

Principles of Modern Physics

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Whenever a new theoretical approach, that is foundational in physics, is proposed to explain some natural phenomenon, in any subject from elementary particle physics to cosmology, it is usually rejected by the establishment with this argument: This idea cannot be true because it violates a particular principle. But what is this principle other than a dogmatic, absolute assertion about the underlying truths of physics.

Some of these principles are a true accounting and some are dogmatic assumptions that imply that there will be no change henceforth in physics. It is this attitude that stifles real progress in science. I will now list some of these principles and comment on them individually.

1. *The Principle of Correspondence.* This principle belongs to the category of knowledge in the history of science. It signifies how the expression of a newly proposed theory goes smoothly into the expression of an abandoned theory it claims to supersede, as certain parameters change asymptotically.

For example, this principle indicates how the predictions of the quantum theory approach the form of classical physics, as Planck's constant h approaches zero, compared with the larger quantities of classical action. It indicates how the discrete energy levels of an atomic system, such as the Bohr atom, come closer and closer together as h approaches zero, yielding in the limit an energy continuum, as in classical physics.

Another example indicates how Einstein's theory of relativistic mechanics, applied to particle motion, approaches Newtonian mechanics as the speed of light c becomes infinitely large, compared with ordinary speeds of matter. In relativistic mechanics the speed c is fundamentally the *finite* speed of propagation of interactions between matter. When c is infinitely large, this corresponds to *action at a distance*, as in Newtonian *mechanics*, where matter interacts with matter spontaneously, independent of how far apart are the interacting components.

But the fact is that $h \neq 0$ and $c \neq \infty$. Thus, the classical correspondence limits of the quantum and relativity theories are not true; they are only *mathematical*

approximations that are useful as calculational tools under the appropriate physical conditions. These limits are then descriptive, but they are not explanatory in science.

2. *The Principle of Complementarity.* This is a philosophical view, enunciated by Niels Bohr at the onset of the quantum theory, that scientific truth (and generally all truth) is pluralistic, rather than monistic. That is to say, logically dichotomous assertions can both be considered to be true, so long as they are determined at different times and under different types of physical conditions.

An example of this principle in physics is the claim of the Copenhagen school of the truth of *wave-particle dualism*. This idea was originally proposed by Einstein to explain the apparent particle and wave character of the photon. It is a view that he later abandoned as philosophically indefensible. The idea arose again in the 1920s after the experiments on electron diffraction revealed that the electron has a wave character – that is, it is described by continuous fields that interfere. But earlier studies showed that electrons behave like discrete, singular particles. Bohr's principle then claims that both are true features of the electron, even though they are logically dichotomous. What he said was that the *basic nature* of the elementary particle (here the electron) is dependent on the types of observations we carry out, macroscopically, in experimentation. The electron is then not a *thing-in-itself*; its nature is dependent, in part, on the way in which the macro-observer looks at it! This is an epistemological view of *positivism*. The '*Principle of Complementarity*' is then only a speculation about an epistemological view in physics – that is not the only possible interpretation!

3. *The Principle of Linear Superposition.* It is claimed, with the expression of this 'principle', that the laws of electromagnetism (claimed to be the standard form of Maxwell's equations) and the laws of matter in the atomic domain must be mathematically linear. That is, the linear superposition of any number of solutions of the linear differential equations, such as quantum mechanics, that are laws of micro-matter, must also be another possible solution. This is also a feature of a probability calculus. Thus it is claimed that the laws of matter in the atomic domain are laws of probability. To state this as a fundamental principle means that there is no room for laws of nature that are nonlinear. An important law of nature that is nonlinear is

Einstein's theory of general relativity that already explains the phenomenon of gravity. The particles of matter (in the microscopic domain that the quantum theory claims to explain) have inertial mass, and thus they have gravitational forces associated with them. Thus, as in the case of atomic physics, the *Principle of Linear Superposition* is not more than a claim of the truth of the probability interpretation of the laws of matter in a restricted domain; as a general principle it is then generally false!

4. *The Principle of Uncertainty.* This principle was enunciated by Werner Heisenberg at the onset of the quantum theory. It states that there is an *intrinsic* uncertainty in the *measured value* of one of the variables of matter at the expense of the *measured value* of one other of its variables. For example, if Δp is the uncertainty in the *measured value* of the momentum p of a particle, in the x -direction, and Δx is the uncertainty in the *measured value* of its position x , then there follows an inequality: $\Delta p \geq (\hbar/4\pi)(1/\Delta x)$. That is to say, the more certain is the measure of one variable of this matter, say the momentum p , the less certain in the measure of the other variable x , at the same time. In the limit, then, if the measure of the position of the particle is certain, then $\Delta x = 0$, implying that $\Delta p = \infty$. The latter means that the measure of the momentum of the particle could be anything. It is important to take note of the fact that the uncertainties of the variables of the matter are tied to their measures! Thus, they are undefined without a macro-observer. This is another expression of the view of *positivism*.

