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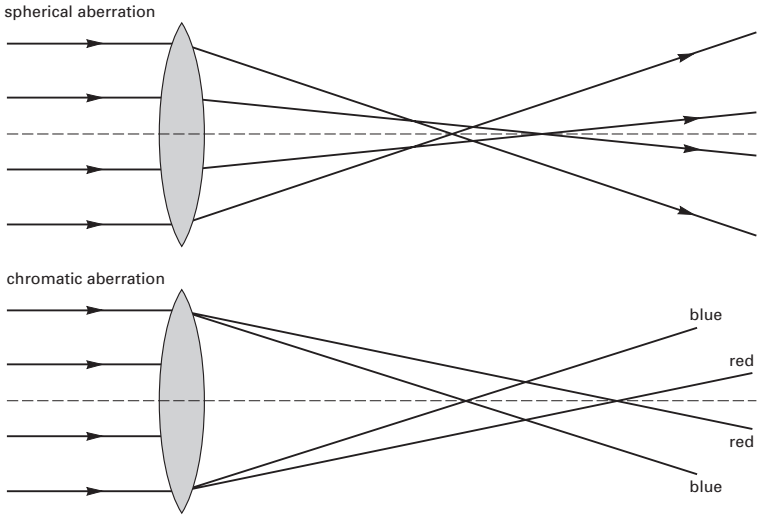
ab- A prefix attached to the name of a practical electrical unit to provide a name for a unit in the electromagnetic system of units (*see* ELECTROMAGNETIC UNITS), e.g. abampere, abcoulomb, abvolt. The prefix is an abbreviation of the word 'absolute' as this system is also known as the **absolute system**. *Compare* STAT-. In modern practice both absolute and electrostatic units have been replaced by *SI units.

Abelian group *See* GROUP THEORY.

aberration **1.** (in optics) A defect in the image formed by a lens or curved mirror. In **chromatic aberration** the image formed by a lens (but not a mirror) has coloured fringes as a result of the different extent to which light of different colours is refracted by glass. It is corrected by using an *achromatic lens. In **spherical aberration**, the rays from the object come to a focus in slightly different positions as a result of the curvature of the lens or mirror. For a mirror receiving light strictly parallel with its axis, this can be corrected by using a parabolic surface rather than a spherical surface. Spherical aberration in lenses is minimized by making both surfaces contribute equally to the ray deviations, and can (though with reduced image brightness) be reduced by



Aberration.

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the use of diaphragms to let light pass only through the centre part of the lens. *See also* ASTIGMATISM; COMA. **2.** (in astronomy) The apparent displacement in the position of a star as a result of the earth's motion round the sun. Light appears to come from a point that is slightly displaced in the direction of the earth's motion. The angular displacement $\alpha = v/c$, where v is the earth's orbital velocity and c is the speed of light.

abscissa *See* CARTESIAN COORDINATES.

absolute **1.** Not dependent on or relative to anything else, e.g. *absolute zero. **2.** Denoting a temperature measured on an **absolute scale**, a scale of temperature based on absolute zero. The usual absolute scale now is that of thermodynamic *temperature; its unit, the kelvin, was formerly called the degree absolute (°A) and is the same size as the degree Celsius. In British engineering practice an absolute scale with Fahrenheit-size degrees has been used: this is the Rankine scale.

absolute expansivity *See* EXPANSIVITY.

absolute humidity *See* HUMIDITY.

absolute permittivity *See* PERMITTIVITY.

absolute pitch (perfect pitch) The ability of a person to identify and reproduce a note without reference to a tuned musical instrument.

absolute space Space that exists as a background to events and processes and is not affected by objects or other entities in the universe. The idea underpins Newtonian physics, although many physicists have always regarded absolute space as an undesirable concept and suggested, as in *Mach's principle, that fundamental physics should be described by *relational theories.

absolute temperature *See* ABSOLUTE; TEMPERATURE.

absolute time Time that exists independently of any events or processes in the universe. Like *absolute space, absolute time is a basic concept in Newtonian physics.

