INTERNATIONAL AS AND A-LEVEL PHYSICS (9630)
Data and Formula Booklet Insert (v1.3)

DATA: FUNDAMENTAL CONSTANTS AND VALUES

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^8	m s^{-1}
permeability of free space	μ_o	$4\pi \times 10^{-7}$	H m^{-1}
permittivity of free space	ε_o	8.85×10^{-12}	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}	$\text{N m}^2 \text{ kg}^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$\text{J K}^{-1} \text{ mol}^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}
electron rest mass (equivalent to 5.5×10^{-4} u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	$\dfrac{e}{m_e}$	1.76×10^{11}	C kg^{-1}
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$\dfrac{e}{m_p}$	9.58×10^7	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	N kg^{-1}
acceleration due to gravity	g	9.81	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	$= \dfrac{4}{3}\pi r^3$

Unit 1

Mechanics and materials

| moments | $\text{moment} = Fd$ |

| velocity and acceleration | $v = \dfrac{\Delta s}{\Delta t}$ | $a = \dfrac{\Delta v}{\Delta t}$ |

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 $\quad F\,\Delta t = \Delta(mv)$

work, energy and power

$$W = F\,s\cos\theta$$

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

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

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

density $\quad \rho = \dfrac{m}{V}$

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

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

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

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

energy stored $\quad E = \dfrac{1}{2} F\Delta L$

Particles, radiation and radioactivity

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

Unit 2

Electricity

| current and pd | $I = \dfrac{\Delta Q}{\Delta t}$ | $V = \dfrac{W}{Q}$ | $R = \dfrac{V}{I}$ |

resistivity $\quad \rho = \dfrac{RA}{L}$

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

resistors in parallel $\quad \dfrac{1}{R_T} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \cdots$

energy transferred $\quad E = IVt$

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

emf $\quad \varepsilon = \dfrac{E}{Q} \qquad \varepsilon = I(R + r)$

Oscillations and waves

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

for a simple pendulum $\quad T = 2\pi\sqrt{\dfrac{l}{g}}$

wave speed $\quad c = f\lambda \qquad$ period $\quad f = \dfrac{1}{T}$

first harmonic $\quad f = \dfrac{1}{2l}\sqrt{\dfrac{T}{\mu}}$

fringe spacing $\quad w = \dfrac{\lambda D}{s} \qquad$ diffraction grating $\quad d\sin\theta = n\lambda$

refractive index of a substance s, $\quad n = \dfrac{c}{c_s}$

for two different substances of refractive indices n_1 and n_2,

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

critical angle $\quad \sin\theta_c = \dfrac{n_2}{n_1}$ for $n_1 > n_2$

photon energy $\quad E = hf = \dfrac{hc}{\lambda}$

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

energy levels $\quad hf = E_1 - E_2$

de Broglie wavelength $\quad \lambda = \dfrac{h}{p} = \dfrac{h}{mv}$

Unit 3

Circular motion and periodic motion

magnitude of angular speed	$\omega = \dfrac{v}{r}$
	$\omega = 2\pi f$
centripetal acceleration	$a = \dfrac{v^2}{r} = \omega^2 r$
centripetal force	$F = \dfrac{mv^2}{r} = m\omega^2 r$
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	$T = 2\pi \sqrt{\dfrac{m}{k}}$
for a simple pendulum	$T = 2\pi \sqrt{\dfrac{l}{g}}$
total energy of an oscillator	$E = \dfrac{1}{2} m \omega^2 A^2$

Gravitational fields and satellites

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

Exponential change

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

Electric fields and capacitance

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

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	$\varepsilon = \dfrac{\Delta\Phi}{\Delta t}$
emf induced in a rotating coil	$\varepsilon = BAN\omega \sin\omega t$
alternating current	$I_{rms} = \dfrac{I_0}{\sqrt{2}}$ $\quad$ $V_{rms} = \dfrac{V_0}{\sqrt{2}}$
transformer equations	$\dfrac{N_s}{N_p} = \dfrac{V_s}{V_p}$
	efficiency $= \dfrac{I_s V_s}{I_p V_p}$

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	$\dfrac{kA\Delta\theta}{L}$
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	$E_{k(rot)} = \frac{1}{2}I\omega^2$
equations of angular motion	$\omega = \omega_0 + \alpha t$
	$\omega^2 = \omega_0^2 + 2\alpha\theta$
	$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$
	$\theta = \dfrac{(\omega_0 + \omega)}{2}t$
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	$I = \dfrac{P}{4\pi r^2}$