Some claim that Heisenberg's uncertainty principle is model-independent – that it is an absolute truth of nature, based on the empirical facts. For example, in his book, *The Feynman Lectures in Physics* (R. P. Feynman, R. B. Leighton and M. Sands, Addison Wesley, 1963, Chapter 37), Feynman said: “*The uncertainty principle “protects” quantum mechanics. Heisenberg recognized that if it were possible to measure the momentum and the position simultaneously with greater accuracy, the quantum mechanics would collapse. So he proposed that it must be impossible. Then people sat down and tried to figure our ways of doing it, and nobody could figure out a way to measure the position and the momentum of anything – a screen, an electron, a billiard ball, anything – with any greater accuracy. Quantum Mechanics maintains its perilous but accurate existence.*” This is a false claim because the derivation of the uncertainty relations is based on two assumptions. One is that the laws of nature are linear, as we

have discussed in the preceding paragraph. The second assumption is that matter is generally atomistic. Again, this is refuted by the theory of general relativity. This is a field theory based on the holistic principle, that there are in fact no separable ‘things’ in nature. It means that what appear as separable particles of matter are in reality correlated modes of a single continuum. The latter is, in principle, the universe.

Thus, we must conclude that the *Principle of Uncertainty* should not be classified as an absolute in nature – it is model-dependent and only as true as the speculative assumptions that lead to the uncertainty relations.

5. *The Principle of Equivalence.* This principle is defined in the context of the theory of general relativity. It has been stated as follows: Matter that is in free fall is equivalent to its being in a stationary state subject to the force of gravity. This is not an absolute principle when the reference is to a gravitational force in the context of Newton’s theory of universal gravitation (based on the force being dependent on the inverse square separation of interacting matter and *action-at-a-distance*). Newton’s theory was superseded by Einstein’s theory of general relativity, as an explanation of the gravitational force. The latter is based on the continuous field concept, where forces propagate at a finite speed, whose maximum is the speed of light c .

I believe that the correct way to state the *Principle of Equivalence* is as follows: The natural path of matter is a geodesic (a path of minimal separation between any of its points) of a curved spacetime (a geometrical basis of the theory of general relativity) is equivalent to its path under the influence of any external force in nature. Here, gravitation is defined in the context of the theory of general relativity alone.

6. *The Principle of Logical/Mathematical Consistency.* This is a principle of science that is not model-dependent or tied to the history of science. It underlies any scientific endeavor that is supposed to explain a natural phenomenon. It is indeed a *necessary* condition that a scientific theory must predict the experimental facts. But this is not *sufficient* in order to call it real science. For it is also required that the theory must be logically and mathematically consistent in order to truly explain any natural phenomenon. It must indeed make unique predictions for unique physical situations.

Consider for example that some physical theory should predict that the orbit of a planet, subject to the gravitational influence of the sun, is circular, with its center at the center of mass of the sun. But suppose that the same physical theory predicts, *at the same time*, that the orbit of the planet is elliptical, with the center of mass of the sun at one of the elliptical foci. While the second prediction is in agreement with the empirical facts, the first prediction from the same theory, simultaneously, must nullify the theory, since it would then not be logically consistent. The planetary orbit cannot be both circular and elliptical at the same time!

On mathematical consistency, consider the present day relativistic quantum field theory and the renormalization program. Here, the solution for the physical theory is expressed in terms of an infinite series that diverges, yielding infinite values for all of the physical properties of matter. The renormalization program then gives us a method of subtracting off the infinite part of the series solution, thereby yielding a finite solution. Even though this procedure has led to predictions of finite results that are in close agreement with the empirical facts, it is not mathematically consistent. This is because one may use other procedures to subtract the infinite part of the original series solution and thus make different predictions for the same physical properties. That is, this mathematical method in the theoretical analysis of a theory of matter does not give unique answers for unique physical situations – even though one of its predictions does agree with the experimental facts! This is then not a mathematically consistent scientific theory.

A contemporary innovation in elementary particle physics is the ‘string theory’. It is a generalization of relativistic quantum field theory that attempts to overcome the problem of infinities by describing ‘particles’ as finite strings in a 10-dimensional space, rather than the usual 4-dimensional spacetime. Unfortunately, after many years of research, this theory has not predicted a single empirical fact nor has it successfully removed the infinities of the ordinary quantum field theory. Its adherents, nevertheless, support it with the *subjective* claim that it is ‘beautiful’! However, this ‘feeling’ does not make the scheme *explanatory* science – it does not meet the necessary and sufficient criteria of 1) successfully matching empirical facts and 2) mathematical/logical consistency. While beauty is in the eye of the beholder, the string theory does not meet the requirements for an *objective* scientific truth!

7. *The Principle of Reproducibility*

One further requirement of any scientific theory is that of *reproducibility* – that any experimental discovery must be reproducible under the same conditions of observation. This principle is not model-dependent – it is an absolute requirement in science that defines its truth.

Summing up, except for the *Principles of Logical/Mathematical Consistency and Reproducibility*, the other principles we have discussed are statements in the contexts of different theories in physics. They are not absolute foundational assertions of physics, never to be changed! Scientific truth is in principle refutable; this characterizes the change of paradigms in the history of science.