Great experiments in Physics

1: Galileo's experiment from the Leaning Tower of Pisa(1589)

For almost two millennia, Aristotle's ideas reigned supreme in the western world. Aristotle, had argued that heavier objects fall faster, so a feather and a stone fall at different speeds because the stone weighs more.

In his famous experiment, Italian scientist Galileo Galilei (then professor of mathematics at the University of Pisa, in Italy) proved this wrong. It is said that he dropped two balls of different masses from the Leaning Tower of Pisa. Despite their different masses, the balls reached the ground at the same instant.

According to Galileo, a feather and a ball dropped from the same height at the same instant will reach the ground at the same time, if there is no air present. In practice the feather will hit the ground by taking more time than a stone because air resistance slows the feather down as it falls. Galileo's experiment led to the conclusion that (in vacuum), all objects under gravity fall with the same acceleration. This was the beginning of a new era in science where controlled experiments became a key factor in acquiring new knowledge.

2: Isaac Newton splits white light into colours (1672)

The English scientist Isaac Newton in 1665 conducted the classic experiment that showed how ordinary light is made up of different colours.

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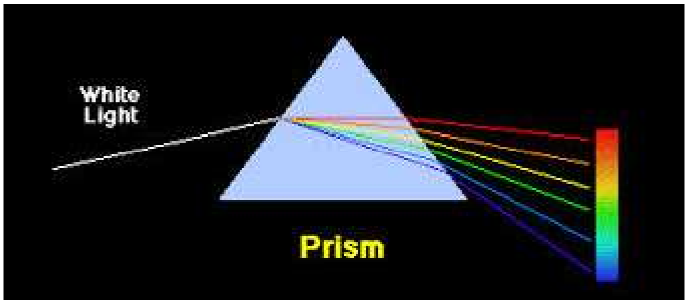
Newton was a young scientist studying at Trinity College in Cambridge University at that time. He directed sunlight from a hole in the window of his chamber onto a triangular-shaped wedge of glass (a prism). The result was a spectacular multicolored band of light just like a rainbow. Newton called this multicolored band of light a s***pectrum***.

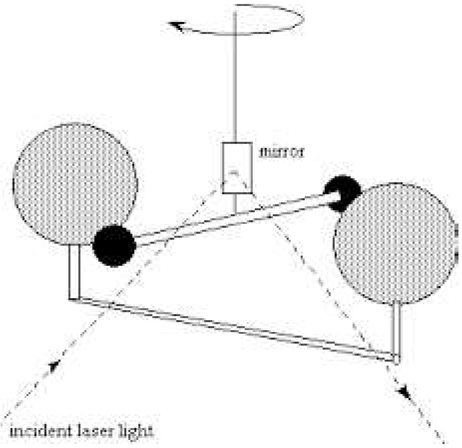


Newton concluded that all the colors he saw in the spectrum were in the sunlight shining into his chamber. He thought that it should be possible to combine the colors of the spectrum and make the light white again. To test this, he placed a second prism upside-down in front of the first prism. The band of colors combined again into white sunlight. Newton was the first to prove that white light is made up of all the colors that we can see in a spectrum. Newton published the results of the experiment only in 1672.

3: Henry Cavendish weighs the earth (1798)

The Cavendish experiment, performed in 1797–1798 by English scientist Henry Cavendish, measured the force of gravity between masses in the laboratory for the first time and was the first to yield accurate value for the gravitational constant.

The gravitational constant does not appear explicitly in Cavendish's work. Instead, the result was originally expressed as the specific gravity of the Earth, from which its mass can be calculated. His experiment gave the first accurate values for these geophysical constants. Hence in popular notion Cavendish weighed the earth, for the first time.



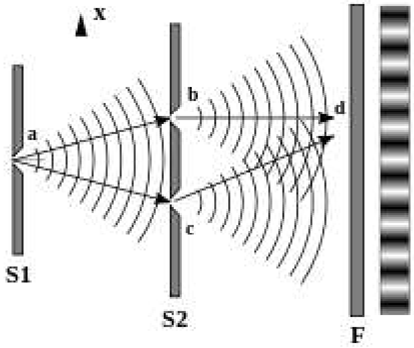
The Cavendish apparatus is relatively simple. It basically consists of two pairs of spheres, each pair forming dumbbells that have a common swivel axis. One dumbbell is suspended from a quartz fiber and is free to rotate by twisting the fiber; the amount of twist measured by the position of a reflected light spot from a mirror attached to the fiber. The second dumbbell can be swiveled so that each of its spheres is in close proximity to one of the spheres of the other dumbbell; the gravitational attraction between two sets of spheres twists the fiber, and by the measurement of this twist the magnitude of the gravitational force can be calculated.

