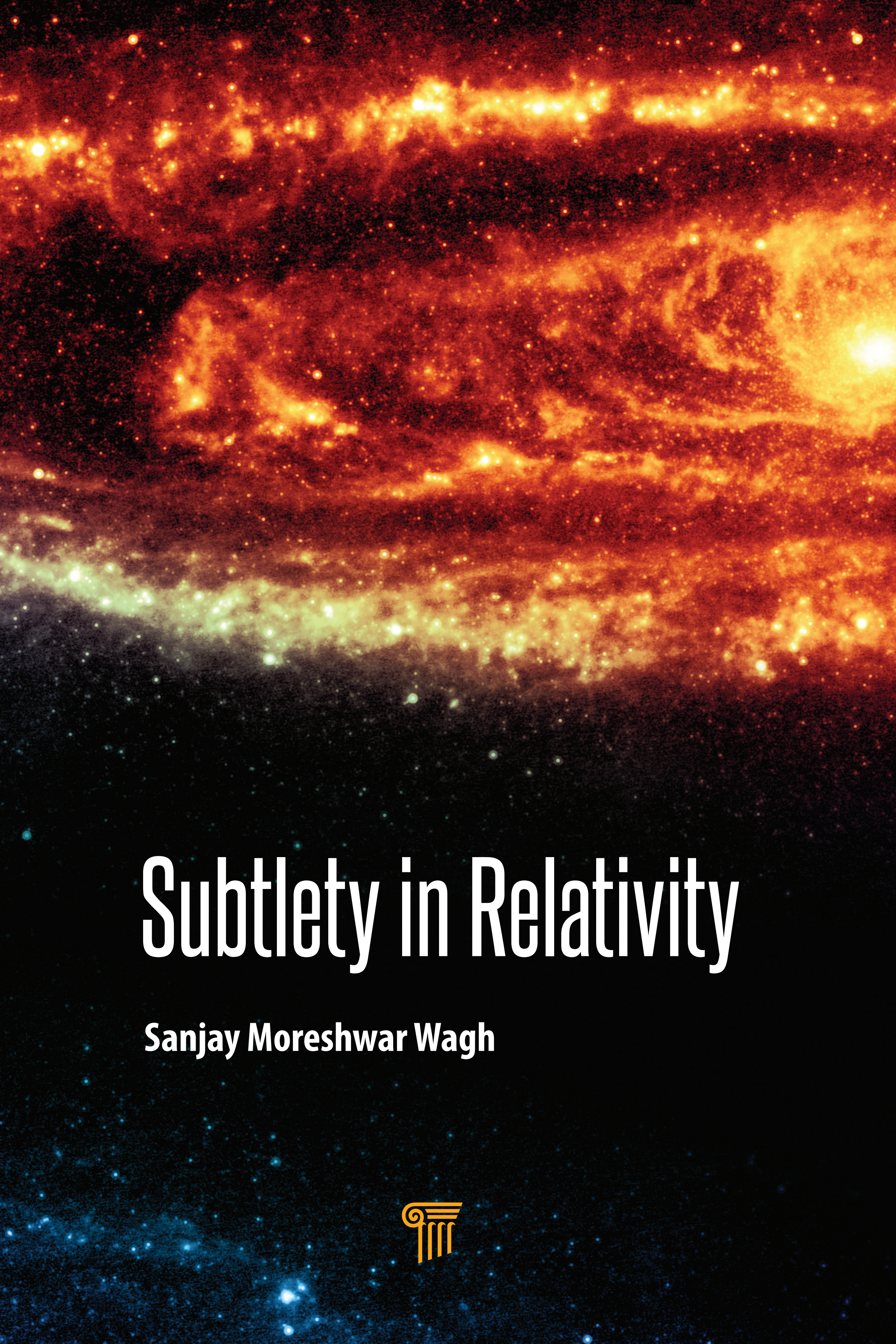

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