Einstein on Principle vs Constructive Theories

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Abstract

The Principle vs Constructive theories dichotomy is Einstein's way to differentiate the extreme versions of how physicists tend to formulate physical theories. Einstein was able to effect a great unification of theoretical ideas under his relativistic theories by finding the essential empirical constraints common to them all — to which he called 'principles'.

1 Introduction

Philosophers of math and physics have long debated how to ensure logical consistency of the postulates (axioms) of a theory. Einstein found a simple and elegant way to do this for physical theories! This is the aspect of the discussion I want to deal with this time, but first I must establish some foundation for all readers.

Einstein defined two major categories of physical theories:

1) the "constructive" theory, and

2) the "principle" theory.

In the constructive theory, the research program, such as that of Lorentz's ether theory of electrodynamics, starts off with a model of a fundamental thing, ether in this case. Then with some more postulates a theory can be built on top of this foundation. And Newton's theory started off with a foundation of the mass particle model with action at a distance or contact forces. As Einstein stated, once Newton added to this research program a specific action at a distance force, i.e., the law of gravity, then he had a real gravitational theory to work with.

In the "principle" theory, such as in Special Relativity (SR), one does not begin the research program with a requirement to construct phenomena out of a some fundamental model of some supposed fundamental thing, such as ether or absolute space. Instead, one assumes a collection of principles which act as constraints on the possible models invented, all consistent with how the measuring instruments of physics will take on experimental values. In this method there is much greater freedom to invent models because no a prior fundamental model is assumed in the research program itself. All the principles that have no physical content belong to the research program's foundation (its formal point of view), and the rest in the theory proper built on top of it.

2 The Evidence

> We can distinguish various kinds of theories in physics. Most of them are constructive. They attempt to build up a picture of the more complex phenomena out of the materials of a relatively simple formal scheme from which they start out. Thus the kinetic theory of gases seeks to reduce mechanical, thermal, and diffusional processes to movements of molecules — i.e., to build them up out of the hypothesis of molecular motion. When we say that we have succeeded in understanding a group of natural processes we invariably mean that a constructive theory has been found which covers the processes in question.
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> Along with this most important class of theories there exists a second, which I will call "principle-theories." These employ the analytic, not the synthetic, method. The elements which form their bases and starting-point are not hypothetically constructed but empirically discovered ones, general characteristics of natural processes, principles that give rise to mathematically formulated criteria which these separate processes or the theoretical representations of them have to satisfy. Thus the science of thermodynamics seeks by analytical means to deduce necessary conditions, which separate events have to satisfy, from the universally experienced fact that perpetual motion is impossible.
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> The advantages of the constructive theory are completeness, adaptability, and clearness, those of the principle theory are logical perfection and security of the foundations.
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> The theory of relativity belongs to the latter class. In order to grasp its nature, one needs first of all to become acquainted with the principles on which it is based. Before I go into these, however, I must observe that the theory of relativity resembles a building consisting of two separate stories, the special theory and the general theory. The special theory, on which the general theory rests, applies to all physical phenomena with the exception of gravitation; the general theory provides the law of gravitation and its relations to the other forces of nature.
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> — Found in: "What is the Theory of Relativity?", Einstein, *Ideas and Opinions*, Three Rivers Press, pp. 228–229.

There is much greater freedom to build various models on top of the research foundation in the principle-theoretic approach than in the constructive approach for the obvious reason that in the constructive approach the theory is itself built with a specific model a priori adhered to! And the existence of this a priori model will place severe restrictions on model invention on top of that.

It's ironic, therefore, that SR tells us less about what matter is made of (by speculation) and deals more about the empirical measurements the experimentalist will get in the lab.

In Lorentz's ether theory (LET), Lorentz a priori committed his theory to use an absolute velocity space, the embodiment of which was the model of the fixed ether. On the other hand was the SR prohibition against using any absolute velocity space whatsoever. Both approaches employ biases for and against doing certain things. Neither approach is true or false. And neither approach can reverse-engineer deep reality. The models employed within successful theories are not necessarily true of deep reality.

So, SR is a principle theory. What are the principles? Well, we all know about the Light Principle (which is part of the SR theory proper) and the SR version of the Relativity Principle (which is part of the research foundation to the SR theory because it is of heuristic value). But there is one more principle that few people think about: I'll call it the Principle of Newtonian mechanics (PNM), which is that Newtonian mechanics is a validated body of knowledge on a restricted domain of applicability (DOA) — that is, the so-called 'low-velocity limit' of SR. And SR uses the PNM as a constraint that SR has to conform to.

SR inherits three important particular models of matter from Newtonian mechanics:

- the point mass particle,
- the rigid rod,
- the existence of unlimited number of identical measuring rods, and an unlimited number of identical synchronizable clocks.

