denoting the microscopic quantities by subscript “mic”, with respect to frame Σ, we have

$$\left.\begin{aligned}
&\nabla \times \boldsymbol{E}_{\mathrm{mic}} + \frac{1}{c^2}\boldsymbol{v} \times \frac{\partial \boldsymbol{E}_{\mathrm{mic}}}{\partial t} = -\frac{\partial \boldsymbol{B}_{\mathrm{mic}}}{\partial t},\\
&\nabla \times \boldsymbol{B}_{\mathrm{mic}} + \frac{1}{c^2}\boldsymbol{v} \times \frac{\partial \boldsymbol{B}_{\mathrm{mic}}}{\partial t} = \mu_0 \boldsymbol{j}_{\mathrm{mic}} + \frac{1}{c^2}\frac{\partial \boldsymbol{E}_{\mathrm{mic}}}{\partial t},\\
&\nabla \cdot \boldsymbol{E}_{\mathrm{mic}} + \frac{1}{c^2}\boldsymbol{v} \cdot \frac{\partial \boldsymbol{E}_{\mathrm{mic}}}{\partial t} = \rho_{\mathrm{mic}} / \varepsilon_0 - \mu_0 \boldsymbol{v} \cdot \boldsymbol{j}_{\mathrm{mic}},\\
&\nabla \times \boldsymbol{B}_{\mathrm{mic}} + \frac{1}{c^2}\boldsymbol{v} \cdot \frac{\partial \boldsymbol{B}_{\mathrm{mic}}}{\partial t} = 0.
\end{aligned}\right\} \qquad (7.150)$$

Then, we regard the macroscopic electromagnetic field quantities as average values of the corresponding microscopic electromagnetic field quantities to physically infinitesimal volume. We evaluate the average values of the electromagnetic field quantities in equations (7.150) to the same physically infinitesimal volume, so gain a set of equations on macroscopic electromagnetic field quantities, which forms are the same completely with the electromagnetic field equations in vacuum in an ordinary inertial frame (7.127a), but here

$$\boldsymbol{E} = \overline{\boldsymbol{E}}_{\mathrm{mic}}, \quad \boldsymbol{B} = \overline{\boldsymbol{B}}_{\mathrm{mic}}, \qquad (7.151)$$

$$\rho = \overline{\rho}_{\mathrm{mic}} = \rho_{\mathrm{f}} + \rho_{\mathrm{p}}, \qquad (7.152)$$

$$\boldsymbol{j} = \overline{\boldsymbol{j}}_{\mathrm{mic}} = \boldsymbol{j}_{\mathrm{f}} + \boldsymbol{j}_{\mathrm{p}} + \boldsymbol{j}_{\mathrm{m}}. \qquad (7.153)$$

The present problem is that how to ascertain the relations between the polarization charge density ρ_{p} (the polarization current intensity $\boldsymbol{j}_{\mathrm{p}}$, the magnetization current density $\boldsymbol{j}_{\mathrm{m}}$) and the polarization intensity vector $\boldsymbol{P}$, the magnetization intensity vector $\boldsymbol{M}$ in an ordinary inertial frame. There are several ways to achieve the solution of the problem. In my view, the following way is a very good choice.

Notice the gained relations: (1) the relations (7.138) between $\rho_{\mathrm{pa}}, \boldsymbol{j}_{\mathrm{pa}}, \boldsymbol{j}_{\mathrm{ma}}$ and $\boldsymbol{P}_{\mathrm{a}}, \boldsymbol{M}_{\mathrm{a}}$; (2) the transformations (7.147) between $\rho_{\mathrm{p}}, \boldsymbol{j}_{\mathrm{p}}, \boldsymbol{j}_{\mathrm{m}}$ and $\rho_{\mathrm{pa}}, \boldsymbol{j}_{\mathrm{pa}}, \boldsymbol{j}_{\mathrm{ma}}$, and the reverse transformations (7.149). If we further gain (3) the transformations between $\boldsymbol{P}_{\mathrm{a}}, \boldsymbol{M}_{\mathrm{a}}$ and $\boldsymbol{P}, \boldsymbol{M}$, we can naturally gain the relations between $\rho_{\mathrm{p}}, \boldsymbol{j}_{\mathrm{p}}, \boldsymbol{j}_{\mathrm{m}}$ and $\boldsymbol{P}, \boldsymbol{M}$, so achieve the solution of the problem.

How do we find the transformations between $\boldsymbol{P}_{\mathrm{a}}, \boldsymbol{M}_{\mathrm{a}}$ and $\boldsymbol{P}, \boldsymbol{M}$? Notice Eq. (7.139) in frame Σ_{a} hold true, namely

$$\boldsymbol{D}_{\mathrm{a}} = \varepsilon_0 \boldsymbol{E}_{\mathrm{a}} + \boldsymbol{P}_{\mathrm{a}}, \quad \boldsymbol{H}_{\mathrm{a}} = \boldsymbol{B}_{\mathrm{a}} / \mu_0 - \boldsymbol{M}_{\mathrm{a}}. \tag{7.154}$$

If we can finally obtain that in frame Σ

$$\boldsymbol{D} = \varepsilon_0 \boldsymbol{E} + \boldsymbol{P}, \quad \boldsymbol{H} = \boldsymbol{B} / \mu_0 - \boldsymbol{M}, \tag{7.155}$$

then the following two sets of quantities

$$\begin{array}{ccc} \varepsilon_0 \boldsymbol{E}_{\mathrm{a}}, \quad \boldsymbol{B}_{\mathrm{a}} / \mu_0 & & \boldsymbol{P}_{\mathrm{a}}, \quad -\boldsymbol{M}_{\mathrm{a}} \\ \downarrow & & \downarrow \\ \varepsilon_0 \boldsymbol{E}, \quad \boldsymbol{B} / \mu_0 & & \boldsymbol{P}, \quad -\boldsymbol{M} \end{array} \tag{7.156}$$

Certainly, have the same corresponding transformations. We have known the transformations (7.115) between $\boldsymbol{E}_{\mathrm{a}}, \boldsymbol{B}_{\mathrm{a}}$ and $\boldsymbol{E}, \boldsymbol{B}$, and the reverse transformations as follows

$$\boldsymbol{E}_{\mathrm{a}} = \gamma \left(\hat{T}^{-1} \boldsymbol{E} - \boldsymbol{v} \times \boldsymbol{B} \right), \quad \boldsymbol{B}_{\mathrm{a}} = \gamma \left(\hat{T}^{-1} \boldsymbol{B} + \boldsymbol{v} \times \boldsymbol{E} / c^2 \right).$$

Notice Eq. (7.5), namely $c^{-2} = \varepsilon_0 \mu_0$, from the above equation we can obtain

$$\varepsilon_0 \boldsymbol{E}_{\mathrm{a}} = \gamma \left[\hat{T}^{-1} (\varepsilon_0 \boldsymbol{E}) - \frac{1}{c^2} \boldsymbol{v} \times \left(\frac{\boldsymbol{B}}{\mu_0} \right) \right], \quad \frac{\boldsymbol{B}_{\mathrm{a}}}{\mu_0} = \gamma \left[\hat{T}^{-1} \left(\frac{\boldsymbol{B}}{\mu_0} \right) + \boldsymbol{v} \times (\varepsilon_0 \boldsymbol{E}) \right].$$

Hence, we should have the reverse transformations of $\boldsymbol{P}, \boldsymbol{M}$

$$\boldsymbol{P}_{\mathrm{a}} = \gamma \left(\hat{T}^{-1} \boldsymbol{P} + \boldsymbol{v} \times \boldsymbol{M} / c^2 \right), \quad \boldsymbol{M}_{\mathrm{a}} = \gamma \left(\hat{T}^{-1} \boldsymbol{M} - \boldsymbol{v} \times \boldsymbol{P} \right). \tag{7.157}$$

Of course, the condition is that equations (7.155) hold true. From Eqs. (7.157) we can also find the transformations of $\boldsymbol{P}, \boldsymbol{M}$.

The transformations of polarization intensity vector $\boldsymbol{P}$ and magnetization intensity vector $\boldsymbol{M}$ and their inverse transformation are concentrated as follows:

$$\begin{aligned} \boldsymbol{P} &= \gamma \left(\hat{T}^{-1} \boldsymbol{P}_{\mathrm{a}} - \boldsymbol{v} \times \boldsymbol{M}_{\mathrm{a}} / c^2 \right), \quad \boldsymbol{M} = \gamma \left(\hat{T}^{-1} \boldsymbol{M}_{\mathrm{a}} + \boldsymbol{v} \times \boldsymbol{P}_{\mathrm{a}} \right), \\ \boldsymbol{P}_{\mathrm{a}} &= \gamma \left(\hat{T}^{-1} \boldsymbol{P} + \boldsymbol{v} \times \boldsymbol{M} / c^2 \right), \quad \boldsymbol{M}_{\mathrm{a}} = \gamma \left(\hat{T}^{-1} \boldsymbol{M} - \boldsymbol{v} \times \boldsymbol{P} \right). \end{aligned} \tag{7.158a}$$

Or by the components of parallel and perpendicular to $\boldsymbol{v}$, Eq. (7.158a) can be re-written as

$$\left. \begin{aligned} \boldsymbol{P}_{\parallel} &= \boldsymbol{P}_{\mathrm{a}\parallel}, & \boldsymbol{M}_{\parallel} &= \boldsymbol{M}_{\mathrm{a}\parallel}, \\ \boldsymbol{P}_{\perp} &= \gamma \left(\boldsymbol{P}_{\mathrm{a}\perp} - \boldsymbol{v} \times \boldsymbol{M}_{\mathrm{a}} / c^2 \right), & \boldsymbol{M}_{\perp} &= \gamma \left(\boldsymbol{M}_{\mathrm{a}\perp} + \boldsymbol{v} \times \boldsymbol{P}_{\mathrm{a}} \right), \\ \boldsymbol{P}_{\mathrm{a}\parallel} &= \boldsymbol{P}_{\parallel}, & \boldsymbol{M}_{\mathrm{a}\parallel} &= \boldsymbol{M}_{\parallel}, \\ \boldsymbol{P}_{a\perp} &= \gamma \left(\boldsymbol{P}_{\mathrm{a}} + \boldsymbol{v} \times \boldsymbol{M}_{\mathrm{a}} / c^2 \right), & \boldsymbol{M}_{\mathrm{a}\perp} &= \gamma \left(\boldsymbol{M}_{\perp} - \boldsymbol{v} \times \boldsymbol{P} \right). \end{aligned} \right\} \tag{7.158b}$$

Starting from the Eqs (7.147) of $\rho_{\mathrm{p}}, \boldsymbol{j}_{\mathrm{p}}$ and $\boldsymbol{j}_{\mathrm{m}}$, and transformations (158) of $\boldsymbol{P}$ and $\boldsymbol{M}$, and using in turn Eqs. (7.138), (7.45), (7.37), (7.34), (7.50) and (7.47), we can find

$$\rho_{\mathrm{p}} = \gamma^{-1} \rho_{\mathrm{pa}} = -\gamma^{-1} \left(\nabla_{\mathrm{a}} \cdot \boldsymbol{P}_{\mathrm{a}} \right) = -\left(\hat{T} \nabla \right) \cdot \left(\hat{T}^{-1} \boldsymbol{P} + \boldsymbol{v} \times \boldsymbol{M} / c^2 \right),$$

Namely

$$\rho_{\mathrm{p}} = -\nabla \cdot \boldsymbol{P} + \frac{1}{c^2}\boldsymbol{v} \cdot \nabla \times \boldsymbol{M}, \tag{7.159}$$

$$\boldsymbol{j}_{\mathrm{p}} + \boldsymbol{j}_m = \hat{T}\left(\frac{\partial \boldsymbol{P}_{\mathrm{a}}}{\partial t_{\mathrm{a}}} + \nabla_{\mathrm{a}} \times \boldsymbol{M}_{\mathrm{a}}\right) - \gamma^2 \rho_{\mathrm{p}} \boldsymbol{v} = \hat{T}\left[\frac{\partial}{\partial t}\left(\hat{T}^{-1}\boldsymbol{P} + \boldsymbol{v} \times \boldsymbol{M} / c^2\right)\right.$$

$$\left. - \gamma^2 (\boldsymbol{v} \cdot \nabla)\left(\hat{T}^{-1}\boldsymbol{P} + \boldsymbol{v} \times \boldsymbol{M} / c^2\right) + \gamma\left(\hat{T}\nabla\right) \times \left(\hat{T}^{-1}\boldsymbol{M} - \boldsymbol{v} \times \boldsymbol{P}\right)\right] - \gamma^2 \rho_{\mathrm{p}} \boldsymbol{v}$$

$$= \frac{\partial \boldsymbol{P}}{\partial t} + \frac{1}{c^2}\boldsymbol{v} \times \frac{\partial \boldsymbol{M}}{\partial t} - \gamma^2 (\boldsymbol{v} \cdot \nabla)\boldsymbol{P} - \left(\gamma^2 - 1\right)\boldsymbol{v}_0 \times \left[(\boldsymbol{v}_0 \cdot \nabla)\boldsymbol{M}\right]$$

$$+ \hat{T}\gamma\left(\hat{T}\nabla\right) \times \left(\hat{T}^{-1}\boldsymbol{M}\right) - \gamma\hat{T}\left(\hat{T}\nabla\right) \times (\boldsymbol{v} \times \boldsymbol{P}) - \gamma^2 \rho_{\mathrm{p}} \boldsymbol{v}.$$

Using in turn Eqs. (7.49), (7.18),(7.28), (7.31) and (7..32) to calculate the latter three terms, we obtain respectively

$$\hat{T}\gamma\left(\hat{T}\nabla\right) \times \left(\hat{T}^{-1}\boldsymbol{M}\right) = \gamma^2 \nabla \times \left(\hat{T}^{-1}\boldsymbol{M}\right) + \hat{T}\gamma(\gamma - 1)\boldsymbol{v}_0 \times \left[\nabla\left(\boldsymbol{v}_0 \cdot \hat{T}^{-1}\boldsymbol{M}\right)\right]$$

$$= \gamma^2 \nabla \times \boldsymbol{M} + \left(\gamma - \gamma^2\right)\nabla \times \left[\boldsymbol{v}_0(\boldsymbol{v}_0 \cdot \boldsymbol{M})\right] + (\gamma - 1)\boldsymbol{v}_0 \times \left[\nabla(\boldsymbol{v}_0 \cdot \boldsymbol{M})\right]$$

$$= \gamma^2 \nabla \times \boldsymbol{M} + \left(\gamma^2 - 1\right)\boldsymbol{v}_0 \times \left[\nabla(\boldsymbol{v}_0 \cdot \boldsymbol{M})\right]$$

$$= \gamma^2 \nabla \times \boldsymbol{M} + \left(\gamma^2 - 1\right)\boldsymbol{v}_0 \times \left[\boldsymbol{v}_0 \times (\nabla \times \boldsymbol{M}) + (\boldsymbol{v}_0 \cdot \nabla)\boldsymbol{M}\right]$$

$$= \gamma^2 \nabla \times \boldsymbol{M} + \left(\gamma^2 - 1\right)\boldsymbol{v}_0\left[\boldsymbol{v}_0 \cdot (\nabla \times \boldsymbol{M})\right] - \left(\gamma^2 - 1\right)\nabla \times \boldsymbol{M} + \left(\gamma^2 - 1\right)\boldsymbol{v}_0 \times \left[(\boldsymbol{v}_0 \cdot \nabla)\boldsymbol{M}\right]$$

$$= \nabla \times \boldsymbol{M} + \left(\gamma^2 - 1\right)\boldsymbol{v}_0\left[\boldsymbol{v}_0 \cdot (\nabla \times \boldsymbol{M})\right] + \left(\gamma^2 - 1\right)\boldsymbol{v}_0 \times \left[(\boldsymbol{v}_0 \cdot \nabla)\boldsymbol{M}\right],$$

$$-\gamma\hat{T}\left(\hat{T}\nabla\right) \times (\boldsymbol{v} \times \boldsymbol{P}) = -\gamma^2\hat{T}\left[\hat{T}^{-1}\nabla \times (\boldsymbol{v} \times \boldsymbol{P})\right] = -\gamma^2(\nabla \cdot \boldsymbol{P})\boldsymbol{v} + \gamma^2(\boldsymbol{v} \cdot \nabla)\boldsymbol{P},$$

$$-\gamma^2 \rho_{\mathrm{p}} \boldsymbol{v} = \gamma^2(\nabla \cdot \boldsymbol{P})\boldsymbol{v} - \left(\gamma^2 - 1\right)\boldsymbol{v}_0\left[\boldsymbol{v}_0 \cdot (\nabla \times \boldsymbol{M})\right].$$

Substituting the gained results into the former equation, we obtain

$$\boldsymbol{j}_{\mathrm{p}} + \boldsymbol{j}_{\mathrm{m}} = \frac{\partial \boldsymbol{P}}{\partial t} + \nabla \times \boldsymbol{M} + \frac{1}{c^2}\boldsymbol{v} \times \frac{\partial \boldsymbol{M}}{\partial t}.$$

Observing and analyzing the above equation, obviously, $\boldsymbol{j}_{\mathrm{p}}$ should be relative to $\boldsymbol{P}$, $\boldsymbol{j}_{\mathrm{m}}$ should be relative to $\boldsymbol{M}$. Rewriting the above results all together, we have

$$\rho_{\mathrm{p}} = -\nabla \cdot \boldsymbol{P} + \frac{1}{c^2}\boldsymbol{v} \cdot \nabla \times \boldsymbol{M}, \quad \boldsymbol{j}_{\mathrm{p}} = \frac{\partial \boldsymbol{P}}{\partial t}, \quad \boldsymbol{j}_{\mathrm{m}} = \nabla \times \boldsymbol{M} + \frac{1}{c^2}\boldsymbol{v} \times \frac{\partial \boldsymbol{M}}{\partial t} \tag{7.160}$$

Substituting Eqs. (7.151)—(7.153) and (7.160) the equations (7.150), where the second equation and the third equation become

$$\nabla\times\boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{B}}{\partial t}=\mu_0\boldsymbol{j}_{\mathrm{f}}+\mu_0\frac{\partial\boldsymbol{P}}{\partial t}+\mu_0\nabla\times\boldsymbol{M}+\mu_0\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{M}}{\partial t}+\frac{1}{c^2}\frac{\partial\boldsymbol{E}}{\partial t},$$

$$\nabla\cdot\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{E}}{\partial t}=\frac{\rho_{\mathrm{f}}}{\varepsilon_0}-\frac{1}{\varepsilon_0}(\nabla\cdot\boldsymbol{P})-\mu_0\boldsymbol{v}\cdot\left(\boldsymbol{j}_{\mathrm{f}}+\frac{\partial\boldsymbol{P}}{\partial t}\right).$$

The above first equation is divided by μ_0, the second equation is multiplied by ε_0, and to notice $c^{-2}=\varepsilon_0\mu_0$, and to define the electric displacement vector $\boldsymbol{D}$ and magnetic field intensity $\boldsymbol{H}$ in frame Σ according to Eq. (155), namely

$$\boldsymbol{D}=\varepsilon_0\boldsymbol{E}+\boldsymbol{P};\quad \boldsymbol{H}=\frac{\boldsymbol{B}}{\mu_0}-\boldsymbol{M},$$

we obtain respectively the new equations on $\nabla\times\boldsymbol{H}$ and $\nabla\cdot\boldsymbol{D}$, writing them in connection with the first equation and the fourth equation, we have

$$\left.\begin{aligned}
&\nabla\times\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}=-\frac{\partial\boldsymbol{B}}{\partial t},\\
&\nabla\times\boldsymbol{H}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{H}}{\partial t}=\boldsymbol{j}_{\mathrm{f}}+\frac{\partial\boldsymbol{D}}{\partial t},\\
&\nabla\cdot\boldsymbol{D}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{D}}{\partial t}=\rho_{\mathrm{f}}-\frac{1}{c^2}\boldsymbol{v}\cdot\boldsymbol{j}_{\mathrm{f}},\\
&\nabla\cdot\boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{B}}{\partial t}=0.
\end{aligned}\right\}\qquad (7.161\text{a})$$

Applying Stokes' theorem and Gauss' theorem in vector analysis we can rewrite Eq. (7.161a) in the corresponding integral form as follows:

$$\left.\begin{aligned}
&\oint_L\boldsymbol{E}\cdot\mathrm{d}\boldsymbol{l}=-\frac{\mathrm{d}}{\mathrm{d}t}\int_s\left(\boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\times\boldsymbol{E}\right)\cdot\mathrm{d}\boldsymbol{s},\\
&\oint_L\boldsymbol{H}\cdot\mathrm{d}\boldsymbol{l}=I_{\mathrm{f}}+\frac{\mathrm{d}}{\mathrm{d}t}\int_s\left(\boldsymbol{D}-\frac{1}{c^2}\boldsymbol{v}\times\boldsymbol{H}\right)\cdot\mathrm{d}\boldsymbol{s},\\
&\oint_s\boldsymbol{D}\cdot\mathrm{d}\boldsymbol{s}=Q_{\mathrm{f}}-\frac{1}{c^2}\int(\boldsymbol{v}\cdot\boldsymbol{j}_{\mathrm{f}})\mathrm{d}V-\frac{1}{c^2}\frac{\mathrm{d}}{\mathrm{d}t}\int_V(\boldsymbol{v}\cdot\boldsymbol{D})\mathrm{d}V,\\
&\oint_s\boldsymbol{B}\cdot\mathrm{d}\boldsymbol{s}=-\frac{1}{c^2}\frac{\mathrm{d}}{\mathrm{d}t}\int_v(\boldsymbol{v}\cdot\boldsymbol{B})\mathrm{d}V.
\end{aligned}\right\}\qquad (7.161\text{b})$$

In the first equation and the second equation in Eqs. (7.161b) L represents an arbitrary closed curve, S represents a surface around bounded by L; I_{f} is the free currents passed through the surface S; In the third equation and the fourth equation in Eqs. (7.161b) S represents an arbitrary closed surface, V represents a volume enclosed by S, Q_{f} is the free charges in volume V.

The equations (7.161) are the electromagnetic field equations in media in an ordinary inertial frame in the differential form and integral form. Whether the media are at rest or move with respect to ordinary inertial frame, the equations (7.161) in media are all valid.

Obviously, taking $\boldsymbol{v}=0$ in Eqs. (7.161) then they return to or revert to Maxwell's equations in media which describe the law of the electromagnetic field motion in vacuum relative to the absolute reference frame. The same, Comparing the equations (7.161) with Maxwell's equations in media (in the differential form and integral form), we can see that the differences are only additions of one or two terms coefficient of which is $\left(v/c^{2}\right)$. These differences are so infinitely small that exceed out of the limits of precision of the present experiments.

7. 7. The Transformations of $\boldsymbol{D}$ and $\boldsymbol{H}$. The Boundary Value Relations. The Constitutive Relations of Moving Media

7. 7. 1. The Transformations of $\boldsymbol{D}$ and $\boldsymbol{H}$

Based upon the definitions (7.139) and (7.155) of the electric displacement vector and magnetic field intensity in the absolute frame Σ_{a} and an ordinary inertial frame Σ given in above section, namely

$$\boldsymbol{D}_{\mathrm{a}}=\varepsilon_{0}\boldsymbol{E}_{\mathrm{a}}+\boldsymbol{p}_{\mathrm{a}},\quad \boldsymbol{H}_{\mathrm{a}}=\left(\boldsymbol{B}_{\mathrm{a}}/\mu_{0}\right)-\boldsymbol{M}_{\mathrm{a}},$$
$$\boldsymbol{D}_{\mathrm{a}}=\varepsilon_{0}\boldsymbol{E}+\boldsymbol{p},\qquad \boldsymbol{H}=\left(\boldsymbol{B}/\mu_{0}\right)-\boldsymbol{M},$$

and the reverse transformations (7.115) of $\boldsymbol{E}$, $\boldsymbol{B}$ and the reverse transformations (7.158) of $\boldsymbol{P},\boldsymbol{M}$, namely

$$\boldsymbol{E}_{\mathrm{a}}=\gamma\left(\hat{T}^{-1}\boldsymbol{E}-\boldsymbol{v}\times\boldsymbol{B}\right),\qquad \boldsymbol{B}_{\mathrm{a}}=\gamma\left(\hat{T}^{-1}\boldsymbol{B}+\boldsymbol{v}\times\boldsymbol{E}/c^{2}\right),$$
$$\boldsymbol{P}_{\mathrm{a}}=\gamma\left(\hat{T}^{-1}\boldsymbol{P}+\boldsymbol{v}\times\boldsymbol{M}/c^{2}\right),\qquad \boldsymbol{M}_{\mathrm{a}}=\gamma\left(\hat{T}^{-1}\boldsymbol{M}-\boldsymbol{v}\times\boldsymbol{P}\right),$$

we easily find

$$\boldsymbol{D}_{\mathrm{a}}=\varepsilon_{0}\gamma\left(\hat{T}^{-1}\boldsymbol{E}-\boldsymbol{v}\times\boldsymbol{B}\right)+\gamma\left(\hat{T}^{-1}\boldsymbol{P}+\boldsymbol{v}\times\boldsymbol{M}/c^{2}\right)$$
$$=\gamma\hat{T}^{-1}\left(\varepsilon_{0}\boldsymbol{E}+\boldsymbol{P}\right)-\gamma\boldsymbol{v}\times\left(\boldsymbol{B}/\mu_{0}-\boldsymbol{M}\right)/c^{2}.$$

That is

$$\boldsymbol{D}_{\mathrm{a}}=\gamma\left(\hat{T}^{-1}\boldsymbol{D}-\boldsymbol{v}\times\boldsymbol{H}/c^{2}\right),\tag{7.162}$$

$$\boldsymbol{H}_{\mathrm{a}}=\gamma\hat{T}^{-1}\left(\boldsymbol{B}/\mu_{0}\right)+\gamma\boldsymbol{v}\times\left(\varepsilon_{0}\boldsymbol{E}\right)-\gamma\left(\hat{T}^{-1}\boldsymbol{M}\right)+\gamma\boldsymbol{v}\times\boldsymbol{P}$$
$$=\gamma\left[\hat{T}^{-1}\left(\frac{\boldsymbol{B}}{\mu_{0}}-\boldsymbol{M}\right)+\boldsymbol{v}\times\left(\varepsilon_{0}\boldsymbol{E}\times\boldsymbol{P}\right)\right].$$

That is

$$\boldsymbol{H}_a = \gamma\left(\hat{T}^{-1}\boldsymbol{H} + \boldsymbol{v}\times\boldsymbol{D}\right). \tag{7.163}$$

Acting on the two sides of Eq. (7.162) by the operator $\gamma^{-1}\hat{T}$ and using Eq. (7.163) we obtain

$$\begin{aligned}\boldsymbol{D} &= \gamma^{-1}\hat{T}\boldsymbol{D}_{\mathrm{a}} + \boldsymbol{v}\times\boldsymbol{H}/c^2 = \gamma^{-1}\hat{T}\boldsymbol{D}_{\mathrm{a}} + \boldsymbol{v}\times\left(\gamma^{-1}\hat{T}\boldsymbol{H}_{\mathrm{a}} - \boldsymbol{v}\times\boldsymbol{D}\right)/c^2 \\ &= \gamma^{-1}\hat{T}\boldsymbol{D}_{\mathrm{a}} + \gamma^{-1}\boldsymbol{v}\times\boldsymbol{H}_{\mathrm{a}}/c^2 + \left(v^2/c^2\right)\boldsymbol{D} - \left(v^2/c^2\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\boldsymbol{D}\right).\end{aligned}$$

Hence, we have

$$\gamma^{-2}\boldsymbol{D} + \left(v^2/c^2\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\boldsymbol{D}\right) = \gamma^{-1}\left(\hat{T}\boldsymbol{D}_{\mathrm{a}} + \boldsymbol{v}\times\boldsymbol{H}_{\mathrm{a}}/c^2\right).$$

Multiplying the two sides of the above equation by γ^2, and using $\gamma^2 v^2/c^2 = \gamma^2 - 1$ and Eqs. (7.19) and (7.40), we obtain

$$\boldsymbol{D} = \gamma\left(\hat{T}^{-1}\boldsymbol{D}_{\mathrm{a}} + \boldsymbol{v}\times\boldsymbol{H}_{\mathrm{a}}/c^2\right). \tag{7.164}$$

Similarly, we obtain

$$\boldsymbol{H} = \gamma\left(T^{-1}\boldsymbol{H}_{\mathrm{a}} - \boldsymbol{v}\times\boldsymbol{D}_{\mathrm{a}}\right). \tag{7.165}$$

Collecting the transformations of the electric displacement vector $\boldsymbol{D}$ and magnetic field intensity $\boldsymbol{H}$ and the reverse transformations as follows

$$\left.\begin{aligned}&\boldsymbol{D} = \gamma\left(T^{-1}\boldsymbol{D}_{\mathrm{a}} + \boldsymbol{v}\times\boldsymbol{H}_{\mathrm{a}}/c^2\right), \quad \boldsymbol{H} = \gamma\left(T^{-1}\boldsymbol{H}_{\mathrm{a}} - \boldsymbol{v}\times\boldsymbol{D}_{\mathrm{a}}\right),\\ &\boldsymbol{D}_{\mathrm{a}} = \gamma\left(T^{-1}\boldsymbol{D} - \boldsymbol{v}\times\boldsymbol{H}/c^2\right), \quad \boldsymbol{H}_{\mathrm{a}} = \gamma\left(T^{-1}\boldsymbol{H} + \boldsymbol{v}\times\boldsymbol{D}\right),\end{aligned}\right\} \tag{7.166a}$$

Or by the components of parallel and perpendicular to $\boldsymbol{v}$, Eq. (7.166a) can be re-written as

$$\left.\begin{aligned}&\boldsymbol{D}_{\|} = \boldsymbol{D}_{\mathrm{a}\|}, && \boldsymbol{H}_{\|} = \boldsymbol{H}_{\mathrm{a}\|},\\ &\boldsymbol{D}_{\perp} = \gamma\left(\boldsymbol{D}_{\mathrm{a}\perp} + \boldsymbol{v}\times\boldsymbol{H}_{\mathrm{a}}/c^2\right), && \boldsymbol{H}_{\perp} = \gamma\left(\boldsymbol{H}_{\mathrm{a}\perp} - \boldsymbol{v}\times\boldsymbol{D}_{\mathrm{a}}\right),\\ &\boldsymbol{D}_{\mathrm{a}\|} = \boldsymbol{D}_{\|}, && \boldsymbol{H}_{\mathrm{a}\|} = \boldsymbol{H}_{\|},\\ &\boldsymbol{D}_{\mathrm{a}\perp} = \gamma\left(\boldsymbol{D}_{\perp} - \boldsymbol{v}\times\boldsymbol{H}/c^2\right), && \boldsymbol{H}_{\mathrm{a}\perp} = \gamma\left(\boldsymbol{H}_{\perp} + \boldsymbol{v}\times\boldsymbol{D}\right).\end{aligned}\right\} \tag{7.166b}$$

7. 7. 2. The boundary Value Relations of Electromagnetic Field

At the surface separating two media there probably appear the distribution of surface charges and surface currents, so the electromagnetic field quantities take place mutation, and the electromagnetic field equations (7.161a) in the differential form are no longer valid. By this time, we can apply the electromagnetic field equations (7.161b) in the integral form to find the relations of the electromagnetic field quantities of the two sides of the separating surface. These are the boundary value relations of the electromagnetic field in an ordinary inertial frame. They are the expressional form of the electromagnetic field equations in media in an ordinary inertial frame at the separating surface of media.

First, we apply the third equation of Eqs. (7.161b) to a small flat cylinder at the interface between two media, as in Fig.7.4. The surface integral of the left side of the third equation is over the top and bottom and side of the cylinder. As the thickness of the cylinder limits to zero, the integral over the side limits to zero. Hence

$$\oint_s \boldsymbol{D}\cdot \mathrm{d}\boldsymbol{S} = \left(D_{1\mathrm{n}} - D_{2\mathrm{n}}\right)\Delta S,$$

where ΔS is the bottom area of the cylinder, $D_{1\mathrm{n}}$ and $D_{2\mathrm{n}}$ are the normal components of the electric displacement vector in medium 1 and medium 2 at the place where the cylinder is, the direction of the normal $\boldsymbol{n}$ is from medium 2 to medium 1. Consider the integral of the right side of the third equation, suppose the surface density of the free charges at the interface is σ_{f} , then

$$Q_{\mathrm{f}} = \sigma_{\mathrm{f}}\Delta S.$$

As the thickness of the cylinder limits to zero, its volume limits to zero, while $\boldsymbol{v}\cdot\boldsymbol{j}_{\mathrm{f}}/c^2$ and $c^{-2}\,\partial\left(\boldsymbol{v}\cdot\boldsymbol{D}\right)/\partial t$ are limited quantities, so

$$-\frac{1}{c^2}\int\left(\boldsymbol{v}\cdot\boldsymbol{j}_{\mathrm{f}}\right)\mathrm{d}V - \frac{1}{c^2}\frac{d}{dt}\int\left(\boldsymbol{v}\cdot\boldsymbol{D}\right)\mathrm{d}V \to 0.$$

Substituting these equations into the third equation of Eqs. (7.161b), we obtain

$$D_{1\mathrm{n}} - D_{2\mathrm{n}} = \sigma_{\mathrm{f}}\ ,\quad \text{or}\quad \boldsymbol{n}\cdot\left(\boldsymbol{D}_1 - \boldsymbol{D}_2\right) = \sigma_{\mathrm{f}}. \qquad (7.167)$$

To magnetic induction intensity $\boldsymbol{B}$, apply the fourth equation of Eqs. (7.161b) to a small flat cylinder at the interface between two media, repeat the above reasoning, we obtain

$$\boldsymbol{B}_{1\mathrm{n}} = \boldsymbol{B}_{2\mathrm{n}}\ ,\quad \text{or}\quad \boldsymbol{n}\cdot\left(\boldsymbol{B}_1 - \boldsymbol{B}_2\right) = 0. \qquad (7.168)$$

Second, to find other two boundary relations, choose a line element $\Delta\boldsymbol{l}$ at the interface between two media, take which as middle line, make out a small long and narrow rectangular circuit which is perpendicular to the interface and a long side of which is in medium 1 and another long side is in medium 2 (Fig.7.5). Apply the second equation of Eqs. (7.161b) to this small rectangular circuit. As the short side of the rectangular circuit limits to zero, the left integral of the second equation

$$\oint_L \boldsymbol{H}\cdot \mathrm{d}\boldsymbol{l} = \left(H_{1\mathrm{t}} - H_{2\mathrm{t}}\right)\Delta\boldsymbol{l},$$

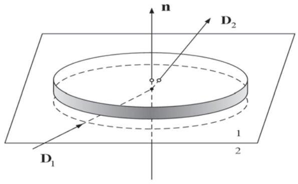


Fig. 7.4

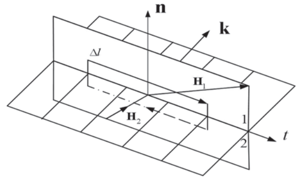


Fig. 7.5

where Δl is the length of the line element $\Delta \boldsymbol{l}$, H_{1t} and H_{2t} are the tangential components of the magnetic field intensity vector in medium 1 and medium 2 at the place where the circuit is, $\boldsymbol{t}$ is the unit vector in the direction of $\Delta \boldsymbol{l}$.

Consider the integral of the right side of the second equation, suppose the linear density of the free surface currents at the circuit is $\boldsymbol{\alpha}_{\mathrm{f}}$, then the first term of the right side

$$I_{\mathrm{f}} = (\boldsymbol{\alpha}_{\mathrm{f}} \cdot \boldsymbol{k})\Delta \boldsymbol{l},$$

where $\boldsymbol{k}$ is the unit vector perpendicular to the directions $\boldsymbol{n}$ and $\boldsymbol{t}$, and $\boldsymbol{k} \times \boldsymbol{n} = \boldsymbol{t}$. As the short side of the circuit limits to zero, its area limits to zero, while $\partial \boldsymbol{D}/\partial t$ and $\boldsymbol{v} \times \boldsymbol{H}/c^2$ are limited quantities, so

$$\frac{\mathrm{d}}{\mathrm{d}t}\int_s \left(\boldsymbol{D} - \frac{1}{c^2}\boldsymbol{v} \times \boldsymbol{H} \right) \cdot \mathrm{d}\boldsymbol{s} \to 0.$$

Substituting these equations into the second equation of Eqs. (7.161b), we obtain

$$H_{1t} - H_{2t} = \boldsymbol{\alpha}_{\mathrm{f}} \cdot \boldsymbol{k}.$$

By

$$H_{1t} - H_{2t} = \boldsymbol{t} \cdot (\boldsymbol{H}_1 - \boldsymbol{H}_2) = (\boldsymbol{k} \times \boldsymbol{n}) \cdot (\boldsymbol{H}_1 - \boldsymbol{H}_2) = [\boldsymbol{n} \times (\boldsymbol{H}_1 - \boldsymbol{H}_2)] \cdot \boldsymbol{k},$$

we obtain

$$\boldsymbol{n} \times (\boldsymbol{H}_1 - \boldsymbol{H}_2) = \boldsymbol{\alpha}_{\mathrm{f}}. \tag{7.169}$$

By the similar reasoning, from the first equation of Eqs. (7.161b) we can find the boundary relation for the electric field $\boldsymbol{E}$

$$\boldsymbol{n} \times (\boldsymbol{E}_1 - \boldsymbol{E}_2) = 0. \tag{7.170}$$

The gained boundary relations for the electromagnetic field are collected as follows:

$$\left.\begin{aligned} &\boldsymbol{n} \times (\boldsymbol{E}_1 - \boldsymbol{E}_2) = 0, \\ &\boldsymbol{n} \times (\boldsymbol{H}_1 - \boldsymbol{H}_2) = \boldsymbol{\alpha}_{\mathrm{f}}, \\ &\boldsymbol{n} \cdot (\boldsymbol{D}_1 - \boldsymbol{D}_2) = \sigma_{\mathrm{f}}, \\ &\boldsymbol{n} \cdot (\boldsymbol{B}_1 - \boldsymbol{B}_2) = 0. \end{aligned}\right\} \tag{7.171}$$

These relations are corresponding to Eqs. (7.161b) one by one. They express the restricted relationship between the changes of the electromagnetic field quantities at interface of media and the charges and currents at the interface.

We have seen that although the electromagnetic field equations in media in an ordinary inertial frame are different from the electromagnetic field equations in media in the absolute inertial frame, namely Maxwell's equations in media, yet the boundary value relations of the electromagnetic field in an ordinary inertial frame are the same completely with that in the absolute inertial frame.

7. 7. 3. The constitutive Relations of Moving Media

To solve problems, the electromagnetic field equations in media in an ordinary inertial frame have to be supplemented by the constitutive relations of media. We will limit to discussion of isotropic and linear media, when which are at rest relative to any ordinary inertial frame, the constitutive relations of media as experimental relations take the simplest form

$$\boldsymbol{D}' = \varepsilon_0\varepsilon_{\mathrm{r}}\boldsymbol{E}' = \varepsilon\boldsymbol{E}', \tag{7.172}$$

$$\boldsymbol{B}' = \mu_0\mu_{\mathrm{r}}\boldsymbol{H}' = \mu\boldsymbol{H}', \tag{7.173}$$

$$\boldsymbol{j}' = \sigma\boldsymbol{E}', \tag{7.174}$$

where the primed letters denote the electromagnetic quantities observed in the frame Σ' at rest relative to the media; ε_{r} and ε are the relative permittivity and permittivity of the medium; μ_{r} and μ are the relative permeability and the permeability of the medium; σ is the electrical conductivity. Below starting from the above equations and using the transformations of the electrodynamics of Standard Space-time Theory, we will find the constitutive relations of moving media.

First, we find the constitutive relations of moving media relative to the absolute inertial frame Σ_{a}. Suppose the velocity of frame Σ' relative to frame Σ_{a} is $\boldsymbol{u}_{\mathrm{a}}$, according to the gained transformations (7.115), (7.166) and (7.60), we have

$$\boldsymbol{E}' = \gamma_0\left(\hat{T}_0^{-1}\boldsymbol{E}_{\mathrm{a}} + \boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{B}_{\mathrm{a}}\right), \qquad \boldsymbol{B}' = \gamma_0\left(\hat{T}^{-1}\boldsymbol{B}_{\mathrm{a}} - \boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{E}_{\mathrm{a}}/c^2\right),$$

$$\boldsymbol{D}' = \gamma_0\left(\hat{T}_0^{-1}\boldsymbol{D}_{\mathrm{a}} + \boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{H}_{\mathrm{a}}/c^2\right), \quad \boldsymbol{H}' = \gamma_0\left(\hat{T}_0^{-1}\boldsymbol{H} - \boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{D}_{\mathrm{a}}\right),$$

$$\boldsymbol{j}' = \hat{T}_0\boldsymbol{j}'_{\mathrm{a}} - \gamma_0\rho_{\mathrm{a}}\boldsymbol{u}_{\mathrm{a}}, \qquad \rho' = \gamma_0^{-1}\rho_{\mathrm{a}},$$

where
$$\gamma_0 = \left(1 - u_a^2/c^2\right)^{-1/2},$$

$$\hat{T}_0 = I + \left(\gamma_0 - 1\right)\boldsymbol{u}_{\mathrm{a}0}\boldsymbol{u}_{\mathrm{a}0}\cdot, \quad \hat{T}_0^{-1} = I + \left(\gamma_0^{-1} - 1\right)\boldsymbol{u}_{\mathrm{a}0}\boldsymbol{u}_{\mathrm{a}0}\cdot$$

where $\boldsymbol{u}_{\mathrm{a}0}$ is the unit vector in the direction of $\boldsymbol{u}_{\mathrm{a}}$. Substituting the above equations respectively into Eqs. (7.172)—(7.174), we easily obtain

$$\boldsymbol{D}_{\mathrm{a}} + \boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{H}_{\mathrm{a}}/c^2 = \varepsilon_0\varepsilon_{\mathrm{r}}\left(\boldsymbol{E}_{\mathrm{a}} + \boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{B}_{\mathrm{a}}\right), \tag{7.175}$$

$$\boldsymbol{B}_{\mathrm{a}} - \boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{E}_{\mathrm{a}}/c^2 = \mu_0\mu_{\mathrm{r}}\left(\boldsymbol{H}_{\mathrm{a}} - \boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{D}_{\mathrm{a}}\right), \tag{7.176}$$

$$\boldsymbol{j}_{\mathrm{a}} - \rho_{\mathrm{a}}\boldsymbol{u}_{\mathrm{a}} = \sigma\gamma_0\left(\hat{T}_0^{-2}\boldsymbol{E}_{\mathrm{a}} + \boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{B}_{\mathrm{a}}\right). \tag{7.177}$$

In the last equation, the total current density $\boldsymbol{j}_{\mathrm{a}}$ include the convention current density $\rho_{\mathrm{a}}\boldsymbol{u}_{\mathrm{a}}$, hence $\boldsymbol{j}_{\mathrm{a}} - \rho_{\mathrm{a}}\boldsymbol{u}_{\mathrm{a}}$ is equal the conduction current density. The last equation can be rewritten by the components of parallel and perpendicular as follows:

$$\boldsymbol{j}_{\mathrm{a}\|} - \rho_{\mathrm{a}}\boldsymbol{u}_{\mathrm{a}} = \sigma\gamma_0^{-1}\boldsymbol{E}_{\mathrm{a}\|}, \quad \boldsymbol{j}_{\mathrm{a}\perp} = \sigma\gamma_0\left(\boldsymbol{E}_{\mathrm{a}\perp} + \boldsymbol{u}_{\mathrm{a}}\times\boldsymbol{B}_{\mathrm{a}}\right). \tag{7.178}$$

Need to notice that the components of parallel and perpendicular in the above equation are correlative with the velocity $\boldsymbol{u}_{\mathrm{a}}$. As $\boldsymbol{u}_{\mathrm{a}}=0$, Eqs. (7.177) and (7.178) return to Eq. (7.174).

Equations (7.175)—(7.177) are the constitutive relations of moving media relative to the absolute inertial frame Σ_{a}.

To an ordinary inertial frame Σ, suppose its velocity relative to frame Σ_{a} is $\boldsymbol{v}$ and the velocity of the medium relative to frame Σ is $\boldsymbol{u}$, substituting the velocity transformation (7.14) and the transformations (7.115) and (7.166) of $\boldsymbol{E}$, $\boldsymbol{B}$ and $\boldsymbol{D}$, $\boldsymbol{H}$ into Eq. (7.175) and acting on the two sides by the operator $\gamma^{-1}\hat{T}$, we obtain

$$\begin{aligned}&\boldsymbol{D}-\boldsymbol{v}\times\boldsymbol{H}/c^2+\hat{T}\left[\left(\gamma^{-1}\hat{T}^{-1}\boldsymbol{u}+\boldsymbol{v}\right)\times\left(\hat{T}^{-1}\boldsymbol{H}+\boldsymbol{v}\times\boldsymbol{D}\right)\right]/c^2\\&=\varepsilon_0\varepsilon_{\mathrm{r}}\left(\boldsymbol{E}-\boldsymbol{v}\times\boldsymbol{B}\right)+\varepsilon_0\varepsilon_{\mathrm{r}}\hat{T}\left[\left(\gamma^{-1}\hat{T}^{-1}\boldsymbol{u}+\boldsymbol{v}\right)\times\left(\hat{T}^{-1}\boldsymbol{B}+\boldsymbol{v}\times\boldsymbol{E}/c^2\right)\right].\end{aligned}\tag{7.179}$$

Using Eqs. (7.38), (7.18) and (7.32) to calculate respectively the third term on the left and the third term on the right in the above equation, we obtain

The third term on the left =

$$\begin{aligned}&=\hat{T}\left[\gamma^{-2}\hat{T}\left(\boldsymbol{u}\times\boldsymbol{H}\right)+\gamma^{-1}\left(\hat{T}^{-1}\boldsymbol{u}\right)\times\left(\boldsymbol{v}\times\boldsymbol{D}\right)+\boldsymbol{v}\times\left(\hat{T}^{-1}\boldsymbol{H}\right)+\boldsymbol{v}\times\left(\boldsymbol{v}\times\boldsymbol{D}\right)\right]/c^2\\&=\left[\gamma^{-2}\hat{T}^2\left(\boldsymbol{u}\times\boldsymbol{H}\right)+\gamma^{-2}\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{D}\right)+\boldsymbol{v}\times\boldsymbol{H}+\gamma\boldsymbol{v}\left(\boldsymbol{v}\cdot\boldsymbol{D}\right)-\boldsymbol{v}^2\hat{T}\boldsymbol{D}\right]/c^2,\end{aligned}$$

The third term on the right =

$$\begin{aligned}&=\varepsilon_0\varepsilon_{\mathrm{r}}\hat{T}\left[\gamma^{-2}\hat{T}\left(\boldsymbol{u}\times\boldsymbol{B}\right)+\gamma^{-1}\left(\hat{T}^{-1}\boldsymbol{u}\right)\times\left(\boldsymbol{v}\times\boldsymbol{E}\right)/c^2+\boldsymbol{v}\times\left(\hat{T}^{-1}\boldsymbol{B}\right)+\boldsymbol{v}\times\left(\boldsymbol{v}\times\boldsymbol{E}\right)/c^2\right]\\&=\varepsilon_0\varepsilon_{\mathrm{r}}\left[\gamma^{-2}\hat{T}^2\left(\boldsymbol{u}\times\boldsymbol{B}\right)+\gamma^{-2}\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{E}\right)/c^2+\boldsymbol{v}\times\boldsymbol{B}+\gamma\boldsymbol{v}\left(\boldsymbol{v}\cdot\boldsymbol{E}\right)/c^2-\boldsymbol{v}^2\left(\hat{T}\boldsymbol{E}\right)/c^2\right].\end{aligned}$$

In the above calculations we applied the following formula, namely

$$\begin{aligned}&\hat{T}\left[\gamma^{-1}\left(\hat{T}^{-1}\boldsymbol{u}\right)\times\left(\boldsymbol{v}\times\boldsymbol{A}\right)\right]=\hat{T}\left[\gamma^{-1}\left(\boldsymbol{u}_{\perp}+\gamma^{-1}\boldsymbol{u}_{\parallel}\right)\times\left(\boldsymbol{v}\times\boldsymbol{A}\right)\right]\\&=\hat{T}\left[\gamma^{-2}\boldsymbol{u}_{\parallel}\times\left(\boldsymbol{v}\times\boldsymbol{A}\right)\right]=\gamma^{-2}\boldsymbol{u}_{\parallel}\times\left(\boldsymbol{v}\times\boldsymbol{A}\right)=\gamma^{-2}\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{A}\right).\end{aligned}\tag{7.180}$$

Substituting the gained third term on the left and third term on the right into the two sides of Eq. (7.179), we obtain

$$\begin{aligned}&\gamma^{-2}\boldsymbol{D}+\boldsymbol{v}\left(\boldsymbol{v}\cdot\boldsymbol{D}\right)/c^2+\gamma^{-2}\left[\hat{T}^2\left(\boldsymbol{u}\times\boldsymbol{H}\right)+\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{D}\right)\right]/c^2\\&=\varepsilon_0\varepsilon_{\mathrm{r}}\left[\gamma^{-2}\boldsymbol{E}+\boldsymbol{v}\left(\boldsymbol{v}\cdot\boldsymbol{E}\right)/c^2\right]+\varepsilon_0\varepsilon_{\mathrm{r}}\gamma^{-2}\left[\hat{T}^2\left(\boldsymbol{u}\times\boldsymbol{B}\right)+\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{E}\right)/c^2\right].\end{aligned}$$

Multiplying the two sides of the above equation by γ^2, and using $\gamma^2v^2/c^2=\gamma^2-1$, and the definition (7.19) of the operator $\hat{T}^n$, we obtain

$$\hat{T}^2\boldsymbol{D}+\hat{T}^2\left(\boldsymbol{u}\times\boldsymbol{H}\right)/c^2+\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{D}\right)/c^2=\varepsilon_0\varepsilon_{\mathrm{r}}\hat{T}^2\boldsymbol{E}+\hat{T}^2\left(\boldsymbol{u}\times\boldsymbol{B}\right)+\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{E}\right)/c^2.$$

Acting on the two sides by the operator $\hat{T}^{-2}$, and using Eq. (7.40), we last obtain

$$\boldsymbol{D}+\boldsymbol{u}\times\boldsymbol{H}/c^2+\hat{T}^{-2}\left[\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{D}\right)/c^2\right]=\varepsilon_0\varepsilon_{\mathrm{r}}\left(\boldsymbol{E}+\boldsymbol{u}\times\boldsymbol{B}\right)+\varepsilon_0\varepsilon_{\mathrm{r}}\hat{T}^{-2}\left[\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{E}\right)/c^2\right],$$

or the above equation is written as

$$\boldsymbol{D}+\boldsymbol{u}\times\boldsymbol{H}/c^2=\varepsilon_0\varepsilon_\mathrm{r}\left(\boldsymbol{E}+\boldsymbol{u}\times\boldsymbol{B}\right)-\hat{T}^{-2}\left\{\boldsymbol{u}\times\left[\boldsymbol{v}\times\left(\boldsymbol{D}-\varepsilon_0\varepsilon_\mathrm{r}\boldsymbol{E}\right)/c^2\right]\right\}. \tag{7.181}$$

Similarly, substituting the velocity transformation (7.14) and transformations (7.115) and (7.166) of $\boldsymbol{E}$, $\boldsymbol{B}$ and $\boldsymbol{D}$, $\boldsymbol{H}$ into Eq. (7.176) and acting on the two sides by the operator $\gamma^{-1}\hat{T}$, we obtain

$$\begin{aligned}&\boldsymbol{B}+\boldsymbol{v}\times\boldsymbol{E}/c^2-\gamma^{-2}\hat{T}^2\left(\boldsymbol{u}\times\boldsymbol{E}\right)/c^2+\gamma^{-1}\hat{T}\left[\left(\hat{T}^{-1}\boldsymbol{u}\right)\times\left(\boldsymbol{v}\times\boldsymbol{B}\right)/c^2\right]\\&\quad-\boldsymbol{v}\times\boldsymbol{E}/c^2+\gamma\boldsymbol{v}\left(\boldsymbol{v}\cdot\boldsymbol{B}\right)/c^2-v^2\left(\hat{T}\boldsymbol{B}\right)/c^2\\&=\mu_0\mu_\mathrm{r}\left\{\boldsymbol{H}+\boldsymbol{v}\times\boldsymbol{D}-\gamma^{-2}\hat{T}^2\left(\boldsymbol{u}\times\boldsymbol{D}\right)+\gamma^{-1}\hat{T}\left[\left(\hat{T}^{-1}\boldsymbol{u}\right)\times\left(\boldsymbol{v}\times\boldsymbol{H}\right)/c^2\right]\right.\\&\quad\left.-\boldsymbol{v}\times\boldsymbol{D}-\gamma\boldsymbol{v}\left(\boldsymbol{v}\cdot\boldsymbol{H}\right)/c^2+v^2\left(\hat{T}\boldsymbol{H}\right)/c^2\right\}.\end{aligned}$$

Using $\gamma^2v^2/c^2=\gamma^2-1$, and acting on the two sides by the operator $\gamma^2\hat{T}^{-2}$, we obtain

$$\begin{aligned}&\boldsymbol{B}-\boldsymbol{u}\times\boldsymbol{E}/c^2+\hat{T}^{-2}\left[\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{B}\right)/c^2\right]\\&=\mu_0\mu_\mathrm{r}\left(\boldsymbol{H}-\boldsymbol{u}\times\boldsymbol{D}\right)+\mu_0\mu_\mathrm{r}\hat{T}^{-2}\left[\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{H}\right)/c^2\right],\end{aligned}$$

or the above equation is written as

$$\boldsymbol{B}-\boldsymbol{u}\times\boldsymbol{E}/c^2=\mu_0\mu_\mathrm{r}\left(\boldsymbol{H}-\boldsymbol{u}\times\boldsymbol{D}\right)-\hat{T}^{-2}\left\{\boldsymbol{u}\times\left[\boldsymbol{v}\times\left(\boldsymbol{B}-\mu_0\mu_\mathrm{r}\boldsymbol{H}\right)/c^2\right]\right\}. \tag{7.182}$$

Equations (7.181) and (7.182) are the constitutive relations of moving media in an ordinary inertial frame. The differences between the above relations and that of the special theory of relativity are only additions of the second terms on the right.

