

# Physics A

## Data and Formulae Booklet

### DATA

#### FUNDAMENTAL CONSTANTS AND VALUES

<i>Quantity</i>	<i>Symbol</i>	<i>Value</i>	<i>Units</i>
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	$k$	$1.38 \times 10^{-23}$	$\text{J K}^{-1}$
the Stefan constant	$\sigma$	$5.67 \times 10^{-8}$	$\text{W m}^{-2} \text{K}^{-4}$
the Wien constant	$\alpha$	$2.90 \times 10^{-3}$	m K
electron rest mass (equivalent to $5.5 \times 10^{-4}$ u)	$m_e$	$9.11 \times 10^{-31}$	kg
electron charge/mass ratio	$e/m_e$	$1.76 \times 10^{11}$	$\text{C kg}^{-1}$
proton rest mass (equivalent to 1.00728 u)	$m_p$	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$e/m_p$	$9.58 \times 10^7$	$\text{C kg}^{-1}$
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

#### GEOMETRICAL EQUATIONS

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

#### ASTRONOMICAL DATA

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

## AS FORMULAE

## PARTICLE PHYSICS

## Rest energy values

class	name	symbol	rest energy /MeV
photon	photon	$\gamma$	0
lepton	neutrino	$\nu_e$	0
		$\nu_\mu$	0
	electron	$e^\pm$	0.510999
	muon	$\mu^\pm$	105.659
mesons	$\pi$ meson	$\pi^\pm$	139.576
		$\pi^0$	134.972
	K meson	$K^\pm$	493.821
		$K^0$	497.762
baryons	proton	p	938.257
	neutron	n	939.551

## Properties of quarks

antiquarks have opposite signs

type	charge	baryon number	strangeness
<b>u</b>	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
<b>d</b>	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
<b>s</b>	$-\frac{1}{3}e$	$+\frac{1}{3}$	-1

## Properties of leptons

	lepton number
particles: $e^-, \nu_e; \mu^-, \nu_\mu$	+1
antiparticles: $e^+, \bar{\nu}_e; \mu^+, \bar{\nu}_\mu$	-1

## Photons and energy levels

photon energy  $E = hf = hc/\lambda$

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

energy levels  $hf = E_1 - E_2$

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

## ELECTRICITY

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

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

resistors in series  $R = R_1 + R_2 + R_3 + \dots$

resistors in parallel  $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$

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

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

alternating current  $I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$   $V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$

## MECHANICS

moments moment =  $Fd$

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

equations of motion  $v = u + at$   $s = \frac{(u+v)t}{2}$

$v^2 = u^2 + 2as$   $s = ut + \frac{at^2}{2}$

force  $F = ma$

work, energy and power  $W = Fs \cos \theta$   $E_K = \frac{1}{2}mv^2$   $\Delta E_p = mg\Delta h$

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

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

## MATERIALS

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

## WAVES

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

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  $n_1 > n_2$

**A2 FORMULAE****MOMENTUM**

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

*impulse*  $F \Delta t = \Delta(mv)$

**CIRCULAR MOTION**

*angular velocity*  $\omega = \frac{v}{r}$

$$\omega = 2\pi f$$

*centripetal acceleration*  $a = \frac{v^2}{r} = \omega^2 r$

*centripetal force*  $F = \frac{mv^2}{r} = m\omega^2 r$

**OSCILLATIONS**

*acceleration*  $a = -(2\pi f)^2 x$

*displacement*  $x = A \cos(2\pi f t)$

*speed*  $v = \pm 2\pi f \sqrt{A^2 - x^2}$

*maximum speed*  $v_{\max} = 2\pi f A$

*maximum acceleration*  $a_{\max} = (2\pi f)^2 A$

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

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

**GRAVITATIONAL FIELDS**

*force between two masses*  $F = \frac{G m_1 m_2}{r^2}$

*gravitational field strength*  $g = \frac{F}{m}$

*magnitude of gravitational field strength in a radial field*  $g = \frac{GM}{r^2}$

*gravitational potential*  $\Delta W = m \Delta V$

$$V = -\frac{GM}{r}$$

$$g = -\frac{\Delta V}{\Delta r}$$

**ELECTRIC FIELDS AND CAPACITORS**

*force between two point charges*  $F = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r^2}$

*force on a charge*  $F = EQ$

*field strength for a uniform field*  $E = \frac{V}{d}$

*field strength for a radial field*  $E = \frac{Q}{4\pi\epsilon_0 r^2}$

*electric potential*  $\Delta W = Q \Delta V$

$$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$$

*capacitance*  $C = \frac{Q}{V}$

*decay of charge*  $Q = Q_0 e^{-t/RC}$

*time constant*  $RC$

*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*  $N\Phi = BAN$

*magnitude of induced emf*  $\epsilon = N \frac{\Delta\Phi}{\Delta t}$

*emf induced in a rotating coil*  $N\Phi = BAN \cos \theta$   
 $\epsilon = BAN \omega \sin \omega t$

