DICTIONARY OF PHYSICS

EDITED BY
JOHN DAINTITH

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A

ab- A prefix used with a practical electrical unit to name the corresponding electromagnetic unit. For example, the electromagnetic unit of charge is called the *abcoulomb*. *Compare* stat-.

aberration A defect in an optical system such that the image is not a true picture of the object. For instance, coloured fringes may appear, the image may not be equally focused, or the shape may show distortion. Techniques of aberration correction exist; these can, however, be complex and costly.

Chromatic (colour) *aberration* is found with a single lens; mirrors do not suffer from chromatic aberration. Because dispersion always accompanies refractive deviation, the 'red' image will be further from the lens than the 'blue'. Consequently, the image is surrounded by coloured fringes. Chromatic aberration is corrected by forming a compound lens, whose elements have different refractive constants.

Spherical aberration always occurs with rays that are distant from the axis and incident on a spherical mirror or lens. It is the cause of the caustic curve. Spherical aberration is corrected by using parabolic reflecting and refracting surfaces.

Astigmatism affects rays neither close nor parallel to the axis. The cone of rays through a lens from an off-axis object does not focus at a point. Instead, two images in the form of short lines are formed at different distances from the lens. Between the two the image appears circular. Mirrors forming images of off-axis points show a similar defect. The best method of minimizing astigmatism is to reduce the aperture with stops, thus allowing light only through the centre of the lens.

Coma is rather similar in cause, effect, and correction to astigmatism. After refraction by a lens, a cone of rays from an off-axis object tends to have a tadpole-shaped section because of coma. *Distortion* is the result of differences in a lens' magnifying power between different axes. Reduction of aperture is the normal solution to both coma and distortion.

absolute expansion *See* expansivity.

absolute humidity The mass of water vapour per unit volume of air, usually measured in kilograms per cubic metre. *Compare* relative humidity. *See also* humidity.

absolute permeability *See* permeability.

absolute refractive constant *See* refractive constant.

absolute temperature Symbol: T A temperature defined by the relationship $T = \theta + 273.15$, where θ is the Celsius temperature. The absolute scale of temperature was a fundamental scale based on Charles' law applied to an ideal gas:

$$V = V_0(1 + \alpha\theta)$$

where V is the volume at temperature θ, V_0 the volume at 0, and α the thermal expansivity of the gas. At low pressures (when real gases show ideal behaviour) α has the value 1/273.15. Therefore, at $0 = -273.15$ the volume of the gas theoretically becomes zero. In practice, of course, substances become solids at these temperatures. However, the extrapolation can be used for a scale of temperature on which -273.15°C corresponds to 0° (absolute zero). The scale is also known as the *ideal-gas scale*; on it temperature intervals were called *degrees absolute* (°A) or *degrees Kelvin* (°K), and were equal to the Celsius degree. It can be shown that the absolute temperature scale is identical to the thermodynamic temperature scale (on which the unit is the kelvin).

absolute zero The zero value of thermodynamic temperature; 0 kelvin or -273.15°C.

absorptance Symbol: α The ratio of the radiant or luminous flux absorbed by a body or material to the incident flux. It was formerly called the *absorptivity*.

absorption A process in which a gas is taken up by a liquid or solid, or in which a liquid is taken up by a solid. In absorption, the substance absorbed goes into the bulk of the material. Solids that absorb gases or liquids often have a porous structure. The absorption of gases in solids is sometimes called *sorption*. *Compare* adsorption.

absorption coefficient *See* Lambert's laws.

absorption of radiation No medium transmits radiation without some energy loss. This loss of energy is called absorption. The energy is converted to some other form within the medium. *See also* Lambert's laws.

absorption spectrum *See* spectrum.

absorptivity *See* absorptance.

abundance 1. The relative amount of a given element amongst others; for example, the abundance of oxygen in the Earth's crust is approximately 50% by weight.