How do we calculate the second terms on the right of Eqs. (7.181) and (7.182)? Notice

$$\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{A}\right)=\left(\boldsymbol{u}\cdot\boldsymbol{A}\right)\boldsymbol{v}-\left(\boldsymbol{u}\cdot\boldsymbol{v}\right)\boldsymbol{A},$$

$$\begin{aligned}\hat{T}^{-2}\left[\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{A}\right)\right]&=\hat{T}^{-2}\left[\left(\boldsymbol{u}\cdot\boldsymbol{A}\right)\boldsymbol{v}-\left(\boldsymbol{u}\cdot\boldsymbol{v}\right)\boldsymbol{A}\right]\\&=\gamma^{-2}\left(\boldsymbol{u}\cdot\boldsymbol{A}\right)\boldsymbol{v}-\left(\boldsymbol{u}\cdot\boldsymbol{v}\right)\boldsymbol{A}-\left(\gamma^{-2}-1\right)\left(\boldsymbol{u}\cdot\boldsymbol{v}\right)\left(\boldsymbol{A}\cdot\boldsymbol{v}_0\right)\boldsymbol{v}_0\\&=\gamma^{-2}\left(\boldsymbol{u}\cdot\boldsymbol{A}\right)\boldsymbol{v}-\left(\boldsymbol{u}\cdot\boldsymbol{v}\right)\boldsymbol{A}+\beta^2\left(\boldsymbol{u}\cdot\boldsymbol{v}_0\right)\left(\boldsymbol{A}\cdot\boldsymbol{v}_0\right)\boldsymbol{v}\end{aligned}$$

Let $\boldsymbol{A}_1=\boldsymbol{D}-\varepsilon_0\varepsilon_r\boldsymbol{E}$, $\boldsymbol{A}_2=\boldsymbol{B}-\mu_0\mu_r\boldsymbol{H}$,

we obtain the formula

$$\begin{aligned}&\hat{T}^{-2}\left\{\boldsymbol{u}\times\left[\boldsymbol{v}\times\left(\boldsymbol{D}-\varepsilon_0\varepsilon_r\boldsymbol{E}\right)/c^2\right]\right\}\\&=\gamma^{-2}\left(\boldsymbol{u}\cdot\boldsymbol{A}_1\right)\boldsymbol{v}/c^2-\left(\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)\boldsymbol{A}_1+\left(\beta^2/c^2\right)\left(\boldsymbol{u}\cdot\boldsymbol{v}_0\right)\left(\boldsymbol{A}_1\cdot\boldsymbol{v}_0\right)\boldsymbol{v},\end{aligned} \tag{7.183}$$

$$\begin{aligned}&\hat{T}^{-2}\left\{\boldsymbol{u}\times\left[\boldsymbol{v}\times\left(\boldsymbol{B}-\mu_0\mu_r\boldsymbol{H}\right)/c^2\right]\right\}\\&=\gamma^{-2}\left(\boldsymbol{u}\cdot\boldsymbol{A}_2\right)\boldsymbol{v}/c^2-\left(\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)\boldsymbol{A}_2+\left(\beta^2/c^2\right)\left(\boldsymbol{u}\cdot\boldsymbol{v}_0\right)\left(\boldsymbol{A}_2\cdot\boldsymbol{v}_0\right)\boldsymbol{v}.\end{aligned} \tag{7.184}$$

Using the theoretical formulas gained in this section, we can completely explain the results of the electromagnetism experiments of moving media (for example, the Wilson-Wilson experiment). These contents will be narrated in Chapter 8.

7. 8. The Electromagnetic Wave Equations in an Ordinary Inertial Frame

An important achievement of Maxwell's equations is that they reveal a time-varying electromagnetic field is possessed of the wave properties. The electromagnetic field propagated in wave form is just the electromagnetic wave. But Maxwell's equations hold true only in the absolute reference frame. In an ordinary inertial frame, the electromagnetic fields laws will manifest definite deviations. These are the gained the electromagnetic field equations (7.127) and (7.161) in an ordinary inertial frame. Starting from them we can further obtain the electromagnetic wave equations in an ordinary inertial frame. The solutions of solving these wave equations indicate that the propagation speed of the electromagnetic wave in the absolute reference frame, i.e., the vacuum background field, is isotropic, and is equal to the constant c , while that in any ordinary inertial frame is anisotropic. For limit of space, the present section researches only the simplest cases, i.e., the propagations of the electromagnetic wave in free space without free charges and free currents (or in homogeneous, isotropic, linear and transparent media).

7. 8. 1. The Electromagnetic Wave Equations in Vacuum in an Ordinary Inertial Frame

Studying the motion of the electromagnetic field in vacuum in an ordinary inertial frame Σ under the circumstances of the absence of charges distribution and currents distribution, i.e., $\rho = 0$ and $\boldsymbol{j} = 0$, from Eqs. (7.127), we obtain

$$\left.\begin{aligned} &\nabla\times\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}=-\frac{\partial\boldsymbol{B}}{\partial t},\\ &\nabla\times\boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{B}}{\partial t}=\varepsilon_0\mu_0\frac{\partial\boldsymbol{E}}{\partial t},\\ &\nabla\cdot\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{E}}{\partial t}=0,\\ &\nabla\cdot\boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{B}}{\partial t}=0. \end{aligned}\right\} \tag{7.185}$$

Calculating the curls of the two sides of the first equation and using the second equation yields

$$\nabla\times\left(\nabla\times\boldsymbol{E}\right)+\frac{1}{c^2}\nabla\times\left(\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}\right)=\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial^2\boldsymbol{B}}{\partial t^2}-\frac{1}{c^2}\frac{\partial^2\boldsymbol{E}}{\partial t^2}.$$

Using the formulas (7.30—(7.32), and the third equation and the first equation of Eqs.(185), we obtain

$$\begin{aligned}\nabla\times\left(\nabla\times\boldsymbol{E}\right)=\nabla\left(\nabla\cdot\boldsymbol{E}\right)-\nabla^2\boldsymbol{E}&=-\frac{1}{c^2}\nabla\left(\boldsymbol{v}\cdot\frac{\partial\boldsymbol{E}}{\partial t}\right)-\nabla^2\boldsymbol{E}\\&=-\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial}{\partial t}\left(\nabla\times\boldsymbol{E}\right)-\frac{1}{c^2}\left(\boldsymbol{v}\cdot\nabla\right)\frac{\partial\boldsymbol{E}}{\partial t}-\nabla^2\boldsymbol{E}\\&=\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial}{\partial t}\left(\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}+\frac{\partial\boldsymbol{B}}{\partial t}\right)-\frac{1}{c^2}\left(\boldsymbol{v}\cdot\nabla\right)\frac{\partial\boldsymbol{E}}{\partial t}-\nabla^2\boldsymbol{E}\\&=\frac{1}{c^4}\boldsymbol{v}\times\left(\boldsymbol{v}\times\frac{\partial^2\boldsymbol{E}}{\partial t^2}\right)+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial^2\boldsymbol{B}}{\partial t^2}-\frac{1}{c^2}\left(\boldsymbol{v}\cdot\nabla\right)\frac{\partial\boldsymbol{E}}{\partial t}-\nabla^2\boldsymbol{E}\\&=\frac{1}{c^4}\boldsymbol{v}\left(\boldsymbol{v}\cdot\frac{\partial^2\boldsymbol{E}}{\partial t^2}\right)-\frac{v^2}{c^4}\frac{\partial^2\boldsymbol{E}}{\partial t^2}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial^2\boldsymbol{B}}{\partial t^2}-\frac{1}{c^2}\left(\boldsymbol{v}\cdot\nabla\right)\frac{\partial\boldsymbol{E}}{\partial t}-\nabla^2\boldsymbol{E},\end{aligned}$$

$$\begin{aligned}\frac{1}{c^2}\nabla\times\left(\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}\right)&=\frac{1}{c^2}\left[\frac{\partial}{\partial t}\left(\nabla\cdot\boldsymbol{E}\right)\right]\boldsymbol{v}-\frac{1}{c^2}\left(\boldsymbol{v}\cdot\nabla\right)\frac{\partial\boldsymbol{E}}{\partial t}\\&=-\frac{1}{c^4}\boldsymbol{v}\left(\boldsymbol{v}\cdot\frac{\partial^2\boldsymbol{E}}{\partial t^2}\right)-\frac{1}{c^2}\left(\boldsymbol{v}\cdot\nabla\right)\frac{\partial\boldsymbol{E}}{\partial t}.\end{aligned}$$

Substituting the gained two equations into the previous equation, we obtain

$$\nabla^2\boldsymbol{E}+\frac{2}{c^2}\left(\boldsymbol{v}\cdot\nabla\right)\frac{\partial\boldsymbol{E}}{\partial t}-\frac{1}{\gamma^2c^2}\frac{\partial^2\boldsymbol{E}}{\partial t^2}=0. \qquad (7.186)$$

Similarly, starting from the second equation of Eqs. (7.185), and calculating the curls of the two sides, using the formulas (7.30) —(7.32) in vector analysis, and the fourth equation and the second equation of Eqs.(7.185), we obtain

$$\nabla^2\boldsymbol{B}+\frac{2}{c^2}\left(\boldsymbol{v}\cdot\nabla\right)\frac{\partial\boldsymbol{B}}{\partial t}-\frac{1}{\gamma^2c^2}\frac{\partial^2\boldsymbol{B}}{\partial t^2}=0. \qquad (7.187)$$

Equations (7.186) and (7.187) are called the wave equations of the electromagnetic field in vacuum in the ordinary inertial frame, where c denotes the propagation speed of the electromagnetic wave propagated in vacuum in the absolute reference frame, also are the average circuit speed of the electromagnetic wave propagated in vacuum in any ordinary inertial frame; $\boldsymbol{v}$ is the velocity of the ordinary inertial frame with respect to the absolute reference frame.

7. 8. 2. The Propagation of Monochromatic Plane Electromagnetic Wave in Vacuum in Ordinary Inertial Frame and Anisotropy of Light Speed

The solutions of wave equations (7.186) and (7.187) include electromagnetic waves of various forms. Below we limit only to discussion of the electromagnetic waves of the definite frequency. In many practical cases, the exciting sources of electromagnetic waves often make sine oscillation with by and large definite frequency, hence radiate electromagnetic waves which also make sine oscillation with corresponding frequency. These electromagnetic waves which make sine oscillation with definite frequency are called monochromatic electromagnetic waves. Suppose the circular frequency of a monochromatic electromagnetic wave is ω, the time-dependent relation of the electromagnetic field is $\cos\omega t$, which is denoted in the complex number form as

$$\begin{aligned} \boldsymbol{E} &= \boldsymbol{E}(\boldsymbol{r},t) = \boldsymbol{E}(\boldsymbol{r})\mathrm{e}^{-\mathrm{i}\omega t}, \\ \boldsymbol{B} &= \boldsymbol{B}(\boldsymbol{r},t) = \boldsymbol{B}(\boldsymbol{r})\mathrm{e}^{-\mathrm{i}\omega t}. \end{aligned} \tag{7.188}$$

Substituting for $\boldsymbol{E}$ from the Eqs. (7.188) into Eq. (7.186) and the third equation and the first equation of Eqs. (7.185), and using the expression of $\boldsymbol{B}$ from Eqs. (7.188), we obtain

$$\left.\begin{aligned} &\nabla^2\boldsymbol{E}(\boldsymbol{r}) - \mathrm{i}\left(2\omega/c^2\right)(\boldsymbol{v}\cdot\nabla)\boldsymbol{E}(\boldsymbol{r}) + (\gamma c)^{-2}\omega^2\boldsymbol{E}(\boldsymbol{r}) = 0, \\ &\nabla\cdot\boldsymbol{E}(\boldsymbol{r}) - \mathrm{i}\frac{\omega}{c^2}\boldsymbol{v}\cdot\boldsymbol{E}(\boldsymbol{r}) = 0, \\ &\boldsymbol{B}(\boldsymbol{r}) = -\frac{\mathrm{i}}{\omega}\nabla\times\boldsymbol{E}(\boldsymbol{r}) - \frac{1}{c^2}\boldsymbol{v}\times\boldsymbol{E}(\boldsymbol{r}). \end{aligned}\right\} \tag{7.189}$$

These are the basic equations for the monochromatic electromagnetic wave, which solutions $\boldsymbol{E}(\boldsymbol{r})$ and $\boldsymbol{B}(\boldsymbol{r})$ represent the space distributions of the field intensities of the electromagnetic wave. Every possible form is called a sort of wave.

Similarly, substituting for $\boldsymbol{B}$ from the Eqs. (7.188) into Eq. (7.187) and the fourth equation and the second equation of Eqs. (7.185), and using the expression of $\boldsymbol{E}$ from Eqs. (7.188), we obtain

$$\left.\begin{aligned} &\nabla^2\boldsymbol{B}(\boldsymbol{r}) - \mathrm{i}\left(2\omega/c^2\right)(\boldsymbol{v}\cdot\nabla)\boldsymbol{B}(\boldsymbol{r}) + (\gamma c)^{-2}\omega^2\boldsymbol{B}(\boldsymbol{r}) = 0, \\ &\nabla\cdot\boldsymbol{B}(\boldsymbol{r}) - \mathrm{i}\frac{\omega}{c^2}\boldsymbol{v}\cdot\boldsymbol{B}(\boldsymbol{r}) = 0, \qquad \boldsymbol{E}(\boldsymbol{r}) = \frac{\mathrm{i}}{\omega}c^2\nabla\times\boldsymbol{B}(\boldsymbol{r}) + \boldsymbol{v}\times\boldsymbol{B}(\boldsymbol{r}). \end{aligned}\right\} \tag{7.190}$$

These are also the basic equations for the monochromatic electromagnetic wave. For the monochromatic electromagnetic wave, Eq. (7.189) or (7.190) are equivalent to Eqs. (7.185).

According to the different excitation and propagation conditions, the space distributions $\boldsymbol{E}(\boldsymbol{r})$ and $\boldsymbol{B}(\boldsymbol{r})$ of the field intensities of the electromagnetic wave can be possessed of various forms. Below we discuss the simplest and the most elementary solution, namely the plane electromagnetic waves which there are in the whole space.

For simplicity, choose the specially arranged two inertial coordinate frames Σ_{a} and Σ , and frame Σ moves with respect to Σ_{a} at a constant velocity $\boldsymbol{v}$ along positive x_a axis of frame Σ_{a}. Suppose a monochromatic plane electromagnetic wave propagate along the positive or negative direction of x axis in frame Σ . The intensity of this plane electromagnetic wave is possessed of the same value at all points of the plane perpendicular to x axis, namely $\boldsymbol{E}(\boldsymbol{r})$ and $\boldsymbol{B}(\boldsymbol{r})$ are relative only to coordinate x , and are denoted by $\boldsymbol{E}(x)$ and $\boldsymbol{B}(x)$ respectively. In this case, the first equations of the basic equations (7.189) and (7.190) become respectively

$$\frac{\mathrm{d}^2}{\mathrm{d}x^2}\boldsymbol{E}(x)-\mathrm{i}\frac{2\omega v}{c^2}\frac{\mathrm{d}}{\mathrm{d}x}\boldsymbol{E}(x)+\frac{\omega}{\gamma^2c^2}\boldsymbol{E}(x)=0, \qquad (7.191)$$

$$\frac{\mathrm{d}^2}{\mathrm{d}x^2}\boldsymbol{B}(x)-\mathrm{i}\frac{2\omega v}{c^2}\frac{\mathrm{d}}{\mathrm{d}x}\boldsymbol{B}(x)+\frac{\omega}{\gamma^2c^2}\boldsymbol{B}(x)=0. \qquad (7.192)$$

Their solutions are respectively

$$\boldsymbol{E}(x)=\boldsymbol{E}_0\mathrm{e}^{\mathrm{i}kx}, \quad \boldsymbol{B}(x)=\boldsymbol{B}_0\mathrm{e}^{\mathrm{i}kx}, \qquad (7.193)$$

where $\boldsymbol{E}_0$ and $\boldsymbol{B}_0$ are constant vectors. The complete expressions of the electric field intensity and magnetic induction intensity are as follows

$$\boldsymbol{E}=\boldsymbol{E}(x)\mathrm{e}^{-\mathrm{i}\omega t}=\boldsymbol{E}_0\mathrm{e}^{\mathrm{i}(kx-\omega t)}, \quad \boldsymbol{B}=\boldsymbol{B}(x)\mathrm{e}^{-\mathrm{i}\omega t}=\boldsymbol{B}_0\mathrm{e}^{\mathrm{i}(kx-\omega t)}. \qquad (7.194)$$

If $k>0$, the above two equations represent the wave propagated along the positive direction of x axis (the right-traveling wave); if $k<0$, they represent the wave propagated along the negative direction of x axis (the left-traveling wave).

Substituting $\boldsymbol{E}(x)$ and $\boldsymbol{B}(x)$ of Eq. (7.193) into Eqs. (7.191) and (7.192), respectively, in the same way, we obtain

$$k^2-\frac{2\omega v}{c^2}k-\frac{\omega^2}{\gamma^2c^2}=0 \text{，or} \quad k^2-\frac{2\omega v}{c^2}k-\left(1-\frac{v^2}{c^2}\right)\frac{\omega^2}{c^2}=0.$$

Solving this quadratic equation, we obtain

$$k=\left(\frac{v}{c^2}\pm\frac{1}{c}\right)\omega=\frac{1}{c}\left(\frac{v}{c}\pm 1\right)\omega. \qquad (7.195)$$

For the right-traveling wave, taking $k>0$, then k and the wave speed are respectively

$$k=\frac{1}{c}\left(1+\frac{v}{c}\right)\omega, \quad u=\frac{\omega}{k}=\frac{c}{1+v/c}. \qquad (7.196)$$

For the left-traveling wave, taking $k<0$， then k and the wave speed are respectively

$$k=-\frac{1}{c}\left(1-\frac{v}{c}\right)\omega, \quad u=\frac{\omega}{k}=-\frac{c}{1-v/c}. \qquad (7.197)$$

Equations (7.196) and (7.197) are the expressions for the wave speed of the right traveling wave and the left traveling wave in vacuum in an ordinary inertial frame. Obviously, the wave speeds of the electromagnetic waves are anisotropic.

Substituting the solution (7.193) into the second equation and the third equation of Eqs. (7.189), and using the formulas (7.37), (7.38) in vector analysis, and Eq. (7.195), we obtain respectively

$$E_x = 0 \tag{7.198}$$

and

$$\boldsymbol{B}(x) = -\frac{\mathrm{i}}{\omega}\nabla\times\left(\boldsymbol{E}_0\mathrm{e}^{\mathrm{i}kx}\right) - \frac{1}{c^2}\boldsymbol{v}\times\boldsymbol{E}(x) = \pm\frac{R}{\omega}\boldsymbol{n}\times\boldsymbol{E}(x) \mp \frac{v}{c^2}\boldsymbol{n}\times\boldsymbol{E}(x) = \frac{1}{c}\boldsymbol{n}\times\boldsymbol{E}(x),$$

or

$$\boldsymbol{B}(x,t) = \frac{1}{c}\boldsymbol{n}\times\boldsymbol{E}(x,t), \quad \boldsymbol{B} = \frac{1}{c}\boldsymbol{n}\times\boldsymbol{E}, \tag{7.199}$$

where $\boldsymbol{n}$ is the unit vector in the direction of the electromagnetic wave propagation.

The above solving results indicate that in the case of that the direction $\boldsymbol{n}$ of the electromagnetic wave propagation is parallel to the characteristic velocity $\boldsymbol{v}$ of the ordinary inertial frame the plane electromagnetic wave in vacuum is possessed of the following properties:

(1) The Electromagnetic waves are transverse waves, and both electric field $\boldsymbol{E}$ and magnetic induction $\boldsymbol{B}$ are perpendicular to the propagation direction of electromagnetic waves.

(2) The electric field $\boldsymbol{E}$ and magnetic induction $\boldsymbol{B}$ are perpendicular to each other, $\boldsymbol{E}\times\boldsymbol{B}$ is along the direction of the electromagnetic wave propagation.

(3) The electric field $\boldsymbol{E}$ and magnetic induction $\boldsymbol{B}$ have the same phase, and the ratio of their amplitudes is c.

Below we simply discuss the solutions of the plane electromagnetic waves of the basic equations (7.189) and (7.190) for the monochromatic electromagnetic wave under the generally arranged two inertial coordinate frames Σ_{a} and Σ.

In this case we also use the rectangular coordinate system, let

$$\begin{aligned} \boldsymbol{E}(\boldsymbol{r}) &= \boldsymbol{E}_0\mathrm{e}^{\mathrm{i}(\boldsymbol{k}\cdot\boldsymbol{r})} = \boldsymbol{E}_0\mathrm{e}^{\mathrm{i}\left(xk_x+yk_y+zk_z\right)}, \ \boldsymbol{E} = \boldsymbol{E}_0\mathrm{e}^{\mathrm{i}(\boldsymbol{k}\cdot\boldsymbol{r}-\omega t)}, \\ \boldsymbol{B}(\boldsymbol{r}) &= \boldsymbol{B}_0\mathrm{e}^{\mathrm{i}(\boldsymbol{k}\cdot\boldsymbol{r})} = \boldsymbol{B}_0\mathrm{e}^{\mathrm{i}\left(xk_x+yk_y+zk_z\right)}, \ \boldsymbol{B} = \boldsymbol{B}_0\mathrm{e}^{\mathrm{i}(\boldsymbol{k}\cdot\boldsymbol{r}-\omega t)}, \end{aligned} \tag{7.200}$$

where the direction of the wave vector $\boldsymbol{k}$ represents the direction of the electromagnetic wave propagation. We can let $\boldsymbol{k} = k\boldsymbol{n}$, $\boldsymbol{n}$ is the unit vector in the direction of the wave propagation. Substituting Eq. (7.200) into the first equation of Eq. (7.189) and the first equation of Eqs. (7.190), and noticing

$$\nabla^2\boldsymbol{E}(\boldsymbol{r}) = \left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}\right)\left[\boldsymbol{E}_0\mathrm{e}^{\mathrm{i}\left(xk_x+yk_y+zk_z\right)}\right] = -\left(k_x^2+k_y^2+k_z^2\right)\boldsymbol{E}(\boldsymbol{r}) = -k^2\boldsymbol{E}(\boldsymbol{r}),$$

$$(\boldsymbol{v}\cdot\nabla)\boldsymbol{E}(\boldsymbol{r})=(\boldsymbol{v}\cdot\nabla)\left[\boldsymbol{E}_0\mathrm{e}^{\mathrm{i}(xk_x+yk_y+zk_z)}\right]=\mathrm{i}(\boldsymbol{v}\cdot\boldsymbol{k})\boldsymbol{E}(\boldsymbol{r})=\mathrm{i}(\boldsymbol{n}\cdot\boldsymbol{v})k\boldsymbol{E}(\boldsymbol{r}),$$

$$\nabla^2\boldsymbol{B}(\boldsymbol{r})=-k^2\boldsymbol{B}(\boldsymbol{r}),\quad (\boldsymbol{v}\cdot\nabla)\boldsymbol{B}(\boldsymbol{r})=\mathrm{i}(\boldsymbol{n}\cdot\boldsymbol{v})k\boldsymbol{B}(\boldsymbol{r}).$$

In the same way, we obtain

$$k^2-\frac{2\omega}{c^2}(\boldsymbol{n}\cdot\boldsymbol{v})k-\frac{1}{\gamma^2c^2}\omega^2=0. \tag{7.201}$$

The electromagnetism experiments up to the present have only measured the first order of effect. Hence, for simplicity, below we only discuss the first order terms of β and neglect terms of order higher β^2. Solving Eq. (7.201), we obtain

$$k=\frac{\omega}{c}\left(1+\frac{\boldsymbol{n}\cdot\boldsymbol{v}}{c}\right),\qquad \text{or}\quad u=\frac{\omega}{k}=\frac{c}{1+\boldsymbol{n}\cdot\boldsymbol{v}/c}. \tag{7.202}$$

These are the expressions for the wave speed of the electromagnetic wave in vacuum at various directions in an ordinary inertial frame. Obviously, these wave speeds of the electromagnetic waves in an ordinary inertial frame are anisotropic.

Besides, substituting Eq. (7.200) into the third equation of Eqs. (7.189) and the third equation of Eqs. (7.190), and noticing

$$\nabla\times\boldsymbol{E}(\boldsymbol{r})=\mathrm{i}\boldsymbol{k}\times\boldsymbol{E}(\boldsymbol{r}),\ \nabla\times\boldsymbol{B}(\boldsymbol{r})=\mathrm{i}\boldsymbol{k}\times\boldsymbol{B}(\boldsymbol{r}),$$

we can obtain respectively

$$\boldsymbol{B}=\left(\frac{1}{\omega}\boldsymbol{k}-\frac{1}{c^2}\boldsymbol{v}\right)\times\boldsymbol{E}=\left(\frac{1}{u}\boldsymbol{n}-\frac{1}{c^2}\boldsymbol{v}\right)\times\boldsymbol{E}, \tag{7.203}$$

$$\boldsymbol{E}=-c^2\left(\frac{1}{\omega}\boldsymbol{k}-\frac{1}{c^2}\boldsymbol{v}\right)\times\boldsymbol{B}=-c^2\left(\frac{1}{u}\boldsymbol{n}-\frac{1}{c^2}\boldsymbol{v}\right)\times\boldsymbol{B}, \tag{7.204}$$

and have

$$\boldsymbol{E}\cdot\boldsymbol{B}=0, \tag{7.205}$$

$$\boldsymbol{E}\times\boldsymbol{B}=E^2\left(\frac{1}{u}\boldsymbol{n}-\frac{1}{c^2}\boldsymbol{v}\right). \tag{7.206}$$

In addition, substituting Eq. (7.200) into the second equation of Eqs. (7.189) and the second equation of Eqs. (7.190), and noticing

$$\nabla\cdot\boldsymbol{E}(\boldsymbol{r})=\mathrm{i}\boldsymbol{k}\cdot\boldsymbol{E}(\boldsymbol{r}),\quad \nabla\cdot\boldsymbol{B}(\boldsymbol{r})=\mathrm{i}\boldsymbol{k}\cdot\boldsymbol{B}(\boldsymbol{r}),$$

we can obtain respectively

$$\left(\frac{1}{\omega}\boldsymbol{k}-\frac{1}{c^2}\boldsymbol{v}\right)\cdot\boldsymbol{E}=0,\quad \left(\frac{1}{\omega}\boldsymbol{k}-\frac{1}{c^2}\boldsymbol{v}\right)\cdot\boldsymbol{B}=0. \tag{7.207}$$

If neglecting terms of v/c^2 in Eqs. (7.206) and (7.207), we obtain

$$\boldsymbol{E}\times\boldsymbol{B}=\frac{1}{u}E^2\boldsymbol{n}, \tag{7.208}$$

$$\boldsymbol{k}\cdot\boldsymbol{E}=0\ ,\quad \boldsymbol{k}\cdot\boldsymbol{B}=0. \tag{7.209}$$

The above solving results indicate that in the general case of that the direction $\boldsymbol{n}$ of the electromagnetic wave propagation is not parallel to the characteristic velocity $\boldsymbol{v}$ of the ordinary inertial frame the plane electromagnetic wave in vacuum is possessed of the following properties:

(1) The electromagnetic waves are not strictly perpendicular to the direction $\boldsymbol{n}$ of the electromagnetic wave propagation, but the difference is infinitesimal, only has the order of v/c^2 . $\boldsymbol{E}$ and $\boldsymbol{B}$ are in the direction perpendicular to the direction of $\left(\boldsymbol{n}/u-\boldsymbol{v}/c^2\right)$.

(2) The electric field $\boldsymbol{E}$ and magnetic induction $\boldsymbol{B}$ are strictly perpendicular to each other, $\boldsymbol{E}\times\boldsymbol{B}$ is along the direction of $\left(\boldsymbol{n}/u-\boldsymbol{v}/c^2\right)$.

(3) The electric field $\boldsymbol{E}$ and magnetic induction $\boldsymbol{B}$ have the same phase.

7. 8. 3. The Propagation of the Electromagnetic Wave in Media in Ordinary Inertial Frame

Similarly, we solve the motion of the electromagnetic field in media in an ordinary inertial frame.

In the circumstances of the absence of the free charges and free currents distribution, namely $\rho_{\mathrm{f}}=0$ and $\boldsymbol{j}_{\mathrm{f}}=0$, the electromagnetic field equations (7.161a) in media in an ordinary inertial frame take the following form

$$\left.\begin{aligned}
&\nabla\times\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}=-\frac{\partial\boldsymbol{B}}{\partial t},\\
&\nabla\times\boldsymbol{H}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{H}}{\partial t}=\frac{\partial\boldsymbol{D}}{\partial t},\\
&\nabla\cdot\boldsymbol{D}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{D}}{\partial t}=0,\\
&\nabla\cdot\boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{B}}{\partial t}=0.
\end{aligned}\right\} \tag{7.210}$$

We study the homogeneous, isotropic, linear and transparent media, and choose an ordinary inertial frame Σ at rest relative to the media. The constitutive relations of the media at rest relative to frame Σ take the simplest form

$$\boldsymbol{D}=\varepsilon_0\varepsilon_{\mathrm{r}}\boldsymbol{E}\ ,\quad \boldsymbol{B}=\mu_0\mu_{\mathrm{r}}\boldsymbol{H}.$$

where ε_{r} and μ_{r} are respectively the relative permittivity and permeability of the medium. Temporarily take no account of dispersion effect, the refractive index of the medium

$$n=\sqrt{\varepsilon_{\mathrm{r}}\mu_{\mathrm{r}}}. \tag{7.211}$$

has the same numerical value for all frequencies.

Substituting the above two equations into Eq. (7.210) and noticing $\varepsilon_0\mu_0=c^{-2}$, we obtain

$$\left.\begin{aligned}
&\nabla \times \boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial \boldsymbol{E}}{\partial t}=-\frac{\partial \boldsymbol{B}}{\partial t},\\
&\nabla \times \boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial \boldsymbol{B}}{\partial t}=\frac{1}{(c/n)^2}\frac{\partial \boldsymbol{E}}{\partial t},\\
&\nabla \cdot \boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial \boldsymbol{E}}{\partial t}=0,\\
&\nabla \cdot \boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial \boldsymbol{B}}{\partial t}=0.
\end{aligned}\right\} \qquad (7.212)$$

The above equations are nearly the same with Eqs. (7.185), except the factor of the right term of the second equation is substituted by n^2/c^2 for $1/c^2=\varepsilon_0\mu_0$. Hence the following method to solve is also completely similar. Below we narrate briefly the solving process.

First, calculate the curls of the first equation of Eqs. (7.212) and use the second equation to yields

$$\nabla\times(\nabla\times\boldsymbol{E})+\frac{1}{c^2}\nabla\times\left(\boldsymbol{v}\times\frac{\partial \boldsymbol{E}}{\partial t}\right)=\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial^2 \boldsymbol{B}}{\partial t^2}-\frac{1}{(c/n)^2}\frac{\partial^2 \boldsymbol{E}}{\partial t^2}.$$

Using the formulas (7.30)—(7.32) in vector analysis, and the third equation and the first equation of Eqs. (7.212), we obtain

$$\nabla\times(\nabla\times\boldsymbol{E})=\frac{1}{c^4}\boldsymbol{v}\left(\boldsymbol{v}\cdot\frac{\partial^2 \boldsymbol{E}}{\partial t^2}\right)-\frac{v^2}{c^4}\frac{\partial^2 \boldsymbol{E}}{\partial t^2}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial^2 \boldsymbol{B}}{\partial t^2}-\frac{1}{c^2}(\boldsymbol{v}\cdot\nabla)\frac{\partial \boldsymbol{E}}{\partial t}-\nabla^2\boldsymbol{E},$$

$$\frac{1}{c^2}\nabla\times\left(\boldsymbol{v}\times\frac{\partial \boldsymbol{E}}{\partial t}\right)=-\frac{1}{c^4}\boldsymbol{v}\left(\boldsymbol{v}\cdot\frac{\partial^2 \boldsymbol{E}}{\partial t^2}\right)-\frac{1}{c^2}(\boldsymbol{v}\cdot\nabla)\frac{\partial \boldsymbol{E}}{\partial t}.$$

Substituting the above two equations into the previous equation, we obtain

$$\nabla^2\boldsymbol{E}+\frac{2}{c^2}(\boldsymbol{v}\cdot\nabla)\frac{\partial \boldsymbol{E}}{\partial t}-\frac{1}{c^2}\left(n^2-\frac{v^2}{c^2}\right)\frac{\partial^2 \boldsymbol{E}}{\partial t^2}=0. \qquad (7.213)$$

Second, similarly, starting from the second equation of Eqs. (7.212), calculating the curls of the two sides, and using the formulas (7.30)—(7.32) in vector analysis, and the fourth equation and the second equation of Eqs. (7.212), we obtain

$$\nabla^2\boldsymbol{B}+\frac{2}{c^2}(\boldsymbol{v}\cdot\nabla)\frac{\partial \boldsymbol{B}}{\partial t}-\frac{1}{c^2}\left(n^2-\frac{v^2}{c^2}\right)\frac{\partial^2 \boldsymbol{B}}{\partial t^2}=0. \qquad (7.214)$$

Equations (7.213) and (7.214) are the wave equations of the electromagnetic field in media in the ordinary inertial frame under the above circumstances. The differences between the above equations and the wave equations (7.186), (7.187) of the electromagnetic field in vacuum in the ordinary inertial frame are only substitution of the factor of the third term on the left side by n^2 for number 1.

The solutions of wave equations (7.213) and (7.214) include electromagnetic waves of various forms. Here we only discuss the monochromatic electromagnetic waves

$$\boldsymbol{E}=\boldsymbol{E}(\boldsymbol{r},t)=\boldsymbol{E}(\boldsymbol{r})\mathrm{e}^{-\mathrm{i}\omega t},\quad \boldsymbol{B}=\boldsymbol{B}(\boldsymbol{r},t)=\boldsymbol{B}(\boldsymbol{r})\mathrm{e}^{-\mathrm{i}\omega t}. \tag{7.215}$$

Substituting Eqs. (7.215) into Eq. (7.213) and the third equation and the first equation of Eqs. (7.212), and using the expression of $\boldsymbol{B}$ from Eqs. (7.215), we obtain

$$\left.\begin{aligned}&\nabla^2\boldsymbol{E}(\boldsymbol{r})-\mathrm{i}\frac{2\omega}{c^2}(\boldsymbol{v}\cdot\nabla)\boldsymbol{E}(\boldsymbol{r})+\frac{1}{c^2}\left(n^2-\frac{v^2}{c^2}\right)\omega^2\boldsymbol{E}(\boldsymbol{r})=0,\\&\nabla\cdot\boldsymbol{E}(\boldsymbol{r})-\mathrm{i}\frac{\omega}{c^2}\boldsymbol{v}\cdot\boldsymbol{E}(\boldsymbol{r})=0,\\&\boldsymbol{B}(\boldsymbol{r})=-\frac{\mathrm{i}}{\omega}\nabla\times\boldsymbol{E}(\boldsymbol{r})-\frac{1}{c^2}\boldsymbol{v}\times\boldsymbol{E}(\boldsymbol{r}).\end{aligned}\right\} \tag{7.216}$$

Similarly, substituting Eqs. (7.215) into Eq. (7.214) and the fourth equation and second equation of Eqs. (7.212), and using the expression of $\boldsymbol{E}$ from Eqs. (7.215), we obtain

$$\left.\begin{aligned}&\nabla^2\boldsymbol{B}(\boldsymbol{r})-\mathrm{i}\frac{2\omega}{c^2}(\boldsymbol{v}\cdot\nabla)\boldsymbol{B}(\boldsymbol{r})+\frac{1}{c^2}\left(n^2-\frac{v^2}{c^2}\right)\omega^2\boldsymbol{B}(\boldsymbol{r})=0,\\&\nabla\cdot\boldsymbol{B}(\boldsymbol{r})-\mathrm{i}\frac{\omega}{c^2}\boldsymbol{v}\cdot\boldsymbol{B}(\boldsymbol{r})=0,\\&\boldsymbol{E}(\boldsymbol{r})=\frac{\mathrm{i}}{\omega n^2}c^2\nabla\times\boldsymbol{B}(\boldsymbol{r})+\frac{1}{n^2}\boldsymbol{v}\times\boldsymbol{B}(\boldsymbol{r}).\end{aligned}\right\} \tag{7.217}$$

According to the different excitation and propagation conditions, the space distributions $\boldsymbol{E}(\boldsymbol{r})$ and $\boldsymbol{B}(\boldsymbol{r})$ of the field intensities of the electromagnetic wave in media can be possessed of various forms. Below we discuss the simplest and the most elementary solution, namely the solution of the plane electromagnetic waves.

For simplicity, choose the specially arranged two inertial coordinate frames Σ_{a} and Σ, and frame Σ moves with respect to Σ_{a} at a constant velocity $\boldsymbol{v}$ along the positive x axis. Discuss a monochromatic plane electromagnetic wave propagated along the positive or negative direction of x axis in frame Σ. In this case $\boldsymbol{E}(\boldsymbol{r})$ and $\boldsymbol{B}(\boldsymbol{r})$ are relative only to coordinate x, and are denoted by $\boldsymbol{E}(x)$ and $\boldsymbol{B}(x)$ respectively. The first equations of the basic equations (7.216) and (7.217) become

$$\frac{\mathrm{d}^2\boldsymbol{E}(x)}{\mathrm{d}x^2}-\mathrm{i}\frac{2\omega v}{c^2}\frac{\mathrm{d}\boldsymbol{E}(x)}{\mathrm{d}x}+\frac{1}{c^2}\left(n^2-\frac{v^2}{c^2}\right)\omega^2\boldsymbol{E}(x)=0, \tag{7.218}$$

$$\frac{\mathrm{d}^2\boldsymbol{B}(x)}{\mathrm{d}x^2}-\mathrm{i}\frac{2\omega v}{c^2}\frac{\mathrm{d}\boldsymbol{B}(x)}{\mathrm{d}x}+\frac{1}{c^2}\left(n^2-\frac{v^2}{c^2}\right)\omega^2\boldsymbol{B}(x)=0. \tag{7.219}$$

Their solutions are respectively

$$\boldsymbol{E}(x)=\boldsymbol{E}_0\mathrm{e}^{\mathrm{i}kx},\quad \boldsymbol{B}(x)=\boldsymbol{B}_0\mathrm{e}^{\mathrm{i}kx}. \tag{7.220}$$

Hence

$$\boldsymbol{E}=\boldsymbol{E}(x)\mathrm{e}^{-\mathrm{i}\omega t}=\boldsymbol{E}_0\mathrm{e}^{\mathrm{i}(kx-\omega t)},\quad \boldsymbol{B}=\boldsymbol{B}(x)\mathrm{e}^{-\mathrm{i}\omega t}=\boldsymbol{B}_0\mathrm{e}^{\mathrm{i}(kx-\omega t)}. \tag{7.221}$$

If $k>0$, the above two equations represent the wave propagated along the positive direction of x axis (the right-traveling wave); if $k<0$, they represent the wave propagated along the negative direction of x axis (the left-traveling wave).

Substituting $\boldsymbol{E}(x)$ and $\boldsymbol{B}(x)$ of Eq. (7.220) into Eqs. (7.218) and (7.219), respectively, the same, we obtain

$$k^2-\frac{2\omega v}{c^2}k-\frac{1}{c^2}\left(n^2-\frac{v^2}{c^2}\right)\omega^2=0,\quad \text{or}\quad k=\frac{n}{c}\left(\frac{v}{nc}\pm 1\right)\omega. \tag{7.222}$$

For the right-traveling wave, taking $k>0$, from the above equation we obtain that k and the wave speed are respectively

$$k=\left(1+\frac{v}{nc}\right)\frac{n}{c}\omega,\quad u=\frac{\omega}{k}=\frac{c/n}{1+(v/nc)}. \tag{7.223}$$

For the left-traveling wave, taking $k<0$, from the above equation we obtain that k and the wave speed are respectively

$$k=-\left(1-\frac{v}{nc}\right)\frac{n}{c}\omega,\quad u=\frac{\omega}{k}=-\frac{c/n}{1-(v/nc)}. \tag{7.224}$$

Eqs. (7.223) and (7.224) are the expressions for the wave speed of the right traveling wave and the left traveling wave in the homogeneous, isotropic, linear and transparent media. Comparing them with the corresponding Eqs. (7.196) and (7.197) in vacuum, we can see that these are not the results of simple substitutions by c/n for c in Eq. (7.18). It is Eqs. (7.223) and (7.224) that can completely explain the results of the Fizeau's running water experiments (see Chapter 8).

7. 9. The Scalar Potential and Vector Potential

7. 9. 1. Representation of Electromagnetic Field by the Scalar Potential φ and Vector Potential A

The same, in an ordinary inertial frame, we describe the electromagnetic field by the electric field intensity $\boldsymbol{E}$ and the magnetic induction intensity $\boldsymbol{B}$, and besides, we can introduce the scalar potential φ and vector potential $\boldsymbol{A}$ to describe the motion of electromagnetic field and the interaction between the electromagnetic field and charges and currents. For simplicity, we will discuss only the motion of the electromagnetic field in vacuum in an ordinary inertial frame.

Starting from Eq. (7.127a) in vacuum in an ordinary inertial frame, namely

$$\left.\begin{aligned}
&\nabla\times\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}=-\frac{\partial\boldsymbol{B}}{\partial t},\\
&\nabla\times\boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{B}}{\partial t}=\mu_0\boldsymbol{j}+\varepsilon_0\mu_0\frac{\partial\boldsymbol{E}}{\partial t},\\
&\nabla\cdot\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{E}}{\partial t}=\rho/\varepsilon_0-\mu_0\boldsymbol{v}\cdot\boldsymbol{j},\\
&\nabla\cdot\boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{B}}{\partial t}=0.
\end{aligned}\right\}$$

Let

$$\boldsymbol{B}=\nabla\times\boldsymbol{A}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{A}}{\partial t}\tag{7.225}$$

and substituting it into the fourth equation of Eq. (7.127a), the fourth equation is satisfied, i.e., using the formulas in vector analysis we have

$$\begin{aligned}
\nabla\cdot\boldsymbol{B}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{B}}{\partial t}&=\nabla\cdot(\nabla\times\boldsymbol{A})+\frac{1}{c^2}\nabla\cdot\left(\boldsymbol{v}\times\frac{\partial\boldsymbol{A}}{\partial t}\right)+\frac{1}{c^2}\boldsymbol{v}\cdot\left[\frac{\partial}{\partial t}\left(\nabla\times\boldsymbol{A}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{A}}{\partial t}\right)\right]\\
&=-\frac{1}{c^2}\boldsymbol{v}\cdot\left(\frac{\partial}{\partial t}\nabla\times\boldsymbol{A}\right)+\frac{1}{c^2}\boldsymbol{v}\cdot\left(\frac{\partial}{\partial t}\nabla\times\boldsymbol{A}\right)=0.
\end{aligned}$$

Substituting Eq. (7.225) into the first equation of Eq. (7.127a), we obtain

$$\nabla\times\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}=-\nabla\times\left(\frac{\partial\boldsymbol{A}}{\partial t}\right)-\frac{1}{c^2}\boldsymbol{v}\times\left(\frac{\partial^2\boldsymbol{A}}{\partial t^2}\right),$$

That is

$$\nabla\times\left(\boldsymbol{E}+\frac{\partial\boldsymbol{A}}{\partial t}\right)+\frac{1}{c^2}\boldsymbol{v}\times\left[\frac{\partial}{\partial t}\left(\boldsymbol{E}+\frac{\partial\boldsymbol{A}}{\partial t}\right)\right]=0.$$

Obviously, let

$$\boldsymbol{E}=-\nabla\varphi-\frac{1}{c^2}\frac{\partial\varphi}{\partial t}\boldsymbol{v}-\frac{\partial\boldsymbol{A}}{\partial t},\tag{7.226}$$

then the first equation of Eq. (7.127a) is satisfied, i.e., using the formulas in vector analysis we have

$$\begin{aligned}
\nabla\times\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}=&-\nabla\times\nabla\varphi-\frac{1}{c^2}\nabla\times\left(\frac{\partial\varphi}{\partial t}\boldsymbol{v}\right)-\frac{\partial}{\partial t}(\nabla\times\boldsymbol{A})\\
&-\frac{1}{c^2}\boldsymbol{v}\times\left(\frac{\partial}{\partial t}\nabla\varphi\right)-\frac{1}{c^4}\boldsymbol{v}\times\left[\frac{\partial}{\partial t}\left(\frac{\partial\varphi}{\partial t}\boldsymbol{v}\right)\right]-\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial^2\boldsymbol{A}}{\partial t^2}\\
=&-\frac{\partial}{\partial t}\left(\nabla\times\boldsymbol{A}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{A}}{\partial t}\right)=-\frac{\partial\boldsymbol{B}}{\partial t}.
\end{aligned}$$

Equations (7.225) and (7.226) represent the electromagnetic field by the scalar potential φ and vector potential $\boldsymbol{A}$. In changing electromagnetic field, the electric field and magnetic field are a whole, we need regard φ and $\boldsymbol{A}$ as a whole to describe the electromagnetic field.

7. 9. 2. Gauge Transformation and Gauge Invariance

The scalar potential φ and vector potential $\boldsymbol{A}$ to describe the motion of electromagnetic field are not sole, namely the given $\boldsymbol{E}$ and $\boldsymbol{B}$ are not corresponding to only one set of φ and $\boldsymbol{A}$. These are because that as the scalar potential φ and vector potential $\boldsymbol{A}$ make a following transformation, we also obtain the same $\boldsymbol{E}$ and $\boldsymbol{B}$. Suppose ψ is an arbitrary scalar function of space and time, to actualize the transformation

$$\varphi \to \varphi' = \varphi - \frac{\partial \psi}{\partial t}, \quad \boldsymbol{A} \to \boldsymbol{A}' = \boldsymbol{A} + \nabla \psi + \frac{1}{c^2}\boldsymbol{v}\frac{\partial \psi}{\partial t}, \tag{7.227}$$

using the formulas in vector analysis we easily prove

$$\begin{aligned}
\nabla \times \boldsymbol{A}' + \frac{1}{c^2}\boldsymbol{v} \times \frac{\partial \boldsymbol{A}'}{\partial t} &= \nabla \times \boldsymbol{A} + \nabla \times (\nabla \psi) + \frac{1}{c^2}\nabla \times \left(\boldsymbol{v}\frac{\partial \psi}{\partial t}\right) + \frac{1}{c^2}\boldsymbol{v} \times \frac{\partial \boldsymbol{A}}{\partial t} \\
&\quad + \frac{1}{c^2}\boldsymbol{v} \times \frac{\partial}{\partial t}(\nabla \psi) + \frac{1}{c^4}\boldsymbol{v} \times \left(\boldsymbol{v}\frac{\partial^2 \psi}{\partial t^2}\right) \\
&= \nabla \times \boldsymbol{A} + \frac{1}{c^2}\boldsymbol{v} \times \frac{\partial \boldsymbol{A}}{\partial t} = \boldsymbol{B},
\end{aligned}$$

$$\begin{aligned}
-\nabla \varphi' - \frac{1}{c^2}\frac{\partial \psi'}{\partial t}\boldsymbol{v} - \frac{\partial \boldsymbol{A}'}{\partial t} &= -\nabla \varphi + \frac{\partial}{\partial t}(\nabla \psi) - \frac{1}{c^2}\frac{\partial \psi}{\partial t}\boldsymbol{v} + \frac{1}{c^2}\frac{\partial^2 \psi}{\partial t^2}\boldsymbol{v} \\
&\quad - \frac{\partial \boldsymbol{A}}{\partial t} - \frac{\partial}{\partial t}(\nabla \psi) - \frac{1}{c^2}\frac{\partial^2 \psi}{\partial t^2}\boldsymbol{v} \\
&= -\nabla \varphi - \frac{1}{c^2}\frac{\partial \varphi}{\partial t}\boldsymbol{v} - \frac{\partial \boldsymbol{A}}{\partial t} = \boldsymbol{E},
\end{aligned}$$

i.e., $(\varphi', \boldsymbol{A}')$ and $(\varphi, \boldsymbol{A})$ describe the same electromagnetic field. The Eqs. (7.227) are called gauge transformation. Every set of $(\varphi, \boldsymbol{A})$ is called a gauge. The different gauges are corresponding to the same $\boldsymbol{E}$ and $\boldsymbol{B}$, therefore if we use the potentials to describe electromagnetic field, the objective law is independent of the special gauge choice of the potentials. When the potentials are actualized the gauge transformation, all physical quantities and physical laws remain unchanged. This invariance is called gauge invariance. Here we have seen that the gauge invariance remains effective in any ordinary inertial frame as in the absolute inertial frame.

The existence of freedom degrees of gauge transformation is because that in the definitions (7.225) and (7.226) the curl of $\boldsymbol{A}$ is given while the divergence of $\boldsymbol{A}$ is not given.

By both the curl and divergence of a vector one can determine this vector, but only by the curl of a vector one cannot determine it. Since the electromagnetic fields $\boldsymbol{E}$ and $\boldsymbol{B}$ do not limit the divergence of $\boldsymbol{A}$, so we can take $\nabla \cdot \boldsymbol{A}$ as an arbitrary value as an auxiliary condition. Every choice is corresponding to a gauge. Adoption of a proper auxiliary condition (namely proper gauge) will simplify the basic equations and calculation processes.

7. 9. 3. The Equations for the Scalar Potential φ and Vector Potential A

From the electromagnetic field equations (7.127a) in vacuum in an ordinary inertial frame and the definitions (7.225) and (7.226) of the scalar potential φ and vector potential $\boldsymbol{A}$ we can derive the basic equations satisfied by the potentials φ and $\boldsymbol{A}$.

Substituting Eq. (7.226) into the third equation of Eq. (7.127a) and using the formulas in vector analysis we obtain

$$\nabla^2\varphi+\frac{2}{c^2}(\boldsymbol{v}\cdot\nabla)\frac{\partial\varphi}{\partial t}+\frac{\partial}{\partial t}(\nabla\cdot\boldsymbol{A})+\frac{v^2}{c^4}\frac{\partial^2\varphi}{\partial t^2}+\frac{2}{c^2}\boldsymbol{v}\cdot\frac{\partial^2\boldsymbol{A}}{\partial t^2}=-\rho/\varepsilon_0+\mu_0\boldsymbol{v}\cdot\boldsymbol{j}. \quad (7.228)$$

Substituting Eq. (7.225) into the second equation of Eq. (7.127a) and using the formulas in vector analysis we obtain

$$\nabla(\nabla\cdot\boldsymbol{A})-\nabla^2\boldsymbol{A}+\frac{1}{c^2}\left[\nabla\times\left(\boldsymbol{v}\times\frac{\partial\boldsymbol{A}}{\partial t}\right)+\boldsymbol{v}\times\frac{\partial}{\partial t}(\nabla\times\boldsymbol{A})\right]$$
$$=\mu_0\boldsymbol{j}-\frac{1}{c^2}\frac{\partial}{\partial t}(\nabla\varphi)-\frac{1}{c^4}\frac{\partial^2\varphi}{\partial t^2}\boldsymbol{v}-\frac{1}{c^2}\frac{\partial^2\boldsymbol{A}}{\partial t^2}.$$

Noticing

$$\nabla\times\left(\boldsymbol{v}\times\frac{\partial\boldsymbol{A}}{\partial t}\right)+\boldsymbol{v}\times\frac{\partial}{\partial t}(\nabla\times\boldsymbol{A})=\left[\frac{\partial}{\partial t}(\nabla\cdot\boldsymbol{A})\right]\boldsymbol{v}-2(\boldsymbol{v}\cdot\nabla)\frac{\partial\boldsymbol{A}}{\partial t}+\nabla\left(\boldsymbol{v}\cdot\frac{\partial\boldsymbol{A}}{\partial t}\right),$$

substituting the above equation into the previous equation, we obtain

$$\begin{aligned}\nabla^2\boldsymbol{A}-\nabla\left[\nabla\cdot\boldsymbol{A}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{A}}{\partial t}+\frac{1}{c^2}\frac{\partial\varphi}{\partial t}\right]-\frac{1}{c^2}\frac{\partial^2\boldsymbol{A}}{\partial t^2}+\frac{2}{c^2}(\boldsymbol{v}\cdot\nabla)\frac{\partial\boldsymbol{A}}{\partial t}\\-\frac{1}{c^2}\left[\frac{\partial}{\partial t}(\nabla\cdot\boldsymbol{A})\right]\boldsymbol{v}-\frac{1}{c^4}\frac{\partial^4\varphi}{\partial t^2}\boldsymbol{v}=-\mu_0\boldsymbol{j}.\end{aligned} \quad (7.229)$$

Observing Eqs. (7.228) and (7.229), we introduce the gauge

$$\nabla\cdot\boldsymbol{A}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{A}}{\partial t}+\frac{1}{c^2}\frac{\partial\varphi}{\partial t}=0, \quad (7.230)$$

or

$$\frac{\partial}{\partial t}(\nabla\cdot\boldsymbol{A})+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial^2\boldsymbol{A}}{\partial t^2}+\frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2}=0. \quad (7.231)$$

Substituting Eqs. (7.230) and (7.231) respectively into Eqs. (7.228) and (7.229), we obtain

$$\left.\begin{aligned} &\nabla^2\varphi+\frac{2}{c^2}(\boldsymbol{v}\cdot\nabla)\frac{\partial\varphi}{\partial t}-\frac{1}{\gamma^2c^2}\frac{\partial^2\varphi}{\partial t^2}=-\frac{\rho}{\varepsilon_0}+\mu_0\boldsymbol{v}\cdot\boldsymbol{j},\\ &\nabla^2\boldsymbol{A}+\frac{2}{c^2}(\boldsymbol{v}\cdot\nabla)\frac{\partial\boldsymbol{A}}{\partial t}-\frac{1}{c^2}\frac{\partial^2\boldsymbol{A}}{\partial t^2}+\frac{1}{c^4}\boldsymbol{v}\left(\boldsymbol{v}\cdot\frac{\partial^2\boldsymbol{A}}{\partial t^2}\right)=-\mu_0\boldsymbol{j}.\end{aligned}\right\}\qquad(7.232)$$

These are the basic equations for the scalar potential φ and vector potential $\boldsymbol{A}$.

