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A2 PHYSICS

All Definitions · Mark-Scheme Wording

Cambridge International A Level — 9702 (2025–2027)

Topics 12 – 25 · Compiled from the syllabus and CAIE mark schemes (2018–2024)

Compiled by Mahad Amer · Physics with MAC

youtube.com/@PhysicswithMAC · instagram.com/mahad_amer · wa.me/923083916365

Telegram 0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic · How to use this booklet

Every definition listed is one that the Cambridge 9702 (2025–2027) syllabus explicitly asks candidates to **define**, **understand**, or **explain**. The wording follows that found in CAIE mark schemes from M/J 2018 to O/N 2024 — phrases marked B1, M1 or A1.

How to memorise

Read each definition aloud three times. Then close the booklet and write it down — compare with the model answer and note any missing key word. The light-shaded box contains the **examinable wording**; italics underneath give helpful context but are not required for the mark.

Common mark-losing mistakes

- Saying "force on a unit" instead of "force per unit".
- Forgetting the phrase "from infinity to the point" in any potential definition.
- Saying "per unit area" instead of "per unit current per unit length" for B (magnetic flux density).
- Confusing random and spontaneous when describing radioactive decay.
- Omitting "per unit positive charge" for electric potential / field — Cambridge insists on the word ‘positive’.

Symbols & sign convention

Where a quantity has a sign (e.g. gravitational potential, work done on a gas), the sign is part of the definition and must be retained.

Telegram 0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 12 Motion in a Circle

Radian

The radian is the angle subtended at the centre of a circle by an arc equal in length to the radius of the circle.

Note: 1 rev = 2π rad ≈ 360°. Always state "at the centre" — Cambridge mark schemes specifically check for this phrase.

Angular displacement (θ)

The angle through which an object has moved about the centre of a circle, measured in radians.

Angular speed (ω)

The rate of change of angular displacement; $\omega = \Delta\theta / \Delta t = 2\pi / T = 2\pi f$.

Note: SI unit: rad s^{-1}.

Period (T) and frequency (f)

T is the time taken for one complete revolution; f is the number of complete revolutions per unit time. $T = 1/f$.

Centripetal acceleration

The acceleration of an object moving in a circular path; it is directed towards the centre of the circle.

Note: Magnitude: $a = v^2/r = r\omega^2$. Caused by a resultant force perpendicular to the velocity.

Centripetal force

The resultant force acting on an object moving in a circle, always directed towards the centre of the circle.

Note: $F = mv^2/r = mr\omega^2$. Does no work on the object because it is perpendicular to v — the speed is constant.

0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 13 Gravitational Fields

Gravitational field

A region of space in which a mass experiences a (gravitational) force.

Gravitational field strength (g)

The (gravitational) force exerted per unit mass on a small test mass placed at a point in the field.

Note: Vector. Units N kg^{-1} (= m s^{-2}). $g = F / m$. Direction: towards the mass producing the field.

Newton's law of gravitation

The (gravitational) force between two point masses is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

Note: $F = G M m / r^2$ (attractive).

Gravitational potential at a point (φ)

The work done per unit mass in bringing a small test mass from infinity to that point.

Note: Scalar. Always negative (taking $\varphi = 0$ at infinity). For a point mass: $\varphi = - GM / r$.

Gravitational potential energy of two point masses

$E_p = - GMm / r$ (defined as zero when $r \to \infty$).

Geostationary orbit

An orbit such that a satellite remains at the same point above the Earth's surface; orbital period 24 h, orbiting from west to east, directly above the Equator.

Note: Used for telecommunications. Orbital radius ≈ 4.23×10^7 m.

0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 14 Temperature & Thermal Properties

Thermal equilibrium

Two regions are in thermal equilibrium when there is no net transfer of (thermal) energy between them; this occurs when they are at the same temperature.

Thermodynamic (Kelvin) temperature scale

A temperature scale that does not depend on the property of any particular substance. Its zero is absolute zero (0 K) — the lowest possible temperature.

