

Physics (B): Physics in Context
Unit 5 Energy Under the Microscope

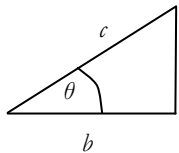
PHYB5

Data and Formulae Booklet

**FUNDAMENTAL CONSTANTS AND
OTHER NUMERICAL DATA**

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^8	m s^{-1}
Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\text{N m}^2 \text{kg}^{-2}$
gravitational field strength	g	9.81	N kg^{-1}
acceleration due to gravity	g	9.81	m s^{-2}
electron rest mass	m_e	9.11×10^{-31}	kg
	m_e	$5.5 \times 10^{-4} \text{ u}$	
electron charge	e	-1.60×10^{-19}	C
proton rest mass	m_p	$1.67(3) \times 10^{-27}$	kg
	m_p	1.00728 u	
neutron rest mass	m_n	$1.67(5) \times 10^{-27}$	kg
	m_n	1.00867 u	
permittivity of free space	ϵ_0	8.85×10^{-12}	F m^{-1}
molar gas constant	R	8.31	$\text{J K}^{-1} \text{mol}^{-1}$
Boltzmann constant	k	1.38×10^{-23}	J K^{-1}
Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
Wien constant	α	2.90×10^{-3}	m K

**GEOMETRICAL
EQUATIONS**

arc length	$r\theta$
circumference of circle	$2\pi r$
area of circle	πr^2
surface area of sphere	$4\pi r^2$
volume of sphere	$\frac{4}{3}\pi r^3$
surface area of cylinder	$2\pi rh$
volume of cylinder	$\pi r^2 h$
	
	$\sin \theta = \frac{a}{c}$
	$\cos \theta = \frac{b}{c}$
	$\tan \theta = \frac{a}{b}$
	$c^2 = a^2 + b^2$

Unit Conversions

1 atomic mass unit (u)	$1.661 \times 10^{-27} \text{ kg}$
1 year (y)	$3.15 \times 10^7 \text{ s}$
1 parsec (pc)	$3.08 \times 10^{16} \text{ m}$
1 parsec	3.26 ly
1 light year (ly)	$9.46 \times 10^{15} \text{ m}$

Particle Properties

Properties of quarks antiquarks have opposite signs

type	charge	Baryon number	strangeness
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	-1

Properties of Leptons

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

AS FORMULAE

Waves		Quantum Physics and Astrophysics	
wave speed	$c = f\lambda$	photon energy	$E = hf$
period	$T = \frac{1}{f}$	Einstein equation	$hf = \phi + E_{k(\max)}$
intensity	$I = \frac{P}{A}$	line spectrum equation	$hf = E_1 - E_2$
stretched string frequency	$f = \frac{1}{2L} \sqrt{\frac{T}{\mu}}$	de Broglie wavelength	$\lambda = \frac{h}{p} = \frac{h}{mv}$
beat frequency	$f = f_1 - f_2$	Doppler shift for $v \ll c$	$\frac{\Delta f}{f} = -\frac{\Delta \lambda}{\lambda} = \frac{v}{c}$
fringe spacing	$w = \frac{\lambda D}{s}$	Wien's law	$\lambda_{\max} T = 0.0029 \text{ m K}$
diffraction grating	$n\lambda = d \sin \theta$	Hubble law	$v = H d$
half beam width	$\sin \theta = \frac{\lambda}{a}$	intensity for a point source	$I = \frac{P}{4\pi r^2}$
refractive index of a substance (s)	$n = \frac{c}{c_s}$	Electricity	
for two different substances of refractive indices n_1 and n_2	$n_1 \sin i_1 = n_2 \sin i_2$	current	$I = \frac{\Delta Q}{\Delta t}$
critical angle	$\sin \theta_c = \frac{n_2}{n_1} \text{ for } n_1 > n_2$	electromotive force (emf)	$\varepsilon = \frac{E}{Q}$
Mechanics			$\varepsilon = I(R + r)$
speed or velocity	$v = \frac{\Delta s}{\Delta t}$	resistance	$R = \frac{V}{I}$
acceleration	$a = \frac{\Delta v}{\Delta t}$	resistors in series	$R = R_1 + R_2 + R_3 + \dots$
equations of motion	$v = u + at$ $s = \frac{(u + v)}{2} t$ $v^2 = u^2 + 2as$ $s = ut + \frac{1}{2} at^2$	resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
force	$F = ma$	resistivity	$\rho = \frac{RA}{L}$
change in potential energy	$\Delta E_p = mg\Delta h$	power	$P = VI = I^2 R = \frac{V^2}{R}$
kinetic energy	$E_k = \frac{1}{2} mv^2$	potential divider formula	$V_o = \left(\frac{R_1}{R_1 + R_2} \right) \times V_i$
momentum	$p = mv$	energy	$E = VIt$
impulse	$F\Delta t = \Delta(mv)$	efficiency	$\frac{\text{useful output power}}{\text{input power}}$
spring stiffness	$k = \frac{F}{\Delta L}$	Energy production and transmission	
energy stored for $F \propto L$	$E = \frac{1}{2} F\Delta L$	rate of heat transfer by conduction	$= UA \Delta \theta$
work done	$W = Fs \cos \theta$	maximum power for a wind turbine	$= \frac{1}{2} \pi r^2 \rho v^3$
power	$P = \frac{\Delta W}{\Delta t} = Fv$		
density	$\rho = \frac{m}{V}$		