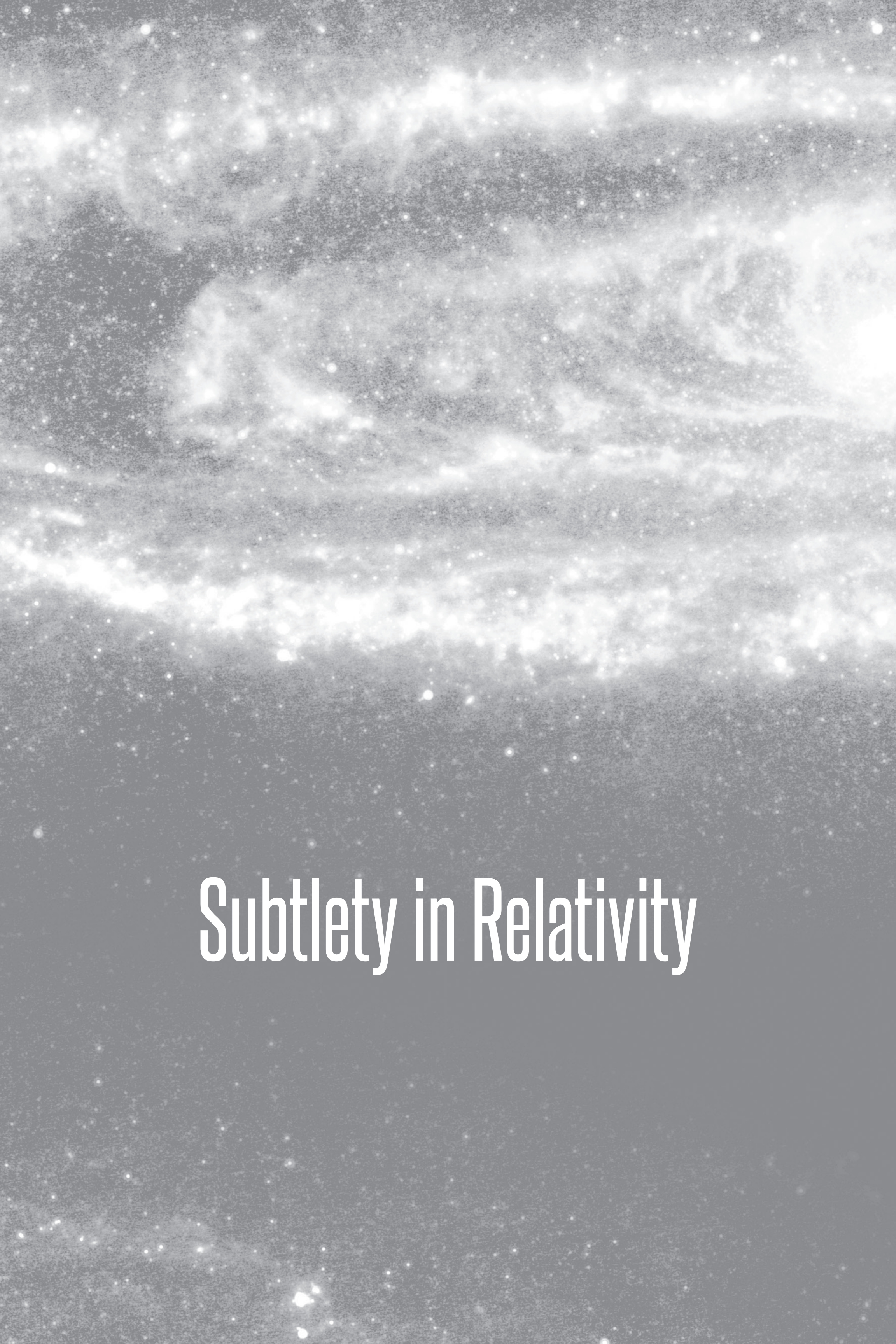

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Preface

Why This Book?

