THE THEORY OF RELATIVITY

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The mass of a single potato can yield as much energy as all the coal from a whole coalmine

EINSTEIN made us more aware of the need to think in terms of four dimensions - length, breadth, width and time. Space has no meaning without time. Let's imagine the bud of a flower unfolding. Without time, there would be no unfolding. Where we see the phrase *space-time*, we're talking of an existence where all four dimensions are present. In the words of scientists', a space-time continuum.

Einstein was always a quiet, modest man. **I have no special gift,** he once said. **I am only passionately curious.**

Einstein was so curious that he came up with his Theory of Relativity. It changed man's view of space and time much more than any other in history. The first part, the *Special Theory of Relativity*, was announced in 1905. The second, the *General Theory of Relativity*, in 1916.

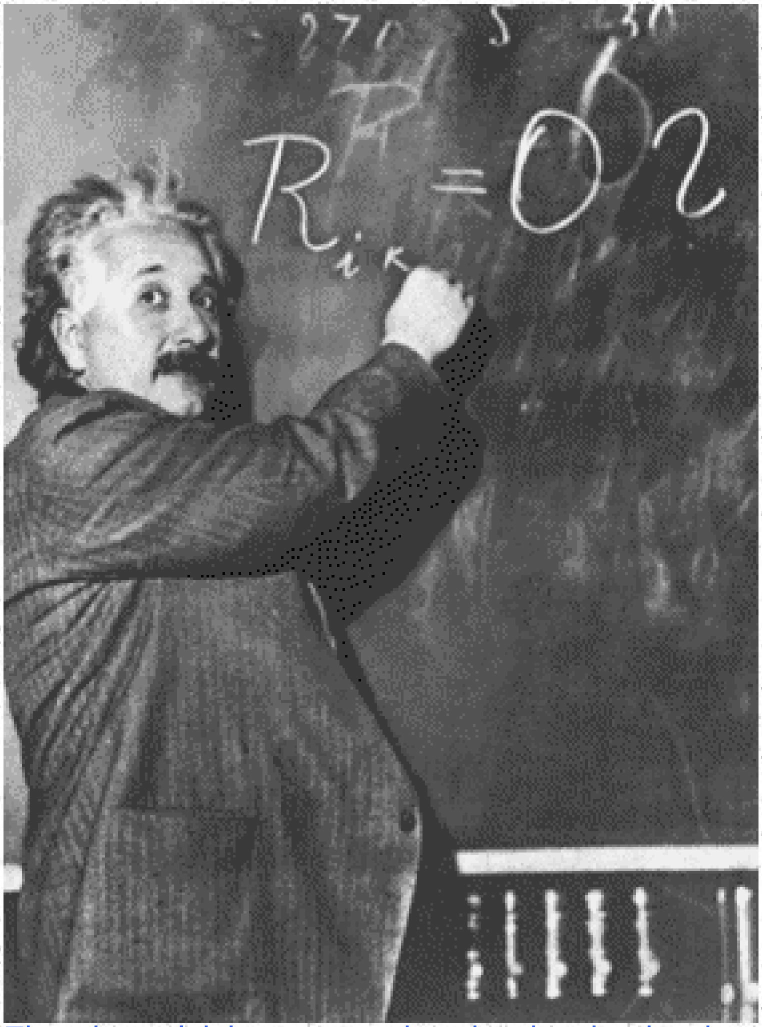
An accelerator is basically a large tubular tunnel built deep underground. The tunnel runs in a circle whose circumference is several kilometres. Scientists use it to perform special experiments such as the study of particles which can be observed only at extremely high speeds.

The tunnel could also be straight such as the Stanford linear accelerator in US. To make it perfectly straight, its supports are of different heights to compensate for the curvature of the Earth.

The accelerator came into operation in May 1966. It is capable of boosting electrons to more than 99.9% of the speed of light.

Why nothing can travel faster than light

As we have seen, if an object, say, a spaceship, were to reach the speed of light, it would shrink to nothing, time



Einstein explaining an equation showing the density of matter in the Milky Way

Relativity is nothing extraordinary

Relativity always exists, but many of us have not taken notice. Or we take them for granted and never look deeper. Let's take a look at one example.

We have two cyclists riding towards each other at 50 k/h. At that precise point when they pass each other, both would, in fact, be travelling at 100 k/h. But to you and I standing nearby as spectators, they would be passing each other at the same 50 k/h. In other words, speed here is relative.

Special Theory of Relativity

Simply put, Einstein theory states that the only constant thing in the Universe is the speed of light. Motion, matter, time and space are all not.

aboard would stop, and its mass would be infinite.

To move that infinite mass, you would need energy greater than infinite. Since there is no such thing as greater than infinite, it follows that you can't move the spaceship. Therefore, it is impossible to travel even near - and never mind faster than - the speed of light.

There are only two known objects that can reach the speed of light. They are photons (quanta of light) and neutrinos (particles released when radioactive elements decay). But these are not ordinary matter. They have no stationary mass and do not exist at any speed below that of light.

Mass benefits or mass destruction

Of all the above relativistic effects discovered by Einstein, the increase in mass has had the greatest implications.

Since increased velocity produces an increase in the mass of an object, Einstein concluded that the extra mass comes from the energy of the object's motion.