2. The amount of a nuclide (stable or radioactive) relative to other nuclides of the same element in a given sample. The *natural abundance* is the abundance of a nuclide as it occurs naturally. For instance, chlorine has two stable isotopes of masses 35 and 37. The abundance of ^{35}Cl is 75.5% and that of ^{37}Cl is 24.5%. For some elements the abundance of a particular nuclide depends on the source.

a.c. *See* alternating current.

acceleration Symbol: a The rate of change of speed (a scalar) or of velocity (a vector). The basic SI unit is the metre per second per second ($m\,s^{-2}$). For constant acceleration:

$$a = (v_2 - v_1)/t$$

v_1 is the speed or velocity when timing starts; v_2 is the speed or velocity after time t. (This is one of the equations of motion.) Negative values of a relate to cases of retardation, or deceleration (slowing down).

The equation gives the mean acceleration during the time interval. If acceleration is not uniform (constant), $a = dv/dt$. If the vector form is being used, acceleration means either rate of change of speed in a given direction or rate of change of velocity, including change of direction. The acceleration of an object depends on the net outside force F acting. From Newton's second law, $F = ma$, where m is the object's mass.

acceleration due to gravity *See* acceleration of free fall.

acceleration of free fall (acceleration due to gravity) Symbol: g The constant acceleration of a mass falling freely (without friction) in the Earth's gravitational field. g is a measure of gravitational field strength — the force on unit mass. The force on a mass m is its weight W, where $W = mg$.

The value of g varies with distance from the Earth's surface. Near the surface it is just under 10 metres per second per second (9.806 65 $m\,s^{-2}$ is the standard value). It varies with latitude, partly because the Earth is not perfectly spherical (it is flattened near the poles).

accelerator A device for accelerating charged particles to high energies so that they are able to penetrate to the nuclei of atoms in a target, causing nuclear reactions. The earliest accelerator was invented by Cockcroft and Walton and was first used to accelerate protons towards a target of lithium.

Two types are now in use. In *linear accelerators* the particles are accelerated in a straight line. *Cyclic accelerators* use magnetic fields to keep the particles moving in circular or spiral paths. Examples of cyclic accelerators are the cyclotron, the synchrocyclotron, and the betatron. *See also* linear accelerator.

acceptor *See* semiconductor.

acceptor circuit *See* resonance.

accommodation The action of the eye in changing its focal power. The normal eye has a high power (short focal distance) for viewing close objects; it relaxes to low power for very distant objects. Accommodation is accomplished by muscles in a ring round the lens of the eye, which are able to change the shape of the lens. The amplitude of accommodation decreases with age — the power range is around 11 dioptres at age 10 and 1 dioptre at age 70. Thus the distance between far point and near point decreases with age. This effect is presbyopia.
See also eye, amplitude of accommodation.

accumulator (secondary cell, storage battery) An electric cell or battery that can be charged by passing an electric current through it. The chemical reaction in the cell is reversible. When the cell begins to run down, current in the opposite direction will convert the reaction products back into their original forms. The most common example is the lead-acid accumulator, used in vehicle batteries.

achromat An achromatic lens.

achromatic colour A colour that has no hue; i.e. black, white, or grey.

achromatic lens A compound lens whose elements differ in refractive constant in order to minimize chromatic aberration. Simple *achromatic doublets* are formed by combining two lenses of different glass. The condition for achromatism is:

$$\omega_1 P_1 + \omega_2 P_2 = 0$$

where ω_1 and ω_2 are the dispersive powers of the glasses of the lenses, and P_1 and P_2 are the powers of the lenses. Achromatic lenses are corrected for chromatic aberration at two different wavelengths. *See also* apochromatic lens.

aclinic line (magnetic equator) *See* isoclinic line.

acoustics The study of the production and properties of sounds. The term is also used to describe the way in which sound is reproduced in practical situations.

actinic radiation Radiation that can cause a chemical reaction; for example, ultraviolet radiation is actinic.

actinometer An instrument for measuring the intensity of radiation.

actinon *See* emanation.

action 1. An out-dated term for force. *See* reaction.
2. The product of energy and time. The Planck constant was originally known as Planck's constant of action.

activated charcoal *See* charcoal.

