Cambridge AS & A Level · Physics 9702

Physics 9702 formulas and definitions: AS Level

All 112 formulas, facts and definitions to learn, by syllabus topic. Formulas the exam gives you are left out.

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AS Level

1 Physical quantities and units

Physical quantity = numerical magnitude × unit

Base units: kg, m, s, A, K

Prefixes: p 10^{-12}, n 10^{-9}, μ 10^{-6}, m 10^{-3}, c 10^{-2}, d 10^{-1}, k 10^{3}, M 10^{6}, G 10^{9}, T 10^{12}

N = kg m s^{-2}, J = kg m^2 s^{-2}, W = kg m^2 s^{-3}, Pa = kg m^{-1} s^{-2}, C = A s, V = kg m^2 s^{-3} A^{-1}, Ω = kg m^2 s^{-3} A^{-2}, Hz = s^{-1}

Percentage uncertainty $= \dfrac{\Delta x}{x} \times 100\%$

$y = a \pm b$: $\Delta y = \Delta a + \Delta b$

$y = \dfrac{a^p b^q}{c^r}$: $\dfrac{\Delta y}{y} = p\dfrac{\Delta a}{a} + q\dfrac{\Delta b}{b} + r\dfrac{\Delta c}{c}$

Repeated readings: value = mean, uncertainty = $\frac{1}{2}$ × range

True value = reading – zero error

Components of F at θ to a direction: $F\cos\theta$ along it, $F\sin\theta$ at right angles

Perpendicular vectors: $R = \sqrt{X^2 + Y^2}$, angle $= \tan^{-1}\dfrac{Y}{X}$

Cosine rule $a^2 = b^2 + c^2 - 2bc\cos A$; sine rule $\dfrac{a}{\sin A} = \dfrac{b}{\sin B}$

Circle $A = \pi r^2$; sphere $V = \frac{4}{3}\pi r^3$; cylinder $V = \pi r^2 l$; cuboid $V = lwh$

2 Kinematics

Speed $= \dfrac{\text{distance}}{\text{time}}$; velocity $v = \dfrac{\Delta s}{\Delta t}$ (rate of change of displacement)

Acceleration $a = \dfrac{\Delta v}{\Delta t}$ (rate of change of velocity)

Average speed $= \dfrac{\text{total distance}}{\text{total time}}$; average velocity $= \dfrac{\text{total displacement}}{\text{total time}}$

Gradient of s–t graph = velocity; gradient of v–t graph = acceleration

Area under v–t graph = displacement; area under a–t graph = change in velocity

$v = u + at$

$s = \frac{1}{2}(u + v)t$

Launch at θ to the horizontal: $u_x = u\cos\theta$, $u_y = u\sin\theta$

Speed from components: $v = \sqrt{v_x^2 + v_y^2}$, angle to horizontal $= \tan^{-1}\dfrac{v_y}{v_x}$

Free-fall experiment: $h = \frac{1}{2}gt^2$, so gradient of h against $t^2 = \frac{g}{2}$

Uncertainty in $g = \dfrac{2h}{t^2}$: $\%g = \%h + 2 \times \%t$

3 Dynamics

Momentum $p = mv$ (a vector; units kg m s^{-1} = N s)

Force = rate of change of momentum, $F = \dfrac{\Delta p}{\Delta t}$

$F = ma$ (resultant force, constant mass; a in the direction of F)

Change in momentum $\Delta p = F\Delta t$ = area under a force–time graph

Gradient of a momentum–time graph = resultant force

Force from a steady stream (jet, rocket, hose): $F = \dfrac{\Delta m}{\Delta t}\,v$

Weight $W = mg$

Conservation of momentum: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ (isolated system)

Kinetic energy $E_k = \frac{1}{2}mv^2$; also $E_k = \dfrac{p^2}{2m}$

Elastic collision: total E_k conserved; relative speed of approach = relative speed of separation

At terminal velocity: resultant force $= 0$ (weight = drag, plus upthrust in a fluid)

4 Forces, density and pressure

Moment $= F \times d$, d = perpendicular distance from the point to the line of action (N m)

Principle of moments: in equilibrium, sum of clockwise moments = sum of anticlockwise moments about the same point

Torque of a couple $= F \times d$, one force × perpendicular distance between the lines of action

Equilibrium: resultant force $= 0$ and resultant torque $= 0$

Three forces in equilibrium form a closed vector triangle

Density $\rho = \dfrac{m}{V}$ (kg m^{-3}; 1 g cm^{-3} $= 1000$ kg m^{-3})

Pressure $p = \dfrac{F}{A}$ (Pa $=$ N m^{-2})

Total pressure at depth h = atmospheric pressure $+\rho g h$

Floating: upthrust = weight; fraction submerged $= \rho_{\text{object}} / \rho_{\text{fluid}}$

Volume of a sphere $\frac{4}{3}\pi r^3$; of a cylinder $\pi r^2 h$

5 Work, energy and power

Work done $W = Fs$, s = displacement in the direction of the force; $W = Fs\cos\theta$ at an angle θ (J)

Work done by a gas at constant pressure $W = p\Delta V$

Change in gravitational potential energy $\Delta E_P = mg\Delta h$ (uniform field)

Kinetic energy $E_K = \frac{1}{2}mv^2$; also $E_K = \dfrac{p^2}{2m}$

Conservation of energy: energy is never created or destroyed; the total energy of a closed system is constant

Efficiency $= \dfrac{\text{useful energy output}}{\text{total energy input}} = \dfrac{\text{useful power output}}{\text{total power input}}$ (no unit)

Power $P = \dfrac{W}{t}$ (W = J s^{-1})