Using the formula

$$v^2/c^2=-\left(\gamma^{-2}-1\right),$$

the third term and the fourth term in left side of the second equation of Eq. (7.232) can rewritten as

$$-\frac{1}{c^2}\frac{\partial^2\boldsymbol{A}}{\partial t^2}+\frac{1}{c^4}\boldsymbol{v}\left(\boldsymbol{v}\cdot\frac{\partial^2\boldsymbol{A}}{\partial t^2}\right)=-\frac{1}{c^2}\left[\frac{\partial^2\boldsymbol{A}}{\partial t^2}-\frac{v^2}{c^2}\boldsymbol{v}_0\cdot\frac{\partial^2\boldsymbol{A}}{\partial t^2}\right]$$

$$=-\frac{1}{c^2}\left[\frac{\partial^2\boldsymbol{A}}{\partial t^2}+\left(\gamma^{-2}-1\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\frac{\partial^2\boldsymbol{A}}{\partial t^2}\right)\right]=-\frac{1}{c^2}\hat{T}^{-2}\left(\frac{\partial^2\boldsymbol{A}}{\partial t^2}\right).$$

Substituting the above equation into the second equation of Eq. (7.232), and writing them in connection with the first equation, we have

$$\left.\begin{aligned} &\nabla^2\varphi+\frac{2}{c^2}(\boldsymbol{v}\cdot\nabla)\frac{\partial\varphi}{\partial t}-\frac{1}{\gamma^2c^2}\frac{\partial^2\varphi}{\partial t^2}=-\frac{\rho}{\varepsilon_0}+\mu_0\boldsymbol{v}\cdot\boldsymbol{j},\\ &\nabla^2\boldsymbol{A}+\frac{2}{c^2}(\boldsymbol{v}\cdot\nabla)\frac{\partial\boldsymbol{A}}{\partial t}-\frac{1}{c^2}\hat{T}^{-2}\left(\frac{\partial^2\boldsymbol{A}}{\partial t^2}\right)=-\mu_0\boldsymbol{j}.\end{aligned}\right\}\qquad(7.233)$$

The equations (7.232) or (7.233), in connection with the gauge condition (7.230), are the basic equations of electrodynamics formulated by the potentials $(\varphi,\boldsymbol{A})$. After finding the solution of the potentials $(\varphi,\boldsymbol{A})$ of these equations, the electromagnetic fields $(\boldsymbol{E},\boldsymbol{B})$ are given by Eqs. (7.225) and (7.226). Obviously, to the absolute inertial frame Σ_{a}, we have that $\boldsymbol{v}=0$, the basic equations (7.232) or (7.233) return to the D'Alembertian equations of the general electrodynamics.

Noticing the right side of the first equation of Eqs. (7.232) or Eqs. (7.233) can be written as $\left(-\rho+c^{-2}\boldsymbol{v}\cdot\boldsymbol{j}\right)/\varepsilon_0$, from Eqs. (7.232) or (7.233) we have seen that the wave of the scalar potential is produced mainly by charges, also is somewhat relative to currents; the wave of the vector potential is produced completely by currents. After leaving the region of charges and currents distribution, the scalar potential and vector potential all propagate in space in the form of wave. Of course, the wave properties of $\boldsymbol{E}$ and $\boldsymbol{B}$ are independent of the gauge.

7. 9. 4. The Transformation of the Scalar Potential φ and Vector Potential A

From the definitions (7.225) and (7.226) of the scalar potential φ and vector potential $\boldsymbol{A}$,

namely

$$\boldsymbol{E}=-\nabla\varphi-\frac{1}{c^2}\frac{\partial\varphi}{\partial t}\boldsymbol{v}-\frac{\partial\boldsymbol{A}}{\partial t},\quad \boldsymbol{B}=\nabla\times\boldsymbol{A}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{A}}{\partial t},\tag{7.234}$$

we easily obtain that to frame Σ_a, $\boldsymbol{v}=0$, so

$$\boldsymbol{E}_a=-\nabla_a\varphi_a-\frac{\partial\boldsymbol{A}_a}{\partial t_a},\quad \boldsymbol{B}_a=\nabla_a\times\boldsymbol{A}_a.\tag{7.235}$$

Starting the above definitions and the reverse transformations (7.115a) $\boldsymbol{E}$ and $\boldsymbol{B}$, namely

$$\boldsymbol{E}_a=\gamma\left(\hat{T}^{-1}\boldsymbol{E}-\boldsymbol{v}\times\boldsymbol{B}\right),\ \ \boldsymbol{B}_a=\gamma\left(\hat{T}^{-1}\boldsymbol{B}+\boldsymbol{v}\times\boldsymbol{E}/c^2\right),$$

and using Eqs. (7.33) and (7.34), namely

$$\nabla=\hat{T}^{-1}\nabla_a,\qquad \nabla_a=\hat{T}\nabla,$$

$$\frac{\partial}{\partial t}=\gamma\frac{\partial}{\partial t_a}+\gamma\boldsymbol{v}\cdot\nabla,\quad \frac{\partial}{\partial t_a}=\gamma^{-1}\frac{\partial}{\partial t}-\gamma\boldsymbol{v}\cdot\nabla,$$

and Eqs. (7.36), (7.28), (7.49) and (7.37), we can find the transformations of the scalar potential φ and vector potential $\boldsymbol{A}$.

First, from the definitions (7.234) and (7.235) of φ and $\boldsymbol{A}$, and the reverse transformation of $\boldsymbol{B}$, we obtain

$$\begin{aligned}
\nabla_a\times\boldsymbol{A}_a&=\gamma\left[\hat{T}^{-1}\left(\nabla\times\boldsymbol{A}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{A}}{\partial t}\right)-\boldsymbol{v}\times\left(\nabla\varphi+\frac{1}{c^2}\frac{\partial\varphi}{\partial t}\boldsymbol{v}+\frac{\partial\boldsymbol{A}}{\partial t}\right)/c^2\right]\\
&=\gamma\hat{T}^{-1}\left(\nabla\times\boldsymbol{A}\right)+\frac{\gamma}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{A}}{\partial t}-\frac{\gamma}{c^2}\boldsymbol{v}\times\nabla\varphi-\frac{\gamma}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{A}}{\partial t}\\
&=\gamma\hat{T}^{-1}\left[\left(\hat{T}^{-1}\nabla_a\right)\times\boldsymbol{A}\right]+\left(\gamma/c^2\right)\left(\hat{T}^{-1}\nabla_a\right)\times\left(\varphi\,\boldsymbol{v}\right)\\
&=\gamma\hat{T}^{-1}\left[\gamma^{-1}\hat{T}\left(\nabla_a\times\boldsymbol{A}\right)+\left(1-\gamma\right)\boldsymbol{v}_0\times\left[\nabla_a\left(\boldsymbol{v}_0\cdot\boldsymbol{A}\right)\right]\right.\\
&\qquad\left.+\hat{T}\left[\nabla_a\times\left(\varphi\,\boldsymbol{v}\right)/c^2\right]+\left(1-\gamma\right)\boldsymbol{v}_0\times\left[\nabla_a\left(\boldsymbol{v}_0\cdot\varphi\,\boldsymbol{v}\right)/c^2\right]\right]\\
&=\nabla_a\times\boldsymbol{A}+\left(\gamma-1\right)\left[\nabla_a\left(\boldsymbol{v}_0\cdot\boldsymbol{A}\right)\right]\times\boldsymbol{v}_0+\left(\nabla_a\varphi\right)\times\boldsymbol{v}/c^2+\left(\gamma-1\right)\left(\nabla_a\varphi\right)\times\boldsymbol{v}/c^2\\
&=\nabla_a\times\boldsymbol{A}+\left(\gamma-1\right)\nabla_a\times\left[\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\boldsymbol{A}\right)\right]+\gamma\left(\nabla_a\varphi\right)\times\boldsymbol{v}/c^2\\
&=\nabla_a\times\left[\boldsymbol{A}+\left(\gamma-1\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\boldsymbol{A}\right)\right]+\gamma\nabla_a\times\left(\varphi\boldsymbol{v}/c^2\right)=\nabla_a\times\left[\hat{T}\left(\boldsymbol{A}+\varphi\,\boldsymbol{v}/c^2\right)\right].
\end{aligned}$$

Considering the gauge invariance, from the above equation we obtain

$$\boldsymbol{A}_a=\hat{T}\left(\boldsymbol{A}+\varphi\boldsymbol{v}/c^2\right).\tag{7.236}$$

Second, from the definitions (7.234) and (7.235), and the transformation of $\boldsymbol{B}$, we obtain

$$-\nabla_a\varphi_a-\frac{\partial\boldsymbol{A}_a}{\partial t_a}=-\gamma\hat{T}^{-1}\left(\nabla\varphi+\frac{1}{c^2}\frac{\partial\varphi}{\partial t}\boldsymbol{v}+\frac{\partial\boldsymbol{A}}{\partial t}\right)-\gamma\,\boldsymbol{v}\times\left(\nabla\times\boldsymbol{A}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{A}}{\partial t}\right)$$

$$=-\gamma\hat{T}^{-1}\left[\left(\hat{T}^{-1}\nabla_{\text{a}}\right)\varphi\right]-\frac{\gamma^2}{c^2}\hat{T}^{-1}\left[\boldsymbol{v}\frac{\partial\varphi}{\partial t_{\text{a}}}+\boldsymbol{v}\left(\boldsymbol{v}\cdot\nabla_{\text{a}}\right)\varphi\right]$$

$$-\gamma\hat{T}^{-1}\left[\gamma\frac{\partial\boldsymbol{A}}{\partial t_{\text{a}}}+\gamma\left(\boldsymbol{v}\cdot\nabla_{\text{a}}\right)\boldsymbol{A}\right]-\gamma\boldsymbol{v}\times\left[\left(\hat{T}^{-1}\nabla_{\text{a}}\right)\times\boldsymbol{A}\right]$$

$$-\frac{\gamma}{c^2}\boldsymbol{v}\times\left\{\boldsymbol{v}\times\left[\frac{\partial\boldsymbol{A}}{\partial t_{\text{a}}}+\left(\boldsymbol{v}\cdot\nabla_{\text{a}}\right)\boldsymbol{A}\right]\right\}.$$

Below solely calculating the first term and the fourth term of the right side of the above equation, and using the formulas indicated above, we have

$$-\gamma\hat{T}^{-1}\left[\left(\hat{T}^{-1}\nabla_{\text{a}}\right)\varphi\right]=-\gamma\hat{T}^{-1}\left[\nabla_{\text{a}}\varphi+\left(\gamma^{-1}-1\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\nabla_{\text{a}}\right)\varphi\right]$$

$$=-\gamma\hat{T}^{-1}\left(\nabla_{\text{a}}\varphi\right)-\left(\gamma^{-1}-1\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\nabla_{\text{a}}\right)\varphi$$

$$=-\gamma\left(\nabla_{\text{a}}\varphi\right)-\gamma\left(\gamma^{-1}-1\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\nabla_{\text{a}}\varphi\right)-\left(\gamma^{-1}-1\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\nabla_{\text{a}}\right)\varphi$$

$$=-\gamma\left(\nabla_{\text{a}}\varphi\right)+\left(\gamma-\gamma^{-1}\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\nabla_{\text{a}}\right)\varphi=-\gamma\left(\nabla_{\text{a}}\varphi\right)+\gamma\left(v^2/c^2\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\nabla_{\text{a}}\right)\varphi,$$

$$-\gamma\boldsymbol{v}\times\left[\left(\hat{T}^{-1}\nabla_{\text{a}}\right)\times\boldsymbol{A}\right]=-\gamma\boldsymbol{v}\times\left\{\gamma^{-1}\hat{T}\left(\nabla_{\text{a}}\times\boldsymbol{A}\right)+\left(\gamma^{-1}-1\right)\boldsymbol{v}_0\times\left[\nabla_{\text{a}}\left(\boldsymbol{v}_0\cdot\boldsymbol{A}\right)\right]\right\}$$

$$=-\boldsymbol{v}\times\left(\nabla_{\text{a}}\times\boldsymbol{A}\right)+\left(\gamma-1\right)\boldsymbol{v}\times\left\{\boldsymbol{v}_0\times\left[\boldsymbol{v}_0\times\left(\nabla_{\text{a}}\times\boldsymbol{A}\right)+\left(\boldsymbol{v}_0\cdot\nabla_{\text{a}}\right)\boldsymbol{A}\right]\right\}$$

$$=-\boldsymbol{v}\times\left(\nabla_{\text{a}}\times\boldsymbol{A}\right)-\left(\gamma-1\right)\boldsymbol{v}\times\left(\nabla_{\text{a}}\times\boldsymbol{A}\right)+\left(\gamma-1\right)\boldsymbol{v}\times\left[\boldsymbol{v}_0\times\left(\boldsymbol{v}_0\cdot\nabla_{\text{a}}\right)\boldsymbol{A}\right]$$

$$=-\gamma\boldsymbol{v}\times\left(\nabla_{\text{a}}\times\boldsymbol{A}\right)+\left(\gamma-1\right)\boldsymbol{v}_0\left\{\boldsymbol{v}_0\cdot\left[\left(\boldsymbol{v}\cdot\nabla_{\text{a}}\right)\boldsymbol{A}\right]\right\}-\left(\gamma-1\right)\left(\boldsymbol{v}\cdot\nabla_{\text{a}}\right)\boldsymbol{A}.$$

Substituting the above two equations into the previous equation, we obtain

$$-\nabla_{\text{a}}\varphi_{\text{a}}-\frac{\partial\boldsymbol{A}_{\text{a}}}{\partial t_{\text{a}}}=-\gamma\left(\nabla_{\text{a}}\varphi\right)+\gamma\frac{v^2}{c^2}\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\nabla_{\text{a}}\right)\varphi-\frac{\gamma}{c^2}\frac{\partial\varphi}{\partial t_{\text{a}}}\boldsymbol{v}-\gamma\frac{v^2}{c^2}\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\nabla_{\text{a}}\right)\varphi-\gamma^2\frac{\partial\boldsymbol{A}}{\partial t_{\text{a}}}$$

$$-\left(\gamma-\gamma^2\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\frac{\partial\boldsymbol{A}}{\partial t_{\text{a}}}\right)-\gamma^2\left(\boldsymbol{v}\cdot\nabla_{\text{a}}\right)\boldsymbol{A}-\left(\gamma-\gamma^2\right)\left(\boldsymbol{v}\cdot\nabla_{\text{a}}\right)\left[\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\boldsymbol{A}\right)\right]$$

$$-\gamma\boldsymbol{v}\times\left(\nabla_{\text{a}}\times\boldsymbol{A}\right)+\left(\gamma-1\right)\boldsymbol{v}_0\left\{\boldsymbol{v}_0\cdot\left[\left(\boldsymbol{v}\cdot\nabla_{\text{a}}\right)\boldsymbol{A}\right]\right\}-\left(\gamma-1\right)\left(\boldsymbol{v}\cdot\nabla_{\text{a}}\right)\boldsymbol{A}$$

$$-\gamma^2\frac{v^2}{c^2}\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\frac{\partial\boldsymbol{A}}{\partial t_{\text{a}}}\right)+\gamma^2\frac{v^2}{c^2}\frac{\partial\boldsymbol{A}}{\partial t_{\text{a}}}-\gamma^2\frac{v^2}{c^2}\boldsymbol{v}_0\left\{\boldsymbol{v}_0\cdot\left[\left(\boldsymbol{v}\cdot\nabla_{\text{a}}\right)\boldsymbol{A}\right]\right\}+\gamma^2\frac{v^2}{c^2}\left(\boldsymbol{v}\cdot\nabla_{\text{a}}\right)\boldsymbol{A}$$

$$=-\gamma\left(\nabla_{\text{a}}\varphi\right)-\gamma\boldsymbol{v}\times\left(\nabla_{\text{a}}\times\boldsymbol{A}\right)-\gamma\left(\boldsymbol{v}\cdot\nabla_{\text{a}}\right)\boldsymbol{A}-\frac{\partial\boldsymbol{A}}{\partial t_{\text{a}}}-\left(\gamma-1\right)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\frac{\partial\boldsymbol{A}}{\partial t_{\text{a}}}\right)-\frac{\gamma}{c^2}\frac{\partial\varphi}{\partial t_{\text{a}}}\boldsymbol{v}$$

But according to the reverse transformation (7.236) of $\boldsymbol{A}$, we have

$$\frac{\partial \boldsymbol{A}_{\mathrm{a}}}{\partial t_{\mathrm{a}}}=\frac{\partial \boldsymbol{A}}{\partial t_{\mathrm{a}}}+(\gamma-1)\boldsymbol{v}_0\left(\boldsymbol{v}_0\cdot\frac{\partial \boldsymbol{A}}{\partial t_{\mathrm{a}}}\right)+\frac{\gamma}{c^2}\frac{\partial\varphi}{\partial t_{\mathrm{a}}}\boldsymbol{v}.$$

Substituting the above equation into the previous equation, we obtain

$$\nabla_{\mathrm{a}}\varphi_{\mathrm{a}}=\gamma(\nabla_{\mathrm{a}}\varphi)+\gamma\boldsymbol{v}\times(\nabla_{\mathrm{a}}\times\boldsymbol{A})+\gamma(\boldsymbol{v}\cdot\nabla_{\mathrm{a}})\boldsymbol{A}=\nabla_{\mathrm{a}}\left[\gamma(\varphi+\boldsymbol{v}\cdot\boldsymbol{A})\right].$$

Considering the gauge invariance, from the above equation we obtain

$$\varphi_{\mathrm{a}}=\gamma(\varphi+\boldsymbol{v}\cdot\boldsymbol{A}).\tag{7.237}$$

From the inverse transformations (7.237) and (7.236) of the scalar potential φ and vector potential $\boldsymbol{A}$, we immediately find the direct transformation. Their direct transformations and inverse transformations are collected as follows:

$$\left.\begin{aligned}\boldsymbol{A}=\hat{T}\left(\boldsymbol{A}_{\mathrm{a}}-\varphi_{\mathrm{a}}\boldsymbol{v}/c^2\right),\quad \varphi=\gamma(\varphi_{\mathrm{a}}-\boldsymbol{v}\cdot\boldsymbol{A}_{\mathrm{a}}),\\ \boldsymbol{A}_{\mathrm{a}}=\hat{T}\left(\boldsymbol{A}+\varphi_{\mathrm{a}}\boldsymbol{v}/c^2\right),\quad \varphi_{\mathrm{a}}=\gamma(\varphi+\boldsymbol{v}\cdot\boldsymbol{A}).\end{aligned}\right\}\tag{7.238}$$

The transformations of the components of parallel and perpendicular of the vector potential $\boldsymbol{A}$ can be re-written as

$$\left.\begin{aligned}\boldsymbol{A}_{\parallel}=\gamma\left(\boldsymbol{A}_{\mathrm{a}\parallel}-\varphi_{\mathrm{a}}\boldsymbol{v}/c^2\right),\quad \boldsymbol{A}_{\perp}=\boldsymbol{A}_{\mathrm{a}\perp},\\ \boldsymbol{A}_{\mathrm{a}\parallel}=\gamma\left(\boldsymbol{A}_{\parallel}+\varphi_{\mathrm{a}}\boldsymbol{v}/c^2\right),\quad \boldsymbol{A}_{\mathrm{a}\perp}=\boldsymbol{A}_{\perp}.\end{aligned}\right\}\tag{7.239}$$

Finally, on the gauge condition (7.230), to the absolute inertial frame Σ_{a}, we have that $\boldsymbol{v}=0$, so obtain

$$\nabla_{\mathrm{a}}\cdot\boldsymbol{A}_{\mathrm{a}}+\frac{1}{c^2}\frac{\partial\varphi_{\mathrm{a}}}{\partial t_{\mathrm{a}}}=0.\tag{7.240}$$

This is the Lorentz condition. Using the transformations (7.238) of the scalar potential φ and vector potential $\boldsymbol{A}$, and Eqs. (7.33) and (7.34), we easily prove that the gauge condition (7.230) and the Lorentz condition (7.240) can be derived from each other.

In fact, for example, starting from the Lorentz condition (7.240), we have

$$\begin{aligned}\nabla_{\mathrm{a}}\cdot\boldsymbol{A}_{\mathrm{a}}+\frac{1}{c^2}\frac{\partial\varphi_{\mathrm{a}}}{\partial t_{\mathrm{a}}}&=\left(\hat{T}\nabla\right)\cdot\left[\hat{T}\left(\boldsymbol{A}+\varphi\boldsymbol{v}/c^2\right)\right]+\frac{\gamma}{c^2}\left[\gamma^{-1}\frac{\partial}{\partial t}-\gamma(\boldsymbol{v}\cdot\nabla)\right](\varphi+\boldsymbol{v}\cdot\boldsymbol{A})\\ &=\nabla\cdot\left(\hat{T}^2\boldsymbol{A}\right)+\nabla\cdot\left(\gamma^2\varphi\boldsymbol{v}/c^2\right)+\frac{1}{c^2}\frac{\partial\varphi}{\partial t}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{A}}{\partial t}-\frac{\gamma^2}{c^2}(\boldsymbol{v}\cdot\nabla)\varphi-\frac{\gamma^2}{c^2}(\boldsymbol{v}\cdot\nabla)(\boldsymbol{v}\cdot\boldsymbol{A})\\ &=\nabla\cdot\boldsymbol{A}+\left(\gamma^2-1\right)\nabla\cdot\left[\boldsymbol{v}_0(\boldsymbol{v}_0\cdot\boldsymbol{A})\right]+\frac{\gamma^2}{c^2}(\boldsymbol{v}\cdot\nabla\varphi)+\frac{1}{c^2}\frac{\partial\varphi}{\partial t}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{A}}{\partial t}-\frac{\gamma^2}{c^2}(\boldsymbol{v}\cdot\nabla\varphi)\\ &\qquad-\gamma^2\frac{v^2}{c^2}\boldsymbol{v}_0\cdot\left[\nabla(\boldsymbol{v}_0\cdot\boldsymbol{A})\right]\\ &=\nabla\cdot\boldsymbol{A}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{A}}{\partial t}+\frac{1}{c^2}\frac{\partial\varphi}{\partial t}.\end{aligned}$$

Namely

$$\nabla_{\mathrm{a}}\cdot\boldsymbol{A}_{\mathrm{a}}+\frac{1}{c^2}\frac{\partial\varphi_{\mathrm{a}}}{\partial t_{\mathrm{a}}}=\nabla\cdot\boldsymbol{A}+\frac{1}{c^2}\boldsymbol{v}\cdot\frac{\partial\boldsymbol{A}}{\partial t}+\frac{1}{c^2}\frac{\partial\varphi}{\partial t}=0. \tag{7.241}$$

In derivation of the above equation, besides Eqs. (7.33) and (7.34), we also used Eqs. (7.45), (7.35), (7.17), (7.19), (7.27) and (7.31).

7. 10. An important supplement

In the above electrodynamics of Standard Space-time Theory, starting completely from the four basic postulates (see Sec.7.1) and carrying out careful analyses and researches independently of the special theory of relativity, we have discovered and formulated the laws of the electromagnetic fields in the ordinary inertial frames. Are there simple methods to achieve the same results? The answer is affirmative. Chapter 11 has prompted and researched a sort of this method. Here we give a simple introduction.

Both Standard Space-time Theory and the special theory of relativity satisfy the principle of the constancy of the average circuit speed of light. If the speed of light is isotropic in any inertial frame and the principle of relativity holds true, we must gain LT. If we consider the speed of light is isotropic only in the absolute inertial frame and the principle of the absolute reference frame holds true, we must gain GGT. Different basic postulates in the two theories lead to the different definition of simultaneity and different method of the synchronization of clocks at different places. Frame Σ_{a} and Σ in GGT are respectively corresponded with S and S' in LT. Noticing the space coordinates under the two assumptions are the same, starting from the postulate of the constancy of the average circuit speed of light, we can obtain the relations between the space-time coordinates in the two theories

$$\left.\begin{aligned}&\boldsymbol{r}_{\mathrm{a}}=\boldsymbol{r}_{\mathrm{r}},\ t_{\mathrm{a}}=t_{\mathrm{r}}\\&\boldsymbol{r}=\boldsymbol{r}'_{\mathrm{r}},\ t=t'_{\mathrm{r}}+\boldsymbol{v}\cdot\boldsymbol{r}'_{\mathrm{r}}/c^2\end{aligned}\right\} \tag{7.242}$$

where the subscript r denotes relativistic quantity, $\boldsymbol{v}$ is the velocity of frame Σ with respect to Σ_{a} and is measured in Σ_{a}, and also is the velocity of frame S' with respect to S and is measured in S. The only difference is given by the above last equation which shows the difference in time coordinates introduced from the different basic postulates and different synchronization method of clocks at different places. Using (7.242), LT and GGT can be derived mutually.

From the definitions of the velocity in every reference frame and (7.242) we can obtain the relations between the velocities in the two theories

$$\left.\begin{aligned}
&\boldsymbol{u}_{\mathrm{r}} = \boldsymbol{u}_{\mathrm{a}}, \\
&\boldsymbol{u}'_{\mathrm{r}} = \frac{\boldsymbol{u}}{1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2}, \quad \boldsymbol{u} = \frac{\boldsymbol{u}'_{\mathrm{r}}}{1+\boldsymbol{u}'_{\mathrm{r}}\cdot\boldsymbol{v}/c^2}, \\
&\frac{1}{\sqrt{1-u'^2_{\mathrm{r}}/c^2}} = \frac{1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2}{\sqrt{(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2-u^2/c^2}}, \\
&\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)\left(1+\boldsymbol{u}'_{\mathrm{r}}\cdot\boldsymbol{v}/c^2\right) = 1.
\end{aligned}\right\} \tag{7.243}$$

where $\boldsymbol{u}_r$ and $\boldsymbol{u}'_{\mathrm{r}}$ represent the velocities of a body measured separately in S and S' according to the synchronization method of clocks at different places in the special theory of relativity, $\boldsymbol{u}_{\mathrm{a}}$ and $\boldsymbol{u}$ represent the velocities of a body measured separately in Σ_{a} and Σ according to the synchronization method of clocks at different places in Standard Space-time Theory. Using these relations, we can easily get formulas of Standard Space-time Theory from the corresponding formulas of the special theory of relativity and vice versa.

For the relations (7.242) we can get the relations between the differential operators of the space-time coordinates in the two theories. To the frame S in the special theory of relativity and the frame Σ_{a} in Standard Space-time Theory, and to the frame S' in the special theory of relativity and the frame Σ in Standard Space-time Theory we have respectively

$$\nabla_{\mathrm{r}} = \nabla_{\mathrm{a}}, \quad \frac{\partial}{\partial t_{\mathrm{r}}} = \frac{\partial}{\partial t_{\mathrm{a}}}, \tag{7.244}$$

$$\nabla'_{\mathrm{r}} = \nabla + \frac{1}{c^2}\boldsymbol{v}\frac{\partial}{\partial t}, \quad \frac{\partial}{\partial t'_{\mathrm{r}}} = \frac{\partial}{\partial t}. \tag{7.245}$$

In the electrodynamics of Standard Space-time Theory starting completely from the four basic postulates and carrying out careful analyses and researches independently of the special theory of relativity we have discovered and formulated the laws of the electromagnetic fields in the ordinary inertial frames. Now it can see that using the relations (7.244) and (7.245), the equations or formulas of Standard Space-time Theory can be obtain easily from the corresponding equations or formulas of the special theory of relativity and vice versa. These equations or formulas have contained such as the equations of electromagnetic field in vacuum or in media with respect to the ordinary inertial frame, the wave equation of the electromagnetic field in vacuum or in media with respect to the ordinary inertial frame, the definitions of the scalar potential and the vector potential of electromagnetic field, gauge transformation, the basic equations of the scalar potential and the vector potential and so on. Of course, these do not replace the former careful analyses and researches, but it has confirmed from another angle the reliability of the results of the electrodynamics of Standard Space-time Theory.

References

1. Purcell E.M., Electricity and Magnetism. Berkeley Physics Course, Vol. 2, Chap. 5, § 5.5 McGraw Hill, 1965.

Chapter 8

Experimental Examinations to Standard Space-time Theory

There are two key factors to evaluate a theory: The first is logic, that is, the clarity and rationality of concepts, the simplicity and self-consistency of logic. The second is empirical facts, that is, the test and confirmation of observational and experimental facts. As discussed in Chapter 3, the special theory of relativity has faced many conceptual difficulties and challenges. Standard Space-time Theory is superior to the special theory of relativity in the rationality of basic assumptions, logical simplicity and logical self-consistency. This chapter deals with the second aspect, namely, the experimental test of Standard Space-time Theory.

Detailed analyses in the present chapter show that all the previous experiments to test space-time theory, including several kinds of experiments, which cannot be explained by the special theory of relativity, can be explained completely in light of Standard Space-time Theory. Main experiments to test special theory of relativity are re-explained in the light of Standard Space-time Theory. Several new kinds of predictive experiments which can be regarded as the judge experiment between Standard Space-time Theory and the special theory of relativity are presented.

8. 1. General Description

Throughout the past century, a great lot of experiment has been carried out to examine the special theory of relativity. Detailed analyses in this chapter show that the experiments examining and verifying the special theory of relativity have been explained over again according to the viewpoints of Standard Space-time Theory, and no given result of experiments that contradicts with Standard Space-time Theory.

Why can Standard Space-time Theory completely explain all experiments to examine the special theory of relativity? First, all closed light circuit experiments (such as the Michelson-Morley experiment, Kennedy-Thorndike experiment, Silvertooth closed light circuit experiment, Trimer triangle interferometer experiment and so on) has only proved the constancy of average circuit speed of light. This kind of experiments cannot detect the earth's absolute motion and cannot prove the constancy of the one-way speed of light. Standard Space-time Theory has taken the constancy of average circuit speed of light as one of the basic postulates, so it can naturally explain the results of this kind of experiments. Second, the differences between the formulas of the kinematics and dynamics of Standard Space-time Theory and the corresponding that of the special theory of relativity are the substitutions of ($1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2$) for 1, and the differences between the equations of the electrodynamics of Standard Space-time Theory and the corresponding that of the electrodynamics of the special theory of relativity are only additions of one or two terms coefficient of which is v/c^2. These differences are so infinitely small that exceed out of the limits of precision of the present experiments. Not only that, all these differences are caused by the difference in time coordinates introduced from the different synchronization method of clocks at different places in the two theories. That is to say, by synchronizing clocks at different places according to the method in the special theory of relativity (isotropy of light speed) to obtain the experimental results accord with the predictions of the special theory of relativity, is commensurate to or equivalent to by synchronizing clocks at different places according to the method in Standard Space-time Theory (anisotropy of light speed) to obtain the experimental results accord with the predictions of Standard Space-time Theory, and vice versa. Whether experimental results have manifested a slight anisotropy of space or not, is dependent on whether the synchronizing clocks at different places introduces the anisotropy of space or not. At this sense, the two theories have predicted the same observational effects.

Although Standard Space-time Theory has obtained the same or similar formulas with the special theory of relativity, and have predicted many the same observational effects, yet space-time views of the two theories are very different. Standard Space-time Theory has definite connotations sharply conflicting with non-conventional components of the special theory of relativity. These are displayed at that principles, conceptions and inferences opposite to the special theory of relativity. Physical studies have never been confined to quantitative calculations starting purely from equations and formulas, but the prior thing is to carry on thoughts and analyses starting first from physical principles, conceptions and inferences. At that starting from the opposite principles, conceptions and inferences, Standard Space-time Theory has predicted many observational effects radically different and completely opposite from the special theory of relativity.

The special theory of relativity cannot explain several kinds of experimental facts following: (1) the cosmic background radiation; (2) the homopolar magnetic induction experiments; (3) the superluminal motion experiments; (4) the distant-correlation experiments. All the previous experiments to test space-time theory, including several kinds of experiments which cannot be explained by the special theory of relativity, have been explained completely in light of Standard Space-time Theory.

8. 2. Closed Light Circuit Experiments and Moving Light Source Experiment

In this section according to the viewpoint of Standard Space-time Theory we will emphatically discuss (1) Michelson-Morley experiment and Kennedy-Thorndike experiment; (2) circuit interferometer experiment; (3) closed moving light source experiment. We will point out that using these kinds of closed light circuit experiments cannot measure the earth's absolute motion speed.

8. 2. 1. Michelson-Morley Experiment and Kennedy-Thorndike Experiment

Fig.8.1 show the Michelson-Morley experiment, where $\boldsymbol{v}$ represents the earth's absolute motion velocity. Please note that $\boldsymbol{v}$ does not necessarily be in the plane determined by the half-reflector mirror M and reflectors M_1, M_2. According to the expression (5.12) of light speed

$$c(\alpha,\beta,\gamma)=\frac{c}{1+\boldsymbol{n}\cdot\boldsymbol{v}/c},$$

the time for beam I going from M to M_1 and back to M is (in case of observing from the earth's reference frame)

$$t_1=\frac{l_1}{c_{\mathbf{n}_1}}+\frac{l_1}{c_{-\mathbf{n}_1}}=\frac{l_1}{c}(1+\boldsymbol{n}_1\cdot\boldsymbol{v}/c)+\frac{l_1}{c}(1+\boldsymbol{n}_1\cdot\boldsymbol{v}/c)=\frac{2l_1}{c}.$$

For the same reason, the time for beam II along path $M\to M_2\to M$ is

$$t_2=\frac{l_2}{c_{\mathbf{n}_2}}+\frac{l_2}{c_{-\mathbf{n}_2}}=\frac{l_2}{c}(1+\boldsymbol{n}_2\cdot\boldsymbol{v}/c)+\frac{l_2}{c}(1+\boldsymbol{n}_2\cdot\boldsymbol{v}/c)=\frac{2l_2}{c}.$$

Hence, the time difference for both beams to meet again is

$$\Delta t=t_2-t_1=2(l_2-l_1)/c. \tag{8.1}$$

If we rotate the interferometer by an angle 90° in plane MM_1M_2, we will have

$$\left.\begin{aligned}&\overline{t_1}=2l_1/c,\overline{t_2}=2l_2/c,\\&\Delta\overline{t}=\overline{t_2}-\overline{t_1}=2(l_2-l_1)/c.\end{aligned}\right\} \tag{8.2}$$

Then we obtain the change in time difference afore and after the rotation to be

$$\delta t = \Delta t - \Delta\overline{t} = 0, \tag{8.3}$$

so that we have explained the zero result of Michelson-Morley experiment.

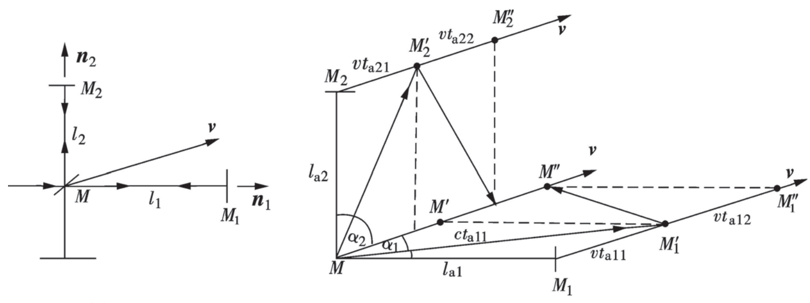


Fig. 8.1

Kennedy-Thorndike's result of their experiment of unequal-length-arms interferometer [1] can also be given a satisfactory explanation from Eqs. (8.1)—(8.3).

Results of Michelson-Morley experiment and Kennedy-Thorndike experiment can be directly explained by applying the length contraction effect and time dilation effect of Standard Space-time Theory. For this end suppose that an observer is in the standard inertial frame Σ_a : M, M_1 and M_2 all move with respect to Σ_a with a velocity $\boldsymbol{v}$, then we find out Δt_a and $\Delta\overline{t_a}$. After this we consider that in practice the observation is made in the earth's frame of reference. To this frame, using the length contraction effect and time dilation effect, from Δt_a and $\Delta\overline{t_a}$ we can get

$$\Delta t = 2(l_2 - l_1)/c,\ \Delta\overline{t} = 2(l_2 - l_1)/c\ ,$$

so $\delta t = \Delta t - \Delta\overline{t} = 0$.

8. 2. 2. Closed Circuit Interferometer Experiment

Here we pay much attention to consider Silvertooth's closed circuit laser interferometer experiment (1972) [2]. As Fig.8.2 shows, a beam of laser (1.06μm) is divided into two beams at the half-reflector *A* and propagates along *ABC* and *AB′C* respectively. Both beams become light with two frequencies (1.06μm and 0.53μm) when one of the beams passes through its double-frequency crystal respectively. They form two sets of interference fringes when they meet about *C*. During the experiment, the interferometer is fixed. Scanning of the direction along with the earth's rotation, no shift of interference fringes is observed.

The location of the interference fringes is determined by the phase difference at *C* of the two beams

$$\Delta\phi = \omega_C \Delta t, \tag{8.4}$$

where ω_C is the angular frequency of the light wave at *C*, while

$$\Delta t = t_{ABC} - t_{AB'C} = \left(\frac{l_{AB}}{c_{AB}} + \frac{l_{BC}}{c_{BC}}\right) - \left(\frac{l_{AB'}}{c_{AB'}} + \frac{l_{B'C}}{c_{B'C}}\right).$$

Substituting the expression (7.48) of light speed into the above equation, we get

$$\begin{aligned} t &= c^{-1}[l_{AB}(1+\boldsymbol{n}_{AB}\cdot\boldsymbol{v}/c) + l_{BC}(1+\boldsymbol{n}_{BC}\cdot\boldsymbol{v}/c)] \\ &= c^{-1}[l_{AB'}(1+\boldsymbol{n}_{AB'}\cdot\boldsymbol{v}/c) + l_{B'C}(1+\boldsymbol{n}_{B'C}\cdot\boldsymbol{v}/c)] = c^{-1}[(l_{AB}+l_{AC}) - (l_{AB'}+l_{B'C})], \end{aligned} \tag{8.5}$$

which has nothing to do with the earth's absolute velocity $\boldsymbol{v}$. Hence, $\Delta\varphi$ does not change along with the earth's motion, and the interference fringes do not shift as the earth moves.

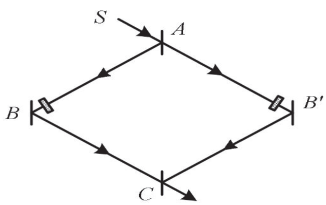


Fig. 8. 2

To the zero result of the triangle interferometer experiment done by Trimer et al. (1973) [3], same explanation can be given.

It was thought by Einstein and many other physicists that the earth's absolute speed can be measured by Michelson-Morley experiment and the closed-circuit interferometer experiment, *etc.*, while the zero result of these experiments (i.e., the given minimum upper limit of the "ether drift speed") affirm the nonexistence of the earth's absolute motion so that they deny the existence of the privileged inertial frame. However, analyses here show that even if there exists the earth's absolute motion, it cannot be detected by Michelson-Morley experiment and the closed-circuit experiment *etc*. because the effect of the earth's absolute motion in these experiments will be counteracted so that it will not be shown. Hence, the zero result of these experiments can't be taken to be the evidence denying the existence of the privileged inertial frame. In fact, these two kinds of experiments can only be taken as the experimental evidence of the principle of the constancy of the average two-way speed of light and the average circulation speed of light.

8. 2. 3. Closed Moving Light Source Experiment

In this section we focus on the stellar aberration phenomenon. Using the velocity transformations (5.7) we can easily deduce the aberration equation.

We choose such a coordinate system of the standard inertial frame Σ_a and the reference frame of the earth Σ that their x-axes lie along the direction of absolute velocity $\boldsymbol{v}$ of the earth, and the observed star locates in plane $x\,y$. Let the angle between the x_a axis of Σ_a and the light beam of the star be α。In order to have the incident light beam be along the optical axis of the telescope, the telescope should be set at a certain angle α_1 to the x axis of frame Σ (Fig.8.3).

In frame Σ_a, the velocity components of the stellar light beam are

$$u_{ax} = -c\cos\alpha,\ u_{ay} = -c\sin\alpha,\ u_{az} = 0\ .$$

According to Eq. (5.7), in frame Σ

$$u_x = -\gamma^2(c\cos\alpha + v), u_y = -\gamma c\sin\alpha, u_z = 0\ .$$

From this we obtain

$$tg\alpha_1 = \frac{u_y}{u_x} = \frac{\sin\alpha}{\gamma(\cos\alpha+\beta)} = \frac{tg\alpha\sqrt{1-\beta^2}}{1+\beta\sec\alpha}\ . \tag{8.6}$$

Starting from Eq. (8.6) and neglecting the β^2 term, by completely similar calculations to those in the special theory of relativity we get

$$\Delta\alpha = \alpha_1 - \alpha = -\beta\sin\alpha = -(v/c)\sin\alpha. \tag{8.7}$$

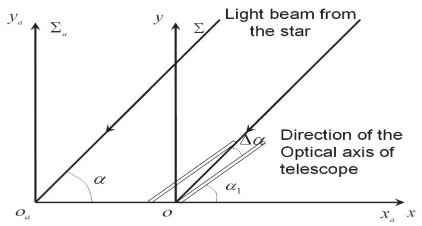


Fig. 8. 3

Equation (8.6) is the aberration equation and Eq. (8.7) is the expression for the aberration angle $\Delta\alpha$ under the first order approximation, which are completely the same as the corresponding result in the special theory of relativity. However, $\boldsymbol{v}$ here does not represent the revolutionary speed of the Earth. The revolutionary speed $\boldsymbol{v}_r$ of the earth is about 30 km/s. According to the measurement of the anisotropy of cosmic background radiation temperature [4], solar speed of absolute motion v_0 is about 390km/sec, and the motion is on the plane of the earth's revolutionary orbit. Hence,

$$\boldsymbol{v} = \boldsymbol{v}_0 + \boldsymbol{v}_r,\quad \text{or}\quad v^2 = v_0^2 + v_r^2 + 2v_0 v_r\cos\varphi\ ,$$

where φ_1 represents the angle between $\boldsymbol{v}_0$ and $\boldsymbol{v}_r$. To two time instant t_1 and t_2 with their interval of six months, the difference of angles α_1, and α_2, or change in aberration angle $\Delta\alpha$ is

$$\begin{aligned}\delta\alpha &= \alpha_2 - \alpha_1 = \Delta\alpha_2 - \Delta\alpha_1 \\ &= (\sqrt{v_0^2 + v_r^2 + 2v_0 v_r\cos\varphi_1} - \sqrt{v_0^2 + v_r^2 - 2v_0 v_r\cos\varphi_1})\sin(\alpha/c).\end{aligned} \tag{8.8}$$

where φ_1 stands for the angle between $\boldsymbol{v}_0$ and $\boldsymbol{v}_r$ at instant t_1. $\boldsymbol{v}_0$ and $\boldsymbol{v}_r$ lie in the same plane, hence there are always such two instants spaced six months every year with the corresponding $\phi_1 = 0, \phi_2 = \pi$ (i.e., $\boldsymbol{v}_\mathrm{r}$ is in the same or the opposite direction of $\boldsymbol{v}_0$). To such two instants,

$$\delta\alpha = \alpha_2 - \alpha_1 = 2v_\mathrm{r}\sin\alpha / c\,. \tag{8.9}$$

If the star is at the ecliptic polar top $(\alpha = 90^\circ)$, to such two instants we obtain the largest change of the aberration angle

$$\delta\alpha = \alpha_2 - \alpha\cos^{-1}\theta_1 = 2v_\mathrm{r} / c = 41''\,. \tag{8.10}$$

Since $v \neq v_\mathrm{r}$, $\Delta\alpha$ calculated from Eq. (8.7) is different from that in the special theory of relativity. But we cannot directly observe and measure the aberration angle $\Delta\alpha$, we can only observe its change $\delta\alpha$, especially the maximum of $\delta\alpha$ $41''$. So, Standard Space-time Theory as well as the special theory of relativity can explain the observation results of the stellar aberration during the year.

In the above discussion, the x axes of frame Σ_a and Σ both point to the direction of the earth's absolute velocity. This is difficult to realize in practice. To improve the above discussion, we can assume that the x axes of Σ_a and Σ point to the direction of the earth's revolutionary velocity $\boldsymbol{v}_\mathrm{r}$ and choose y axes so that the star is in plane $x\,y$. In this case, we can also similarly obtain the results corresponding to astronomical observations.

All the moving light source experiments (other instances are: stellar light source—observation to double star; laboratory light source Michelson-Morley experiment done by moving mirrors or moving light sources; and the measurement to the speed of γ -radiation of high-speed moving particles, etc.) have proved that "the average circulation speed of light and the one-way speed of light have nothing to do with the motion state of the light source." Standard Space-time Theory includes the basic postulate that the average circulation speed of light has nothing to do with the motion of the light source, and from this we can deduce that the one-way speed of light has also nothing to do with the motion state of the light source according to the light speed expression (5.12). So, the results of the moving light source experiments all can be explained by both the special theory of relativity and Standard Space-time Theory.

8. 3. Time-Dilation Experiments

In this section we mainly discuss according to Standard Space-time Theory: (1) the optical Doppler frequency shift effect; (2) the "one-way" light path experiment; (3) the life-time dilation of flying mesons.

8. 3. 1. Optical Doppler Frequency Shift Effect

Suppose the observer (or the receptor) is at rest at the origin of frame Σ, a light source is at the point A of Σ and moves with a speed $\boldsymbol{u}$ along the direction having an angle θ with AO (Fig.8.4). Assume that the light source gives out two successive wave peaks in a time interval $\mathrm{d}t_s = t_B - t_A$. The frequency of the light sources very high and $\mathrm{d}t_s$ is very small so during this time interval the light source travels only a very small distance $AB = u\mathrm{d}t_s$ compared with $\boldsymbol{r}_A$ and $\boldsymbol{r}_B$. From Fig.4 we know that

$$r_B = r_A - u\cos\theta \mathrm{d}t_s . \qquad (8.11)$$

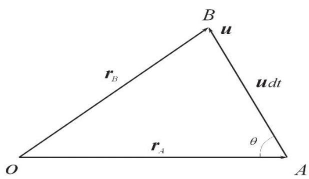


Fig.8.4

The time interval of the two wave peaks received by the receptor is

$$\begin{aligned}\mathrm{d}t &= [t_B + r_B / c_{BO}] - [t_A + r_A / c_{AO}] \\ &= (t_B - t_A) + [(1 + \boldsymbol{n}_{BO} \cdot \boldsymbol{v} / c)(r_B / c) - (1 + \boldsymbol{n}_{AO} \cdot \boldsymbol{v} / c)(r_A / c)] \\ &= \mathrm{d}t_s + (r_B - r_A) / c - (\boldsymbol{r}_B - \boldsymbol{r}_A) \cdot \boldsymbol{v} / c^2.\end{aligned}$$

Using $\boldsymbol{r}_B - \boldsymbol{r}_A = \boldsymbol{AB} = \boldsymbol{u}\mathrm{d}t_s$ and Eq. (8.11) we get

$$\mathrm{d}t = [(1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2) - u\cos\theta / c]\mathrm{d}t_s. \qquad (8.12)$$

Then using $\nu = 1/\mathrm{d}t, \nu_s = 1/\mathrm{d}t_s$ we get

$$\nu = \frac{\nu_s}{(1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2 - u\cos\theta / c)}. \qquad (8.13)$$

According to the time-dilation equation (5.35) and Eq. (5.12) and considering only subluminal motion, we obtain

$$\nu_s = \frac{\sqrt{1 - u_a^2 / c^2}}{\sqrt{1 - v^2 / c^2}} \nu_0 = \sqrt{(1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2)^2 - u^2 / c^2} \nu_0, \qquad (8.14)$$

where ν_s and ν_0 stand for the frequencies of the light wave measured by an observer in Σ and an observer together with the light source, separately. Substituting the above equation into Eq. (8.13) and writing the final result in a form suitable to any inertial frame Σ_i, we get

$$\nu = \frac{\sqrt{(1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2)^2 - u^2 / c^2}}{(1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2) - u\cos\theta / c} \nu_0, \qquad (8.15)$$

where ν, u, θ represent the light wave frequency, the magnitude and direction of the velocity of the light source measured in frame Σ_i。To $i = \mathrm{a}$, i.e., frame Σ_a, we should take $\boldsymbol{v} = 0$.

This is the formula for Doppler's frequency shift effect of Standard Space-time Theory, the difference of which from the formula in the special theory of relativity

$$\nu_\mathrm{r} = \frac{\sqrt{1-u^2/c^2}}{1-u\cos\theta/c}\nu_0 \tag{8.16}$$

is that it uses $(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)$ instead of 1. This difference is vital although it is not big, and it will show evident effect under certain conditions. Hence, in principle we can use this formula to measure the velocity of the earth's absolute motion. To make this point concretely, we next discuss the 'one-way' light path experiment.

8. 3. 2. "One-way" light path experiment

In the so called "one-way" light path experiment the observer observes the transverse Doppler's effect in fact. J. P. Cedarholm et al. (1958) [5] used two ammonia molecules maser of the same type to have completed the first such experiments. In the experiment the two ammonia molecular beams flight in opposite directions, and the electromagnetic radiation perpendicular to the molecular beams' direction was observed. No evident change in transverse Doppler frequency difference was observed when the total device was rotated an angle of 180° ($<0.02\ \mathrm{sec}^{-1}$).

The precision of this experiment is better than that of the best Michelson-Morley experiment, hence the textbooks [6] on the special theory of relativity have such a view: this experiment has determined that the upper limit of the earth's absolute velocity is 30m/s, hence one can say that this experiment has delivered a fatal blow to the ether hypothesis. However, from viewpoint of Standard Space-time Theory, this conclusion does not hold true.

According to Eq. (8.15), taking $\theta = \pi/2$, we can get the transverse Doppler relative frequency and the first several terms of the transverse Doppler relative frequency shift to be

$$\nu = \frac{\sqrt{(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - u^2/c^2}}{1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2}\nu_0, \tag{8.17a}$$

$$\frac{\Delta\nu}{\nu_0} = \frac{\nu-\nu_0}{\nu_0} = -\frac{1}{2}\left(\frac{u}{c}\right)^2 - \left(\frac{u}{c}\right)^2\left(\frac{\boldsymbol{u}}{c}\cdot\frac{\boldsymbol{v}}{c}\right) - \frac{1}{8}\left(\frac{u}{c}\right)^4 - \cdots. \tag{8.17b}$$

The special theory of relativity has predicted transverse Doppler's effect, and from Eq. (8.16) gets the transverse Doppler relative frequency and the relative frequency shift to be

$$\left.\begin{aligned} &\nu_\mathrm{r} = \sqrt{1-u^2/c^2}\,\nu_0, \\ &\frac{\Delta\nu_\mathrm{r}}{\nu_0} = \frac{\nu_\mathrm{r}-\nu_0}{\nu_0} = -\frac{1}{2}\left(\frac{u}{c}\right)^2 - \frac{1}{8}\left(\frac{u}{c}\right)^4 - \frac{1}{16}\left(\frac{u}{c}\right)^6 - \cdots. \end{aligned}\right\} \tag{8.18}$$

That is to say, according to Standard Space-time Theory, the second-order transverse Doppler's effect has nothing to do with the earth's absolute motion and is consistent with the result in the special theory of relativity. Hence, the experiment of the second order transverse Doppler's effect cannot measure the absolute velocity of the earth.

From Eq. (8.17), to two moving light sources along opposite directions $\left(\boldsymbol{u}_1 = -\boldsymbol{u}_2 = \boldsymbol{u}\right)$, their transverse frequency difference is

$$\delta\nu = \nu_2 - \nu_1 = (\nu_2 - \nu_0) - (\nu_1 - \nu_0) = 2\left(\frac{u}{c}\right)^2 \left(\frac{\boldsymbol{u}}{c}\cdot\frac{\boldsymbol{v}}{c}\right)\nu_0. \quad (8.19)$$

The change in frequency difference after a rotation of 180° of the entire device is

$$2\delta\nu = 4\left(\frac{u}{c}\right)^2 \left(\frac{\boldsymbol{u}}{c}\cdot\frac{\boldsymbol{v}}{c}\right)\nu_0. \quad (8.20)$$

According to the Cedarholm experimental data, u = 0.6 km/sec, ν_0 =2.4×10^{10}sec^{-1}, $\boldsymbol{v}$= 400 km/sec, c =3×10^5 km/sec, assuming $\boldsymbol{u} \parallel \boldsymbol{v}$, then $2\delta\nu \approx 1\times10^{-9}$ sec^{-1}. Such a small change in frequency difference cannot be measured. Hence, the Cedarholm experiment cannot measure the absolute velocity of the earth, one can't talk that it is not a fatal blow to the ether hypothesis.

We can see from Eq. (8.20) that to short-wavelength radiations emitted by two light sources moving with high opposite velocities, only if the speed u of the light source is high enough and the radiation frequency is high enough, one can observe their change in the transverse Doppler frequency difference and hence measure the earth's absolute speed.

8. 3. 3. Life-Time Dilation of Flying Mesons

Decay experiments of μ mesons are described below.

The μ meson is a kind of particle whose physical properties are very similar to those of the electron, and its mass is 206.769 times that of the electron.

There are two kinds of μ meson, negatively charged and positively charged. The negatively charged μ meson will spontaneously decay into an electron e^- and two neutrinos with different properties ν_μ and $\tilde{\nu}_\mathrm{e}$:

$$\mu \to \mathrm{e}^- + \nu_\mu + \tilde{\nu}_\mathrm{e},$$

where ν_μ is a μ -type neutrino and $\tilde{\nu}_\mathrm{e}$ is an electron type neutrino.

The decay process of the μ mesons are exponential. According to the law of radioactive decay, suppose there is N_0 radioactive particles at the beginning ($t = 0$), and after time t, there will be left

$$N = N_0 \mathrm{e}^{-t/\tau_0}, \quad (8.21)$$

where τ_0 is called the average lifetime of the radioactive particle. That is, the actual lifetime of each particle is long or short, but the average lifetime is τ_0. This average lifetime τ_0 is the time it takes for N_0 radioactive particles to decay until only $N = N_0 / \mathrm{e} = N_0 / 2.718282$ particles remain.

It has been experimentally determined that the average lifetime of a stationary μ(muon) is $\tau_0 = 2.2 \times 10^{-6}$ seconds. The μ mesons in the cosmic radiation generally come from the decay of π mesons produced by the interaction of primary cosmic rays with atmospheric molecular nuclei in the upper atmosphere (note that the upper limit of the troposphere is about 6 to 18 km, which varies with latitude and season). For μ mesons in cosmic rays, if the flying particles exist only 2.2×10^{-6} seconds relative to the earth, even if they travel at the light speed, their average distance before decay is only $c\tau_0 = 660$ meters, and the μ(muons) produced at the top of the atmosphere cannot be expected to reach the sea level. In fact, however, the experiment detected that a significant portion of the μ mesons reached sea level. To solve this contradiction, we either consider that the μ meson moves at a speed faster than the light speed relative to the geocentric reference frame, or that the life τ_0 span of the particle is longer than its inherent life span. Experiments on elementary particles have not established the existence of such tachyon. Therefore, we can only consider the time delay effect of the high-speed flight relative to the geocentric reference system.

For moving particles, the measurement to time relate to the synchronization of clocks at different places. In this case, using N_0 to stand for the number at $t = 0$, and $x = 0$, we can measure the number of undecayed particles after going through a given distance x

$$N = N_0 \mathrm{e}^{-x/\lambda}. \tag{8.22}$$

From Eq. (8.22) we can calculate the value of λ in it. We can rewrite Eq. (8.22) as

$$N = N_0 \mathrm{e}^{-x/\lambda} = N_0 \mathrm{e}^{-ut/\lambda} = N_0 \mathrm{e}^{-t/\tau}, \tag{8.23}$$

where $\tau = \lambda / u$ is the mean life-time of the moving particle, u is the speed of the particle and it can be calculated from measuring the momentum p of the particle.

