Physics A

AS Level Physics A (H156)
A Level Physics A (H556)

Data, Formulae and Relationships Booklet

INSTRUCTIONS
- Do **not** send this Booklet for marking. Keep it in the centre or recycle it.

INFORMATION
- This document has **8** pages.

Data, Formulae and Relationships

Data

Values are given to three significant figures, except where more – or fewer – are useful.

Physical constants

acceleration of free fall	g	$9.81\,\mathrm{m\,s^{-2}}$
elementary charge	e	$1.60 \times 10^{-19}\,\mathrm{C}$
speed of light in a vacuum	c	$3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
Planck constant	h	$6.63 \times 10^{-34}\,\mathrm{J\,s}$
Avogadro constant	N_A	$6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
molar gas constant	R	$8.31\,\mathrm{J\,mol^{-1}\,K^{-1}}$
Boltzmann constant	k	$1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	G	$6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$
permittivity of free space	ε_0	$8.85 \times 10^{-12}\,\mathrm{C^2\,N^{-1}\,m^{-2}}$ $(\mathrm{F\,m^{-1}})$
electron rest mass	m_e	$9.11 \times 10^{-31}\,\mathrm{kg}$
proton rest mass	m_p	$1.673 \times 10^{-27}\,\mathrm{kg}$
neutron rest mass	m_n	$1.675 \times 10^{-27}\,\mathrm{kg}$
alpha particle rest mass	m_α	$6.646 \times 10^{-27}\,\mathrm{kg}$
Stefan constant	σ	$5.67 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$

Quarks

up quark	charge = $+\frac{2}{3}e$
down quark	charge = $-\frac{1}{3}e$
strange quark	charge = $-\frac{1}{3}e$

Conversion factors

unified atomic mass unit	$1\,u = 1.661 \times 10^{-27}\,kg$
electronvolt	$1\,eV = 1.60 \times 10^{-19}\,J$
day	$1\ \text{day} = 8.64 \times 10^{4}\,s$
year	$1\ \text{year} \approx 3.16 \times 10^{7}\,s$
light year	$1\ \text{light year} \approx 9.5 \times 10^{15}\,m$
parsec	$1\ \text{parsec} \approx 3.1 \times 10^{16}\,m$

Mathematical equations

arc length = $r\theta$

circumference of circle = $2\pi r$

area of circle = πr^2

curved surface area of cylinder = $2\pi rh$

surface area of sphere = $4\pi r^2$

area of trapezium = $\frac{1}{2}(a + b)h$

volume of cylinder = $\pi r^2 h$

volume of sphere = $\frac{4}{3}\pi r^3$

Pythagoras' theorem: $a^2 = b^2 + c^2$

cosine rule: $a^2 = b^2 + c^2 - 2bc\cos A$

sine rule: $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$

$\sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$ for small angles

$\log(AB) = \log(A) + \log(B)$ (Note: $\lg = \log_{10}$ and $\ln = \log_e$)

$\log\left(\frac{A}{B}\right) = \log(A) - \log(B)$

$\log(x^n) = n\log(x)$

$\ln(e^{kx}) = kx$

Formulae and relationships

Module 2 – Foundations of physics	
vectors	$F_x = F \cos \theta$ $F_y = F \sin \theta$
Module 3 – Forces and motion	
uniformly accelerated motion	$v = u + at$ $s = \frac{1}{2}(u + v)t$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
force	$F = \frac{\Delta p}{\Delta t}$ $p = mv$
turning effects	moment = Fx torque = Fd
density	$\rho = \frac{m}{V}$
pressure	$p = \frac{F}{A}$ $p = h\rho g$
work, energy and power	$W = Fx \cos \theta$ efficiency = $\frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$ $P = \frac{W}{t}$ $P = Fv$
springs and materials	$F = kx$ $E = \frac{1}{2}Fx$; $E = \frac{1}{2}kx^2$ $\sigma = \frac{F}{A}$ $\varepsilon = \frac{x}{L}$ $E = \frac{\sigma}{\varepsilon}$