Note: Conversion: $T / K = \theta / °C + 273.15$.

Absolute zero

The lowest possible temperature on the thermodynamic temperature scale, equal to 0 K (≈ −273.15 °C). At absolute zero, particles have minimum (zero) kinetic energy.

Specific heat capacity (c)

The (thermal) energy required per unit mass to raise the temperature of a substance by one degree (1 K), without change of state.

Note: $Q = m\,c\,\Delta T$. Units: $J\,kg^{-1}\,K^{-1}$.

Specific latent heat (L)

The (thermal) energy required per unit mass to change the state of a substance without any change of temperature.

Note: $Q = m\,L$.

Specific latent heat of fusion (Lf)

The energy per unit mass required to change a substance from solid to liquid (or liquid to solid) at constant temperature.

Specific latent heat of vaporisation (Lv)

The energy per unit mass required to change a substance from liquid to vapour (or vapour to liquid) at constant temperature.

Note: Lv > Lf because vaporising requires complete separation of molecules and (usually) work done against atmospheric pressure as the gas expands.

0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 15 Ideal Gases

Mole (mol)

The SI base unit of amount of substance. One mole contains a number of particles equal to the Avogadro constant, NA = 6.02 × 10^{23} mol^{-1}.

Avogadro constant (NA)

The number of atoms in 12 g of carbon-12, equal to 6.02 × 10^{23} mol^{-1}.

Ideal gas

A gas that obeys the equation of state pV = nRT (equivalently pV ∝ T) at all pressures, volumes and temperatures.

Note: Equivalent: pV = NkT, where k = R/NA is the Boltzmann constant.

Kinetic theory of gases — basic assumptions

(1) A gas consists of a large number of identical molecules in random motion. (2) The volume of the molecules is negligible compared with the volume occupied by the gas. (3) Forces between molecules are negligible except during collisions. (4) Collisions between molecules and with the walls are elastic and of negligible duration.

Note: These exact phrases are the ones that score in mark schemes.

Mean square speed $\langle c^2 \rangle$

The mean of the squares of the speeds of all the molecules of a gas.

Root-mean-square speed ($c_{r.m.s.}$)

$c_{r.m.s.} = \sqrt{\langle c^2 \rangle}$

Mean (translational) kinetic energy of a molecule

$\frac{1}{2} m \langle c^2 \rangle = (3/2) k T$ — proportional to thermodynamic temperature.

0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 16 Thermodynamics

Internal energy (U)

The sum of the random distribution of kinetic and potential energies associated with the molecules of a system.

Note: KE depends on temperature; PE depends on intermolecular separation (state of matter).

Work done on a gas at constant pressure

$W = -p\,\Delta V$. If the gas expands ($\Delta V > 0$), work is done by the gas, so $W < 0$ (negative work done on it).

First law of thermodynamics

The increase in internal energy of a system equals the sum of the heat supplied to the system and the work done on the system.

Note: $\Delta U = q + W$.

0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 17 Oscillations

Simple harmonic motion (SHM)
Motion in which the acceleration of a body is proportional to its displacement from a fixed point and is always directed towards that point (i.e. opposite in direction to the displacement).

Note: Defining equation: $a = -\omega^2 x$. The minus sign indicates the acceleration is opposite to displacement.

Displacement (x)
The distance, in a specified direction, of an oscillating object from its equilibrium position.

Amplitude (x_0)
The maximum displacement of an oscillating object from its equilibrium position.

Period (T)
The time taken for one complete oscillation.

Frequency (f)
The number of complete oscillations per unit time. $f = 1 / T$.

Angular frequency (ω)
$\omega = 2\pi / T = 2\pi f$. Units: rad s^{-1}.

Phase difference
A measure of how much one oscillation leads or lags another, expressed as a fraction of a cycle or as an angle (rad or °).

Free / natural oscillation
An oscillation in which there is no resistive force acting and no periodic driving force; the system oscillates at its natural frequency.

