

The Negative Principle and the Formal Point of View in Physics

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May 12, 2021

Abstract

In the construction of a physical theory, one may need to be critically aware of the existence of restrictive constraints on the behavior of the system under consideration. Einstein stressed the distinction between ‘constructive’ theories and ‘principled’ theories. One question is how to convert a negative principle into a positive principle. Beyond that, we need to be aware that there are formal principles that we must accept, either because they are conventional or else we need to invent new ones that define a formal point of view that will, hopefully, lead one to a workable theory.

1 Introduction

First, we define the ‘formal point of view’ and then a ‘negative principle’ and then look closely at how Einstein regarded both of them.

This notion of ‘the formal point of view’ was often stated by Einstein in his essays. A formal point of view is defined by its many formal constraints and choices of modeling allowances: For example, will we model matter as continuous or particulate? We will model noncontact forces as ‘acting at a distance’ or as taking time to propagate through space? Will we model light as a wave or as a particle? How do we define a law of physics? Does a law have to be covariant with respect to some transformation among all inertial frames or not?

These constraints and modeling allowance are *formal* in the sense that no one of them is required in order to construct a workable theory. In other words, one might construct a different workable theory by making some other choice of these allowances and constraints.

To Einstein, the constructive theory was the mainstay of the ‘Mechanical Program’ of doing physics, starting with Newton. It stressed beginning with a model of matter as composed of material particles and then constructing dynamical equations on top of that. But this program met its match when it encountered electromagnetism, which demanded that light, being a wave, was to be modeled as a propagating disturbance in some kind of fixed material ether that permeates all space.

Since I have written a lot about Einstein formulation of the dichotomy between constructive and principle theories in other of my essays, I won't pursue it here, except to say that, although the Mechanical Program died, that doesn't mean that all constructive formal points of view are also dead.

2 Einstein's Philosophy on Theory Formation

Einstein characterizes, in his personal view, what quantum mechanics is from the perspective of what I call the "negative principle," which stresses the existence of a hard constraint—usually an impossibility. With regard to quantum mechanics, he had this to say in terms of a negative characterization of it:

Quantum physics abandons the individual laws of elementary particles and states directly the statistical laws governing aggregations. It is impossible, on the basis of quantum physics, to describe positions and velocities of an elementary particle or to predict its future path as in classical physics. Quantum physics deals only with aggregations, as its laws are for crowds and not for individuals.

Found in: *The Evolution of Physics*, Einstein & Infeld, Touchstone, 1938, p. 286.

The amazing thing is that the negative principle is often the central concept bridging the gap between some empirical conundrum and the development of a "formal point of view," which Einstein claimed is the beginning of a research program on to which a theory gets built. The formal point of view of quantum mechanics being that: "Quantum physics deals only with aggregations, as its laws are for crowds and not for individuals." Einstein said of the "formal point of view":

In order to construct a theory, it is not enough to have a clear conception of the goal. One must also have a formal point of view which will sufficiently restrict the unlimited variety of possibilities.

Found in: *Ideas and Opinions*, "The fundamentals of theoretical physics," p. 328.

So, we have seen the benefits of allowing oneself to engage in counterfactual and negative-principle (constraint-based) thinking. Here's what Einstein had to say about it:

Fundamental ideas play the most essential role in forming a physical theory. Books on physics are full of mathematical formulae. But thought and ideas, not formulae, are the beginning of every physical theory.

Found in: *The Evolution of Physics*, Einstein & Infeld, Touchstone, 1938, p. 277.

Usually, between the formal point of view and the research program declaration, the negative principles get “converted” into “positive principles,” which are inspired by them and usually retain the negative principles as constraints.

Let me give an example of how the negative principle helps to fill the gap between the set of empirical observations and some positive principles. Think of the Galilean Principle of Relativity—that the laws of mechanics are the same form for all inertial reference frames. This is certainly a positive statement (in heuristic form), but it is not so clear how it relates back to the body of empirical knowledge that inspired it. Now I’ll interject the following negative principle and you decide if it increases the clarity of the argument for adopting the Galilean Principle of Relativity or not:

It is impossible to perform a mechanical experiment within an inertial reference frame which can be used to determine the absolute velocity of the frame.