activity Symbol: *A* For a radioactive substance, the average number of atoms disintegrating per unit time.

acuity, visual The ability of the eye to see separately two points close to each other. It is a measure of the resolving power of the eye's optical system and depends on the density of cells in the retina. The maximum acuity of the normal human eye is around 0.5 minutes of arc — points separated by this angle at the eye should be seen as separate. *See* resolution.

additive process A process of colour mixing by addition. *See* colour.

adiabatic change A change during which no energy enters or leaves the system.
In an adiabatic expansion of a gas, mechanical work is done by the gas as its volume increases and the gas temperature falls. For an ideal gas undergoing a reversible adiabatic change it can be shown that

$$pV^\gamma = K_1$$

adiabatic demagnetization

$$T^{\gamma}p^{1-\gamma} = K_2$$
and $$TV^{\gamma-1} = K_3$$
where K_1, K_2, and K_3 are constants and γ is the ratio of the principal specific heat capacities.
Compare isothermal change.

adiabatic demagnetization A method of producing temperatures close to absolute zero. A sample of paramagnetic salt is cooled in liquid helium in a strong magnetizing field. The field is removed, demagnetizing the sample and cooling it further.

admittance Symbol: Y The reciprocal of impedance, measured in siemens (S). It is a measure of the response of an electric circuit to an alternating signal. *See also* impedance.

adsorption A process in which a layer of atoms or molecules of one substance forms on the surface of a solid or liquid. All solid surfaces take up layers of gas from the surrounding atmosphere. The adsorbed layer may be held by chemical bonds (*chemisorption*) or by weaker van der Waals forces (*physisorption*). *Compare* absorption.

advanced gas-cooled reactor *See* gas-cooled reactor.

aerosol A dispersion of small particles of solid or droplets of liquid in a gas.

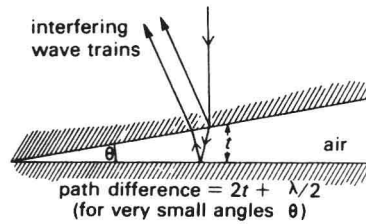
aether *See* ether.

agate A crystalline form of silica used, because of its hardness, in making knife edges in balances, pendulums, etc.

agonic line *See* isogonic line.

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

air wedge An arrangement producing localized interference patterns by reflection at the two sides of a wedge-shaped film of air (as between two glass slides at an angle). Newton's rings (variable wedge angle) and thin films (zero wedge angle) produce similar effects. In an air wedge the fringes (with monochromatic light) are light and dark bands parallel to the thin edge of the wedge. A bright fringe occurs when $2t + \lambda/2 = m\lambda$, t being the thickness and m an integer. For a bright fringe $2t = m\lambda$. *See also* interference.



Air wedge

albedo The ratio of the amount of light reflected from a surface to the amount of incident light.

alcohol thermometer A liquid-in-glass thermometer that uses ethanol as its working substance. The ethanol commonly contains a red dye to make the liquid more visible. *See also* thermometer.

allotropy The existence of a solid substance in different physical forms. Tin, for example, has metallic and non-metallic crystalline forms. Carbon has two crystalline allotropes: diamond and graphite.

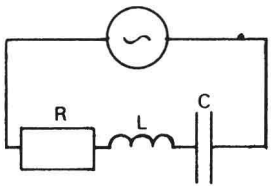
alloy A mixture of two or more metals (e.g. bronze or brass) or of a metal with small amounts of non-metals (e.g. steel). Alloys may be completely homogeneous mixtures or may contain small particles of one phase in the other phase.

alpha decay A type of radioactive decay in which the unstable nucleus emits a helium nucleus. The resulting nuclide has a mass number decreased by 4 and a proton number decreased by 2. An example is:

$$^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$$

The particles emitted in alpha decay are *alpha particles*. Streams of alpha particles are *alpha rays* or *alpha radiation*. They are less penetrating than beta particles. *See also* beta decay.

alternating current (a.c.) Electric current that regularly reverses its direction. In the simplest case, the current varies with time (t) in a simple harmonic manner, represented by the equation $I = I_0 \sin 2\pi ft$, f being the frequency. Alternating current can be described by its peak value I_0, or by its root-mean-square value I_{RMS} ($= I_0/\sqrt{2}$ for a sine wave). In the U.K., the mains electricity supply is alternating, about 250 V (RMS) at a frequency of 50 hertz. In the U.S. it is 220 V (RMS) at a frequency of 60 hertz. *Compare* direct current.