According to the time-dilation (5.35) of Standard Space-time Theory, we obtain

$$\tau = \frac{\lambda}{u} = k_1 \tau_0 = \frac{\tau_0}{\sqrt{(1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2)^2 - u^2 / c^2}}, \quad \frac{\lambda}{\tau_0} = \frac{u}{\sqrt{(1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2)^2 - u^2 / c^2}}. \tag{8.24}$$

Substituting Eq. (5.56), i.e.

$$\boldsymbol{P} = \frac{m_0 \boldsymbol{u}}{\sqrt{(1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2)^2 - u^2 / c^2}}$$

into Eq. (8.24), we get

$$\lambda / \tau_0 = P / m_0. \tag{8.25}$$

Considering that according to the time delay effect of the special theory of relativity, let $\gamma_u = \left(1 - u^2 / c^2\right)^{-1/2}$, we should have

$$\tau = \frac{\lambda}{u} = \gamma_u \tau_0 = \frac{\tau_0}{\sqrt{1 - u^2 / c^2}}, \quad \frac{\lambda}{\tau_0} = \frac{u}{\sqrt{1 - u^2 / c^2}}. \tag{8.26}$$

Substituting the equations

$$\boldsymbol{P}=\frac{m_0\boldsymbol{u}}{\sqrt{1-u^2/c^2}}\ ,\quad E=mc^2=\frac{m_0c^2}{\sqrt{1-u^2/c^2}}$$

into Eq. (8.25), we also get the same formula

$$\lambda/\tau_0=P/m_0\,. \tag{8.27}$$

For μ mesons produced in the cosmic rays the experiments measure its proper life-time to be $\tau_0=2.2\times10^{-6}$ sec. If the flying μ mesons exist only for $\tau_0=2.2\times10^{-6}$ sec. with respect to the Earth, even they fly with the speed of light, the mean distance of their flying is only $c\tau_0=660$ m, so one should not expect that μ mesons produced in atmosphere of the height 10—20 km can reach the sea surface. But practically experiments measured that a great part of μ mesons reached the sea surface. The mass of μ meson is 207 times of the mass of electron ($m_u c^2=105.66$ Mev). The μ meson reached the sea surface has momentum of about 3×10^{-9} ev/c.

According to the time-dilation effect of the special theory of relativity, we can calculate from the above data and obtain

$$\gamma_u=(1-u^2/c^2)^{-1/2}\approx 28\ ,\quad u\approx 0.9994c\,.$$

The mean life-time of μ mesons flying with respect to the reference frame of the Earth is $\tau=\gamma_u\tau_0\approx\ 28\times2.2\times10^{-6}$ sec. The mean distance of their flying with respect to the Earth before decay is 18.5 km, so they have very large probability to reach the sea surface.

According to the time-dilation (5.24) of Standard Space-time Theory, we can yield

$$k_1=\left[(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2-u^2/c^2\right]^{-1/2}\approx 28\,.$$

Taking the speed of the absolute motion of the Earth $v\approx 390$ km/s, and considering the two extreme cases, i.e., $\boldsymbol{u}$ is parallel or anti-parallel to $\boldsymbol{v}$, we can calculate from the above equation and obtain

$$u\approx 0.9981c\sim 1.0006c\,.$$

The mean life-time of μ mesons flying with respect to the reference frame of the Earth is $\tau=k\tau_0\approx\ 28\times2.2\times10^{-6}$ sec. The mean distance of their flying with respect to the Earth before decay is also 18.5 km, so they have very large probability to reach the sea surface.

We have expounded that there are the great conceptive differences between the Lorge-Lorentz time dilation of Standard Space-time Theory and the time dilation of the special theory of relativity. For example, according to Standard Space-time Theory, an observer in the standard frame or in the ordinary frames which have smaller absolute motion speed can observe the time dilation effect of the motion process of the material system at rest relative to an inertial frame which have the absolute motion speed larger than that of the former frame; an observer in an ordinary frame, owing to the time dilation of its clock, will observe the time shortening effect of a motion process of the material system at rest relative to the standard frame or the ordinary frames which haves the absolute speed smaller than that of the former frame. It is affirmable that the speed of the absolute motion of the flying μ mesons is larger than that of the Earth. So only the observer in the Earth frame can observe the time dilation effect of flying μ mesons. This just is the fact attested by experiments on life-time dilation of flying mesons. It is predictable that an observer in the reference frame of flying μ meson should observe the time shortening effect of a motion process of mater at rest relative to the Earth.

8. 4. Dynamics Experiments

In this section we mainly discuss: (1) experiment of the mass of a moving particle; (2) experimental examinations of the mass-energy relation; (3) Experiments on isotropy of inertial mass.

8. 4. 1. Experiment of the Mass of a Moving Particle

According to the expressions for mass and momentum of a moving particle in the special theory of relativity we can obtain the quantity

$$H = m^{-1}\sqrt{m_0^2 + p^2 / c^2} = 1, \tag{8.28}$$

which has nothing to do with the magnitude and direction of the velocity of the moving particle. To two particles 1 and 2 with equal rest mass m_0 and equal magnitude of velocity $\boldsymbol{u}$ but opposite in direction we can get

$$\Delta m / m_0 = (m_2 - m_1) / m_0 = 0, \tag{8.29}$$

$$\Delta H = H_2 - H_1 = 0\,. \tag{8.30}$$

From the expressions for mass and momentum of a moving particle in Standard Space-time Theory (consider only subluminal particles) we can get the quantity

$$H = m^{-1}\sqrt{m_0 + p^2 / c^2} = 1 - \boldsymbol{u}\cdot \boldsymbol{v} / c^2, \tag{8.31}$$

which is related to the value and direction of the velocity of the particle. To two particles 1 and 2 with equal rest mass m_0 and equal magnitude of velocity $\boldsymbol{u}$ but opposite in direction we can get

$$\begin{aligned}\Delta m / m_0 &= (m_2 - m_1) / m_0 \\ &= [(1 - \boldsymbol{u}\cdot \boldsymbol{v} / c^2)^2 - u^2 / c^2]^{-1/2} - [(1 + \boldsymbol{u}\cdot \boldsymbol{v} / c^2)^2 - u^2 / c^2]^{-1/2} \\ &\approx [2 + 3(u / c)^2]\boldsymbol{u}\cdot \boldsymbol{v} / c^2,\end{aligned} \tag{8.32}$$

$$\Delta H = H_2 - H_1 = 2\boldsymbol{u}\cdot\boldsymbol{v}/c^2 . \tag{8.33}$$

The expressions for mass and momentum of a moving particle in the two theories are different. Differences between Eq. (8.28) and (8.31), and (8.29) and (8.32), and (8.30) and (8.33) are more obvious. Hence, if the precision is high enough, the experimental measurements to the mass and momentum of a moving particle can measure the earth's speed of absolute motion.

Next let's discuss some experiments done in this field.

M.M. Rogers and others (1940) [6] measured the dependence relation of the mass of the electron to its velocity. The comparison between the experiment and theory is listed in the following table:

Velocity of electron	m/m_0 measured value	m/m_0 theoretical value of STR	m/m_0 theoretical value of SST
0.6337c	1.298	1.293	1.291-1.295
0.6961c	1.404	1.393	1.390-1.395
0.7496c	1.507	1.511	1.507-1.514

The last column of the table provides the theoretical value of Standard Space-time Theory according to two cases that $\boldsymbol{u}$ is parallel or anti-parallel with the earth's absolute velocity $\boldsymbol{v}$ (taken as 400 km/sec), values in other cases are between the above two values. Rogers' precision of *m/e* measurement is 1.0%, and the experimental error is greater than the difference of the two theoretical values. Hence, it can be said that the experimental results are consistent with the calculated values of the two theories within the experimental error range.

V. Meyer et al. (1963) [7] did their experimental research on the relation between the mass and momentum of electrons with velocity ranging from 0.987c to 0.990c by the comparison of electron and proton, in which the momentum of the electron is determined by the magnetic deflection method. The experimental results were given in terms of the average value (notice!) of $Y = H^{-1}$: Y = 1.00037 ± 0.00036 with the precision 0.04%, which is conform to the theoretical value $Y = H^{-1} = 1$ in the special theory of relativity. According to formula (5.28) of Standard Space-time Theory, we obtain then the following table:

Velocity of electron	$Y = H^{-1} = (1 - \boldsymbol{u}\cdot\boldsymbol{v}/c^2)^{-1}$
0.987c	0.998686 –1.001318
0.990c	0.998682 –1.001322

In which the calculated values are given in the same way as above, i.e., according to the two cases in which $\boldsymbol{u}$ is parallel or anti-parallel to the earth's absolute velocity $\boldsymbol{v}$ (also taken as 400 km/sec), values in other cases are between the two values. Therefore, Meyer experimental result is not contrary to Standard Space-time Theory. If we can further improve Meyer experiment, for example, rotate the whole device by 180^o while not destroy other conditions, and do this experiment again carefully, it is possible to judge whether the value of H is related to the magnitude and direction of the velocity of the particle.

8. 4. 2. Experimental Examinations to the Mass-energy Relation

The experimental examinations to the mass-energy relation are not made directly in general but are realized by measuring the change of energy ΔE and that of mass Δm in transformation process between mass and energy. It has been stated that no matter to which one, form or content, the formula

$$\Delta E = c^2 \Delta m$$

holds true to Standard Space-time Theory as well as to the special theory of relativity. A great deal of experiments on nuclear reactions (including fission and fusion reactions) and annihilation or production of positron-electron pair has proved the validity of this formula with high precision.

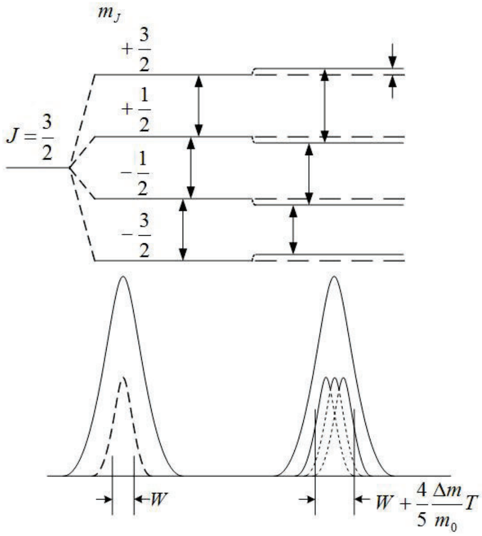
However, the mass-energy relation $E = mc^2 - \boldsymbol{p} \cdot \boldsymbol{v}$ in Standard Space-time Theory is obviously not all the same as the one $E = mc^2$ in the special theory of relativity.

8. 4. 3. Experiments on Isotropy of Inertial Mass

As we know, the special theory of relativity considers that inertial mass of a particle is isotropic in space. But Mach's principle put forward the problem of anisotropy in space of inertial mass. Mach considers that the inertial force on a body is caused by its accelerative motion of the body relative to distant stars and all the mass distribution in the whole universe. It practically is the gravitational interaction of all the mass distribution in the universe on the body. Hence the inertial mass of a body is determined by all the mass distribution in the universe. According to the property of the gravity, a huge mass distribution in the neighborhood of a body will bring definite influence upon the inertial mass of this body. The Galaxy is a flat system of stars, and the Sun is not in the center of the Galaxy, the distance from which is about 8.5kpc. So, Mach's principle considers that when a particle moves with acceleration to or from the center of the Galaxy, its inertial mass should manifest a small difference. This is the anisotropy of the inertial mass.

V. W. Hughs and et al. and R. W. P. Drever and et al. made the experiments on anisotropy of inertial mass.

V. W. Hughs and et al.[8] observed the resonance absorption of photon by nucleus ^{7}Li in magnetic field of 0.47 T. As shown in Fig. 8.5, the spin of the ground state ^{7}Li is $3/2$, so in an external magnetic field it splits as four energy levels. If the law of the nuclear physics is unchanged in rotation, then the intervals between them should be the same. In this case, the



Isotropy of the inertial mass Anisotropy of the inertial mass

Fig. 8.5

three transitions between contiguous states have the same changes of energy. The absorption factor of photons should appear the single peak value at this energy. But if the inertial mass is anisotropic, then the four magnetic sub-states are not strictly possessed of the same intervals, so there appear not one but three different resonance lines which are near very much. V. W. Hughs and et al. observed over a 12-hour period, and have not discovered line split which width greater 5.3×10^{-21} MeV to be appeared. The magnetic field and ^{7}Li are at rest relative to the earth, and over this 12-hour period the north-south direction of the earth with the magnetic field and ^{7}Li at 22^0degrees toward the center of our galaxy changes as 104^0 degrees toward the center of our galaxy because of the rotation of the earth. If we regard nucleus ^{7}Li as that in which a single proton of angular momentum $3/2$ is combined with the other nucleuses by a central potential, the anisotropy of inertial mass of proton Δm should be

$$\Delta\left(\frac{p^2}{2m_0}\right)\simeq\frac{\Delta m}{m_0}\left(\frac{p^2}{2m_0}\right)\leq 5.3\times10^{-21}\text{Mev},$$

where $p^2/2m_0$ is the kinetic energy of the proton. From $p^2/2m_0>1/2\text{Mev}$ we can infer that the anisotropy of inertial mass should satisfy the following inequality

$$(\Delta m)/m_0<5\times10^{-20}. \tag{8.34}$$

R. W. P. Drever and et al.[9] made the similar experiments and the gained result is

$$(\Delta m)/m_0<5\times10^{-23}. \tag{8.35}$$

Notice Mach said anisotropy of inertial mass in allusion to the rest mass of a particle. In Standard Space-time Theory, as well as the special theory of relativity, for the same subluminal particle, its rest masses m_{0i} measured in any frame Σ_i are the same, and are equal just the rest mass m_0 measured in Σ_a. It is naturally isotropic in space. This is diametrically opposed to Mach's viewpoint, and there is not the problem of anisotropy in space of rest inertial mass.

8. 5. Problem about Space Isotropy or Anisotropy

As to the problem about space isotropy or anisotropy of inertial mass of a moving body or general physical quantities in an ordinal reference frame, we can make detailed statement.

The special theory of relativity and Standard Space-time Theory both demand that the conservation law of momentum hold true in any inertial reference frame according to the assumption of uniformity of space-time, starting from this, obtain the expressions of mass increase effect of a moving body or particle with its speed, respectively

$$m_\mathrm{r} = \frac{m_{0\mathrm{r}}}{\sqrt{1-u_\mathrm{r}^2/c^2}}, \tag{8.36a}$$

$$m = \frac{m_0}{\sqrt{\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)^2 - u^2/c^2}}, \tag{8.36b}$$

where letters subjoined subscript r denote relativistic quantity and letters not subjoined subscript represent the quantities in Standard Space-time Theory. Noticing that according the special theory of relativity and Standard Space-time Theory, to the same body or particle, its rest masses measured in any frame are the same, and are equal just the rest mass m_0, and

$$m_0 = m_{0\mathrm{r}}. \tag{8.37}$$

Experiments related to space isotropy or anisotropy of inertial mass of a moving body cannot make judgment on the two theories. Why?

By the difference in time coordinates introduced from the different synchronization methods of clocks at different places in the two theories we obtain the relations of the space-time coordinates in the two theories

$$\left.\begin{array}{l} x_\mathrm{a} = x_\mathrm{r},\ y_\mathrm{a} = y_\mathrm{r},\ z_\mathrm{a} = z_\mathrm{r},\ t_\mathrm{a} = t_\mathrm{r};\ v = v_\mathrm{r}, \\ x = x_\mathrm{r},\ y = y_\mathrm{r},\ z = z_\mathrm{r},\ t = t_\mathrm{r} + (v/c^2)x_\mathrm{r}, \end{array}\right\} \tag{8.38}$$

or

$$\left.\begin{aligned} &\boldsymbol{r}_{\mathrm{a}}=\boldsymbol{r}_{\mathrm{r}},\ \ t_{\mathrm{a}}=t_{\mathrm{r}},\\ &\boldsymbol{r}=\boldsymbol{r}'_{\mathrm{r}},\ \ t=t'_{\mathrm{r}}+\boldsymbol{v}\cdot\boldsymbol{r}'_{\mathrm{r}}/c^2.\end{aligned}\right\} \tag{8.39}$$

and the relations of the velocities in the two theories

$$\boldsymbol{u}_{\mathrm{r}}=\boldsymbol{u}_{\mathrm{a}},\quad \frac{1}{\sqrt{1-u_{\mathrm{r}}^2/c^2}}=\frac{1}{\sqrt{1-u_{\mathrm{a}}^2/c^2}}, \tag{8.40}$$

$$\boldsymbol{u}'_{\mathrm{r}}=\frac{\boldsymbol{u}}{1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2},\ \boldsymbol{u}=\frac{\boldsymbol{u}'_{\mathrm{r}}}{1+\boldsymbol{u}'_{\mathrm{r}}\cdot\boldsymbol{v}/c^2},\ \frac{1}{\sqrt{1-u'^2_{\mathrm{r}}/c^2}}=\frac{1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2}{\sqrt{(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2-u^2/c^2}}, \tag{8.41}$$

$$\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)\left(1+\boldsymbol{u}'_{\mathrm{r}}\cdot\boldsymbol{v}/c^2\right)=1. \tag{8.42}$$

The relations of the space-time coordinates, velocities in the two theories are essentially relationship between these physical quantities in the special theory of relativity and that in Standard Space-time Theory. In popular parlance, a theory has obtained a result about certain physical quantity (such as velocity), another theory does not obtain the same result, but that gained by means of the former result to add, subtract, multiply or divide by certain quantities. Applying these relationships to predicts and analyses of experiments will offer results substitutive each other of the two theories.

Using Eq. (8.41) (to get rid of the prime of u'_{r}) and substituting them into Eq. (8.36a) or Eq. (8.36b), we obtain

$$m_{\mathrm{r}}=m\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right),\qquad m=m_{\mathrm{r}}\left(1+\boldsymbol{u}_{\mathrm{r}}\cdot\boldsymbol{v}/c^2\right). \tag{8.43}$$

That is to say, space anisotropy of inertial mass of a moving body or particle in an ordinal reference frame in Standard Space-time Theory is introduced by synchronizing clocks at different places of Standard Space-time Theory (anisotropy of the one-way speed of light). When we consider the difference in time introduced from different synchronization methods of clocks, they have practically predicted the same observational effects.

Next cite the transverse Doppler's effect for example. The special theory of relativity got

$$\left.\begin{aligned} &\nu_{\mathrm{r}}=\sqrt{1-u_{\mathrm{r}}^2/c^2}\,\nu_0,\\ &\frac{\Delta\nu_{\mathrm{r}}}{\nu_0}=\frac{\nu_{\mathrm{r}}-\nu_0}{\nu_0}=-\frac{1}{2}\left(\frac{u_{\mathrm{r}}}{c}\right)^2-\frac{1}{8}\left(\frac{u_{\mathrm{r}}}{c}\right)^4-\frac{1}{16}\left(\frac{u_{\mathrm{r}}}{c}\right)^6-\cdots.\end{aligned}\right\} \tag{8.44}$$

Standard Space-time Theory got

$$\left.\begin{aligned} &\nu=\frac{\sqrt{\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)^2-u^2/c^2}}{1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2}\nu_0,\\ &\frac{\Delta\nu}{\nu_0}=\frac{\nu-\nu_0}{\nu_0}=-\frac{1}{2}\left(\frac{u}{c}\right)^2-\left(\frac{u}{c}\right)^2\left(\frac{\boldsymbol{u}}{c}\cdot\frac{\boldsymbol{v}}{c}\right)-\frac{1}{8}\left(\frac{u}{c}\right)^4-\cdots.\end{aligned}\right\} \tag{8.45}$$

The differences between the formulas of the special theory of relativity and the corresponding that of Standard Space-time Theory are less than $(\boldsymbol{u}\cdot\boldsymbol{v})(u^2/c^4)$. This difference is so infinitely small that exceed out of the limits of precision of the present experiments. Not only that, speed u_{r} in formulas (8.44) and speed u in formulas (8.45) are measured respectively according to the different synchronization method of clocks at different places in the two theories. If one obtains the experimental results accord with the predictions (8.44) of the special theory of relativity by synchronizing clocks at different places according to the method in the special theory of relativity (isotropy of light speed), then, in virtue of (8.41), substituting it into (8.44) we obtain (8.45). That is to say, in Standard Space-time Theory apprehension, space anisotropy has been obliterated by synchronization method of clocks of the special theory of relativity; if one synchronizes clocks at different places according to the method in Standard Space-time Theory (anisotropy of light speed), the experimental results accord with the predictions (8.44) of the special theory of relativity is commensurate to or equivalent to the results accord with the predictions (8.45) of Standard Space-time Theory, and vice versa. Whether experimental results have manifested a slight anisotropy of space or not, is dependent on whether the synchronizing clocks at different places introduces the anisotropy of space or not. At this sense, the two theories have predicted the same observational effects.

To sum up, to experiments relating to space isotropy or anisotropy such as the mass of moving body or particle and the Doppler frequency shift of moving light source, one obtain the experimental results accord with the prediction (space isotropy) of the special theory of relativity by synchronizing clocks at different places according to the method in the special theory of relativity (isotropy of light speed), this is commensurate to or equivalent to that one obtain the results accord with the predictions (space anisotropy) of Standard Space-time Theory by synchronizing clocks at different places according to the method in Standard Space-time Theory (anisotropy of light speed), and vice versa. Whether experimental results have manifested a slight anisotropy of space is dependent on whether the synchronizing of clocks at different places introduces the anisotropy of space or not. At this sense, the two theories have predicted the same observational effects.

8. 6. Electromagnetism Experiments in Moving Material

In this section we discuss: (1) Trouton-Noble's experiment; (2) Fizeau's experiment; (3) Zeeman's experiment; (4) Wilson-Wilson experiments.

8. 6. 1 Trouton-Noble's Experiment

Let us consider two equal and opposite point electric charges $+q$ and $-q$ connected by a rigid rod of length l which is at rest relative to the reference frame of the Earth, as shown Fig.8.6. For the earth's rotation on its axis and revolution around the sun and the motion of the sun, the reference frame of the Earth Σ cannot be the absolute reference frame. Suppose the Earth frame Σ moves with velocity $\boldsymbol{v}$ relative to the absolute frame Σ_a. The x axis of the coordinate system $Oxyz$ of the frame Σ is taken along the direction of $\boldsymbol{v}$, and $-q$ is located at the origin O, and $+q$ is placed at point P in the plane Oxy. The observer in the frame Σ observe that this pair of point charges is rest, between them there exist only mutually attractive Coulomb's force, which is in the direction of the beeline joining the two charges. But, the observer in the frame Σ_a observe that this pair of point charges is in motion, between them besides the electric force there exist also magnetic action, which produce a couple to this system of charges. According to Newton's mechanics, the action of the couple will cause the beeline joining the two charges to turn to the direction perpendicular to $\boldsymbol{v}$. All lines except $z(z_a)$ axis in Fig.10 are in the plane $Oxyz$, but the magnetic fields $\boldsymbol{B}$ at points O and P produced by another moving point charge are perpendicular to the plane $Oxyz$.

In 1903 F. T. Trouton and H. R. Noble [10] carried out an experiment of this type. They substituted the pair of point charges by a charged parallel-plate capacitor which suspended by a phosphor bronze strip, such that the plates of the capacitor were in the vertical plane. They observed carefully the rotation effect of the capacitor, but the experiment failed to give any indication of such a couple.

Many researchers consider that the zero result of Trouton-Noble's experiment has shown that there exists no absolute inertial frame, and the principle of relativity holds true to the electromagnetic phenomena. Practically, this judgment radically does not catch hold of the key to the problem, and it is completely untenable.

First, as the special theory of relativity has faced the zero result of Trouton-Noble's experiment, the inference fallen into theoretical puzzledom is the same. According to the special theory of relativity, when a pair of charges $\pm q$ is at rest with respect to a inertial frame Σ, the observer in the frame Σ observe that between this pair of point charges there exist only mutually attractive Coulomb's force; but this pair of charges necessarily move relative to another inertial frame Σ' (it needn't be regarded as the absolute inertial frame), the observer in the frame Σ' observe that between this pair of charges there exist necessarily also action of magnetic force couple besides the electric force action. Hence the inference seems that in the frame Σ there exist no magnetic force couple and this pair of charges does not rotate; in another inertial frame Σ' there exist magnetic force couple and the effect of its rotation should be observed. So, to the special theory of relativity, whether one has observed the rotation effect or not, it seems to make up of a paradox. Second, of course, the special theory of relativity explained finally why have not the experiments observed the rotation effect, and consequently overcome the theoretical difficulty.

Standard Space-time Theory can perfectly explain the zero result of Trouton-Noble's experiment.

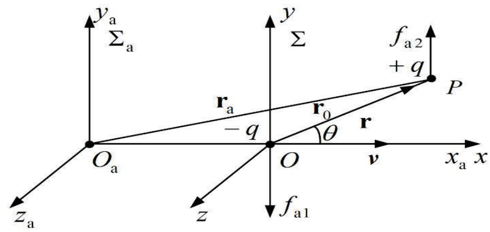


Fig. 8.6

According to the electrodynamics of Standard Space-time Theory, a pair of charges $\pm q$ is at rest with respect to the Earth reference frame Σ, then the Coulomb's law is suitable. One observes in the frame Σ that there exist the Coulomb's forces attracting mutually between the two charges. Let $\boldsymbol{r} = \boldsymbol{op}$, then $\boldsymbol{f}_1$ exerted on $-q$ and $\boldsymbol{f}_2$ exerted on $+q$ can represent respectively as follows

$$\boldsymbol{f}_1 = \frac{q^2 \boldsymbol{r}}{4\pi\varepsilon_0 r^3}, \quad \boldsymbol{f}_2 = -\frac{q^2 \boldsymbol{r}}{4\pi\varepsilon_0 r^3}. \tag{8.46}$$

With respect to the frame Σ_a, $\pm q$ move at the velocity $\boldsymbol{v}$, so besides the electric force, according to Eq. (7.79), $+q$ produce magnetic field at the place of $-q$

$$\boldsymbol{B}_{a2} = \frac{\mu_0 q(1-\beta^2)\, \boldsymbol{v}\times\boldsymbol{r}_0}{4\pi r_0^3 (1-\beta^2 \sin^2\theta)^{3/2}}, \tag{8.47}$$

which is perpendicular to the plane oxy and directs the negative z axis, where

$$\boldsymbol{r}_0 = \boldsymbol{r}_a - \boldsymbol{v}t_a = (\boldsymbol{op})_a .$$

It represents the radius vector from $-q$ to $+q$ measured in the frame Σ_a, and θ represents the angle between the directions of $\boldsymbol{r}_0$ and $\boldsymbol{v}$. So according to the Lorentz force formula, the force exerted on $-q$ by the magnetic field $\boldsymbol{B}_{a2}$

$$\boldsymbol{f}_{a1} = -q\boldsymbol{v}\times\boldsymbol{B}_{a2} = -\frac{\mu_0 q^2 (1-\beta^2)\boldsymbol{v}\times(\boldsymbol{v}\times\boldsymbol{r}_0)}{4\pi(1-\beta^2\sin^2\theta)^{3/2}}, \tag{8.48}$$

which directs to the $-y$ axis. The same, we can also obtain the magnetic field $\boldsymbol{B}_{a1}$ produced by $-q$ at the place of $+q$, and $\boldsymbol{B}_{a1}$ and $\boldsymbol{B}_{a2}$ are equal in magnitude and the same in direction, the force exerted on $+q$ by this magnetic field

$$\boldsymbol{f}_{a2} = q\boldsymbol{v}\times\boldsymbol{B}_{a1} = -\frac{\mu_0 q^2 (1-\beta^2)\boldsymbol{v}\times(\boldsymbol{v}\times\boldsymbol{r}_0)}{4\pi r_0^3 (1-\beta^2\sin^2\theta)^{3/2}}, \tag{8.49}$$

which directs to the $+y$ axis. These two magnetic forces $\boldsymbol{f}_{a1}$ and $\boldsymbol{f}_{a2}$ produce a torque of the couple

$$M=\frac{v^2q^2(1-\beta^2)\sin\theta\cos\theta}{4\pi\varepsilon_0c^2(1-\beta^2\sin^2\theta)^{3/2}r_0}\approx\frac{1}{4\pi\varepsilon_0}\frac{v^2}{c^2}\frac{q^2}{r_0}\sin\theta\cos\theta. \tag{8.50}$$

According to the dynamics of Standard Space-time Theory, we can know from Eq. (5.58) that the direction of the force exerted on a particle is different from the direction of the acceleration of the particle. But obviously whether the system rotates or not, is only dependent on the direction of the acceleration of the particle after force action. It can be proved that with respect to the frame Σ_a the acceleration of every one of the two charges after force actions of the electromagnetic field produced by another moving charge is still along the beeline connecting them.

In fact, in the frame Σ, the mass of the charged particle is denoted by $m=m_0$, then the accelerations $\boldsymbol{a}_1$ of $-q$ and $\boldsymbol{a}_2$ of $+q$ are respectively

$$\boldsymbol{a}_1=\frac{\boldsymbol{f}_1}{m_0}=\frac{q^2\boldsymbol{r}}{4\pi\varepsilon_0m_0r^3},\quad \boldsymbol{a}_2=\frac{\boldsymbol{f}_1}{m_0}=-\frac{q^2\boldsymbol{r}}{4\pi\varepsilon_0m_0r^3}. \tag{8.51}$$

Using the previous formulas (6.40), (6.47), (5.50) and (7.74) of Standard Space-time Theory, i.e.

$$\boldsymbol{r}_a=\hat{T}^{-1}\boldsymbol{r}+\gamma t\boldsymbol{v}=\hat{T}^{-1}\boldsymbol{r}+t_a\boldsymbol{v},$$
$$\hat{T}^{-1}\boldsymbol{r}=\boldsymbol{r}_a-t_a\boldsymbol{v}=\boldsymbol{r}_0=(\boldsymbol{op})_a,$$
$$m_a=\gamma m_0,$$
$$r^3=\gamma^3r_0^3(1-\beta^2\sin^2\theta)^{3/2},$$

we can easily obtain that observing in the frame Σ_a the accelerations $\boldsymbol{a}_{a1}$ of $-q$ and $\boldsymbol{a}_{a2}$ of $+q$ are respectively

$$\boldsymbol{a}_{a1}=-\boldsymbol{a}_{a2}=\gamma^{-2}\hat{T}^{-1}\boldsymbol{a}_1=\frac{\gamma^{-2}q^2\hat{T}^{-1}\boldsymbol{r}}{4\pi\varepsilon_0m_0r^3}=\frac{q^2(1-\beta^2)\boldsymbol{r}_0}{4\pi\varepsilon_0m_ar^3(1-\beta^2\sin^2\theta)^{3/2}}. \tag{8.52}$$

These have shown that observing in the frame Σ_a the accelerations of the two charges are still along the beeline joining them so this system of charges is unable to rotate.

8. 6. 2. Fizeau's Experiment

As early as 1851 Fizeau carried out an experiment on the velocity of light in a moving medium. Fizeau's experimental arrangement is illustrated in Fig.8.7. Monochromatic light ray from a slit source of light L is divided by a weakly silver-coated glass plate P, which is placed at an angle of 45^0 to the direction of propagation, into two beams, a reflected beam 1 and a transmitted beam 2. The two light beams enter into a water tube. When the water flows in the direction shown in Fig. 8.7, the beam 1 always goes in the direction of water flow, while beam 2 always travels in a direction opposite to the direction of water flow. The two beams finally enter into the telescope T and combine to produce interference fringes.

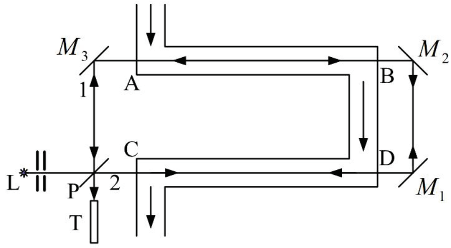


Fig. 8.7

As we know, the Fresnel's theory of the partly dragged ether and the Lorentz ether theory both completely explained the result of the Fizeau's experiment. Can Standard Space-time Theory based the principle of the absolute reference frame explain this result? The answer is affirmative. Consider that the frame Σ, which is at rest relative to the moving medium, moves with a uniform velocity $\boldsymbol{v}$ relative the frame Σ_a along the positive direction of the common x axis. We discuss propagation of the monochromatic plane electromagnetic wave along the common x axis. In this case the electrodynamics of Standard Space-time Theory has obtained that the speed of light relative to the frame Σ in the direction of flow of the water and that in the direction opposite to the direction of flow of the water are expressed by Eqs. (7.223) and (7.224), i.e.

$$u = \frac{c/n}{1 \pm v/(nc)}, \tag{8.53}$$

where v is the speed of the moving medium relative to the absolute reference frame Σ_a. Neglecting terms of the order $\geq v^2/c^2$, we obtain approximate expression

$$u = \frac{c}{n} \mp \frac{1}{n^2} v. \tag{8.54}$$

By virtue of the velocity transformations (5.11), neglecting terms of the order of v^2/c^2, we obtain the speed of light in the moving medium relative to the absolute reference frame Σ_a

$$u_a = \frac{c}{n} \pm f v, \quad f = 1 - \frac{1}{n^2}. \tag{8.55}$$

The above two equations are completely identical with Fresnel's formulas. It is easily to confirm that using Eqs. (8.53)—(8.55) we can completely explained the result of the Fizeau experiment.

8. 6. 3. Zeeman's Experiment

As the dispersion effect cannot be neglected, the Fresnel's theory of the partly dragged ether has fallen across the difficulties. Since the refractive index n of a dispersive medium is a function of the frequency ν of the light used, the dragging coefficient $f=\left(1-1/n^2\right)$ had to vary depending on the color or frequency ν of the light used. Then there must be a sort of independent ether relative to the light of every frequency. White light is composed of light of all frequencies which vary continuously, so one had to suppose that there are infinite sorts of ether. Of course, here one postulates to not prepare to put forward another conception of ether which has different dragging coefficients for the different frequencies of the light.

In 1892—1895 starting from his electron theory H. A. Lorentz deduced the velocity of light in a moving transparent medium relative to the absolute inertial frame Σ_a

$$\boldsymbol{u}_a=\frac{c}{n}\boldsymbol{n}+f_1\boldsymbol{v}, \qquad f_1=1-\frac{1}{n^2}+\frac{\nu}{n}\frac{dn}{d\nu}. \tag{8.56}$$

When the direction $\boldsymbol{n}$ of the light propagation is along (or opposite to) the direction of the velocity $\boldsymbol{v}$ of the moving medium, the above equation can be written as

$$u_a=\frac{c}{n}\pm f_1 v. \tag{8.57}$$

By and large, the Lorentz's formulas (8. 56) and (8.57) are the same with Fresnel's formulas, the only difference is the substitution of the Lorentz's coefficient f_1 for Fresnel's coefficient f as compared with which f_1 has added the last dispersive term which is a small correction term.

In 1914—1922 Zeeman carried out accurate experiments on the velocity of light in a moving water and a moving quartz rods, and showed that the inclusion of a dispersive term was necessary.

Here we introduce only Zeeman's experiment on moving water. The relative values of the experimental results and theoretical calculations are given in the below two tables. In the first table Δ_{ob} is the fringe shift observed by experiment, Δ_f and Δ_{f_1} are the values calculated respectively according to the Fresnel's formula (55) and the Lorentz's formula (8.56). Using the data in the first table one obtained dragging coefficients shown in the second table.

Table: The results of Zeeman's experiment

Wavelength (A)	Δ_{ob}	Δ_{f_1}	Δ_f
4500	0.826±0. 007	0.825	0.786
4580	0. 808±0. 005	0.808	0.771
5461	0. 656±0. 005	0.660	0.637
6870	0. 511±0. 007	0.513	0.500

Table: The dragging coefficients gained from the results of Zeeman's experiment

Wavelength (A)	f_{ob}	f_1	f
4500	0.465	0.464	0.443
4580	0.463	0.463	0.442
5461	0.451	0.454	0.439
6870	0.445	0.447	0.435

How does Standard Space-time Theory explain the Zeeman's experiment?

In Eqs. (8.53) —(8.55), n is the refractive index of water appropriate to the frequency ν' of the light measured in the frame Σ which is at rest relative to the moving water. But the problem is that owing to Doppler's effect, to the same monochromatic light, the frequency ν' of the light measured in the frame Σ is not equal to the frequency ν measured in the laboratory reference frame. Hence in these equations one should substitute n with n', where n is the refractive index of water to the frequency ν of light, and n' is the refractive index of water to the frequency ν' of light.

According to the same consideration as that of the derivation of equation (8.15), by virtue of Eq. (8.53) of the speed of light in moving medium, one can find that the frequency of light in the direction along (or opposite to) the direction of the motion of the medium (water)

$$\nu' = \frac{\sqrt{(1-\boldsymbol{v}'\cdot\boldsymbol{v}/c^2)-v^2/c^2}}{(1-\boldsymbol{v}'\cdot\boldsymbol{v}/c^2)+nv'\cos\theta/c}\nu, \tag{8.58}$$

where $\boldsymbol{v}$ is the velocity of the moving medium relative to the frame Σ_{a}, $\boldsymbol{v}'$ is the velocity of the moving medium relative to the laboratory reference frame, $\cos\theta=\pm1$. Expanding Eq. (8.58) to term of the first order of v'/c we have

$$\nu' = (1\mp nv'/c)\nu, \quad \text{or} \quad \nu'-\nu = \mp n\nu v'/c\,.$$

The refractive index n' as a function of frequency ν' can be expanded in a Taylor expansion up to terms of order v'/c as follows

$$n' = n(\nu)+\frac{\mathrm{d}n}{\mathrm{d}\nu}(\nu'-\nu) = n(\nu)\mp n\nu\frac{v'}{c}\frac{\mathrm{d}n}{\mathrm{d}\nu} = n\left[1\mp\frac{v'}{c}\nu\frac{\mathrm{d}n}{\mathrm{d}\nu}\right].$$

The second term inside the bracket is the dispersive term which is a small correction term. Its contribution to the term $fv=(1-1/n'^2)v$ in Eq. (8.55), which is itself very much smaller than c/n', can be neglected. From Eq. (8.55) we get that the speed of light in the direction along (or opposite to) the direction of the motion of the medium (water) relative to the absolute reference frame Σ_{a}

$$u_{\text{a}} = \frac{c}{n'}\pm v(1-\frac{1}{n'^2}) = \frac{c}{n\left[1\mp\frac{v'}{c}\nu\frac{\mathrm{d}n}{\mathrm{d}\nu}\right]}\pm v(1-\frac{1}{n^2})\,.$$

Only reserving the terms of the first order of v'/c, and noting $v = v_e + v'$, where v_e is the velocity of the absolute motion of the earth, we get

$$u_a = \frac{c}{n} \pm f_1 v' \pm f v_e, \tag{8.59}$$

where
$$f_1 = 1 - \frac{1}{n^2} + \frac{v}{n}\frac{dn}{dv}, \qquad f = 1 - \frac{1}{n^2}. \tag{8.60}$$

Since the influence of the motion of the earth relative to the ether to experimental result takes place in the order $(v_e/c)^2$ or the order higher than $(v_e/c)^2$, the term $f v_e$ in Eq. (8.59) can be removed, so Eq. (8.59) is the same with Eq. (8.57). Hence the theoretical calculation of Standard Space-time Theory is accorded with the result of Zeeman's experiment.

8. 6. 4. The Wilson-Wilson Experiment

In 1908 Einstein and Laub suggested an experiment to test the validity of Minkowski's theory of the electrodynamics of moving medium. The experiment was carried out in a slightly modified form by Wilson and Wilson [11] in 1913.

Consider the experimental arrangement as shown in Fig. 8.8. A large parallel plate capacitor is lying with its plates parallel to the xy plane. The dielectric between the plates has a relative permittivity ε_r and a relative permeability μ_r, $\mu_r > 1$ (paramagnet) in the inertial frame in which the medium is at rest. The whole capacitor moves with uniform velocity $\boldsymbol{u}$ in the positive x direction relative to the laboratory reference frame Σ. There is a ballistic galvanometer which makes sliding contact with the outsides of the plates of the moving capacitor, by a wire which is stationary in the frame Σ. Let there be a uniform magnetic field $\boldsymbol{H}$ in Σ in the positive y direction. When the direction of the magnetic field is reversed, the galvanometer displays that a current flows. The total charges flowing can be measured by the ballistic galvanometer.

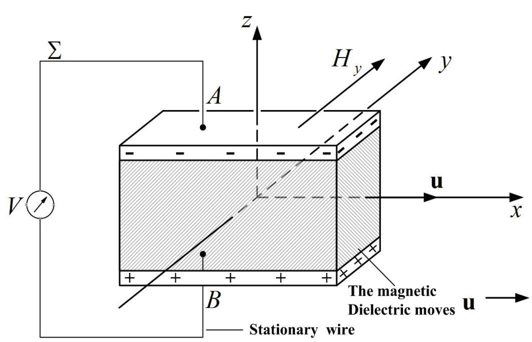


Fig. 8.8

Can Standard Space-time Theory explain the result of this experiment? The answer is also affirmative.

Suppose that the laboratory reference frame Σ moves with velocity $\boldsymbol{v}$ relative to the absolute reference frame Σ_{a}. Consider the steady state when the magnetic field $\boldsymbol{H}$ in the positive y direction remains unchanged. According to the first equation of (7.161a) in the electrodynamics of Standard Space-time Theory, in the frame Σ

$$\nabla\times\boldsymbol{E}+\frac{1}{c^2}\boldsymbol{v}\times\frac{\partial\boldsymbol{E}}{\partial t}=-\frac{\partial\boldsymbol{B}}{\partial t}.$$

The right $\partial\boldsymbol{B}/\partial t=0$, while the second term of the left can be neglected, these mean that the line integral of $\boldsymbol{E}$ around a closed loop $AVBA$ which is constituted by the stationary wire and a path in the moving medium

$$\oint\boldsymbol{E}\cdot d\boldsymbol{l}=\int_s\left(\nabla\times\boldsymbol{E}\right)\cdot\mathrm{d}\boldsymbol{s}=0.$$

Because the electric field outside the capacitor is zero, i.e., $\boldsymbol{E}_{\mathrm{out}}=0$, the above formula illuminates that the component $\boldsymbol{E}_z$ of the electric field inside the moving medium must also be zero. This is the electric field measured by an observer at rest in the frame Σ, and relative to whom the medium is moving with uniform velocity $\boldsymbol{u}$.

According to the equations (7.181) and (7.182) in the electrodynamics of Standard Space-time Theory, the constitutive equation for the moving medium of the capacitor in the frame Σ can be rewritten as

$$\boldsymbol{D}+\boldsymbol{u}\times\boldsymbol{H}/c^2=\varepsilon_0\varepsilon_{\mathrm{r}}\left(\boldsymbol{E}+\boldsymbol{u}\times\boldsymbol{B}\right)-\hat{T}^{-2}\left\{\boldsymbol{u}\times\left[\boldsymbol{v}\times\left(\boldsymbol{D}-\varepsilon_0\varepsilon_{\mathrm{r}}\boldsymbol{E}\right)/c^2\right]\right\},\quad(8.61)$$

$$\boldsymbol{B}-\boldsymbol{u}\times\boldsymbol{E}/c^2=\mu_0\mu_{\mathrm{r}}\left(\boldsymbol{H}-\boldsymbol{u}\times\boldsymbol{D}\right)-\hat{T}^{-2}\left\{\boldsymbol{u}\times\left[\boldsymbol{v}\times\left(\boldsymbol{B}-\mu_0\mu_{\mathrm{r}}\boldsymbol{H}\right)/c^2\right]\right\}.\quad(8.62)$$

Let

$$\boldsymbol{A}=\boldsymbol{A}_1=\boldsymbol{D}-\varepsilon_0\varepsilon_{\mathrm{r}}\boldsymbol{E}\quad\text{or}\quad\boldsymbol{A}=\boldsymbol{A}_2=\boldsymbol{B}-\mu_0\mu_{\mathrm{r}}\boldsymbol{H},$$

The second terms of the above equations can be calculated according to the below formula

$$\begin{aligned}\hat{T}^{-2}\left[\boldsymbol{u}\times\left(\boldsymbol{v}\times\boldsymbol{A}\right)/c^2\right]=&\gamma^{-2}\left(\boldsymbol{u}\cdot\boldsymbol{A}\right)\boldsymbol{v}/c^2-\left(\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)\boldsymbol{A}\\&+\left(\beta^2/c^2\right)\left(\boldsymbol{u}\cdot\boldsymbol{v}_0\right)\left(\boldsymbol{A}\cdot\boldsymbol{v}_0\right)\boldsymbol{v}.\end{aligned}\quad(8.63)$$

Substituting $E_z=0$ into Eq. (8.61), and noticing velocity $\boldsymbol{u}$ is along the positive x direction and $\boldsymbol{H}$ is along the positive y direction, and applying Eq. (63) and neglecting term which coefficient is β^2/c^2 in it, we have

$$D_z+uH_y/c^2=\varepsilon_0\varepsilon_{\mathrm{r}}uB_y+(\boldsymbol{u}\cdot\boldsymbol{v}/c^2)D_z,$$

or

$$(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2D_z=-(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)uH_y/c+(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)\varepsilon_0\varepsilon_{\mathrm{r}}\mu B_y.\quad(8.64)$$

Substituting $E_z=0$ into Eq. (8.62), for the y component we have

$$B_y = \mu_0\mu_r(H_y + uD_z) + (\boldsymbol{u}\cdot\boldsymbol{v}/c^2)(B_y - \mu_0\mu_r H_y),$$

or

$$(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)B_y = (1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)\mu_0\mu_r H_y + \mu_0\mu_r uD_z\,. \tag{8.65}$$

Substituting Eq. (8.65) into Eq. (8.64) we get

$$\left[(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - (u^2/c^2)\varepsilon_r\mu_r\right]D_z = (1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)(\varepsilon_r\mu_r - 1)\frac{u}{c^2}H_y.$$

From this equation we get

$$D_z = a(\varepsilon_r\mu_r - 1)(u/c^2)H_y, \tag{8.66}$$

where

$$a = \frac{1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2}{\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)^2 - \left(u^2/c^2\right)\varepsilon_r\mu_r}.$$

According to the boundary relation (7.167) in Chap.7, we take the medium of the capacitor as the second medium, in which the normal component of the electric displacement D_{2n} just is D_z in Eqs. (8.64) — (8. 66); and there is no electric charge outside the capacitor, $D_{1n} = 0$. Hence we may conclude that there must be electric surface charges of equal magnitude but opposite sign on the upper and below surfaces of the plates of the capacitor, which surface density

$$\sigma_f = \mp D_z = \mp a\left(\varepsilon_r\mu_r - 1\right)u\,H_y/c\,. \tag{8.67}$$

When the direction of the magnetic field $\boldsymbol{H}$ is reversed, then the direction of charge of the capacitor is also reversed, and the charge on the plates of the capacitor must change its own signs respectively. Then a transient current will flow through the stationary circuiting wire *AVB*. Using a ballistic galvanometer, we can measure the total charges flowing, which should be proportional to $a(\varepsilon_r\mu_r - 1)$. Because a wondrously approach 1, according to the electrodynamics of Standard Space-time Theory we have obtained nearly the same calculative result as those of the special theory of relativity.

8. 7. A Judgment Experiment of Space-time Theory ——Measurement of the One-Way Speed of Light

Is there an absolute reference frame or a standard inertial frame? The special theory of relativity and Standard Space-time Theory each take the opposite answer as the starting point of their own theories. Is the speed of light isotropic or anisotropic in a general inertial frame?

The special theory of relativity and Standard Space-time Theory give completely opposite assertions. Which theory gives a more reasonable and correct description of the laws of nature? Which theory provides a more appropriate space-time framework for understanding and describing the physical world and natural phenomena? This is undoubtedly a major issue of primary importance in natural science. Only through experiments can we finally make an accurate judgment. Empirical facts are necessarily impartial judges.

In fact, empirical facts have given a definite answer to this important question of first importance in natural science. Standard Space-time Theory, as a basic theoretical discovery of natural science, may need further experimental testing before it can be accepted by the world scientific community. One of the most critical experiments is the measurement of the one-way speed of light.

Einstein's principle of constancy of the speed of light holds that in any inertial reference frame, the speed of light in any direction in vacuum is equal to a constant c, while Standard Space-time Theory derives the speed of light in any direction in an inertial reference frame

$$c(\alpha,\beta,\gamma)=\frac{c}{1+\left(v\cos\alpha/c\right)}=\frac{c}{1+\boldsymbol{n}\cdot\boldsymbol{v}/c}, \tag{8.68}$$

where $\boldsymbol{v}$ is the velocity of motion of the general inertial frame relative to the absolute reference frame, and for the absolute reference frame itself, $\boldsymbol{v}=0$; $\boldsymbol{n}$ is the unit vector in the direction of light propagation in the inertial reference frame, and α,β,γ are the direction angles in the direction of light propagation in the inertial reference frame. This shows that the velocity of light is isotropic in the absolute reference frame, but anisotropic in the general inertial frame, which is related to the absolute velocity $\boldsymbol{v}$ and orientation $\boldsymbol{n}$ of the reference frame. According to the results of cosmic background radiation detection, the absolute speed $\boldsymbol{v}$ of the earth (or the solar system) is about 390 kilometers per second, in the direction of the equatorial coordinate system right ascension 11h ($\pm 0.5^{\mathrm{h}}$), north latitude 60 (± 10 %). According to Standard Space-time Theory, when the propagation direction $\boldsymbol{n}$ of light is the same as or opposite to the absolute motion direction $\boldsymbol{v}$ of the earth (or the solar system), there are

$$c_{+}=299400000\,ms^{-1};\qquad c_{-}=300180000\,ms^{-1}$$

The anisotropy of the speed of light has reached ± 1.3 ‰, showing the variation of the same periodic function as the rotation period and the revolution period of the earth.

I and my collaborators have proposed and described two experiments that can be carried out on the ground (that is, on high mountains) and between two mountains under the condition of existing technology. They can measure the one-way speed of light with high accuracy and clear reading, and confirm whether there is an absolute reference frame and accurately determine the speed of the absolute motion of the earth (including its value and direction). This is the most important judgment experiment tween the special theory of relativity and Standard Space-time Theory.

The experiment will be carried out high on high on the ground, that is, on a high mountain. On the peaks of the selected mountains, the land will be leveled to build an east-west experimental base about 100 meters long, including roads, laboratories, water, electricity and telecommunications supplies. Within 60 meters from east to west of the laboratory, there must be no other higher mountains blocking it. To this end, the most important issue is to raise funds for the experiment. This involves the whole social problem and is not mentioned here. After obtaining funding and successfully completing the experiment, we will report our experimental scheme and results in a timely manner.

Finding and confirming the existence of absolute reference system is the goal that people have been striving for more than three hundred years after Newton's mechanics was put forward. What is an inertial reference frame? Popularly speaking, the reference system in which Newton's law of inertia holds is called the inertial coordinate system. Newton's law of inertia states that all objects in an inertial reference system that are not subject to external forces always remain in a state of rest or uniform linear motion. Newtonian mechanics is closely linked to the existence of the inertial frame of reference. However, before the discovery of cosmic background radiation in 1965, the existence of inertial reference system had not been confirmed by experiments. Newton's opponents (such as Leibniz, Mach and others) criticized that the theoretical basis of Newton's mechanics (that is, the inertial frame hypothesis) was based on pure logical cycle. This logical flaw also remains in Einstein's special theory of relativity, without any improvement. After the discovery of the cosmic background radiation, many famous physicists clearly pointed out that the principle of relativity was violated on the cosmic scale, and the cosmic background radiation determined an isotropic absolute reference frame. Almost no physicist directly disputes this. But does the cosmic background radiation mean that there is an absolute inertial frame, which constitutes a falsification of Einstein's special theory of relativity? The mainstream school of modern physics is still in opposition, conflict, or disapproval, turning a blind eye. If the one-way light speed measurement experiment is successful and the one-way light speed anisotropy is obtained, which conforms to Eq. (8.68), it will mean that for the first time, human beings have found and confirmed the existence of Newton's absolute inertial frame through experiments on the earth's ground, and directly negated Einstein's principle of constancy of light speed and the special theory of relativity. Solve once and for all this major problem involving the foundations of physics. This is bound to cause a global sensation.

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8. 8. Conclusion

Throughout the past century a great deal of experiments has been carried out to examine the special theory of relativity. Detailed analyses show that all the experiments to test the special theory of relativity can be reinterpreted from the viewpoints of Standard Space-time Theory, and none of the experimental results contradicts Standard Space-time Theory. Here it is impossible to discuss these experiments one by one.

The special theory of relativity cannot explain several kinds of experimental facts following:

(1) The cosmic microwave background radiation;

(2) The homopolar magnetic induction experiments;

(3) The superluminal motion experiments;

(4) The distant-correlation experiments.

The above every kind of experiments has included many experiments. The cosmic background radiation has indicated that the principle of relativity has been destroyed. We will discuss in detail the homopolar magnetic induction experiments in Chap. 9 and will explicitly expounded that these experiments have shown the existence of background space and the vacuum which is not void space. The Astronomical observations and experimental discovers of superluminal motion have indicated that the special theory of relativity has violated the causality. The distant-correlation experiments examining Bell's inequalities have indicated negation of Einstein's locality principle. These experimental facts have deeply revealed internal contradictions of the special theory of relativity, and they are collided with the special theory of relativity. On the contrary, Standard Space-time Theory is founded based on these experimental facts and has given complete explanations for all of these experiments. The four kinds of experiments can regard as the judge experiments between Standard Space-time Theory and the special theory of relativity.

Time will lead humankind to approach truth and to accept truth. It can be expected that

Standard Space-time Theory will be widely accepted by people through the accumulation of more experimental facts.

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Chapter 9

Homopolar Magnetic Induction Experiments Show Existence of Background Space

Homopolar magnetic induction experiments, including Kennard's experiment and Muller's experiment, cannot be explained by the special theory of relativity. Standard Space-time Theory, based on the two basic postulates, i. e., (1) the principle of the absolute reference frame and (2) the principle of the constancy of the average circuit speed of light, has inherited Maxwell's and Lorentz's ideas, and has recognized that the infinite vacuum background fields are carrier of electromagnetic field, and the electromagnetic field are not an independent form of matter but a description of the local motion state of the vacuum background fields spread all over the space. Homopolar magnetic induction experiments have demonstrated the existence of background space. Standard Space-time Theory has explained completely all results of the homopolar magnetic induction experiments.

9. 1. Description of Experimental Phenomena

In 1832, M. Faraday made the rotating disk experiment, which has demonstrated generation of induced electromotive force. As Fig. 9.1 shows, a conducting disk is made to rotate with a constant angular frequency $\boldsymbol{\omega}$ about its central axis, and the disk is placed in a uniform magnetic field $\boldsymbol{B}$ that is perpendicular to the disk plane. $DABC$ is a wire at rest in laboratory, the two ends of which are respectively made sliding connect with the center O and the edge of the disk, and constitute a closed loop $DABCOD$. When the disk rotates, a steady continuous current will flow in the loop. M. Faraday discovered still that when the magnet which produce magnetic field and the disk rotate all together and there is no relative motion between them, the induced electromotive force (EMF) in the loop is also observable.