Einstein's ideas rocked the world during the twentieth century. The twin paradoxes of special relativity, the warped space-time of his theory of gravity, the bending of light by the sun, black holes, the expanding universe, etc., have formed headlines across media in the past and do so even in the present.

At the same time, Planck's idea of the quantum of light had challenged the classical Newtonian ideas. Schrödinger, Heisenberg, Bohr, Born, Dirac, and others developed the initial ideas (of Planck, Einstein, and de Broglie) into a mathematical theory of the quantum world. This probabilistic quantum theory predicts only the chance of an event. But as Einstein would say, this theory does not describe the constituents of that event.

Then, we have to ask, is it that the physical world is based on only chance happenings? Is our world governed only by the laws of chance? Or, as Einstein, Schrödinger, and some other physicists had believed, is our world governed by deterministic laws?

Schrödinger's cat paradox and the Einstein–Podolsky–Rosen paradox are famous interesting examples of some perplexing issues underlying probabilistic ideas of quantum theory.

These issues have surfaced periodically One reads about our world being deterministic or indeterministic. The imaginary world of physicists meets the real world of us all! How is this so? This has been the subject of many discussions of the past.

A reader may then begin to wonder, why is another book being written on these old issues? Don't we already know enough? Haven't we heard enough already? What has changed since then?

The justification of this book rests with the following:

This book is the only one that has been written after the author's discovery of a new way in which the wave phenomena happen. In the history of science, this is the first time we have realized this new way, the emission origin of the waves, of producing wave phenomena. This drastically changes most issues of the old debate about the world being deterministic or probabilistic.

The features of the phenomena of nature dictate, indeed, our theoretical constructions. Still, the concepts of theory remain free constructions of the human mind. However, this is seldom mentioned in the literature on issues relating to quantum theory.

(Young) Einstein had, emphatically and very aptly, said that "concepts that have proved to be useful in ordering things easily acquire such an authority over us that we forget their human origin and accept them as invariable. Then they become "necessities of thought," "given a priori," etc. The path of scientific progress is then, by such errors, barred for a long time."

(Old) Einstein too had continued with this line of thought to say in later years that "the prejudice . . . consists in the faith that facts by themselves can and should yield scientific knowledge without free conceptual construction. Such a misconception is possible only because one does not easily become aware of the free choice of such concepts, which, through verification and long usage, appear to be immediately connected with the empirical material."

This applies also to the debate about the issues of the quantum ideas. Adherents of determinism could be accused of prejudice, and so could be those favoring indeterminism.

One may also quote Pauli, a physicist: "If new features of the phenomena of nature are discovered that are incompatible with the system of theories assumed at that time, the question arises, which of the known principles used in the description of nature are general enough to comprehend the new situation and which have to be modified or abandoned."

The newly discovered emission origin for the wave phenomena is not incompatible with the ideas of quantum theory; rather, this new and novel way (in which waves can get generated) justifies the use of the mathematical and probabilistic methods of quantum theory. We are not required to modify quantum theory then. However, the emission origin for the waves shows that quantum theory is statistically incomplete, and that too in precisely Einstein's sense!

Underlying the ideas of quantum theory, there exists then a certain, previously unexplored, conceptual framework. Is this the theory that Einstein and others were looking for then? How is this way of thinking related to the ideas of relativity? Is this a relativistic theory in the usual sense of this word? This is the journey we proceed on in this book.

Concepts Are Free Creations of the Human Mind

> What do we mean by physical understanding of Nature? How do we relate it to experiments we perform, to observations we make of the Universe? How is it that the "concepts of physics" are the free creations of the human mind?

The purpose of a physical theory is to explain observations of nature. Concepts of a physical theory are the tools to formulate relations between them; and such relations are, ultimately, the predictions of that theory. Ultimate or testable relations are to be expressed so as to be applicable or usable in the context of an observation and/or experiment.

An experiment is an intentional arrangement of physical bodies that then aims to test a relation of observable quantities as implied by the theory under considerations. Then, an experimental device is an arrangement of bodies that responds according to a certain relationship of observable quantities, under an appropriate control of change to other observable quantities. An experiment must necessarily therefore possess the underlying theory it is attempting to verify or negate.