absolute value (modulus) The square root of the sum of the squares of the real numbers in a *complex number, i.e. the absolute value of the complex number $z = x + iy$ is $|z| = \sqrt{(x^2 + y^2)}$.

absolute zero Zero of thermodynamic *temperature (0 kelvin) and the lowest temperature theoretically attainable. It is the temperature at which the kinetic energy of atoms and molecules is minimal. It is equivalent to –273.15°C or –459.67°F. *See also* ZERO-POINT ENERGY; CRYOGENICS.

absorptance Symbol α. The ratio of the radiant or luminous flux absorbed by a body to the flux falling on it. Formerly called **absorptivity**, the absorptance of a *black body is equal to 1 by definition.

absorption **1.** The take-up of a gas by a solid or liquid, or the take-up of a liquid by a solid. Absorption differs from *adsorption in that the absorbed

substance permeates the bulk of the absorbing substance. **2.** The conversion of the energy of electromagnetic radiation, sound, streams of particles, etc., into other forms of energy on passing through a medium. A beam of light, for instance, passing through a medium, may lose intensity because of two effects: scattering of light out of the beam, and absorption of photons by atoms or molecules in the medium. When a photon is absorbed, there is a transition to an excited state.

absorption coefficient **1.** (in physics) *See* LAMBERT'S LAWS. **2.** (in chemistry) The volume of a given gas, measured at standard temperature and pressure, that will dissolve in unit volume of a given liquid.

absorption spectrum *See* SPECTRUM.

absorptivity *See* ABSORPTANCE.

abundance **1.** The ratio of the total mass of a specified element in the earth's crust to the total mass of the earth's crust, often expressed as a percentage. For example, the abundance of aluminium in the earth's crust is about 8%. **2.** The ratio of the number of atoms of a particular isotope of an element to the total number of atoms of all the isotopes present, often expressed as a percentage. For example, the abundance of uranium–235 in natural uranium is 0.71%. This is the **natural abundance**, i.e. the abundance as found in nature before any enrichment has taken place.

a.c. *See* ALTERNATING CURRENT.

acceleration Symbol a. The rate of increase of speed or velocity. It is measured in m s^{-2}. For a body moving linearly with constant acceleration a from a speed u to a speed v,

$$a = (v - u)/t = (v^2 - u^2)/2s$$

where t is the time taken and s the distance covered.

If the acceleration is not constant it is given by $dv/dt = d^2s/dt^2$. If the motion is not linear the vector character of displacement, velocity, and acceleration must be considered. *See also* ROTATIONAL MOTION.

acceleration of free fall Symbol g. The acceleration experienced by any massive object falling freely in the earth's gravitational field. Experimentally this is almost constant for all positions near the earth's surface, independent of the nature of the falling body (provided air resistance is eliminated). This is taken to indicate the strict proportionality of *weight (the force causing the acceleration) and inertial *mass, on the basis of *Newton's second law of motion. There is some variation of g with latitude, because of the earth's rotation and because the earth is not completely spherical. The standard value is taken as 9.806 65 m s^{-2}. The acceleration of free fall is also called the **acceleration due to gravity**.

accelerator An apparatus for increasing the kinetic energies of charged particles. Particle accelerators are used extensively in both nuclear physics, to investigate nuclear reactions, and particle physics, to search for new particles.

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There are two types: linear accelerators and cyclic accelerators. *See* CYCLOTRON; LINEAR ACCELERATOR; SYNCHROCYCLOTRON; SYNCHROTRON.

SEE WEB LINKS

- A list of world particle accelerators and accelerator laboratories, with links, from the ELSA website at the University of Bonn

acceptor A substance that is added as an impurity to a *semiconductor because of its ability to accept electrons from the valence bands, causing *p*-type conduction by the mobile positive holes left.

acceptor levels Energy levels of an acceptor atom in a *semiconductor, such as aluminium, in silicon. These energy levels are very near the top of the valence band, and therefore cause *p*-type conduction. *See also* ENERGY BANDS.

accommodation The process by which the focal length of the *lens of the eye is changed so that clear images of objects at a range of distances are displayed on the retina. In man and some other mammals accommodation is achieved by relaxation and contraction of muscles within the ciliary body.

