Can we time travel? A theoretical physicist provides some answers

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Credit: George Becker from Pexels

Time travel makes regular appearances in popular culture, with innumerable time travel storylines in movies, television and literature. But it is a surprisingly old idea: one can argue that the Greek tragedy Oedipus Rex, written by Sophocles over 2,500 years ago, is the first time

travel story.

But is time travel in fact possible? Given the popularity of the concept, this is a legitimate question. As a theoretical physicist, I find that there are several possible answers to this question, not all of which are contradictory.

The simplest answer is that time travel cannot be possible because if it was, we would already be doing it. One can argue that it is forbidden by the laws of physics, like the second law of thermodynamics or relativity. There are also technical challenges: it might be possible but would involve vast amounts of energy.

There is also the matter of time-travel paradoxes; we can—hypothetically—resolve these if free will is an illusion, if many worlds exist or if the past can only be witnessed but not experienced. Perhaps time travel is impossible simply because time must flow in a linear manner and we have no control over it, or perhaps time is an illusion and time travel is irrelevant.

Laws of physics

Since Albert Einstein's theory of relativity—which describes the nature of time, space and gravity—is our most profound theory of time, we would like to think that time travel is forbidden by relativity. Unfortunately, one of his colleagues from the Institute of Advanced Study, Kurt Gödel, invented a universe in which time travel was not just possible, but the past and future were inextricably tangled.

We can actually design time machines, but most of these (in principle) successful proposals require negative energy, or negative mass, which does not seem to exist in our universe. If you drop a tennis ball of negative mass, it will fall upwards. This argument is rather

unsatisfactory, since it explains why we cannot time travel in practice only by involving another idea—that of negative energy or mass—that we do not really understand.

Mathematical physicist Frank Tipler conceptualized a time machine that does not involve negative mass, but requires more energy than exists in the universe.

Time travel also violates the second law of thermodynamics, which states that entropy or randomness must always increase. Time can only move in one direction—in other words, you cannot unscramble an egg. More specifically, by traveling into the past we are going from now (a high entropy state) into the past, which must have lower entropy.

This argument originated with the English cosmologist Arthur Eddington , and is at best incomplete. Perhaps it stops you traveling into the past, but it says nothing about time travel into the future. In practice, it is just as hard for me to travel to next Thursday as it is to travel to last Thursday.

Resolving paradoxes

There is no doubt that if we could time travel freely, we run into the paradoxes. The best known is the "grandfather paradox": one could hypothetically use a time machine to travel to the past and murder their grandfather before their father's conception, thereby eliminating the possibility of their own birth. Logically, you cannot both exist and not exist.

Kurt Vonnegut's anti-war novel "Slaughterhouse-Five," published in 1969, describes how to evade the grandfather paradox. If free will simply does not exist, it is not possible to kill one's grandfather in the past, since he was not killed in the past. The novel's protagonist, Billy

Pilgrim, can only travel to other points on his world line (the timeline he exists in), but not to any other point in space-time, so he could not even contemplate killing his grandfather.

The universe in "Slaughterhouse-Five" is consistent with everything we know. The second law of thermodynamics works perfectly well within it and there is no conflict with relativity. But it is inconsistent with some things we believe in, like free will—you can observe the past, like watching a movie, but you cannot interfere with the actions of people in it.

Could we allow for actual modifications of the past, so that we could go back and murder our grandfather—or Hitler? There are several multiverse theories that suppose that there are many timelines for different universes. This is also an old idea: in Charles Dickens' "A Christmas Carol," Ebeneezer Scrooge experiences two alternative timelines, one of which leads to a shameful death and the other to happiness.

Time is a river

Roman emperor Marcus Aurelius wrote that: "Time is like a river made up of the events which happen, and a violent stream; for as soon as a thing has been seen, it is carried away, and another comes in its place, and this will be carried away too."

We can imagine that time does flow past every point in the universe, like a river around a rock. But it is difficult to make the idea precise. A flow is a rate of change—the flow of a river is the amount of water that passes a specific length in a given time. Hence if time is a flow, it is at the rate of one second per second, which is not a very useful insight.

Theoretical physicist Stephen Hawking suggested that a "chronology

protection conjecture" must exist, an as-yet-unknown physical principle that forbids time travel. Hawking's concept originates from the idea that we cannot know what goes on inside a black hole, because we cannot get information out of it. But this argument is redundant: we cannot time travel because we cannot time travel!

Researchers are investigating a more fundamental theory, where time and space "emerge" from something else. This is referred to as quantum gravity, but unfortunately it does not exist yet.

So is time travel possible? Probably not, but we don't know for sure!

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