LCR circuit

L and R in series

alternating-current circuit A circuit containing a resistance R, capacitance C, and inductance L, with an alternating voltage supply, is called an *LCR circuit*. The simplest type is one in which L, C, and R are all in series. The impedance of such a circuit is given by

$$Z = \sqrt{[(X_L - X_C)^2 + R^2]}$$

where X_L is the reactance of the inductor ($2\pi fL$), and X_C is the reactance of the capacitor ($1/2\pi fC$). The current I is given by V/Z. There is a phase difference between the current in the circuit and the voltage. Current lags behind voltage by a phase angle ϕ:

$$\tan \phi = (X_L - X_C)/R$$

See also resonance.

alternator A generator for producing an alternating electric current.

AM *See* amplitude modulation.

Amagat's experiments *See* Andrews' experiments.

amalgam An alloy of mercury with one or more other metals. Amalgams may be liquid or solid.

ammeter A meter used to measure electric current. Ammeters have to have low resistance as they are connected in series in the circuit. Commonly, moving-coil instruments are used with shunt resistors to increase the current range. For alternating current a rectifier is necessary. Moving-iron instruments can be used both for d.c. and a.c. High-frequency currents may be measured with a hot-wire instrument.

amorphous Denoting a solid that has no crystalline structure; i.e. there is no long-range ordering of atoms. Many substances that appear to be amorphous are in fact composed of many tiny crystals. Soot and glass are examples of truly amorphous materials. *See also* glass.

amount of substance Symbol: n A measure of the number of entities present in a substance. *See* mole.

ampere Symbol: A The SI base unit of electric current, defined as the constant current that, maintained in two straight parallel infinite conductors of negligible circular cross section placed one metre apart in vacuum, would produce a force between the conductors of 2×10^{-7} newton per metre.

ampere balance *See* current balance.

Ampere-Laplace law *See* Ampère's law.

Ampère's law 1. (Ampère-Laplace law) The elemental force, dF, between two current elements, $I_1 dl_1$ and $I_2 dl_2$, parallel

to each other at a distance r apart in free space is given by:
$dF = \mu_0 I_1 dl_1 I_2 dl_2 \sin\theta / 4\pi r^2$
Here μ_0 is the permeability of free space and θ is the angle between either element and the line joining them.
2. The principle that the sum or integral of the magnetic flux density B times the path length along a closed path round a current-carrying conductor is proportional to the current I. For a circular path of radius r round a long straight wire in a vacuum, $B.2\pi r = \mu_0 I$. (μ_0 is the magnetic permeability of free space.) Ampère's law enables the value of B inside a solenoid to be calculated using the equation $B.dl = \mu_0 I$.

ampere-turn Symbol: At The SI unit of magnetomotive force (m.m.f.) equal to the magnetomotive force produced by a current of one ampere flowing through one turn of a conductor. *See also* magnetic circuit.

amplification factor *See* triode.

amplifier A device that increases an electrical signal applied to it as an input. If the input is an alternating voltage, the output voltage has a similar waveform with an increased amplitude.
The ratio of the output signal to the input signal (called the *gain*), will usually vary with the signal frequency. Amplifiers are usually designed to give a particular current, voltage, or power gain over the required frequency range. Some circuits containing a number of amplifying stages can cope with frequencies from 0 hertz (steady direct current) to radiofrequencies. In modern solid-state electronics, all of the amplifier circuit components, including many individual amplifying stages, are manufactured in a single integrated circuit.

amplitude The maximum value of a varying quantity from its mean or base value. In the case of a simple harmonic motion — a wave or vibration — it is half the maximum peak-to-peak value.

amplitude modulation (AM) A type of modulation in which the amplitude of a carrier wave is modulated by an imposed signal, usually at audio frequency.
In this way communication of a signal is made between two distant points using a radio transmission as carrier. When the carrier wave is received the audio component is extracted by the process of demodulation, and the original sound may be reproduced. *See also* carrier wave, demodulation.

amplitude of accommodation The eye's range of accommodation in terms of power (in dioptres). It is given by $(1/u_1 - 1/u_2)$, where u_1 is the distance from the near point to the lens and u_2 is the distance from the far point to the lens.