Damping
A force (resistive force) acting on an oscillating system that opposes the motion and removes energy from the system, causing the amplitude to decrease.

Light damping
Amplitude decreases (approximately exponentially) with time; period is almost unchanged.

Critical damping
The amount of damping that returns the system to equilibrium in the shortest time without oscillating.

Heavy (over) damping
Damping so strong that the system returns slowly to equilibrium without oscillating.

Forced oscillation
An oscillation maintained by an external periodic driving force at a frequency f (the driving frequency).

Resonance
A maximum amplitude of (forced) oscillations occurs when an oscillating system is driven at a frequency equal to its natural frequency.

Telegram 0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 18 Electric Fields

Electric field
A region of space in which a charged object experiences an electric force.

Electric field strength (E)
The (electric) force exerted per unit positive charge on a small test charge placed at a point in the field.

Note: Vector. Units: N C^{-1} (= V m^{-1}). $E = F / q$.

Coulomb's law
The (electric) force between two point charges in free space is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.

Note: $F = Q_1Q_2 / (4\pi\varepsilon_0 r^2)$.

Electric potential at a point (V)
The work done per unit positive charge in bringing a small test charge from infinity to the point.

Note: Scalar. Units: J C^{-1} = V. For a point charge: $V = Q / (4\pi\varepsilon_0 r)$. May be positive (around +Q) or negative (around −Q).

Electric potential energy of two point charges
$E_p = Qq / (4\pi\varepsilon_0 r)$ — taken as zero when $r \to \infty$.

Field – potential relationship
The electric field at a point is equal to the negative of the potential gradient at that point: $E = -dV/dx$. Field points from high potential to low potential.

0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 19 Capacitance

Capacitance (C)

Charge stored per unit potential difference across the capacitor.

Note: Applies both to an isolated spherical conductor (V is its potential) and to a parallel-plate capacitor (V is the p.d. between plates). Units: 1 F = 1 C V^{-1}.

Energy stored in a capacitor

$W = \frac{1}{2} Q V = \frac{1}{2} C V^2 = \frac{1}{2} Q^2 / C$. Equal to the area under a Q–V graph (a triangle).

Time constant (τ)

The time taken for the charge (or current, or p.d.) on a capacitor to fall to 1/e (≈ 37%) of its initial value when discharging through a resistor. $\tau = RC$.

Note: After one τ during charging, charge has risen to (1 − 1/e) ≈ 63% of the final value.

Discharge equation

$x = x_0 e^{(-t/RC)}$, where x is current, charge or p.d. across the capacitor.

Capacitors in series and parallel

Series: $1/C_{total} = 1/C_1 + 1/C_2 + \ldots$ (same Q on each, V adds). Parallel: $C_{total} = C_1 + C_2 + \ldots$ (same V across each, Q adds).

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Telegram 0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 20 Magnetic Fields

Magnetic field

A region of space in which a moving charge or a current-carrying conductor (or a magnetic material) experiences a force; produced either by moving charges or by permanent magnets.

Magnetic flux density (B)

The force acting per unit current per unit length on a (long, straight) wire placed at right angles to the magnetic field.

Note: Vector. SI unit: tesla (T) = N A^{-1} m^{-1}. $F = BIL \sin\theta$.

Force on a moving charge

$F = BQv \sin\theta$. Direction perpendicular to both v and B (Fleming's left-hand rule). The force does no work — speed is unchanged; in a uniform B field the path is circular with $r = mv / (BQ)$.

Hall voltage (VH)

The potential difference set up across a current-carrying conductor, perpendicular to both the current and the magnetic field, when placed in a magnetic field.

Note: $VH = B I / (n t q)$, where n = number density of charge carriers, t = thickness, q = charge of carrier.

Magnetic flux (Φ)

The product of the magnetic flux density and the cross-sectional area perpendicular to the direction of the magnetic flux density.

Note: $\Phi = B A \cos\theta$. Units: weber (Wb) = T m^2.

