

# 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	$c$	$3.00 \times 10^8$	$\text{m s}^{-1}$
permeability of free space	$\mu_0$	$4\pi \times 10^{-7}$	$\text{H m}^{-1}$
permittivity of free space	$\epsilon_0$	$8.85 \times 10^{-12}$	$\text{F m}^{-1}$
magnitude of the charge of electron	$e$	$1.60 \times 10^{-19}$	C
the Planck constant	$h$	$6.63 \times 10^{-34}$	J s
gravitational constant	$G$	$6.67 \times 10^{-11}$	$\text{N m}^2 \text{kg}^{-2}$
the Avogadro constant	$N_A$	$6.02 \times 10^{23}$	$\text{mol}^{-1}$
molar gas constant	$R$	8.31	$\text{J K}^{-1} \text{mol}^{-1}$
the Boltzmann constant	$k$	$1.38 \times 10^{-23}$	$\text{J K}^{-1}$
electron rest mass (equivalent to $5.5 \times 10^{-4}$ u)	$m_e$	$9.11 \times 10^{-31}$	kg
electron charge/mass ratio	$\frac{e}{m_e}$	$1.76 \times 10^{11}$	$\text{C kg}^{-1}$
proton rest mass (equivalent to 1.00728 u)	$m_p$	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$\frac{e}{m_p}$	$9.58 \times 10^7$	$\text{C kg}^{-1}$
neutron rest mass (equivalent to 1.00867 u)	$m_n$	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	$g$	9.81	$\text{N kg}^{-1}$
acceleration due to gravity	$g$	9.81	$\text{m s}^{-2}$
atomic mass unit (1u is equivalent to 931.5 MeV)	u	$1.661 \times 10^{-27}$	kg

### Astronomical data

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

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