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A-Level Physics

Equations · Formula Sheet

A-Level Physics | Formula Sheet | 55 entries

The key A-Level Physics equations across the whole course - with what each symbol means and when to use it.

Mechanics and materials

Equations of motion (suvat)	**Equation:** $v = u + at$; $s = ut + \frac{1}{2}at^2$; $v^2 = u^2 + 2as$; $s = \frac{1}{2}(u + v)t$. **Where:** s is displacement in m, u is initial velocity in m s^{-1}, v is final velocity in m s^{-1}, a is acceleration in m s^{-2} and t is time in s. **Use when:** motion is in a straight line with uniform (constant) acceleration.
Newton's second law	**Equation:** $F = ma$, or more generally $F = \Delta p \div \Delta t$. **Where:** F is the resultant force in N, m is mass in kg, a is acceleration in m s^{-2} and $\Delta p \div \Delta t$ is the rate of change of momentum. **Use when:** relating a resultant (net) force to the acceleration it produces.
Weight	**Equation:** $W = mg$. **Where:** W is weight in N, m is mass in kg and g is the gravitational field strength, about 9.81 N kg^{-1} at the Earth's surface. **Use when:** finding the downward force of gravity on a mass near a planet's surface.
Momentum	**Equation:** $p = mv$. **Where:** p is momentum in kg m s^{-1}, m is mass in kg and v is velocity in m s^{-1}. **Use when:** describing the quantity of motion of a body, and in any collision or explosion problem.
Conservation of momentum	**Equation:** $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$. **Where:** m is each mass in kg, u is each velocity before in m s^{-1} and v is each velocity after in m s^{-1}. **Use when:** analysing a collision or explosion with no external resultant force; total momentum stays the same.
Work done	**Equation:** $W = Fs\cos\theta$. **Where:** W is work done in J, F is force in N, s is distance moved in m and θ is the angle between the force and the direction of motion. **Use when:** a force moves its point of application; energy is transferred mechanically.
Kinetic energy	**Equation:** $E_k = \frac{1}{2}mv^2$. **Where:** E_k is kinetic energy in J, m is mass in kg and v is speed in m s^{-1}. **Use when:** finding the energy a body has because of its motion.
Gravitational potential energy (near surface)	**Equation:** $\Delta E_p = mg\Delta h$. **Where:** ΔE_p is the change in potential energy in J, m is mass in kg, g is gravitational field strength in N kg^{-1} and Δh is the change in height in m. **Use when:** a mass is raised or lowered through a small height in a uniform (constant) field near a planet's surface.
Power	**Equation:** $P = W \div t$, and for a moving body $P = Fv$. **Where:** P is power in W, W is work done or energy transferred in J, t is time in s, F is force in N and v is velocity in m s^{-1}. **Use when:** finding the rate of doing work or transferring energy.
Hooke's law	**Equation:** $F = k\Delta L$. **Where:** F is the applied force in N, k is the spring constant (stiffness) in N m^{-1} and ΔL is the extension in m. **Use when:** a spring or wire is stretched within its limit of proportionality, so extension is proportional to force.
Stress, strain and Young modulus	**Equation:** stress $\sigma = F \div A$; strain $\varepsilon = \Delta L \div L$; $E = \sigma \div \varepsilon$. **Where:** σ is stress in Pa, F is force in N, A is cross-sectional area in m^2, ε is strain (no unit), ΔL is extension in m, L is original length in m and E is the Young modulus in Pa. **Use when:** comparing the stiffness of materials independently of sample size.