An experiment uses many experimental devices at the same time. Results of any experiment are dependent on the implicit assumption that all devices respond according to the correspondingly verified relationships of all of the involved observable quantities.

On the basis of the responses of the devices used within an experiment, we then arrive at the observed relationship of some observable quantities. This observed relationship is then the basis of the phenomenological theory underlying the corresponding experimental observation. A phenomenological theory then means the conceptual medley of the workings of experimental devices used within an experiment. Any experiment has such a theory underlying it, always. Such a theory underlying an experiment is, however, not the theory that we aim at in theoretical physics.

A phenomenological theory is not a complete theoretical understanding of the underlying behavior of physical bodies.

Such a theory only provides us guidelines for formulating a correspondingly complete theory, which transcends limits of that specific experiment and helps us predict results of new experiments.

Notice that the phenomenological theory of the new experiments can be quite different than that of the experiment we began with.

The same phenomenological theory of one experiment can be consistent with more than one underlying, more complete, theoretical frameworks of concepts. Only the results of a new experiment may then decide in favor of one of many competing theories by providing for them a new phenomenological theory to be consistent with.

Out of many competing theories, we choose the one agreeing with the new phenomenological theory, for it has a proven wider applicability. Then concepts of the theory of wider applicability are to be accepted as more appropriate for the description of nature. This is, incidentally, the sole purpose behind the act of performing an experiment.

An observation, in the sense of astronomy, is a naturally occurring arrangement of bodies leading to a result as if an experiment has been performed in the above sense. The formulation of a phenomenological theory underlying an observation is then based, first, on imagining an arrangement of bodies to correspond to that naturally occurring one. This is a mandatory step we have to take in such situations first.

On having imagined satisfactory arrangement of bodies to correspond to naturally occurring arrangement of bodies, we then follow the same steps as those leading to a phenomenological theory of observation. This is modeling a physical system; and we may neglect some bodies as being irrelevant to the situation to simplify the model.

We check predictions of a model against observations. If any kind of discrepancy is seen between the results of the model and those of the observation, then we have a choice of changing the model or call into question the theory assumed in the construction of the model. This is involved and laborious, no doubt. But in astronomy as well as in the atomic and subatomic world, we have no options than to resort to it.

When results of an experiment agree with the prediction of the theory, a relation of observable quantities is supported, but not all the concepts of that theory! Concepts remain free creations of the human mind.

An “ugly” experimental fact can destroy a “beautiful” theory. We will encounter many examples of this in the sequel. We will see how Descartes and many others compared light with sound waves. Concepts underlying waves of pressure in sound did not, however, agree with the observed properties of light, specifically, its polarization properties.

We will see that Newton’s corpuscular picture of light also did not lead to explanations of the wave properties of light. We will see how Robert Brown’s concepts of atoms of living matter had to be abandoned. Concepts of cold and hot radiation got abandoned, also.

Originally, Young, and Fresnel next, had realized that the vibrations of light can be taking place in a direction transverse to that of its propagation; in contrast to the longitudinal vibrations of particles in a sound wave. Thus, we needed to not abandon but modify the concept of a wave when applying to light. The concept of wave was not then abandoned but modified suitably so as to be consistent with the polarization properties of light. In other words, we had discovered a new type of wave, a transverse wave.

With Young’s idea of transverse wave for light, Newton’s corpuscular picture of light went out of favor. For over a century, the corpuscular concept of light was forgotten and efforts were directed at detection of the medium of the propagation of light as a transverse wave. The picture of light as a wave was as per Maxwell’s theory of electromagnetism.

Since efforts to detect the medium of propagation of light were inconclusive and mutually contradictory, Lorentz proposed that an electromagnetic wave is not a wave propagating in any medium but is rather to be looked upon as wavy or oscillatory changes of the electric and magnetic vector fields existing in space, which can be free.

