General Certificate of Education
Advanced Level Examination
January 2010

Physics (B): Physics in Context — PHYB5
Unit 5 Energy Under the Microscope

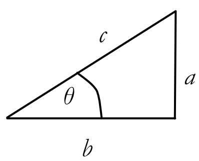
Data and Formulae Booklet

FUNDAMENTAL CONSTANTS AND OTHER NUMERICAL DATA

Quantity	*Symbol*	*Value*	*Units*
speed of light in vacuo	c	3.00×10^{8}	$\mathrm{m\,s^{-1}}$
Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\mathrm{N\,m^{2}\,kg^{-2}}$
gravitational field strength	g	9.81	$\mathrm{N\,kg^{-1}}$
acceleration due to gravity	g	9.81	$\mathrm{m\,s^{-2}}$
electron rest mass	m_e	9.11×10^{-31}	kg
	m_e	5.5×10^{-4} 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_o	8.85×10^{-12}	$\mathrm{F\,m^{-1}}$
molar gas constant	R	8.31	$\mathrm{J\,K^{-1}\,mol^{-1}}$
Boltzmann constant	k	1.38×10^{-23}	$\mathrm{J\,K^{-1}}$
Avogadro constant	N_A	6.02×10^{23}	$\mathrm{mol^{-1}}$
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)	1.661×10^{-27} kg
1 year (y)	3.15×10^{7} s
1 parsec (pc)	3.08×10^{16} m
1 parsec	3.26 ly
1 light year (ly)	9.46×10^{15} 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: $e^+, \overline{\nu_e};\ \mu^+, \overline{\nu_\mu};\ \tau^+, \overline{\nu_\tau}$	**−1**

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AS FORMULAE

Waves

wave speed	$c = f\lambda$
period	$T = \dfrac{1}{f}$
intensity	$I = \dfrac{P}{A}$
stretched string frequency	$f = \dfrac{1}{2L}\sqrt{\dfrac{T}{\mu}}$
beat frequency	$f = f_1 - f_2$
fringe spacing	$w = \dfrac{\lambda D}{s}$
diffraction grating	$n\lambda = d \sin \theta$
half beam width	$\sin\theta = \dfrac{\lambda}{a}$
refractive index of a substance s	$n = \dfrac{c}{c_s}$
for two different substances of refractive index n_1 and n_2	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
critical angle	$\sin\theta_c = \dfrac{n_2}{n_1}$ for $n_1 > n_2$

Mechanics

speed or velocity	$v = \dfrac{\Delta s}{\Delta t}$
acceleration	$a = \dfrac{\Delta v}{\Delta t}$
equations of motion	$v = u + at$
	$s = \dfrac{(u+v)}{2}t$
	$v^2 = u^2 + 2as$
	$s = ut + \dfrac{1}{2}at^2$
force	$F = ma$
change in potential energy	$\Delta E_p = mg\Delta h$
kinetic energy	$E_k = \dfrac{1}{2}mv^2$
momentum	$p = mv$
impulse	$F\Delta t = \Delta(mv)$
spring stiffness	$k = \dfrac{F}{\Delta L}$
energy stored for $F \propto L$	$E = \dfrac{1}{2}F\Delta L$
work done	$W = Fs$
power	$P = \dfrac{\Delta W}{\Delta t} = Fv$
density	$\rho = \dfrac{m}{V}$

Quantum Physics and Astrophysics

photon energy	$E = hf$
Einstein equation	$hf = \phi + E_{k(max)}$
line spectrum equation	$hf = E_1 - E_2$
de Broglie wavelength	$\lambda = \dfrac{h}{p} = \dfrac{h}{mv}$
Doppler shift for $v << c$	$\dfrac{\Delta f}{f} = -\dfrac{\Delta\lambda}{\lambda} = \dfrac{v}{c}$
Wien's law	$\lambda_{max} T = 0.0029 \text{ m K}$
Hubble law	$v = H d$
intensity for a point source	$I = \dfrac{P}{4\pi r^2}$

Electricity

current	$I = \dfrac{\Delta Q}{\Delta t}$
electromotive force (emf)	$\varepsilon = \dfrac{E}{Q}$
	$\varepsilon = I(R + r)$
resistance	$R = \dfrac{V}{I}$
resistors in series	$R = R_1 + R_2 + R_3 + \ldots$
resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \ldots$
resistivity	$\rho = \dfrac{RA}{L}$
power	$P = VI = I^2R = \dfrac{V^2}{R}$
potential divider formula	$V_o = \left(\dfrac{R_1}{R_1 + R_2}\right) \times V_i$
energy	$E = VIt$
efficiency	$\dfrac{\text{useful output power}}{\text{input power}}$

Energy production and transmission

rate of heat transfer by conduction	$= UA\,\Delta\theta$
maximum power for a wind turbine	$= \dfrac{1}{2}\pi r^2 \rho v^3$

A2 FORMULAE

Gravitational fields and Mechanics

gravitational force	$F = \frac{GMm}{r^2}$
gravitational field strength	$g = \frac{F}{m}$
magnitude of field strength	$g = \frac{GM}{r^2}$
for point masses	$\Delta E_p = GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$
potential	$V = -\frac{GM}{r}$
rocket equation	$v_f = v_e \ln\left(\frac{m_0}{m_f}\right)$
escape velocity	$v_{esc} = \sqrt{\frac{2GM}{R}}$
Stokes' law	$F = 6\pi\eta rv$

Electric fields

field strength for uniform field	$E = \frac{V}{d}$
force on a charge	$F = EQ$
field strength for radial field	$F = \frac{Q}{4\pi\varepsilon_0 r^2}$
for point charges	$F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
electron gun equation	$eV = \frac{1}{2}mv^2$

Magnetic fields

force on current – carrying conductor	$F = BIl$
force on moving charge	$F = BQv$
magnetic flux	$\Phi = BA$
magnetic flux linkage	$N\Phi = BAN$ $\Phi = N\phi$
magnitude of induced emf	$\varepsilon = N\frac{\Delta\Phi}{\Delta t}$

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	$RC \ln 2$

Relativity

mass increase	$m = \frac{m_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$
time dilation	$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$
length contraction	$l = l_0\sqrt{1 - \frac{v^2}{c^2}}$

Circular Motion

angular velocity	$\omega = \frac{v}{r}$
angular acceleration	$a = \frac{\Delta\omega}{\Delta t}$
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	$I = \frac{T}{\alpha}$
torque	$T = F\,d$
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	$P = T\omega$

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	$pV = \frac{1}{3} Nm(c_{\mathrm{rms}})^2$
kinetic energy of gas molecule	$\frac{1}{2} m(c_{\mathrm{rms}})^2 = \frac{3}{2} kT$
root mean square speed of molecules	$c_{\mathrm{rms}} = \sqrt{\langle c^2 \rangle}$
energy to change temperature	$Q = mc\Delta\theta$
first law of thermodynamics	$\Delta U = Q + W$ W = 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	$W = p\Delta V$

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	$T = 2\pi\sqrt{\frac{l}{g}}$

Radioactivity and nuclear physics

absorption of radiation	$I = I_0 e^{-\mu x}$
radioactive decay	$N = N_0 e^{-\lambda t}$
half-life	$T_{½} = \frac{\ln 2}{\lambda}$
activity	$A = \lambda N$
mass-energy equivalence	$\Delta E = \Delta m\, c^2$