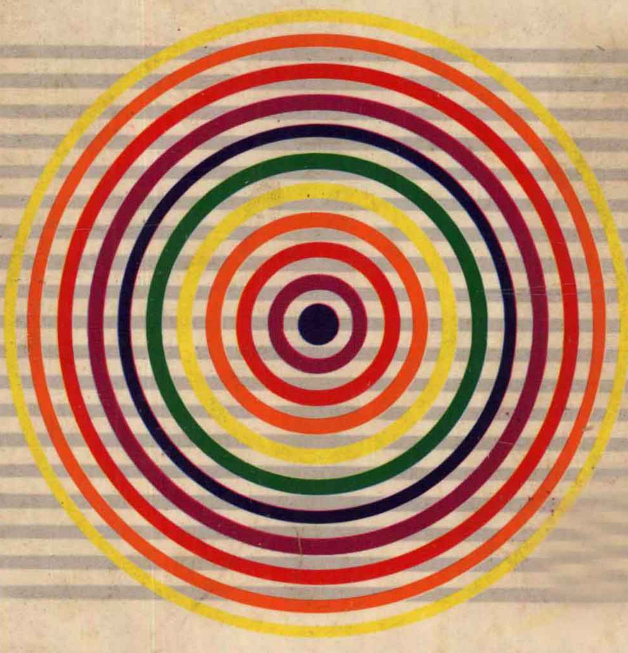
Edited by Valerie H. Pitt

The Penguin Dictionary of

PHYSICS



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THE PENGUIN DICTIONARY OF PHYSICS

Valerie Pitt was educated at Northwood College, Middlesex, and was awarded an honours degree in physics from Bristol University and a post-graduate degree, M. Phil., in radiation physics from London University. After two years of biochemical research in Melbourne, she became a science writer and has both written for and edited several science dictionaries and encyclopedias.

THE PENGUIN DICTIONARY OF

PHYSICS

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CONTENTS AND TABLES

PREFACE

THIS dictionary is an abridged version of the recently revised and published *New Dictionary of Physics* (Longman, 1975). Both books were prepared by members of the scientific staff of Laurence Urdang Associates Ltd. Entries in the Longman's dictionary that have been omitted from this dictionary include all biographies and entries concerned with experimental determinations of constants. Other entries have been shortened and updated where necessary and some additions have been made.

Although this dictionary is primarily concerned with the terminology of contemporary physics, words with a physical basis that are used in other scientific fields, such as physical chemistry, computing, astronomy, geophysics, medical physics, engineering subjects, and music, have also been included. SI units are used throughout.

The dictionary should thus prove useful to students and teachers of physics and related subjects, to doctors, and to scientists, technologists, and technicians in research and industry. It contains many long entries in which a word of major importance is defined and discussed together with closely associated words. Shorter definitions supplement the longer entries.

The editor thanks Mr H. J. Gray and Dr Alan Isaacs, editors of the *New Dictionary of Physics*, and also the contributors to the Longman's dictionary, in particular Dr John Daintith, for entries that have passed into the *Penguin Dictionary of Physics*. With the exception of some of the longer electronic entries, which have been shortened by the original authors (Carol and John Young), the abridgements have been made by the editor without consulting the original contributors. Any changes of emphasis or style are therefore the responsibility of the editor.

VALERIE H. PITT, 1976

NOTES

An asterisk indicates a cross reference.

An entry having an initial capital letter is either a proper name or a trade name.

Syn. is an abbreviation for 'synonymous with'.

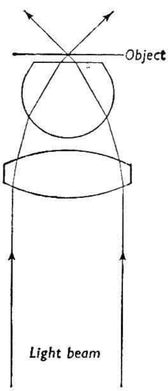
All other abbreviations will be found in the Tables of SI units (page 422) and the Table of Symbols (pages 426–8).

A

Å (or Å.U. or A.U.). Symbol for ångstrom.

ab-. A prefix which, when attached to the name of a practical electrical unit, denotes the corresponding unit in the *CGS system of electromagnetic units. This system of units is no longer employed.

Abbe condenser. A simple two lens *condenser that has good light-gathering ability, the *numerical aperture being 1·25. It is therefore extensively used in general microscopy. Aberrations are not well corrected. A modified Abbe condenser called a *variable-focus condenser* is used to obtain a greater illuminated field area. The lower lens can be adjusted to bring light to a focus between the lenses producing a parallel beam.



