

INTERNATIONAL AS AND A-LEVEL PHYSICS (9630) Data and Formulae Booklet Insert (v1.4)

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_0	$4\pi \times 10^{-7}$	H m^{-1}
permittivity of free space	ϵ_0	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	$\frac{e}{m_e}$	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	$\frac{e}{m_p}$	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	$= 2\pi r h$
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	$W = F s \cos \theta$ $E_k = \frac{1}{2} m v^2$ $\Delta E_p = mg\Delta h$ $P = \frac{\Delta W}{\Delta t}, P = Fv$ 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	$R_T = R_1 + R_2 + R_3 + \dots$
resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
energy transferred	$E = IVt$
power	$P = VI = I^2 R = \frac{V^2}{R}$
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	$T_{1/2} = \ln 2 RC$
capacitor charging	$Q = Q_0(1 - e^{-\frac{t}{RC}})$
capacitor discharging	$Q = Q_0 e^{-\frac{t}{RC}}$
radioactive decay	$\frac{\Delta N}{\Delta t} = -\lambda N$
	$N = N_0 e^{-\lambda t}$
activity	$A = \lambda N$
	$A = A_0 e^{-\lambda t}$
half-life	$T_{1/2} = \frac{\ln 2}{\lambda}$

Electric fields and capacitance

force between point charges in a vacuum	$F = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r^2}$
force on a charge	$E = \frac{F}{Q}$
field strength for a uniform field	$E = \frac{V}{d}$
field strength for a radial field	$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$
work done moving a charge Q	$\Delta W = Q\Delta V$
	$Fd = Q\Delta V$
electric potential	$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$
	$E = \frac{\Delta V}{\Delta r}$
capacitance	$C = \frac{Q}{V}$
	$C = \frac{A\epsilon_0\epsilon_r}{d}$
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	$\epsilon = \frac{\Delta \Phi}{\Delta t}$
emf induced in a rotating coil	$\epsilon = BAN\omega \sin \omega t$
alternating current	$I_{rms} = \frac{I_0}{\sqrt{2}} \quad V_{rms} = \frac{V_0}{\sqrt{2}}$
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 $E = mc^2$

Energy sources

moment of inertia $I = mr^2$
 $I = \Sigma mr^2$

angular kinetic energy $E_{k(\text{rot})} = \frac{1}{2}I\omega^2$

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 $I = \frac{P}{4\pi r^2}$