Einstein

In 1905 Albert Einstein, a lowly 26 year old clerk in the Swiss Patent office, published papers that changed the way we see the whole universe.

The papers were on Brownian motion (Einstein mathematically modelled this phenomenon to prove the existence of atoms), the photoelectric effect (Einstein's theory showed light behaved like a particle, the paper won him a Nobel Prize, and helped to start the thinking behind Quantum Physics) and special relativity (all about how moving clocks run slow and objects can shrink & gain mass at the same time). Ten years later Einstein would come up with a general theory of relativity which filled in the gaps and introduced gravity into his view of spacetime (it explained how time passes faster on the tops of mountains than in valleys).

The paper on special theory of relativity (actually called "On the Electrodynamics of Moving Bodies") was amazing because it had no footnotes or citations, made no specific mention of any work that had influenced or preceded it and acknowledged the help of only one other person (a friend from work called Besso; and Albert's wife Mileva was also involved in many of the discussions).

The effects of relativity are not only real, they have now been measured using modern technology, backing up Einstein's theories.

Relativity and Time

Essen's caesium clock

Such is the accuracy with which time can now be measured, modern timekeepers now need to contend with complications arising from the subtle, but real, effects predicted by Einstein's theories of relativity. Einstein's special theory deals with clocks moving with respect to each other and his general theory deals with clocks operating in a gravitational field.

Special relativity and time – "moving clocks run slow"

A clock in a moving aircraft would be seen to run slow as judged by an observer on the ground. Modern atomic clocks have nanosecond accuracy, so time dilation has to be taken into account whenever they are moved.

General relativity and time – "high clocks run fast"

Two clocks initially ticking at exactly the same rate will change when one is taken to the top of a mountain. Someone in the valley will see the mountain clock to be running fast, while someone on the mountain will see the valley clock to be running slow. This is due to the valley clock being nearer the centre of the Earth, so the gravitational potential is stronger. A clock will speed up by 1.09 parts in 10^{13} for every kilometre above sea level, this works out at about 9.43 nanoseconds per day. In October 1971 two scientists (Hafele-Keating) took four atomic clocks around the world on commercial aircraft, the time lost (due to speed) and gained (due to height) matched their predictions and proved Einstein correct.

Relativity and the Kilogram

The kilogram is currently defined as the mass of the international prototype kilogram, a cylinder of platinum-iridium kept at the Bureau International des Poids et Mesures (BIPM) near Paris. Each country has a copy of the prototype kept at a national standard laboratory. The UK's copy (number 18) is kept at the National Physical Laboratory (NPL) in Teddington. Metrologists (Measurement Scientists) are looking at ways to define the kilogram in terms of fundamental physical constants rather than by an artefact. One way to do this is to define the kilogram in terms of a frequency - one conclusion of Einstein's theory of relativity is that energy produces mass. A photon of light or x-ray of a specified frequency will have a particular energy and will thus produce a defined mass. So the kilogram could be defined as the mass of a certain number of photons of a specified frequency.

The UK kilogram 18 in its storage unit

Energy & Mass

$E=mc^2$

energy = mass x speed of light x speed of light

The speed of light is enormous, so the square of the speed of light is incredibly big, so a tiny amount of matter has a gigantic amount of energy locked up in it. There is enough energy locked up in a grain of sand to boil 10000000 kettles and the energy equivalent of the average adult is about 7×10^{18} (7000000000000000000) joules of potential energy, enough to explode with the force of thirty hydrogen bombs!

5 things you probably didn't know about Einstein

Einstein did not learn to talk until he was three – It's said that, when he was introduced to his newborn sister, he asked "Where are the wheels?"

Einstein explained why the sky was blue – The air scatters sunlight, and the scattered light shines from all parts of the sky. Violet is scattered more than blue, which is scattered more than green and so on. But, because our eyes are not very sensitive to violet light, we see the sky as blue. Though Einstein didn't come up with this theory, he developed maths that helped prove it.

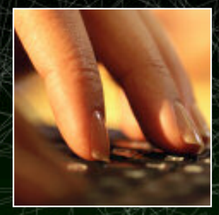
Einstein was expelled from school – In 1894 he managed to get himself expelled from school for undermining the authority of his teachers and being a disruptive influence (please don't try this at school even if you think you are a genius).

Einstein did not like wearing shoes and socks – In 1917 after a holiday on the Baltic coast Einstein discovered that he enjoyed going barefoot so much that he avoided them whenever possible.

Einstein's brain was removed after he died on April 18, 1955 aged 76 years old – At his request, Einstein's brain was removed for research. Many years later, careful measurements revealed a number of differences to normal brains.

"NPL is the UK's national measurement laboratory"

Scale



Speed of fingernail growing
= 0.000 000 001 metre per second

Speed of hair growing
= 0.000 000 004 metre per second

Speed of man sprinting
= 10 metres per second

Speed of Formula 1 car = 107 metres per second

Speed of jumbo jet
= 250 metres per second

Speed of sound
= 344 metres per second

Speed of light
= 299 792 458 metres per second

NPL
National Physical Laboratory

If you have a measurement-related scientific question contact us on: telephone 020 8943 6880 email: enquiry@npl.co.uk or visit our web site which has lots of measurement related information at http://www.npl.co.uk