Thus, if the laws of mechanics cannot be forced to admit to employing the absolute velocity of one’s reference frame, they can at best employ only relative velocities between frame and the objects under description of their motion. And if that is the case, there ought to be a way to transform this description between any two reference frames. The Galilean transformation of coordinates confirms this hypothesis for the Newtonian Laws of Mechanics when considering only inertial frames of reference.

Special relativity can be presented as one result of forming an extension to Galilean relativity on the basis of the following extension to the Galilean negative principle, done this way:

It is impossible to perform any mechanical or optical experiment within an inertial reference frame that can be used to determine the absolute velocity of the frame.

Einstein explained it for us this way:

While I was thinking of this problem in my student years, I came to know the strange result of Michelson’s experiment. Soon I came to the conclusion that our idea about the motion of the Earth with respect to the ether is incorrect, if we admit Michelson’s null result as a fact. This was the first path which led me to the special theory of relativity. Since then I have come to believe that the motion of the Earth cannot be detected by any optical experiment, though the Earth is revolving around the Sun.

Found in: “How I created the theory of relativity,” a transcribed speech of a talk given by Einstein in Japan in 1922. translated by Yoshimasa A. Ono, *Physics Today*, Aug. 1982, p. 45–47.

Einstein said elsewhere that the ether had become the embodiment of absolute rest space. Now, did you notice the negative principle hidden in this quote from Einstein?

This brings me to clarify the connection between some negative principle close to empirical knowledge and the adoption of a formal point of view based on it. There is no logical connection between empirical knowledge and the concepts we use to account for this knowledge. Einstein put it this way:

There is no inductive method which could lead to the fundamental concepts of physics. Failure to understand this fact constituted the basic philosophical error of so many investigators of the nineteenth century. It was probably the reason why the molecular theory and Maxwell's theory were able to establish themselves only at a relatively late date. Logical thinking is necessarily deductive; it is based upon hypothetical concepts and axioms.

Found in: "Physics and Reality," A. Einstein, *Ideas and Opinions*, Three Rivers Press, p. 307.

and

Physical concepts are free creations of the human mind, and are not, however it may seem, uniquely determined by the external world.

The Evolution of Physics, Einstein & Infeld, Touchstone, 1938, p. 31.

Now, to finish off, let's do the extension to general relativity: It is impossible to perform any type of experiment within any "rigid" reference frame that can differentiate between linear acceleration and a perfect (idealized) uniform gravitational field (Principle of Equivalence, stated in negative-principle form). Of course, this statement uses idealized situations to make its claims, but so too did Galileo's Principle of Inertia!

For some reason, Einstein was appalled at the thought of an absolute space that somehow acts on material objects to give them their inertia, yet is not reciprocally acted upon by those material particles. That is why he adopted the metaphorical language of referring to such an absolute reference frame as a "ghost." He felt similarly about absolute time.

The ghosts of absolute motion and the inertial coordinate systems can be expelled from physics and a new relativistic physics built.

Found in: *The Evolution of Physics*, p. 222.

and

The equations from the new theory [General Relativity] are, from the formal point of view, more complicated, but their assumptions are, from the point of view fundamental principles, much simpler. The two frightening ghosts, absolute time and an inertial system, have disappeared.

Found in: *The Evolution of Physics*, p. 238

To Einstein, the absolute frame that defines absolute accelerations is a ghost too far.

Now, we turn to a few of the many claims Einstein made about the heuristic value of covariance, especially general covariance, in his search for a physics free of these frightening ghosts of an absolute nature:

The great power possessed by the general principle of relativity lies in the comprehensive limitation which is imposed on the laws of nature in consequence of what we have seen.

Found in: *Albert Einstein's Theory of General Relativity*, reprinted Albert Einstein, *Relativity*, p. 91–92.]