Waves and optics

Wave speed	**Equation:** $v = f\lambda$. **Where:** v is wave speed in m s^{-1}, f is frequency in Hz and λ is wavelength in m. **Use when:** linking how fast a wave travels to its frequency and wavelength for any wave.
Frequency and period	**Equation:** $f = 1 \div T$. **Where:** f is frequency in Hz and T is the period (time for one cycle) in s. **Use when:** converting between how often a wave repeats and the time it takes for one full oscillation.
Refractive index	**Equation:** $n = c \div c_s$. **Where:** n is the refractive index (no unit), c is the speed of light in a vacuum, about 3.00×10^8 m s^{-1}, and c_s is the speed of light in the substance in m s^{-1}. **Use when:** describing how much a medium slows down and bends light.
Snell's law of refraction	**Equation:** $n_1 \sin\theta_1 = n_2 \sin\theta_2$. **Where:** n_1 and n_2 are the refractive indices of the two media and θ_1 and θ_2 are the angles to the normal in each medium. **Use when:** light crosses a boundary between two transparent media and changes direction.
Critical angle	**Equation:** $\sin\theta_c = n_2 \div n_1$. **Where:** θ_c is the critical angle, n_1 is the refractive index of the denser medium and n_2 is that of the less dense medium (with $n_1 > n_2$). **Use when:** finding the angle beyond which total internal reflection occurs, as in an optical fibre.
Two-source interference (Young's slits)	**Equation:** $w = \lambda D \div s$. **Where:** w is the fringe spacing in m, λ is wavelength in m, D is the slit-to-screen distance in m and s is the slit separation in m. **Use when:** finding the spacing of bright fringes in a double-slit interference pattern.
Diffraction grating	**Equation:** $d \sin\theta = n\lambda$. **Where:** d is the grating spacing (1 ÷ lines per metre) in m, θ is the angle of the maximum, n is the order (an integer) and λ is wavelength in m. **Use when:** finding the directions of the bright maxima produced by a diffraction grating.
Path difference for maxima and minima	**Equation:** constructive: path difference = nλ ; destructive: path difference = (n + ½)λ. **Where:** n is an integer and λ is wavelength in m. **Use when:** deciding whether two coherent waves arrive in phase (a bright fringe) or out of phase (a dark fringe).

Electricity

Electric current and charge	**Equation:** $I = \Delta Q \div \Delta t$. **Where:** I is current in A, ΔQ is charge in C and Δt is time in s. **Use when:** relating the flow of charge to current, or finding charge from current over time.
Potential difference	**Equation:** $V = W \div Q$. **Where:** V is potential difference in V, W is the energy transferred in J and Q is charge in C. **Use when:** finding the energy given to each coulomb of charge as it passes through a component.
Ohm's law	**Equation:** $V = IR$. **Where:** V is potential difference in V, I is current in A and R is resistance in Ω. **Use when:** a component is ohmic, so at constant temperature current is proportional to voltage.
Resistivity	**Equation:** $R = \rho L \div A$. **Where:** R is resistance in Ω, ρ is resistivity in Ω m, L is the length of the conductor in m and A is its cross-sectional area in m^2. **Use when:** finding the resistance of a wire from the material and its dimensions.
Electrical power	**Equation:** $P = IV = I^2R = V^2 \div R$. **Where:** P is power in W, I is current in A, V is potential difference in V and R is resistance in Ω. **Use when:** finding the rate at which a component transfers electrical energy; choose the form that fits the known quantities.
Electromotive force and internal resistance	**Equation:** $\varepsilon = I(R + r) = V + Ir$. **Where:** ε is the e.m.f. in V, I is current in A, R is external resistance in Ω, r is internal resistance in Ω and V is the terminal potential difference in V. **Use when:** a real cell loses some voltage across its own internal resistance under load.

Potential divider	**Equation:** $V_{out} = V_{in} \times R_2 \div (R_1 + R_2)$. **Where:** V_{out} is the output voltage in V, V_{in} is the supply voltage in V and R_1, R_2 are the two resistances in Ω. **Use when:** two resistors share a supply voltage to provide a chosen smaller output, as in a sensor circuit.

Further mechanics (circular and SHM)

