
Time Travel

Relativity and Culture:

It is difficult to choose a single event as beginning popular interest in time travel, but the best candidate is probably H. G. Wells' publication of *The Time Machine* in 1895. In this story, a time traveler explains that time is simply a fourth dimension that can be traversed just like any spatial dimension. Of course, this is not correct, but it firmly established the idea of the fourth dimension in popular culture. Earlier mathematicians had explored the possibility of a hypothetical fourth dimension being either spatial or temporal, and philosophers had speculated as to why humans experience exactly three spatial dimensions, but these discussions did not enter public consciousness. Wells' story, by contrast, was immediately popular, even receiving a positive review in *Nature*. It continues to serve as a basis for most time travel stories today.

In 1908, Hermann Minkowski formulated the four-dimensional model of spacetime to explain Einstein's special relativity. It is important to remember that, in this model, space and time are not mathematically equivalent (spatial and temporal dimensions have different signs in the spacetime interval, for example). That said, Wells' novel 13 years earlier proved to be surprisingly close to later scientific developments. It is unknown whether Minkowski or Einstein had read *The Time Machine* before publishing their theories.

However, for some, Wells' work seemed to have unfortunate philosophical implications. If time was simply another dimension that one could travel along forward and backward, then it would appear that the past and the future exist in the same sense as the present does, right now. This echoes Parmenides' concept of the block universe, in which all events in the universe--past, present, and future--exist simultaneously and unendingly. There is no possibility for free will, since everything is already determined. As mentioned above, Minkowski's actual conception of time has been misunderstood in popular thought. His formulation of a useful mathematical model does not immediately imply a block universe. However, questions of free will have appeared in many time travel stories throughout the 20th century.

Key Ideas:

- Fiction both responds to developments in physics and shapes popular perception of science. It can make a theory easier to understand or put it in a more engaging context, but also, knowingly or unknowingly, distort the theory's intended meaning.

Topics for Illustrating Time Travel and Relativity:

- Wells' time machine would not work because it remains stationary. As soon as it begins to move backwards through time, it would collide with itself from a moment ago.
- If the Klingons fire a missile that travels faster than light, it will hit its target before it was launched.
- Dirac's formulation of electrons as extended bodies resulted in a third-order differential equation that suggested the possibility of pre-acceleration: an electron subject to external forces will begin accelerating a tiny fraction of a billionth of a second before the pulse reaches it, seeming to violate causality. This also suggests the possibility of using the electron's radiation to send signals faster than light.

- Feynman observed that positrons moving forward in time are equivalent to electrons moving backward in time.
- Gödel theorized that, in a rigid, uniformly rotating universe, there is a certain critical distance from the axis of rotation where the future light cone at one point tips over into the past light cone at an adjacent point. Traveling at this critical distance in the opposite direction of rotation would allow the traveler to move backwards in time without ever exceeding the speed of light. This is impossible in our universe, as it is not rotating as Gödel described.
 - A similar effect can be achieved by Tipler's infinitely-long rotating cylinder, which also tips over light cones until past and future overlap.
- Time travel via stable wormholes would require large Casimir plates to create a region of negative energy density around a rotating black hole.
- Time travel paradoxes: there are many possible examples (many variations on the grandfather paradox), but one of the most interesting is Heinlein's "All You Zombies," in which a single individual is both father and mother to himself/herself.

Bibliography:

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