*transformer equations*  $\frac{N_s}{N_p} = \frac{V_s}{V_p}$

$$\text{efficiency} = \frac{I_s V_s}{I_p V_p}$$

**RADIOACTIVITY AND NUCLEAR PHYSICS**

*the inverse square law for  $\gamma$  radiation*  $I = \frac{k}{x^2}$

*radioactive decay*  $\frac{\Delta N}{\Delta t} = -\lambda N, N = N_0 e^{-\lambda t}$

*activity*  $A = \lambda N$

*half-life*  $T_{1/2} = \frac{\ln 2}{\lambda}$

*nuclear radius*  $R = r_0 A^{1/3}$

*energy-mass equation*  $E = mc^2$

**GASES AND THERMAL PHYSICS**

*gas law*  $pV = nRT$

$$pV = NkT$$

*kinetic theory model*  $pV = \frac{1}{3} N m (c_{\text{rms}})^2$

*kinetic energy of gas molecule*  $\frac{1}{2} m (c_{\text{rms}})^2 = \frac{3}{2} kT = \frac{3RT}{2N_A}$

*energy to change temperature*  $Q = mc\Delta T$

*energy to change state*  $Q = ml$

**OPTIONS FORMULAE****ASTROPHYSICS**

1 astronomical unit =  $1.50 \times 10^{11}$  m

1 light year =  $9.46 \times 10^{15}$  m

1 parsec =  $206265$  AU =  $3.08 \times 10^{16}$  m  
= 3.26 light years

Hubble constant,  $H = 65 \text{ km s}^{-1} \text{ Mpc}^{-1}$

lens equation  $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$

in normal adjustment  $M = \frac{f_o}{f_e}$

resolving power  $\theta \approx \frac{\lambda}{D}$

magnitude equation  $m - M = 5 \log \frac{d}{10}$

Wien's law  $\lambda_{\text{max}} T = 0.0029 \text{ m K}$

Hubble's law  $v = H d$

Stefan's law  $P = \sigma A T^4$

Doppler shift for  $v \ll c$   $z = \frac{\Delta f}{f} = -\frac{\Delta \lambda}{\lambda} = \frac{v}{c}$

Schwarzschild radius  $R_s = \frac{2GM}{c^2}$

**MEDICAL PHYSICS**

lens equations  $P = \frac{1}{f}$

$$m = \frac{v}{u}$$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

intensity level intensity level =  $10 \log \frac{I}{I_0}$

absorption  $I = I_0 e^{-\mu x}$

$$\mu_m = \frac{\mu}{\rho}$$

**APPLIED PHYSICS**

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

angular kinetic energy  $E_k = \frac{1}{2} I \omega^2$

equations of angular motion

$$\omega_2 = \omega_1 + \alpha t$$

$$\omega_2^2 = \omega_1^2 + 2\alpha\theta$$

$$\theta = \omega_1 t + \frac{1}{2} \alpha t^2$$

$$\theta = \frac{1}{2} (\omega_1 + \omega_2) t$$

torque

$$T = I \alpha$$

angular momentum

$$\text{angular momentum} = I \omega$$

work done

$$W = T \theta$$

power

$$P = T \omega$$

thermodynamics

$$Q = \Delta U + W$$

$$W = p \Delta V$$

adiabatic change

$$pV^\gamma = \text{constant}$$

isothermal change

$$pV = \text{constant}$$

heat engines

$$\text{efficiency} = \frac{W}{Q_{\text{in}}} = \frac{Q_{\text{in}} - Q_{\text{out}}}{Q_{\text{in}}}$$

$$\text{maximum efficiency} = \frac{T_{\text{H}} - T_{\text{C}}}{T_{\text{H}}}$$

work done per cycle = area of loop

input power = calorific value  $\times$  fuel flow rate

indicated power = (area of  $p$ - $V$  loop)  $\times$  (no of cycles per second)  $\times$  number of cylinders

output or brake power  $P = T \omega$

friction power = indicated power - brake power

heat pumps and refrigerators

$$\text{refrigerator: } COP_{\text{ref}} = \frac{Q_{\text{out}}}{W} = \frac{Q_{\text{out}}}{Q_{\text{in}} - Q_{\text{out}}}$$

$$\text{heat pump: } COP_{\text{hp}} = \frac{Q_{\text{in}}}{W} = \frac{Q_{\text{in}}}{Q_{\text{in}} - Q_{\text{out}}}$$

**TURNING POINTS IN PHYSICS**

electrons in fields  $F = \frac{eV}{d}$

$$F = Bev$$

$$r = \frac{mv}{Be}$$

$$\frac{1}{2} mv^2 = eV$$

$$\frac{QV}{d} = mg$$

$$F = 6\pi \eta r v$$

wave particle duality  $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$$

special relativity

$$E = mc^2 = \frac{m_0 c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

$$l = l_0 \left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}} \quad t = t_0 \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$$