But Hertz’s discovery of photoelectric effect led to Lenard’s subsequent experimental investigations. Einstein’s explanation of photoelectric effect, based on Planck’s hypothesis of the quantum of light, and Millikan’s subsequent experimental investigations forced the return of the corpuscular picture of light in the form of a quantum of light.

Light thence acquired a “schizophrenic” existence: depending on the experimental setup involving light, it was imagined by Heisenberg to exhibit the wave nature or the quantum nature.

Louis de Broglie’s daring hypothesis that matter, customarily or usually considered to be corpuscular in nature, must also exhibit the wave nature received great experimental confirmation by diffraction of electrons and neutrons by crystalline matter. Not only light but also matter acquired the aforementioned schizophrenic existence as a consequence.

In total conformity with de Broglie’s relation, $\lambda = h/\mathbf{p}$, where h is Planck’s constant and λ is the wavelength associated with the physical body in question having a momentum $\mathbf{p}$, Schrödinger put forward a suitable equation for the waves associated with a body of mass m.

Independently, Heisenberg put forward a matrix formulation of the same phenomenon, and Schrödinger then showed its equivalence with his own formulation of an equation for the waves associated with a physical body, or the famous Schrödinger’s equation.

Max Born then showed that the solutions of the Schrödinger equation possess interpretation as probability; the amplitude of the solution is the probability density of finding a physical body under considerations at a spatial location and at an instant of time.

These developments led to quantum theory, which had provided only a probabilistic description of the nature. As far as the mathematical framework of this quantum theory is considered and its probabilistic character is concerned, it is unexceptional. It led to many theoretical as well as experimental advances. Many of its predictions have been experimentally verified, and much of the modern technology is a consequence of the understanding of nature gained on the basis of this theory.

However, importantly, notice that quantum theory does not explain the schizophrenic existence of physical bodies, for it is based on de Broglie’s revolutionary hypothesis. This theory does not therefore explain de Broglie’s relation; rather it assumes this relation.

Demonstration of Heisenberg’s uncertainty relation using quantum theory is reminiscent of the fact that it is based on de Broglie’s relation $\lambda = h/\mathbf{p}$. The position of the body will be indeterminate within the wavelength $\delta x = \lambda$, and momentum will be indeterminate within $\delta\mathbf{p} = h/\lambda$, and we have $\delta\mathbf{p} \times \delta x \approx h$, which is Heisenberg's indeterminacy relation.

It does not constitute an explanation of this relation or that of de Broglie's relation. Rather, any such demonstration of the uncertainty relations only shows that the mathematical framework of quantum theory has successfully incorporated de Broglie's relation.

The issue of the explanation of de Broglie's relation or, equivalently, that of Planck's relation, $\in = hv$, then remains open, and out of the reach of quantum theory, importantly.

Then, how can any physical body know in advance what kind of experimental setup it is going to encounter? How can it be a wave and a quantum at the same time? Such questions led Einstein to say, in 1927, that "what nature demands from us is not a quantum theory or a wave theory; rather, nature demands from us a synthesis of these two views . . ." Quantum theory is not this synthesis, Einstein believed.

In this context, we will see that the emission wave mechanism provides such a synthesis then . . . even when each quantum moves along straight line path; it explains how the quanta, and not a single quantum, can be producing a wavy pattern of their numbers.

This then brings us to the following discussion of what we mean by observable physical quantity. Science is, importantly, based on measurable quantities related to the natural bodies.

From observations of bodies in nature, we formulate common concepts, applicable to them all. Concepts, which are our "free" creations related to a natural body, are not that natural body. If a concept does not agree with observations, we need to abandon or change it as required.

Measurements involve a specific arrangement of bodies. The measurement of a quantity for a body, in general, involves a specifically created arrangement of natural bodies in which we compare the value of that quantity for that body with its value for a reference body. We also assume that the creation of the arrangement of bodies for measurement does not uncontrollably affect the bodies and the value of a quantity is a real number.