Module 4 – Electrons, waves and photons	
charge	$\Delta Q = I\Delta t$
current	$I = Anev$
work done	$W = VQ$; $W = \mathcal{E}Q$; $W = VIt$
resistance and resistors	$R = \frac{\rho L}{A}$ $R = R_1 + R_2 + \ldots$ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots.$
power	$P = VI$, $P = I^2R$ and $P = \frac{V^2}{R}$
internal resistance	$\mathcal{E} = I(R + r)$; $\mathcal{E} = V + Ir$
potential divider	$V_{out} = \frac{R_2}{R_1 + R_2} \times V_{in}$ $\frac{V_1}{V_2} = \frac{R_1}{R_2}$
waves	$v = f\lambda$ $f = \frac{1}{T}$ $I = \frac{P}{A}$ $\lambda = \frac{a\,x}{D}$
refraction	$n = \frac{c}{v}$ $n \sin\theta$ = constant $\sin C = \frac{1}{n}$
quantum physics	$E = hf \quad E = \frac{hc}{\lambda}$ $hf = \phi + KE_{max}$ $\lambda = \frac{h}{p}$

Module 5 – Newtonian world and astrophysics	
thermal physics	$E = mc\Delta\theta$
	$E = mL$
ideal gases	$pV = NkT$; $pV = nRT$
	$pV = \frac{1}{3}Nm\,\overline{c^2}$
	$\frac{1}{2}m\,\overline{c^2} = \frac{3}{2}kT$
	$E = \frac{3}{2}kT$
circular motion	$\omega = \frac{2\pi}{T}$; $\omega = 2\pi f$
	$v = \omega r$
	$a = \frac{v^2}{r}$; $a = \omega^2 r$
	$F = \frac{mv^2}{r}$; $F = m\omega^2 r$
oscillations	$\omega = \frac{2\pi}{T}$; $\omega = 2\pi f$
	$a = -\omega^2 x$
	$x = A\cos\omega t$; $x = A\sin\omega t$
	$v = \pm\omega\sqrt{A^2 - x^2}$
gravitational field	$g = \frac{F}{m}$
	$F = -\frac{GMm}{r^2}$
	$g = -\frac{GM}{r^2}$
	$T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$
	$V_g = -\frac{GM}{r}$
	energy $= -\frac{GMm}{r}$
astrophysics	$hf = \Delta E$; $\frac{hc}{\lambda} = \Delta E$
	$d\sin\theta = n\lambda$
	$\lambda_{max} \propto \frac{1}{T}$
	$L = 4\pi r^2\sigma T^4$

cosmology	$\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$
	$p = \frac{1}{d}$
	$v = H_0 d$
	$t = H_0^{-1}$

Module 6 – Particles and medical physics

capacitance and capacitors	$C = \frac{Q}{V}$
	$C = \frac{\varepsilon_0 A}{d}$
	$C = 4\pi\varepsilon_0 R$
	$C = C_1 + C_2 + \ldots$
	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots.$
	$W = \frac{1}{2}QV$; $W = \frac{1}{2}\frac{Q^2}{C}$; $W = \frac{1}{2}V^2C$
	$\tau = CR$
	$x = x_0 e^{-\frac{t}{CR}}$
	$x = x_0(1 - e^{-\frac{t}{CR}})$
electric field	$E = \frac{F}{Q}$
	$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$
	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$
	$E = \frac{V}{d}$
	$V = \frac{Q}{4\pi\varepsilon_0 r}$
	energy $= \frac{Qq}{4\pi\varepsilon_0 r}$
magnetic field	$F = BIL\sin\theta$
	$F = BQv$

electromagnetism	$\Phi = BA\cos\theta$ $\mathcal{E} = -\frac{\Delta(N\Phi)}{\Delta t}$ $\frac{n_s}{n_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s}$
radius of nucleus	$R = r_0 A^{1/3}$
radioactivity	$A = \lambda N$; $\frac{\Delta N}{\Delta t} = -\lambda N$ $\lambda t_{1/2} = \ln(2)$ $A = A_0 e^{-\lambda t}$ $N = N_0 e^{-\lambda t}$
Einstein's mass-energy equation	$\Delta E = \Delta mc^2$
attenuation of X-rays	$I = I_0 e^{-\mu x}$
ultrasound	$Z = \rho c$ $\frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ $\frac{\Delta f}{f} = \frac{2v\cos\theta}{c}$