$P = Fv$

Component of weight down a slope $mg\sin\theta$

6 Deformation of solids

Hooke's law $F = kx$ (within the limit of proportionality)

Spring constant $k = \dfrac{F}{x}$ (N m^{-1})

Stress $\sigma = \dfrac{F}{A}$ (Pa = N m^{-2})

Strain $\varepsilon = \dfrac{x}{L}$ (no unit)

Young modulus $E = \dfrac{\sigma}{\varepsilon} = \dfrac{FL}{Ax}$ (Pa)

$k = \dfrac{EA}{L}$ for a wire

Area of a circular cross-section $A = \pi r^2 = \dfrac{\pi d^2}{4}$

Elastic potential energy $E_P = \frac{1}{2}Fx = \frac{1}{2}kx^2$ (within the limit of proportionality)

Work done = area under the force–extension graph

Springs in series $\dfrac{1}{k} = \dfrac{1}{k_1} + \dfrac{1}{k_2}$; in parallel $k = k_1 + k_2$

7 Waves

$v = f\lambda$ (and $c = f\lambda$ for electromagnetic waves)

$f = \dfrac{1}{T}$

Phase difference $= \dfrac{\Delta x}{\lambda} \times 360^\circ = \dfrac{\Delta t}{T} \times 360^\circ$

Intensity $I = \dfrac{P}{A}$ (W m^{-2})

$I \propto (\text{amplitude})^2$

Malus's law $I = I_0 \cos^2\theta$ (amplitude $A = A_0 \cos\theta$)

CRO: period $=$ divisions $\times$ time-base; amplitude $=$ divisions $\times$ y-gain

Visible light: 400 nm to 700 nm; the order and ranges of the spectrum

8 Superposition

Superposition: resultant displacement $=$ sum of the individual displacements

In phase: amplitude $A_1 + A_2$; antiphase: amplitude $|A_1 - A_2|$

$v = f\lambda$ (and $c = f\lambda$)

Stationary wave: node to node $= \frac{\lambda}{2}$, node to antinode $= \frac{\lambda}{4}$

String fixed at both ends or tube open at both ends: $L = \frac{n\lambda}{2}$

Tube closed at one end: $L = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}, \ldots$

Maximum: path difference $n\lambda$; minimum: $(n + \frac{1}{2})\lambda$ (sources in phase)

Phase difference $= \frac{\text{path difference}}{\lambda} \times 360^\circ$

Double slit: $\lambda = \dfrac{ax}{D}$

Diffraction grating: $d\sin\theta = n\lambda$, with $d = \frac{1}{\text{lines per metre}}$

Highest order: largest whole number $n \leq \frac{d}{\lambda}$; total maxima $2n_{\max} + 1$

Intensity $\propto$ (amplitude)^2

9 Electricity

$Q = It$

Number of carriers $N = \dfrac{Q}{e}$

Number density $n = \dfrac{\text{number of carriers}}{\text{volume}}$

$V = \dfrac{W}{Q}$, so $W = QV = VIt$

$P = VI = I^2R = \dfrac{V^2}{R}$

$P = \dfrac{W}{t}$

$R = \dfrac{V}{I}, V = IR$

$R = \dfrac{\rho L}{A}$

Area of a round wire $A = \dfrac{\pi d^2}{4} = \pi r^2$

Units: $1\ \mathrm{C} = 1\ \mathrm{A\ s}, 1\ \mathrm{V} = 1\ \mathrm{J\ C^{-1}}, 1\ \Omega = 1\ \mathrm{V\ A^{-1}}$, ρ in Ω m

10 D.C. circuits

E.m.f. $E = \dfrac{W}{Q}$ (energy to electrical, per unit charge)

P.d. $V = \dfrac{W}{Q}$ (electrical energy to other forms, per unit charge)

$E = V + Ir = I(R + r)$

Terminal p.d. $V = E - Ir$; V–I graph: intercept E, gradient $-r$

Power: total EI, external VI, wasted in the cell $I^2 r$

Kirchhoff's first law: $\sum I_{\text{in}} = \sum I_{\text{out}}$ (conservation of charge)

Kirchhoff's second law: round a closed loop, $\sum E = \sum IR$ (conservation of energy)

Potential divider $V_{\text{out}} = \dfrac{R_2}{R_1 + R_2} V_{\text{in}}$, $\dfrac{V_1}{V_2} = \dfrac{R_1}{R_2}$

Potentiometer (uniform wire, same current) $\dfrac{V_1}{V_2} = \dfrac{L_1}{L_2}$

Balanced dividers $\dfrac{R_1}{R_2} = \dfrac{R_3}{R_4}$

11 Particle physics

$A = Z + N$ (nucleons = protons + neutrons)

α: $A \to A - 4$, $Z \to Z - 2$; β^-: $Z \to Z + 1$; β^+: $Z \to Z - 1$; γ: no change

α: mass 4 u, charge $+2e$; β^-: charge $-e$; β^+: charge $+e$; β mass 5.5×10^{-4} u

Quark charges: u, c, t $= +\frac{2}{3}e$; d, s, b $= -\frac{1}{3}e$; antiquarks opposite

Proton uud, neutron udd; baryon = 3 quarks, meson = quark + antiquark

β^-: $\mathrm{d} \to \mathrm{u} + \mathrm{e}^- + \bar{\nu}$; β^+: $\mathrm{u} \to \mathrm{d} + \mathrm{e}^+ + \nu$

Charge-to-mass ratio $= \dfrac{q}{m}$ (C kg^{-1})

$E_{\mathrm{k}} = \frac{1}{2}mv^2$, momentum $p = mv$ (from Dynamics)