Abbe condenser

Abbe criterion. *See* resolving power.

Abbe number. *Syn.* constringence. The reciprocal of dispersive power. *See* dispersion.

aberration. (1) Of a lens or mirror. Any of a number of image defects revealed as blurring or distortion. The theory of *centred optical systems holds good for rays passing close to the axis. For larger angles, it is no longer accurate to replace the sine of the angle by the angle itself (as is done in the simple theory), the point, line and plane correspondence between object and image no longer holds good, and certain defects in the image or aberrations occur.

By expanding the sine series to two or more terms, $\sin\theta = \theta - \theta^3/3! + \theta^5/5! - \ldots$, the deviations of the path of a ray from that predicted by the simple theory can be expressed in terms of five sums called the *Seidel sums* or the *Seidel terms*. The presence of one or more of these terms can be linked with certain recognizable defects in the image, i.e. those called *spherical aberration, *coma, *astigmatism, *curvature of field, and *distortion. In addition, if light of more than one colour is involved, false colour effects may be introduced in the image, a defect which is known as *chromatic aberration. Of these six defects only spherical and chromatic aberrations are found in the images of axial points. The other four aberrations occur only when extra-axial points are involved.

(2) Of light. The seasonal small displacement of stars, attributable to the effect of the orbital motion of the Earth round the Sun on the direction of arrival of the light.

(3) A defect in the image produced by an *electron lens system.

ablation. The removal of material from the surface of a body by decomposition or vaporization. It can result from friction with the atoms or molecules of the atmosphere.

absolute expansion. *See* coefficient of expansion.

absolute humidity. *See* humidity.

absolute magnitude. *See* magnitude.

absolute permittivity. *See* permittivity.

absolute temperature. *See* thermodynamic temperature.

absolute unit. If a quantity y is uniquely defined in terms of quantities $x_1, x_2, \ldots$ by

$$y = f(x_1, x_2, \ldots),$$

the unit U_y of y can be obtained from the units U_{x_1}, U_{x_2} of x_1, x_2 from the equation

$$U_y \propto f(U_{x_1}, U_{x_2}, \ldots).$$

In any given system an absolute unit is one for which the constant of proportionality is unity. All units of the *SI system are absolute.

absolute zero. The lowest temperature theoretically possible; the temperature at which the thermal energy of random motion of the particles of a system in thermal equilibrium is zero. It is, therefore, the zero of *thermodynamic temperature: $0\ K = -273{\cdot}15°C = -459{\cdot}67°F$.

absorbance. *See* internal transmission density.

absorbed dose. *See* dose.

absorptance. *Syn.* absorption factor. Symbol: α. A measure of the ability of a body or substance to absorb radiation as expressed by the ratio of the absorbed *radiant or *luminous flux to the incident radiant or luminous flux. For radiant heat the absorptance of a body, measured against a vacuum, depends on the thermodynamic temperature T of the body receiving the radiation and on the wavelength. The absorptance at a fixed frequency of radiation is called the *spectral absorptance*. *See also* internal absorptance.

absorption. (1) Of electromagnetic radiation. When radiation passes from one medium to another three processes can occur: *reflection, *transmission, or absorption. Absorption is the transformation of the energy of the radiation into a different form. The nature of this process depends on the frequency of the radiation and on the substance involved. For example, infrared radiation may be converted directly to heat by exciting the vibrations of atoms or molecules, visible radiation may cause electronic transitions, and X-rays and ultraviolet radiation may cause ionization of the material (*see* photoelectric effect; photoionization). The extent to which this process occurs is given by the absorptance of the specimen or medium. *See also* linear attenuation coefficient; linear absorption coefficient.

(2) Of sound. When energy in the form of a sound wave passes from any one medium to another a portion of the energy of the incident radiation is absorbed into the second medium. The ratio of the absorbed energy to the incident energy is called the *absorption coefficient.

The loss in sound energy as it passes through a medium is given by the equation:

$$E = E_0\, e^{-\mu_\alpha x},$$

where E_0 is the incident energy, E the energy after a distance x, and μ_α a constant called the absorption coefficient or, to avoid confusion with the absorption coefficient mentioned earlier, the *linear absorption coefficient.

The absorption of sound energy is caused principally by viscous forces opposing the relative motion of the particles as the sound passes (involving transformation of mechanical energy into heat) and by heat being conducted from the compressed particles to the rarefied ones. This results in an increase of *entropy. Heat radiated from compressions to rarefactions also causes some energy dissipation at low frequencies.