Faraday's disk experiment is slightly changed, i.e., the disk and wire are at rest, and the magnet producing magnetic field is made to rotate, then one will observe homopolar magnetic induction phenomena. So-called homopolar magnetic induction means the electromagnetic induction phenomena of moving magnet. As shown in Fig. 9.2, a cylindrical conductible permanent magnet rotates with a constant angular velocity about its symmetrical axis. Using sliding contacts C and D, a wire at rest relative to the laboratory is connected with the side and the central axis of the rotating magnet. When the magnet rotates, in the loop $DABCOD$ there is a steady current to flow. The equipment of this type adopted technically is called "homopolar generator".

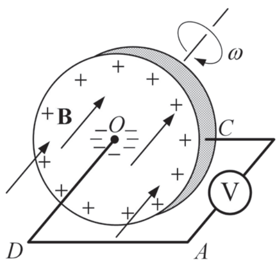

Fig.9.1

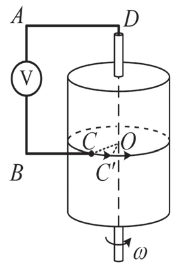

Fig.9.2

In Kennard's experiment [1] reported in 1917, the Faraday's disk is substituted by a radial wire OC and two coaxial cylinders, the latter of which forms a capacitor; the magnet is substituted by a current-carrying solenoid which produces a uniform magnetic field and coaxially ringed round the capacitor. An electrometer is always stationary, and directly connected with the coaxial capacitor by two brushes. Measuring the induced EMF between OC , E.H. Kennard obtained results as follows: (1) When the radial wire-capacitor rotate while the current-carrying solenoid is stationary, one measures to find that there is the EMF to appear; (2) When the current-carrying solenoid rotates while the radial wire-capacitor are stationary, the EMF is unable to appear; (3) When the radial wire-capacitor and the current-carrying solenoid rotate together synchronously, one measures also to find that there is the EMF to appear, which magnitude is the same with that when the radial wire-capacitor rotate alone with the same angle velocity.

Kennard's experiment has demonstrated that production of the induced EMF depends only on the motion of the radial wire-capacitor, is independent of the rotation of the current-carrying solenoid and the relative motion between the radial wire-capacitor and the solenoid.

In 1987 F. Muller made a further experiment. He not only obtained the same result with Kennard's experiment, but also could make sure of the location of the induced EMF to appear. Although I make great efforts, yet I did not find the original literature of Muller. The Muller's experiment narrated below is cited from the article of Xu Shao-Zhi [2].

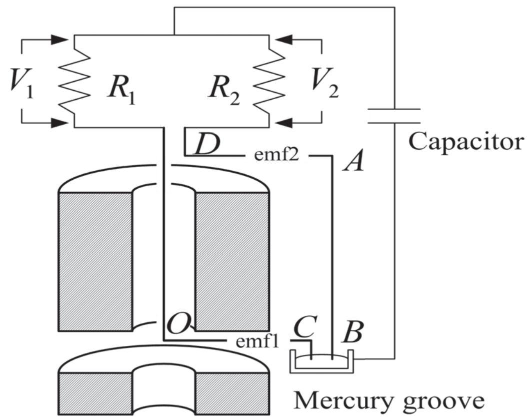

Fig. 9. 3

The Muller's experiment is shown in Fig.9.3. The Faraday's disk is substituted by a radial wire OC or DA. The wires OC and DA , and the cylindrical permanent magnet can alone or all together swing back and forth (but cannot rotate unilaterally). The experimental results are as follows (see the table below): (1) when the wire OC makes a fast (as compared with the decay time of the loop RC) swing while the wires DA remains stationary, in the two ends of the wire OC the EMF appears, which brings about that in the ends of the resistance R_1 the oscillatory voltage V_1 appears, while there is no EMF to appear in the two ends of the wire DA; (2) when the wire DA makes a fast (as compared with the decay time of the loop RC) swing while the wires OC remains stationary, in the two ends of the wire DA the EMF appears, which brings about that in the ends of the resistance R_2 the oscillatory voltage V_2 appears, while there is no EMF to appear in the two ends of the wire OC; (3) production of the induced EMF depends only on the swing of the radial wire, is independent of whether the permanent magnet swing or not, is also independent of the relative motion between the radial wire and the magnet.

Kennard's experiment and Muller's experiment have demonstrated that the magnetic field is located in an inertial space of the laboratory reference frame, and no matter whether the magnet rotates or not, if only the wire is moving perpendicularly to the direction of the magnetic field (or contains a component of the transverse motion) with respect to the inertial space of the laboratory frame, in this wire the induced electric field and the induced EMF are able to appear. No matter whether the magnet rotates or not, there is no induced EMF in thewire at rest relative to the laboratory reference frame. The induced EMF appears in the

	case of swing	location of emf
	Magnet wire OC wire DA	emf1 emf2
1	— — —	0 0
2	— — ω	0 +
3	— ω —	+ 0
4	ω — —	0 0
5	— ω ω	counteracted
6	ω — ω	0 +
7	ω ω —	+ 0
8	ω ω ω	counteracted

Note: the sign " ω " represents that there is a (angular) swing, while the sign "—" represents that there is no (angular) swing; the sign "+" represents that there is the induced EMF to be observed, while the sign "0" represents that there is no induced EMF to be observed; the "counteracted" in cases 5 and 8 mean that the induced emf1 in the wire OC and emf2 in the wire DA counteracted each other.

swinging wire OC or DA set by oneself, it is produced by the motion of the swinging OC or DA as a section of the conducting loop relative to the laboratory and the magnetic field in the space of the laboratory.

9. 2. Explanation of Classical Electromagnetism to Homopolar Magnetic Induction Experiments

The first it should be indicated that the homopolar magnetic induction phenomena do not violate the Faraday's law of induction. In homopolar generator (see Fig. 9.2), the magnetic flux through the loop $DABCOD$ remains unchanged, so if formally using the Faraday's law, then one will obtain a conclusion that EMF and induced current are unable to be produced. But, in fact, one need to consider that the radius joining the two points O and C is moving at every moment in the magnetic field. When the magnet rotated through an infinitesimal angle $\mathrm{d}\varphi$, the radius OC rotates also through the same angle, and reaches OC' and swept over an area $\mathrm{d}S = (1/2)R^2\mathrm{d}\varphi$, where R is the radius of the cylindrical magnet. Hence the induced EMF is

$$\varepsilon = \frac{\mathrm{d}\phi_{\mathrm{m}}}{\mathrm{d}t} = \frac{\mathrm{d}}{\mathrm{d}t}\int_S \boldsymbol{B}\cdot \mathrm{d}\boldsymbol{S} = B\frac{\mathrm{d}S}{\mathrm{d}t} = \frac{1}{2}B\omega R^2. \tag{9.1}$$

According to Lenz' law, when the magnetic field is perpendicular upwards and the magnet rotates rightwards (as shown Fig. 9.2), ε is point from O to C. The above operations mean that when we calculate the induced EMF by Faraday's law of induction, we need to apply it to the area closed by the same material loop, that is to say, the particles constituting a loop at the moment $t+\mathrm{d}t$ must be entirely the same with that of the loop at the moment t. A careful study of the derivation of Faraday's law can confirm that this is entirely correct understanding. Therefore, the claims that the homopolar magnetic induction phenomena violate Faraday's law of induction, or the classical electrodynamics cannot explain the homopolar magnetic induction phenomena cannot hold.

The homopolar magnetic induction phenomena can be explained directly from the Lorentz force formula. The Lorentz force is a non-electrostatic force. According to the Lorentz force formula and the definition of EMF, we obtain the non-electrostatic field $\boldsymbol{E}_{\mathrm{ne}}$ and the EMF of the whole loop as follows

$$\boldsymbol{E}_{\mathrm{ne}} = \frac{\boldsymbol{f}_{\mathrm{m}}}{q} = \boldsymbol{v}\times\boldsymbol{B}, \tag{9.2}$$

$$\begin{aligned}\varepsilon = \oint \mathrm{d}\varepsilon = \int_o^c \boldsymbol{E}_{ne}\cdot \mathrm{d}\boldsymbol{l} = \int_o^R (\boldsymbol{v}\times\boldsymbol{B})\cdot \mathrm{d}\boldsymbol{r} \\ = B\omega\int_o^R r\mathrm{d}r = (1/2)B\omega R^2.\end{aligned} \tag{9.3}$$

When the magnetic field $\boldsymbol{B}$ is perpendicular upwards and the magnet rotates rightwards, ε is point from O to C. It is now clear that the Lorentz force exerting on the charges moving along with the rotating magnet in magnetic field is the source which separates positive and negative charges and generates the induced EMF.

9. 3. The Special Theory of Relativity cannot Explain the Homopolar Magnetic Induction Experiments

In 1907 A. Einstein indicated that using the transformation of the electromagnetic quantities in two arbitrary inertial frames S and S' one can explain the homopolar magnetic induction phenomena. The transformations of the electric field intensity $\boldsymbol{E}$ and the magnetic induction intensity $\boldsymbol{B}$ and the inverse ones of the special theory of relativity can be written as follows:

$$\left.\begin{array}{ll} \boldsymbol{E}'_{\parallel} = \boldsymbol{E}_{\parallel}, & \boldsymbol{E}_{\parallel} = \boldsymbol{E}'_{\parallel}, \\ \boldsymbol{E}'_{\perp} = \gamma\left(\boldsymbol{E} + \boldsymbol{v}\times\boldsymbol{B}\right)_{\perp}, & \boldsymbol{E}_{\perp} = \gamma\left(\boldsymbol{E}' - \boldsymbol{v}\times\boldsymbol{B}'\right)_{\perp}, \end{array}\right\} \tag{9.4}$$

$$\left.\begin{array}{ll} \boldsymbol{B}'_{\parallel} = \boldsymbol{B}_{\parallel}, & \boldsymbol{B}_{\parallel} = \boldsymbol{B}'_{\parallel}, \\ \boldsymbol{B}'_{\perp} = \gamma(\boldsymbol{B} - \boldsymbol{v}\times\boldsymbol{E}/c^2)_{\perp}, & \boldsymbol{B}_{\perp} = \gamma(\boldsymbol{B}' + \boldsymbol{v}\times\boldsymbol{E}'/c^2)_{\perp}, \end{array}\right\} \tag{9.5}$$

where "parallel" or "perpendicular" is correlative with the velocity $\boldsymbol{v}$ of the inertial frame S' relative to the inertial frame S. Based on these transformations Einstein considered [3]: "This makes the question as to the seat of those electromotive forces (in unipolar machines) pointless, since the answer varies depending on the choice of the state of motion of the reference system used." (see *On the Relativity Principle and the Conclusions Drawn from it* (1907))

According to the special theory of relativity, one can give the prediction of the homopolar magnetic induction phenomena as follows (cf. [4]). As shown in Fig. 2, suppose the wire $DABC$ at rest in the laboratory is the frame S, the frame at rest relative to the magnet is the frame S'. Obviously, in the frame S' there are no nonzero distributions of static charge and no varying magnetic field, so there can be but one outcome that the electric field $\boldsymbol{E}$ equals zero and the magnetic field $\boldsymbol{B}$ is a constant vector (unvarying with time):

$$\boldsymbol{E}' = 0, \qquad \boldsymbol{B}' \neq 0. \tag{9.6}$$

According to the transformations (9.4) and (9.5) one gets

$$\boldsymbol{E} = -\gamma\boldsymbol{v}\times\boldsymbol{B}', \quad \boldsymbol{B} = \boldsymbol{B}'_{\parallel} + \gamma\boldsymbol{B}'_{\perp}. \tag{9.7}$$

In the approximation of the first order β the above two equations are rewritten as

$$\boldsymbol{E} = -\boldsymbol{v}\times\boldsymbol{B}', \qquad \boldsymbol{B} = \boldsymbol{B}', \tag{9.8}$$

where $\boldsymbol{v}$ is the velocity of a particle in the radius OC by virtue of the magnet rotation relative to the frame S. Of course, strictly speaking, the transformations (9.4) and (9.5) are suitable merely to inertial frames. But in the case of the small angle velocity, the influence of the rotation to the electromagnetic effect is negligible, so the transformations (9.4) and (9.5) can be suitable approximately the case of slow rotation. On the basis of Eq. (9.8) in the wire $DABC$ at rest in the laboratory there is an electric field

$$\boldsymbol{E} = -\boldsymbol{v}\times\boldsymbol{B}. \tag{9.9}$$

The EMF of the two ends of the wire $DABC$ is

$$\varepsilon = \int_{DABC} \boldsymbol{E}\cdot \mathrm{d}\boldsymbol{l} = -\int_{DABC} \left(\boldsymbol{v}\times\boldsymbol{B}\right)\cdot \mathrm{d}\boldsymbol{l} = \int_{DABC} \boldsymbol{B}\times\left(\boldsymbol{\omega}\times\boldsymbol{r}\right)\cdot \mathrm{d}\boldsymbol{l}. \tag{9.10}$$

It is just this EMF produce a steady current in the loop $DABCOD$. Noticing the magnetic field $\boldsymbol{B}$ outside the cylindrical magnet is not uniform, so from the right of Eq. (9.10) one cannot further integrate and obtain the final result. It is affirmable that in general cases one is unable to get the same numerical result with that of Eq. (9.3). In addition, whether EMF is generated on the radius OC is also a question to be discussed, omitted for the time being.

The difficulty of the above interpretation of the special theory of relativity lies in its prediction that the EMF emerges in the wire $DABC$ at rest in the laboratory. That completely violates the experimental facts of Kennard's experiment and Muller's experiment.

The special theory of relativity considers that all inertial reference frames are equivalent. Einstein said [5]: "Motion show always a relative motion of a body to another body (for example, that of a car to the ground, or the earth to the sun and stars). The motion is absolutely unable to be observed as 'the motion to the space', or so-called ' absolute motion'." The special theory of relativity has practically restored the natural picture in which vacuum is void space with nothingness, so it can be possible to talk and describe matter and matter motion only relative to the reference frame at rest relative to certain body or bodies' system. Then it is incomprehensible to leaves the inertial reference frame at rest relative to the magnet but to talk about that the magnetic field produced by the rotating magnet is located in another inertial space. According to the interpretation of the special theory of relativity on the homopolar magnetic induction phenomena, the inevitable results are: (1) As long as there is a relative motion between the magnet and the copper disk (or wire), whatever the magnet rotates while the wire is stationary, or the wire rotates while the magnet is stationary, the induced EMF should be produced; (2) If the magnet and the copper disk (or the wire) rotate with the same angular velocity and so both of them are relatively stationary, the induced EMF in the loop is unable to be produced.

But Kennard's experiment and Muller's experiment have shown that the magnetic field is located in an inertial space S_e of the laboratory reference frame, and no matter whether the magnet rotates or not, if only the wire is moving (suppose the velocity is $\boldsymbol{v}$) with respect to the frame S_e, in this wire the induced electric field and the induced EMF as the line integral of the induced electric field are able to appear. The appearance and magnitude of the induced electric field and the induced EMF are independent of the relative motion between the magnet and the copper disk (or the wire), or the frame S' and frame S. The information of Mother Nature revealed by Kennard's experiment and Muller's experiment is contrary to the spirit of pure relativism of the special theory of relativity.

9. 4. Explanation of Standard Space-time Theory to Homopolar Magnetic Induction Experiments

As stated previously, the magnetic field is located in an inertial space of the laboratory reference frame. How should one comprehend this sentence? What are its deep meaning and origin?

According to the Maxwell's and Lorentz's idea, the ubiquitous and continuously distributive ether is carrier of the electromagnetic fields, and the electromagnetic waves are wave processes propagating the electromagnetic turbulence in the ether. Standard Space-time Theory has developed this understanding. Standard Space-time Theory has followed the aggregated-dispersed states natural images of the material world and admitted that infinite vacuum background field is the background generating all matter processes, it constitutes the absolute inertial reference frame. The vacuum background field is carrier of the electromagnetic fields; and the electromagnetic fields are not an independent matter form, but a description of the motion state of the vacuum background field.

In general, the sources of the field produce field, and the moving and varying sources of the field produce varying field. Put aside that the periodically varying field forms the electromagnetic waves propagating with the light speed in the vacuum background field, the moving and varying field in the ambient space about the sources of the field moves along with the sources of the field with respect to the vacuum background field. Speaking in this meaning, the field is carried by the field source. If one draw field lines of force (electric field lines or magnetic field lines) according to the definitions, the lines of force drawn artificially necessarily move along with the sources of the field with respect to the vacuum background field. But obviously, magnetic field lines are only an assistant conception describing magnetic field, they are not a sort of material organization, and there exists no physical process to cut magnetic field lines. The electromagnetic fields are a description of a sort of property or motion state of the vacuum background field; the real problems are interrelation between sources of the field and electromagnetic field, and interaction between charges (or charged particles) and electromagnetic field.

Since the electromagnetic fields are a description of a sort of property or motion state of the vacuum background field excited and influenced by the sources of the field, to the steady distribution of the electromagnetic field which is produced by the source possessed of symmetry and is possessed of the same symmetry, there exists no problem that the electromagnetic field makes symmetrical motion along with the source of the field relative to the vacuum background field, just as when a cylinder of strict axial symmetry rotates about the symmetrical axis, if a little element violating the above symmetry is not added artificially and intentionally, no physical change of picture in the screen of TV is brought about and so the rotation of the cylinder is unable to be shown. The homopolar magnetic induction phenomenon is an example. A uniform cylindrical permanent magnet possesses axial symmetry, and the magnetic field produced by the magnet possesses also the steady distribution of axial symmetry relative to the magnet. Hence the rotation of the magnet about its symmetrical axis is unable to produce any influence to the distribution of the magnetic field. The magnetic field produced by the magnet makes uniform rectilinear motion along with the magnet and the earth with respect to the vacuum background field (i.e., the absolute reference frame Σ_a), but there exists no rotation about the fixed axis along with the magnet. These are the meaning and origin of the statement that the magnetic field is located in an inertial space of the laboratory reference frame.

Here it is necessary to make a supplementary explanation. Notice the microscopic organization of the magnet, i.e., the atoms and molecules constituted the magnet are not possessed of the microscopic axial symmetry. When a cylindrical magnet rotates about its symmetrical axis, speaking from microscopic scale, the microscopic field at every point inside the magnet is periodically varying with time for the periodical rotation of the microscopic organization of the magnet about a fixed axis. But now we study the macroscopic electromagnetism, the macroscopic magnetic field (as the mean value in the physically infinitesimal volume which contains a vast number of atoms and molecules) and its space distribution are not varying with time with respect to the magnet reference frame. The narration of the above paragraph is in point of the macroscopic electromagnetic field.

It is based on the above clear idea that we say that classical electromagnetism can explain the homopolar magnetic induction phenomenon. Please notice that when we wrote: "In fact, one need to consider that the radius joining the two points O and C is moving at every moment in the magnetic field", "The Lorentz force exerting on the charges moving along with the rotating magnet in magnetic field is the source which separates positive and negative charges and generates the EMF", these are based on the clear idea that the magnetic field is located in the inertial space of the laboratory reference frame.

Based on the above idea, Standard Space-time Theory as perfection and systematization of the Lorentz ether theory can perfectly explain the experimental phenomena of the homopolar magnetic induction.

The first, according to the first one of equations (7.127b),

$$\oint_L \boldsymbol{E} \cdot d\boldsymbol{l} = -\frac{\mathrm{d}}{\mathrm{d}t}\int_S \left(\boldsymbol{B} + \frac{1}{c^2}\boldsymbol{v} \times \boldsymbol{E}\right) \cdot \mathrm{d}\boldsymbol{S},$$

neglecting the small term of high order $\boldsymbol{v}\times\boldsymbol{E}/c^2$, we get

$$\int_L \boldsymbol{E}\cdot \mathrm{d}\boldsymbol{l} = -\frac{\mathrm{d}}{\mathrm{d}t}\int_S \boldsymbol{B}\cdot \mathrm{d}\boldsymbol{S}, \quad \text{or} \quad \varepsilon = -\frac{\mathrm{d}}{\mathrm{d}t}\int \boldsymbol{B}\cdot \mathrm{d}\boldsymbol{S}. \tag{9.11}$$

Applying Eq. (9.11) to the closed loop $DABCOD$ in the laboratory reference frame, according to the same with the reasoning in Sec. 9.2, we can obtain

$$\varepsilon = -\frac{1}{2}B\omega R^2, \tag{9.12}$$

where the negative sign expresses the direction of the induced EMF. So, we can explain the homopolar magnetic induction phenomena.

The second, according to the transformations of the electric field intensity $\boldsymbol{E}$ and the magnetic induction intensity $\boldsymbol{B}$ of Standard Space-time Theory (see Eq. (7.115 a))

$$\left.\begin{aligned} &\boldsymbol{E}=\gamma\left(\hat{T}^{-1}\boldsymbol{E}_{\mathrm{a}}+\boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}\right), \quad \boldsymbol{B}=\gamma\left(\hat{T}^{-1}\boldsymbol{B}_{\mathrm{a}}-\boldsymbol{v}\times E_{\mathrm{a}}/c^{2}\right), \\ &\boldsymbol{E}_{\mathrm{a}}=\gamma\left(\hat{T}^{-1}\boldsymbol{E}-\boldsymbol{v}\times\boldsymbol{B}\right), \quad \boldsymbol{B}_{\mathrm{a}}=\gamma\left(\hat{T}^{-1}\boldsymbol{B}+\boldsymbol{v}\times\boldsymbol{E}/c^{2}\right), \end{aligned}\right\} \tag{9.13}$$

we can find the electric field intensity $\boldsymbol{E}$ relative to the frame (in despite of the rotating magnet or the rotating wire) that moves with respect to the laboratory reference frame.

According to the comprehension of Standard Space-time Theory, the magnetic field is located in the inertial space of the laboratory reference frame Σ_{e}. Here we use the letter Σ_{e} to denote the laboratory reference frame in convention of Standard Space-time Theory. So, in the frame Σ_{e}, ,we have

$$\boldsymbol{E}_{\mathrm{e}}=0, \quad \boldsymbol{B}_{\mathrm{e}}\neq 0. \tag{9.14}$$

From the transformations (9.13) we find that in the absolute frame Σ_{a}

$$\left.\begin{aligned} &\boldsymbol{E}_{\mathrm{a}}=\gamma_{\mathrm{e}}\left(\hat{T}_{\mathrm{e}}^{-1}\boldsymbol{E}_{\mathrm{e}}-\boldsymbol{v}_{\mathrm{e}}\times\boldsymbol{B}_{\mathrm{e}}\right)=-\gamma_{\mathrm{e}}\boldsymbol{v}_{\mathrm{e}}\times\boldsymbol{B}_{\mathrm{e}}, \\ &\boldsymbol{B}_{\mathrm{a}}=\gamma_{\mathrm{e}}\left(\hat{T}_{\mathrm{e}}^{-1}\boldsymbol{B}_{\mathrm{e}}+\boldsymbol{v}_{\mathrm{e}}\times\boldsymbol{E}_{\mathrm{e}}/c^{2}\right)=\gamma_{\mathrm{e}}\hat{T}_{\mathrm{e}}^{-1}\boldsymbol{B}_{\mathrm{e}}, \end{aligned}\right\} \tag{9.15}$$

where
$$\gamma_{\mathrm{e}}=\left(1-\beta_{\mathrm{e}}^{2}\right)^{-1/2}, \quad \beta_{\mathrm{e}}=v_{\mathrm{e}}/c, \tag{9.16}$$

where $\boldsymbol{v}_{\mathrm{e}}$ is the velocity of the absolute motion of the earth. In the approximation of the first order $\beta_{\mathrm{e}}=v_{\mathrm{e}}/c$ the above two equations are rewritten as

$$\boldsymbol{E}_{\mathrm{a}}=-\boldsymbol{v}_{\mathrm{e}}\times\boldsymbol{B}_{\mathrm{e}}=-\boldsymbol{v}_{\mathrm{e}}\times\boldsymbol{B}_{\mathrm{a}}, \ \boldsymbol{B}_{\mathrm{a}}=\boldsymbol{B}_{\mathrm{e}}. \tag{9.17}$$

Suppose the wires OC and DA (for Kennard's experiment and Muller's experiment) or the radius OC of the conducting magnet (for homopolar magnetic induction generator) rotates with an angular velocity $\boldsymbol{\omega}$ relative to the laboratory reference frame Σ_{e}. The velocity of a point on them (use $\boldsymbol{r}$ to denote the radius vector of the point) relative to the frame Σ_{e} is $\boldsymbol{u}=\boldsymbol{\omega}\times\boldsymbol{r}$, and its velocity relative to the frame Σ_{a} is

$$\boldsymbol{v}=\boldsymbol{v}_{\mathrm{e}}+\boldsymbol{u}=\boldsymbol{v}_{\mathrm{e}}+\boldsymbol{\omega}\times\boldsymbol{r}. \tag{9.18}$$

From transformations (9.13) and (9.17) we find that in frame Σ_{r} at rest relative to the point $\boldsymbol{r}$

$$\boldsymbol{E}=\gamma\left(\hat{T}^{-1}\boldsymbol{E}_{\mathrm{a}}+\boldsymbol{v}\times\boldsymbol{B}_{\mathrm{a}}\right)=-\gamma\gamma_{\mathrm{e}}\hat{T}^{-1}\left(\boldsymbol{v}_{\mathrm{e}}\times\boldsymbol{B}_{\mathrm{e}}\right)+\gamma\gamma_{\mathrm{e}}\boldsymbol{v}\times\left(\hat{T}_{\mathrm{e}}^{-1}\boldsymbol{B}_{\mathrm{e}}\right),$$

$$\boldsymbol{B}=\gamma\left(\hat{T}^{-1}\boldsymbol{B}_{\mathrm{a}}-\boldsymbol{v}\times\boldsymbol{E}_{\mathrm{a}}/c^{2}\right)=\gamma\gamma_{\mathrm{e}}\hat{T}^{-1}\left(\hat{T}_{\mathrm{e}}^{-1}\boldsymbol{B}_{\mathrm{e}}\right)-\gamma\gamma_{\mathrm{e}}\boldsymbol{v}\times\left(\boldsymbol{v}_{\mathrm{e}}\times\boldsymbol{B}_{\mathrm{e}}\right)/c^{2},$$

where
$$\gamma=\left(1-v^{2}/c^{2}\right)^{-1/2}.$$

In the approximation of the first order of $\beta=v/c$ and $\beta_{\mathrm{e}}=v_{\mathrm{e}}/c$ we have

$$\left.\begin{aligned} &\boldsymbol{E}=-\boldsymbol{v}_{e}\times\boldsymbol{B}_{e}+\boldsymbol{v}\times\boldsymbol{B}_{\mathrm{e}}=-\boldsymbol{v}_{\mathrm{e}}\times\boldsymbol{B}_{\mathrm{e}}+\left(\boldsymbol{v}_{\mathrm{e}}+\boldsymbol{u}\right)\times\boldsymbol{B}_{\mathrm{e}}=\boldsymbol{u}\times\boldsymbol{B}_{\mathrm{e}}=\left(\boldsymbol{\omega}\times\boldsymbol{r}\right)\times\boldsymbol{B}_{\mathrm{e}}, \\ &\boldsymbol{B}=\boldsymbol{B}_{\mathrm{e}}. \end{aligned}\right. \tag{9.19}$$

From these equations we can find that in the wire (or the radius) OC or the wire DA there exists the induced EMF and

$$\varepsilon = \int_{O(D)}^{C(A)} \boldsymbol{E}\cdot \mathrm{d}\boldsymbol{r} = \int_0^R \left[(\boldsymbol{\omega}\times\boldsymbol{r})\times\boldsymbol{B}_{\mathrm{e}} \right]\cdot \mathrm{d}\boldsymbol{r}. \tag{9.20}$$

To the radius OC of the conducting magnet we can find further

$$\varepsilon = B_{\mathrm{e}}\omega\int_o^R r\mathrm{d}r = \frac{1}{2}B_{\mathrm{e}}\omega R^2, \tag{9.21}$$

where $\boldsymbol{B}_{\mathrm{e}}$ is the magnetic induction intensity measured in the laboratory reference frame, that is equated to the vector $\boldsymbol{B}$ in Eq.(9.1), ω is an angular velocity of the rotation of the wire (or the radius) OC or the wire DA about the symmetrical axis relative to the laboratory reference frame. Hence no matter whether the magnet rotates or not, if only the wire (or the radius) OC or the wire DA is rotating with respect to the laboratory reference frame, in this wire or radius the induced EMF as shown in Eq. (9.21) is able to be produced. On the contrary, even if the magnet is rotating, there will be no induced electromotive force on the wires OC or the wire DA at rest stationary relative to the laboratory $(\omega=0)$. Thus, Standard Space-time Theory has perfectly explained all the experimental phenomena of the homopolar magnetic induction, including Kennard’s experiment and Mahler’s experiment.

9. 5. Conclusion

The homopolar magnetic induction phenomena do not violate the Faraday’s law of induction. The special theory of relativity cannot explain the homopolar magnetic induction phenomena, but Standard Space-time Theory has explained completely all the experimental results of the homopolar magnetic induction experiment, including the Kennard’s experiment and Muller’s experiment. The homopolar magnetic induction phenomena have shown that the vacuum is not a void space with nothingness and have shown the existence of the background space.

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Chapter 10

The Slide-Down Paradox in the Special Theory of Relativity and Its Resolving Scheme

This chapter expounds a paradox called the slide-down paradox of the special theory of relativity and reveals the deep logical contradiction caused by the special theory of relativity which only emphasizes the relativity of motion but denies the absoluteness of motion. If the absolute reference frame is admitted, according to the Fitzgerald-Lorentz length contraction effect and the Lodge-Lorentz time dilation effect, the slide-down paradox can be eliminated. Standard Space-time Theory is based on two basic postulates, namely, (1) the principle of absolute reference frame, and (2) the principle of the constancy of the average light speed. It is a logically rigorous theoretical system, which is consistent with all current observations and experimental facts. It includes Fitzgerald-Lorentz length contraction and Lodge-Lorentz time dilation as part of its logical reasoning. There is no the slide-down paradox in Standard Space-time Theory.

10. 1. Introduction

The word “paradox” has several meanings. The this chapter will use this word in the following meaning, i.e. paradox is two contradictory propositions deduced logically from the generally accepted transparent knowledge, or involuntarily corroborated common intuitions, or a certain specific theory system (the above-mentioned is called background knowledge for short). Background knowledge, logical inference and two contradictory propositions are three elements constituted a paradox.

The slide-down paradox in the special theory of relativity described in this chapter is a logical paradox in this strict meaning.

10. 2. Slide-down Paradox in The Special Theory of Relativity

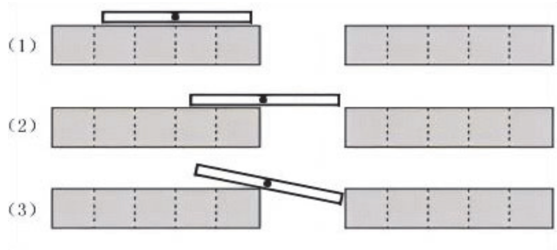
As we know, the special theory of relativity has derived the space-time coordinates transformation between two inertial frames, i.e., the Lorentz transformation starting from the principle of relativity and the principle of the constancy of light speed; and has derived the length contraction effect and time dilation effect from the Lorentz transformation, or direct from the above two principle.

According to the special theory of relativity, all inertial reference frames are equivalent and equal in right, and the length contraction effect and the time dilation effect are relative and mutually reversible. Observing in every inertial frame, the clocks in other inertial frames moving relative to that inertial frame will all become slow and the ruler in other inertial frames moving relative to that inertial frame will all become short. In popular parlance, you and I are observers in relative motion, and you have observed my clock to be slower than yours and my ruler to be shorter than yours, while I have observed your clock to be slower than mine and your ruler to be shorter than mine. Your and my judgments are undoubtedly opposite, but both your and my statements are simultaneously valid in science. What is more, except the above it is not possible there exists "an objective and fair-minded judgment".

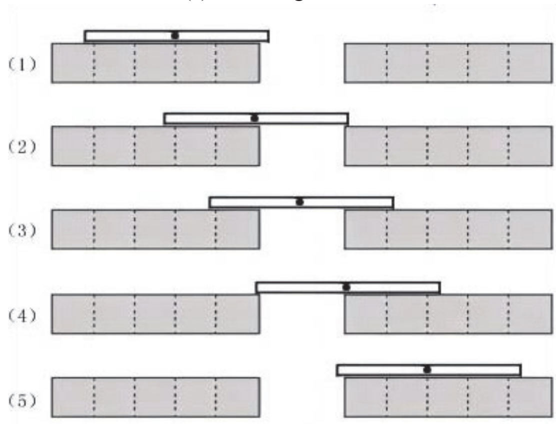
In most cases the relative and mutually reversible length contraction effect and the time dilation effect in the special theory of relativity have smooth dealing on every side, and have not shown its surprising flaws. But the present chapter expounds that there exists the slide-down paradox in the special theory of relativity, and that reveals the deep logic contradiction caused by its mere stress of relativity of motion but negation of absoluteness of motion.

As Fig. 10.1 shows, a smooth rigid rod with uniform density and a small rectangle section moves at a uniform velocity v along a smooth and horizontal table-plane S rightward (taken as positive direction of Ox axis). In the middle of the plane across which the rod will pass there is a big square hole symmetrical relative to Ox axis. To the cases of low-speed motion, according to the classical mechanics, (1) if the length of the rod is longer than twice of the width of the hole, the rod will favorably slide over the hole but will not be locked into the hole; (2) if the length of the rod is shorter than twice of the width of the hole, when the center of mass of the rod enter into the edge of the hole, the rod will incline from horizontal plane under the action of gravity, and will finally slide down and will be locked into the hole. Suppose the width (the proper length) of the hole is l_0, the proper length of the rigid rod is $2l_0 + \Delta$, $2l_0 > \Delta > 0$. In this case the rod should pass favorably over the hole and continuously slide on the plane.

Considering (1) the acceleration g of a body on the earth caused by gravitational field of the earth is small; (2) the special theory of relativity holds not true for gravitational field, and



(a) observing in frame S



(b) observing in frame S'

Fig.10.1

the general relativistic effects must be considered when the gravitational field is strong, we assume that gravitational field is substituted by magnetic field attracting iron rod, and the experiment is made in outer space without gravitational field or ground circumstance where magnetic force is far greater than gravity. According to the present physical experiments [1], in magnetic field $B_z = 18000$ Gauss, $\mathrm{d}B_z/\mathrm{d}z = 1700$ Gauss/cm magnetic force exerted on 1g iron is 4×10^5 dynes, so the acceleration attained by the iron rod in this magnetic field is $4\times10^3\ \mathrm{m/s^2}$ which is large than 400 times of gravity acceleration. Suppose the arrangement of the magnetic field causes the magnetic force exerted on the iron rod to be uniform in space. In such cases the above two conclusion gained according to the classical mechanics for the low-speed motion are still hold true.

Now consider the rigid rod in high-speed motion according to Einstein length contraction effect. Suppose the speed of the rod motion relative to the table-plane S is very great so that an observer A in frame S at rest relative to this table-plane observes that the rod shows the Einstein length contraction and its length is contracted from the proper length $2l_0 + \varDelta$ to $2l_0 - \varDelta$, i.e.,

$$(2l_0 + \Delta)\sqrt{1-v^2/c^2} = 2l_0 - \Delta,$$

or

$$v = \frac{\sqrt{8l_0\Delta}}{2l_0 + \Delta}c. \tag{10.1}$$

Hence as observed by the observer *A*, the rod will incline under the magnetic force, and finally will slide down and be locked into the hole. But to the observer *B* in frame S' *), which is another inertial reference frame uniformly moving along the smooth table-plane rightward at the initial velocity $\boldsymbol{v}$ of the rod, the length of the rod still is $2l_0 + \Delta$, and the hole and the table-place S move relative to the rod leftward with the speed v, as also shows by formulas (10.1), hence the width of the hole shows the Einstein length contraction and is contracted to be

$$l_0\sqrt{1-v^2/c^2} = l_0\frac{2l_0 - \Delta}{2l_0 + \Delta} < l_0. \tag{10.2}$$

As observed by the observer *B*, the rod should favorably slide over the hole and continuously slide on the table-plane but not locked into the hole. Which observer's description is correct?

These are two contradictory results derived in analyzing the problem of the slide down according to Einstein special theory of relativity. This is the slide down paradox in the special theory of relativity.

W. Rindler discussed a similar problem in a paper [2], merely the relative sizes of the rod and the hole are different. He supposes that a 10-in. long rigid rod moves longitudinally over a flat table, and on its path, there is a hole 10 in. wide, and the rod moves so fast that its Lorentz contraction factor $\gamma = (1-v^2/c^2)^{-1/2} = 10$. In this case, to an observer *A* at rest relative to the table-plane, the rigid rod in high-speed motion is contracted to be only 1 in. long, and the width of the hole still is 10-in. and the rod will fall and consequently strike the edge of the hole and will be stopped; to an observer *B* in frame S', the hole is only 1 in. wide, the rod still is 10 in. long, and the rigid rod will pass unhindered over the hole. Which observer's description is correct?

He considers that the resolution of the paradox has already been hinted at the word "rigid" of the rigid rod, i.e., the rod simply cannot remain rigid in *B*'s inertial frame (see Fig. 10. 2, this figure is taken from reference [2], here to take $\gamma = 4$ for drawing convenience). W. Rindler maintains first that *A*'s description is correct, hence to the frame S of the observer *A*,

*) For example, another skateboard, which is placed in parallel with the rigid rod and rightward moves with the initial velocity $\boldsymbol{v}$ of the rod, without passing through the square hole, or with a longer suitable length, so that even the length contraction does not slide into the hole, can be regarded as another inertial reference frame S'.

taking the instant when the hind end of the rod leaves the table-plane as the zero of the time ($t = 0$), and making the rod to remain horizontal but not incline in $t < 0$, the coordinate of the bottom of the rod in vertical direction (taken as z axis which positive direction is vertically downwards) is

$$Z = 0, \qquad \text{when } t < 0,$$

$$Z = (1/2)at^2, \qquad \text{when } t \geq 0.$$

Then according to the Lorentz transformation

$$Z = Z', \qquad t = \gamma(t' + vx'/c^2),$$

to frame S' of the observer B we get

$$Z' = 0, \quad \text{when} \quad x' < -c^2t'/v, \tag{10.3}$$

$$Z' = (1/2)a\gamma^2(t' + vx'/c^2)^2, \text{ when } x' \geq -c^2t'/v. \tag{10.4}$$

That is to say, a straight rigid rod in the frame S is no longer rigid in the frame S', and it bends downwards into a parabola and finally strikes the far edge of the hole and falls into the hole.

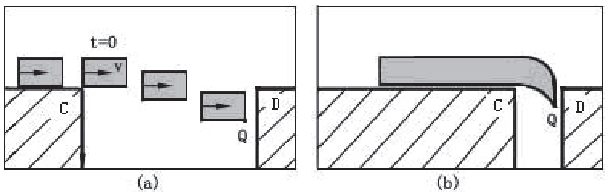


Fig. 10.2

W. Rindler's argument is strained, and it is obviously not an explanation in accordance with logic.

First, Einstein himself said: "The special theory of relativity is an adaption of the foundation of physics to be fitted for the Maxwell-Lorentz electrodynamics. It takes from earlier physics the assumption of the validity of Euclidean geometry for the possible position of rigid bodies." [3] According to W. Rindler, even in the rest frame the conception of rigid body is not applicable, and a straight rigid rod in the frame S is no longer rigid in the frame S' and bends downwards into a parabola. Where then can the non-relativistic elastic theory of solids possibly apply? This has violated the experimental facts, is very strange and incomprehensible.

Secondly, according to W. Rindler, we choose the coordinate systems S and S', and take the instant at which the origins of the two frame coincide as the zero of the time ($t = 0$ and $t' = 0$) (see Fig. 10.3). To the frame Σ_a, at instant $t' = t = 0$ simultaneously reading the coordinates x'_C and x'_D of the two edges C、D of the hole (point C is the origin of the frame S), according to the Lorentz transformation

$$x = \gamma(x' + vt'), \quad t = \gamma(t' + vx' / c^2), \tag{10.5}$$

$$x = \gamma(x' + vt'), \quad t = \gamma(t' + vx' / c^2). \tag{10.6}$$

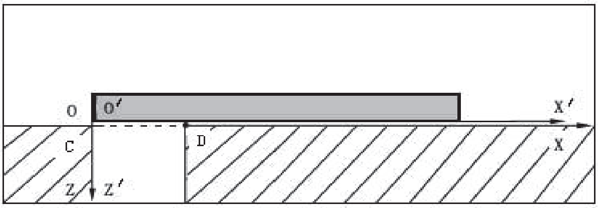


Fig. 10.3

we can get the width of the hole

$$x'_D - x'_C = (x_D - x_C)\sqrt{1 - v^2 / c^2}, \quad \text{or} \quad l' = l_0\sqrt{1 - v^2 / c^2}. \tag{10.7}$$

Hence the observer *B* in the frame S' observes at $t' = 0$ that the width of the hole $l' = l_0 / 10$, but the rigid rod itself has still the proper length, i.e., 9/10 of the rod itself already passed over the hole. Such being the case, it is quite impossible that after $t = 0$ the rod huddles itself up and bends downwards into a parabola shown as Fig. 10.2 (b) and crowds in the narrow hole. W. Rindler is sure to say that the observer *B*'s description is untenable! But, very obviously, this statement violates the basic postulate of the special theory of relativity, i.e., the relativity principle, according to which the observer *A*'s description and the observer *B*'s description are equivalent and equal in rights.

Thirdly, W. Rindler considers that *A*'s description is correct and *B*'s description is wrong, probably because for W. Rindler's sample the rod is sure to slide down into the hole in the low-speed motion. For the sample I give in this chapter, on the contrary, the rod is sure to slide over and pass the hole in the low-speed motion. Does W. Rindler consider that *A*'s description is wrong and *B*'s description is correct? Obviously, further discussions are unnecessary, W. Rindler's argument about the slide down paradox is untenable.

I ponder deeply and carefully this matter and affirm that the slide down paradox in the special theory of relativity is a logical paradox in strict meaning. Paradox is two contradictory propositions deduced from background knowledge through correct logical inference. Discovery of a paradox shows that the background knowledge must be rejected at least partially. Paradox is an important means of falsification. The existence of the slide down paradox has broken the logic strictness and reliability, and is a negation to the special theory of relativity.

10. 3. Resolving Scheme of Slide down Paradox

Discovery and resolution of paradox is forever internal force to propel science development. B. Russull [4] considers that resolving scheme of a paradox should satisfy at least three conditions: (1) to let the paradox clear away; (2) to let the mathematics keep as possible as its original form; (3) it has also other reasons to put forward the scheme.

How is the slide down paradox resolved? First of all, this involves the relativity and absoluteness of length contraction. As mentioned earlier, the special theory of relativity and Standard Space-time Theory have different understandings of this. If we abandon the understanding of the complete relativity of time and space in the special theory of relativity, while follow Standard Space-time Theory, taking into account the relativity and absoluteness of time and space at the same time, the problem will be solved.

J. S. Bell (1928—1990) is an excellent scientist at CERN. His viewpoints are clear especially. Bell said [5]:

"I would say that the cheapest solution is something like going back to relativity as it was before Einstein, when people like Lorenz and Poincare thought that there was an ether—a preferred frame of reference...Now, in that way you can imagine that there is a preferred frame of reference, and in this preferred frame of reference things do go faster than light. "

"What is not sufficiently emphasized in textbook, in my opinion, is that the pre-Einstein position of Lorenz and Poincare, Larmor and Fitzgerald was perfectly coherent, and is not inconsistent with relativity theory. The idea that there is an ether, and these Fitzgerald contraction and Larmor dilation occur, and that as a result the instruments do not detect motion through the ether—that is a perfectly coherent point of view."

"I find that there are lots of problems which are solved more easily by imagining the existence of the ether. The reason I want to go back to the idea of the ether here is because in these EPR experiments there is the suggestion that behind the scenes something is going faster than light."

The cheapest solution is to return the Lorentz's ether theory. But the Lorentz's efforts, as described in the introduction, are accomplished by adding a series of revisions and supplements and additions of hypothesis to classical physics. Lorentz's ether theory is not systematic and thorough. Lorenz did not establish a theory of space and time consistent with the principles of logical simplicity and logical self-chastity. And the Lorentz transformation goes against the original ideas of ether. So simply returning to Lorentz's ether theory is not the most perfect resolving means.

Standard Space-time Theory, as an inventive theoretical achievement originally, is perfection and systematization of the Lorentz ether theory, and is a new self-consistent theoretical system based upon on the two basic postulates， i. e., (1) the principle of the absolute reference frame and (2) the principle of constant average circuit speed of light. Standard Space-time Theory has perfectly explained up to now all observational and experimental facts, including several kinds of experiments which cannot be explained by the special theory of relativity. There is not the slide down paradox in Standard Space-time Theory.

Standard Space-time Theory has proved that the Fitzgerald-Lorentz length contraction effect and the Lodge-Lorentz time dilation effect, as a part of the logical inferences of the two basic postulates of Standard Space-time Theory, are contained in Standard Space-time Theory. According to Lorentz's ideas and Standard Space-time Theory, the length contraction and time dilation of the moving matter relative to the absolute inertial frame are not products of surface or external relation but a kind of real changes and possess absolute meaning. These changes should be attributed to the result of interaction between the moving material system and ether (i.e., the vacuum background field spoken in Standard Space-time Theory). In what follows we recount how directly to use Fitzgerald-Lorentz length contraction effect and Lodge-Lorentz time dilation effect to eliminate the slide down paradox.

Now we represent the absolute inertial frame by Σ_a, represent an ordinary inertial frame by Σ , which frame moves at a constant velocity $\boldsymbol{v}$ along the positive x_a axis of the frame Σ_a with respect to Σ_a. Here $\boldsymbol{v}$ is relative to Σ_a and is measured in Σ_a. The x (x_a) axes of the two reference frames are taken along the same direction and at the instant the origins of the two frames coincide, we let the clocks there read $t_a = 0$ and $t = 0$.

Suppose the rigid rod moves longitudinally relative to frame Σ_a, with velocity $\boldsymbol{u}_a$, which is parallel to the velocity $\boldsymbol{v}$. According to the Fitzgerald-Lorentz length contraction effect, considering simultaneously the real length change of the rod and the ruler of the reference frame, we can get the length of the rod measured in an ordinary inertial frame Σ

$$L = L_0 \frac{\sqrt{1-u_a^2/c^2}}{\sqrt{1-v^2/c^2}}, \tag{10.8}$$

where L_0 represents the proper length of the rod. The rigid rod and the ruler at rest relative to any inertial frame are both in the same motion state relative to the absolute inertial frame and have the same length contraction per unit length, so when an observer of every inertial frame measure the length of the same rod at rest relative to this inertial frame($\boldsymbol{u}_a = \boldsymbol{v}$), every observer is sure to get the same result, this is the proper length of the rod.

Therefore, the result of measuring the spatial length of moving body has its duality: on the one hand it has absoluteness which reflects real length change of the measured object (the rod) due to its motion with respect to the absolute inertial frame; on the other hand, it has relativity, or in other words, the result of measurement is related to the frame in which measurements are made, and this reflects the length contraction of the tools of measurement (i.e. the ruler) of the reference frame due to their motion together with the reference frame relative to the absolute inertial frame.

Similarly, suppose the observed matter moves relative to the frame Σ_{a} with velocity $\boldsymbol{u}_{\mathrm{a}}$, which is parallel to the velocity $\boldsymbol{v}$. According to the Lodge-Lorentz time dilation effect, considering simultaneously the real time dilation of the motion process of the matter and the clock of the reference frame, we can get the time interval of the motion process of the matter measured in an ordinary inertial frame Σ

$$\tau = \tau_0 \frac{\sqrt{1 - v^2 / c^2}}{\sqrt{1 - u_{\mathrm{a}}^2 / c^2}}, \tag{10.9}$$

where τ_0 represents the time interval of the motion process of the matter measured in the reference frame at rest relative to the moving matter, i.e., the proper time interval. The clock and the motion process of the moving matter at rest relative to any inertial frame are both in the same motion state relative to the absolute inertial frame and have the same time dilation effect, so when an observer of an inertial frame at rest relative to the matter measures the time interval of the same process of the matter ($\boldsymbol{u}_{\mathrm{a}} = \boldsymbol{v}$), every observer is sure to get the same result, this is the proper time interval of the process.

Therefore, the result of measuring the time interval of the motion process of the matter has its duality: on the one hand it has absoluteness which reflects real time change of the measured object due to its motion with respect to the absolute inertial frame; on the other hand, it has relativity, or in other words, the result of measurement is related to the frame in which measurements are made, and this reflects the time dilation of the tools of measurement (i.e. the clock) of the reference frame due to their motion together with the reference frame relative to the absolute inertial frame.

Differing from the length contraction effect of the special theory of relativity, according to the Fitzgerald-Lorentz length contraction effect, length contraction at the motion direction of the body at rest relative to an inertial frame can be observed by an observer in the absolute inertial frame or in the ordinary inertial frames which haves the same direction of absolute motion and the speed smaller than that of former frame. An observer in an ordinary inertial frame, owing to the length contraction at the motion direction of its ruler, will observe the lengthened length along the motion direction of the body at rest relative to the absolute inertial frame or the ordinary inertial frames which haves the same direction of absolute motion and the smaller speed as compared with that of former frame.

In the same way, differing from the time dilation effect of the special theory of relativity, according to the Lodge-Lorentz time dilation effect, the time dilation of the motion process of matter at rest relative to an inertial frame can be observed by an observer in the absolute inertial frame or in the ordinary inertial frames which haves the absolute motion speed smaller than that of the former frame; but an observer in an ordinary inertial frame, owing to the time dilation of its clock, will observe the time shortening of the motion process of the matter at rest relative to the absolute inertial frame or ordinary inertial frames which haves the absolute speed smaller than that of the former frame. \

From Eq. (10.8) or (10.9) we can validate that the above judgments are true.

According to the Fitzgerald-Lorentz length contraction effect and the Lodge-Lorentz time dilation effect, we can directly find that when a particle moves relative to the frame Σ_a with velocity $\boldsymbol{u}_a$, and $\boldsymbol{u}_a$ is parallel to $\boldsymbol{v}$, then the transformation between the velocity $\boldsymbol{u}$ of the particle measured in the frame Σ and the velocity $\boldsymbol{u}_a$ of the particle measured in the frame Σ_a can be written as

$$u = \frac{u_a - v}{1-\beta^2}, \quad u_a = u(1-\beta^2) + v, \tag{10.10}$$

where $\beta = v/c$. Practically, when the reference frame transform from frame Σ_a to frame Σ, the length contraction effect of the ruler will cause the length in direction of Ox axis measured in the frame Σ lengthened as γ times the length measured in the frame Σ_a, but the lengths in direction of Oy and Oz axes remain unchanged; the time dilation effect of the clock will cause the time interval of the motion process of the matter measured in the frame Σ shortened as $\left(1-\beta^2\right)^{1/2}$ times the time interval measured in the frame Σ_a. The velocity as the limited value of the proportion of displacement to time interval necessarily satisfy the velocity transformation (10.10).

Equations (10.8)、(10.9) and (10.10) are all certain special cases of the equations derived by Standard Space-time Theory from the two basic postulates, i.e. the principle of the absolute reference frame and the principle of constant average circuit speed of light in even more extensive meaning.

From the Fitzgerald-Lorentz length contraction effect and Lodge-Lorentz time dilation effect and the above Eqs. (10.8), (10.9) and (10.10) we can eliminate the slide down paradox.

According to Standard Space-time Theory, the inertial frame S at rest relative to the horizontal table-plane, and another inertial frame S' which uniformly moves with the initial velocity $\boldsymbol{v}$ of the rigid rod relative to the table-plane, can be regarded as two ordinary inertial frames, expressed by symbols Σ_1 and Σ_2 respectively. As Fig. 10.1 shows, suppose the table-plane S as an ordinary inertial frame Σ_1 moves together with the laboratory reference frame relative to the absolute reference frame Σ_a with the velocity $\boldsymbol{v}_1$ ($\boldsymbol{v}_1$ directs to the α star in Leo). For the sake of simplicity, the positive direction of Ox axis of the table-plane frame Σ_1 is arranged in the direction of $\boldsymbol{v}_1$. The rigid rod moves relative to the table-plane along the positive direction of Ox axis with an initial velocity $\boldsymbol{v}$. The ordinary inertial frame Σ_2 uniformly moves relative to the frame Σ_1 along the positive direction of Ox axis of the table-plane frame Σ_1 with the initial velocity $\boldsymbol{v}$ of the rod. According to the velocity transformation (10.10), the velocity $\boldsymbol{v}_2$ of the frame Σ_2 relative to the absolute reference frame Σ_a as follows

$$v_2 = u_{a2} = v(1-\beta_1^2) + v_1 > v_1, \tag{10.11}$$

where $\beta_1 = v_1/c$. The width (the proper length) of the hole is still L_0, the proper length of the rod is $2l_0 + \Delta$, $2l_0 > \Delta > 0$. In the case of the low-speed motion the rod should pass favorably over the hole and continuously slide on the table-plane.

Now suppose the rigid rod is in high-speed motion relative to the table-plane along the positive direction of Ox axis of the frame Σ_1, an observer A in the frame Σ_1 observes that the rod shows the Fitzgerald-Lorentz length contraction and its length is contracted from the proper length $2l_0 + \varDelta$ to $2l_0 - \varDelta$. According to Eq. (10.8) we have

$$(2l_0 + \varDelta)\frac{\sqrt{1 - v_2^2/c^2}}{\sqrt{1 - v_1^2/c^2}} = 2l_0 - \varDelta. \tag{10.12}$$

Hence as observed by the observer A, as long as the velocity of the rigid rod is large enough to satisfy the upper equation, the rod will incline under the magnetic force, and finally will slide down and be locked into the hole.

To the observer B in the inertial frame Σ_2, the length of the rod still is $2l_0 + \varDelta$. The proper length of the width of the hole is L_0, but both the hole and the table-plane Σ_1 are in the high-speed motion leftward relative to the frame Σ_2. Because the absolute speed $\boldsymbol{v}_2$ of frame Σ_2 is larger than the absolute speed v_1 of the table-plane Σ_1, according to Eq. (10.8), to the observer B in the frame Σ_2 the width of the hole is not be contracted but is lengthened as

$$l = \frac{\sqrt{1 - v_1^2/c^2}}{\sqrt{1 - v_2^2/c^2}} l_0 = \frac{2l_0 + \varDelta}{2l_0 - \varDelta} l_0 = l_0 (1 + \frac{\varDelta}{2l_0})(1 + \frac{\varDelta}{2l_0} + \frac{\varDelta^2}{4l_0{}^2} + \cdots) > \frac{1}{2}(2l_0 + \varDelta).$$

That is

$$2l_0 + \varDelta < 2l. \tag{10.13}$$

Hence as observed by the observer B, the rod can also not favorably slide over the hole, it will incline and finally slide down and be locked into the hole. Both observer A and observer B gain the same observational prediction, so there is not the slide down paradox.

