Science › Physics › Matter & Energy

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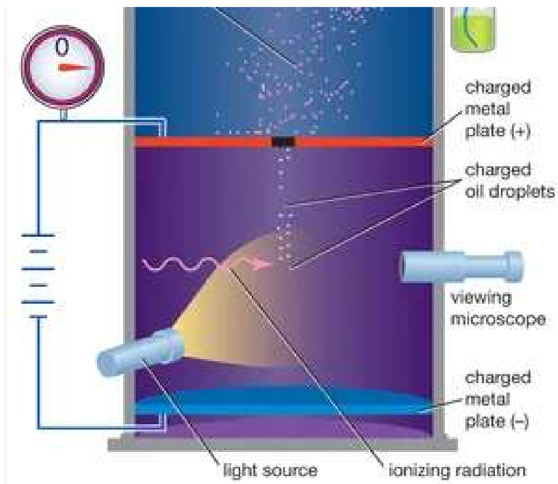

Millikan oil-drop experiment Between 1909 and 1910 the American physicist Robert Millikan conducted a series of oil-drop...(more)

Key People: Robert Millikan

Related Topics: charge conservation • electron charge

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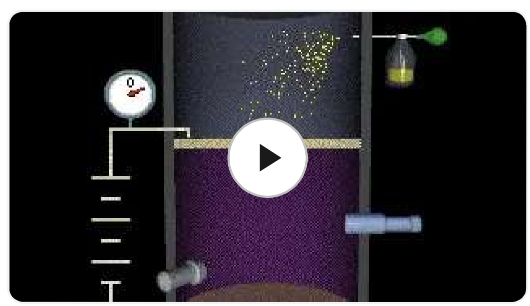

Robert Millikan's method for measuring the charge of an electron Millikan oil-drop experiment.

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Millikan oil-drop experiment, first direct and compelling measurement of the electric charge of a single electron. It was performed originally in 1909 by the American physicist Robert A. Millikan, who devised a straightforward method of measuring the minute electric charge that is present on many of the droplets in an oil mist. The force on any electric charge in an electric field is equal to the product of the charge and the electric field. Millikan was able to measure both the amount of electric force and magnitude of electric field on the tiny charge of an isolated oil droplet and from the data determine the magnitude of the charge itself.

Millikan's original experiment or any modified version, such as the following, is called the oil-drop experiment. A closed chamber with transparent sides is fitted with two parallel metal plates, which acquire a positive or negative charge when an electric current is applied. At the start of the experiment, an atomizer sprays a fine mist of oil droplets into the upper portion of the chamber. Under the influence of gravity and air resistance, some of the oil droplets fall through a small hole cut in the top metal plate. When the space between the metal plates is ionized by radiation (e.g., X-rays), electrons from the air attach themselves to the falling oil droplets, causing them to acquire a negative charge. A light source, set at right angles to a viewing microscope, illuminates the oil droplets and makes them appear as bright stars while they fall. The mass of a single charged droplet can be calculated by observing how fast it falls. By adjusting the potential difference, or voltage, between the metal plates, the speed of the droplet's motion can be increased or decreased; when the amount of upward electric force equals the known downward gravitational force, the charged droplet remains stationary. The amount of voltage needed to suspend a droplet is used along with its mass to determine the overall electric charge on the droplet. Through repeated application of this method, the values of the electric charge on individual oil drops are always whole-number multiples of a lowest value—that value being the elementary electric charge itself (about 1.602×10^{-19} coulomb). From the time of Millikan's original experiment, this method offered convincing proof that electric charge exists in basic natural units. All subsequent distinct methods of measuring the basic unit of electric charge point to its having the same fundamental value.

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This article was most recently revised and updated by Erik Gregersen.