4: Thomas Young proves light is a wave (1803)

The dominance of Issac Newton’s corpuscular theory of light was undermined by the famous experiment by the English scientist Thomas Young in 1803. Though a physician by training, Young also studied Physics, and established definitely the wave theory of light.

Young knew that sound was a wave phenomenon, and, hence, that if two sound waves of equal intensity, but out of phase, reach the ear then they cancel each other out, and no sound is heard. This phenomenon is called interference. Young reasoned that if light were actually a wave phenomenon, then a similar interference effect should occur for light. To prove this he set out to perform an experiment which is now famous as Young's double-slit experiment.

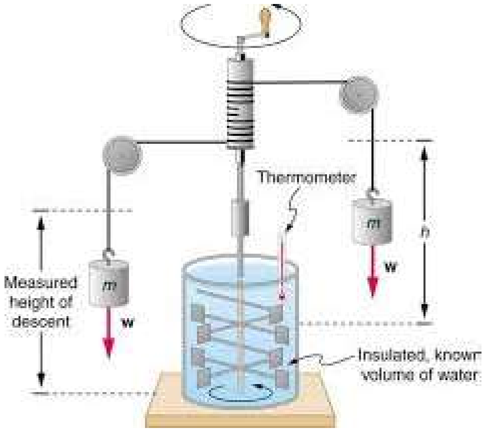
Young made two narrow slits in a board and placed a light source in front of them so that light shone through both slits simultaneously onto a wall behind. If Newton were right about light, Young would have obtained a central bright area on the wall and darkness either side. But when the experiment was done, what he actually saw was a pattern of light and dark areas where the light rays from the two slits "interfered." In some places, light from one slit added to light from the other and made a bright area; in other places, light from the two slits cancelled each other and left a dark area. This interference pattern proved that the light rays were traveling not as particles but as waves.



5: James Prescott Joule demonstrates the conservation of energy (1844)

The English scientist James Prescott Joule's experiment conclusively established that heat is a form of energy. He showed thst always the same amount of heat was produced by spending a given amount of mechanical work. It is immaterial what type of arrangement is used for doing mechanical work.

In 1844-1854 Joule conducted his experiments which became an important milestone in science. Joule's experiment had a big influence and was one of the most relevant results around the emergence of the principle of conservation of energy. His ingenious experiment and extraordinary precision changed the way scientists understood heat, and contributed to the birth of modern thermodynamics.



In his experiment, there was a large container full of water that had a paddle wheel fixed inside it. The paddle wheel was connected to an axle around which a string was wrapped many times. The string was looped over a pulley and had a heavy weight on the end of it. When Joule released the weight, it pulled the string around the pulley, turned the axle, and made the paddle wheel spin, which heated up the water. His calculations showed that the amount of potential energy lost by the falling weight was exactly equal to the amount of heat energy gained by the water. This was a way of expressing the conservation of energy: you can't create or destroy energy, but you can convert it from one form into another.

6: Fizeau's measurement of the speed of light (1849)

Armand Hippolyte Louis Fizeau (1819-1896) was the first to measure the speed of light on earth, without any recourse to astronomical observations.
. In July 1849 Fizeau set up a mirror at his parents' home at Suresnes and another on Montmartre, the hill on the right bank of Paris. These were 8633 metres apart. Between them he set up a rapidly rotating toothed wheel and determined the speed of rotation necessary for the time taken by the light travelling between the mirrors to equal the time taken for the wheel to rotate by one tooth. He was thus the first to make a successful terrestrial measurement of the velocity of light

He sent a beam of light at a mirror so it bounced through the wheel rotating hundreds of times per second. Like a gear, the wheel had teeth cut into its edge and the light shot through one of them. Fizeau arranged the mirror such that light hit it and bounced back the same way, coming back through it and into a telescope through which he was looking . He knew how far the light beam had traveled, so all he had to measure was how long it took. The rotating gear wheel was effectively his clock: knowing how many teeth it had and how fast it was spinning, he could adjust its speed until it just blocked out the light from the far mirror. At that point, he knew that the light beam had traveled only once from his lamp to the mirror and back again (a distance he had measured), and he also knew how much time had elapsed between the light beam departing and coming back again. So all he had to do was divide the distance by the time to calculate the speed of light. His figure was about 3.1×10^8m/s, which was about 5 percent too high—but a very impressive result.