Magnetic flux linkage

The product of the number of turns and the magnetic flux through a coil. Magnetic flux linkage = N Φ.

Faraday's law of electromagnetic induction

The (magnitude of the) e.m.f. induced in a circuit is equal to (proportional to) the rate of change of magnetic flux linkage.

Note: $\varepsilon = - d(N\Phi)/dt$.

Lenz's law

The direction of the induced e.m.f. (or current) is such that its effect opposes the change producing it.

Note: Consequence of conservation of energy — explains the minus sign in Faraday's law.

Telegram 0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 21 Alternating Currents

Alternating current
A current whose direction reverses periodically. For a sinusoidal a.c.: $I = I_0 \sin(\omega t)$.

Period (T) and frequency (f) of an a.c.
T is the time for one complete cycle of the alternating quantity; $f = 1/T$ is the number of complete cycles per second.

Peak value (I_0, V_0)
The maximum value of the alternating current or voltage during a cycle.

Root-mean-square (rms) value
The value of a steady direct current that would dissipate energy at the same average rate in a given resistor as the alternating current.

Note: For a sinusoidal a.c.: $I_{rms} = I_0 / \sqrt{2}$; $V_{rms} = V_0 / \sqrt{2}$.

Mean power (resistive load, sinusoidal a.c.)
$\langle P \rangle = \frac{1}{2} I_0 V_0 = I_{rms} V_{rms} = I_{rms}^2 R = V_{rms}^2 / R$.

Half-wave rectification
Use of a single diode so that only one half (positive or negative) of each cycle is allowed to pass; the other half is blocked. Output is a series of single half-cycle pulses.

Full-wave rectification
Use of four diodes (a bridge rectifier) so that both halves of each cycle pass through the load in the same direction; doubles the average output.

Smoothing (with capacitor)
A capacitor connected in parallel with the load smooths the rectified output: it charges quickly when the rectified voltage rises and supplies current to the load when the rectified voltage falls, leaving only a small ripple. Larger C or larger R → smoother output (smaller ripple).

Telegram 0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 22 Quantum Physics

Photon
A quantum (discrete packet) of electromagnetic energy. $E = hf = hc/\lambda$.

Electronvolt (eV)
The energy gained by an electron when it is accelerated through a potential difference of 1 volt. 1 eV = 1.60×10^{-19} J.

Photoelectric effect
The emission of electrons (photoelectrons) from the surface of a metal when electromagnetic radiation of sufficiently high frequency is incident on it.

Threshold frequency (f_0)
The minimum frequency of incident electromagnetic radiation that will cause photoelectrons to be emitted from a particular metal surface.

Threshold wavelength (λ_0)
The maximum wavelength of incident radiation that will cause photoelectric emission from a particular metal surface. $\lambda_0 = c / f_0$.

Work function energy (φ)
The minimum energy required to remove an electron from the surface of a metal (i.e. to liberate a photoelectron from the surface).

Note: $\varphi = h f_0$. Einstein's photoelectric equation: $hf = \varphi + \frac{1}{2} m v_{max}^2$.

Maximum kinetic energy of photoelectrons
$KE_{max} = hf - \varphi$. Independent of the intensity of the incident radiation; the photoelectric current is proportional to intensity (above threshold).

de Broglie wavelength
The wavelength associated with a moving particle: $\lambda = h / p = h / (mv)$.

Note: Evidence: electron diffraction through a thin crystal.

Discrete energy levels in atoms
Within an isolated atom, electrons can only have certain fixed (discrete) energies. Transitions between two levels emit/absorb photons of fixed energy: $hf = E_1 - E_2$. This explains line emission and absorption spectra.

0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 23 Nuclear Physics

Mass–energy equivalence
Mass and energy are equivalent and related by $E = m c^2$. A change of mass Δm corresponds to a change of energy $\Delta E = c^2 \Delta m$.

Mass defect (Δm)
The difference between the total mass of the separated nucleons (protons and neutrons) and the mass of the nucleus.