One basic principle of physics is that no quantity should be introduced that cannot, at least in principle, be measured. It distinguishes science, and therefore physics, from other (nonscientific) thought systems. Such principles of science establish its practical utility.

Measurable are the physical quantities, and bodies to which these concepts apply are the physical bodies. Then, physical bodies are hypothetical and are defined to always obey our conceptions.

Quantities that can be directly measured in an arrangement of physical bodies are to be called directly observable quantities. In other words, a physical quantity is directly measurable when its value can be ascertained within a single attempt of its measurement. In contrast to directly observable quantities, a quantity is indirectly observable if its value has to be necessarily inferred from those of the directly observable quantities.

Now, the question arises as to which physical quantities are directly and which ones are indirectly observable quantities. The issue of some physical quantity being directly observable or not is determined by the nature of the corresponding concept and its interrelationships with other concepts.

As an example of a quantity that is indirectly observable, consider probability. We cannot measure it in a single arrangement of bodies. This is so because we may repeat the same arrangement of natural bodies many times, note the measured value for a specific physical quantity for every instance of the arrangement of bodies, and then determine the probability for the specific value of its measurement.

We tacitly assume that the arrangement of bodies is repeatable, in other words, the experiment of measurement of a physical quantity is repeatable as many times as we wish. Repeatability of experiments is quite an important principle of physics, and science, in general.

Furthermore, we may also assume that the physical quantity with which the probability is being associated is directly observable. We are free to conceptually associate probability with both directly and indirectly observable physical quantities.

The structure of concepts and their interrelationships, in totality, are the theoretical construction. In contrast to the above case with probability being an indirectly observable quantity posited after the introduction of some directly observable physical quantities, like position, we may begin with the concept of probability for the theoretical construction.

In this case, we associate a priori probability for the value of the physical quantity like position prior to or with disregard to its measurement.

Probability provided by the distribution of errors of measurement of the position of a body can itself, for example, be taken to be the a priori probability for the value of the position of that body without measurement. Einstein had stressed this issue on many occasions.

With the a priori probability associated with the value of any physical quantity, it is then necessarily indirectly observable within this conceptual framework, for we have only the likelihood of its value within such a theoretical construction that disregards or completely ignores the procedure for its measurement. Probability continues to be indirectly observable, for we need to repeat the measurement to verify its a priori distribution. That is to say, probability is not any directly observable physical quantity and is to be inferred from the ensemble properties, always.

For quantum theory, the above nature of probability underlies its incomplete character as a theory, Einstein had argued.

Einstein describes this situation in succinct words: "It is the theory which decides what we can observe." ("Observe" means "directly observe" in our sense.) In quantum theory, no direct measurement, but only indirect measurement, of the value of physical quantity is permitted.

Now, as we will see in the sequel, universal relativity is the most general theory about the physical world, for its mathematical framework is independent of how we may represent a physical body.

Then its explanations can be expected to be based on minimally formulated assumptions about characters of physical bodies and their interactions.

Universal relativity begins by recognizing that the natural or the inertial state of motion of a physical body is as prescribed by Galileo. It recognizes that a body of nonzero inertia has nonzero momentum.

Then, it recognizes that any body of vanishing inertia is only a momentumless energy quantum.

With the above mutually consistent and minimally formulated assumptions about the characteristics of physical bodies of nature, universal relativity aims to explain all physical phenomena on the basis of their possible interactions. It is a theory of "the reality" as it exists independent of the act of observation.

Organization of This Book

This book is divided into two parts. The first part is less mathematical and more conceptual in its orientation. The second part focuses on mathematical ideas needed to implement physical concepts.

Part I deals with how certain physical concepts developed historically. It is more accessible to a general reader. This discussion is neither chronologically ordered nor complete in all the historical details. It is only kaleidoscopic in character. Nevertheless, it aims to provide an overview of how some physical concepts got developed, with some getting modified and some others getting abandoned in view of results of experiments. A reader is advised to read Part I carefully.

