



Physics

The study of the energy, matter, and forces in the Universe

Why do stars move in the sky? How can heat be changed into electricity? What is the difference between an atom of one substance and an atom of another? Why do sound and light sometimes behave in similar ways and sometimes behave differently? These and many other questions have given rise to the science of physics, which studies the Universe much like a mechanic would study an engine.

Physicists consider everything from subatomic particles (the tiny particles that make up atoms) to planets and galaxies. Different physical theories (testable ideas) are often needed to explain the behavior of these widely differing systems. Once it was believed that everything could be explained with the classical physics developed between the time of the ancient Greeks and the end of the 19th century. At the turn of the 20th century, however, scientists found that they needed to add other theories for a better explanation of the Universe. Today, some scientists are trying to make a single theory that explains everything.

Classical physics

The theories of physics developed before the 20th century are generally referred to as classical physics. They are based on the idea of a highly organized, very predictable Universe that ticks along like a clock. The science of mechanics, for example, explains how objects move around and how their movement changes when forces act on them. Mechanics developed both from the ideas of ancient Greek thinkers, such as Aristotle (384–322 B.C.E.), and the astronomical theories and experiments of scientists such as Italian physicist Galileo Galilei (1564–1642). The most important laws of mechanics were those developed by English mathematician Sir Isaac Newton (1642–1727). It is a tribute to the brilliance of this scientist that, for most purposes, his laws are just as valid today.

Classical physics is not just about mechanics. It also includes early theories of electricity and magnetism. Today, these two phenomena are known to be caused by the same thing and are studied in a branch of physics called electromagnetism. Once, they were regarded as two separate things. The ancient Greeks understood static electricity and magnetism. The idea that there were two different kinds of electrical charges—positive and negative—emerged in the 18th century with the work of U.S. statesman and scientist Benjamin Franklin (1706–1790). Between the middle of the 18th century and the middle of the 19th century, several physicists managed to demonstrate that electric and magnetic phenomena were very closely related. British scientist Michael Faraday (1791–1867) showed that electricity could be produced by changing a magnetic field (the invisible force of magnetism that extends beyond a magnet). Electricity and

magnetism were finally united with the work of another British scientist, James Clerk Maxwell (1831–1879), in his four important equations of electromagnetism.

HIGHLIGHTS

- Classical physics includes theories of motion, gravity, electromagnetism, and thermodynamics developed before 1900.
- Modern physics developed after 1900 following the discoveries of relativity and quantum mechanics.
- Two of the newest branches of modern physics are nuclear physics, which has given rise to nuclear energy and nuclear weapons, and particle physics, which seeks to understand the tiny particles from which atoms are made.

Besides mechanics and electromagnetism, classical physics also includes thermodynamics. This is the study of heat and how it relates to other forms of energy. Originally, heat was not thought of in this way at all, but as a unique substance called caloric (kah-LAW-rihk) that entered or left objects as they heated up or cooled down. However, the experiments of British physicist James Prescott Joule (1818–1889) demonstrated that a certain amount of mechanical work could be changed into an equivalent amount of heat. Joule's experiment is an example of another important law of physics called the conservation of energy. This explains that, although energy can be converted (changed) from one form to another, it cannot appear from nowhere or disappear into nothing. Three laws of thermodynamics, which offer a more detailed explanation of how heat energy behaves, were later worked out by French physicist and engineer Sadi Carnot (1796–1832) and others.

The revolution in physics

By the early 20th century, physicists had arrived, at a remarkably complete picture of how the Universe worked. Or that is what they believed. However, within a few years, the world of physics was turned on its head by new theories.

The first of these theories, relativity, was proposed by German-born U.S. physicist Albert Einstein (1879–1955) while he was working in Switzerland. This theory showed that classical physics could not explain the behavior of objects moving at speeds close to the speed of light (186,000 miles per second or 300,000 km/sec). Based on the idea that the speed of light is always constant, Einstein's theory of relativity led to some apparently extraordinary suggestions. These include the ideas that a clock would appear to work faster or slower when observed by people traveling at different speeds to the clock, and that all objects would appear to shorten in the direction in which an observer was moving. Another aspect of relativity developed by Einstein changed ideas about gravity (the force that pulls objects to Earth). Einstein explained that gravity was not a mysterious, invisible force, but a curvature (bending) of space and time caused by heavy objects.