According to Standard Space-time Theory we can also gain the following prediction: if the rod moves leftward relative to the table-plane frame Σ_1 along the negative direction of Ox axis of the frame Σ_1, i.e. along the opposite direction of the absolute velocity $\boldsymbol{v}_1$ of the table-plane frame Σ_1, then there is also not the slide down paradox, but both observer A and observer B gain the same observational prediction that the rod will favorably slide over the hole.

You can also imagine a variety of other situations in which the rigid rod or pass smoothly over the hole or slide-down into the hole. You can analyze, think and calculate every situation according to Standard Space-time Theory, both observer A and B will get the same answers and predictions. There is no the slide-down paradox in Standard Space-time Theory.

Based on the above principle experimental physicist can design experimental scheme that is really put in practice.

10. 4. Conclusion

There is the slide down paradox in the special theory of relativity, and that reveals the deep logic contradiction caused by its mere stress of relativity of motion but negation of absoluteness of motion. If the absolute reference frame is admitted, in accordance with Fitzgerald-Lorentz length contraction effect and Lodge-Lorentz time dilation effect，the slide down paradox can be eliminated. Standard Space-time Theory based on the two basic postulates (the principle of the absolute reference frame and the principle of the constancy of the average circuit speed of light), is perfection and systematization of the Lorentz ether theory, and is a new self-consistent theoretical system. The Fitzgerald-Lorentz Length contraction effect and the Lodge-Lorentz time dilation effect as a part of logical inferences of the two basic postulates of Standard Space-time Theory are contained in Standard Space-time Theory. There is not the slide down paradox in Standard Space-time Theory.

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Chapter 11

Review and Prospect

This chapter, as a summary of the whole book, is an important part of the book. It will establish the connection between the space-time coordinate transformation of Standard Space-time Theory, that is, the Generalized Galileo Transformation (GGT), and the space-time coordinate transformation of the special theory of relativity, that is, the Lorentz Transformation (LT). We will elaborate further: Standard Space-time Theory, as an original theoretical research achievement and a rigorous logic system, is a new space-time theory which is different from Newton's absolute space-time view and Einstein's relativity space-time view, and abandons their one-sidedness, contains the reasonable elements of these two space-time views. Standard Space-time Theory is integrating and upgrading of Newton's and Einstein's concepts of space and time. Standard Space-time Theory reflects the objectivity, relativity and absoluteness of matter and motion, space and time, and reveals the close relationship between space and time with a specific and rigorous theoretical form, as well as the interdependent relationship between space and time and material motion. It is a more accurate description to the natural nature of space-time. It provides a more reasonable space-time framework for people to understand and describe the physical world and even natural phenomena. Such a new theory definitely represents the progress of human understanding of nature.

We will try to understand and solve some important problems faced by modern physics according to Standard Space-time Theory. Firstly, in the direction advocated by Einstein and de Broglie, on the basis of the aggregated-dispersed states natural images and the non-locality concept, we should accept and improve the achievements of the existing quantum mechanics, give deterministic description of the physical picture and motion law of a single microscopic system, and establish the quantum theory for complete description of the microscopic systems. That is Wave-Particle Mechanics, which will make contribution to the coordination of space-time theory and quantum mechanics. This will provide a correct basis and starting point for the reconstruction of the basis of modern physics, and promotes the fourth breakthrough and development of physics. The last section of this chapter will introduce the basic concepts of Wave-Particle Mechanics.

11. 1. Comparison between Generalized Galilean Transformation and Lorentz Transformation

In the previous chapters, based on the principle of the absolute reference system and principle of the constancy of the average circuit speed of light, the whole theoretical system of Standard Space-time Theory is established independently of the special theory of relativity. Although they are two different space-time theories, there is still some connection between them. This correlation first lies in that they both satisfy the principle of the constancy of the average circuit speed of light. In this section, the space-time coordinates relations of the two theories are derived from the principle of the constancy of the average circuit speed of light, which proves that the generalized Galileo transformation and Lorentz transformation can be derived from each other according to these relations, and further the relations between the differential operators of the velocity and space-time coordinates of the two theories are obtained. After obtaining these results, the physical meaning behind these mathematical relations is expounded, and it is emphasized that Standard Space-time Theory is not equivalent to the special theory of relativity.

11. 1. 1. The Principle of the Constancy of the Average Circuit Speed of Light and the General Lorentz Transformation

As stated in Sec. 3.3, the principle of the constancy of the average circuit speed of light is a summary of a large number of experimental facts. In this section, the relationship between the principle of the constancy of the average circuit speed of light and the general Lorentz transformation is discussed. In order to narrative succinctness, the principle of the constancy of the average circuit speed of light is referred to as the "Circuit Principle" in this section and below. What conclusions can be derived simply from the Circuit Principle?

As Chapter 4, under the Circuit Principle, the time of light propagating along a non-closed path *AB* is

$$t_B - t_A = \int_A^B \frac{\mathrm{d}r}{c(\alpha,\beta,\gamma)}. \tag{11.1}$$

Using equation (4.8) and (4.10) and noticing that *X, Y, Z* and *R* should be independent of space coordinates, according to the assumption of uniformity of space and time, we obtain from the above equation (11.1) that

$$\begin{aligned} t_B - t_A &= \int_A^B \frac{1-R}{c}\mathrm{d}r = \int_A^B \frac{1}{c}(1 - X\cos\alpha - Y\cos\beta - Z\cos\gamma)\mathrm{d}r \\ &= \left[L/c\right] - \left[X(x_B - x_A) - Y(y_B - y_A) - Z(z_B - z_A)\right]/c \\ &= \left[t_{rB} - (Xx_B + Yy_B + Zz_B)/c\right] - \left[t_{rA} - (Xx_A + Yy_A + Zz_A)/c\right], \end{aligned}$$

or

$$t_B - t_A = [t_{rB} - (Xx_B + Yy_B + Zz_B)/c] - [t_{rA} - (Xx_A + Yy_A + Zz_A)/c],$$

where subscripts r denotes relativistic quantity and $t_{rB} - t_{rA} = L/c$ and L is the length of the path AB. From this we obtain the relation between the time t of an event under the assumption of the Circuit Principle and the relativistic time t_r of the same event

$$t = t_r - (Xx + Yy + Zz)/c. \tag{11.2}$$

Besides, noticing the space coordinates are the same under two assumptions, i.e.

$$\boldsymbol{r} = \boldsymbol{r}_r. \tag{11.3}$$

Choose two inertial reference frames $K(x, y, z, t)$ and $K'(x', y', z', t')$. At the initial instant $t = t' = 0$ the three coordinates of the two frames coincide mutually. The frame K' moves at a constant velocity $\boldsymbol{v}$ along the positive x axis of K with respect to K. For convenience, consider the simple case in which symmetry relative to $x(x')$ axis exists, i.e. the speeds of light in the directions of the positive and the negative $y(y')$ axes and the positive and the negative $z(z')$ axes are all equal, merely the speeds of light in the directions of the positive and the negative $x(x')$ axes are not equal. According to the Circuit Principle this mean (see Sec.4.3)

$$\left.\begin{aligned} c_y = c_{-y} = c,\ Y = 0;\ \ c_{y'} = c_{-y'} = c,\ \ Y' = 0, \\ c_Z = c_{-Z} = c,\ Z = 0;\ \ c_{Z'} = c_{-Z'} = c,\ \ Z' = 0, \end{aligned}\right\} \tag{11.4}$$

$$c_x = \frac{c}{1-X},\ c_{-x} = \frac{c}{1+X};\ c_{x'} = \frac{c}{1-X'},\ c_{-x'} = \frac{c}{1+X'}, \tag{11.5}$$

where c represents the average circuit speed of light, and

$$-1 \le X,\ X' \le +1 \tag{11.6}$$

The light speed parameters X and X' are a representation of the direction property of the propagation velocity of the light signal in the frames K and K'. To special theory of relativity, according to the principle of the constancy of the one-way speed of light, $X = X' = 0$; To Standard Space-time Theory, the frame K is absolute inertial frame Σ_a, $X = 0$, and the frame K' is an ordinary frame Σ, $X' = -v/c$.

Starting from the Circuit Principle and adding other consideration, the following general Lorentz transformation (GLT) can be derived [1]

$$\begin{aligned} &x' = \eta(x - vt) \\ &y' = y,\ z' = z \\ &t' = \eta\{[1 + \beta(X + X')]t + [\beta(X^2 - 1) + X - X'](x/c)\}, \end{aligned} \tag{11.7}$$

where

$$\eta = \left[(1 + \beta X)^2 - \beta^2\right]^{-1/2},\ \ \beta = v/c.$$

It should be pointed that merely starting from the Circuit Principle we cannot derive the above transformation. We must introduce also, for example, the principle of the inertial frame (It can be narrated as that there exists a inertial reference frame; a reference frame that moves uniformly in a straight line with respect to the inertial frame is also an inertial reference frame) and the assumption of uniformity of space-time to prove that the space-time coordinates transformations between two inertial frames are linear. Then by virtue of the Circuit Principle we can determine the coefficients of the linear transformations. But derivation of the general Lorentz transformation is independent of the relativity principle of SR and the principle of the absolute reference frame of Standard Space-time Theory. For these, no further detailed analysis is made here.

The frames K and K' in GLT are represented by the frames S and S' in LT. Applying Eqs. (11.2) and (11.3) separately to the frames $K(x,y,z,t)$ and $S\left(x_{\mathrm{r}},y_{\mathrm{r}},z_{\mathrm{r}},t_{\mathrm{r}}\right)$, and the frames $K'(x',y',z',t')$ and $S'\left(x'_{\mathrm{r}},y'_{\mathrm{r}},z'_{\mathrm{r}},t'_{\mathrm{r}}\right)$ of the coordinates arrangement in the simple case, we can obtain the relations of the space-time coordinates of an event in the two theories

$$\begin{aligned} &x=x_{\mathrm{r}},\quad y=y_{\mathrm{r}},\quad z=z_{\mathrm{r}};\quad t=t_{\mathrm{r}}-\left(x/c\right)X,\\ &x'=x'_{\mathrm{r}},\ \ y'=y'_{\mathrm{r}},\ \ z'=z'_{\mathrm{r}};\ \ t'=t'_{\mathrm{r}}-\left(x'/c\right)X'. \end{aligned} \tag{11.8}$$

From the definitions of the velocity in the frames K and S, the frames K' and S'

$$\boldsymbol{u}=\frac{\mathrm{d}\boldsymbol{r}}{\mathrm{d}t},\ \boldsymbol{u}_{\mathrm{r}}=\frac{\mathrm{d}\boldsymbol{r}_{\mathrm{r}}}{\mathrm{d}t_{\mathrm{r}}}, \tag{11.9}$$

$$\boldsymbol{u}'=\frac{\mathrm{d}\boldsymbol{r}'}{\mathrm{d}t'},\ \boldsymbol{u}'_{\mathrm{r}}=\frac{\mathrm{d}\boldsymbol{r}'_{\mathrm{r}}}{\mathrm{d}t'_{\mathrm{r}}}, \tag{11.10}$$

and the relations of the space-time coordinates in the two theories (11.8) we can find the relations of the velocities in the two theories as follows

$$\boldsymbol{u}=\frac{\boldsymbol{u}_{\mathrm{r}}}{1-u_{\mathrm{r}x}X/c},\quad \boldsymbol{u}_{\mathrm{r}}=\frac{\boldsymbol{u}}{1+u_{x}X/c}, \tag{11.11}$$

$$\boldsymbol{u}'=\frac{\boldsymbol{u}'_{\mathrm{r}}}{1-u'_{\mathrm{r}x}X'/c},\quad \boldsymbol{u}'_{\mathrm{r}}=\frac{\boldsymbol{u}'}{1+u'_{x}X'/c}. \tag{11.12}$$

Noticing that the velocity $\boldsymbol{v}$ of the frame K' relative to the frame K measured in K is along positive x axis, correspondingly, the velocity $\boldsymbol{v}_{\mathrm{r}}$ of the frame S' relative to the frame S measured in S is along positive x_{r} axis, from (11.11) we obtain

$$\boldsymbol{v}=\frac{\boldsymbol{v}_{\mathrm{r}}}{1-v_{\mathrm{r}}X/c},\quad \boldsymbol{v}_{\mathrm{r}}=\frac{\boldsymbol{v}}{1+vX/c}. \tag{11.13}$$

Substituting Eqs.(11.8) and (11.13) into GLT (11.7) we can obtain the well-known LT

$$x'_{\mathrm{r}}=\gamma(x_{\mathrm{r}}-vt_{\mathrm{r}}),\ y'_{\mathrm{r}}=y_{\mathrm{r}},\ z'_{\mathrm{r}}=z_{\mathrm{r}},\ t'_{\mathrm{r}}=\gamma(t_{\mathrm{r}}-vx_{\mathrm{r}}/c^{2}), \tag{11.14}$$

where $\gamma=\left(1-v_{\mathrm{r}}^{2}/c^{2}\right)^{-1/2}$.

Conversely, we can obtain the GLT (11.7) by substituting Eqs.(11.8) and (11.13) into usual LT (11.14). That is to say, if we take into account the difference in time coordinates introduced from the different synchronization method of clocks at different places, the two transformations can be derived mutually.

11. 1. 2. The relation between Generalized Galileo Transformation and Lorentz Transformation

The relation between the generalized Galileo transformation(GGT) and Lorentz transformation (LT) has been discussed in Sec. 4.5. The root of this relation lies in the fact that they all satisfy the Circuit Principle. The relationship between the time t and position vector $\boldsymbol{r}$ of an event in any inertial system derived from the Circuit Principle and the time t_r and position vector $\boldsymbol{r}_\mathrm{r}$ of the same event in this inertial system of the special theory of relativity obtained from the principle of the constancy of the one-way speed of light is shown in formula (11.2)—(11.3).

Frames Σ_a and Σ in GGT are corresponded with S and S' in LT. In the case that coordinate axis (such as x-axis) coincides with the characteristic velocity $\boldsymbol{v}$, applying Eqs. (11.2) and (11.3) separately to frames $\Sigma_\mathrm{a}\left(x_\mathrm{a}, y_\mathrm{a}, z_\mathrm{a}, t_\mathrm{a}\right)$ and $S\left(x_\mathrm{r}, y_\mathrm{r}, z_\mathrm{r}, t_\mathrm{r}\right)$, and $\Sigma\left(x, y, z, t\right)$ and $S'\left(x'_\mathrm{r}, y'_\mathrm{r}, z'_\mathrm{r}, t'_\mathrm{r}\right)$, and noticing according to the Sec. 4.3, that $X_\mathrm{a} = Y_\mathrm{a} = Z_\mathrm{a} = 0$, in the frame Σ_a, and $X = -v/c$, $Y = 0$, $Z = 0$ in the frame Σ, we can obtain

$$\left.\begin{aligned} &x_\mathrm{a} = x_\mathrm{r}, \quad y_\mathrm{a} = y_\mathrm{r}, \quad z_\mathrm{a} = z_\mathrm{r}; \quad t_\mathrm{a} = t_\mathrm{r}, \\ &x = x'_\mathrm{r}, \quad y = y'_\mathrm{r}, \quad z = z'_\mathrm{r}; \quad t = t'_\mathrm{r} + \left(v/c^2\right)x', \end{aligned}\right\} \tag{11.15}$$

where $\boldsymbol{v}$ is the velocity of the frame Σ relative to Σ_a, and is measured in Σ_a and is along the positive x_a axis of frame Σ_a. And $\boldsymbol{v}$ is also the velocity of the frame S' relative to S, and is measured in frame S and is along the positive x_r axis of frame S.

Therefore, to the space-time coordinates of an event in the frames Σ_a and S, Σ and S' (not space-time coordinates transformation) the only difference is given by the above last equation, which shows the difference of time coordinates introduced from the different postulates and different synchronization method of clocks at different places deduced from these postulates. It can be written as

$$t = t'_\mathrm{r} + v r'_\mathrm{r} / c^2, \quad t'_\mathrm{r} = t - v x / c^2. \tag{11.16}$$

Substituting Eq. (11.15) into GGT (4.48), i.e.,

$$x = \gamma(x_\mathrm{a} - v t_\mathrm{a}), \quad y = y_\mathrm{a}, \quad z = z_\mathrm{a}, \quad t = \gamma^{-1} t_\mathrm{a}, \tag{11.17}$$

can easily obtain LT

$$\left.\begin{aligned} &x'_\mathrm{r} = \gamma(x_\mathrm{r} - v t_\mathrm{r}), \\ &y'_\mathrm{r} = y_\mathrm{r}, \quad z'_\mathrm{r} = z_\mathrm{r}, \\ &t'_\mathrm{r} = \gamma(t_\mathrm{r} - v x_\mathrm{r} / c^2), \end{aligned}\right\} \tag{11.18}$$

and vice versa, i.e., as soon as substituting Eqs. (11.15) and (11.16) into LT (11.18) we obtain GGT (11.17). That is to say, if we take into account the difference in time coordinates introduced from the different basic postulates and different synchronization method of clocks at different places deduced from these basic postulates, GGT and LT can be derived mutually.

We can now clear up the essence of GGT and LT. GGT and LT both satisfy the Circuit Principle. Different basic postulates lead to different definition of simultaneity and different method of the synchronization of clocks at different places. If the speed of light is isotropic in any inertial reference frame and the principle of relativity holds true, we must take $X_\mathrm{r} = X'_\mathrm{r} = 0$ and gain LT; if we consider the speed of light is isotropic only in one (standard or absolute) inertial frame and the principle of the absolute reference frame holds, we must take $X_\mathrm{a} = 0,\ X = -\beta$ and gain GGT.

The above results easily are generalized to the general case in which coordinate axes (such as x-axis) do not coincide with the characteristic velocity $\boldsymbol{v}$.

Applying Eqs. (11.2) and (11.3) separately to frames Σ_a and S, and Σ and S' of the general coordinates arrangement and noticing that $X_\mathrm{a} = Y_\mathrm{a} = Z_\mathrm{a} = 0$ in the frame Σ_a and $X = -v_x / c,\quad Y = -v_y / c,\ Z = -v_z / c$ in the frame Σ, we can obtain the relations of the space-time coordinates of an event in the two theories

$$\left.\begin{aligned} \boldsymbol{r}_\mathrm{a} &= \boldsymbol{r}_\mathrm{r}, \quad t_\mathrm{a} = t_\mathrm{r}, \\ \boldsymbol{r} &= \boldsymbol{r}'_\mathrm{r}, \quad t = t'_\mathrm{r} + \boldsymbol{v}\cdot\boldsymbol{r}'_\mathrm{r} / c^2, \end{aligned}\right\} \tag{11.19}$$

where $\boldsymbol{v}$ is the velocity of the frame Σ relative to Σ_a and is measured in Σ_a, and is also the velocity of the frame S' relative to S, and is measured in S.

Therefore, to the space-time coordinates of an event in the frames Σ_a and S, Σ and S' (not space-time coordinates transformation) the only difference is given by last formula of the above equation (11.19). It can be written as

$$t = t'_\mathrm{r} + \boldsymbol{v}\cdot\boldsymbol{r}'_\mathrm{r} / c^2,\ \ t'_\mathrm{r} = t' - \boldsymbol{v}\cdot\boldsymbol{r} / c^2. \tag{11.20}$$

We can easily prove that substituting the above two equations into GGT under the general coordinate system (6.32), i.e.

$$\boldsymbol{r} = \boldsymbol{r}_\mathrm{a} + [(\gamma - 1)(\boldsymbol{r}_\mathrm{a}\cdot\boldsymbol{v}) / v^2 - \gamma\, t_\mathrm{a}]\boldsymbol{v}, \quad t = \gamma^{-1} t_\mathrm{a}, \tag{11.21}$$

we obtain LT under the general coordinate system

$$\begin{aligned} \boldsymbol{r}'_\mathrm{r} &= \boldsymbol{r}_\mathrm{r} + \left[(\gamma - 1)(\boldsymbol{r}_\mathrm{r}\cdot\boldsymbol{v}) / v^2 - \gamma\, t_\mathrm{r}\right]\boldsymbol{v}, \\ t'_\mathrm{r} &= \gamma\, [\, t_\mathrm{r} - (\boldsymbol{r}_\mathrm{r}\cdot\ \boldsymbol{v}) / c^2] \end{aligned} \tag{11.22}$$

and vice versa, i.e., as soon as substituting Eqs. (11.19) and (11.20) into LT we obtain GGT. That is to say, if we take into account the difference in time coordinates introduced from the different synchronization method of clocks at different places, GGT and LT can be derived mutually.

From the definitions of the velocity in the frames Σ_a and S, Σ and S'

$$\boldsymbol{u}_a=\frac{d\boldsymbol{r}_a}{dt_a},\quad \boldsymbol{u}_r=\frac{d\boldsymbol{r}_r}{dt_r},\quad \boldsymbol{u}=\frac{d\boldsymbol{r}}{dt},\quad \boldsymbol{u}_r'=\frac{d\boldsymbol{r}_r'}{dt_r'}$$

and the relations of the space-time coordinates in the two theories (11.19) and (11.20), we can find the relations of the velocities in the two theories as follows

$$\boldsymbol{u}_r=\boldsymbol{u}_a, \tag{11.23}$$

$$\frac{1}{\sqrt{1-u_r^2/c^2}}=\frac{1}{\sqrt{1-u_a^2/c^2}}, \tag{11.24}$$

$$\boldsymbol{u}_r'=\frac{\boldsymbol{u}}{1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2},\quad \boldsymbol{u}=\frac{\boldsymbol{u}_r'}{1+\boldsymbol{u}_r'\cdot\boldsymbol{v}/c^2}, \tag{11.25}$$

$$\frac{1}{\sqrt{1-u_r'^2/c^2}}=\frac{1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2}{\sqrt{(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2-u^2/c^2}}, \tag{11.26}$$

and we have

$$\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right)\left(1+\boldsymbol{u}_r'\cdot\boldsymbol{v}/c^2\right)=1, \tag{11.27}$$

where $\boldsymbol{u}_r$ and $\boldsymbol{u}_r'$ are separately the velocity of a body measured in S and S' according to the synchronization method of clocks at different places in the special theory of relativity, $\boldsymbol{u}_a$ and $\boldsymbol{u}$ are separately the velocity of the same body measured in Σ_a and Σ according to the synchronization method of clocks at different places in Standard Space-time Theory.

From the relations of the space-time coordinates in the two theories (11.19) and (11.20) we can further find the relations between the differential operators of space-time coordinates in the two theories.

First, we easily prove that the differential operators of the $S(x_r, y_r, z_r, t_r)$ frame of the special theory of relativity and the absolute frame $\Sigma_a(x_a, y_a, z_a, t_a)$ of Standard Space-time Theory, i.e.

$$\nabla_r=\boldsymbol{i}\frac{\partial}{\partial x_r}+\boldsymbol{j}\frac{\partial}{\partial y_r}+\boldsymbol{k}\frac{\partial}{\partial z_r}\quad\text{and}\quad \nabla_a=\boldsymbol{i}\frac{\partial}{\partial x_a}+\boldsymbol{j}\frac{\partial}{\partial y_a}+\boldsymbol{k}\frac{\partial}{\partial z_a}$$

satisfy

$$\nabla_r=\nabla_a \tag{11.28}$$

and we have

$$\frac{\partial}{\partial t_r}=\frac{\partial}{\partial t_a}. \tag{11.29}$$

Secondly, for the $S'(x_r', y_r', z_r', t_r')$ frame of the special theory of relativity and an ordinary frame $\Sigma(x, y, z, t)$ of Standard Space-time Theory we can find

$$\nabla'_{\mathrm{r}} = \boldsymbol{i}\frac{\partial}{\partial x'_{\mathrm{r}}} + \boldsymbol{j}\frac{\partial}{\partial y'_{\mathrm{r}}} + \boldsymbol{k}\frac{\partial}{\partial z'_{\mathrm{r}}}$$

$$= \boldsymbol{i}\left(\frac{\partial}{\partial x}\frac{\partial x}{\partial x'_{\mathrm{r}}} + \frac{\partial}{\partial t}\frac{\partial t}{\partial x'_{\mathrm{r}}}\right) + \boldsymbol{j}\left(\frac{\partial}{\partial y}\frac{\partial y}{\partial y'_{\mathrm{r}}} + \frac{\partial}{\partial t}\frac{\partial t}{\partial y'_{\mathrm{r}}}\right) + \boldsymbol{k}\left(\frac{\partial}{\partial z}\frac{\partial z}{\partial z'_{\mathrm{r}}} + \frac{\partial}{\partial t}\frac{\partial t}{\partial z'_{\mathrm{r}}}\right),$$

$$= \boldsymbol{i}\frac{\partial}{\partial x} + \boldsymbol{j}\frac{\partial}{\partial y} + \boldsymbol{k}\frac{\partial}{\partial z} + \frac{1}{c^2}\left(\boldsymbol{i}v_x + \boldsymbol{j}v_y + \boldsymbol{k}v_z\right)\frac{\partial}{\partial t},$$

i.e.

$$\nabla'_{\mathrm{r}} = \nabla + \frac{1}{c^2}\boldsymbol{v}\frac{\partial}{\partial t}, \tag{11.30}$$

and we have

$$\frac{\partial}{\partial t'_{\mathrm{r}}} = \frac{\partial}{\partial t}\frac{\partial t}{\partial t'_{\mathrm{r}}} + \frac{\partial}{\partial x}\frac{\partial x}{\partial t'_{\mathrm{r}}} + \frac{\partial}{\partial y}\frac{\partial y}{\partial t'_{\mathrm{r}}} + \frac{\partial}{\partial z}\frac{\partial z}{\partial t'_{\mathrm{r}}} = \frac{\partial}{\partial t},$$

i.e.

$$\frac{\partial}{\partial t'_{\mathrm{r}}} = \frac{\partial}{\partial t}. \tag{11.31}$$

In electrodynamics of Standard Space-time Theory, we find and express the law of electromagnetic field in general inertial system through careful analysis and study. it can now be seen that using the relation between the differential operators of space-time coordinates of two theories (11.28)—(11.31), it is easy to obtain the corresponding equations or formulas of Standard Space-time Theory from some equations or formulas of the special theory of relativity quickly, or in turn obtain the corresponding equation or formula of the special theory of relativity from some equations or formulas of Standard Space-time Theory. Of course, this is not a substitute for careful analysis and research before, but it confirms the reliability of the results we obtained. The said equations or formulas include the vacuum electromagnetic field equations in the general inertial system, the electromagnetic field equations within the medium, the wave equations of the vacuum electromagnetic field, the definition of the scalar potential and the vector potential, the gauge transformation, the Lorentz gauge conditions, the basic equations about the scalar potential and the vector potential, etc.

Using the relations between the coordinates of space and time of the two theories (11.19) and (11.20), and the differential operators of the coordinates of space and time (11.28)—(11.31), the corresponding equations or formulas of the two theories can be derived from each other. What exactly does this mean? Does this mean that the two theories are equivalent, or can they have significant differences? That was the question J. Bell asked me that year. To this, the following section will give a clear answer.

11. 2. The Opposition between Standard Space-time Theory and Special Theory of Relativity

11. 2. 1. Point of View of Conventionalism and the Experiments of Spatial Anisotropy

Based on the mathematical results narrated in the above section, some physicists have put forward a point of view which is summarized as follows: [1, 2]

Under the Circuit Principle if we consider the difference in time coordinates introduced from the different synchronization methods of clocks at different places according to the different values of the light speed parameters X and X', the GLT and the usual LT can be derived mutually; to any values of X and X', all results of GLT can one-for-one change the results of the usual LT. Hence the assumption of anisotropy of light speed (X and X' to take various nonzero values) and the assumption of isotropy of light speed ($X = X' = 0$) are entirely the same in effect. That is to say, the space-time theories under the Circuit Principle and Einstein's special theory of relativity have predicted the same observable effects. Any physical experiment, only if it has negated the GLT which takes certain values of X and X', then has negated all GLT which takes all other values of X and X' (including $X = X' = 0$). Hence all GLT which takes various possible values of X and X' are equivalent each other, so are equivalent with the usual LT of the special theory of relativity, and there is no question of the only correct values of X and X'. As far as observations and experiments are concerned, one can adopt any view he wishes, as long as it is consistent with the fact that the circuit speed of light is *c*. For most problems the most convenient assumption is still that of isotropic space, i.e., the Einstein's principle of the constancy of the one-way speed of light.

The above cognition means that the value of the one-way light speed in any inertial system can be arbitrarily choose within a certain range, according to which the clocks in different places can be calibrated. Therefore, the simultaneity relation in every inertial system contains a kind of conventional factor that cannot be eliminated. The various possible conventions are all equivalent for observations and experiments.

The above points of view can be called the view of conventionalism of the one-way speed of light and synchronization of clocks, or VCS for short.

As we know, Einstein's principle of the constancy of the one-way speed of light is devoid of experimental basis. The principle of the constancy of the one-way speed of light is not examinable, and is artificial and excessive postulate. As Einstein said, "it is a prescript by me according to my free volition for definition of synchronization." [3] Hence although Einstein has not put forward the Circuit Principle, and has not also derived GLT from the Circuit

Principle, but the view of conventionalism of the one-way speed of light must be claimed by him.

Is the VCS correct or not?

We first point out that these two theories do predict almost identical observational effects with differences beyond the general experimental accuracy when the problem does not involve the opposite principles, concepts and inferences, such as the absolute reference frame and vacuum background field, the absoluteness of simultaneity and time sequence, superluminal motion, etc. Both the closed light path experiment and the moving light source experiment (see Chap. 8) belong to this observation effect.

As mentioned above, the special theory of relativity derives the effects of time delay, length contraction and mass increase from the principle of relativity and the principle of constancy of light speed. In the special theory of relativity, these are measurement effects with the completely relative and reciprocal nature. However, observation and experiment are always carried out in a certain inertial system, and the verification of these relativistic effects will not be directly affected by the relative and reciprocal nature of these effects. In addition, the study of Standard Space-time Theory found, even if we proceed from the inverse proposition of relativity principle, that is, the absolute reference system principle, coupled with the principle of the constancy of the average circuit speed of light, the difference of the results derived in this way is only reflected in the correction of the factor $\alpha = 1 - \boldsymbol{u} \cdot \boldsymbol{v} / c^2$ (which is very close to 1) to replace 1, which is beyond the general experimental accuracy. Here, $\boldsymbol{u}, \boldsymbol{v}$ are respectively the velocity of the observed object and the inertial system of reference. Thus, within a certain range of accuracy, the special theory of relativity, like Standard Space-time Theory, describes the dependence of the space and time properties of matter on the motion of matter.

Experiments involving spatial anisotropy cannot be judged between the two theories. Why? Please see the relation of the two theories given in the previous section about the space-time coordinate, velocity, space-time coordinates differential operator, which is essentially the "relation" between these corresponding physical quantities of the two theories. Generally speaking, one theory gets one result about a certain physical quantity (e.g., velocity), and the other theory does not get the same result, but adds, subtracts, multiplies, divides a certain quantity over that result. Applying these "connections" to experimental predictions and analyses will give the results of the two theories that can replace each other.

Taking the transverse Doppler's effect as an example, Standard Space-time Theory leads to (8.17), and the special theory of relativity leads to (8.18). The only difference between the two formulas is that there is one more term $(\boldsymbol{u} \cdot \boldsymbol{v} / c^2)$ in Eq. (8.17), which is extremely small and beyond the accuracy of general physical experiments. Not only that, the speed u in Eq. (8.17) and the speed u_r in Eq. (8.18) are measured respectively according to the different synchronization method of clocks at different places in the two theories. If one obtains the experimental results accord with the predictions (8.18) by synchronizing clocks at different places according to the method in the special theory of relativity (isotropy of light speed), then, in virtue of Eq. (11.26), substituting it into Eq. (8.18) we obtain Eq. (8.17). That is to say, in Standard Space-time Theory apprehension, space anisotropy has been obliterated by synchronization method of clocks of the special theory of relativity. If one synchronizes clocks at different places according to the method in Standard Space-time Theory (anisotropy of light speed), obtain the experimental results accord with the predictions (8.17), then, in virtue of Eq. (11.26), substituting it into Eq. (8.17) we obtain Eq. (8.18). That is to say, in the special theory of relativity apprehension, the space would have been isotropic, and the anisotropy of experimental results is brought about by the synchronization method of Standard Space-time Theory. Whether experimental results have manifested a slight anisotropy of space or not, is dependent on whether the synchronizing clocks at different places introduces the anisotropy of space or not. At this sense, the two theories have predicted the same observational effects. Therefore, the experiment cannot make a judgment between the two theories.

As to the problem about space isotropy or anisotropy of the inertial mass of a moving body or particle in an ordinal reference frame, we can make the same statement. Both the special theory of relativity and Standard Space-time Theory require that the conservation law of momentum hold true in any inertial reference frame according to the assumption of spatial uniformity, from which the expressions of mass increase effect of a moving body or particle with its speed are obtained respectively

$$m = \frac{m_{0\mathrm{r}}}{\sqrt{1-u_{\mathrm{r}}^2/c^2}}, \tag{11.32}$$

$$m = \frac{m_0}{\sqrt{(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2 - u^2/c^2}}. \tag{11.33}$$

Noticing that according the special theory of relativity and Standard Space-time Theory, to the same body or particle, its rest masses m_{0i} measured in any frame are the same, and are equal just the rest mass m_0, and

$$m = m_{0\mathrm{r}}. \tag{11.34}$$

But by the difference in time coordinates introduced from the different synchronization methods of clocks at different places in the two theories we obtain Eqs. (11.25) and (11.26). Using them (to get rid of the prime of u_{r}') and substituting them and (11.34) into (11.32) or (11.33) we obtain

$$m_{\mathrm{r}} = m\left(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2\right), \quad m = m_{\mathrm{r}}\left(1+\boldsymbol{u}_{\mathrm{r}}\cdot\boldsymbol{v}/c^2\right). \tag{11.35}$$

That is to say, space anisotropy of the inertial mass of a moving body or particle in an ordinal reference frame in Standard Space-time Theory is introduced by synchronizing clocks at different places according to the method of Standard Space-time Theory (anisotropy of the one-way speed of light). When we consider the difference in time coordinates introduced from the different synchronization methods of clocks at different places, they have practically predicted the same observational effects.

To sum up, to experiments relating to space isotropy or anisotropy such as the Doppler frequency shift of moving light source and the mass of moving body or particle, one obtain the experimental results accord with the prediction (space isotropy) of the special theory of relativity by synchronizing clocks at different places according to the method in the special theory of relativity (isotropy of light speed), this is commensurate to or equivalent to that one obtain the results accord with the predictions (space anisotropy) of Standard Space-time Theory by synchronizing clocks at different places according to the method in Standard Space-time Theory (anisotropy of light speed), and vice versa. Whether experimental results have manifested a slight anisotropy of space is dependent on whether the synchronizing of clocks at different places introduces the anisotropy of space or not. At this sense, the two theories have predicted the same observational effects.

The above is just one aspect of the problem. The following describes the other aspect of the problem, namely, the sharp opposition between the two theories.

11. 2. 2. Standard Space-time Theory is not Equivalent to Special Theory of Relativity. The Sharp Opposition of the Two Theories

The view of conventionalism asserts that the GLT and its corresponding space-time theory about the possible values of the light speed parameters are all equivalent to each other and therefore to the usual LT and its special theory of relativity, and all of them predict the same observational effect. This argument is correct only on the premise of maintaining the principle of relativity. However, applying of this assertion to the relationship between Standard Space-time Theory and the special theory of relativity is totally untenable. Although Standard Space-time Theory and the special theory of relativity predict many almost identical observational effects, unlike the GLT and its corresponding space-time theory of other values of X and X', Standard Space-time Theory have the connotation of sharp conflict with the non-conventional components of the special theory of relativity. This is manifested in the principles, concepts, and inferences that are opposed to the special theory of relativity. The study of physics is by no means limited to quantitative calculations based solely on equations and formulas. More importantly, first of all, it must be considered and analyzed on the basis of physics principles, concepts and inferences. There are many significant differences between Standard Space-time Theory and the special theory of relativity in basic principles, concepts and inferences. When the problem involves opposing principles, concepts and inferences, there are sharp oppositions between the two theories.

(1) In accordance with different basic assumptions, there are fundamental differences between the special theory of relativity and Standard Space-time Theory in terms of the values of the light speed parameters X and X'.

The special theory of relativity is based on the principle of relativity and the principle of the constancy of the one-way light speed. For the special theory of relativity, according to the principle of the constancy of the one-way speed of light, must take $X = X' = 0$. If we replace the principle of the constancy of the one-way light speed with the principle of the Circuit Principle, still retain the principle of relativity, for the inertial coordinate system $K(x, y, z, t)$ and $K'(x', y', z', t')$ involved by the space-time coordinate transformation, the light speed parameters X and X' can certainly take many possible values, but the values are not completely arbitrary. Note that the relativity principle holds that all inertial systems are equivalent or equal rights. Therefore, X and X' must take constant values independent of the characteristics of the inertial reference system (e.g., the characteristic velocity $\boldsymbol{v}$ of the inertial reference system), otherwise, it must be contrary to the principle of relativity.

To Standard Space-time Theory, the value of the one-way speed of light is not an artificial and arbitrary appointment.

In Standard Space-time Theory, what is the value of one-way light speed is a logical conclusion derived from the basic assumptions of the theory itself. Standard Space-time Theory has affirmed the existence of the absolute frame in which space appears to be isotropic. Only in this frame there is the strict isotropy of the cosmic background radiation, which degree of anisotropy represented by temperature undulation is $\delta T / T \sim 10^{-5}$. Hence in the absolute frame the one-way speed of light is isotropic necessarily. As W. Pauli said, this is the genuine essence of the old ether theory. For an inertial reference frame space appears to be isotropic, if one presumes further that to another or any reference frame moving uniformly in a straight line with respect to the former space appears also to be isotropic, like Einstein's special theory of relativity presume, that is unnatural and strained. Standard Space-time Theory does not require this strained and additional assumption. Starting from the above two principle based on the experimental facts Standard Space-time Theory has obtained that the one-way speed of light with respect to any ordinary inertial frame is anisotropic and $X = -\beta = -v / c$. The greater the velocity of motion of the ordinary inertial frame to the absolute reference system, the greater the degree of anisotropy of the light speed in it. In a word, in Standard Space-time Theory, the values of the one-way speed of light ($X_a = 0, X = -\beta$) are not an appointment but a necessary result of the theory; VCS is incorrect, $X_a = 0$, $X = -\beta$ are only correct values.

(2) The basic postulates as the axiomatic system of Standard Space-time Theory meets the requirements of authenticity (or objectivity), and the basic assumptions of the special theory of relativity violates precisely this indispensable requirement.

As stated in the introduction, the axiomatic method plays a very important role in the progress of the whole science. The axiom system must satisfy the three requirements of independence, completeness and harmony (or consistency), that is, the axioms constituting the axiom system must be not many, not less and not contradictory. In detail, the so-called independence means that every axiom in an axiom system cannot be proved by the other axioms in the axiom system by logical reasoning; on completeness there are different understandings, one understanding is that all axioms in the axiom system are sufficient to describe the object discussed in the axiom system and cannot add the new axiom to the axiom system; The so-called harmony (or compatibility) means that all axioms in the axiom system and all propositions deduced from them cannot be contradictory to each other. The special theory of relativity, like Standard Space-time Theory, satisfies the three requirements of independence, completeness and harmony (or compatibility).

In my opinion, an axiom system should not only meet the requirements of independence, completeness and harmony, but also meet the requirements of authenticity (or objectivity) at least for the theoretical system of physics, that is, each axiom of the axiom system should conform to objective reality, and they should be the summary or expression of objective or experimental facts.

As mentioned earlier (see Introduction, Chapter 3 of this book, etc.), the relativity principle of the special theory of relativity has been denied by astronomical observation. Einstein's principle of the constancy of the one-way speed of light is an artificial stipulation and an excessive assumption lacking the experimental basis. On the contrary, the principle of absolute reference frame and the Circuit Principle of Standard Space-time Theory have a solid experimental basis. Therefore, differently from the artificial stipulation of the special theory of relativity, Standard Space-time Theory adheres to the viewpoint of "objective realism" in the logical starting point. If an axiom system not only meets the requirements of independence, completeness and harmony, but also meets the requirements of authenticity (or objectivity), and starting from the reliable basic assumptions, and seriously and accurately carrying out logical reasoning and mathematical calculus, only such a theory will be able to reflect the essence of nature.

(3) Absolute reference frame, vacuum background field and dispersion state matter

The special theory of relativity is based on the principle of relativity, and time delay and length contraction are relative and reciprocal effects. Standard Space-time Theory holds that there is an absolute reference system, and both the time delay and length contraction are the result of the interaction of the object with the vacuum background field, which has absolute significance. Therefore, the former cannot while the latter can be compatible with observational facts such as modern cosmology and cosmic background radiation; the former exists and the latter does not have the slide-down paradox.

The special theory of relativity restores the image of the vacuum that is the void space with nothingness, so it can talk about and describe matter and motion of the matter only relative to the reference system attached to an object system.

The philosophical basis of Standard Space-time Theory is the aggregated-dispersed states natural images of the material world, which holds that matter can be divided into two different forms, namely, aggregated state and dispersed state; vacuum is not empty, the vacuum background field as the dispersed-state matter is the background of all material processes, and it is also the carrier of electromagnetic field. Therefore, it can understand and explain the homopolar magnetic induction experiments. The phenomena such as the cosmic background radiation and the homopolar magnetic induction reveal the existence of background space.

(4) Absoluteness of simultaneity and absoluteness of time order

On the premise that there is an absolute reference system showing isotropy in space ($X_{\mathrm{a}} = 0$), Standard Space-time Theory obtained $X = -\beta$, which is the only value that can lead to the absoluteness of simultaneity and the absoluteness of time sequence. This is an important corollary of Standard Space-time Theory, and it is also a qualitative leap of the concept of time. Any other value of the light speed parameter cannot get this result. This is completely opposite to the relativity of simultaneity and the relativity of time order in the special theory of relativity. Thus, contrary to the special theory of relativity, Standard Space-time Theory allows superluminal motion to exist without violating causality.

(5) Superluminal motion and non-locality

The standard space-time theory breaks the limit theory of the speed of light. Its theoretical predictions do not conflict with the existence of superluminal motion, but are compatible with the non-locality of quantum mechanics, and are consistent with all observed experimental facts.

Einstein’s principle of limitation of light speed and principle of locality are important corollaries of the special theory of relativity. The experimental facts show that above Einstein’s two principles gave artificial and false descriptions of nature. Standard Space-time Theory breaks the principle of limitation of the light speed. Its theoretical predictions do not conflict with the existence of superluminal motion, but are compatible with the non-locality of quantum mechanics, and are also consistent with all observed experimental facts. Standard Space-time Theory gives a unified theoretical description of subluminal motion and superluminal motion.

To look at Standard Space-time Theory again, we can understand it as follows: the concept of time in Standard Space-time Theory is qualitatively close to that in quantum mechanics, that is, the simultaneity and time order of any two events is absolute, and all inertial reference frames will get the same judgment and result; and quantitatively close to that of time delay in the special theory of relativity, that is, the properties of space and time of matter and their measurements are related to the state of matter's motion. It is, however, a real delay, not a relative and reciprocal property as described by the special theory of relativity. Is not that logical conclusion drawn from the two basic postulates in Standard Space-time Theory exactly the proper meaning of the development of modern physics? Is not this exactly the perfect synthesis of the truth elements of quantum mechanics and the special theory of relativity!

The special theory of relativity must make a wrong judgment on the nature of the world because of its concept of void space with nothingness and the artificial hypothesis of the constancy of the one-way light speed. The special theory of relativity must make the logical conclusion, that is, to deny the existence of the dispersed state matter and the superluminal motion. This negates one of the two classes of matter (i.e., aggregated state and dispersed state) and one of the two classes of motion (subluminal and superluminal). This is not a question of the accuracy of the theoretical description, but a major qualitative error. Denying and discarding half country of the matter and its motion, and leaving them beyond theoretical description and investigation, inevitably blocks the way to the discovery of truth. Obviously, only by breaking through the space-time concept of the special theory of relativity can we achieve a truly higher level of development.

To sum up, Standard Space-time Theory is not equivalent to the special theory of relativity, and it is a new theory that accords with the standard of theoretical progress. Time will lead mankind to approach truth and accept truth. Through the accumulation of more experimental facts, Standard Space-time Theory will be widely accepted.

11. 3. Talk about Newton's and Einstein's Views of Space and Time again

The second chapter of this book has discussed Newton's absolute space-time view and Einstein's relativity space-time view. Although this chapter is a review of the book, some repetition is inevitable, but excessive repetition will be tiresome. It is often said that the highest state of physics is philosophy, and the highest state of philosophy is religion. Indeed! After the construction and narration of the whole Standard Space-time Theory, this section will focus on investigating Newton's absolute space-time view and Einstein's relativity space-time view from the philosophical perspective. From this we can see the comparison between Newton's and Einstein's thinking power of logical reasoning and the imagination of natural images. I give Newton my highest praise.

11. 3. 1. On Newton’s Absolute View of Space-Time again

As mentioned in Sec. 2. 2, in modern language, Newton’s absolute view of space-time can be decomposed into the following three elements :(1) the objective reality of space and time; (2) concepts of absolute space and absolute time; (3) the irrelevance between space-time and the motion of matter. The relevant contents have been elaborated in details in Sec. 2.2. Please review and peruse it now.

Newton introduced the concept of absolute space to judge the motion state of all things in the universe. The reference system in which Newton's law of inertia holds, that is, the reference system in which an object keeps its state of rest or uniform linear motion unchanged without force, is called inertial reference system, or inertial system for short. Newton laid a solid foundation for his theory. At the same time, it means that Newton's scientific thought actually goes further, that is, the absolute space filled by the continuous diffuse medium is the absolute inertial reference system of course.

Notice my statement: According to Newton, although absolute space is not directly perceived by the senses, it’s an objective, real existence; Absolute space is the absolute inertial reference frame, referred to as the absolute reference frame. The discovery of the cosmic microwave background radiation confirms Newton’s predictions of the absolute space and absolute reference frame.

Newton emphasized in *Principle* [4] that absolute space is “true space”, absolute time is “true time” and absolute motion is “true motion”. Speaking of the “absolute place”, Newton said, “But because the parts of (absolute) space cannot be seen, or distinguished from one another by our senses, therefore in their stead we use sensible measures of them.... But in philosophical disquisitions, we ought to abstract from our senses, and consider things themselves, distinct from what are only sensible measures of them.” He believes that relative time, space and motion are only a “representation”. In short, in Newton’s view, absolute space, time and motion are all true things and true existence. However, we cannot directly perceive it through our senses, but can only understand and grasp it through the “representation” of relative time, space and motion perceived by our senses.

Newton said, “It is indeed a matter of great difficulty to discover, and effectually distinguish, the true motion of particular bodies from the apparent; because the parts of that immovable space, in which those motions are performed, do by no means come under the observation of our senses. Yet the things in not altogether desperate; for we have some arguments to guide us, partly from the apparent motion, which are the differences of the true motion; partly from the forces, which are the causes and effects of the true motions.” “The causes by which true and relative motions are distinguished, one from the other, are the forces impressed upon bodies to generate motion.” said Newton, “True motion is neither generated nor altered, but by some force impressed upon the body moved; but relative motion may by generated or altered without any force impressed upon the body. For it is sufficient only to impressed some force on other bodies with which the former is compared, that by their giving way that relation may be changed, in which the relative rest or motion of this other body did consist. Again, true motion suffers always some change from any force impressed upon the moving body; but relative motion does not necessarily undergo any change by such forces. For if the some forces are likewise impressed on those other bodies, with which the comparison is made, that the relative position may be preserved, then that condition will be preserved in which the relative motion consists. And therefore any relative motion may be changed when the true motion remains unaltered, and the relative motion may be preserved when the true suffers some change. Thus, the true motion by no means consists in such relations."

As long as you read carefully, Newton's statements are actually very clear.

Newton thought that the absolute rotation (that is, the rotation relative to the absolute space) could be observed. "The effects which distinguish absolute from relative motion are, the forces of receding from the axis of circular motion." Newton proposed two famous experiments involving absolute rotation to observe and recognize absolute rotation: One is the rotating bucket experiment; one is the spin two-ball experiment. In Sec. 2.2 the introduction of the rotating bucket experiment has been made. The absolute motion of water (or bucket) is a combination of the translation of water (or bucket) with respect to absolute space and the rotation of water (or bucket) about its axis of symmetry with respect to absolute space, if the effect of the earth's rotation is ignored (the angular velocity of the earth's rotation is relatively negligible). The bucket experiment clearly shows that the relative motion between the water and the bucket is not the cause of the concave in the water surface; the concave surface of the water shows the true absolute (that is, relative absolute space) rotational motion of the water.

Absolute rotation is observable; observation of absolute rotation shows the existence of absolute space. This is an important idea of Newton. It is of great value not only in the field of mechanics, but also in other fields of physics such as electromagnetism. The experimental phenomenon of homopolar magnetic induction described in Chap. 10 shows the existence of background space through the rotation of axisymmetric cylindrical permanent magnets.

Therefore, according to Newton, (1) the objective reality of space and time, and (2) absolute space and absolute time as an objective existence, are certain. So, what effect does the existence of absolute space and absolute reference frame have on the motion of matter? Newton made a series of experiments (such as the pendulum experiment) to discover the effect of absolute space (ether) on the motion of matter. We now know that this effect is reduced to an order of magnitude of u^2 / c^2, where the meaning of $\boldsymbol{u}$, and c is the same as before. Newton must have gotten zero results. Newton learned from his experiments that if the ether did exist, its effect on the motion of matter with form and image was negligible. This means that the ether is not the usual material. The ether is an invisible, weightless, dispersion state matter of very different properties. It forms the backgrounds of motion of all tangible matter. It is also the medium through which all interactions take place.

It can be inferred that Descartes' "Etheric vortex theory", which holds that the Etheric vortex can carry the planets around the sun, is just a kind of imagination, which exaggerates the effect of the ether on tangible matter. According to the Descartes' "Etheric vortex", the shape of the earth should be a polar radius longer than the equatorial radius; Newton's law of gravity showed the opposite, with the poles flatter than the equator. This is the sharp opposition between the two systems of the universe and is also the two directly testable scientific predictions. It was because the shape of the earth predicted by Newton was confirmed by field measurements that Europeans (especially the French, with their strong national pride) finally abandoned the Descartes' theory and accepted the Newtonian system.

Since it is not possible to discover the effect of the ether, which constitutes absolute space, on the motion of tangible matter, the laws of mechanics have the same form in different inertial systems of uniform linear motion. So, in the *Principle*, Newton followed up the three laws of motion and gave the principle of relativity. This is the Galilean principle of mechanical relativity.

The above discussion shows that the main part of Newton's view of space and time, that is its first and second elements (especially the concepts of absolute space and absolute reference frame), are correct and still guide the way of scientific exploration. With the progress of The Times, scientific experiments become more and more elaborate, the idea of being able to confirm that it has to give up and has to change is the third element of it, that is, the irrelevance of space-time to the motion of matter. The third element of Newton's view of space and time reflects the limitation of scientific understanding caused by the impossibility of discovering the weak influence of absolute space and time on the motion of matter at the beginning of the development of science and technology. This should not be demanding from our predecessors.

Despite the criticism and questioning of his contemporaries Huygens and Leibniz, Newton's concept of absolute space and absolute space has been generally accepted for more than two hundred years. After Einstein's theory of relativity gained wide acceptance, people always referred to Newton's absolute view of space and time in a derogatory sense, as if it were a metaphysical historical trace that could be brushed aside and dismissed. This is a very one-sided understanding.

Newton was the greatest scientist since the beginning of the history. What else can we ask of Newton, since he so effectively constructed the grand system of the universe in this way of thinking, and the world has been using it for 300 years? Has there ever been a way to give us more real knowledge of the world? Newton had the highest power of thought and creativity, and did the greatest work that could be done in his time. I give Newton the highest praise. He is indeed the symbol of the highest wisdom of mankind.

11. 3. 2. On Einstein's Views of Space and Time again

This section will explain that Einstein's special theory of relativity is the inheritance and full play of Mach's philosophical views. Let's start with Mach and Mach's philosophy.

Who's Mach? E. Mach (1838 — 1916) was an Austrian, a distinguished physicist, physiologist, psychologist, and a philosopher of great influence. Maher was primarily devoted to the study of experimental physics and was also a critical theoretical physicist.

We should not be immersed in an absolute, one-sided thinking: for example, to comment on someone or something, good is absolutely good, bad is absolutely bad. This is not the way things really are. This is especially true to Mach.

Mach is full of humanistic spirit, pursues truth, loves peace, upholds justice, is concerned about the future and destiny of mankind, devotes himself to the cause of emancipating the human mind, and has a high sense of social responsibility. Mach was a freethinker of rare independent judgment. The process of his thought is based on his own judgment and choice, and the only presupposition is the adaptation of thought to facts and the adaptation to each other between thought to thought, rather than the superstition and blind obedience to the supreme authority and the eternally immutable dogma. Mach advocated the spirit of skepticism and freedom of thought, and insisted that science must continue to develop.

Mach wrote several books with a strong epistemological and historical perspective. Among them, the book *The Science of Mechanics*: *A Critical and Historical Account of its Development* (referred to as *The Historical Commentary on Mechanics*) has spread almost all over the world and has had a profound impact on the development of physics. This book is a systematic criticism of Newton's mechanical system by Mach. Mach opposed the mechanistic view of reducing all natural phenomena to mechanical phenomena, attributing all changes to mechanical changes, and explaining all natural phenomena by mechanical motions. The enlightenment criticism of Mach awakened the dogmatic physicists, cleared the way for the further development of physics, and gave the first sound of the revolution of physics at the turn of the century. Einstein and several physicists at the Copenhagen school of quantum mechanics were deeply influenced by Mach's ideas.

The defect of Mach's life lies in the one-sidedness of his philosophical thought. Mach's research fields range from science to the history of science, and then to the epistemology of science. Mach inherited the ideological lines of the subjective empiricism of British philosophers G. Berkeley and D. Hume and the positivism of French philosopher A. Comte.

According to Mach, the world is made up of neutral elements, and both material and spiritual things are the complex of such elements. The elements are color, sound, pressure, space, time, what we usually call feeling. He believed that matter, motion and law were not objective things, but only useful assumptions in people's lives.

In book *Materialism and Empiricism* (1908) Lenin one-sidedly described Mach as nothing is right, and made a sharp criticism of Mach philosophy. Lenin called Mach's philosophy a "reactionary philosophy" and Mach was a "petty philosopher" and "learned associate of theologians". Lenin's criticism, which Mach saw as far removed from the problem, was not defended.