The first observation is that the principle of general relativity IMPOSES EXCEEDINGLY STRONG RESTRICTIONS on the theoretical possibilities. Without this restrictive principle it would be practically impossible for anybody to hit on the gravitational equations, not even by using the principle of special relativity, even though one knows that the field has to be described by a symmetric tensor. No amount of collection of facts could lead to these equations unless the principle of general relativity were used. This is the reason why all attempts to obtain a deeper knowledge of the foundations of physics seem doomed to me unless the basic concepts are in accordance with general relativity from the beginning. This situation makes it difficult to use our empirical knowledge, however comprehensive, in looking for the fundamental concepts and relations of physics, and it forces us to apply free speculation to a much greater extent than is presently assumed by most physicists. I do not see any reason to assume that the heuristic significance of the principle of general relativity is restricted to gravitation and that the rest of physics can be dealt with separately on the basis of special relativity, with the hope that later on the whole may be fitted consistently into a general relativistic scheme. [Emphasis mine.]

Found in: *Ideas and Opinions*, “On the generalized theory of gravitation,” p. 352.

...We are thus led to extend the transformations to arbitrary continuous transformations. This implies the general principle of relativity: Natural laws must be covariant with respect to arbitrary continuous transformations of the coordinates. This requirement (combined with that of the greatest possible logical simplicity of the laws) limits the natural laws concerned incomparably more strongly than the special principle of relativity.

Found in: Appendix V of *Relativity: the special and general theory*, “Relativity and the problem of space,” (July 1952)

Have you ever wondered what the significance of the thought experiment Einstein claimed to have when he was sixteen (about the absurdity of being able to sit in a reference frame traveling at the speed of light and seeing a standing light wave) has to do with his formulating a formal point of view that led him to special relativity? It is a bit clearer to appreciate the role it played when it is cast into this simple negative-principle form:

It is impossible for a reference frame to travel at the speed of light.

The upshot of which is that it appears that Newton's mechanics, which has no intrinsic upper speed limit built into it to limit the speed that matter can take, was now in contradiction with optics. This was to Einstein a clear and troubling disharmony between mechanics and optics: the former claiming no upper speed limit, the latter claiming it is the speed of light.

Einstein's relativity is a particular formal point of view to optimally deal with the interplay of the three fundamental concepts of

- metrical phenomena,
- reference frame,
- laws of physics,

all consistent with operational definitions, minimization of concepts overall (logical economy), and harmony. That is in essence Einstein's formal point of view.

3 Conclusion

I have studied the essays of Einstein for over thirty years now, and one thing stands out: Einstein seemed to hold tenaciously to the instrumentalist view of science when he donned the philosopher's hat, yet held just as tenaciously to the realist's view when he donned the physicist's hat.

The instrumentalist view of physics is that physical theories are free creations of the human mind, and that they are mere instruments of thought to lead one to a theory that works. The deep meaning of its physical models are irrelevant in physics, per se.

I get the feeling that such a view of physical theories was not only an admission that physics is not metaphysics, but also that theories should be allowed to compete on merit, unhindered by irrelevant political and social agendas, inside or outside the halls of science. Thus we need a view of physical theories that will level the playing field so that they can compete fairly and objectively against one another.

Still, the instrumentalist philosophy does not rule out the possibility that a particular formal point of view is the 'correct' pathway to the truth of deep reality, and that seemed to have been a comforting hope to Einstein throughout his career, especially during his dark years trying to defeat the Copenhagenist interpretation of quantum mechanics.

Now I leave you with what I consider to be the most beautiful paragraph ever written by any physicist:

What has nature to do with our coordinate systems and their state of motion? If it is necessary for the purpose of describing nature, to make use of a coordinate system arbitrarily introduced by us, then the choice of its state of motion ought to be subject to no restriction; the laws ought to be entirely independent of this choice (general principle of relativity).

Found in: *Albert Einstein's General Relativity*, Crown Publication, New York, 1979, p. 63.