EVERYDAY SCIENCE

Geophysics

Geophysics involves using the techniques and theories of physics to study the structure of Earth. Petroleum engineers look for oil by bouncing sound waves down into Earth's crust and studying the waves that are reflected back. Measurements of Earth's magnetic field (geomagnetism) or tiny variations in the strength of Earth's gravity also provide important information about the materials from which Earth is made.

Some techniques developed in geophysics have become important in archaeology (ar-kee-AH-luh-gee). They can be used to locate objects quite precisely without actually digging holes. Radiocarbon dating (telling the age of objects from the amount of radioactivity they contain) can also date ancient objects quite accurately once they have been found.

Classical physics works very well in most everyday situations on Earth, and even provides a good description of the motions of stars and planets. Einstein's relativity theories show that it works less well near very heavy objects, such as black holes or neutron stars, or for the Universe as a whole. The second revolutionary theory of 20th century physics showed that classical physics also breaks down on the very small scale.

At the turn of the 20th century, physicists were trying to understand what matter (the stuff of the Universe) was actually made of. In 1897, British physicist J. J. Thomson (1856–1940) discovered the tiny negatively charged particle called the electron. Another British physicist, Ernest Rutherford (1871–1937) and his coworkers discovered that most of the mass of an atom is in the form of protons and neutrons in its tiny nucleus (NOO-klee-uhs). These and other discoveries opened up a whole new world, vastly smaller than anything anyone had imagined before. Just as classical physics failed on the large scale, so it now also failed in the tiny subatomic (smaller than an atom) world. A number of physicists in many different countries developed a new science for this new world. Quantum mechanics, as this was called, said that energy exists only in packets of certain sizes called quanta (KWAHN-tuh).

Modern physics

The twin theories of relativity and quantum mechanics, combined with classical physics, have given physicists a much more complete understanding of how the Universe works. Physicists continue to study problems that have challenged great minds for thousands of years. Thanks to relativity and quantum mechanics, the 20th century has also seen the development of a number of many new branches of physics. These include condensed-matter physics, nuclear physics, and particle physics.

Greek philosopher Democritus (around 468–370 B.C.E.) believed that matter was made up of tiny particles that could not be divided any further. If he were alive today, Democritus might well be studying condensed-matter physics, the modern theory of how solids behave. Condensed-matter physics helps to explain how electrons can interact with the regular arrangement of atoms in a crystal lattice (a solid network of atoms). It also explains the phenomenon of superconductivity, the way a material can become a perfect conductor of electricity at low

temperatures.

Few scientific fields have changed the world so dramatically as nuclear physics. Nuclear energy and nuclear weapons have both developed directly from the discovery of the atomic nucleus. The idea of nuclear physics is that the nuclei of atoms can be broken up or combined under the right conditions. Sometimes a large atom, such as uranium, will split into smaller atoms through a process called fission. At other times, two atoms can be joined together to make a larger atom through the process of fusion. In both cases, a huge amount of energy is released—to make electricity or the blast of a nuclear bomb.

LOOK CLOSER

The Scientific Method

Scientists explain the world using a technique called the scientific method. After making observations about the world, they try to think of a theory (sometimes called a hypothesis; hy-PAH-thuh-suhs) that explains what they have seen. Once they have a theory, they try to make some predictions about things they have not yet observed. Then they carry out experiments to test the predictions. If the predictions are proved to be wrong, they change the theory and come up with some different predictions that they can test in another way. Gradually, with many scientists all working on different theories, a better understanding of how the world works is gained.

When one atom changes into another, the nuclear reaction that takes place involves subatomic particles being gained or lost. Once, atoms were thought of as the smallest building blocks of matter. However, physicists at the start of the 20th century discovered that atoms were made of smaller protons, neutrons, and electrons.

However, research into particle physics led to the discovery of hundreds of subatomic particles. To begin with, this discovery seemed very confusing, and all the new particles made little sense. U.S. physicists Murray Gell-Mann (1929–) and George Zweig (1937–) put forward the idea that the larger particles, such as protons and neutrons, are made up of smaller particles, which have been named quarks (KWAWRKS).

Modern physicists have a very detailed understanding of the Universe, but they are still a very long way from knowing everything. Physicists may never be able to achieve this goal because by observing a quantum system, they change what was there in the first place.

See also: [ELECTROMAGNETISM](#); [ENERGY](#); [MATTER](#); [MECHANICS](#); [MOMENTUM](#); [NEWTONIAN PHYSICS](#); [NUCLEAR PHYSICS](#); [OPTICS](#); [PARTICLE PHYSICS](#); [QUANTUM THEORY](#); [RELATIVITY](#); [THERMODYNAMICS](#).

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