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INTERNATIONAL AS AND A-LEVEL
PHYSICS

(9630)

Data and formula booklet
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v1.2

DATA: FUNDAMENTAL CONSTANTS AND VALUES

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^{8}	$\mathrm{m\ s^{-1}}$
permeability of free space	μ_o	$4\pi \times 10^{-7}$	$\mathrm{H\ m^{-1}}$
permittivity of free space	ε_o	8.85×10^{-12}	$\mathrm{F\ m^{-1}}$
magnitude of the charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\mathrm{N\ m^{2}\ kg^{-2}}$
the Avogadro constant	N_A	6.02×10^{23}	$\mathrm{mol^{-1}}$
molar gas constant	R	8.31	$\mathrm{J\ K^{-1}\ mol^{-1}}$
the Boltzmann constant	k	1.38×10^{-23}	$\mathrm{J\ K^{-1}}$
electron rest mass (equivalent to 5.5×10^{-4} u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	$\frac{e}{m_e}$	1.76×10^{11}	$\mathrm{C\ kg^{-1}}$
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$\frac{e}{m_p}$	9.58×10^{7}	$\mathrm{C\ kg^{-1}}$
neutron rest mass (equivalent to 1.00867 u)	m_n	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	g	9.81	$\mathrm{N\ kg^{-1}}$
acceleration due to gravity	g	9.81	$\mathrm{m\ s^{-2}}$
atomic mass unit (1u is equivalent to 931.5 MeV)	u	1.661×10^{-27}	kg

Astronomical data

Body	Mass/kg	Mean radius/m
Sun	1.99×10^{30}	6.96×10^{8}
Earth	5.98×10^{24}	6.37×10^{6}

Geometric equations

arc length	$= r\theta$
circumference of circle	$= 2\pi r$
area of circle	$= \pi r^2$
surface area of cylinder	$= 2\pi rh$
area of sphere	$= 4\pi r^2$
volume of sphere	$= \frac{4}{3}\pi r^3$

Unit 1

Mechanics and materials

moments: $\text{moment} = Fd$

velocity and acceleration: $v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$

equations of motion: $v = u + at$

$v^2 = u^2 + 2as$

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

$s = ut + \frac{1}{2}at^2$

force: $F = ma$

$F = \frac{\Delta(mv)}{\Delta t}$

impulse: $F\,\Delta t = \Delta(mv)$

work, energy and power: $W = F s \cos\theta$

$E_K = \frac{1}{2}m v^2$ $\Delta E_P = mg\Delta h$

$P = \frac{\Delta W}{\Delta t}$, $P = Fv$

$\text{efficiency} = \frac{\text{useful output power}}{\text{input power}}$

density: $\rho = \frac{m}{V}$

Hooke's law: $F = k\,\Delta L$

Young modulus = $\frac{\text{tensile stress}}{\text{tensile strain}}$

tensile stress = $\frac{F}{A}$

tensile strain = $\frac{\Delta L}{L}$

energy stored: $E = \frac{1}{2}F\Delta L$

Particles, radiation and radioactivity

inverse square law for γ radiation: $I = \frac{I_0}{r^2}$

Unit 2

Electricity

current and pd: $I = \frac{\Delta Q}{\Delta t}$ $V = \frac{W}{Q}$ $R = \frac{V}{I}$

resistivity: $\rho = \frac{RA}{L}$

resistors in series: $R_T = R_1 + R_2 + R_3 + \ldots$

resistors in parallel: $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

energy transferred: $E = IVt$

power: $P = VI = I^2R = \frac{V^2}{R}$

emf: $\varepsilon = \frac{E}{Q}$ $\varepsilon = I(R + r)$

Oscillations and waves

for a mass-spring system: $T = 2\pi\sqrt{\frac{m}{k}}$

for a simple pendulum: $T = 2\pi\sqrt{\frac{l}{g}}$

wave speed: $c = f\lambda$ period: $f = \frac{1}{T}$

first harmonic: $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

fringe spacing: $w = \frac{\lambda D}{s}$ diffraction grating: $d\sin\theta = n\lambda$

