

**Advanced Subsidiary GCE (H156)
Advanced GCE (H556)****Physics A****Data, Formulae and Relationships Booklet**

The information in this booklet is for the use of candidates following the Advanced Subsidiary in Physics A (H156) or the Advanced GCE in Physics A (H556) course.

The data, formulae and relationships in this datasheet will be printed for distribution with the examination papers.

Copies of this booklet may be used for teaching.

This document consists of **8** pages.

Instructions to Exams Officer/Invigilator

- **Do not send this Data Sheet for marking; it should be retained in the centre or destroyed.**

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

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

Mathematical equations

$$\text{arc length} = r\theta$$

$$\text{circumference of circle} = 2\pi r$$

$$\text{area of circle} = \pi r^2$$

$$\text{curved surface area of cylinder} = 2\pi rh$$

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

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

$$\text{volume of cylinder} = \pi r^2 h$$

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

$$\text{Pythagoras' theorem: } a^2 = b^2 + c^2$$

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

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

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

$$\log(AB) = \log(A) + \log(B)$$

(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

$$\text{moment} = Fx$$

$$\text{torque} = Fd$$

density

$$\rho = \frac{m}{V}$$

pressure

$$p = \frac{F}{A}$$

$$p = h\rho g$$

work, energy and power

$$W = Fx \cos \theta$$

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$$

$$P = \frac{W}{t}$$

$$P = Fv$$

springs and materials

$$F = kx$$

$$E = \frac{1}{2}Fx ; E = \frac{1}{2}kx^2$$

$$\sigma = \frac{F}{A}$$

$$\epsilon = \frac{x}{L}$$

$$E = \frac{\sigma}{\epsilon}$$

Module 4 – Electrons, waves and photons

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

Module 5 – Newtonian world and astrophysics

thermal physics

$$E = mc\Delta\theta$$

$$E = mL$$

ideal gases

$$pV = NkT; \quad pV = nRT$$

$$pV = \frac{1}{3}Nm\overline{c^2}$$

$$\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$$

$$E = \frac{3}{2}kT$$

circular motion

$$\omega = \frac{2\pi}{T}; \quad \omega = 2\pi f$$

$$v = \omega r$$

$$a = \frac{v^2}{r}; \quad a = \omega^2 r$$

$$F = \frac{mv^2}{r}; \quad F = m\omega^2 r$$

oscillations

$$\omega = \frac{2\pi}{T}; \quad \omega = 2\pi f$$

$$a = -\omega^2 x$$

$$x = A\cos\omega t; \quad x = A\sin\omega t$$

$$v = \pm\omega\sqrt{A^2 - x^2}$$

gravitational field

$$g = \frac{F}{m}$$

$$F = -\frac{GMm}{r^2}$$

$$g = -\frac{GM}{r^2}$$

$$T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$$

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

$$\text{energy} = -\frac{GMm}{r}$$

astrophysics

$$hf = \Delta E; \quad \frac{hc}{\lambda} = \Delta E$$

$$d\sin\theta = n\lambda$$

$$\lambda_{\max} \propto \frac{1}{T}$$

$$L = 4\pi r^2 \sigma T^4$$

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

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

$$C = \frac{\epsilon_0 A}{d}$$

$$C = 4\pi\epsilon_0 R$$

$$C = C_1 + C_2 + \dots$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

$$W = \frac{1}{2} QV; \quad W = \frac{1}{2} \frac{Q^2}{C}; \quad W = \frac{1}{2} V^2 C$$

$$\tau = CR$$

$$x = x_0 e^{-\frac{t}{CR}}$$

$$x = x_0 (1 - e^{-\frac{t}{CR}})$$

electric field

$$E = \frac{F}{Q}$$

$$F = \frac{Qq}{4\pi\epsilon_0 r^2}$$

$$E = \frac{Q}{4\pi\epsilon_0 r^2}$$

$$E = \frac{V}{d}$$

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

$$\text{energy} = \frac{Qq}{4\pi\epsilon_0 r}$$

magnetic field

$$F = BIL \sin \theta$$

$$F = BQv$$

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

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