accretion disk A disk-shaped rotating mass formed by gravitational attraction. *See* BLACK HOLE; NEUTRON STAR; WHITE DWARF.

accumulator (secondary cell; storage battery) A type of *voltaic cell or battery that can be recharged by passing a current through it from an external d.c. supply. The charging current, which is passed in the opposite direction to that in which the cell supplies current, reverses the chemical reactions in the cell. The common types are the *lead–acid accumulator and the *nickel–iron accumulator and nickel–cadmium accumulator. *See also* SODIUM–SULPHUR CELL.

achromatic lens A lens that corrects for chromatic *aberration by using a combination of two lenses, made of different kinds of glass, such that their *dispersions neutralize each other although their *refractions do not. The aberration can be reduced further by using an **apochromatic lens**, which consists of three or more different kinds of glass.

acoustics **1.** The study of sound and sound waves. **2.** The characteristics of a building, especially an auditorium, with regard to its ability to enable speech and music to be heard clearly within it. For this purpose there should be no obtrusive echoes or resonances and the reverberation time should be near the optimum for the hall. Echoes are reduced by avoiding sweeping curved surfaces that could focus the sound and by breaking up large plane surfaces or covering them with sound-absorbing materials. Resonance is avoided by avoiding simple ratios for the main dimensions of the room, so that no one wavelength of sound is a factor of more than one of them. If the reverberation time is too long, speech will sound indistinct and music will be badly articulated, with one note persisting during the next. However, if it is too short, music sounds dead. Reverberation time is long in a bare room with hard walls, and can be deliberately reduced by carpets, soft furnishings, and sound-absorbent ('acoustic') felt. Reverberation times tend to be reduced by

the presence of an audience and this must be taken into account in the design of the building.

SEE WEB LINKS

- The website of the Acoustical Society of America
- The website of the UK Institute of Acoustics

acoustoelectronic devices (electroacoustic devices) Devices in which electronic signals are converted into acoustic waves. Acoustoelectronic devices are used in constructing *delay lines and also in converting digital data from computers for transmission by telephone lines.

actinic radiation Electromagnetic radiation that is capable of initiating a chemical reaction. The term is used especially of ultraviolet radiation and also to denote radiation that will affect a photographic emulsion.

actinium Symbol Ac. A radioactive metallic element belonging to group 3 of the periodic table; a.n. 89; mass number of most stable isotope 227 (half-life 21.7 years); m.p. 1050 ± 50°C; b.p. 3200°C (estimated). Actinium–227 occurs in natural uranium to an extent of about 0.715%. Actinium–228 (half-life 6.13 hours) also occurs in nature. There are 22 other artificial isotopes, all radioactive and all with very short half-lives. Its main use is as a source of alpha particles. The element was discovered by A. Debierne in 1899.

actinium series *See* RADIOACTIVE SERIES.

actinoid contraction A smooth decrease in atomic or ionic radius with increasing proton number found in the actinoids.

actinometer Any of various instruments for measuring the intensity of electromagnetic radiation. Modern actinometers use the *photoelectric effect; earlier instruments depended either on the fluorescence produced by the radiation on a screen or on the amount of chemical change induced in some suitable substance.

action at a distance A direct and instantaneous interaction between bodies that are not in physical contact with each other. This type of interaction is not consistent with the special theory of *relativity, which states that nothing (including interactions) can travel through space faster than the *speed of light in a vacuum. For this reason it is more logical to describe interactions between bodies by *field theories or by the exchange of virtual particles (*see* VIRTUAL STATE) rather than theories based on action at a distance.

action potential The change in electrical potential that occurs across a cell membrane during the passage of a nerve impulse. As an impulse travels in a wavelike manner along the axon of a nerve, it causes a localized and transient switch in electric potential across the cell membrane from –60 mV (millivolts; the resting potential) to +45 mV. The change in electric potential is caused by an influx of sodium ions. Nervous stimulation of a muscle fibre has a similar effect.

action spectrum A graphical plot of the efficiency of electromagnetic

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radiation in producing a photochemical reaction against the wavelength of the radiation used. For example, the action spectrum for photosynthesis using light shows a peak in the region 670–700 nm. This corresponds to a maximum absorption in the absorption spectrum of chlorophylls in this region.