Note: $\Delta m = Z m_p + (A - Z) m_n - m_nucleus$.

Binding energy
The (minimum) energy required to separate a nucleus completely into its constituent nucleons (or, equivalently, the energy released when the nucleus is assembled from its individual nucleons).

Note: Binding energy = $(\Delta m) c^2$.

Binding energy per nucleon
The total binding energy of a nucleus divided by its nucleon number A. Greater binding energy per nucleon → more stable nucleus. Iron-56 lies at the peak of the curve.

Nuclear fission
The splitting of a (heavy) nucleus into two smaller (lighter) nuclei (often by neutron bombardment), releasing energy.

Nuclear fusion
The joining of two light nuclei to form a heavier nucleus (usually initiated by very high temperatures), releasing energy.

Random nature of decay
The decay of a particular nucleus cannot be predicted; each undecayed nucleus has the same probability of decaying in unit time, independent of all other nuclei.

Spontaneous nature of decay
Radioactive decay is unaffected by external factors such as temperature, pressure or the chemical state of the substance.

Activity (A)
The rate at which nuclei of a radioactive sample disintegrate (decays per unit time).

Note: $A = \lambda N$. Units: becquerel (Bq) = decays per second.

Decay constant (λ)
The probability of decay of an individual nucleus per unit time.

Half-life (t½)
The (mean) time taken for the number of undecayed nuclei (or activity, or count rate) of a radioactive sample to fall to half of its initial value.

Note: $t_{½} = \ln 2 / \lambda = 0.693 / \lambda$.

Exponential decay law
$x = x_0 e^{(-\lambda t)}$, where x can be number of undecayed nuclei N, activity A, or received count rate.

Telegram 0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 24 Medical Physics

Piezoelectric crystal
A crystal that changes shape when a potential difference is applied across it, and conversely generates an e.m.f. when its shape is changed.

Note: Used in ultrasound transducers as both transmitter and receiver.

Ultrasound transducer (piezoelectric)
A device containing a piezoelectric crystal driven by an alternating p.d. at the crystal's resonant (natural) frequency to produce ultrasound; reflected ultrasound makes the crystal vibrate, generating an alternating p.d. that is processed to produce diagnostic information.

Specific acoustic impedance (Z)
The product of the density of a medium and the speed of sound in that medium.

Note: $Z = \rho c$. Units: kg m^{-2} s^{-1}.

Intensity reflection coefficient
$I_r / I_0 = (Z_2 - Z_1)^2 / (Z_2 + Z_1)^2$. A large mismatch in Z between two media (e.g. air–tissue) reflects almost all the incident intensity, hence the use of coupling gel.

Attenuation in matter
The reduction in intensity of an ultrasound or X-ray beam as it passes through matter, given by $I = I_0 e^{(-\mu x)}$, where μ is the linear absorption coefficient and x is thickness.

Note: Half-value thickness $x_{½} = \ln 2 / \mu$.

Contrast (in X-ray imaging)
The difference in intensity (degree of darkening on the image) between two adjacent regions caused by different absorptions of X-rays in those regions; bones (high μ) appear lighter than soft tissue (low μ).

Computed tomography (CT) scan
A medical imaging technique in which multiple X-ray images of a section of the body, taken from different angles, are combined by computer to form a 2-D image of that section; repeating along an axis and combining 2-D sections produces a 3-D image.

Tracer (PET)
A substance containing radioactive nuclei that is introduced into the body and is absorbed by the tissue being studied; in PET scanning the tracer decays by β^+ emission.

Annihilation
The process in which a particle and its antiparticle interact and their (rest) mass is converted into energy in the form of two (or more) photons; mass–energy and momentum are conserved.

Note: In PET: $e^+ + e^- \rightarrow 2\ \gamma$ photons, each of energy 511 keV, travelling in opposite directions.