What kind of philosophy is Mach's philosophy? In 1926, M. Schlick gave a speech [5] on "Philosopher Mach" at the unveiling of the bronze statue of Mach held by the municipal government of Vienna, which expressed Mach's philosophical views in a concentrated, objective and fair way. M. Schlick said:

"Maher claims that our scientific research can only be based on a single starting point, which can exist in all scientific activities, that is, the sensory world. But according to the general point of view (that is, the simple viewpoint of realism mentioned by Mach), the sensuous sense is the function of the objects (beyond consciousness) existing outside us on our selves. Mach's argument, however, is that this view is not necessary, and on the contrary, this view represents a problematic, redundant, and dangerous interpretation of the facts, because all of our statements that are so-called external statements can only be based on feelings. Thus, according to Mach, the sensation and the combination of sensations can be and must be the sole object of those statements about the external world, there is no need at all to assume an underlying, unknowable reality behind the senses. In this way he rejected the existence of the thing in itself as an unwarranted and unnecessary assumption. An object, a physical object, is nothing more than a compound of sensations, a sensory association with varying degrees of persistence, that is, they are made up of color, sound, heat, pressure, etc. There is nothing in the world but feelings and their interconnections. "

Mach's philosophy attempts to reconcile the opposition between materialism and idealism, and to establish his monism of sensory elements. The philosophy he insisted on was a thorough empiricism. This is the objective evaluation of Mach's philosophy. In essence, Mach's philosophical viewpoint is one of subjective idealism.

The serious defects of radical empiricism lie in the following: (1) it holds that there is no need to assume at all, and thus it actually negates the objective real world that exists behind the senses. (2) But, in fact, what is called experience is the sensation and impression of the surface phenomena of objective things acquired by direct contact with external things through the sense organs. (3) Human cognitive activity is a dynamic, cyclical and even endless process from perceptual knowledge to rational knowledge, and then from rational knowledge to practice on the basis of practice, which involves not only perceptual experience, but also rational thinking. (4) The essence of rational thinking is to admit the existence of the objective real world after feeling; without rational thought, it is impossible to determine the connections between the sensory phenomena and nature behind them, so that human beings cannot become intelligent life, but reduce to ordinary animals. (5) If we deny the objective real world and only admit the perceptual experience, we will put the unknown world (such as the dispersion state background field and many physical processes in the microscopic world) that human beings cannot perceive temporarily out of the vision of scientific exploration. For example, electromagnetic waves, gravitational waves, atoms and atomic energy, absolute reference system cannot become the object of scientific research and enter the field of technological application. I'm just going to make a brief discussion here; for a detailed exposition, see my book *Meditation on Modern Materialist Philosophy*. [6]

For a long time (from about 1865 until 1908, when experiments confirmed the existence of atoms), Mach criticized and rejected atomism, which he wanted to prove as a theory was inappropriate and dangerous. He objected to the assumption that the concept of the atom had a realistic or ontological meaning. In his opinion, the concept of atom is the theoretical entity of this metaphysics and should be deleted naturally.

Later, atomic theory achieved great success and even proved the existence of atoms. Einstein went to Vienna to visit Mach in September 1913, and to ask Mach such a question: If it is proved that it is possible to predict a property of a gas by assuming the existence of atoms—a property that cannot be predicted without the atomic hypothesis, and this is a kind of property that can be observed, —so what position should he take? At that time, Mach replied that if it was possible for the atomic hypothesis to make a logical connection between certain observable properties, which could never be made without the hypothesis, he would have to accept the atomic hypothesis. In such cases, it should be "economical" to assume that atoms may exist, because one can deduce the relationship between observations from this. We see that Mach accepted the atom theory, which had been so successful, that is still starting from the standpoint of radical empiricism and the economic principles of thought.

Mach's *The Historical Commentary on Mechanics* makes a historical investigation of the concepts and principles of mechanics. As mentioned above, on the one hand, this book is of progressive significance because it criticizes the mechanistic viewpoint and clears the obstacles for the further development of physics; on the other hand, from the empirical viewpoint, it denies Newton's concept of absolute time and absolute space, and gives a purely relativistic understanding of the nature of inertia, which deeply affects the later development of physics. The idea of pure relative motion first came from Mach.

According to the views of thorough empiricism, it is easy for readers to expect that Mach only recognizes the existence of heavy substances with shape and image which can produce the feeling of "different degree of permanence" (the "substances" in the following Mach quotations all refer to such substances). As for that kind of the matter in dispersion state no shape and image that also didn't find any physical effect at that time (qi of the intangible universe, ether or vacuum background field), he rejected it as a "groundless and unnecessary assumption". According to the logic of Mach, Newton's concept of absolute space is rejected of course. He even wanted to exclude the concept of "space" in general.

Mach not only has an unbreakable skepticism and independent critical spirit, but also has enough intelligence to support his skepticism and criticism. Mach's critique of the Newtonian view of the bucket experiment demonstrated his great intelligence and had a great impact on physics.

In Chap. 2 (Sec.7) of Mach's *The Historical Commentary on Mechanics*, "a general critique of Newton's views", he describes his opposition to Newtonian absolute space. "For me, there is only relative motion," Mach wrote, "Centrifugal force occurs when an object revolves relatively stationary stars; when it rotates relative to something other than fixed stars, no centrifugal force is created." What Mach meant was that the effect of other nearby objects on rotating water was negligible compared to the effect of stationary stars on rotating water. "Newton's experiments with the rotating bucket only tell us that the relative rotation of water against the wall of the bucket does not cause significant centrifugal force, which is caused by the rotation of water with respect to the earth and other celestial bodies. If the walls of the bucket get thicker and heavier, until they are several kilometers thick, no one can say what the results of the experiment will be."

The above ideas of Mach are generally summarized as the "Mach Principle", which can be expressed as follows: there is only relative motion, and all motion is relative to some tangible physical entity; The inertial forces acting on an object are caused by the accelerated motion of the object relative to the distant stars and the entire distribution of matter in the universe. The material distribution here refers to the distribution of tangible matter, and in the mind of Mach, there is only the distribution of tangible matter.

According to Mach, the concave of the water surface in Newton's water bucket is related to its relative rotation with respect to the distribution of matter in the universe, including all stars. The rotation of an object relative to the distribution of matter in the universe is equivalent to the rotation of the distribution of matter in the universe relative to this object. According to Newton's concept of absolute space, if the bucket and water do not rotate and to make the stars in the universe revolve around the bucket and water, the water must remain level. Newton's concept of absolute space makes absolute motion and absolute acceleration meaningful. But, according to Mach's view, if the bucket and water do not rotate, and try to make all the stars in the universe rotate around the bucket and water, the water surface will also be concave into a paraboloid. That is, according to the Mach principle, only relative motion and relative acceleration make sense. This is the exact opposite of Newton.

As for Mach principle, the following comments can be made.

First, Mach firmly denies absolute space and absolute motion, but according to Mach's principle, he introduces another absolute reference system, which is the inertial reference system determined by the distribution of all matter with shape and image from distant stars to the whole universe.

Second, according to Mach principle, the inertial mass is anisotropic in space. According to Mach, the inertial force acting on an object is caused by the accelerated motion of the object relative to the distant stars and even all the matter distribution in the whole universe. It is actually the gravity of all the matter distribution in the universe acting on the object. Therefore, the inertial mass of an object is determined by the distribution of all matter in the universe. According to the nature of gravitation, the distribution of big mass near an object will have the greatest influence on the inertial mass of the object. The Milky Way is a highly flat star system with a diameter of about 50 kpc and a thickness of about 1-2 kpc. The solar system is not at the center of the Milky Way. It is 8 kpc north of the galactic plane and about 8.5 kpc away from the center of the Milky Way. Here 1pc = 3.086 km = 3.262 light years. Therefore, according to Mach principle, when particles accelerate toward or away from the center of Milky Way, the inertia mass will be slightly different. This is the anisotropy of the inertia mass. However, as described in § 6.4, V. W. Hughes etc. and R. W. P. Drever etc. have done anisotropic experiments on the inertial mass, and the result is $(\Delta m)/m_0 < 5\times10^{-20}$ or 5×10^{-23}, that is, confirm that the inertial mass is spatially isotropic.

Third, I would like to point out that Mach only recognized the existence of the substances which are with shape and image and can produce "lasting feelings of different degrees", and denies the existence of absolute space and the dispersion media which is no shape and no image and outside of feelings (ether, qi of the intangible universe or vacuum background field). However, there are two sides to everything, these means that Mach accepts the existence of the void space with nothingness, and his gravitational action must be a kind of action at a distance.

Fourth, I would like to further point out that Mach's assertion that "the concave of the water surface in Newton's water bucket is related to its relative rotation with respect to the distribution of matter in the universe, including all stars" can only be established on the premise of admitting the existence of the void space with nothingness and the action at a distance. If the vacuum is not empty, the vacuum is full of the background field of dispersion media, the gravitational action of stars is realized through the contact action of the gravitational field, according to the principle of cosmology, the universe is highly homogeneous and isotropic, Newton's bucket and the relative rotation of the matter distribution in the universe, apart from the tiny anisotropy of inertial mass caused by the relative rotation of nearby galaxies such as the Milky Way (even this has been denied by experiments), will not cause changes in the gravitational field of the surrounding space inside and outside the bucket. Since this relative rotation will not cause the change of the gravitational field around the bucket, it means that this relative rotation cannot be the reason why the water surface in Newton's bucket is concave into a paraboloid

The third and fourth points are the understanding that I achieved by carefully analysis and thinking. Therefore, the conclusion is that Mach's view on the bucket experiment is not tenable.

We will not discuss Mach and the Mach principle further. The reason why Mach is discussed here is that Mach's philosophy view and physics thought had a great influence on Einstein. In his early years Einstein worshiped and admired Mach as a pioneer of relativity, although Mach himself denied it. Einstein's special theory of relativity does inherit and strengthen the Mach view that only relative motion exists. In the paper "Relativity: The Nature of Relativity", Einstein wrote, "The name 'relativity' has something to do with the fact that, from a possible empirical point of view, motion always shows the relative motion of one object to another (such as the car to the ground, or the earth to the sun and stars). Motion can never be observed as 'motion relative to space', or 'absolute motion'. In its broadest sense, 'the principle of relativity' is contained in the following statement: All physical phenomena have the feature that they do not provide any basis for the introduction of the concept of 'absolute motion'; or in a relatively short but less precise way, there is no absolute motion." [7] (455)

Of course, Einstein's own view also is in the process of change or swing. Later, general relativity actually began to restore the image of ether, and the physical space of general relativity played the role of ether. In 1931, Einstein said, "The belief that there is an external world independent from the subject of perception is the basis of all natural sciences." [7] (p.292) In 1948, Einstein wrote to his friend M. Besso in his youth, "I think Mach's weakness lies in his belief that science is only an arrangement of empirical materials, that is to say, in the formation of concepts, he did not recognize the elements of free construction. He even came to the point where he not only regarded 'feeling' as the only material that must be studied, but also regarded 'feeling' as the brick to build the real world. Therefore, he believed that he could overcome the difference between psychology and physics. As long as he carries out this idea to the end, he will not only negate atomism, but also negate the concept of physical reality." [7] (p.438) These views expressed by Einstein in 1931 and 1948 are undoubtedly correct.

Regardless of the later changes in philosophic thinking, Einstein highly praised Mach's thought in the early years, and regardless of Mach's categorical negation, Mach's philosophy is indeed the pioneer of the special theory of relativity. The special theory of relativity, founded in 1905, does inherit and strengthen Mach's view: It only admits the existence of ponderable matter with shape and image, categorically denies the existence of dispersed medium no shape and no image; it only admits the existence of relative motion, categorically denies the existence of absolute space and absolute motion. The foundation of this theory is the subjective idealism of thorough empiricism.

In order to negate absolute motion, firstly need to negate ether, absolute space and absolute frame of reference. The special theory of relativity, like Mach, restores the vacuum as a physical image of the void space with nothingness. Now we have been able to confirm that the basic assumptions and conclusions derived from the subjective idealistic philosophy have been proved wrong by experiments.

11. 4. Comments on the View of Space-Time of the Standard Space-time Theory

As mentioned above, the view of space-time of Standard Space-time Theory abandons the one-sidedness of the absolute space-time view and relativistic space-time view, and inherits and synthesizes their reasonable elements. It is the integrating and upgrading of the space-time concept of Newton and Einstein. Standard Space-time Theory provides a more suitable framework for understanding and describing physical world and natural phenomena. This section makes further elaboration and explanation on several issues.

11. 4. 1. Failure of Relativity Principle

First of all, on the basis of experimental facts, Standard Space-time Theory holds that there is a special superior inertial reference system, which is the standard inertial system (or absolute reference system); there is absolute motion, which is the motion relative to the standard inertial system or absolute reference system. Standard Space-time Theory uses the standard inertial system principle (or absolute reference system principle) as one of the two basic postulates. Obviously, Standard Space-time Theory holds that the principle of relativity is no longer valid.

Second, according to the principle of relativity, physical phenomena are carried out in the same way in all inertial systems. According to Fokker [8], if a process can be described as a function $\varphi_j(x)$, $j=0,1,2,3$, in the coordinate system (x), then there will be another process, which can be described as the same function $\varphi_j(x')$, $j=0,1,2,3$, in the coordinate system (x'), and vice versa. Examining the formulas of Standard Space-time Theory, most of them contain the characteristic velocities $\boldsymbol{v}_j\,(j=1,2,3)$ of inertial system. For example, the dynamic equation (5.57) of Standard Space-time Theory about the subluminal particles in the general inertial system can be written as (the characteristic velocity of the inertial system is expressed in $\boldsymbol{v}$):

$$\boldsymbol{f}=\frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t}=\frac{\mathrm{d}}{\mathrm{d}t}\frac{m_0\boldsymbol{u}}{\sqrt{\alpha^2-u^2/c^2}}=\frac{\mathrm{d}}{\mathrm{d}t}\frac{m_0\boldsymbol{u}}{\sqrt{(1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2)^2-u^2/c^2}}. \tag{11.36}$$

The problem is that for different inertial systems, the sizes and directions of $\boldsymbol{v}$ are different, that is, $\boldsymbol{v}$ is different vectors. Therefore, the requirements of Fokker's relativity principle will not be satisfied in Standard Space-time Theory.

Third, according to the principle of relativity, "The phenomenon occurring in a closed system is independent of the non-accelerated motion of the system." [8] However, all formulas of Standard Space-time Theory (e.g., Eq. (11.36)) show that the phenomena occurring in an inertial system are related to the non-accelerated motion of the system, i.e., the characteristic velocity $\boldsymbol{v}$. Therefore, in principle, these formulas can be used to measure the characteristic velocity of the inertial system.

Finally, the "relativity principle of direction" is examined. This principle is "assuming that all directions in space, or all positions in Descartes' coordinates system, are physically equivalent" [9]. If it holds, the inversion transformation of physical laws to space will not change. Newton's dynamic equation and Einstein's relativistic dynamic equation both meet the requirements of space inversion invariance. In Standard Space-time Theory, the dynamic equation and the expressions of momentum, kinetic energy and energy contain a quantity $\alpha=1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2$, where $\boldsymbol{v}$ is a constant vector for the determined inertial system. Under the space inversion (expressed in P), the polar vector changes the sign, and the value of α will change into: $P\alpha=1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2$. Therefore, besides the standard inertial system ($\boldsymbol{v}=0$) keeps the space inversion in-variance, the laws of physics do not have the space inversion in-variance in the general inertial system ($\boldsymbol{v}\neq 0$). The appearance of pseudoscalar $\boldsymbol{u}\cdot\boldsymbol{v}/c^2$ indicates the destruction of spatial inversion. When $v \ll c$, or $u \ll c$, the effect is negligible; when the value of v or u is very large, especially when u exceeds the speed of light (please consider the case of weak interaction), the space inversion asymmetry of the laws of physics will be clearly shown. Therefore, Standard Space-time Theory does not meet the requirements of "the principle of relativity of direction".

In the university physics textbook, the principle of Galileo's mechanical relativity will be first described in detail. According to the principle of mechanical relativity, all the mechanical processes in a reference frame which moves relatively to an inertial frame with uniform linear motion are not affected by the uniform linear motion of the reference frame (as a whole). The principle of Galileo's mechanical relativity can be expressed as follows: In all inertial systems that move in a uniform straight line relative to each other, the laws of mechanics have the same form; or in any mechanical experiment conducted in an inertial system, the motion speed of the inertial system itself cannot be determined.

We can now clearly state that Galileo principle of relativity is only an approximate result that can be established only when the experimental accuracy is not high. Strictly speaking, it is not established. The principle of relativity in the special theory of relativity is the extension of Galileo principle of relativity in mechanics to the whole field of physics. According to Standard Space-time Theory, Galileo principle of relativity in mechanics and the principle of relativity of the special theory of relativity are not valid, or its scope of application is limited. Obviously, only when the absolute speed $\boldsymbol{v}$ of the inertial system and the moving speed $\boldsymbol{u}$ of the matter are satisfied:

$$\boldsymbol{u}\cdot\boldsymbol{v}/c^2 << 1. \tag{11.37}$$

Galileo principle of relativity in mechanics and its generalization, i.e., the principle of relativity in the special theory of relativity are holds true approximately. For subluminal motion, the formulas of Standard Space-time Theory are nothing more than using integral factor $\alpha = 1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2$ or α^2 replacing the number 1 in formulas of the special theory of relativity. When formula (11.37) is satisfied, formulas of subluminal motion in Standard Space-time Theory are simplified to formulas in special theory of relativity. Therefore, in the subluminal regime, Einstein's special theory of relativity is an approximation of Standard Space-time Theory under the above condition $\boldsymbol{u}\cdot\boldsymbol{v}/c^2 << 1$.

11. 4. 2. Standard Theory Covariance Replaces Lorentz Covariance

The principle of relativity holds that the laws of physics have the same form in all inertial systems. According to Einstein's special theory of relativity, from one inertial coordinate system to another, the space-time coordinates satisfy the Lorentz transformation, and the laws of physics keep their forms unchanged. This is called relativistic covariance or Lorentz covariance. It is regarded as the requirement that the equation to express a correct law of physics must meet. Lorentz covariance has dominated and influenced the development of physics since it was proposed in the early 20th century.

According to the experimental facts and theoretical analysis, Standard Space-time Theory firmly believes that the principle of relativity is not established. In this case, physics should give up the Lorentz covariance. What kind of new situation will this bring to modern physics? It is a question that must be carefully considered.

First of all, although the principle of relativity is not tenable, it can be seen from the discussion in Sec. 8.4 that the four-dimensional dynamic equations still meet the equation covariance requirements. Similarly, in the electrodynamics of Standard Space-time Theory, it is not difficult to write the equations of motion of electromagnetic field satisfying the equation covariance. This situation does not cause any contradiction. Under the transformation of the inertial reference system, the property of the invariance of the form of the physical equation is called covariance. As Fokker [10] said, “It is necessary to clearly distinguish the difference between the physical principle of determining the existence of corresponding phenomena in different computing systems and the simple requirement of equation covariance when changing from one computing system to another. It is clear that the covariance of the equation can be obtained from the principle of relativity, and the reverse doesn’t hold true: when the principle of relativity is not satisfied, the covariance of the differential equation may exist.” “The requirement of covariance is well-founded and natural. This is the natural requirement of pure logic, so that the equations written in different coordinates are the same mathematically without prior indication of the coordinate system.” Equation covariance requires that “it is necessary, and it can be achieved everywhere.” Weinberg [11] expressed the same idea in the fourth chapter of Gravitation and Cosmology.

Therefore, according to Standard Space-time Theory, the principle of relativity is not tenable, but the theory and law of physics should meet the requirement of covariance of equations, that is, the equations expressing these theories and laws should keep their forms unchanged under the generalized Galileo transformation. This can be called Standard Theory Covariance. In short, Standard Theory Covariance should replace Lorentz Covariance.

Second, it can be expected that the replacement of Lorentz Covariance by Standard Theory Covariance will not lead to the retrogression of physics; On the contrary, it will bring about the progress of physics. As mentioned in Sec. 11.1.1, considering the difference of time coordinates introduced by different methods of clock calibration in different places of the special theory of relativity and Standard Space-time Theory, the Lorentz transformation and generalized Galileo transformation can be derived from each other by using Eqs. (11.15) and (11.19). Furthermore, many formulas of the two theories can be derived from each other by using the relation between the velocities of the two theories Eqs. (11.23)—(11.26) and the relation between the differential operators of space-time coordinates Eqs. (11.28)—(11.31). This means that the two transformations and two theories predict the same observation effect without involving the opposite principles, concepts and inferences, or more specifically, the absolute reference system and background space, the absoluteness of simultaneity and superluminal motion. In this case, Standard Space-time Theory can “accommodate” the theoretical results of the special theory of relativity according to the above relation substitution. However, in the opposite case, which involves absolute reference system and background space, the absoluteness of simultaneity and superluminal motion, as described in Sec. 11.2.2, the special theory of relativity falls into the trap of theory, showing a serious conflict between the concepts of time of the special theory of relativity and quantum mechanics; in this case, Standard Space-time Theory definitely gives a correct description of the nature. It will certainly bring about progress in physics.

Finally, I would like to comment on Dirac's passage. In 1979, Dirac [12] said in his report "Why Do We Believe in Einstein Theory" at the Einstein Memorial conference in Princeton, USA, "The further development of Lorentz transformation theory shows that when you try to establish an electronic motion equation consistent with Lorentz transformation and the basic laws of quantum mechanics, You're bound to get a theory that explains the spin of the electron. If we go further, we will lead to the existence of antimatter. These are the consequences of Lorentz transformation. They all come smoothly from Einstein's hypothesis that Lorentz transformation dominates physics. This dominance of Lorentz transformation is extremely important, and it has been influencing physics since it was proposed at the beginning of this century." This is Dirac's experience in describing his own creation of the Dirac equation of relativistic quantum mechanics. It also represents the infinite nostalgia of physicists for the special theory of relativity and the way of work in the past.

The success of Dirac's equation first shows that the special theory of relativity and Lorentz transformation contain some truths. By giving up absolute space and absolute motion, the special theory of relativity achieved the recognition of the dependence of the space-time property of matter on the motion of matter based on the principle of relativity and man-made principle of the constancy of the one-way light speed, and gives the motion law applicable to the high-speed moving object. As mentioned before, the basic reason why the special theory of relativity can still achieve great success is that the dispersed-state medium (i.e., vacuum background field) as absolute space has little influence on the motion of the matter with shape and image. Now it has been known that its effect is as small as the order of magnitude $\boldsymbol{u}\cdot\boldsymbol{v}/c^2$, which will not be shown in general observation and experiment. But even so, special theory of relativity has paid a price for this. The price is the void space with nothingness, relativity of simultaneity, limit of light speed and Einstein localization, which have been denied by experiments. Standard Space-time Theory recovers the concepts of absolute reference system and absolute motion. Based on the two principles with solid experimental basis, it accurately achieves the understanding of the dependence of material space-time properties on material motion, and also gives the motion law applicable to high-speed moving objects, in which the influence of inertial reference system on material motion is only reflected in the correction of factor $\alpha = 1-\boldsymbol{u}\cdot\boldsymbol{v}/c^2$, the whole theory is compatible with the absolute reference system and background space, the absoluteness of simultaneity and superluminal motion, and thus with quantum mechanics.

In the concept of time, relativity and quantum theory have been in conflict. Quantum mechanics uses the concept of time in an absolute sense, and simultaneity has an absolute meaning. Quantum mechanics allows the superluminal phenomenon, which is the so-called non-locality. All these are not allowed by relativity. Standard Space-time Theory not only describes the laws of matter motion of high-speed moving objects, but also time concept is consistent with quantum mechanics, which does not indicate the progress of physics?

As for the relativistic wave equation established in that year (Klein-Gordon equation, 1926; Dirac equation, 1928), it can also be obtained from Standard Space-time Theory.

For subluminal motion, the same Mass-Momentum Relation (5.68) that gotten from Standard Space-time Theory as gotten from the special theory of relativity, that is:

$$E^2 = p^2c^2 + m_0^2c^4, \tag{11.38}$$

or

$$E = \sqrt{c^2p^2 + m_0^2c^4}. \tag{11.39}$$

Klein and Gordon, starting from formula (11.38), apply both sides of the equation to the wave function Ψ , and replace E and $\boldsymbol{p}$ in the equation with the corresponding operators, i.e.,

$$E \to i\hbar\frac{\partial}{\partial t}, \quad \boldsymbol{p} \to -i\hbar\nabla. \tag{11.40}$$

So, we get the Klein-Gordon equation of free particles

$$\nabla^2\Psi - \frac{1}{c^2}\frac{\partial\Psi}{\partial t^2} = \frac{m^2c^2}{\hbar^2}\Psi. \tag{11.41}$$

Dirac started from Eq. (11.39), considering that the operator of quantum mechanics should be a linear operator, he assumed that the right end of Eq. (11.39) could be written in the following linear form:

$$\sqrt{c^2p^2 + m_0^2c^4} = c\boldsymbol{\alpha}\cdot\boldsymbol{p} + \beta m_0c^2.$$

Because of the uniformity of time and space, there is no relation between α, β and (x, y, z, t). Substituting the above formula into Eq. (11.39), the static mass m_0 is expressed m instead, and thus

$$E = c\boldsymbol{\alpha}\cdot\boldsymbol{p} + \beta mc^2. \tag{11.42}$$

The two sides of the above formula act on the wave function Ψ , and then according to formula (11.40), replace the energy E and momentum $\boldsymbol{p}$ with corresponding operators to get

$$\mathrm{i}\hbar\frac{\partial\Psi}{\partial t} = \left(-i\hbar c\boldsymbol{\alpha}\cdot\nabla + \beta mc^2\right)\Psi. \tag{11.43}$$

This is the Dirac equation for free particles. The natures of the operators $\boldsymbol{\alpha}, \beta$ are to be determined.

Klein Gordon equation (11.41) and Dirac equation (11.43) can be written in the form of covariance satisfying the standard theory. However, we are here to stop the further discussion. The above hundreds of words at least show that starting from Standard Space-time Theory it can also enter the research of high-speed microscopic physics. It is an important topic for the further exploration of Standard Space-time Theory.

Standard theory covariance replaces Lorentz covariance, and high-speed microscopic physics will enter a new field, where there are many rich minerals to be mined.

11. 4. 3. Aggregation State and Dispersion State. Subluminal World and Superluminal World

The first chapter has described the history of the development of human natural view at all times and in all countries. It combines the natural view of Yuanqi theory with the natural view of Atomism to form a new natural images of modern science, which I call the aggregated-dispersed states natural images of the material world. Although the name is old-fashioned and familiar, in fact, this is a new understanding and recognition of the overall image of nature that I creatively put forward.

Through the study of Standard Space-time Theory, we have further realized that the aggregated-state matter which is gathered but formed and has form and image, and the dispersed-state matter which is scattered but not gathered and has no form and image, constitute the subluminal world and superluminal world respectively. The dispersed-state background field is the carrier of the continuous superluminal physical motion process; the particles are only condensed granular structures by the superluminal rotational motion of the dispersed-state matter, their overall motion speeds are less than the speed of light, and the speed of light is still the limit speed of the whole movement of particles and the macroscopic objects and celestial bodies composed of the particles. Therefore, it can be said that there is no superluminal particle, that is, there is no particle state structure moving at superluminal speed as a whole, but the subluminal particles are also a kind of material structure existing in the state of superluminal rotation of dispersed-state matter.

According to Standard Space-time Theory, (1) It is impossible for subluminal particles, photons and superluminal materials to change each other through the choice of inertial systems; (2) There is a "light barrier" between subluminal particles and superluminal materials, that is, the direct dynamic conversion between two types of materials requires infinite energy, so it is impossible to achieve. In this way, the material world can be divided into subluminal world and superluminal world.

As mentioned before, in the concept of time, as two pillars of modern physics, relativity and quantum mechanics have always been in conflict. In the special theory of relativity, the relativity of simultaneity and the relativity of time sequence are obtained by the principle of the constancy of the one-way light speed (or Lorentz transformation). Quantum mechanics use the concept of time in an absolute sense, and the simultaneity has an absolute meaning, which relativity holds is not allowed. However, Bell's inequality experiment falsified Einstein's localization principle.

In Standard Space-time Theory, from the GGT, the transformation formula of the time interval between two events is obtained

$$\Delta t = \gamma^{-1}\Delta t_{\mathrm{a}} = \Delta t_{\mathrm{a}}\sqrt{1-\beta^{2}}\,. \qquad (11.44)$$

Therefore, if there is $\Delta t_i = t_{i2} - t_{i1} = 0$ (or $\Delta t_i > 0$, or $\Delta t_i < 0$) for an inertial frame Σ_i, there is $\Delta t_i = t_{i2} - t_{i1} = 0$（or $\Delta t_i > 0$ or $\Delta t_i < 0$ for any inertial frame Σ_i $(i = \mathrm{a}, 1, 2, 3, \cdots)$. This leads to the absoluteness of simultaneity and time order. Therefore, we can see that the time concept of Standard Space-time Theory is qualitatively close to that of quantum mechanics. On the other hand, since formula (11.44) is established, the numerical measurement of time interval is not absolute, which is related to the selection of inertial system. The time concept of Standard Space-time Theory is close to the time delay concept of relativity quantitatively.

Standard Space-time Theory does not appear virtual mass and does not violate the law of causality. Although this theory allows the existence of superluminal motion and does not set an upper limit of the speed of matter motion, but according to its speed transformation formula (see Eq. (6.42)), that is

$$\boldsymbol{u} = \gamma \hat{T}(\boldsymbol{u}_{\mathrm{a}} - \boldsymbol{v}) = \gamma \left\{ \boldsymbol{u}_{\mathrm{a}} + \left[(\gamma - 1)(\boldsymbol{u}_{\mathrm{a}} \cdot \boldsymbol{v}) / v^2 - \gamma \right] \boldsymbol{v} \right\}, \tag{11.45}$$

the limited speed in an inertial system (even the speed of superlight) is limited in any inertial system. In this way, it can avoid the real infinite speed, and not fall into the mire of instantaneous action at a distance. Therefore, Standard Space-time Theory has no other difficulties such as virtual mass, causality and instantaneous action at a distance that cannot be extricated by other theories of superluminal speed. Standard Space-time Theory deals with the problems of kinematics and dynamics of subluminal particles and superluminal matter in a unified way, that is, it gives a unified description of subluminal and superluminal motion in a unified and symmetrical way. In this regard, Standard Space-time Theory is a desirable theory of superluminal motion.

It is not completely impossible for aggregate matter and diffuse matter, subluminal world and superluminal world to be transformed into each other. Through their interaction and conversion with photons or light waves, subluminal particles and superluminal materials can indirectly convert each other with photons or light waves as the intermediate media. In addition, in the dispersion state vacuum background field, the superposition of superluminal waves can form particles.

To study and master the science and technology of superluminal motion is a great cause of unparalleled significance. According to the investigation of the existing civilization of the earth, the motion of matter is usually divided into five basic forms from low to high: mechanical motion (i.e., displacement motion), physical motion, chemical motion, life motion and social motion. However, if human beings master the science and technology of superluminal motion and establish friendly relations and cooperation with intelligent life outside the earth, the existing civilization of the earth will have a huge qualitative leap. A new and higher form of material motion, —the interstellar social motion, will appear in human civilization. This prospect is described in “The Law of Circulation Evolution” [13]:

"In a highly reasonable and beautiful society, human thinking is highly developed, and human beings have a deep understanding of the laws of material motion (such as the laws of motion of substances in dispersion state, the laws of transformation between substances in dispersion state and physical objects, and the laws of motion of human body and human brain itself). As a result, their ability to control materials and energy is greatly improved, who can move to other planets, freely travel in the interstellar space, has established friendly relations and cooperative relations with intelligent life outside the earth, and jointly formed the interstellar society. At this time, a new and more advanced basic form of motion, which can be called the interstellar social motion, came into being." Only by studying and mastering the science and technology of superluminal motion, can we truly get rid of loneliness and ignorance, connect with alien civilization and enter an absolutely new era of interstellar social motion!

11. 4. 4. Variable Speed of Light

The speed of light we are talking about is the speed of light in the vacuum background field. Einstein's special theory of relativity is characterized by the constancy of the light speed. The principle of the constancy of the average circuit speed of light in Standard Space-time Theory has allowed the speed of light in every inertial system, the speed of light in every direction of the inertial system are variable, and the law of change is described by the formula (5.12).

Our considerations can move forward. In fact, the principle of the absolute reference system and the principle of the constancy of the average circuit speed of light are relative to the macroscopic scale. On the cosmic scale, that is, by the time scale of the universe (e.g., tens of thousands, hundreds of millions or more years), the vacuum background field is subject to obvious change. This is the subject of cosmology. The light wave or electromagnetic wave, as the propagation process of electromagnetic disturbance in the vacuum background field, its propagation velocity obviously changes with the change of the vacuum background field (first of all, its density). Therefore, according to Standard Space-time Theory, the absolute reference system is not absolute from the time scale of the universe, and the speed of light is variable. This is in line with the views of the British Joao Magueijo. [14]

Therefore, Standard Space-time Theory also needs to be developed, and it can be considered to establish a space-time theory that considers the change of the speed of light caused by the change of the vacuum background field according to the time scale of the universe. How does the average density of the universe and the vacuum background field of the cosmic change? This is the subject of cosmological research. Therefore, this theory must be based on cosmology.

11. 4. 5. The Suitable Framework Described by the Standard Space-time Theory

As mentioned above, Standard Space-time Theory provides a more appropriate space-time framework for understanding and describing the physical world and even natural phenomena. What is the more appropriate framework of space and time?

As we all know, in the 16th century (i.e., 1543), Copernicus' Sun Center Theory came out, which replaced Ptolemy's Earth Center Theory. It is a sign of the independence of modern natural science and a milestone in the history of human thought. After careful consideration, it can be clear that although in terms of people's daily visual effects, we can see the sun rising in the East and setting in the West every day, and there is almost no difference between the explanation of the geocentricism and the heliocentricism, but now we have understood that only the sun center theory reflects the reality of nature when we stand in the larger space; If there is no the heliocentric theory, Newton's law of universal gravitation and Newton's mechanics system could not have been produced, and the development of natural science and the arrival of the space age could not have followed. Later, the development of Natural Science showed that the sun was only a star in the Milky Way, and it was not the center of the universe. All the stars, galaxies, even galaxy clusters are moving in relative motion. Observations show that the universe is homogeneous and isotropic on a large scale. In other words, the universe has no center at all.

Summarizing the development of modern science, Standard Space-time Theory provides the following picture of the new space-time framework: Matter can be divided into two different forms, namely, aggregated state and dispersed state; all stars, galaxies, and even galaxy clusters move in the background field of the cosmic vacuum in the dispersed state. On the macroscopic or cosmic scale, the vacuum background field can be regarded as a uniform distribution, which constitutes what we call the absolute reference frame. Only relative to this absolute reference system, the propagation of cosmic background radiation and light wave is uniform and isotropic. In principle, the velocity of each celestial body (such as the earth or the sun) relative to this absolute reference system can be determined.

The natural view based on Standard Space-time Theory (the aggregated-dispersed states natural images) and Standard Space-time Theory itself explain the cosmic microwave background radiation, and gives and establishes the physical image of the solar system flying in the cosmic background field. This is what people often call "new ether drift".

All of these will immediately send us to the starting point of many practical applications.

According to Standard Space-time Theory, the speed of light can be derived in a general inertial reference system (such as the earth reference system) as follows：

$$c(\alpha,\beta,\gamma)=\frac{c}{1+(v\cos\alpha/c)}=\frac{c}{1+\boldsymbol{n}\cdot\boldsymbol{v}/c},$$

where $\boldsymbol{v}$ indicates the velocity of the general inertial reference system relative to the absolute reference system. Here as the two inertial coordinate systems Σ_a and Σ specially configured, the general inertial system Σ moves along the positive direction of the common axis $x_a(x)$ of the two systems with constant velocity $\boldsymbol{v}$; $\boldsymbol{n}$ represents the unit vector in the direction of light propagation in the general inertial reference system, and α,β,γ represent the direction angle between $\boldsymbol{n}$ and three coordinate axes in the absolute reference system.

For practical application, it is necessary to measure the motion velocity $\boldsymbol{v}$ (including direction and size) of solar reference system relative to absolute reference system (i.e., cosmic vacuum background field) accurately. We have proposed an experimental scheme to realize this measurement on the earth's surface [15]. On this basis, the expression of the speed of light in any direction $\boldsymbol{n}_e$ in the geocentric coordinate system is obtained by correctly establishing the coordinate transformation from the universal standard coordinate system to the solar coordinate system and then to the geocentric coordinate system. It must be a periodic function that changes with year, month, day, hour, minute and second. The speed of light obtained in this way is an accurate expression of the speed of light that can be used to accurately measure time and distance. Using it will greatly improve the accuracy of modern time measurement and timing technology. For example, it will improve or simplify the operation of GNSS and improve the positioning accuracy of GNSS.

According to the aggregated-dispersed states natural images of the material world and the theoretical results of Standard Space-time Theory, it can provide an opportunity for the real breakthrough and development of quantum mechanics and the whole physics. A more detailed description of this issue is given in the following section.

11. 5. Moving forward: The Coordination of Space-time Theory and Quantum Mechanics

We will understand and solve some important problems faced by modern physics according to the space-time view and the theoretical achievements of Standard Space-time Theory. According to the aggregated-dispersed states natural images of the material world and the non-locality of Standard Space-time Theory, we can clarify the physical picture of a single microscopic system, establish the physical basis of quantum mechanics, and overcome the difficulties of heat death theory of thermodynamics, and so on, so as to provide a correct basis and starting point for the breakthrough and development of modern physics.

Note a few facts in modern physics: (1) the physical interpretation of wave functions ψ is at the center of the debate about quantum mechanics this century. But we know that the phase velocity of the wave function ψ is always faster than light. (2) According to the classical image of electron spin, the linear velocity of electron spin is faster than light. This explanation is abandoned only because of the limit of light speed in the special theory of relativity. However, until now, no reasonable explanation has been found yet. (3) Inflationary cosmology proves that physical particles are the products of superluminal inflation of the pseudo-vacuum matter. The interaction of the matter expanding beyond the speed of light inevitably leads to the rotational motion. (4) Finally, and most importantly, the experimental tests of Bell's inequality confirm that quantum entanglement is a real physical phenomenon, and that there is a superluminal causal connection or influence between two entangled particles.

This section mainly describes that quantum mechanics needs a real breakthrough and development, and explains how I accept and improve the achievements of existing quantum mechanics, in the direction advocated by Einstein and de Broglie, on the basis of the aggregated-dispersed states natural images of the material world and the concept of non-locality of Standard Space-time Theory, establish the quantum theory for complete description of microscopic systems, that is, Wave-Particle Mechanics.

11. 5. 1. Quantum Mechanics Needs Real Breakthroughs and Developments

Physics is the basis of the whole natural science. The establishment and successful application of relativity and quantum mechanics have greatly promoted the development of science and technology and the progress of human society. Physics based on Einstein's theory of relativity and quantum mechanics is generally considered to be modern physics. However, UNESCO pointed out in the 1998 World Science Report, "Einstein's theory of relativity and quantum mechanics are the two major academic achievements of the 20th century. Unfortunately, these two theories have so far proved to be opposed to each other and become a serious obstacle."

The famous physicist Dirac wrote in 1975 that the "conflict" between quantum mechanics and relativity "has been the main problem of physics in the last forty years. It can be said that the main efforts of physicists revolve around the problem of reconciling relativity and quantum mechanics. A great deal of work has been done on this subject, but there is no solution in sight". [16] In 1981, Wheeler, a famous American physicist, said, "We often say that the biggest problem in physics is to coordinate quantum theory and relativity theory. We now say more clearly that quantum theory and relativity theory cannot be coordinated at all.” [17]

Physicists generally believe that if there are still 100 physical problems plaguing mankind, the problem of coordination between quantum mechanics and relativity is the root of all problems compared with the other 99 problems.

How to coordinate quantum mechanics with relativity? Why do some people say that quantum mechanics and relativity cannot be coordinated?

The first difficulty and problem are that the special theory of relativity restores the image of vacuum as the empty space with nothingness. This concept of vacuum is certainly confusing and unacceptable; what other microscopic movements and changes can occur in the empty space with nothingness? How can quantum theory and relativity possibly be coordinated? Second, the problem is the principle of the limitation of the light speed in the special theory of relativity.

The 2022 Nobel Prize in Physics was awarded to A. Aspect, J. F. Clauser, and A. Zeilinger for their work on experiments with entangled photons, experiments to test Bell inequality violations, and quantum information science. This indicates that quantum entanglement gained a high degree of recognition. The experimental test of Bell’s inequality confirms that quantum entanglement is a real physical phenomenon, and that there is a superluminal causal connection or influence between two entangled particles. This is obviously a sure conclusion and a landmark achievement. It can be asserted that if quantum mechanics is the correct theory for describing the microcosm, the non-locality must be an important feature of the microcosm.

Standard Space-time Theory eliminates the opposition between the special theory of relativity and quantum mechanics in the concept of time. This creates a basis for the coordination of space-time theory and quantum mechanics. Has this solved all the problems? No. The reason is that quantum mechanics itself has serious problems. To sum up, quantum mechanics is not a quantum theory of complete description of the microscopic system, quantum mechanics itself is in urgent need of a new real breakthrough and development.

Standard Space-time Theory eliminates the opposition between the special theory of relativity and quantum mechanics in the concept of time. This creates a basis for the coordination of space-time theory and quantum mechanics. Has this solved all the problems? No. The reason is that quantum mechanics itself has serious problems. In short, quantum mechanics is not a quantum theory of complete description about the microscopic system, quantum mechanics itself urgently needs a new real breakthrough and development.

Quantum mechanics is undoubtedly the most powerful physical theory about the microscopic world today, and no theory can compete with it. Quantum mechanics provides a set of calculation rules, which can be used to correctly calculate the values and probabilities of the physical quantities of a microscopic system, the most important of which is the energy eigenvalues of the system and the probabilities of transitions between energy levels, and the results are consistent with experimental observations, many of which are beyond the understanding and explanation of classical theories. However, the objects involved in the whole calculating process of quantum mechanics have no clear physical meaning and no corresponding physical image. Although the concept of particles has been preserved throughout all narratives and demonstrations, quantum mechanics does not provide a method for determining the position of particles in space and time, and it has completely lost the causal description and the imagination of physical processes of the motion of individual microscopic systems.

P. Feynman believed [18] that no one in the world understood quantum mechanics. “It was said in the newspapers that only twelve people knew the theory of relativity,” he said, “I don’t believe it ever happened.... But, on the other hand, I think it’s true that no one understands quantum mechanics.” Did Einstein, de Broglie, Schrodinger, Bohr and Heisenberg also not understand quantum mechanics? Indeed, no one can articulate the foundations and concepts of quantum mechanics. In this regard, R. P. Feynman’s statement was correct.

“Quantum mechanics is a mysterious and confusing discipline,” M. Gellman wrote in 1980. “People know how to use it, but no one can understand it. It does a good job of describing physical reality, but it’s very unintuitive. Quantum mechanics is not a theory, but only a framework in which any (future) correct theory must fit.” [19]

Most of the leading minds of the last century—the leading physicists—made important contributions to the development of quantum theory. However, at the same time, there was a protracted and unprecedented fierce debate between Einstein (including De Broglie and Schrodinger) and Bohr’s Copenhagen School (including Heisenberg, Born and Pauli et al.) on the significance, interpretation and future development of quantum mechanics.

Most of the first-class minds of the last century—the first-class physicists have made important contributions to the development of quantum physics. But the views of Einstein (including De Broglie and Schrödinger et al.) and Bohr’s Copenhagen school (including Heisenberg, Born and Pauli et al.) on the meaning, status, and future of quantum mechanics are diametrically opposed, and there has been a long, unprecedented fierce debate between them.

As a representative of the mainstream school for a long time, Bohr believed that quantum mechanics reflected people’s understanding of the observed phenomena of the microcosm, and did not directly reflect any objective and realistic characteristics of the microcosm. What exactly is the microscopic system? Bohr believed that the language of people’s daily life and the concept of classical physics could not describe the processes that occur inside the atom; it is impossible to have a descriptive explanation of the microscopic system. They believe that the mathematical description of microscopic systems in quantum mechanics is complete and unsurpassable and that anyone who wants to develop this theory is trying to do the something impossible to do. [20]

Einstein's view is diametrically opposite to that of Bohr and others. Einstein insisted on the objective reality of the world. He believed that the wave function of quantum mechanics describes the statistical behavior of a large number of systems (ensembles), so it is not a complete description of the real state of a single system. He believed that a complete description of a single system should eventually be possible, that physics must strive to obtain a realistic description of a single system, and that quantum mechanics would eventually be replaced by a deterministic theory of a complete description of reality.

Although the experimental test of Bell's inequality denies Einstein's principle of locality and is consistent with the time concept and non-locality prediction of quantum mechanics, and although the goal of Standard Space-time Theory is obviously to replace Einstein's special theory of relativity, this is only one aspect of the problem. On the other hand, this does not mean that Einstein is all wrong. Einstein's many views on quantum mechanics and his quest to establish a complete description of quantum theory fully demonstrate the expectations of human beings for the development of science, the spontaneous materialist stand of a great scientist, the great personality of integrity and the persistent pursuit of truth. On the contrary, many of the views of the Copenhagen School are unacceptable. Quantum mechanics is not a satisfactory theory, and it needs real breakthrough and development.

Dirac, an important figure of Copenhagen school and a famous physicist, in 1975 wrote [21], "I don't think the basis of quantum mechanics has been correctly established.... People are too happy to accept a fundamentally flawed theory." In what direction should quantum mechanics develop? "I think maybe the result will prove Einstein is right in the end, because the existing form of quantum mechanics should not be considered as the final form. There are some great difficulties in existing quantum mechanics...., it is the best theory that people can give so far, but it should not be thought that it can exist forever. I think it's likely that at some point in the future, we'll get an improved quantum mechanics, which will bring it back to determinism, so that we can prove Einstein's view is correct. However, such a return to determinism can only be achieved at the expense of giving up some basic ideas, which we now think are without problems."

In the future development of quantum mechanics and particle physics, I think the most important problem is that in the view of nature, people can't only remember particles, particles and particles. In fact, if among the particles there were not dispersion matter, which extensiveness is much greater than the particles', all the particles would be like scattered grains of sand. We need to study not only the particles, the interaction between particles, but also the dispersion state field, the transformation and interaction between particles and dispersion field. This is the natural image of aggregation state-dispersion state elaborated in the first chapter. Just as we understand Newton's concept of absolute space, we should remember the concept of absolute space formed by the continuous dispersion medium (ether or plenum). According to this view to understand the wave function ψ of quantum mechanics, entangled particles and so on, everything becomes clear and easy to understand. Starting from the aggregated-dispersed states natural images and accepting the theoretical results of Standard Space-time Theory, I strive to make real progress in quantum mechanics in the direction of Einstein's return determinism.

11. 5. 2. Schrödinger's Wave-Packet and de Broglie's Double Solution Theory

We know that the existing quantum mechanics can only describe the probability of the microscopic system. For example, a free particle is associated with a plane wave, its momentum is completely determined, but its position is completely uncertain, and the probability of finding it anywhere in space is the same. By calculating the average of the mechanical quantities of free particles according to the rules of quantum mechanics, almost all the results will be zero or infinite. No one can say whether a single free particle is a particle, a wave-packet or anything else. The existing quantum mechanics cannot give it a physical model.

Many physicists represented by Einstein, Schrödinger and de Broglie disagree with the view of the Copenhagen school. They believe that physicists will not be satisfied with this indirect description of reality for a long time; the current quantum mechanics will eventually be replaced by a deterministic theory of complete description of reality. The work of de Broglie and Schrödinger was the first attempt in the direction of creating a complete quantum theory.

In 1924, de Broglie hypothesized that microscopic particles have wave particle duality. Each particle has a wave associated with it. The relationship between the energy E of the particle and the angular frequency ω of the associative wave, the momentum $\boldsymbol{p}$ of the particle and the wave vector $\boldsymbol{k}$ of the associative wave is as follows

$$E=\hbar\omega, \quad \boldsymbol{P}=\hbar\boldsymbol{k}. \qquad (11.46)$$

This is the de Broglie relation. It is the starting point of the development of Wave Dynamics.

In the early days of wave dynamics, Schrödinger formed the idea that the function ψ itself represents reality and is the only reality; the atomic structure on which the field ψ should make some statements does not exist at all, at least as a structure localized in a place. Schrödinger did not believe in local particles. In his view, particle is no longer eternal attribute, but only response characteristics to experimental equipment. In this sense, Schrödinger tried to think of particles as a wave-packet superposed by the eigen solutions of

Schrödinger's equation, and holds that a wave-packet with smaller scale obeys the same law of motion as a single particle as a mechanical system.

Almost all physicists believe that the frequency and wavelength of each component of the wave-packet are related to the energy and momentum of the particle according to the de Broglie relation. According to this understanding, it is found that Schrödinger's wave-packet spreads spontaneously rapidly and infinitely. For example, considering a free particle in one-dimensional motion, its wave-packet is expressed as the superposition of the plane wave of de Broglie satisfying Schrödinger's equation:

$$u(x,t)=\int_{k_0-\Delta k}^{k_0+\Delta k}\phi(x,t,k)\mathrm{d}k=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{+\infty}f(k-k_0)\mathrm{e}^{\mathrm{i}(kx-\omega t)}\mathrm{d}k\ , \qquad (11.47)$$

where $f(k-k_0)$ is the weight function. From the de Broglie relation, the expression of the relation between ω and k is as follows:

$$E=\hbar\omega,\quad \boldsymbol{P}=\hbar\boldsymbol{k},\ E=p^2/2m,\ \omega=\hbar k^2/2m\ . \qquad (11.48)$$

It has been proved that as long as

$$\beta=(\frac{\mathrm{d}^2\omega}{\mathrm{d}k^2})_{k_0}=\frac{\hbar}{m}\neq 0, \qquad (11.49)$$

The wave-packet will spread, and after a long enough time, the width of the wave-packet will become as large as possible, and it will spread indefinitely. If the weighting functions are Gaussian distribution, then the wave-packet width

$$\Delta x\cong\Delta x_0\left[1+\beta^2t^2/(\Delta x_0)^4\right]^{1/2}, \qquad (11.50)$$

where Δx_0 is the width of the wave-packet when $t=0$. The smaller the mass m of the particle is, and the smaller the initial width Δx_0 of the wave-packet is, then the faster the wave-packet spreads. For electrons, the wave-packet will expand to 10^{18} times of the initial linearity in about 10^{-8} seconds.

Such a rapidly and infinitely spreading wave-packet can never be a representation of microscopic particles (even nonlocal particles in the sense of Schrödinger). Even so, until his death, Schrödinger still insisted on his idea of wave-packets, and thought that the difficulties were not insurmountable. He hopes that the quadratic quantization method can make arrangements for particles. However, in fact, the difficulty of wave-packet spontaneous spread has not been solved. This shows that in the scope of existing quantum mechanics, that is, from Schrödinger's equation alone, it is impossible to describe the particle properties of the microscopic system in accordance with the objective reality.

The problem has not been solved, but we know that in the existing quantum mechanics, we still use the linear superposition of the solution of the Schrödinger equation to form the wave-packet function, and try to use this wave-packet (we call it Schrödinger's wave-packet) to represent particle, at least to provide an explanation for the motion of particle. It's just a one-way willingness. The real representation of the particles cannot be given by the so rapidly and infinitely spreading Schrödinger wave-packet. In fact, the spread of Schrödinger's wave-packet is the main argument that Einstein argued that quantum mechanics could not provide a complete description of a single system [7] (P.598).

De Broglie is the originator of wave mechanics. On the wave-particle duality, he is different from Copenhagen school. In the view of Copenhagen school, microscopic object is shown as particle in some cases and wave in others. Strictly speaking, it is neither particle nor wave, and there is no description based on classical concepts. On the contrary, de Broglie believes that we can't give up the desire to get a clear expression of the physical world in the framework of space and time. The microscopic object is both a particle and a wave, and the particle always associates with a wave. Therefore, the microscopic object is essentially the association of waves and particles, and the coexistence of waves and particles. De Broglie recognized the localization of particles or particles of localization, and regarded particles as the center of extended wave phenomenon. De Broglie expressed particles as singular points (or very small singular areas) embedded in the extended wave phenomenon to obtain the combination of waves and particles.

On the basis of the above ideas, de Broglie put forward the theory of double solution in 1927. After arduous exploration and several revisions, the double solution principle can be described as follows [22]:

For each continuous solution of the wave dynamics equation satisfying certain boundary conditions

$$\Psi(\boldsymbol{r},t)=a(\boldsymbol{r},t)\mathrm{e}^{\mathrm{i}\varphi(\boldsymbol{r},t)/\hbar}, \tag{11.51}$$

there must be a singular solution which obeys an unknown nonlinear equation.

$$u(\boldsymbol{r},t)=f(\boldsymbol{r},t)\mathrm{e}^{\mathrm{i}\varphi'(\boldsymbol{r},t)/\hbar}. \tag{11.52}$$

It satisfies the same boundary conditions, and its amplitude $f(\boldsymbol{r},t)$ includes a small singular region which can be moved generally, and at least near the small singular region, $\varphi'(\boldsymbol{r},t)=\varphi(\boldsymbol{r},t)$.

According to de Broglie, two wave functions are used to describe the state of quantum system, among which, the ordinary wave function $\Psi(\boldsymbol{r},t)$ satisfies Schrödinger's equation, and the square of its absolute value represents the probability density of particle occurrence, and another wave function, i.e., singular region of singular solution $u(\boldsymbol{r},t)$ represents the microscopic particle. This kind of particle combined in the extensive wave phenomenon, just like in the classical picture, will be clearly localized in space and obey the strict causal law.

De Broglie's above idea is consistent with Einstein's idea of the problem. The double solution principle of de Broglie was supported by Einstein. In May 1953, Einstein said in his letter to de Broglie [23], "You suggest that taking the following form represent the concept of the physical reality (complete description): $\Psi = \psi u$, in this product, one factor represents the structure of particle, and the other represents the structure of wave. There is no doubt that there is a satisfactory concept of double solutions that we can accept experimentally. This is really a new theory, not a supplement to the old one."

