

The theories of Albert Einstein dominated the field of physics throughout the 20th century. From the year he published his first revolutionary scientific papers in 1905 until well beyond his death in 1955, he influenced science in a way that few scientists, before or after, ever have. Even half a century after his death he remains the best known scientist of all time.

Early life

Albert Einstein was born on March 14, 1879 in Ulm Germany. His father Hermann was a salesman who, a year after Albert's birth, moved to Munich and opened an electrical and engineering business. Young Einstein was a bright student, but did not stand out academically at school. He preferred to do his own reading and investigation. His father and his uncle Jakob stimulated his love of mathematics and science and Max Talmud, a young medical student who regularly visited the family, helped further young Albert's science education well beyond that of his secondary school peers.

When his parents moved to Italy, leaving him alone to continue his studies in Munich, he quit school, renounced his German citizenship and left Germany (partly to escape doing military service). Einstein then contemplated a career as an electrical engineer but he failed an entry exam for a polytechnical school in Zurich. This made him more



Einstein and his first wife Mileva Maric in 1910

determined to finish school and go on to university to indulge his love of science. He studied physics and mathematics at the renowned Eidgenössische Technische Hochschule (ETH) the Federal Institute of Technology in Zurich, graduating in 1900 and becoming a Swiss citizen the same year. It was at the ETH that he met Mileva Maric, whom he would marry in 1903. On graduation he failed to get an academic position at the ETH and so he became a teacher and then got a job in the Swiss patent office. This allowed him time to formulate his ideas on physics.



Playing the violin at Princeton, 1931

“Einstein was neither God nor the Devil, but an ordinary man, with mortal weaknesses, and an outstanding talent for deciphering the mysteries of the Universe”

Michael White & John Gribbin in *Einstein: A Life In Science* (Simon & Schuster)

1905: Annus mirabilis

While working at the patent office Einstein continued to think about several ideas that interested him. He produced an astounding five papers in this one "miracle year" that were published in the monthly journal *Annalen der Physik*. He wrote "A New Determination of Molecular Dimensions" looking at how to measure the number of molecules in a given quantity of substance and the sizes of ions in solution based on their pressure and diffusion. The paper earned him a Ph.D.

His next paper was on the motion of small particles suspended in a stationary liquid. This paper explained Brownian Motion, the movement of molecules in liquid, as molecules colliding with each other.

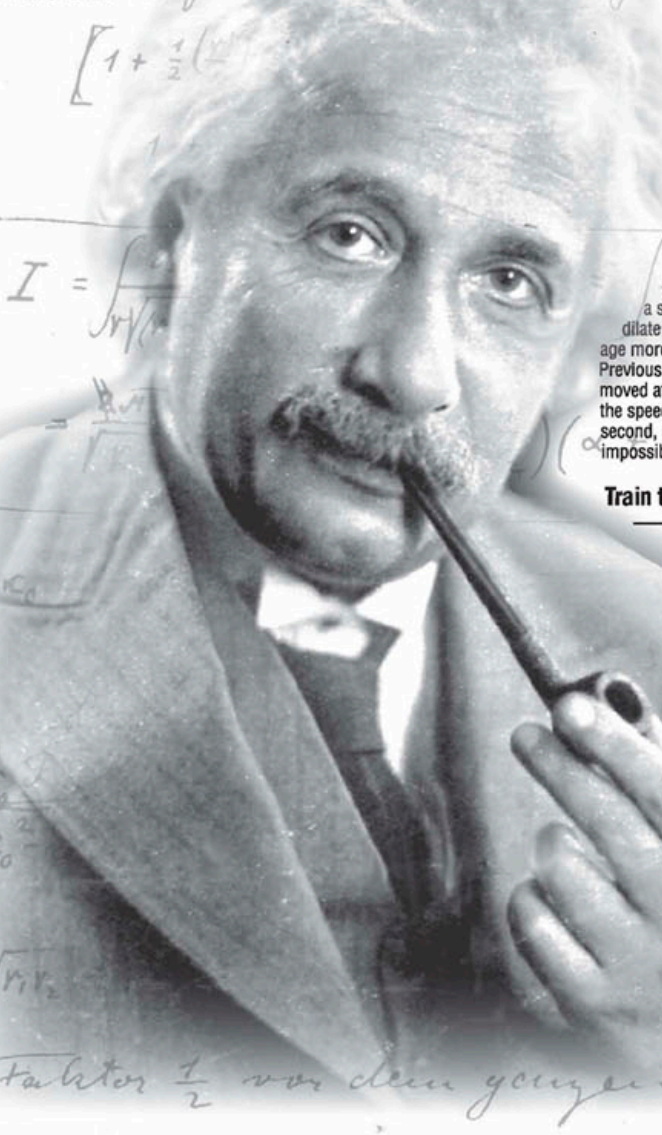
His paper "On a Heuristic Viewpoint Concerning the Production and Transformation of Light" was also, in his own words, "revolutionary". In this paper he was able to explain certain things that other physicists had been unable to by treating light as particles.