However, because Einstein proffered a principle theory of SR, he did not need to speculate too deeply on the exact nature of these matter models. But how do we define what we mean by identicalness of clocks or rods apart from some explanatory theory, or, at the very least, some dogma?

But what happens if the a priori models chosen for the constructive theory become, in the course of time, more of a burden than a benefit? Well, then the whole edifice is in danger of collapse! But in the principle theory, one can modularly insert any number of possible models on top of the theory because the theory itself is not dependent on any specific model (besides the assumptions on the nature of the set of measuring devices used to test the theory). If one model loses its potency, then just invent new models and go from there.

So, it is the explicit use of the external knowable world, which is presumed to be self-consistent, that Einstein assumed that one could reasonably assume that our knowledge of it would also be self-consistent and thus would provide for a research program's theory a "security of the foundations" and "logical perfection" (i.e., logical consistency) I quoted above. All Einstein has to assume was that the "laws of physics" do not change very much over time, but this is no more than any other physicist assumes.

As an example, the photon model used in SR is not really a part of SR proper, but rather is added on top of it, just as would be expected. The photon model is free of all constraint except so far as the Light Principle constrains its measured speed in all inertial reference frames to be the Lorentz-invariant value of c.

Let's look closer at this notion of logical consistency of physical theories. Einstein was concerned about this issue, and rightfully so, in my opinion.

One particular example of relevance here is that of the physical law on its DOA. Physical laws are not about models, per se, except to the degree that all laws are based on measurement, and measuring devices themselves have to be theoretically modeled. In a sense these physical laws represent inductions on physical measurements. We come to believe that they are useful for making predictions based on our faith in them based on our previous successful experience with using them within a certain DOA. We cannot prove that any physical law is actually true. Instead we simple admit that our physical laws are accepted on the basis that we have a reasonable basis for believing in them.

Another example of relevance here is our noticing that among the laws of physics are certain similarities of form which suggest themselves. These manifest themselves to us most emphatically in covariances of the forms of the "laws" themselves. When a set of "laws" satisfy a particular covariance we conclude two things: 1) that they are relatable into a single theory, and 2) that they give a deeper meaning to the whole notion of "physical law" than is possible without them. Hence, a unification of ideas.

So, to those that think of covariance this way, it is impossible to consider formulating a physical theory without making covariance relationships fundamental to the entire enterprise! So, if we start off with the notion of a "physical law" being a relationship on the anthropomorphic variables of physics which is 1) either a direct statement of physical content, or 2) a statement which is coupled to some law/s which itself/themselves has/have physical content, then we have the basis of a sort of higher-order notion of induction, which states that the form of a "law of physics" is constrained by some covariance property.

This principle takes the practical form of a heuristic, for it has no empirical content of its own. But the history of physics over the last 120 years has shown quite conclusively that this particular heuristic is a great usefulness in formulating the "laws of physics." Einstein called a "law of physics" that satisfied a covariance property a "general law of Nature." I prefer to be less metaphysical about it and refer to it myself as a "general law of physics."

The method of unification then to Einstein was clearly guided by the belief that two theories — distinguished by their different covariances — can be "unified" only by finding a way to find a single covariance for the entire set of them. Einstein had taken on the problem of uniting Newtonian mechanics, covariant under Galilean transformations, and optics, covariant under Lorentz transformations. This was the initial phase of his relativistic research program.

Einstein's attempt at unification (as artificial from the philosophical viewpoint as it may be) succeeded, not based on formal models of matter within various theories, but within commonalities of behaviors of various physical systems constrained by empirically derived principles. But these behaviors are founded on the general laws they they are encoded in, and those are the physical laws (artificially placed within a certain form) that we believe dictate the behaviors of physical systems, at least while they are being measured! But in Einstein's viewpoint, the way to understand the very concept of "general physical law" is with respect to the concept of form covariance. Thus, it is within relativity that the concepts of both "general physical law" and of formal "unification of subjects" has become at long last rationally meaningful.

3 Conclusion

Authors Strunk and White (*The Elements of Style*) told us that a sentence should contain no unnecessary words, just as a machine should contain no unnecessary parts. In like manner, a physical theory should also contain no unnecessary parts. To Einstein, speculation on the physical nature of a medium of light propagation was introducing an unnecessary 'part' (a mechanical ether) into electrodynamics, which he toiled in earnest for a year to make it work — following in the footsteps of Maxwell and Lorentz — but was ultimately unsuccessful. In the end, he sought to eliminate the unnecessary 'part', and was ultimately successful at that by laying a new foundation of empirically derived mathematical constraints that he had strong confidence in.