activation analysis An analytical technique that can be used to detect elements when present in a sample. In **neutron activation analysis** the sample is exposed to a flux of thermal neutrons in a nuclear reactor. Some of these neutrons are captured by nuclides in the sample to form nuclides of the same atomic number but a higher mass number. These newly formed nuclides emit gamma radiation, which can be used to identify the element present by means of a gamma-ray spectrometer. Activation analysis has also been employed using high-energy charged particles, such as protons or alpha particles.

SEE WEB LINKS

- An overview of neutron activation analysis from the Archaeometry Laboratory, Missouri Research Reactor
- Information about NAA from the Worcester Polytechnic Institute

active device **1.** An electronic component, such as a transistor, that is capable of amplification. **2.** An artificial *satellite that receives information and retransmits it after amplification. **3.** A radar device that emits microwave radiation and provides information about a distant body by receiving a reflection of this radiation. *Compare* PASSIVE DEVICE.

active galactic nucleus *See* ACTIVE GALAXY.

active galaxy A galaxy that contains an **active galactic nucleus** (**AGN**), i.e. a central region that gives off a great deal of electromagnetic radiation. This emission is thought to be due to the accretion of matter into a supermassive *black hole, at the centre of the galaxy. *See also* RELATIVISTIC JETS.

activity **1.** Symbol *a*. A thermodynamic function used in place of concentration in equilibrium constants for reactions involving nonideal gases and solutions. For example, in a reaction

$$A \rightleftharpoons B + C$$

the true equilibrium constant is given by

$$K = a_B a_C / a_A$$

where a_A, a_B, and a_C are the activities of the components, which function as concentrations (or pressures) corrected for nonideal behaviour. **Activity coefficients** (symbol γ) are defined for gases by $\gamma = a/p$ (where p is pressure) and for solutions by $\gamma = aX$ (where X is the mole fraction). Thus, the equilibrium constant of a gas reaction has the form

$$K_p = \gamma_B p_B \gamma_C p_C / \gamma_A p_A$$

The equilibrium constant of a reaction in solution is

$$K_c = \gamma_B X_B \gamma_C X_C / \gamma_A X_A$$

The activity coefficients thus act as correction factors for the pressures or

concentrations. *See* FUGACITY. **2.** Symbol *A*. The number of atoms of a radioactive substance that disintegrate per unit time. The **specific activity** (*a*) is the activity per unit mass of a pure radioisotope. *See* RADIATION UNITS.

additive process *See* COLOUR.

adiabatic approximation An approximation used in *quantum mechanics when the time dependence of parameters, such as the internuclear distance between atoms in a molecule is slowly varying. This approximation means that the solution of the *Schrödinger equation at one time goes continuously over to the solution at a later time. This approximation was formulated by Max Born and the Soviet physicist Vladimir Alexandrovich Fock (1898–1974) in 1928. The *Born–Oppenheimer approximation is an example of the adiabatic approximation.

adiabatic demagnetization A technique for cooling a paramagnetic salt, such as potassium chrome alum, to a temperature near *absolute zero. The salt is placed between the poles of an electromagnet and the heat produced during magnetization is removed by liquid helium. The salt is then isolated thermally from the surroundings and the field is switched off; the salt is demagnetized adiabatically and its temperature falls. This is because the demagnetized state, being less ordered, involves more energy than the magnetized state. The extra energy can come only from the internal, or thermal, energy of the substance. It is possible to obtain temperatures of about 0.005 K in this way. *See also* LOW-TEMPERATURE PHYSICS (Feature).

adiabatic process Any process that occurs without heat entering or leaving a system. In general, an adiabatic change involves a fall or rise in temperature of the system. For example, if a gas expands under adiabatic conditions, its temperature falls (work is done against the retreating walls of the container). The **adiabatic equation** describes the relationship between the pressure (p) of an ideal gas and its volume (V), i.e. $pV^{\gamma} = K$, where γ is the ratio of the principal specific *heat capacities of the gas and K is a constant.

admittance Symbol *Y*. The reciprocal of *impedance. It is measured in siemens.