In Chapter 1, we begin with the history of the wave theory of light. Then, we discuss how our ideas of electricity and magnetism evolved to form our concept of an electromagnetic wave. Next, we explore as to how the atomic nature of matter was discovered. Interaction of atomic matter and radiation is the subject of our further explorations into the history of related ideas. In particular, we elaborate on the role of thermodynamics in the formulation of statistical methods in physics also.

Next, we discuss the idea of what a quantum is. The notion of a quantum jump in energy is distinguished from that of a quantum jump in space. Beginning with paradoxes related to the ideas of a quantum, we then discuss the emission origin of the wave of quanta as a newly discovered manner in which waves of particles get produced in nature.

In Chapter 2, ideas of the theory of relativity and what the word "relativity" actually means are our focus.

Our account of this interesting history must, necessarily, begin with Galileo's ideas of the inertia of a body and its inertial state of motion. We then explore the structure of Newton's idea of a force vis-à-vis Galileo's notion of inertia. Likewise, to Einstein's special relativity, Newton's theory is also 4D, three of space and one of time, except that time is absolute in Newton's considerations. We stress that massless bodies do not obey Newton's laws, in particular, the Newtonian law of addition of velocities. This observation escaped notice in the past.

In the sequel, we discuss how Einstein's idea of relative time is untenable and that time is absolute, that is to say, it runs at the same rate for all observers irrespective of their state of motion.

A genuine theory of relativity is, necessarily, a theory of everything, that is, its formalism must encompass all physical bodies. Einstein's general principle of relativity is then a statement of point of view that needs to be adopted for formulating such a theory.

However, this principle is silent about how we may implement it mathematically.

We then discover the universal principle of relativity that overcomes the aforementioned lacuna of the general principle of relativity by providing us the nature of mathematics needed to implement it. This mathematical framework is that of category theory.

Before we explore the ideas of category theory, we explore the way a massless quantum of light needs to be treated in universal relativity. In this discussion, we emphasize that Einstein's ensemble interpretation of the probabilistic quantum theory is the right point of view. In other words, we emphasize that the (usual) probabilistic quantum theory is incomplete in precisely Einstein's sense.

In Chapter 3, we discuss the Doppler effect. We point out that a historical mistake in the derivation of the standard Doppler shift formula eventually leads to contradiction of special relativity with experiments. Then Einstein's concept of relative time gets experimentally rejected.

In this chapter, we further discuss how observed Doppler shifts must be interpreted to arrive at physically proper results. This discussion is aimed at astronomers and astrophysicists.

Part II deals with technical matters related to ideas of the universal theory of relativity. It begins with ideas of category theory that is essential to ideas of universal relativity.

In Chapter 4, we develop the notion of what we mean by a category. We focus on the most general definition of a category.

In Chapter 5, we discuss properties of arrows and objects that form a category. Some of these properties are crucial to defining measures within the categorical context.

In Chapter 6, functors as arrows connecting categories are our focus. We also discuss the equivalence of categories.

In Chapter 7, we explore the concept of universal association by functors, and in Chapter 8, the concept of adjunction or adjoint situation of categories is developed.

A categorical notion of "measure" is developed in Chapter 9. The notion of a measure is crucial to the development of further ideas.

After developing relevant ideas of category theory, we discuss their applications to ideas of universal relativity in Chapter 10.

Readers interested in further technical details of physical concepts and their development may refer to references 1 to 24 for general physics, atomic theory, and astronomy and astrophysics; references 25 to 42 for quantum theory; references 43 to 48 for the Doppler effect, Lorentz transformations, and applications; references 49 to 52 for Einstein's ideas and the theory of relativity; references 53 to 58 for category theory; references 58 to 64 for measure theory and dynamical systems; and references 65 to 83 for ideas and stages of development of universal relativity.

Note: All figures in Chapter 1 and Fig. 2.2 (Chapter 2) have been taken from the following references:

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