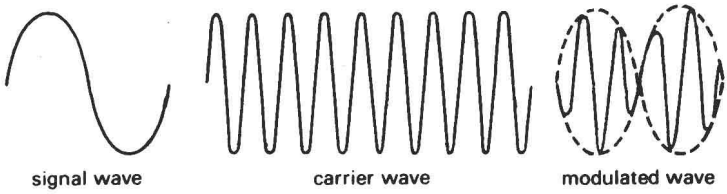
amu *See* atomic mass unit.

analyser A device for determining the plane of *polarization* of plane-polarized radiation. Maximum intensity is transmitted if the plane is parallel with the analyser's direction of polarization; the intensity is a minimum (theoretically zero) if the two are perpendicular. For visible radiation, analysers are usually Polaroid sheets or Nicol prisms.

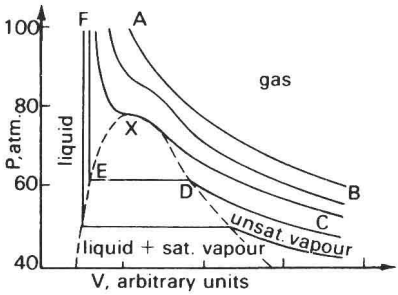
anastigmatic lens A lens designed so as to minimize its astigmatic aberration. Anastigmatic lenses have different curvatures in different directions; the surface of an anastigmatic lens is part of a toroid.

AND gate *See* logic gate.

Andrews' experiments Experiments performed (1863) on the effect of pressure and temperature on carbon dioxide. Andrews used two thick-walled glass capillary tubes, one containing dry carbon dioxide and the other dry nitrogen. The top end of each tube was closed and the bottom end contained a plug of mercury to trap the gas. The bottom ends of the tubes were sealed into a case containing water, and pressure could be applied by means of a pair of screws. In this way Andrews achieved



Amplitude modulation



Andrews' isothermal for CO_2

pressures up to above 10 MPa. The nitrogen was used to measure the pressure by assuming that it obeyed Boyle's law. The apparatus was surrounded by a constant temperature bath, so that isothermals (p–V curves) could be plotted at different temperatures.

In this way Andrews showed the behaviour near the critical temperature, and the liquefaction of carbon dioxide by pressure below the critical temperature. Similar experiments were done on carbon dioxide and other gases by Amagat.

anechoic chamber (dead room) A room designed so that there is little or no reflection of sound from its internal walls. The walls are covered with pyramid shapes so that stationary waves are not produced between parallel surfaces. They are coated with absorbing material. Anechoic chambers are used for experiments in acoustics.

aneroid (non-liquid) barometer *See* barometer.

angle of deviation *See* deviation.

angle of dip *See* inclination.

angle of incidence The angle between a ray incident on a surface and the normal to the surface at the point of incidence.

angle of polarization *See* Brewster angle.

angle of reflection The angle between a ray reflected by a surface and the normal to the surface at the point of reflection.

angle of refraction The angle between a ray refracted at the surface between two media and the normal to the surface at the point of refraction.

angstrom Symbol: Å A unit of length defined as 10^{-10} metre. The angstrom is sometimes used for expressing wavelengths of light or ultraviolet radiation or for the sizes of molecules.

angular acceleration Symbol: α The rotational acceleration of an object about an axis:

$$\alpha = d\omega/dt \text{ or } \alpha = d^2\theta/dt^2$$

Here ω is angular velocity; θ is angular displacement. Angular acceleration is directly analogous to linear acceleration, *a*. *See also* equations of motion, rotational motion.

