Time Travel

Time Travel – is it possible? In these notes, I go over a few methods of time travel that people have thought of over the years.

Time Travel to the Future via Special Relativity

Of course time travel to the future is possible – we're currently doing it, 1 second per second! The question is, can we move arbitrarily far into the future of our *surroundings* while we ourselves age only slightly? According to special relativity, the answer is a resounding YES.

Here's how: simply find a spaceship, take off from Earth, eventually reaching a speed very close to the speed of light, and then turn around, eventually returning to Earth. Suppose your spaceship travels at 99.9992% the speed of light, for example, and you travel away from Earth for 5 years (at a reasonably constant speed), and then spend 5 years returning to Earth (again, at a reasonably constant speed). Then, while 10 years have passed by for you, 1,000 years will have passed by for Earth!

This result is, of course, due to time dilation – the effect of special relativity that *moving clocks run slow*. According to an observer on Earth, the clocks on your spaceship will be moving slower than the observer's clock. Therefore, the amount of time that elapses for you, while you are on the spaceship, will always be less than the amount of time elapsed by a clock on Earth. (But wait! Can't *you*, the spaceship observer, just as well say that the *Earth* clocks are running slow, and therefore while 1,000 years passes by for you, only 10 years will pass by for the them? No, you can't!!! You aren't truly an inertial observer, because you have to *decelerate* once you decide to turn around and return to Earth. Remember that inertial observers are those moving at constant velocity.)

That's all there is to it! Of course, how you can actually *get* a manned spacecraft up to a speed of 99.9992% the speed of light is another question... The highest speed approached so far by a manned spacecraft is only 0.0037% the speed of light. However, the highest speed we've ever sped tiny *particles* up to is over 99.9999% the speed of light. So, in principle, it is possible to accelerate anything very fast. All that we currently lack is the technology and the resources.

<u>General Relativity and Time Travel</u>

Although special relativity provides a way for theoretically time-traveling into the future, it does not provide a way for you to return to the past! However, *general* relativity – the extension of relativity to include gravity – might. But, before going over how time travel to the past might be possible, we first need to know a bit about how general relativity works.

Curved Spacetime

According to general relativity, *mass curves spacetime*. And the more mass there is in a region of space, the more spacetime will be curved there. Now, what *is* spacetime, and what does it mean for it to be *curved*? Well, according to general relativity, space and time are intimately connected, and they may together be thought of as forming a unified object called "spacetime." In a world where this is no gravity, we say that spacetime is not curved; it is *flat.* This is the world of special relativity. Where spacetime is flat, space and time operate exactly as described in the notes "Special Relativity Formulas": moving clocks run slow, objects in motion are shorter than they are at rest, and so on – each according to certain special-relativistic formulas found in those notes.

Interestingly, it turns out that space and time operate differently in curved spacetime than in flat spacetime. In curved spacetime, those special relativity formulas are no longer true. For example, one of the coolest features about curved spacetime – not present in flat spacetime – is an effect known as *gravitational time dilation*. According to general relativity, clocks tick slower near massive bodies than far away from them. In other words, the greater the gravity, the slower a clock will tick; therefore, the more curved spacetime is, the slower a clock will tick. Thus, a clock on the surface of the Earth will run slower than a clock 10 miles above the Earth's surface, because the former clock is in a region where spacetime is more curved than in the latter region.

As you may already see, gravitational time dilation presents an alternative method for traveling into the future! Suppose you sit near a very massive object, where spacetime is very curved. Then (depending on how massive the object is), while a very short amount of time may elapse for you, a very long amount of time may elapse for someone far away from the very massive object. As a result, you'll have effectively traveled into the future!

Time Travel to the Past

I mentioned earlier that general relativity allows for the possibility of time travel to the past. I'll now describe one method how (yes, there are others!). This method involves *wormholes*.

General relativity, in its bizarre yet wonderful nature, allows for the existence of very strange entities known as "wormholes." A wormhole is simply a path between two places in space. However, it isn't *any* old path between two places – it's a *shortcut* between them. For example, the star Sirius is approximately 54 trillion miles away, so that if you traveled at nearly the speed of light, it would ordinarily take you about 9 years to reach it. But if the Earth and Sirius were connected by a *wormhole*, then it's possible for you to travel *through* the wormhole – which may only be 10 feet long – and thereby reach the Andromeda Galaxy in a matter of seconds! The diagram below illustrates this connectedness:

(Image removed due to copyright restrictions. Please see: http://science.howstuffworks.com/time-travel4.htm)

Figure 1. Earth and the star Sirius connected by a wormhole. Space is imagined to be 2-dimensional for visualization purposes. Also, "hyperspace" isn't an actual part of our Universe. It's only there to help us imagine *how* the wormhole connects Earth and Sirius.

Now here's how a hypothetical time machine, capable of traveling into the past, could be made out of a wormhole connecting Earth and Sirius. First, (somehow) take the end, or "mouth," of the wormhole near Earth, accelerate it up to a very high speed – near the speed of light – and then bring it back to Earth. As a result of the type of time dilation discussed in "Time Travel to the Future via Special Relativity," we then expect that the accelerated mouth of the wormhole will have aged *less* than the mouth of the wormhole that remained stationary near Sirius. However, it is a very peculiar prediction of general relativity that this observation is only true for observers *outside* the wormhole! If you were *inside* the wormhole, then general relativity predicts that, according to you, both mouths of the wormhole will age *just as much* – they will always be synchronized, regardless of their motion.

So, let's suppose that you entered the mouth of the wormhole which was just accelerated, and it resulted in that mouth aging 5 years while the other mouth aged 10 years. And say that, at the end of the process, it's the year 3005 at the accelerated mouth and the year 3010 at the mouth that remained stationary. Then, you go inside the wormhole, and you observe that it's 3005 at the stationary end. Once you exit through the stationary end, it will still be 3005 there. Thus, you've traveled into the past of the stationary mouth of the wormhole!

Just to give you some real-world perspective, the two mouths could theoretically be located in your living room, before you accelerate one of the mouths. So, initially, it might be the year 3000. You accelerate one of the mouths up to a very high speed, and then bring it back to your living room, where your calendar shows it to be the year 3010. So, the accelerated mouth of the wormhole aged 5 years whereas the stationary mouth aged 10. Well, according to general relativity, if you walk through that accelerated mouth into the other mouth located in the living room, you'll soon find it to be the year 3005 again! How lovely!

Unfortunately, wormholes are highly unstable objects, meaning that very shortly after they're constructed they fall apart. However, this instability can be overcome if you've got some *exotic material* – matter which essentially has negative mass(!). Also, the actual construction of a wormhole appears to be rather difficult, since, for example, a time machine might be required for the construction process. But if you can overcome these difficulties, the past is yours!

Finally, it must be said that this type of time machine only allows time travel to as far back in time as when the time machine was created. Alas, it doesn't look like we'll be able to re-witness (through wormhole time machines, anyway) the birth of rock 'n' roll, or our nation's declaration of independence,... or Einstein's discovery of relativity – which led to all this beautiful mess!