Chapter One

# Peculiar Consequences

Imagine that you are an astronaut on a trip to the moon. Actually, this is not too hard to imagine. You've seen pictures of it happening in real life. But your trip is a special one. You will be the first to travel at anywhere near the speed of light.

In real life it takes only about one second for a pulse of light to get to the moon. But let's imagine that physicists figured out how to slow down the so-called "constant" speed of light by punching wormholes in the fabric of space-time.  The reason they did it was that NASA scientists had decided interstellar space exploration would only be practical if the speed of light were much slower, so they got everyone to agree to change it by a factor of 186. Instead of 186,000 miles per second the new speed is a nice round 1000 miles per second. Your crew is the first one to test NASA's idea by making a quick trip to the moon.

Prior to your trip the new speed of light (S) was been measured by bouncing a light beam off the moon and timing how long it takes to come back to Earth. It took 4 minutes one-way, as expected, so going at 80% of S your spaceship will take longer: 4/.80 = 5 minutes for the trip. This should give you plenty of time to hard-boil your morning egg, which normally takes 4 minutes. You can munch it while you take a quick look at the back side of the moon. You start the egg cooking just as you leave earth orbit, turn over your 4-minute hour-glass, and wait…. spoon in hand.

Whoops! The navigator suddenly announces that you are passing the moon. But your hourglass has not emptied. It must have clogged up. You break open the egg and it's still gooey. Observers on the Permanent Moon Station confirm that your trip took exactly 5 minutes as scheduled. How come the egg didn't get done? You soon find out why: your on-board computer's clock shows an elapsed time of only THREE minutes for the trip. What's going on?

Now you remember the pre-flight briefing about "time dilation": clocks in a space ship run slower than the clocks in the Earth-moon stations. Before S

was changed this effect was so small that no one noticed it, but now, traveling at 80 % of S, your clock showed only 3 minutes elapsed instead of the real 5 minutes on the stationary Earth-moon clocks. But you assumed that time dilation only affected clocks…not hour glasses and eggs!
How about people? Are you really 2 minutes younger than you would have been if you had stayed home this morning? Time dilation is based on Einstein's Theory of Relativity, which states that any two observers traveling at constant speed relative to each other will derive the same laws of physics. But your clock was slower than the earth-moon clocks. Why wasn't it the other way around? Why weren't they slower? What's going on here?

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The above story was a bit of science fiction, but just a bit. No one knows how to slow down the speed of light but if you could get an egg (and a stove) up near the speed of light it definitely would take longer to cook. Let me explain.

Albert Einstein was the first person to take seriously the idea that motion could affect the flow of time. In his famous paper of 1905, *On the Electrodynamics of Moving Bodies*, he starts out by making two postulates that hold for all observers moving at constant velocity relative to one another:

- They will all deduce the same laws of physics.
- They will all measure the same speed for a beam of light.

Both postulates were needed to make James Clerk Maxwell's highly successful laws of electromagnetism logically consistent. The second postulate also agreed with mounting evidence that the eighteen-year old experiments of Michelson and Morley were correct. In 1887 when Albert Einstein was only eight years old Michelson and Morley measured the speed of light when the Earth was going around the Sun at different times during the year. Their intention was to find the speed of the Earth through the (assumed) stationary "ether" in which light waves supposedly traveled. In its orbit around the Sun, in September the Earth is moving towards the constellation Gemini at .0001 of the speed of light. In March it's moving away from Gemini with the same speed. Michelson and Morley sent beams of light both towards and away from Gemini, and also perpendicular to those directions, at various times during the year. The differing speed of the Earth through the putative “ether” should produce a variation in the measured speed of their light beams. This in turn would allow them to compute the speed and direction of the Earth through the ether.

Michelson and Morley’s idea can be understood with a simple analogy. Suppose you are on a stationary oil rig in the middle of the ocean on a dark foggy night. You want to know the speed and direction of the ocean current but you can’t see the water. So you send out a boat and tell the driver to measure how long it takes to go 100 yards away from your rig. He needs to do this at several different points around the compass. The direction that takes him the shortest time will be the <u>direction</u> the current is going and the <u>speed</u> of the current can be found by subtracting the speed of the boat in still water from the net speed of the boat plus current. That is:

(Speed of current) = (Net speed) – (Speed of boat in still water)

Where: (Net speed) = 100 yds/(shortest time)

The experiment of Michelson and Morley was brilliantly conceived and brilliantly executed. The only trouble was they could never find any difference in the speed of light: it was always the same winter, summer, spring and fall. This seemed to mean that light beams do <u>not</u> travel in some sort of stationary ether. It was a surprising, puzzling result that is actually quite difficult to believe: so difficult that not even Michelson himself could believe it; not until his dying day.

The problem with this result is that it seems to violate our experience in the “real” world. If you’re riding in a car, traveling along with a nearby train, it’s obvious that your speed, relative to the train, is much smaller than if the train were at rest. If you are going only slightly faster than the train it will take you a long time to pass it. Likewise, if the train is coming towards you, your relative speed is greater than it would be if the train were at rest; you go past it in a hurry.

Now imagine that you’re an astronomer studying a pulsating star in some distant galaxy. You measure the speed of the star’s light pulses as they arrive in your telescope and you get the standard value of 299,792,458 meters/second. It so happens that you are in communication with a spaceship that is traveling at a speed of 1000 m/s directly <u>away</u> from the pulsar. If they measure the speed of the pulses going by them they should get 299,79<u>1</u>,458 meters/second, right? No, wrong. According to Einstein’s second postulate you will both measure exactly the <u>same</u> speed for the light pulses. This is basically what Michelson’s experiments were telling him and what he couldn’t believe.

But what Michelson couldn’t believe Einstein was able to use as the basis for a revolutionary change in our understanding of the physical world. First he showed that his two postulates fixed up Maxwell’s equations in a very elegant way. Thus being convinced that his two postulates were true he went on to explore what he called their “peculiar consequences”. He found, for example, that moving clocks would be retarded and moving meter sticks would be shortened. Strange as this must have seemed, he found nothing that contradicted any physical measurements, so decided these peculiar things must be true. That was the difference between Einstein and Michelson….the difference between a genius and just another really smart guy.

Einstein referred to his postulates as the “Principle of Relativity”. Four months later he published another paper which used these same ideas to show that a change in a body’s energy was equivalent to a change in its mass multiplied by the square of the speed of light: $E=Mc^2$ . Nowadays the content of these two papers is referred to as the Special Theory of Relativity.

Back to the car and the train: if a car going 40 mph approaches a train going 60 mph isn’t their relative speed 100 mph? Einstein’s answer is no, but it’s so close to 100 mph that it would never be noticed. The correct relative speed is slightly less than 100 mph by .00000000000054 mph. The effects of Special Relativity only become important when the relative velocity of two objects is an appreciable fraction of the velocity of light. If the speed of light were only 100 mph the relative speed of the car and the train would be only 80.6 mph, that is, quite noticeably different than 100 mph.

The slowing down of moving clocks is referred to as “time dilation”. Many years after Einstein’s 1905 papers the equations of time dilation were confirmed by experiments using high-speed elementary particles. It takes them longer to decay when they’re moving than when they’re at rest. In 1980 it was even confirmed using extremely accurate clocks in airplanes.

It’s weird, but moving eggs really do cook slowly.

And moving astronauts, if you can get them up near the speed of light, could live a long, long time. You want to live 5,000 years? Just pedal yourself up to 99.995 % of the speed of light and you can stretch 50 into 5,000.