5d. Physics A data sheet

Data, Formulae and Relationships

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

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 = $-\frac{1}{3}e$

5

Conversion factors

unified atomic mass unit	$1\ \text{u} = 1.661 \times 10^{-27}$ kg
electronvolt	$1\ \text{eV} = 1.60 \times 10^{-19}$ 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

5

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	$p = \frac{m}{V}$
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	$F = kx$ $E = \frac{1}{2}Fx;\ E = \frac{1}{2}kx^2$ $\sigma = \frac{F}{A}$ $\varepsilon = \frac{x}{L}$ $E = \frac{\sigma}{\varepsilon}$

5

5

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	$R = \frac{\rho L}{A}$ $R = R_1 + R_2 + \dots$ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$
power	$P = VI$, $P = I^2 R$ and $P = \frac{V^2}{R}$
internal resistance	$\mathcal{E} = I(R + r)$; $\mathcal{E} = V + Ir$
potential divider	$V_{out} = \frac{R}{R_1 + R_2} \times V_{in}$ $\frac{V_1}{V_2} = \frac{R_1}{R_2}$
waves	$v = f\lambda$ $f = \frac{1}{T}$ $I = \frac{P}{A}$ $\lambda = \frac{ax}{D}$
refraction	$n = \frac{c}{v}$ $n \sin\theta = \text{constant}$ $\sin C = \frac{1}{n}$
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	$g = \frac{F}{m}$ $F = -\frac{GMm}{r^2}$ $g = -\frac{GM}{r^2}$ $T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$ $V_g = -\frac{GM}{r}$ $\text{energy} = -\frac{GMm}{r}$
astrophysics	$hf = \Delta E$; $\frac{hc}{\lambda} = \Delta E$ $d\sin\theta = n\lambda$ $\lambda_{max} \propto \frac{1}{T}$ $L = 4\pi r^2\ \sigma T^4$

5

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	$F = BIL\sin\theta$ $F = BQv$

5

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

5