Relativity theory was first put forward in the work "On the Electrodynamics of Moving Bodies" which overturned the Newtonian idea of absolute space by saying that the speed of light was the only constant and that space and time were relative.

His final paper for 1905 was the one in which he put forward the relationship between energy and matter as $m = E/c^2$, where m is mass, E is energy and c is the speed of light. This would later be more commonly written as $E = mc^2$.

“The world needs heroes and it's better that they be harmless men like me than villains like Hitler.”

Albert Einstein

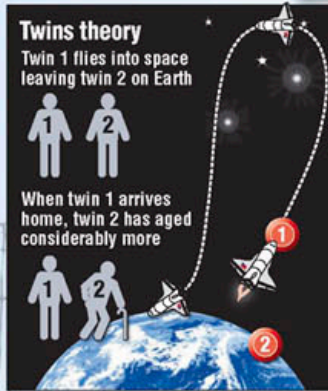


Albert Einstein

$$E = mc^2$$

Theory of relativity

In 1905 Einstein published his groundbreaking work paper "On the Electrodynamics of Moving Bodies" which included what is known as his special theory of relativity. In it he said that the laws of physics were the same for any observer moving at a constant speed, but that space and time were relative to the observer. Time slows down and space contracts for a person or object in motion. This is barely noticeable at low speeds, but the effect increases the faster the person or object travels. So that if one of a set of twins travels into space, time will dilate or slow down on their craft and they will age more slowly than their twin back on Earth. Previous scientists had shown that light always moved at the same speed. Einstein theorised that the speed of light, 299,792,458 metres per second, is an absolute beyond which it was impossible to travel.



Even light shining from a source aboard a moving object will still only move at light speed, not light speed plus the speed of the object.



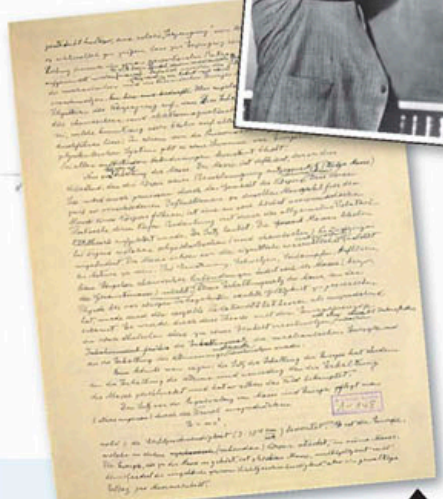
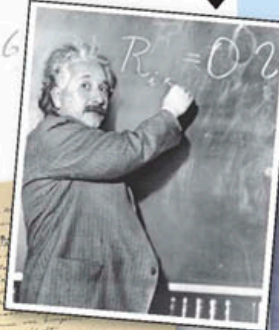
The quest for a unified field theory

Einstein was obsessed with the idea that there was a theory or a simple set of equations that could explain all of the forces of the universe. In his time he knew of two of these forces: gravity and electromagnetism. He admired how James Maxwell had demonstrated that electricity, magnetism and light were all manifestations of the same force known as electromagnetism. Einstein believed that the same must be true of gravity, that one could "unify the field" by finding a single explanation that would cover both gravity and electromagnetism.



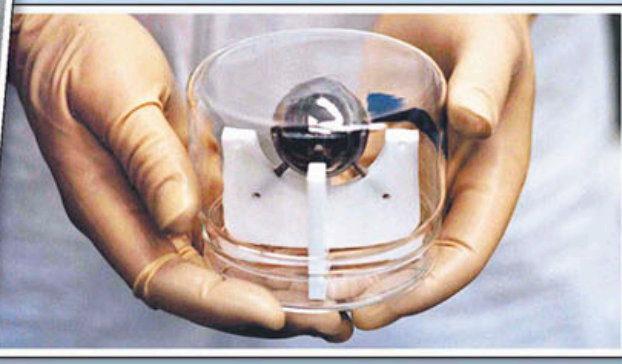
Modern physicists now know of two other forces strong nuclear force and weak nuclear force, which determine the behaviour of sub-atomic (smaller than atoms) particles, and they are still searching for the theory that will explain all of these forces. One possibility is known as "string theory", which looks at the basis of every sub atomic particle as vibrating strings of energy. Although string theory seems to pose an explanation of how the forces are unified, it is currently impossible to test it experimentally.