7: Michelson and Morley Experiment 1887

The physicists in the late 19th century assumed that light travels through an invisible, ubiquitous medium dubbed the “luminiferous ether.” Working together at what is now Case Western Reserve University in Ohio, Albert Michelson and Edward W. Morley set out to prove this ether’s existence. What followed is arguably the most famous failed experiment in history.

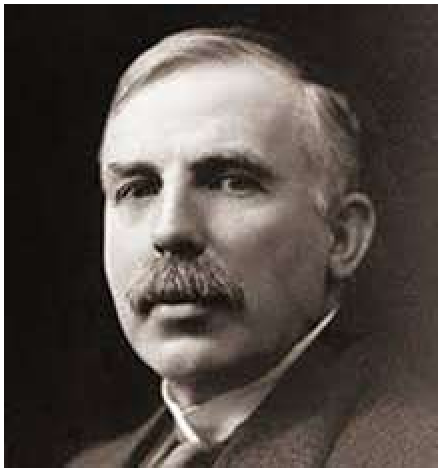
The scientists' hypothesis was thus: As Earth orbits the sun, it constantly plows through ether, generating an ether wind. When the path of a light beam travels in the same direction as the wind, light should move a bit faster compared with sailing against the wind.

In the early 1880s Michelson had invented a type of interferometer, an instrument that creates an interference pattern of light. A Michelson interferometer beams light through a one-way mirror. The light splits in two, and the resulting beams travel at right angles to each other. After some distance, they reflect off mirrors back toward a central meeting point. If the light beams arrive at different times, due to some sort of unequal displacement during their journeys (say, from the ether wind), they create a distinctive interference pattern.

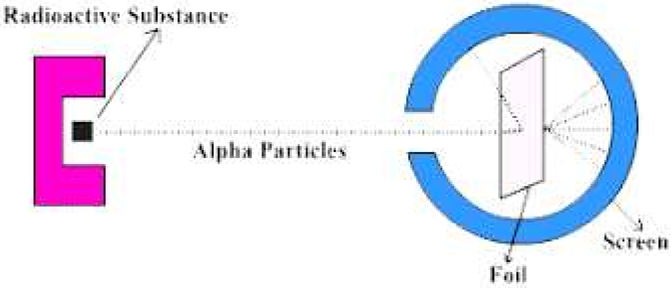
But Michelson and Morley failed to notice any interference pattern when the experiment was performed. This implied that light was travelling at a constant speed. The ether theory was discredited. This set off a chain of further experimentation and theorizing that finally led to Albert Einstein's new revolutionary paradigm shift in 1905 the theory of special relativity.

8: Ernest Rutherford's Alpha scattering Experiment

Ernest Rutherford wanted to verify J.J.Thomson's plum-pudding model of the atom. According to Thomson, atoms are like solid spheres of positive charge on which negatively charged electrons are embedded like plum in pudding. In any substance, atoms are arranged in a clos pack structure.



Working at Manchester University in England, Rutherford got two of his students, Hans Geiger and Ernest Marsden, to fire positively charged (alpha) particles at a thin sheet of gold foil. Even a thin gold foil will have a number of layers of atoms. If these atoms are closely packed solid spheres, then all the alpha particles should bounce back. But, most of the alpha particles shot straight through the gold foil but a tiny number were bent through large angles and some even bounced right back.



Rutherford and his colleagues were astonished. As he famously stated: "It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you." He explained the results of the experiment by rejecting Thomson's model of the atom. Atoms must consist of a positively charged core (the nucleus) with electrons in the vast empty space surrounding it. Most of the alpha particles shot straight through this electron cloud and were unaffected. The few that were deflected had been fired very near or directly at the nucleus, so their positive charge was repelled by the positive charge there. It was this experiment that confirmed our modern picture of the atom with a central nucleus and electrons arranged around it.