angular displacement Symbol: θ The rotational displacement of an object about an axis. If the object (or a point

on it) moves from point P_1 to point P_2 in a plane perpendicular to the axis, θ is the angle P_1OP_2, where O is the point at which the perpendicular plane meets the axis. *See also* rotational motion.

angular frequency (pulsatance) Symbol: ω The number of complete rotations per unit time. A simple harmonic motion of frequency f can be represented by a point moving in a circular path at constant speed. The foot of a perpendicular from the point to a diameter of the circle moves with simple harmonic motion. The angular frequency of this motion is $2\pi f$, where f is the frequency. The unit is the hertz.

angular magnification (magnifying power) Symbol: M The ratio of the angle subtended at the eye by an image to that subtended by the object: $M = \theta_1/\theta_0$. The object and image are considered to be at their actual positions, except in the case of microscopes. Here it is conventional to measure θ_0 for the object at the standard near-point distance (250 mm from the eye). The maximum useful magnifying power depends on the resolving power of the viewing system — i.e. the acuity of the eye or the grain of the photographic emulsion. *See also* magnification.

angular momentum Symbol: L The product of the moment of inertia of a body and its angular velocity. *See also* rotational motion.

angular velocity Symbol: ω The rate of change of angular displacement: $\omega = d\theta/dt$. *See also* rotational motion.

anharmonic oscillator A system whose vibration, while still periodic, cannot be described in terms of simple harmonic motions (i.e. sinusoidal motions). In such cases, the period of oscillation is not independent of the amplitude.

anion A negatively charged ion, formed by addition of electrons to atoms or molecules. In electrolysis anions are attracted to the positive electrode (the anode). *Compare* cation.

anisotropy A medium is anisotropic if a certain physical quantity differs in value in different directions. Most crystals are anisotropic electrically; important polarization properties result from differences in transmission of electromagnetic radiation in different directions. *Compare* isotropy.

annealing The process of heating a solid to a temperature below the melting point, and then cooling it slowly. Annealing removes crystal imperfections and strains in the solid.

annihilation A reaction between a particle and its antiparticle; for example, between an electron and a positron. The energy produced is equivalent to the sum of the rest masses of the annihilating particles and their kinetic energies. In order that momentum be conserved two photons are formed, moving away in opposite directions. This radiation (*annihilation radiation*) is in the gamma-ray region of the electromagnetic spectrum.
Annihilation also can occur between a nucleon and its antiparticle. In this case mesons are produced.

annual variation The direction and strength of the Earth's magnetic field at any point changes with time. This must be allowed for by navigators. One such change is a variation with a period of a year, but there are others. The amplitude of the annual variation is greatest during maximum sun-spot activity.
See also Earth's magnetism, magnetic variation.

annular eclipse *See* eclipse.

anode In electrolysis, the electrode that is at a positive potential with respect to the cathode. In any electrical system, such as a discharge tube or a solid-state electronic device, the anode is the terminal at which electrons flow out of the system.

anomalous dispersion A discontinuity in the curve of refractive constant against wavelength caused by high absorptivity of the medium at certain wavelengths. It occurs at wavelengths in the region of absorption bands in the spectrum of the absorbing substance. *See* dispersion.

anomalous expansion An increase in volume resulting from a decreased temperature. Most liquids increase in volume as their temperature rises. The density of the liquid falls with increased temperature. Water, however, shows anomalous behaviour. Between 0 and 4°C the density increases with increasing temperature.

antiferromagnetism A phenomenon found in certain solids that have two or more types of atom with magnetic moments. The magnetic moments of one type can align antiparallel with those of the other type. In antiferromagnetism the susceptibility increases with temperature up to a certain point (the *Néel temperature*). Above this temperature the material becomes paramagnetic. Ferrimagnetism is a particular form of antiferromagnetism. *See also* magnetism.

antimatter Matter formed of antiparticles. Nuclei of antimatter would consist of antiprotons and antineutrons, and would be surrounded by orbiting positrons. When matter encounters antimatter annihilation occurs.