The theory of double solutions has encountered great difficulties in mathematics. According to de Broglie, "the mathematical proof of double solution theory is beyond my ability even if it is possible." [22] In my opinion, in fact, the main reason is that the theory of double solution has not made a breakthrough in the past hundred years because it has not broken through the shackles of some traditional ideas and concepts. The nonlinear equation obeyed by the singular solution $u(\boldsymbol{r},t)$ is not found. Attempts to construct the wave-packet functions $u(\boldsymbol{r},t)$ by superposition of waves cannot overcome the difficulty of spontaneous spreading of wave-packets. Therefore, the theory of double solutions remains at the stage of principle hypothesis and general ideas. "I hope very much that young theorists gifted with physical insight, and experienced mathematicians as well, will be good enough to take an interest in the hypotheses which I have put forward in the conclusion of my work without being able to give real justification for them." de Broglie said. [22]

At last, it is pointed out that when de Broglie proposed the principle of double solution in 1927 both ψ wave and u wave was regarded as two related and forever solutions of Schrödinger's equation, so it was called "double solution". However, later studies have shown that ψ and u should satisfy different equations. De Broglie stressed that this is an absolutely necessary and indispensable assumption. Therefore, it is not appropriate to call it the double solution principle, rather than the double wave function principle.

11. 5. 3. Basic Postulates of Wave-Particle Mechanics

De Broglie's pioneering work deserves high praise, but we need to move forward. Next, I will describe my thinking and see what real progress can be made in the direction of creating a complete deterministic quantum theory.

The particle property and wave property, two completely different properties, as the two sides of the contradiction, how to unify the opposites and form a complete image of the microscopic object? The first problem is how to construct a stable wave-packet. A localized stable wave-packet is hereafter called a wave-particle. We next narrate the main ideas on the construction of stable wave-packets.

Stable wave-packets can be constructed only at the cost of abandoning or improving some of the basic ideas of quantum mechanics. Our ideas include: (1) An ensemble of free particles is associated with a plane wave, but instead of a plane wave, a wave packet is associated with a single free particle. (2) A particle can only have one energy value and momentum value at any time, and it is impossible and should not let the angular frequency ω and wave vector $\boldsymbol{k}$ of each partial wave component of the wave-packet representing the particle be related to the energy E and momentum $\boldsymbol{p}$ of the particle according to the de Broglie relation.

With regard to the first point above, I realize that although de Broglie's principle of double solutions (or rather the principle of double wave functions) stays at the stage of principle hypothesis, I think that it is a correct concept. The principle of double wave function can be taken as the first postulate (Postulate 1) for establishing Wave-Particle Mechanics, which is described as follows:

The state of a quantum system is described by a pair of wave functions $\psi(\boldsymbol{r},t)$ and $u(\boldsymbol{r},t)$, and all the properties of the system can be obtained from them. The ordinary wave function $\psi(\boldsymbol{r},t)$ should satisfy three conditions: continuity, finiteness and singleness. Another wave function $u(\boldsymbol{r},t)$ is called wave-packet function, which describes the corresponding single system, and should satisfy the same boundary conditions as the ψ function. In general, its amplitude must contain a movable small singular region. It is the true representation of a single microscopic system.

With regard to the second point above, according to the original meaning of the wave-packet concept, the wave-particle function should be represented as a superposition of waves with different angular frequencies and different wave vectors, represented as a stable wave-packet. To this end, the second postulate (Postulate 2), known as postulate of the wave-packet and wave-packet center component, is proposed as follows:

What associated with a single microscopic system is not a plane wave, but a wave-packet described by the wave-packet function $u(\boldsymbol{r},t)$ and composed of the superposition of plane waves with different angular frequencies ω and different wave vectors $\boldsymbol{k}$; The energy E and momentum $\boldsymbol{p}$ of the microscopic system are only related to the angular frequency ω_0 and wave vector $\boldsymbol{k}_0$ of the central component of this wave-packet, which satisfies the relationship:

$$E = \hbar\omega_0, \qquad \boldsymbol{p} = \hbar\boldsymbol{k}_0. \tag{11.53}$$

This postulate naturally defines the relationship between ω_0 and $\boldsymbol{k}_0$ with the E and $\boldsymbol{p}$ of an individual system, where the central component of the wave-packet is the stationary wave function satisfying the Schrödinger equation and describes a pure quantum ensemble. This leaves additional options for determining the frequency ω and wave vector $\boldsymbol{k}$ of the general superposition terms of stable wave-packet functions. Thus, this postulate prevents the wave-packet from becoming a spreading Schrödinger wave-packet, creating the possibility of constructing stable wave-packets.

How can the frequency ω and wave vector $\boldsymbol{k}$ of the general superposition term of wave-packets be determined? The necessary requirement for solving this problem is to ensure the stability of the wave-packet, and the starting point of solving this problem is the Lagrangian equations and Hamiltonian principle of the analytical mechanics.

Which equation does the stable wave-packet function $u(\boldsymbol{r},t)$ satisfy? Starting from the original definition of the Hamiltonian

$$H=\sum_{\alpha} p_{\alpha}\dot{q}_{\alpha}-L$$

where $\alpha=1,2,\cdots,s$; and p_{α}, $\dot{q}_{\alpha}$, s denote the generalized momentum, generalized velocity, and number of generalized coordinates, respectively. The Lagrangian function $L=T-V$ is the difference between the kinetic energy T and potential energy V of the system. So,

$$H=\sum_{\alpha} p_{\alpha}\dot{q}_{\alpha}-(T-V)$$

For a quantum ensemble in a determined microscopic environment, by solving the Schrödinger equation, both a series of energy eigenvalues and their corresponding stationary wave functions are obtained. We now consider the law of motion of a single system under a certain energy eigenvalue and its corresponding stationary wave function ψ. How can the Hamiltonian of an individual microscopic system be determined in this context?

Note that the objects treated by quantum mechanics satisfy the condition that the Lagrange equations must satisfy. For a quantum ensemble in a definite microscopic environment, although the total energy E_n does not change with time under the condition that no energy level transition occurs, its various systems have various possible energy eigenvalues E_n forming the energy eigenvalue spectrum of the quantum ensemble, and thus have various possible kinetic energy functions $E_n-V(\boldsymbol{r})$. Wave-Particle Mechanics deals with a single system, which is in the determined microscopic environment and under the determined energy eigenvalue, has the determined potential energy function and total energy, and thus has a determined kinetic energy function with no overall change in the kinetic energy function. The only quantity with an overall change was the momentum p_{α} Thus, the Hamiltonian of an individual system under the determined energy eigenvalues becomes

$$H=\sum_{\alpha=1}^{s} p_{\alpha}\dot{q}_{\alpha}-L=\sum_{\alpha=1}^{s} p_{\alpha}\dot{q}_{\alpha}+(V-T)=\sum_{\alpha=1}^{s} p_{\alpha}\dot{q}_{\alpha}+(E-2T), \qquad (11.54)$$

which corresponds to the determined total energy, potential energy function, and kinetic energy function, respectively.

Noting that the variations of the Hamiltonian function H only include the variations of the generalized coordinates q_{α} and the generalized momentum p_{α}, but not the variations of the generalized velocity q_{α}, starting from the original definition of the Hamiltonian function, we can let only for the physical quantities that change as a whole for Wave-Particle Mechanics be transformed into corresponding operators; namely, the Hamiltonian H and the component p_{α} of the generalized momentum of a single system are converted to the following operators, respectively.

$$H \to \mathrm{i}\hbar\frac{\partial}{\partial t}; \quad p_\alpha \to -\mathrm{i}\hbar\frac{\partial}{\partial q_\alpha}, \tag{11.55}$$

while the other physical quantities L or T, E, V remain unchanged, letting the quantity thus obtained to act on acting on the wave-packet function $u(\boldsymbol{r},t)$, thus making it possible to construct an equation satisfied by the wave-packet function $u(\boldsymbol{r},t)$.

Here we consider only a system composed of a single particle, or a single particle in the system, which is not constrained, note that $\dot{q}_\alpha = \upsilon_\alpha = p_\alpha / m$ the stable wave-packet function $u(\boldsymbol{r},t)$ satisfies

$$\mathrm{i}\hbar\frac{\partial u}{\partial t} = \frac{\boldsymbol{p}}{m}\cdot(-\mathrm{i}\hbar\nabla u) - Lu, \tag{11.56}$$

$$\begin{cases} \mathrm{i}\hbar\dfrac{\partial u}{\partial t} = \dfrac{\boldsymbol{p}}{m}\cdot(-\mathrm{i}\hbar\nabla u) + \left(V - \dfrac{p^2}{2m}\right)u, \\ \mathrm{i}\hbar\dfrac{\partial u}{\partial t} = \dfrac{\boldsymbol{p}}{m}\cdot(-\mathrm{i}\hbar\nabla u) + \left(E - \dfrac{p^2}{m}\right)u, \end{cases} \tag{11.57}$$

where $m, \boldsymbol{p}, V$ and E denote the mass, momentum, potential energy, and energy of an individual system, respectively. In the Eq. (11.57), the relation formula $E = V + p^2/(2m)$ is used. Wave-Particle Mechanics regards the uncertainty relation as the statistical dispersion relation of complementary physical quantities measured on a large number of particles of a quantum ensemble, that is, statistical dispersion. Therefore, in the theoretical framework of Wave-Particle Mechanics, this relationship holds for a single system.

Introducing the operator

$$\hat{T} = \frac{\boldsymbol{p}}{m}\cdot(-\mathrm{i}\hbar\nabla) + \left(V - \frac{p^2}{2m}\right) = \frac{\boldsymbol{p}}{m}\cdot(-\mathrm{i}\hbar\nabla) + \left(E - \frac{p^2}{m}\right), \tag{11.58}$$

Eq. (11.57) can be shortened for

$$\mathrm{i}\hbar\frac{\partial u(\boldsymbol{r},t)}{\partial t} = \hat{T}u(\boldsymbol{r},t). \tag{11.59}$$

Equations (11.57) and (11.59) are stable wave-packet equations. The wave-packet function $u(\boldsymbol{r},t)$ should be taken as a normalized function. A single system described by a stable wave-packet may be either a wave-particle or an extensive wave lump or wave circle. However, considering that the main feature of Wave-Particle Mechanics is to describe the particle behavior of a single system, when a single system presents a localized particle state, the stable wave-packet equation is often called the wave-particle equation, and the stable wave-packet function is often called the wave-particle function.

Because the wave-packet function $u(\boldsymbol{r},t)$ is composed of the superposition of the plane wave of different angular frequencies ω and different wave vectors $\boldsymbol{k}$, the wave-particle component function $\phi(\boldsymbol{r},t,k)=\phi_k(\boldsymbol{r},t)$ and the wave-particle function $u(\boldsymbol{r},t)$ obey the same form of equation:

$$\mathrm{i}\hbar\frac{\partial\phi_k}{\partial t}=\hat{T}\phi_k, \tag{11.60}$$

where operator $\hat{T}$ is the same as that in Eq. (11.58) are called wave-particle equation and wave-particle component equation, respectively. The function ϕ should be taken as a normalized function.

The wave-particle equation contains the momentum $\boldsymbol{p}$ of a single system and its square which is defined as

$$p^2=\boldsymbol{p}\cdot\boldsymbol{p} \tag{11.61}$$

while momentum $\boldsymbol{p}$ will be given by Assumption 6, using which in advance we write the expression of the momentum of the system. In fact, it forms a differential integral equation together with Eq. (11.59). This yields the third basic postulate (Postulate 3) of Wave-Particle Mechanics:

The wave function ψ describing quantum ensemble satisfies the Schrödinger equation

$$\mathrm{i}\hbar\frac{\partial\psi(\boldsymbol{r},t)}{\partial t}=\hat{H}\psi(\boldsymbol{r},t). \tag{11.62}$$

The wave-packet function $u(\boldsymbol{r},t)$ describing the individual system in the ensemble satisfies the stable wave-packet equation, namely wave-particle equation

$$\left.\begin{aligned}\mathrm{i}\hbar\frac{\partial u(\boldsymbol{r},t)}{\partial t}&=\hat{T}u(\boldsymbol{r},t),\\ \boldsymbol{p}&=\int u^*(\boldsymbol{r},t)(-\mathrm{i}\hbar\nabla)\psi(\boldsymbol{r},t)\mathrm{d}\tau.\end{aligned}\right\} \tag{11.63}$$

This is a differential-integral equation.

In particular, it should be pointed out that, unlike the history of the Schrödinger equation, the wave-particle equation is constructed according to such a basic principle: starting from the Hamiltonian principle and Hamiltonian function, the physical quantities that change as a whole in the problem under consideration are expressed by the corresponding operators. This is the principle of constructing basic quantum theory equations. Starting from this principle, the Schrödinger equation can also be constructed, and according to the change in the object of study, the mutual derivation or transition between the wave-particle equation and the Schrödinger equation can be realized. Due to the limitation of space, the proof of this assertion is omitted here.

To solve the wave-particle equation, the wave-packet function should satisfy two standard conditions: ① the condition of a stable wave-packet; and ② the requirement of the correspondence principle. The so-called correspondence principle implies that in the case of a large number of quantum numbers, quantum theory should tend toward classical theory. We do not intend to find the general solution of the wave-particle equation, but to find a particular solution that satisfies the standard conditions.

We wish to retain the operator representation rules for physical quantities in quantum mechanics as the fourth basic postulate (Postulate 4) of Wave-Particle Mechanics:

The physical quantities of a microscopic system are represented by the linear Hermitean operators. Its coordinates and momentum are represented by the Hermitean operators $\hat{\boldsymbol{r}} = \boldsymbol{r}$, $\hat{\boldsymbol{p}} = -\mathrm{i}\hbar\nabla$ respectively. The operator representing a general physical quantity is obtained by replacing *t* momentum $\boldsymbol{p}$ with the operator $\hat{\boldsymbol{p}} = -\mathrm{i}\hbar\nabla$ in its classical expression. The operators representing physical quantities have eigenfunctions that constitute complete systems.

Using the ensemble interpretation of quantum mechanics, we assume the expansion assumption of the wave function as the fifth basic postulate (Postulate 5) of Wave-Particle Mechanics. This can be described as follows:

Coordinates, momentum, angular momentum, kinetic energy and energy of the system can only take the eigenvalues of the corresponding Hermitian operator. The wave function $\psi(\boldsymbol{r},t)$ are expanded with the eigenfunctions ϕ_n of the operator $\left(\hat{F}\phi_n = \lambda_n\phi_n, \hat{F}\phi_\lambda = \lambda\phi_\lambda\right)$:

$$\psi = \sum_n c_n\phi_n + \int c_\lambda\phi_\lambda \mathrm{d}\lambda, \qquad (11.64)$$

where the square of the absolute value of the coefficient $|c_n|^2$ (or $|c_\lambda|^2 \mathrm{d}\lambda$) gives the probabilities or relative frequencies of the results taking λ_n (or $\lambda \to \lambda + \mathrm{d}\lambda$) in a large number of repeated experiments measuring the physical quantity F of the system in the state ψ.

The Wave-Particle Mechanics accepts Einstein's ensemble interpretation of quantum mechanics, and holds that the object described by the wave function of quantum mechanics is the quantum ensemble; the so-called quantum ensemble refers to the set of a large number of microscopic systems that are independent of each other in a certain microscopic environment described by same Hamiltonian function. Quantum mechanics provides a set of calculation rules, which can be used to correctly calculate the values and probabilities of various physical quantities of the microscopic systems in the ensemble, the most important of which is the energy eigenvalue of the systems and the probabilities of transitions between energy levels. On this basis, Wave-Particle Mechanics will further research for the deterministic motion law of a single system.

How to determine the physical quantities of a single system? First, the wave-particle function $u(\boldsymbol{r},t)$ is found as Postulates 1 – 3. Note then that, at least in a stable force field, a definite single system must have a definite energy in the stable state. The behavior of a single system should be examined for certain energy eigenstates obtained from the Schrödinger equation. The sixth basic postulate (Postulate 6), i.e., the formula for calculating the physical quantities of wave particles, which is described as follows:

In the state described by the stable wave-packet function $u(\boldsymbol{r},t)$ and corresponding stationary wave function $\psi(\boldsymbol{r},t)$, measuring the physical quantity $F(\boldsymbol{r},\boldsymbol{p})$ of a single microscopic system yields the determined values

$$F(t)=\int u^{*}(\boldsymbol{r},t)\hat{F}(\boldsymbol{r},-\mathrm{i}\hbar\nabla)\psi(\boldsymbol{r},t)\mathrm{d}\tau, \qquad (11.65)$$

where the integral extends throughout the entire region of the variable change.

The so-called "corresponding stationary state wave function" in Assumption 6 refers to the stationary state wave function that corresponds to the central component of the stable wave-packet function and describes the pure ensemble.

When the system has a continuous energy spectrum, representing the value of the continuous energy in E, the stable wave-packet function and its corresponding stationary wave function plus a subscript E, written as $u_E(\boldsymbol{r},t)$ and $\psi_E(\boldsymbol{r},t)$, then the upper equation is written as

$$F(t)=\int u_E^{*}(\boldsymbol{r},t)\hat{F}(\boldsymbol{r},-\mathrm{i}\hbar\nabla)\psi_E(\boldsymbol{r},t)\mathrm{d}\tau.. \qquad (11.66)$$

When the system has a discrete energy spectrum, representing the n th eigenvalue of the energy operator in E_n, the stable wave-packet function and its corresponding stationary wave function plus the subscript n, written as $u_n(\boldsymbol{r},t)$ and $\psi_n(\boldsymbol{r},t)$, then the upper equation is written

$$F(t)=\int u_n^{*}(\boldsymbol{r},t)\hat{F}(\boldsymbol{r},-\mathrm{i}\hbar\nabla)\psi_n(\boldsymbol{r},t)\mathrm{d}\tau. \qquad (11.67)$$

For the momentum of an individual system, it is obtained by (15)

$$\boldsymbol{p}_c=\int u^{*}(\boldsymbol{r},t)(-\mathrm{i}\hbar\nabla)\psi(\boldsymbol{r},t)\mathrm{d}\tau. \qquad (11.68)$$

Hereafter, for the sake of clarity, it is often written with the subscripts c, for example F_c, to indicate the physical quantities of wave-particles. However, if this is not necessary, for simplicity, the subscript c is often omitted.

The coordinates, momentum, kinetic energy, energy and angular momentum of the system are called the physical quantities of the wave-particles, among which the most critical and important ones are the central position coordinates and momentum of the wave-particle. Only by identifying them, can we master the law of wave-particle motion.

To satisfy the mass and charge conservation laws, the following two equations were used:

$$\int u_E^{*}(\boldsymbol{r},t)\psi_E(\boldsymbol{r},t)\mathrm{d}\tau=1, \quad \int u_n^{*}(\boldsymbol{r},t)\psi_n(\boldsymbol{r},t)\mathrm{d}\tau=1. \qquad (11.69)$$

It must be noted that, as in quantum mechanics, Wave-Particle Mechanics affirms and admits that the laws of conservation of energy, momentum, and angular momentum are applicable to micro system.

From the sixth postulates, the coordinates, momentum and energy of the wave-particles are calculated as follows

$$x_c = \int_{-\infty}^{+\infty} u_n^*(x,t) x \psi_n(x,t)\,\mathrm{d}x, \tag{11.70}$$

$$p_{\alpha c} = \int_{-\infty}^{+\infty} u_n^*(x,t)\left(-\mathrm{i}\hbar\frac{\partial}{\partial x}\right)\psi_{n\alpha}(x,t)\,\mathrm{d}x, \tag{11.71}$$

$$E_c = \int_{-\infty}^{+\infty} u_n^*(x,t)\, i\hbar\frac{\partial}{\partial x}\psi_n(x,t)\,\mathrm{d}x. \tag{11.72}$$

When dealing with practical problems, we can use a direct corollary of the first and the fifth postulate, namely, according to the following two principles to determine the weight coefficient of wave-particle function (or superposition coefficient) and the corresponding angular frequency $\omega = \omega(k)$: (1) The principle of generalized function δ, the wave function of the particle can be expressed by generalized function δ, as the wave-particle function extensive property measurement, the mean square deviation should be tends to zero, namely $\left(x^2\right)_{-} = \left(x_c\right)^2$; (2) The principle of real numbers of physical quantities, that is, physical quantities of the wave-particle must generally take real values. However, when a microscopic system with energy E enters the high potential region $V > E$ or in some other cases, the momentum of the system may take an imaginary value. This means that in this exceptional case, there is no localized particle state, and a single microscopic object appears as an extensive wave-lump or wave-circle in dispersed-state.

11. 5. 4. Stable Wave-packet Representation of Free Particle

As a simple application example, this section introduces the application of Wave-Particle Mechanics to the solution of free particle problems.

Quantum mechanics can only give a probabilistic description of microscopic systems. Plane wave solutions are obtained from Schrödinger's equation for free particles, so free particles are associated with plane waves

$$\psi(\boldsymbol{r},t) = A\mathrm{e}^{\mathrm{i}(\boldsymbol{k}\cdot\boldsymbol{r}-\omega t)}, \tag{11.73}$$

where A is a constant, and the relations of the angular frequency ω with the energy E of the free particle, and the wave vector $\boldsymbol{k}$ with the momentum $\boldsymbol{p}$ of the free particle satisfy de Broglie's relation, that is

$$E = \hbar\omega, \qquad \boldsymbol{p} = \hbar\boldsymbol{k}. \tag{11.74}$$

According to the probability interpretation of the wave function, this solution means that the particle position is completely uncertain and that the probability of finding it in any part of the space is the same. Plane wave solutions cannot represent the physical states of a single localized particle. The most important problem is that, almost without exception, it is agreed that the wave vector of each plane wave constituting the wave-packet is related to the momentum of the particle by the de Broglie relation. Thus, according to (11.73) and (11.74), it is easy to prove that a wave-packet must spread rapidly over time during the propagation. Taking the initial scale of 1×10^{-15} meters, the wave-packet will expand to 10^{18} times the size of the initial scale in approximately 10^{-8} seconds, and it will almost diffuse into the entire space in an instant. Therefore, quantum mechanics cannot be used to describe a single free particle.

According to Wave-Particle Mechanics, a single microscopic particle is associated with a wave-packet composed of the superposition of plane waves with different frequency ω and different wave vector $\boldsymbol{k}$. The energy E and momentum $\boldsymbol{p}$ of the microscopic particle are related to the frequency ω_0 and wave vector $\boldsymbol{k}_0$ of the central component of the wave-packet according to the de Broglie relation (11.53). The one-dimensional and three-dimensional forms of the wave-packet formed by the superposition of such plane waves can be written as

$$\left.\begin{aligned} u(x,t) &= \int_{k_0-\Delta k}^{k_0+\Delta k} \phi(x,t,k)\mathrm{d}k, \\ u(\boldsymbol{r},t) &= \int_{\boldsymbol{k}_0-\Delta \boldsymbol{k}}^{\boldsymbol{k}_0+\Delta \boldsymbol{k}} \phi(\boldsymbol{r},t,\boldsymbol{k})\mathrm{d}k_x\mathrm{d}k_y\mathrm{d}k_z, \end{aligned}\right\} \tag{11.75}$$

where the central component of the wave-packet can be written accordingly, which is an eigen solution satisfying Schrödinger's equation of the free particle

$$\left.\begin{aligned} \phi(x,t,k_0) &= \psi(x,t) = (2\pi)^{-1/2}\mathrm{e}^{\mathrm{i}(k_0x-\omega_0t)}, \\ \phi(\boldsymbol{r},t,\boldsymbol{k}_0) &= \psi(\boldsymbol{r},t) = (2\pi)^{-3/2}\mathrm{e}^{\mathrm{i}(\boldsymbol{k}_0\cdot\boldsymbol{r}-\omega_0t)}. \end{aligned}\right\} \tag{11.76}$$

How can we determine the relationship between ω and $\boldsymbol{k}$ of the general superposition term of the wave-packet function? Following Postulate 3, the wave-packet component function $\phi(x,t,k)=\phi_k(x,t)$, similar to the wave-particle function $u(\boldsymbol{r},t)$, follows the equation of the same form.

For simplicity, the wave particle component equation in one dimension is solved first.

Let the momentum $p=+\hbar k_0$ of a particle be positive or negative. When the momentum p is along the positive direction of the x axis, the particle travels to the right, and $p=\hbar k_0>0$; when the momentum p is along the negative direction of the x axis, the particle travels to the left, and $p=\hbar k_0<0$. The wave particle component equation is written as

$$\mathrm{i}\hbar\frac{\partial\phi_k(x,t)}{\partial t} = -\mathrm{i}\hbar\frac{p}{m}\frac{\partial\phi_k(x,t)}{\partial x} + \left(E-\frac{p^2}{m}\right)\phi_k(x,t). \tag{11.77}$$

By letting $\phi_k = f(t)\varphi(x)$, and substituting it into Eq.(11.77), we can separate variables and obtain

$$\mathrm{i}\hbar\frac{1}{f}\frac{\mathrm{d}f}{\mathrm{d}t}=-\mathrm{i}\hbar\frac{p}{m}\frac{1}{\varphi}\frac{\mathrm{d}\varphi}{\mathrm{d}x}+\left(E-\frac{p^2}{m}\right).$$

Now let both left and right sides equal to constant $\hbar\omega$, one gets

$$\frac{\mathrm{d}f}{\mathrm{d}t}=-i\omega f,\quad f\left(t\right)=c_1\mathrm{e}^{-\mathrm{i}\omega\left(t-t_0\right)}.$$

Using Eq. (11.53), we obtain from the above formula

$$\mathrm{i}\hbar\frac{p}{m}\frac{\mathrm{d}\varphi}{\mathrm{d}x}=\left(-\hbar\omega+E-\frac{p^2}{m}\right)\varphi.$$

Let

$$\omega-\omega_0=\frac{\hbar k_0}{m}\left(k-k_0\right)=\upsilon\left(k-k_0\right),\tag{11.78}$$

where m and υ indicate the mass and velocity of the particle (excluding the direction and plus-minus sign), respectively. From this we obtain

$$\left.\begin{aligned}\varphi\left(x\right)&=C\mathrm{e}^{\pm\mathrm{i}k\left(x-x_0\right)},\\ \phi\left(x,t,k\right)&=\left(2\pi\right)^{-1/2}\mathrm{e}^{\pm\mathrm{i}\left[k\left(x-x_0\right)\mp\omega\left(t-t_0\right)\right]},\end{aligned}\right\}\tag{11.79}$$

$$u\left(x,t\right)=\left(2\pi\right)^{-1/2}\int_{k_0-\Delta k}^{k_0+\Delta k}\mathrm{e}^{\pm\mathrm{i}\left[k\left(x-x_0\right)\mp\omega\left(t-t_0\right)\right]}\mathrm{d}k,\tag{11.80}$$

where $\left(2\pi\right)^{-1/2}$ is the normalization constant, and ω and k are related by Eq. (11.78).

In the three-dimensional case, one can similarly obtain

$$\phi\left(\boldsymbol{r},t,\boldsymbol{k}\right)=\left(2\pi\right)^{-3/2}\mathrm{e}^{\pm\mathrm{i}\left[\boldsymbol{k}\cdot\left(\boldsymbol{r}-\boldsymbol{r}_0\right)\mp\omega\left(t-t_0\right)\right]};\tag{11.81}$$

$$u\left(\boldsymbol{r},t\right)=\left(2\pi\right)^{-3/2}\int_{\boldsymbol{k}_0-\Delta\boldsymbol{k}}^{\boldsymbol{k}_0+\Delta\boldsymbol{k}}\mathrm{e}^{\pm\mathrm{i}\left[\boldsymbol{k}\cdot\left(\boldsymbol{r}-\boldsymbol{r}_0\right)\mp\omega\left(t-t_0\right)\right]}\mathrm{d}k_x\mathrm{d}k_y\mathrm{d}k_z,\tag{11.82}$$

where $\left(2\pi\right)^{-3/2}$ is the normalization constant, and the relation of ω and $\boldsymbol{k}$ can be expressed as

$$\omega-\omega_0=\frac{\hbar\boldsymbol{k}_0}{m}\cdot\left(\boldsymbol{k}-\boldsymbol{k}_0\right)=\boldsymbol{\upsilon}\cdot\left(\boldsymbol{k}-\boldsymbol{k}_0\right).\tag{11.83}$$

The physical significance of the real parameters x_0 (or $\boldsymbol{r}_0$) and t_0 introduced in the solution process and appearing in the expression of the wave-particle function is as follows: at time $t=t_0$, the wave particle center is located at $x=x_0$ (or $\boldsymbol{r}=\boldsymbol{r}_0$). The reasons for this will be described later.

From Eqs. (11.78) and (11.83), we obtain that when $k=k_0$ (or $\boldsymbol{k}=\boldsymbol{k}_0$), there is $\omega=\omega_0$, conversely, when $\omega=\omega_0$, there is $k=k_0$ (or $\boldsymbol{k}=\boldsymbol{k}_0$). If the difference in the phase factor $\exp\left[-\mathrm{i}\left(\boldsymbol{k}_0\cdot\boldsymbol{r}_0-\omega_0 t_0\right)\right]$ is ignored, when $k=k_0$ (or $\boldsymbol{k}=\boldsymbol{k}_0$) the the center component of the wave-particle function

$$\phi\left(x,t,k_0\right)=\phi\left(x,t\right)=\left(2\pi\right)^{-1/2}\mathrm{e}^{\pm\mathrm{i}\left[k_0\cdot\left(x-x_0\right)\mp\omega_0\left(t-t_0\right)\right]},\tag{11.84}$$

$$\phi\left(\boldsymbol{r},t,\boldsymbol{k}_0\right)=\phi\left(\boldsymbol{r},t\right)=\left(2\pi\right)^{-1/2}\mathrm{e}^{\pm\mathrm{i}\left[\boldsymbol{k}_0\cdot\left(\boldsymbol{r}-\boldsymbol{r}_0\right)\mp\omega_0\left(t-t_0\right)\right]}.\tag{11.85}$$

This wave function has a determined momentum and satisfies the Schrödinger equation for a free particle.

From the relations (11.78) and (11.83) of ω and $\boldsymbol{k}$, for the cases of one and three dimensions, we obtain, respectively,

$$\frac{\mathrm{d}\omega}{\mathrm{d}k}=\upsilon,\ \frac{\mathrm{d}^2\omega}{\mathrm{d}k^2}=0;\ \frac{\mathrm{d}\omega}{\mathrm{d}k_\alpha}=\upsilon_\alpha,\ \frac{\mathrm{d}^2\omega}{\mathrm{d}k_\alpha^2}=0, \tag{11.86}$$

where $\alpha=1,2,3$ corresponds to the x,y,z component. The analysis shows that the wave packets formed by the linear superposition of the component functions ϕ, satisfying conditions (11.78) and (11.83), are stable wave-packets.

Starting from Eq. (11.80), and using Eq. (11.78), and letting $\xi=\Delta k\left(x-x_c\right)$, $x_c=x_0+\upsilon\left(t-t_0\right)$, the calculation yields

$$\begin{aligned} u(x,t)&=(2\pi)^{-1/2}\int_{k_0-\Delta k}^{k_0+\Delta k}\mathrm{e}^{\mathrm{i}k\left[(x-x_0)-\upsilon(t-t_0)\right]}\mathrm{d}k\cdot\mathrm{e}^{-\mathrm{i}(\omega_0-k_0\upsilon)(t-t_0)}\\ &=\frac{2}{\sqrt{2\pi}}\frac{\sin\xi}{\xi}\Delta k\,\mathrm{e}^{\mathrm{i}\left[k_0(x-x_0)-\omega_0(t-t_0)\right]}\\ &=(2\pi)^{1/2}\frac{\sin\Delta k\left(x-x_c\right)}{\pi\left(x-x_c\right)}\mathrm{e}^{\mathrm{i}\left[k_0(x-x_0)-\omega_0(t-t_0)\right]}, \end{aligned} \tag{11.87}$$

where $$x_c=x_0+\left(\hbar k_0/m\right)\left(t-t_0\right)=x_0+\upsilon\left(t-t_0\right).$$

When $p=\hbar k_0>0,\ \upsilon>0$, it describes a right travelling wave particle; when $p=\hbar k_0<0,\ \upsilon<0$, it describes a left travelling wave particle.

From Eqs. (11.82) and (11.83) one can obtain similarly

$$\begin{aligned} u(\boldsymbol{r},t)&=(2\pi)^{-3/2}\int_{\boldsymbol{k}_0-\Delta\boldsymbol{k}}^{\boldsymbol{k}_0+\Delta\boldsymbol{k}}\mathrm{e}^{\mathrm{i}\boldsymbol{k}\cdot\left[(\boldsymbol{r}-\boldsymbol{r}_0)-\omega(t-t_0)\right]}\mathrm{d}k_x\mathrm{d}k_y\mathrm{d}k_z\cdot\mathrm{e}^{-\mathrm{i}\left[(\omega_0-\boldsymbol{k}_0\boldsymbol{\upsilon})(t-t_0)\right]}\\ &=\left(\frac{2}{\pi}\right)^{3/2}\prod_{\alpha=1}^{3}\frac{\sin\xi_\alpha}{\xi_\alpha}\Delta k_\alpha\mathrm{e}^{\mathrm{i}\left[\boldsymbol{k}_0\cdot(\boldsymbol{r}-\boldsymbol{r}_0)-\omega_0(t-t_0)\right]}\\ &=(2\pi)^{3/2}\prod_{\alpha=1}^{3}\frac{\sin\Delta k_\alpha\left(x_\alpha-x_{\alpha c}\right)}{\pi\left(x_\alpha-x_{\alpha c}\right)}\mathrm{e}^{\mathrm{i}\left[\boldsymbol{k}_0\cdot(\boldsymbol{r}-\boldsymbol{r}_0)-\omega_0(t-t_0)\right]} \end{aligned} \tag{11.88}$$

where $\xi_\alpha=\Delta k_\alpha\left[x-x_{\alpha0}-\upsilon_\alpha\left(t-t_0\right)\right],\alpha=1,2,3$ corresponding to the x,y,z components, respectively, and we have

$$x_{\alpha c}=x_{\alpha0}+\left(\hbar k_0/m\right)\left(t-t_0\right)=x_{\alpha0}+\upsilon\left(t-t_0\right),\ \alpha=1,2,3.$$

The $s(\xi)=\sin\xi/\xi$ is an δ -like function. When $\xi=0$, namely $x=x_0+\upsilon\left(t-t_0\right)$, ha $s^2(\xi)=1$; when $\xi=\pm\pi,\pm2\pi,\pm3\pi,\cdots,\pm m\pi$ (m is an integer), has $s^2(\xi)=0$. Between the two zeros, when $\xi=\pm\mathrm{tg}\xi$, i.e., $\xi=\pm1.430\pi,\ \pm2.459\pi,\ \pm3.47\pi$ etc., $s^2(\xi)$ takes the secondary maximum of 0.047, 0.016, and 0.008, respectively. Thus, $s^2(\xi)$ can be seen as concentrated between the intervals $\xi=\pm\pi$, with an error of no more than 5%, Outside this interval, it rapidly approaches to zero.

From

$$\xi=\left[x-x_c\right]\Delta k=\left[x-x_0-\upsilon\left(t-t_0\right)\right]\Delta k=\pm\pi, \tag{11.89}$$

the expression of the wave particle scale is gotten as

$$\Delta x=2\pi/\left(\Delta k\right). \tag{11.90}$$

Obviously, this wave-particle function does not spread spontaneously over time, it is a stable wave-packet, center of which is located at $x_c=x_0+\upsilon\left(t-t_0\right)$ and moves over time, when $t=t_0$, the center is $x_c=x_0$. This is the physical meaning of the real parameters x_0 and t_0.

It should be noted that for a wave-particle function of a certain scale Δx, the interval Δk of the continuously changing wave vector cannot be less than a certain value. Because the scale Δx of microscopic particles is small, this interval Δk is large. For example, for an electron, the upper bound on its scale is experimentally determined to be is $10^{-15}\,\mathrm{m}$, which gives $\Delta k\approx 2\pi\times 10^{15}\,\mathrm{m}^{-1}$ from the above equation. If the upper bound of the scale is $10^{-18}\,\mathrm{m}$, then $\Delta k\approx 2\pi\times 10^{18}\,\mathrm{m}^{-1}$. On the other hand,

$$k_0=\frac{p}{\hbar}=\frac{m_0\upsilon}{\hbar\sqrt{1-\upsilon^2/c^2}}=8.7\times 10^3\frac{\upsilon}{\sqrt{1-\upsilon^2/c^2}}\quad(\mathrm{m}^{-1}).$$

Thus, at least in the case where the particle velocity is much smaller than the speed of light, that is $k_0\ll\Delta k$, in the wave-particle function, Δk can be viewed as approximately infinity.

Note an expression of the δ function

$$\lim_{\Delta k\to\infty}\frac{\sin\Delta k\left(x-x'\right)}{\pi\left(x-x'\right)}=\delta\left(x-x'\right). \tag{11.91}$$

Therefore, under the condition that Δk can be regarded as infinite, the function expressions of the one-dimensional and three-dimensional wave particle are obtained from Eqs. (11.87) and (11.88), respective

$$\left.\begin{aligned}u\left(x,t\right)&=\left(2\pi\right)^{1/2}\delta\left(x-x_c\right)\mathrm{e}^{\mathrm{i}\left[k_0\left(x-x_0\right)-\omega_0\left(t-t_0\right)\right]},\\ u\left(\boldsymbol{r},t\right)&=\left(2\pi\right)^{3/2}\delta\left(\boldsymbol{r}-\boldsymbol{r}_c\right)\mathrm{e}^{\mathrm{i}\left[k_0\left(r-r_0\right)-\omega_0\left(t-t_0\right)\right]}.\end{aligned}\right\} \tag{11.92}$$

However, Δk only takes a large value, thus defining the δ -like function or the generalized δ function as follows:

$$\delta\left(x-x',\Delta k\right)=\frac{\sin\Delta k\left(x-x'\right)}{\pi\left(x-x'\right)}=\frac{\Delta k}{\pi}\frac{\sin\xi}{\xi}. \tag{11.93}$$

It satisfies

$$\int_{-\infty}^{+\infty}\delta\left(x-x',\Delta k\right)\mathrm{d}x=\int_{-\infty}^{+\infty}\frac{\sin\Delta k\left(x-x'\right)}{\pi\left(x-x'\right)}\mathrm{d}x=1, \tag{11.94}$$

which can be readily derived using the residue theory of complex functions. Using Eq. (11.93), the wave-particle functions $u(x,t)$ and $u(\boldsymbol{r},t)$ can be accurately expressed as

$$\left.\begin{aligned} u(x,t) &= (2\pi)^{1/2}\,\delta(x-x_c,\Delta k)\,\mathrm{e}^{\mathrm{i}\left[k_0(x-x_0)-\omega_0(t-t_0)\right]},\\ u(\boldsymbol{r},t) &= (2\pi)^{3/2}\,\delta(\boldsymbol{r}-\boldsymbol{r}_c,\Delta k)\,\mathrm{e}^{\mathrm{i}\left[\boldsymbol{k}_0\cdot(\boldsymbol{r}-\boldsymbol{r}_0)-\omega_0(t-t_0)\right]}.\end{aligned}\right\}$$

These are the expressions of a stable wave-packet centered at $x_c = x_0 + \upsilon(t-t_0)$ or $\boldsymbol{r}_c = \boldsymbol{r}_0 + \boldsymbol{\upsilon}(t-t_0)$ moving at speed $\boldsymbol{\upsilon}$ and confined to $\Delta x = 2\pi/(\Delta k) = 10^{-18}\mathrm{m}$ (for an electron). However, in our later narrative, for the sake of simplicity, we will only write it as $\delta(x-x_c)$ or $\delta(\boldsymbol{r}-\boldsymbol{r}_c)$ functions.

The above calculation was performed only for the right travelling waves. The calculation process for the left travelling wave is the same; therefore, it is omitted (hereafter, the same).

Reviewing the above derivations, we see that the superposition of plane waves with different angular frequencies ω and different wave vectors $\boldsymbol{k}$ constitutes stable wave-packets. Evidently, the superposed waves propagate superluminally. The central component $\phi(\boldsymbol{r},t,\boldsymbol{k})$ of the wave-packet is the solution of Schrödinger's equation, let its propagation velocity is denoted by u_0, according to Postulate 2, we have $\phi_{k_0}(x,t)$

$$u_{w0} = \nu_0\lambda_0 = \frac{\omega_0}{k_0} = \frac{\hbar\omega_0}{\hbar k_0} = \frac{E}{p} = \frac{mc^2}{m\upsilon} = \frac{c^2}{\upsilon} > c. \tag{11.95}$$

It apparently travels faster than light. As for the propagation speeds $u_i = \nu\lambda = \omega/k$ of the waves of the other components, note that ω and k satisfy Eqs. (11.78) and (11.83), that is, $\omega-\omega_0 = \boldsymbol{\upsilon}\cdot(\boldsymbol{k}-\boldsymbol{k}_0)$, ω and k must increase or decrease synchronously, and the propagation speed of the component waves can also remain within the range of the superluminal speed. Thus, the physical significance of Eq. (11.95) is that the superluminal propagating waves in the background field in dispersed-state superimposed to form a stable wave-packet, which is the true representation of the microscopic particles. However, the velocity of motion of the macroscopic body is subluminal.

By directly solving the wave-particle equation, we can also obtain a wave-particle function solution representing a stable wave-packet.

Substituting the obtained wave-particle function (11.92) into Eqs.(11.70)—(11.72), the energy, momentum and position coordinates of the free wave particle can be easily obtained

$$E_c = \int_{-\infty}^{+\infty} u^*(x,t)\,\mathrm{i}\hbar\frac{\partial}{\partial t}\psi(x,t)\,\mathrm{d}x = \hbar\omega_0, \tag{11.96}$$

$$p_c = \int_{-\infty}^{+\infty} u^*(x,t)\left(-\mathrm{i}\hbar\frac{\partial}{\partial x}\right)\psi(x,t)\,\mathrm{d}x = \hbar k_0, \tag{11.97}$$

$$x_c = \int_{-\infty}^{+\infty} u^*(x,t)\,x\,\psi(x,t)\,\mathrm{d}x = x_0 + \frac{p}{m}(t-t_0) \tag{11.98}$$

From the above results we see that the momentum and the position of a single free particle have determined values at the same time. In Wave-Particle Mechanics, the uncertainty relation is regarded as the statistical dispersion relation of the results obtained by measuring complementary physical quantities on a large number of particles in a quantum ensemble, that is, the statistical dispersion. For a single system, the uncertainty relation does not hold.

In quantum mechanics, according to its calculation rules, the average value of the mechanical quantities of free particles is almost zero. This situation has shown the truth of the matter. According to Wave-Particle Mechanics, quantum mechanics calculates the average value of mechanical quantities for quantum ensembles containing free particles with different positions and momenta, which inevitably leads to zero results. This clearly shows that quantum mechanics can not describe a single microscopic system, and quantum mechanics needs to be correctly understood and truly developed.

11. 5. 5. Conclusion

Einstein, de Broglie and Schrödinger made a long and lifelong effort to obtain a quantum theory for complete description of microscopic systems. Einstein himself must have done careful thinking about it. He once said: “I have spent a hundred times more thought on quantum problems than on the general relativity.” Schrödinger has been seeking to describe particles by wave-packet, but Schrödinger’s wave-packet is always instantaneous spreads, which cannot overcome the difficulty of “the spread of wave-packet” for nearly a century. De Broglie, Schrödinger, Bohm, Weinberg, Yukawa Hideki and other famous physicists have proposed their own solutions, but they cannot describe a single particle and its motion, and cannot solve the fundamental problem raised by de Broglie, that is, to describe the association and coexistence of wave and particle. About a century has passed, and the quantum theory for complete description has not achieved perfect results and success.

I have worked long and hard to create Wave-Particle Mechanics in the direction indicated by Einstein and de Broglie. The Relevant papers have been published. The book [24] *Wave-Particle Mechanics—The Quantum Theory for Complete Description of Microscopic Systems* (408 pages, about 500000 words) has been published by Hunan Education Publishing House in July 2022. The book elaborates on the origin and development of Wave-Particle Mechanics, its basic theory and the solution of various quantum problems. The last section of this chapter is a general introduction to Wave-Particle Mechanics.

Relevant papers have been published.

Wave-Particle Mechanics was founded based on the aggregated-dispersed states natural images and the theoretical results of Standard Space-time Theory. The basic concept of wave Wave-Particle Mechanics is that the existing quantum mechanics is a statistical description of quantum ensembles in a definite microscopic environment; in addition, a deterministic description of a single microscopic system must be developed; the superposition of superluminal waves in the dispersed-state vacuum background field form stable wave-packets; and the stable wave-packet is the true representation of the microscopic system as the center of extensive wave phenomena. This is the deep physical origin behind the non-locality of quantum phenomena. According to Wave-Particle Mechanics, the ordinary wave functions $\psi(\boldsymbol{r},t)$ describe quantum ensembles, but they cannot completely determine the behavior of individual microscopic systems. Combining the wave function $\psi(\boldsymbol{r},t)$ with the wave-particle function $u(\boldsymbol{r},t)$, according to the wave-particle equation, the position and trajectory of a single microscopic system can be calculated, and its deterministic law of motion can be clarified, and the position and momentum of the particle have definite values at the same time. This natural and clear physical picture can clarify the physical essence of quantum entanglement of correlated particles and telepathy of twins.

Starting from the six basic postulates mentioned above, the theoretical framework for Wave-Particle Mechanics is established, achieving a series of significant advancements.

1. Wave-Particle Mechanics constructs stable wave-packets and completely solves the century physics puzzle of the Schrödinger wave-packet divergence.

2. The wave-particle equation is put forward, and the basic principle of constructing the basic equation of quantum theory is expounded. Starting from this basic principle, we can construct the two basic equations of quantum theory, namely the Schrödinger equation and the wave-particle equation, and can realize the mutual derivation or transition between the two equations .

3. Wave-Particle Mechanics provides complete deterministic description for the motion of single microscopic systems. By using the wave-particle equation, the main examples of one-dimensional motion of particles (as single linear harmonic oscillator) and the motion of particles in a central force field, especially the motion of electrons of a single hydrogen atom, are solved accurately, and the corresponding clear and complete physical pictures are expounded.

4. The formulas of physical quantities of wave-particles varying with time are derived. It gives three restrictive conditions. If the three restrictive conditions are satisfied, a single microscopic system is in a localized particle state, otherwise, the system appears as a wave lump or a wave circle in the dispersed-state. It is proved that the motion of wave-particles strictly obeys the classical Newton’s law of motion.

5. Based on the aggregated-dispersed states natural images and the theoretical result on the subluminal and superluminal worlds of Standard Space-time Theory, Wave-Particle Mechanics has provided a clear physical picture for quantum entanglement.

Wave-Particle Mechanics has also obtained a series of other important physical result

Starting from the crisis of modern physics and clear philosophical orientation, the new physical theories, i.e., Standard Space-time Theory and Wave-Particle Mechanics are created and show a broad field of development. Through these deepening and development, space-time theory and quantum theory have achieved a deeper integration, which provides a new and correct basis and starting point for the breakthrough and development of modern physics. All these great changes involving the concept of nature and space-time will certainly promote the fourth breakthrough and development of physics.

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Appendix

Appendix 1
Letters from the Famous Scientist Qian Xuesen

1. To Zhao Yijun

Beijing, February 16th, 1984

Dear Comrade Zhao Yijun*),

Your letter of February 8th, as well as Comrade Tan Shusheng's letter of January 24th and his papers have all been received.

Recently I read an article on the quantum gravitational field in the *Scientific American* (December, 1983) and I have learnt the following:

(1) In special theory of relativity, space-time is flat, there is no matter inside, and therefore different coordinate systems are equivalent. In the actual space-time, there is some matter inside and space-time is thus curved. Naturally there is standard space-time, and different coordinate systems are not equivalent. In General Relativity, there is no equivalence between different coordinate systems.

(2) The 2.7K cosmic background radiation is relative to the cosmic matter distribution and originates from our cosmic matter distribution, so it has its own "standard coordinate system".

(3) Overall, because space-time is not empty, Standard Space-time Theory holds true.

(4) But in our universe, G is small in general, thus the curvature of the space-time is small, and could be ignored in small domains; the space-time looks flat, the error should not be serious.

(5) Speaking of small domain, it is still "macroscopic", or of the element particle scale. But the domain is not too small. When the scale is as small as 10^{-33} cm, the quantum field effect would show; the macro gravity theory is no longer suitable.

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*) Zhao Yijun is an academician of the Chinese Academy of Engineering.

(6) Thus, Tan Shusheng's theory should most likely be applicable to the phenomena near the earth. It is a relative truth, not merely the words of one school.

If you agree to what I said, I suggest Comrade Tan Shusheng make some change to his paper, especially the "introduction", stating the theory is a part of an integral theory, which has an applying domain, and is yet a very precise theory in such domains. This point of view is in accordance with Marxism philosophy, which explains why we are wiser than foreigners.

Besides, the concept of velocity is a macroscopic one. What is velocity in quantum mechanics? So, there is also a mistake of conceptual confusion in Bell's inequalities!

Sincerely yours,

Qian Xuesen

2. To Tan Shusheng

Beijing, March 5th, 1990

Dear Professor Tan Shusheng:

Your masterpiece "Laozi's 'beings are born of nothing' and the Natural Image of Modern Science" was read in the first issue of Dialectics of Nature in 1990. This is a good article. At the same time, I also read He Xiangtao and Qiao Ge's Quasar and Redshift Debate. This brings me to an idea, which is written below for your consideration:

Yu Jingyuan, Dai Ruwei and I published an article in the first issue of Nature Journal in 1990, which enriched my short article in the tenth issue of Philosophical Research last year, and put forward the concept of open complex giant system and its unique research method, the comprehensive integration method combining qualitative and quantitative analysis. The article also cites examples of open complex giant systems, including the human body and the universe. In your work on the science of the human body, you have probably been aware of the fact that the human body is an open, complex, giant system; I have described this in more detail in my articles on the science of the human body. But now I think that the universe is also an open complex giant system, and the old method of combining qualitative and quantitative methods is not enough. In fact, Laozi's "beings are born of nothing" quoted in your article is a qualitative understanding, while the modern scientific theory of the universe behind it is some quantitative understanding. It is already a combination of qualitative and quantitative.

But I want you to go one step further: to really apply the concept of open complex giant systems to the study of cosmology-the study of the big universe, including the universe we live in. Is an open complex giant system, do not simplify! There is no need to argue about the redshift. The redshift of stars and the redshift of quasars can coexist completely, but the nature is different. I believe that the study of the universe will increasingly confirm my point of view, so it is the direction of cosmological research. Please consider.

……

Your future research object should not be limited to “the natural image of modern science", but should be the cosmic image of Marxist science.

What’s the above? please give your comment.

Regards Salute!

Qian Xuesen

Appendix 2
Letters from the Famous Physicist B. d’Espagnat

1

University Paris 11, Orsay Centre, France, Sept. 30, 1985

Dear Mr. Tan,

Let me apologize for having been so long in answering your June 15th letter and in acknowledging receipt of your “Standard Space-Time Theory” article. On this, I am all the more unforgivable as I think you have quite a nice point when you show that, by themselves, the experiments involving light travelling along some closed paths do not necessarily entail ordinary “special relativity” since they are compatible with a conception that is quite significantly different. This I did not know and, although the proof is simple, the (few) physicists with whom I discussed the matter were not aware of this fact either. Of course, one of the main virtues of special theory of relativity is that it gave rise to general relativity, a theory whose existence is especially important in accounting for local cosmological effects such as black holes and so on. Could your theory compete with it on these grounds? This is one of the many questions that come to mind in connection with your paper, but of course the existence of these questions does not alter the interest of your remark.

with best regards.

B. d’Espagnat

2

Addresser: Bernard Despagnat <bernard.despagnat@free.fr>
Addressee: tansst@vip.sina.com
Date: 2010-02-20 18:26:18

Dear Dr. Tan Shu Sheng

I read the documents you sent me with great interest. If the publisher asks me my opinion about publishing them my answer will be a favorable one for I think your (very revolutionary) views are worth being known and discussed by genuine experts. On the other hand, the matters you deal with are quite delicate ones, and it would take me much too much time to reach full certainty about them. So, I think the preface should be written by somebody much more familiar than I am with these questions.

Witth my best wishes
Bernard d'Espagnat

Appendix 3 Several Academicians' Comments on Standard Space-time Theory

1

Song Jian, an academician of the Chinese Academy of Sciences, the former president of the Chinese Academy of Engineering, former state councilor and director of the National Science and Technology Commission, and former vice-chairman of the Chinese People's Political Consultative Conference, paid great attention to the publication of the book *From special theory of relativity to Standard Space-time Theory*, and wrote a preface for the book. In the preface, he pointed out:

"Professor Tan Shusheng has devoted more than 20 years' efforts to create Standard Space-time Theory. As a self-consistent new theoretical system, it inherits and integrates the basic ideas and achievements of Newtonian mechanics and Einstein's special theory of relativity. It contains the known, and has the innovation, has cleared up the original paradox, has opened up the new field of vision, has the vital significance to the physics development."

2

Cheng Jinpei, an acad*emi*cian of the Chinese Academy of Sciences and former vice minister of the Ministry of State Science & Technology and former deputy director of the Education, Science, Culture and Health Commission of the National People's Congress, wrote to Tan on January 14, 2009:

"I can learn about this major theoretical innovation result in modern physics through your book. I would like to express my sincere admiration for your spirit that you are willing to sit on the bench, dare to challenge authority, decades of hard exploration. China needs so many scientists like you who have devoted their lives to the pursuit of truth. And I sincerely congratulate on your scientific achievements.

"The establishment and acceptance of an essential original theory may need a very long time, decades or even longer. A real scientist must have this patience. Your decades of theoretical pursuit have fully demonstrated that you possess these excellent characteristics, which are extremely rare and really valuable. Whereas, I believe this day will finally come and we all can witness it."

3

Zhao Yijun, an academician of the Chinese Academy of Engineering, wrote in his review of the publication of Professor Tan Shusheng's book Standard Space-time Theory:

"This book will make contribution to the reconstruction of the basis of physics. The main advantages of this book are: (1) the two basic postulates of Standard Space-time Theory have a solid experimental basis. (2) The mathematical calculations and logical inferences in this book are all correct. (3) Standard Space-time Theory gained the absolute simultaneity so it permits the existence of superluminal motion and action without the difficulties of the causality violation. Its time idea is qualitatively near that of quantum mechanics, so it is in keeping with non-locality of quantum mechanics. (4) The laws of electromagnetic fields in general inertial systems are discovered and expressed by Standard Space-time Theory. The transformation relationship between the amount of electromagnetic field in the absolute reference frame and the amount of electromagnetic field in the general inertial frame is established and used to explain and predict various electromagnetic experimental phenomena. (5) Standard Space-time Theory perfectly explains all experimental results so far. (6) In a word, it establishes and forms a self-consistent and systematic theoretical system.

“I do not know of any existing publications on this subject or manuscripts in preparation which are likely to compete with the book. I have not seen any existing publication which states a self-consistent and systemic theoretical system that can compete with Einstein’s Special Theory of Relativity.

“Of course, the author is not familiar to foreign friends, but Standard Space-time Theory inherits and integrates the basic ideas and achievements of Newtonian mechanics and Einstein’s special theory of relativity, which will make a contribution to the reconstruction of the foundation of physics, so the author will have an important position in the field of modern physics.”