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electric charge

physics

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Also known as: charge, electrical charge

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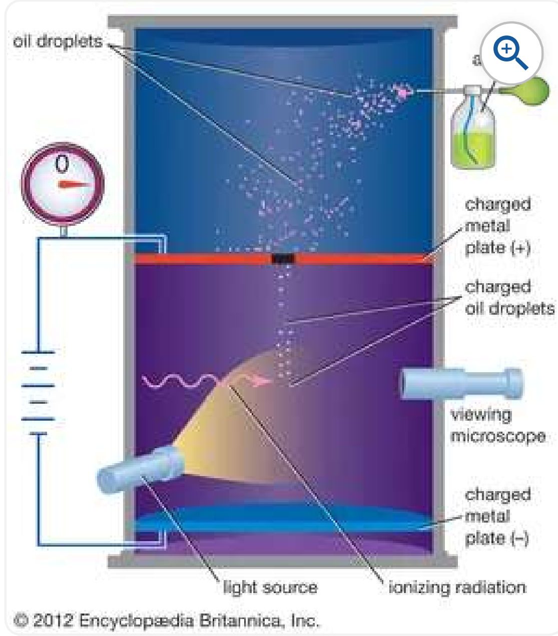
electric charge, basic property of matter carried by some elementary particles that governs how the particles are affected by an electric or magnetic field. Electric charge, which can be positive or negative, occurs in discrete natural units and is neither created nor destroyed.



Millikan oil-drop experiment Between 1909 and 1910 the American physicist Robert Millikan conducted a series of oil-drop...(more)

Key People: George Johnstone Stoney • Charles François de Cisternay Du Fay

Related Topics: Coulomb force • charge conservation • space charge • point charge • charge transfer

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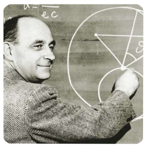
Electric charges are of two general types: positive and negative. Two objects that have an excess of one type of charge exert a force of repulsion on each other when relatively close together. Two objects that have excess opposite charges, one positively charged and the other negatively charged, attract each other when relatively near. (*See* Coulomb force.)

Many fundamental, or subatomic, particles of matter have the property of electric charge. For example, electrons have negative charge and protons have positive charge, but neutrons have zero charge. The negative charge of each electron is found by experiment to have the same magnitude, which is also equal to that of the positive charge of each proton. Charge thus exists in natural units equal to the charge of an electron or a proton, a fundamental physical constant. A direct and convincing measurement of an electron's charge, as a natural unit of electric charge, was first made (1909) in the Millikan oil-drop experiment. Atoms of matter are electrically neutral because their nuclei contain the same number of protons as there are electrons surrounding the nuclei. Electric current and charged objects involve the separation of some of the negative charge of neutral atoms. Current in metal wires consists of a drift of electrons of which one or two from each atom are more loosely bound than the rest. Some of the atoms in the surface layer of a glass rod positively charged by rubbing it with a silk cloth have lost electrons, leaving a net positive charge because of the unneutralized protons of their nuclei. A negatively charged object has an excess of electrons on its surface.



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Physics and Natural Law

Electric charge is conserved: in any isolated system, in any chemical or nuclear reaction, the net electric charge is constant. The algebraic sum of the fundamental charges remains the same. (*See* charge conservation.)

The unit of electric charge in the metre–kilogram–second and SI systems is the coulomb and is defined as the amount of electric charge that flows through a cross section of a conductor in an electric circuit during each second when the current has a value of one ampere. One coulomb consists of 6.24×10^{18} natural units of electric charge, such as individual electrons or protons. From the definition of the ampere, the electron itself has a negative charge of $1.602176634 \times 10^{-19}$ coulomb.

An electrochemical unit of charge, the faraday, is useful in describing electrolysis reactions, such as in metallic electroplating. One faraday equals 96485.332123 coulombs, the charge of a mole of electrons (that is, an Avogadro's number, $6.02214076 \times 10^{23}$, of electrons).

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electron

subatomic particle

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Also known as: negative electron

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electron, one of the three basic subatomic particles—along with protons and neutrons—that make up atoms, the basic building blocks of all matter and chemistry. The negatively charged electrons circle an atom's central nucleus, which is formed by positively charged protons and the electrically neutral particles called neutrons. (The nucleus of the ordinary hydrogen atom is an exception, containing only one proton and no neutrons.) Like opposite ends of a magnet that attract one another, the negative electrons are attracted to a positive force, which binds them to the nucleus. The nucleus is small and dense compared with the electrons, which are the lightest charged particles in nature. The electrons circle the nucleus in orbital paths called shells, each of which holds only a certain number of electrons.