antinodal line A line joining the antinodes (positions of maximum disturbance) in an interference pattern. *See* interference.

antinode A point of maximum vibration in a stationary wave pattern. *Compare* node.

antiparallel Having parallel lines of action that are directed in opposite directions.

antiparticle A particle of the same mass and spin, but opposite charge (and other properties) to its corresponding particle. For example, a proton and antiproton both have mass 1836 times that of an electron and spin $\frac{1}{2}$ unit, but the charge on the proton is +1 unit, while that on the antiproton is -1 unit. For unstable particles, such as an isolated neutron, the particle and antiparticle have the same half-life. For uncharged particles the antiparticle is indicated by a bar above the symbol, such as $\bar{n}$ for the antineutron. For charged particles the distinction is indicated by the sign, for example, e^+ is the positron, the antiparticle of an electron.

aperture A measure of the effective diameter (d) of a mirror or lens compared with its focal distance (f):

$$\text{aperture} = d/f$$

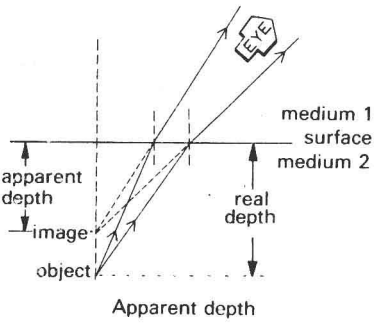
Thus a 50 mm camera lens may be used with an aperture diameter of 12.5 mm. Then, aperture = 12.5/50. This is usually described with the *f-number*. In this case the aperture diameter is *f*/4, often written as f4.

The transmitted light intensity depends on aperture diameter, so that I is proportional to d^2. However, large apertures lead to large aberrations although diffraction effects are more serious at small apertures. In many optical instruments, iris diaphragms vary the aperture to obtain the optimum results.

aplanatic lens A lens designed so as to minimize both its astigmatic and coma aberration.

apochromatic lens A lens designed to correct for chromatic aberration at three different wavelengths. Apochromatic lenses are constructed of three or more kinds of glass. They thus have better correction than achromatic lenses, which correct at two different wavelengths (usually in the red and blue regions of the spectrum).

apparent depth Because radiation travels at different speeds in different media, the apparent depth or thickness of a transparent sample is not the same as its real depth or thickness. The effect is



Apparent depth

very obvious when one looks down into a glass of water or a clear pool. It is associated with the fact that a long object partly submerged in water seems bent at the water surface.

The refractive constant of the substance can be defined on this basis:

refractive constant = real depth/apparent depth

The relation is used in a number of methods for finding the refractive constant of a transparent medium. It applies to all wave radiations, not just to visible radiation.

apparent expansion *See* expansivity.

aqueous humour The watery substance between the cornea and the lens in the eye. *See* eye.

arc, electric *See* electric arc.

Archimedes' principle The upward force on an object totally or partly submerged in a fluid is equal to the weight of fluid displaced by the object. The upward force, often called *upthrust*, results from the fact that the pressure in a fluid (liquid or gas) increases with depth. If the object displaces a volume V of fluid of density ρ, then:

$$\text{upthrust } u = v\rho g$$

where g is the acceleration of free fall.

If the upthrust on the object equals the object's weight, the object will float. *See* flotation, law of.

armature 1. The part of an electric motor or generator that carries the principal current. This is the rotating coil in a small motor but the stationary coil in a large motor or generator. Torque acting on the armature enables work to be done against the load. *See also* electric motor, rotor, stator.

2. The moving part of any electromechanical device, such as an electric bell or relay.

artificial radioactivity Radioactivity induced by bombarding stable nuclei with high-energy particles, such as with neutrons in a nuclear reactor. For example:

$$^{27}_{13}\text{Al} + {}^{1}_{0}\text{n} \rightarrow {}^{24}_{11}\text{Na} + {}^{4}_{2}\text{He}$$

represents the bombardment of aluminium with neutrons, which produces an artificially radioactive isotope of sodium of mass 24 and an alpha particle. Artificially produced radioactive nuclides can decay in a variety of ways; for example $^{24}_{11}$Na decays by beta emission with a half-life period of about 15 h.