PET (positron-emission tomography) scan
A medical imaging technique in which positrons emitted by a β^+-decaying tracer annihilate with electrons in the body; the pairs of γ-photons produced are detected outside the body, and the arrival times are processed to construct an image of tracer concentration in the tissue.

Telegram 0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic 25 Astronomy & Cosmology

Luminosity (L)

The total power of (electromagnetic) radiation emitted by a star.

Note: Units: W.

Radiant flux intensity (F)

The power of radiation passing normally through unit area at the observer; $F = L / (4\pi d^2)$ for a source of luminosity L at distance d (inverse-square law).

Standard candle

An astronomical object of known luminosity. By measuring its radiant flux intensity F at the observer and using $F = L / (4\pi d^2)$, the distance d to the object (and hence to its host galaxy) can be determined.

Wien's displacement law

The wavelength λ_{max} at which the spectral intensity of a black body is a maximum is inversely proportional to the thermodynamic temperature T: $\lambda_{max} \propto 1/T$ ($\lambda_{max} T = 2.9 \times 10^{-3}$ m K).

Stefan–Boltzmann law

The total power radiated by a black body of surface area A at thermodynamic temperature T is $L = A \sigma T^4$. For a star (assumed spherical) of radius r: $L = 4\pi r^2 \sigma T^4$.

Note: $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}.

Redshift

An increase in the observed wavelength (decrease in observed frequency) of electromagnetic radiation from a source moving away from the observer.

Note: For $v \Delta \lambda$ c:/ $\lambda \approx \Delta f / f \approx v / c$.

Hubble's law

The recession speed v of a distant galaxy is proportional to its distance d from the observer: $v = H_0 d$.

Note: $H_0 \approx 2.4 \times 10^{-18}$ s^{-1}. Age of the Universe ≈ 1 / H_0.

Big Bang theory

The Universe began from an extremely hot, dense initial state and has been expanding ever since. Evidence: galactic redshift (Hubble's law) and the cosmic microwave background (~2.7 K).

0309 2656780 mahad__amer mahadamerchaudhry@gmail.com

Topic ✔ Writing Definitions in the Exam

Top-mark phrasing rules

1. Always write "per unit ___" for any field or potential definition. Cambridge insists on the words **force per unit mass / per unit positive charge / per unit current per unit length**.

2. Always include "**from infinity to the point**" in any potential definition (gravitational, electric).

3. State the **sign convention** where it matters (gravitational potential is negative, work done on a gas is $-p\Delta V$).

4. For laws (Newton's, Coulomb's, Faraday's, Hubble's): name **the two quantities involved** and how they are related ("directly proportional", "inversely proportional to the square of").

5. Use SI base units in the exam unless specified otherwise. Cambridge sometimes notes "candidates will only be required to use SI units" — take the hint.

Pairs that are commonly confused

- **Random vs spontaneous** (radioactive decay): random = which nucleus decays, when, is unpredictable; spontaneous = unaffected by external conditions.
- **Mean vs root-mean-square** (a.c., kinetic theory): rms is the d.c. equivalent for power; mean of sin is zero.
- **Specific latent heat of fusion vs vaporisation**: fusion = solid↔liquid; vaporisation = liquid↔gas.
- **Mass defect vs binding energy**: mass defect is a **mass** (Δm); binding energy is the equivalent **energy** ($\Delta m\, c^2$).
- **Threshold frequency vs work function**: f_0 is a frequency (Hz); $\varphi = h f_0$ is an energy (J).

Definitions you must know word-perfect

Radian, gravitational field, gravitational potential, electric field, electric potential, capacitance, magnetic flux density, magnetic flux, e.m.f. & Faraday's law, Lenz's law, simple harmonic motion, resonance, photon, photoelectric effect, work function, de Broglie wavelength, mass defect, binding energy, half-life, decay constant, activity, specific acoustic impedance, luminosity, redshift, Hubble's law.

Memorise the green box · understand the italics · pass with confidence

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Telegram 0309 2656780 mahad__amer mahadamerchaudhry@gmail.com