refractive index of a substance *s*, $n = \frac{c}{c_s}$

for two different substances of refractive indices n_1 *and* n_2,

law of refraction: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

critical angle: $\sin\theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$

photon energy: $E = hf = \frac{hc}{\lambda}$

photoelectricity: $hf = \phi + E_{k(max)}$

energy levels: $hf = E_1 - E_2$

de Broglie wavelength: $\lambda = \frac{h}{p} = \frac{h}{mv}$

Unit 3

Circular motion and periodic motion

magnitude of angular speed	$\omega = \frac{v}{r}$
	$\omega = 2\pi f$
centripetal acceleration	$a = \frac{v^2}{r} = \omega^2 r$
centripetal force	$F = \frac{mv^2}{r} = m\omega^2 r$
acceleration	$a = -\omega^2 x$
displacement	$x = A\cos(\omega t)$
speed	$v = \pm\omega\sqrt{A^2 - x^2}$
maximum speed	$v_{max} = \omega A$
maximum acceleration	$a_{max} = \omega^2 A$
for a mass-spring system	$T = 2\pi\sqrt{\frac{m}{k}}$
for a simple pendulum	$T = 2\pi\sqrt{\frac{l}{g}}$
total energy of an oscillator	$E = \frac{1}{2} m\omega^2 A^2$

Gravitational fields and satellites

force between point masses	$F = \frac{Gm_1 m_2}{r^2}$
gravitational field strength	$g = \frac{F}{m}$
magnitude of gravitational field strength in a radial field	$g = \frac{GM}{r^2}$
work done	$\Delta W = m\Delta V$
gravitational potential	$V = -\frac{GM}{r}$
	$g = -\frac{\Delta V}{\Delta r}$

Exponential change

time constant	RC
time to halve	$T_{½} = \ln 2\, RC$
capacitor charging	$Q = Q_0(1 - e^{-\frac{t}{RC}})$
capacitor discharging	$Q = Q_0 e^{-\frac{t}{RC}}$
radioactive decay	$\frac{\Delta N}{\Delta t} = -\lambda N$
	$N = N_0 e^{-\lambda t}$
activity	$A = \lambda N$
	$A = A_0 e^{-\lambda t}$
half-life	$T_{½} = \frac{\ln 2}{\lambda}$

Electric fields and capacitance

force between point charges in a vacuum	$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$
force on a charge	$E = \frac{F}{Q}$
field strength for a uniform field	$E = \frac{V}{d}$
field strength for a radial field	$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$
work done moving a charge Q	$\Delta W = Q\Delta V$
	$Fd = Q\Delta V$
electric potential	$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$
	$E = \frac{\Delta V}{\Delta r}$
capacitance	$C = \frac{Q}{V}$
	$C = \frac{A\varepsilon_0\varepsilon_r}{d}$
capacitor energy stored	$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$

Magnetic fields

force on a current	$F = BIl$
force on a moving charge	$F = BQv$
magnetic flux	$\Phi = BA$
magnetic flux linkage	$N\Phi = BAN\cos\theta$
magnitude of induced emf	$\varepsilon = \frac{\Delta\Phi}{\Delta t}$
emf induced in a rotating coil	$\varepsilon = BAN\omega\sin\omega t$
alternating current	$I_{rms} = \frac{I_0}{\sqrt{2}}$ $V_{rms} = \frac{V_0}{\sqrt{2}}$
transformer equations	$\frac{N_s}{N_p} = \frac{V_s}{V_p}$
	efficiency $= \frac{I_s V_s}{I_p V_p}$

Unit 4

Thermal physics

energy to change temperature	$Q = mc\Delta\theta$
energy to change state	$Q = ml$
gas law	$pV = nRT$ $pV = NkT$
kinetic theory model	$pV = \frac{1}{3}Nm\,(c_{rms})^2$
kinetic energy of gas molecule	$\frac{1}{2}m\,(c_{rms})^2 = \frac{3}{2}kT = \frac{3RT}{2N_A}$
thermodynamics	$\Delta U = Q + W$ $W = p\Delta V$
rate of energy transfer by conduction	$\frac{kA\Delta\theta}{L}$
rate of energy transfer	$UA\Delta\theta$

Nuclear physics

nuclear radius	$R = R_0\,A^{1/3}$
energy-mass equation	$E = m\,c^2$

Energy sources

moment of inertia	$I = mr^2$ $I = \Sigma mr^2$
angular kinetic energy	$E_{\mathrm{k(rot)}} = \frac{1}{2}I\omega^2$
equations of angular motion	$\omega = \omega_0 + \alpha\,t$ $\omega^2 = {\omega_0}^2 + 2\alpha\theta$ $\theta = \omega_0 t + \frac{1}{2}\alpha t^2$ $\theta = \frac{(\omega_0 + \omega)}{2}t$
torque	$T = I\alpha$ $T = Fr$
angular momentum	$I\omega$
angular impulse	$T\Delta t = \Delta(I\omega)$
work done	$W = T\theta$
power	$P = T\omega$
maximum power available from a turbine	$P = \frac{1}{2}\pi r^2\rho v^3$
solar intensity	$I = \frac{P}{4\pi r^2}$