Einstein writing out an equation for density of Milky Way in 1931



Page 2 of Albert Einstein's E=mc^2

A supersensitive gyroscope that is part of the Gravity Probe B experiment to try to prove whether Einstein was right about the warping of space and time by strong gravitational fields. For more details see www.gravityprob.com



From relative obscurity to relativity fame: 1904-1933

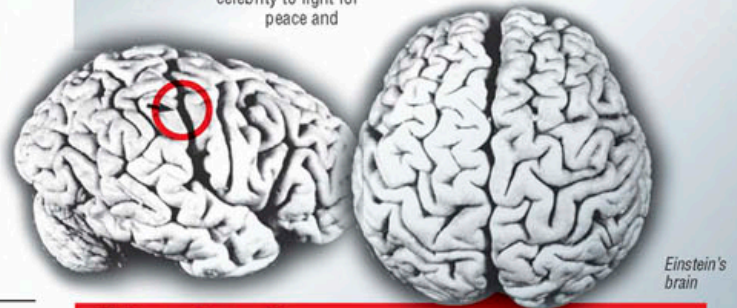
Einstein continued his work at the patent office while working on scientific papers. His first son Hans was born in 1904. It was in his miracle year, 1905, that Einstein finally won his doctorate. But it was not until 1908 that he got his first academic appointment, at the University of Bern. His second son Eduard was born in 1910. Soon he began to receive even more recognition for his work and in 1911 he was given his first full professorship. He accepted a position at the Prussian Academy of Sciences in Berlin in 1914, taking up German citizenship again. Unfortunately he found himself separated from his family when World War I broke out. This separation would lead to divorce in 1914. While denouncing Germany's militarism he continued to work on his theory of

gravity and the general theory of relativity, which he published in the *Annalen der Physik* in 1916. When part of his theory was verified by observations made during an eclipse in 1919 he became famous. In the same year he married Elsa Lowenthal. He received the 1921 Nobel Prize "for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect" which further enhanced his fame. He became involved in political as well as scientific discussions. The bleak political climate of Europe in 1930s led to Einstein renouncing his German citizenship and emigrating to the US in 1933, where he took a position at Princeton's Institute of Advanced Study.

Last years 1933-1955

Einstein lived his final years working on his unified field theory. Although he had embraced the new quantum physics and its implication that unification was most likely impossible, he persisted with his own methods of thinking out the problem. He was by this time not just the most famous scientist but one of the most famous people in the world. He disliked the hero worship but used his celebrity to fight for peace and

social justice in several different causes, including that of a Jewish homeland. In one celebrated case he joined with other scientists to write to the US president Roosevelt about the possibility of constructing an atomic bomb, to counter the Nazi quest for the same weapon. In 1952 he was offered the presidency of Israel but declined. He died on April 18, 1955.



Einstein's brain

Did you know?

- When Einstein died his brain was removed – without the permission of his family – by pathologist Dr Thomas Harvey during the autopsy. On examination it was found to be smaller than the average brain but with a greater density of neurons than a normal brain and more glial cells per neuron and bridging where there is normally a deep groove in the parietal cortex, an area related to maths and visuo-spatial processing.
- In 1902 Einstein's then girlfriend Mileva gave birth to a girl. The child was given up for adoption and to this day nobody knows what happened to the girl that Einstein and Mileva wanted to name Lieserl.
- Einstein's achievement in 1905 is made all the more incredible when you consider that he was not a graduate of one of the great universities but had a teaching diploma from a technical college, that he did not even have his doctorate, that he was mostly working in isolation from the scientific community and that he was a clerk in a patent office at the time.

Einstein classroom activities

- Science**
- List some of the problems Einstein tried to address and the solutions he developed.
 - How did Einstein demonstrate the relationship between mass and energy?

- Design an experiment to prove one of Einstein's theories or re-create another of his experiments.

- Draw a timeline showing the development of theoretical physics from Newton to Einstein.

- Sometimes it is fun to think about science. Discuss these ideas in small groups and share your thoughts with the class. If you were travelling at the speed of light: Would you age? What would a mechanical clock do? What would a digital clock do? If you planted seeds what would happen to them? Would a broken bone mend?

- Art**
- Design a T-shirt print based on Einstein's scientific equations.

- History**
- At times science has been used by governments in a way different to the scientist's original intention, e.g. Einstein wanted the atomic bomb demonstrated but not used on people. Discuss this point with reference to the Second World War. In hindsight was Einstein right in writing to US President Roosevelt and prompting the Manhattan Project? Draw your own conclusions and write your own letter to Roosevelt as if you were Einstein.

- SOSE**
- Einstein has become a scientific icon. What does that mean? Discuss how Einstein and his discoveries (such as the hearing aid) have changed the way you see the world and live a satisfying life. Make a classroom display demonstrating Einstein's iconic status.

- Debate: "Nuclear weapons bring peace". Write five points for and five points against the statement. Make your own conclusion and share this with the class.

- Find out about the doomsday clock. What time is it?

- Maths**
- Some of the building blocks of science are the physical quantities we use to express the laws of physics. List as many of these as you can think of to make a table with the headings Quantity (e.g. length), Name (e.g. metre) Symbol (e.g. m). Other examples include mass and time.

- English**
- Write your own thoughts on Einstein's quote: "The most beautiful experience we can have is the mysterious ... Whoever does not know it and can no longer wonder, no longer marvel, is as good as dead." Write five profound sayings as if they were quotes by Albert Einstein.

- Write the death notice for Albert Einstein as if for *The Mercury*.