All the transuranic elements (atomic numbers 93 and above) are artificially radioactive since they do not occur in nature.

asdic *See* sonar.

astable circuit (pulse generator) A multivibrator circuit that switches continuously and regularly from one state to another. Unlike other forms of multivibrator, no trigger pulse is needed. It is used in computers as a source of clock pulses for counting, because the output is a rectangular voltage waveform.

In the astable multivibrator, two transistors are arranged with the base terminal of each connected to the collector terminal of the other through capacitors *C1* and *C2* respectively. There is a steady voltage supply. *C1* charges and *C2* discharges until the transistors switch from one state to another and the charging direction reverses. The value of the capacitances and resistances determines the switching frequency. *See also* multivibrator.

astatic coils Two identical coils connected together in series and suspended on the same axis. When a current passes through them, any external magnetic field will result in the same turning force on each, but in opposite directions. Thus neither the Earth's magnetic field, nor any other external magnetic disturbance, will affect the rotation of the axis.

astatic pair Two identical magnetic needles suspended on the same vertical axis with their N- and S-poles pointing in opposite directions. The rotating forces on the needles from an external magnetic field, such as the Earth's, are equal and opposite. Astatic pairs are used in very sensitive galvanometers in which the current-carrying coils are wound round each needle in opposite directions. The current therefore rotates them both in the same direction and external magnetic effects are cancelled out.

astigmatism 1. A common eye defect in which the observer cannot focus on horizontal objects and vertical objects at the same distance at the same time. The cause is usually a non-spherical cornea. Visual astigmatism may be corrected with a lens with a suitable degree of cylindrical curvature. *See* anastigmatic lens.
2. *See* aberration.

astronomical unit (au, AU) The mean distance between the Sun and the Earth, used as a unit of distance in astronomy for measurements within the solar system. It is approximately 1.496×10^{11} metres.

astronomical telescope *See* telescope.

atmolysis The separation of a mixture of gases by using their different rates of diffusion.

atmosphere *See* standard pressure.

atmospheric pressure *See* pressure of the atmosphere.

atom The smallest part of an element that can take part in a chemical reaction. Atoms consist of a small dense positively charged nucleus, made up of neutrons and protons, with electrons in a cloud around this nucleus. The chemical reactions of an element are determined by the number of electrons (which is normally equal to the number of protons in the nucleus). All atoms of a given element have the same number of protons (the proton number). A given element may have two or more isotopes, which differ in the number of neutrons in the nucleus.

The electrons surrounding the nucleus are grouped into *shells* — i.e. main orbits around the nucleus. Within these main orbits there may be sub-shells. These correspond to atomic orbitals. An electron in an atom is specified by four quantum numbers:

(1) The *principal quantum number* (n), which specifies the main energy levels. n can have values 1, 2, etc. The corresponding shells are denoted by letters K, L, M, etc., the K shell ($n = 1$) being the nearest to the nucleus. The maximum number of electrons in a given shell is $2n^2$.

(2) The *orbital quantum number* (l), which specifies the angular momentum. For a given value of n, l can have possible values of n-1, n-2, ... 2, 1, 0. For instance, the M shell ($n = 3$) has three sub-shells with different values of l (0, 1, and 2). Sub-shells with angular momentum 0, 1, 2, and 3 are designated by letters s, p, d, and f.

(3) The *magnetic quantum number* (m) This can have values $-l$, $-(l - 1)$ ... 0 ... $+ (l + 1)$, $+ l$. It determines the orientation of the electron orbital in a magnetic field.

(4) The *spin quantum number* (m_s), which specifies the intrinsic angular momentum of the electron. It can have values $+1/2$ and $-1/2$.

Each electron in the atom has four quantum numbers and, according to the Pauli exclusion principle, no two electrons can have the same set of quantum numbers. This explains the electronic structure of atoms. *See also* Bohr theory.