This further means that energy has mass, and mass and energy are two sides of the same coin.

Einstein calculated that mass found in a given amount of energy is very small -

$$m=E/c^2$$

mass is equal to energy divided by the speed of light squared

Einstein reasoned that since energy has mass, then mass must have energy. To calculate the amount of energy we can get from mass, he simply rewrote the equation to -

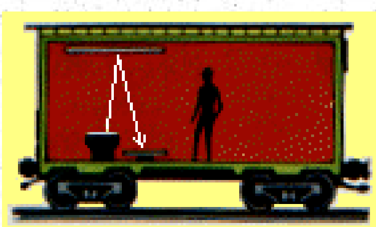
$$E=m/c^2$$

This shook the world. Because it means that we can get an enormous amount of

Time becomes pregnant

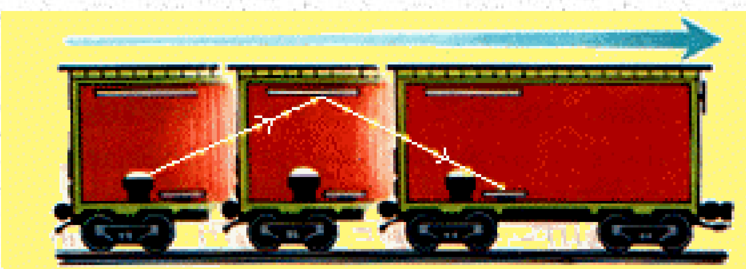
How can we tell if the speed of time isn't constant?

One way is to imagine ourselves trying to measure how long it takes for light to tavel in a stationary railroad car. We put a flashlight on the floor, a mirror in the ceiling and the target a little farther away on the floor (diagram below). Let's say we find that the time the light takes to hit the target is *t*.



Now, if the train were to move away, at whatever speed, and we perform our experiment again, our stopwatch would still register *t*.

A colleague of ours performing the same experiment outside will get different results. To him or her, the distance that the light beam has to travel will be greater. See the diagram below. It follows that the result he obtains will be greater than *t*. This means that time inside the car has slowed down.



Of course, it is near impossible to perform this particular experiment, but Einstein's idea has been proved correct with more sophisticated experiments. Also, in 1972, sensitive atomic clocks carried on spacecraft and then compared with similar clocks on the ground after the flight were found to have slowed down.

Space loses weight

energy from a tiny mass. Just one ounce of any matter could produce the same amount of energy from burning 20 million gallons of petrol (gasoline). Or, one potato is as good as all the coal from a coalmine.

Proof The first proof came 40 years later, when a test A-bomb was detonated at Alamogordo in New Mexico.

General Theory of Relativity

One of the ideas put forward by Einstein in this second part of his Theory is space warp.

The pull of gravity that isn't

Suspicious of the traditional view that an invisible force was reaching out millions of kilometres to pull objects, Einstein got busy again.

Now he came up with the idea that what we call gravity was grossly misunderstood. He said that instead of invisibly tugging on other objects, a body creates a gravitational field around itself. The more massive the body, the stronger the field created.

Within that field, the basic geometry or shape of space is altered in a predictable way.

So, matter passing near a massive object is not pulled onto a curved path by a force. What actually happens is that the matter continues on the shortest possible path. But the massive object so distorts the space around itself that there are no straight lines in its vicinity.

To see what he meant, let's take a look at the diagram below. We have a heavy ball, say a bowling ball, put on a trampoline. If we roll, say, a golf ball across the surface of the trampoline, it will of course curve around the bowling ball.

With the same experiment above, we can see that space is also affected.

If the beam of light is set up to travel in the direction of the car's motion, and synchronized clocks tell us how long it takes to travel from back to front, we have in effect a measurement of the car's length.

But for a stationary observer, the car's motion increases the distance the light must travel.

Therefore, the moving car is shorter than it was at rest.

If the person inside the car were to measure its length, breadth and height, however, he will find that none has changed. The reason is simply that his measuring tape has contracted lengthwise in the same proportion as the car itself.

Space slims while mass gains weight

Mass increases with velocity (speed). The higher the velocity, the more massive an object becomes.

In our layman's language, mass is weight.

This increase in mass has been proved, particularly in accelerators when it was found that the mass of electrons increased hundreds of thousands times on being accelerated.

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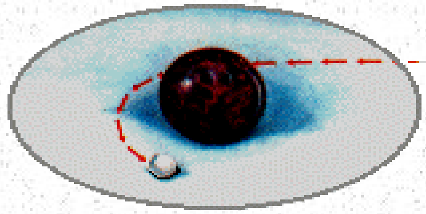

Proof During an eclipse in 1919, astronomers studied the behaviour of starlight passing near the Sun's edge. A star, whose actual location was known, appeared to have moved slightly. This could only mean that its light rays were 'bent' as they passed through the Sun's gravitational field. And they did almost to the exact degree that Einstein had calculated.

Other ideas

Einstein has put forward other great ideas. One of these is the unified field theory which sought to express electromagnetism, gravitation, and the strong and weak nuclear forces that hold the atomic nucleus together into a single theory. This theory has been disputed by several other great scientists recently (after his death) who have access to new developments in physics and mathematics. But, generally, his work has stood well under vigorous and continual testing and re-evaluation.