ADSL (asymmetric digital subscriber line) A mechanism by which *broadband communication via the Internet can be made available using pre-existing telephone lines, while allowing simultaneous use of the line for normal telephone calls. Data communication by ADSL is asymmetric in that upstream (transmitting) communication is slower than downstream (receiving) communication, typically half as fast. ADSL coexists with standard telephone operation on the same line by the use of band separation filters at each telephone socket.

adsorbate A substance that is adsorbed on a surface.

adsorption The formation of a layer of gas, liquid, or solid on the surface of a solid or, less frequently, of a liquid. There are two types depending on the nature of the forces involved. In **chemisorption** a single layer of molecules,

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atoms, or ions is attached to the adsorbent surface by chemical bonds. In **physisorption** adsorbed molecules are held by the weaker *van der Waals' forces. Adsorption is an important feature of surface reactions, such as corrosion, and heterogeneous catalysis. The property is also utilized in adsorption chromatography.

adsorption isotherm An equation that describes how the amount of a substance adsorbed onto a surface depends on its pressure (if a gas) or its concentration (if in a solution), at a constant temperature. Several adsorption isotherms are used in surface chemistry including the *BET isotherm and the *Langmuir adsorption isotherm. The different isotherms correspond to different assumptions about the surface and the adsorbed molecules.

advanced gas-cooled reactor (AGR) *See* NUCLEAR REACTOR.

aerial (antenna) The part of a radio or television system from which radio waves are transmitted into the atmosphere or space (**transmitting aerial**) or by which they are received (**receiving aerial**). A **directional** or **directive aerial** is one in which energy is transmitted or received more effectively from some directions than others, whereas an **omnidirectional aerial** transmits and receives equally well in all directions.

aerodynamics The study of the motion of gases (particularly air) and the motion of solid bodies in air. Aerodynamics is particularly concerned with the motion and stability of aircraft. Another application of aerodynamics is to the flight of birds and insects. The branch of aerodynamics concerned with the flow of gases through compressors, ducts, fans, orifices, etc., is called **internal aerodynamics**.

Aerodynamic drag is the force that opposes the motion of a body moving relative to a gas and is a function of the density of the gas, the square of the relative velocity, the surface area of the body, and a quantity called the **drag coefficient**, which is a function of the *Reynolds number. **Aerodynamic lift** is an upward force experienced by a body moving through a gas and is a function of the same variables as aerodynamic drag.

aerogenerator *See* WIND POWER.

aeronautics The branch of *aerodynamics concerned with the design, construction, and operation of aircraft and rockets.

aerosol A colloidal dispersion of a solid or liquid in a gas. The commonly used aerosol sprays contain an inert propellant liquefied under pressure. Halogenated alkanes containing chlorine and fluorine (chlorofluorocarbons, or CFCs) were formerly used in aerosol cans. They have now largely been replaced by volatile hydrocarbons because of their effect on the *ozone layer.

aerospace The earth's atmosphere and the space beyond it.

AFM *See* ATOMIC FORCE MICROSCOPY.

after-heat Heat produced by a nuclear reactor after it has been shut down.

The after-heat is generated by radioactive substances formed in the fuel elements.

age of the earth The time since the earth emerged as a planet of the sun, estimated by *dating techniques to be about 4.6×10^9 years. The oldest known rocks on earth are estimated by *radioactive dating to be about 3.5×10^9 years old. The earth is older than this because of the long time it took to cool. An estimate for the cooling time is included in the estimate for the age of the earth.

age of the universe A time determined by the reciprocal of the value of the *Hubble constant to be about 13.7 billion years. The calculation of the Hubble constant, and hence the age of the universe, depends on which theory of *cosmology is used. Usually, the age of the universe is calculated by assuming that the *expansion of the universe can be described by the *big-bang theory.

AGN Active galactic nucleus. *See* ACTIVE GALAXY.

AGR Advanced gas-cooled reactor. *See* NUCLEAR REACTOR.