The effects of viscosity and heat conduction are summed up in the *Stokes–Kirchhoff equation*:

$$\mu_\alpha = \frac{4\pi^2}{v\rho}\left(\frac{4}{3}\eta + \frac{(c_p - c_v)}{c_p c_v}\lambda\right)f^2,$$

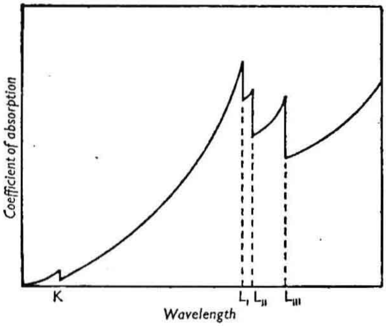
where v is the velocity of sound, ρ the density of gas, η its viscosity, c_p and c_v its principal specific heat capacities, λ its thermal conductivity, and f the frequency of the sound.

Absorption of sound by gases is basically due to viscosity, the conduction and radiation effects becoming more important for waves of larger amplitude. Water vapour content (humidity) also affects the absorption, μ_α taking a maximum value at about 15% relative humidity.

absorption bands (and lines). *See* absorption spectrum.

absorption coefficient. (1) Of electromagnetic radiation. *See* linear absorption coefficient. (2) Of sound. Symbol: α. The ratio of the absorbed sound energy at a boundary to the incident sound energy. Its value depends on the material and on the frequency of the sound.

absorption edge (discontinuity or limit). An abrupt discontinuity in the graph relating the *linear absorption coefficient of X-rays in a given substance with the wavelength of the radiation. At certain wavelengths the absorption shows a sudden decrease in value. This occurs when the energy quantum of the radiation becomes smaller than the work required to eject an electron from one or other of the energy levels in the absorbing atom, and the radiation thus ceases to be absorbed in that level. Thus, radiation of wavelength greater than the K absorption edge cannot eject electrons from the K level of the absorbing substance.



Absorption discontinuity

absorption factor. *See* absorptance.

absorption spectrum. When light from a high temperature source producing a continuous emission spectrum is passed through a medium into a spectroscope, the spectrum reveals dark regions where absorption has taken place (*continuous*, *line*, and *band* types). In general, the medium absorbs those wavelengths which it would emit if its temperature were raised high enough. The absorbed radiation excites atoms from the *ground state to an *excited state. Solids and liquids show broad continuous absorption spectra, gases give more discontinuous types (line and band). *See* spectrum.

absorptivity. (1) A measure of the ability of a substance to absorb radiation, as expressed by the *internal absorptance of a layer of substance when the path of the radiation is of unit length and the boundaries of the material have no influence. (2) Symbol: a_λ. Former term for *absorptance.

abundance. Symbol: *C*. The number of atoms of a given isotope in a mixture of the isotopes of an element; usually expressed as a percentage of the total number of atoms of the element.

Natural abundance, symbol: C_o, is the abundance in a naturally occurring isotopic mixture of an element. *Cosmic abundance* is the abundance of a nuclide or element in the universe expressed as a fraction of the total.

acceleration. (1) Linear acceleration. Symbol: a. The rate of increase of velocity with time expressed in metres per second per second ($m\ s^{-2}$) or other similar units. (2) Angular acceleration. Symbol: α. The time rate of increase of angular velocity in radians per second per second ($rad\ s^{-2}$) or other similar units.

acceleration of free fall. *See* free fall.

accelerator. A machine for increasing the kinetic energy of charged particles or ions, such as protons or electrons, by accelerating them in an electric field. A magnetic field is used to maintain the particles in the desired direction. The particles can either travel in a straight or circular path. *See* linear accelerator; betatron; cyclotron; synchroton; synchrocyclotron; Van de Graaff generator. *See also* focusing; intersecting storage ring.

accelerometer. Any device used to measure acceleration. An *integrating accelerometer* is capable of performing one integration to obtain the velocity and a subsequent integration to obtain the distance travelled.

acceptor. (1) The *impedance of a circuit comprising *inductance and *capacitance in *series has a minimum value at one particular frequency (the frequency to which the circuit is tuned – *see* tuned circuit). Such a circuit is an acceptor for that frequency. In practice, the effective resistance of such a circuit cannot be made zero and hence the impedance at the frequency to which the circuit is tuned cannot be zero either. *See also* rejector. (2) *See* semiconductor.

