Lecture 22
Einstein's Two Principles

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Principle of relativity

The principle (128)

If two coordinate systems are in uniform translational motion relative to each other, the laws according to which the states of a physical system change do not depend on which of the two systems these changes are related to.

Reasons to believe it (123–24)

1. The laws of mechanics satisfy the principle.
   - If Newton's laws of motion hold in one coordinate system they also hold in any other coordinate system in uniform translational motion relative to that system.
2. Electrodynamic *phenomena* seem to satisfy the principle.
   - Moving a magnet near a stationary wire generates a current in the wire. Moving a wire near a stationary magnet generates the same current if the relative motion is the same.

Accepted electrodynamic *theory* violated the principle (123)

According to accepted theory:

- A moving magnet generates an electric field and this field creates a current in a stationary wire.
- When the magnet is stationary and the wire is moved, no electric field is created; the current in the wire is due to the electric charges in the wire moving through the magnetic field of the magnet.
- Hence, an electric field is generated relative to a coordinate system fixed in the wire but not relative to one fixed in the magnet, though these are moving uniformly with respect to each other. This violates the principle of relativity.

Einstein believed a correct formulation of the laws of physics would not have this kind of asymmetry.

Principle of the constancy of the velocity of light

The principle (128)

Every light ray moves in the "rest" coordinate system with a fixed velocity c, independently of whether this ray of light is emitted by a body at rest or in motion.

- Note that this principle refers only to the rest system.
- Einstein didn't give reasons to believe this principle in this paper, but it was implied by accepted theory.

Length of a moving rod

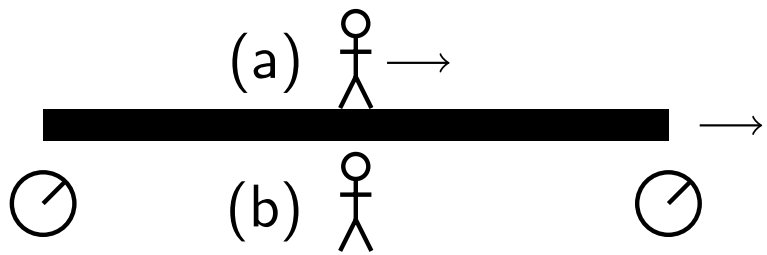
Description of the setup (128)

Take a rigid rod at rest; let its length, measured by a measuring rod that is also at rest, be l. Now imagine the axis of the rod placed along the X-axis of the rest coordinate system, and the rod then set into uniform parallel translational motion (with velocity v) along the X-axis in the direction of increasing x. We now inquire about the length of the moving rod, which we imagine to be ascertained by the following two operations.

Two methods of measurement (128)

(a) *The observer moves together with the aforementioned measuring rod and the rigid rod to be measured, and measures the length of the rod by laying out the measuring rod in the same way as if the rod to be measured, the observer, and the measuring rod were all at rest.*

(b) *Using clocks at rest and synchronous in the rest system as outlined [previously], the observer determines at which points of the rest system the beginning and end of the rod to be measured are located at some given time t. The distance between these two points, measured with the rod used before—but now at rest—is also a length that we can call the "length of the rod."*



Names and results of these methods (129)

- *According to the principle of relativity, the length determined by operation (a), which we shall call "the length of the rod in the moving system," must equal the length l of the rod at rest.*
  - This method of measurement is the same as was used to determine the length of the rod when it was at rest in the rest system; the only difference is that now the rod and observer are moving with uniform velocity in the rest system.
  - The principle of relativity says the laws of physics are the same in the rest system and in a system with uniform translational motion relative to the rest system.
  - Therefore, the length of the rod in the moving system is the same as in the rest system, which is l.
- *The length determined using operation (b), which we shall call "the length of the (moving) rod in the rest system," will be determined on the basis of our two principles, and we shall find that it differs from l.*

Questions

1. What is Einstein's (1905) principle of relativity? What are two reasons for believing this principle mentioned by Einstein?
2. Did electrodynamic theory, as understood in 1905, satisfy Einstein's principle of relativity? Explain.
3. State Einstein's principle of the constancy of the velocity of light. Your statement should indicate what coordinate system(s) the principle refers to and what it claims does not alter the velocity of light.
4. Suppose a rigid rod is moving with constant velocity in the rest system. What does Einstein mean by (a) the length of the rod in the moving system, and (b) the length of the rod in the rest system?
5. If a rigid rod has length l when at rest in the rest system, what is its length when it is moving with uniform velocity in the rest system, if by length we mean length in the moving system? Explain how your answer follows from Einstein's principles.

Reference


Albert Einstein.
On the electrodynamics of moving bodies.
In John Stachel, editor, *Einstein's Miraculous Year: Five Papers That Changed the Face of Physics*. Princeton University Press, 1998.
Numbers in parentheses are page numbers of this edition.
I corrected the translation and modernized notation in places.