AI *See* ARTIFICIAL INTELLIGENCE.

air *See* EARTH'S ATMOSPHERE.

albedo **1.** The ratio of the radiant flux reflected by a surface to that falling on it. **2.** The probability that a neutron entering a body of material will be reflected back through the same surface as it entered.

algebraic sum The total of a set of quantities paying due regard to sign, e.g. the algebraic sum of 3 and –4 is –1.

algorithm A method of solving a problem, involving a finite series of steps. In computing practice the algorithm denotes the expression on paper of the proposed computing process (often by means of a flowchart) prior to the preparation of the program. If no algorithm is possible a *heuristic solution has to be sought. *See also* TURING MACHINE.

allowed bands *See* ENERGY BANDS.

allowed transitions *See* SELECTION RULES.

alloy A material consisting of two or more metals (e.g. brass is an alloy of copper and zinc) or a metal and a nonmetal (e.g. steel is an alloy of iron and carbon, sometimes with other metals included). Alloys may be compounds, *solid solutions, or mixtures of the components.

alloy steels *See* STEEL.

Alnico A tradename for a series of alloys, containing iron, aluminium, nickel, cobalt, and copper, used to make permanent magnets.

alpha particle A helium–4 nucleus emitted by a larger nucleus during the course of the type of radioactive decay known as **alpha decay**. As a helium–4 nucleus consists of two protons and two neutrons bound together as a stable entity the loss of an alpha particle involves a decrease in *nucleon number of

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4 and decrease of 2 in the *atomic number, e.g. the decay of a uranium–238 nucleus into a thorium–234 nucleus. A stream of alpha particles is known as an **alpha-ray** or **alpha-radiation**.

alternating current (a.c.) An electric current that reverses its direction with a constant *frequency (*f*). If a graph of the current against time has the form of a *sine wave, the current is said to be **sinusoidal**. Alternating current, unlike direct current, is therefore continuously varying and its magnitude is either given as its peak value (I_0) or its *root-mean-square value ($I_0/\sqrt{2}$ for a sinusoidal current). This r.m.s. value is more useful as it is comparable to a d.c. value in being a measure of the ability of the current to transmit power. The instantaneous value of a sinusoidal current (I) is given by $I = I_0 \sin 2\pi ft$.

If a direct current is supplied to a circuit the only opposition it encounters is the circuit's *resistance. However, an alternating current is opposed not only by the resistance of the circuit but also by its *reactance. This reactance is caused by *capacitance and *inductance in the circuit. In a circuit consisting of a resistance (R), an inductance (L), and a capacitance (C) all in series, the reactance (X) is equal to $(2\pi fL) - (1/2\pi fC)$. The total opposition to the current, called the *impedance (Z), is then equal to the ratio of the r.m.s. applied p.d. to the r.m.s. current and is given by $\sqrt{(R^2 + X^2)}$.

alternator An *alternating-current generator consisting of a coil or coils that rotate in the magnetic field produced by one or more permanent magnets or electromagnets. The electromagnets are supplied by an independent direct-current source. The frequency of the alternating current produced depends on the speed at which the coil rotates and the number of pairs of magnetic poles. In the large alternators of power stations the electromagnets rotate inside fixed coils; many bicycle dynamos are alternators with rotating permanent magnets inside fixed coils.

altimeter A device used to measure height above sea level. It usually consists of an aneroid *barometer measuring atmospheric pressure. Aircraft are fitted with altimeters, which are set to the atmospheric pressure at a convenient level, usually sea level, before take off. The height of the aircraft can then be read off the instrument as the aircraft climbs and the pressure falls.

ALU (arithmetic/logic unit) The part of the central processor of a *computer in which simple arithmetic and logical operations are performed electronically. For example, the ALU can add, subtract, multiply, compare two numbers, or negate a number.

Alvarez, Luis Walter (1911–88) US physicist most of whose working life was spent at the University of California, Berkeley. After working on radar and the atomic bomb during World War II, he concentrated on particle physics. In 1959 he built the first large *bubble chamber and developed the technique for using it to study charged particles, for which he was awarded the 1968 Nobel Prize for physics. He later became interested in the extinction of the dinosaurs.