Angular speed	**Equation:** $\omega = 2\pi \div T = 2\pi f$, and $v = r\omega$. **Where:** ω is angular speed in rad s^{-1}, T is the period in s, f is frequency in Hz, v is linear speed in m s^{-1} and r is radius in m. **Use when:** describing how fast an object turns around a circle and linking it to linear speed.
Centripetal acceleration	**Equation:** $a = v^2 \div r = \omega^2 r$. **Where:** a is centripetal acceleration in m s^{-2}, v is linear speed in m s^{-1}, r is radius in m and ω is angular speed in rad s^{-1}. **Use when:** an object moves in a circle; its acceleration points toward the centre.
Centripetal force	**Equation:** $F = mv^2 \div r = m\omega^2 r$. **Where:** F is the centripetal force in N, m is mass in kg, v is speed in m s^{-1}, r is radius in m and ω is angular speed in rad s^{-1}. **Use when:** finding the net inward force needed to keep a body moving on a circular path.
Defining equation of SHM	**Equation:** $a = -\omega^2 x$. **Where:** a is acceleration in m s^{-2}, ω is angular frequency in rad s^{-1} and x is displacement from equilibrium in m. **Use when:** acceleration is proportional to displacement and directed back toward equilibrium, the condition for simple harmonic motion.
SHM displacement and velocity	**Equation:** $x = A\cos(\omega t)$; $v = \pm\omega\sqrt{(A^2 - x^2)}$; $v_{max} = \omega A$. **Where:** x is displacement in m, A is amplitude in m, ω is angular frequency in rad s^{-1}, t is time in s and v is velocity in m s^{-1}. **Use when:** finding position or speed at any point of a simple harmonic oscillation.
Period of a mass-spring system	**Equation:** $T = 2\pi\sqrt{(m \div k)}$. **Where:** T is the period in s, m is the mass in kg and k is the spring constant in N m^{-1}. **Use when:** finding the time for one oscillation of a mass bouncing on a spring.
Period of a simple pendulum	**Equation:** $T = 2\pi\sqrt{(l \div g)}$. **Where:** T is the period in s, l is the length of the pendulum in m and g is gravitational field strength in N kg^{-1}. **Use when:** finding the period of a pendulum swinging through a small angle.

Thermal physics and gases

Specific heat capacity	**Equation:** $Q = mc\Delta\theta$. **Where:** Q is energy in J, m is mass in kg, c is specific heat capacity in J kg^{-1} K^{-1} and Δθ is the temperature change in K. **Use when:** a substance changes temperature without changing state.
Specific latent heat	**Equation:** $Q = mL$. **Where:** Q is energy in J, m is mass in kg and L is the specific latent heat in J kg^{-1}. **Use when:** a substance changes state at constant temperature, melting, freezing, boiling or condensing.
Ideal gas equation	**Equation:** $pV = nRT = NkT$. **Where:** p is pressure in Pa, V is volume in m^3, n is the amount in mol, R is the molar gas constant 8.31 J mol^{-1} K^{-1}, T is temperature in K, N is the number of molecules and k is the Boltzmann constant 1.38×10^{-23} J K^{-1}. **Use when:** relating the pressure, volume and temperature of a fixed amount of ideal gas.
Kinetic theory of gases	**Equation:** $pV = \frac{1}{3}Nm(c_{rms})^2$. **Where:** p is pressure in Pa, V is volume in m^3, N is the number of molecules, m is the mass of one molecule in kg and c_{rms} is the root-mean-square speed in m s^{-1}. **Use when:** linking the large-scale pressure of a gas to the motion of its molecules.
Mean kinetic energy of a molecule	**Equation:** $\frac{1}{2}m(c_{rms})^2 = (3 \div 2)kT$. **Where:** m is the mass of one molecule in kg, c_{rms} is the root-mean-square speed in m s^{-1}, k is the Boltzmann constant in J K^{-1} and T is temperature in K. **Use when:** showing that the average kinetic energy of a gas molecule is proportional to absolute temperature.

Fields (gravitational, electric, magnetic, capacitance)