A2 FORMULAE

Gravitational fields and Mechanics		Magnetic fields	
gravitational force	$F = \frac{GMm}{r^2}$	force on current – carrying conductor	$F = BIl$
gravitational field strength	$g = \frac{F}{m}$	force on moving charge	$F = BQv$
magnitude of field strength	$g = \frac{GM}{r^2}$	magnetic flux	$\Phi = BA$
for point masses	$\Delta E_p = GMm \left(\frac{1}{r_1} - \frac{1}{r_2} \right)$	magnetic flux linkage	$N\Phi = BAN$
potential	$V = -\frac{GM}{r}$	magnitude of induced emf	$\varepsilon = N \frac{\Delta\Phi}{\Delta t}$
rocket equation	$v_f = v_e \ln \left(\frac{m_0}{m_f} \right)$		
escape velocity	$v_{\text{esc}} = \sqrt{\frac{2GM}{R}}$	Capacitors	
Stokes' law	$F = 6\pi\eta av$	capacitance	$C = \frac{Q}{V}$
Electric fields		energy stored	$E = \frac{1}{2}QV$
		decay of charge	$Q = Q_0 e^{-t/RC}$
		time constant	RC
		time to halve	$RC \ln 2$
		Relativity	
field strength for uniform field	$E = \frac{V}{d}$		
force on a charge	$F = EQ$		
field strength for radial field	$E = \frac{Q}{4\pi\epsilon_0 r^2}$		
for point charges	$F = \frac{1}{4\pi\epsilon_0} \frac{Qq}{r^2}$		
electric potential	$V = \frac{Q}{4\pi\epsilon_0 r}$	mass increase	$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$
electron gun equation	$eV = \frac{1}{2}mv^2$	time dilation	$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$
		length contraction	$l = l_0 \sqrt{1 - \frac{v^2}{c^2}}$

Circular Motion

angular velocity	$\omega = \frac{v}{r}$
angular acceleration	$\alpha = \frac{\Delta\omega}{\Delta t}$
angular frequency	$\omega = 2\pi f$
centripetal force	$F = \frac{mv^2}{r} = m\omega^2 r$
centripetal acceleration	$a = \frac{v^2}{r} = r\omega^2$
angular momentum	$L = I\omega$
angular kinetic energy	$E_k = \frac{1}{2} I\omega^2$
moment of inertia	$I = \frac{r}{\alpha}$
torque	$T = Fd$
equations of angular motion	$\omega_2 = \omega_1 + \alpha t$ $\omega_2^2 = \omega_1^2 + 2\alpha\theta$ $\theta = \frac{(\omega_1 + \omega_2)}{2} t$ $\theta = \omega_1 t + \frac{1}{2} \alpha t^2$
power	$P = T\omega$

Oscillations

acceleration	$a = -(2\pi f)^2 x$
displacement	$x = A \cos(2\pi f t)$
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	$T = 2\pi \sqrt{\frac{l}{g}}$

Gases and Thermal Physics

pressure	$p = \frac{F}{A}$
gas law (N is number of atoms)	$pV = NkT$
gas law (n is quantity in mol)	$pV = nRT$
kinetic theory model	$pV = \frac{1}{3} Nm \langle c^2 \rangle$
kinetic energy of gas molecule	$\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$
energy to change temperature	$E = mc\Delta\theta$
first law of thermodynamics	$\Delta U = Q + W$ $W = \text{work done on the system}$
entropy change	$\Delta S = \frac{Q}{T}$
maximum thermal efficiency	$\eta = \frac{T_H - T_C}{T_H}$
work done	$W = p\Delta V$

Radioactivity and nuclear physics

absorption of radiation	$I = I_0 e^{-\mu x}$
radioactive decay	$N = N_0 e^{-\lambda t}$
half-life	$T_{1/2} = \frac{\ln 2}{\lambda}$
radioactive change represented by	$dN/dt = -\lambda N$
activity	$A = \lambda N$
mass-energy equivalence	$\Delta E = \Delta mc^2$