9: Millikan's Oil Drop Experiment (1910)

American experimental physicist Robert Millikan measured the smallest unit of electric charge by spraying oil droplets between horizontally kept electrically charged plates. After giving them an electric charge, he found he could move them up and down by adjusting the voltage on the plates, and by measuring the speed of their motion he could calculate the charge on the droplets.

In 1909 Millikan began a series of experiments to determine the electric charge carried by a single electron. He began by measuring the course of charged water droplets in an electric field. The results suggested that the charge on the droplets is a multiple of the elementary electric charge, but the experiment was not accurate enough to be convincing. He obtained more precise results in 1910 with his famous oil-drop experiment in which he replaced water (which tended to evaporate too quickly) with oil.

When an oil droplet falls downward by its weight through the air it reaches its terminal velocity, which could be measured. Milikan gave the droplets a negative electric charge so he could stop them falling by applying a positive voltage to the upper plate. With the voltage applied, he found that some drops fell more slowly, some stopped moving, and some even moved upward. He concluded that drops must be carrying multiples of the basic unit of electric charge (multiple electrons, in other words) . By measuring their terminal velocity with the power on, and comparing it to their terminal velocity with the power off, he calculated the basic unit of electrical charge—now known as the charge on the electron—with reasonably high accuracy. Milikan was awarded the Nobel prize for this important work.

10: Enrico Fermi demonstrates the nuclear chain reaction (1942)

Chicago Pile-1 (CP-1) was the world's first artificial nuclear reactor. On 2 December 1942,Enrico Fermi and other scientists initiated the first human-made self-sustaining nuclear chain reaction in this ‘atomic pile’. This was the precurser of all nuclear reactors and nuclear bombs.

Three years before the experiment, it had been discovered that when an atom of uranium was bombarded by neutrons, the uranium atom was split, or fissioned. Later, it had been found that when an atom of uranium fissioned, additional neutrons were emitted and became available for further reaction with other uranium atoms. These facts implied the possibility of a chain reaction. The facts further indicated that if a sufficient quantity of uranium could be brought together under the proper conditions, a self-sustaining chain reaction would result. Each time a Uranium atom splits, there is a loss of small amount of mass. According to Einstein’s theory of relativity, this small amount of mass gets converted into a large amount of energy. A chain reaction will thus release huge amounts of energy.

Fermi tested this out at the University of Chicago experimentaly with the help of the "atomic pile". In his experiment, he fired a neutron at an atom of uranium-235 to convert it into two smaller atoms and two neutrons . The total mass of the smaller atoms and the two neutrons was less than the mass of the uranium-235 and the first neutron. —and that difference in mass was converted into energy, according to Einstein's famous equation $E = mc^2$. The two neutrons then flew off and hit two other uranium-235 atoms, making two more reactions happen... which then made four reactions happen... and so on. This is the famous chain reaction that powers nuclear bombs and nuclear power plants.

11. Higg’s Boson is discovered in CERN’s LHC experiment(2012)

The theory of electroweak interactions and Quantum Chromodynamics (the theory of the strong force) form the basis of the Standard Model. The Standard Model successfully describes all of the elementary particles we know and how they interact with one another. But our understanding of Nature is incomplete. In particular, the Standard Model as originally conceived cannot answer one basic question: Why do most of these elementary particles have masses? Peter Higgs proposed a mechanism by which fundamental particles acquire mass. It required the existence of an unseen particle, which is now called the Higgs boson.

CERN's Large Hadron Collider (LHC) is a mammoth particle accelerator. The particles go around in a 17-mile-long circular tunnel under Geneva, Switzerland, crossing the French border and back again. Large number of protons, cycle around the tunnel in both directions and they are accelerated to just below the speed of light. At such speeds, the protons go around the tunnel about 11,000 times each second, and when directed by the huge superconducting magnets kept around the tunnel, engage in millions of collisions in a short time. These collisions, in turn, produce innumerable particles, which huge detectors capture and record.

On 4 July 2012, the ATLAS and CMS experiments at Large Hadron Collider announced they had each observed a new particle in the mass region around 125 GeV, and this was identified as the Higgs boson.