Newton's law of gravitation	**Equation:** $F = Gm_1m_2 \div r^2$. **Where:** F is the gravitational force in N, G is the gravitational constant 6.67×10^{-11} N m^2 kg^{-2}, m_1 and m_2 are the masses in kg and r is their separation in m. **Use when:** finding the attractive force between two point or spherical masses.
Gravitational field strength	**Equation:** $g = F \div m$, and for a radial field $g = GM \div r^2$. **Where:** g is field strength in N kg^{-1}, F is force in N, m is the test mass in kg, M is the mass producing the field in kg and r is distance from its centre in m. **Use when:** describing the gravitational pull per kilogram at a point.
Gravitational potential	**Equation:** $V = -GM \div r$. **Where:** V is gravitational potential in J kg^{-1}, G is the gravitational constant, M is the mass in kg and r is distance from its centre in m. **Use when:** finding the energy per kilogram needed to bring a mass from infinity to that point; it is always negative.
Coulomb's law	**Equation:** $F = Q_1Q_2 \div (4\pi\varepsilon_0 r^2)$. **Where:** F is the electric force in N, Q_1 and Q_2 are the charges in C, ε_0 is the permittivity of free space 8.85×10^{-12} F m^{-1} and r is the separation in m. **Use when:** finding the force between two point charges; like charges repel, unlike attract.
Electric field strength	**Equation:** $E = F \div Q$; radial $E = Q \div (4\pi\varepsilon_0 r^2)$; uniform $E = V \div d$. **Where:** E is field strength in N C^{-1} or V m^{-1}, F is force in N, Q is charge in C, r is distance in m, V is potential difference in V and d is plate separation in m. **Use when:** describing the force per coulomb at a point in an electric field.
Capacitance	**Equation:** $C = Q \div V$. **Where:** C is capacitance in F, Q is the stored charge in C and V is the potential difference in V. **Use when:** finding how much charge a capacitor stores for each volt across it.
Energy stored in a capacitor	**Equation:** $E = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = Q^2 \div (2C)$. **Where:** E is energy in J, Q is charge in C, V is potential difference in V and C is capacitance in F. **Use when:** finding the energy stored on a charged capacitor; it equals the area under a charge-voltage graph.
Force on a current-carrying conductor	**Equation:** $F = BIl \sin\theta$. **Where:** F is force in N, B is magnetic flux density in T, I is current in A, l is the length of conductor in the field in m and θ is the angle between current and field. **Use when:** a wire carrying a current sits in a magnetic field; the force is greatest when the wire is at 90° to the field.
Magnetic flux and flux linkage	**Equation:** $\Phi = BA$; flux linkage $N\Phi = BAN\cos\theta$. **Where:** Φ is magnetic flux in Wb, B is flux density in T, A is area in m^2, N is the number of turns and θ is the angle between the field and the coil normal. **Use when:** finding the magnetic flux through a coil, the starting point for induction.
Faraday's and Lenz's laws of induction	**Equation:** $\varepsilon = -N(\Delta\Phi \div \Delta t)$. **Where:** ε is the induced e.m.f. in V, N is the number of turns, ΔΦ is the change in flux in Wb and Δt is the time in s. **Use when:** a changing flux links a coil; the minus sign (Lenz's law) shows the induced e.m.f. opposes the change causing it.
Transformer equation	**Equation:** $V_s \div V_p = N_s \div N_p$, and for an ideal transformer $V_pI_p = V_sI_s$. **Where:** V is voltage in V, N is the number of turns and I is current in A, with subscripts p for primary and s for secondary. **Use when:** finding how a transformer steps an alternating voltage up or down.

Nuclear and particle physics

Mass-energy equivalence	**Equation:** $E = mc^2$, so $\Delta E = \Delta m\, c^2$. **Where:** E is energy in J, m is mass in kg, Δm is the mass change in kg and c is the speed of light, about 3.00×10^8 m s^{-1}. **Use when:** finding the energy released when mass is lost in fission, fusion or radioactive decay.

Radioactive decay	**Equation:** $N = N_0 e^{-\lambda t}$, with activity $A = \lambda N$. **Where:** N is the number of undecayed nuclei at time t, N_0 is the initial number, λ is the decay constant in s^{-1}, t is time in s and A is activity in Bq. **Use when:** finding how many nuclei remain, or the activity, of a sample at a given time.
Half-life	**Equation:** $t_{½} = \ln 2 \div \lambda$. **Where:** $t_{½}$ is the half-life in s and λ is the decay constant in s^{-1}. **Use when:** finding the time for half the nuclei in a sample to decay, or converting between half-life and decay constant.
Photon energy	**Equation:** $E = hf = hc \div \lambda$. **Where:** E is photon energy in J, h is the Planck constant 6.63×10^{-34} J s, f is frequency in Hz, c is the speed of light in m s^{-1} and λ is wavelength in m. **Use when:** finding the energy of a single photon of electromagnetic radiation.
Photoelectric equation	**Equation:** $hf = \varphi + E_{k(max)}$. **Where:** hf is the photon energy in J, φ is the work function in J and $E_{k(max)}$ is the maximum kinetic energy of the emitted electron in J. **Use when:** light ejects electrons from a metal surface and only photons above the threshold frequency cause emission.
de Broglie wavelength	**Equation:** $\lambda = h \div p = h \div mv$. **Where:** λ is the de Broglie wavelength in m, h is the Planck constant in J s, p is momentum in kg m s^{-1}, m is mass in kg and v is speed in m s^{-1}. **Use when:** treating a moving particle, such as an electron, as having wave-like behaviour.