Key People: P.A.M. Dirac • J.J. Thomson • Louis de Broglie • Jacques Dubochet • Joachim Frank

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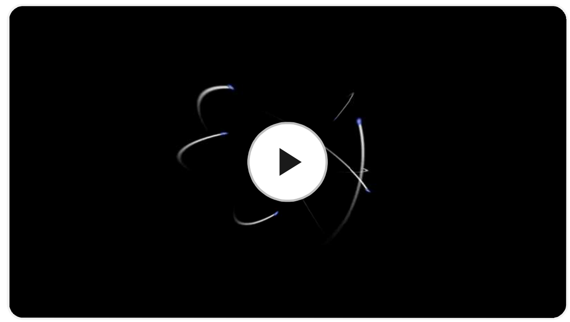

A simplified look into the structure of an atom Explore an atom's interior to discover the layout of its nucleus, protons, and...(more)

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The electron was discovered in 1897 by the English physicist J.J. Thomson during investigations of cathode rays. His discovery of electrons, which he initially called corpuscles, played a pivotal role in revolutionizing knowledge of atomic structure. Under ordinary conditions electrons are bound to the positively charged nuclei of atoms by the attraction between opposite electric charges. In a neutral atom the number of electrons is identical to the number of positive charges on the nucleus. Any atom, however, may have more or fewer electrons than positive charges and thus be negatively or positively charged as a whole; these charged atoms are known as ions. Not all electrons are associated with atoms; some occur in a free state with ions in the form of matter known as plasma.

atoms How atoms can be seen.

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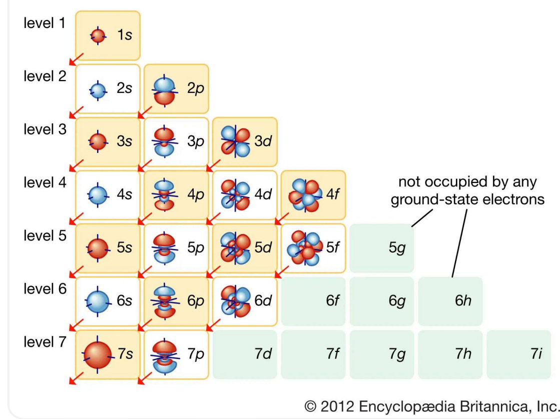
Within any given atom, electrons move about the nucleus in an orderly arrangement of orbitals, the attraction between electrons and nucleus overcoming repulsion among the electrons that would otherwise cause them to fly apart. These orbitals are organized in concentric shells proceeding outward from the nucleus with an increasing number of subshells. The electrons in orbitals closest to the nucleus are held most tightly; those in the outermost orbitals are shielded by intervening electrons and are the most loosely held by the nucleus. As the electrons move about within this structure, they form a diffuse cloud of negative charge that occupies nearly the entire volume of the atom. The arrangement of electrons in orbitals and shells around the nucleus is referred to as the electronic configuration of the atom. This electronic configuration determines not only the size of an individual atom but also the chemical activity of the atom. The classification of elements within groups of similar elements in the periodic table, for example, is based on the similarity in their electron structures.

Britannica Quiz

Facts You Should Know: The Periodic Table Quiz

Within the field of particle physics, there are two ways of classifying electrons. The electron is a fermion, a type of particle named after the Fermi-Dirac statistics that describe its behaviour. All fermions are characterized by half-integer values of their spin, where spin corresponds to the intrinsic angular momentum of the particle. The concept of spin is embodied in the wave equation for the electron formulated by P.A.M. Dirac. The Dirac wave equation also predicts the existence of the antimatter counterpart of the electron, the positron. Within the fermion group of subatomic particles, the electron can be further classified as a lepton. A lepton is a subatomic particle that reacts only by the electromagnetic, weak, and gravitational forces; it does not respond to the short-range strong force that acts between quarks and binds protons and neutrons in the atomic nucleus.

The lightest stable subatomic particle known, the electron carries a negative charge of $1.602176634 \times 10^{-19}$ coulomb, which is considered the basic unit of electric charge. The rest mass of the electron is $9.1093837015 \times 10^{-31}$ kg, which is only $^{1}/_{1,836}$ the mass of a proton. An electron is therefore considered nearly massless in comparison with a proton or a neutron, and the electron mass is not included in calculating the mass number of an atom.



atomic orbitals Electrons fill in shell and subshell levels in a semi-regular process, as indicated by the arrows above. After fi...(more)

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