access time. The mean time interval between demanding a particular piece of information from a computer *storage device and obtaining it.

accommodation. The ability of the eye to alter its focal length and to produce clear images of objects at different distances. *See* near point.

accumulator. A device for the reversible interchange of electrical and chemical energy. The common 'lead' accumulator consists in principle of two plates coated with lead sulphate immersed in aqueous sulphuric acid. If connected to a suitable d.c. supply, current is sent through the cell, and the anode is converted to lead peroxide and the cathode reduced to metallic lead. If the two plates are then connected through an external circuit, the chemical action is reversed and current flows round the external circuit from the brown peroxide plate to the grey lead plate. The action may be summarized in the equation:

$$\underset{(+\text{ plate})}{PbO_2} + \underset{(-\text{ plate})}{Pb} + 2H_2SO_4 \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftharpoons}} 2PbSO_4 + 2H_2O$$

See also Edison accumulator.

achromat. *See* achromatic lens.

achromatic colours. Colours having no hue or saturation but only lightness. White, greys, and black are examples.

achromatic condenser. A *condenser corrected for chromatic and spherical *aberrations, usually by having four elements, two of which are an *achromatic lens. It has a *numerical aperture of 1·4. It is used in microscopes when high magnification is required. *See also* Abbe condenser.

achromatic lens. *Syn.* achromat. A combination of two lenses using, if necessary, different kinds of glass, designed to remove the major part of *chromatic aberration. The elementary theory assumes two lenses of powers P_1 and P_2 placed in contact (with total power $P = P_1 + P_2$) made of glasses of *dispersive powers ω_1 and ω_2 so that the condition for achromatism ($\omega_1 P_1 + \omega_2 P_2 = 0$) is satisfied. To produce an achromatic converging lens, e.g. for telescope or photographic objectives, the dispersive power of the higher power convergent lens must be less than that of the divergent lens of the combination. It is thus possible to bring two colours, say red and blue, to the same focus. There will still be some residual colour effects known as a *secondary spectrum*. *See also* apochromatic lens.

achromatic prism. A combination of two or more prisms which produces the same deviation of two or more colours so that objects viewed through them will not appear coloured (*see* chromatic aberration). As with thin lenses, 'narrow angle' prisms are placed in contact in opposition, so that the *dispersive powers of the two glasses are inversely proportional to their angles of *deviation.

achromatism. The removal of *chromatic aberration, or chromatic differences of magnification, or both, arising from dispersion of light. Owing to irrationality of dispersion the correction is attempted for two colours in the first approximation, and for three colours in higher corrections.

aclinic line. *Syn.* magnetic equator. A curve drawn in such a manner that all places on the curve have zero magnetic dip. *See* isoclinal.

acoustic absorption coefficient. *See* sound absorption coefficient.

acoustic capacitance. The imaginary component of acoustic *impedance due to the stiffness or elasticity (k) of the medium; it is equal to S^2/k where S is the area in vibration.

acoustic delay line. *See* delay line.

acoustic filters. Just as in the case of electrical filters lines of acoustic *impedances can be made by proper adjustment to transmit high frequencies only (high-pass filter) or low frequencies only (low-pass filter) or any given band of frequency (band-pass filter).

If any simple harmonic motion is impressed on equal impedances Z_1 connected in a conduit and separated by branches containing other equal impedances Z_2, it will not pass through unless the ratio Z_1/Z_2 for the frequency of this SHM lies between certain values; i.e. all other frequencies which do not satisfy this condition will be rapidly attenuated and only those covering this range will get through.

acoustic grating. A series of objects, such as rods of equal size, placed in a row a fixed distance apart constitute an acoustic grating having similar properties to an optical *diffraction grating. When a sound wave is incident upon an acoustic grating, secondary waves are set up which reinforce each other or cancel out according to whether or not they are in phase. The result for a sinusoidal sound wave is a series of maxima and minima spaced round the grating. When the incident sound is normal to the grating the condition for a maximum diffracted sound at an angle θ to the normal is: $\sin\theta = m\lambda/e$, where λ is the wavelength of the sound, e is the width of a rod plus the space between it and the next and m is an integer. e must be greater than λ for a diffraction pattern to be formed and this condition necessitates very large gratings for low frequency sounds.

acoustic impedance. *See* impedance.