

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

**PHYB5**

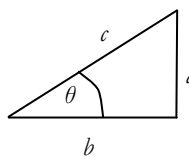
**Data and Formulae Booklet**

**FUNDAMENTAL CONSTANTS AND  
OTHER NUMERICAL DATA**

Quantity	Symbol	Value	Units
speed of light in vacuo	$c$	$3.00 \times 10^8$	$\text{m s}^{-1}$
Planck constant	$h$	$6.63 \times 10^{-34}$	J s
gravitational constant	$G$	$6.67 \times 10^{-11}$	$\text{N m}^2 \text{kg}^{-2}$
gravitational field strength	$g$	9.81	$\text{N kg}^{-1}$
acceleration due to gravity	$g$	9.81	$\text{m s}^{-2}$
electron rest mass	$m_e$	$9.11 \times 10^{-31}$	kg
	$m_e$	$5.5 \times 10^{-4} \text{ u}$	
electron charge	$e$	$-1.60 \times 10^{-19}$	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	$\epsilon_0$	$8.85 \times 10^{-12}$	$\text{F m}^{-1}$
molar gas constant	$R$	8.31	$\text{J K}^{-1} \text{mol}^{-1}$
Boltzmann constant	$k$	$1.38 \times 10^{-23}$	$\text{J K}^{-1}$
Avogadro constant	$N_A$	$6.02 \times 10^{23}$	$\text{mol}^{-1}$
Wien constant	$\alpha$	$2.90 \times 10^{-3}$	m K

**GEOMETRICAL  
EQUATIONS**

arc length	$r\theta$
circumference of circle	$2\pi r$
area of circle	$\pi r^2$
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
<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
<i>particles:</i> $e^-, \nu_e; \mu^-, \nu_\mu; \tau^-, \nu_\tau$	<b>+1</b>
<i>antiparticles:</i> $e^+, \bar{\nu}_e; \mu^+, \bar{\nu}_\mu; \tau^+, \bar{\nu}_\tau$	<b>-1</b>

## AS FORMULAE

	<b>Waves</b>		<b>Quantum Physics and Astrophysics</b>
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)	$n = \frac{c}{c_s}$		
for two different substances of refractive indices $n_1$ and $n_2$	$n_1 \sin i_1 = n_2 \sin i_2$		
critical angle	$\sin \theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$		
	<b>Mechanics</b>		<b>Electricity</b>
speed or velocity	$v = \frac{\Delta s}{\Delta t}$	current	$I = \frac{\Delta Q}{\Delta t}$
acceleration	$a = \frac{\Delta v}{\Delta t}$	electromotive force (emf)	$\varepsilon = \frac{E}{Q}$
equations of motion	$v = u + at$ $s = \frac{(u+v)}{2} t$ $v^2 = u^2 + 2as$ $s = ut + \frac{1}{2} at^2$	resistance	$\varepsilon = I(R+r)$
force	$F = ma$	resistors in series	$R = \frac{V}{I}$
change in potential energy	$\Delta E_p = mg\Delta h$	resistors in parallel	$R = R_1 + R_2 + R_3 + \dots$ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
kinetic energy	$E_k = \frac{1}{2} mv^2$	resistivity	$\rho = \frac{RA}{L}$
momentum	$p = mv$	power	$P = VI = I^2 R = \frac{V^2}{R}$
impulse	$F\Delta t = \Delta(mv)$	potential divider formula	$V_o = \left( \frac{R_1}{R_1 + R_2} \right) \times V_i$
spring stiffness	$k = \frac{F}{\Delta L}$	energy	$E = VIt$
energy stored for $F \propto L$	$E = \frac{1}{2} F\Delta L$	efficiency	$\frac{\text{useful output power}}{\text{input power}}$
work done	$W = Fs \cos \theta$		
power	$P = \frac{\Delta W}{\Delta t} = Fv$		
density	$\rho = \frac{m}{V}$		
		<b>Energy production and transmission</b>	
		rate of heat transfer by conduction	$= UA \Delta \theta$
		maximum power for a wind turbine	$= \frac{1}{2} \pi r^2 \rho v^3$

## 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	$v_{\text{esc}} = \sqrt{\frac{2GM}{R}}$		
Stokes' law	$F = 6\pi\eta av$		
		Capacitors	
		capacitance	$C = \frac{Q}{V}$
		energy stored	$E = \frac{1}{2} QV$
		decay of charge	$Q = Q_0 e^{-t/RC}$
		time constant	$RC$
		time to halve	$RC \ln 2$
	Electric fields		
field strength for uniform field	$E = \frac{V}{d}$	time constant	$RC$
force on a charge	$F = EQ$	time to halve	$RC \ln 2$
field strength for radial field	$E = \frac{Q}{4\pi\epsilon_0 r^2}$		
for point charges	$F = \frac{1}{4\pi\epsilon_0} \frac{Qq}{r^2}$		
		Relativity	
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	$l = l_0 \sqrt{1 - \frac{v^2}{c^2}}$

<b>Circular Motion</b>		<b>Gases and Thermal Physics</b>	
angular velocity	$\omega = \frac{v}{r}$	pressure	$p = \frac{F}{A}$
angular acceleration	$\alpha = \frac{\Delta\omega}{\Delta t}$	gas law ( $N$ is number of atoms)	$pV = NkT$
angular frequency	$\omega = 2\pi f$	gas law ( $n$ is quantity in mol)	$pV = nRT$
centripetal force	$F = \frac{mv^2}{r} = m\omega^2 r$	kinetic theory model	$pV = \frac{1}{3}Nm\langle c^2 \rangle$
centripetal acceleration	$a = \frac{v^2}{r} = r\omega^2$	kinetic energy of gas molecule	$\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT$
angular momentum	$L = I\omega$	energy to change temperature	$E = mc\Delta\theta$
angular kinetic energy	$E_k = \frac{1}{2}I\omega^2$	first law of thermodynamics	$\Delta U = Q + W$ $W = \text{work done on the system}$
moment of inertia	$I = \frac{Tr}{\alpha}$	entropy change	$\Delta S = \frac{Q}{T}$
torque	$T = Fd$	maximum thermal efficiency	$\eta = \frac{T_H - T_C}{T_H}$
equations of angular motion	$\omega_2 = \omega_1 + \alpha t$ $\omega_2^2 = \omega_1^2 + 2\alpha\theta$ $\theta = \frac{(\omega_1 + \omega_2)}{2}t$ $\theta = \omega_1 t + \frac{1}{2}\alpha t^2$	work done	$W = p\Delta V$
power	$P = T\omega$		
<b>Oscillations</b>		<b>Radioactivity and nuclear physics</b>	
acceleration	$a = -(2\pi f)^2 x$	absorption of radiation	$I = I_0 e^{-\mu x}$
displacement	$x = A \cos(2\pi f t)$	radioactive decay	$N = N_0 e^{-\lambda t}$
maximum speed	$v_{\max} = 2\pi f A$	half-life	$T_{1/2} = \frac{\ln 2}{\lambda}$
maximum acceleration	$a_{\max} = (2\pi f)^2 A$	radioactive change represented by	$dN/dt = -\lambda N$
for a mass-spring system	$T = 2\pi\sqrt{\frac{m}{k}}$	activity	$A = \lambda N$
for a simple pendulum	$T = 2\pi\sqrt{\frac{l}{g}}$	mass-energy equivalence	$\Delta E = \Delta mc^2$