OCR
RECOGNISING ACHIEVEMENT

OCE/26291

Data, Formulae and Relationships Booklet
(Revised Version 2.2)

GCE Advanced Level and Advanced Subsidiary

Physics B (Advancing Physics)

Physics units G491, G492, G494, G495

Instructions to Exams Officer/Invigilator

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

These data, formulae and relationships are for the use of candidates following the Physics B (Advancing Physics) specification.

Clean copies of this booklet must be available in the examination room, and must be given up to the invigilator at the end of the examination.

Copies of this booklet may be used for teaching.

GCE Physics B (Advancing Physics)
DC (SLM) 26291/9
CST254

Data

Values are given to three significant figures, except where more – or fewer – are useful.

Physical constants

speed of light	c	$3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permittivity of free space	ε_0	$8.85 \times 10^{-12}\,\mathrm{C^2\,N^{-1}\,m^{-2}}$ (or $\mathrm{F\,m^{-1}}$)
electric force constant	$k = \dfrac{1}{4\pi\varepsilon_0}$	$8.98 \times 10^{9}\,\mathrm{N\,m^2\,C^{-2}}$ ($\approx 9 \times 10^{9}\,\mathrm{N\,m^2\,C^{-2}}$)
permeability of free space	μ_0	$4\,\pi \times 10^{-7}\,\mathrm{N\,A^{-2}}$ (or $\mathrm{H\,m^{-1}}$)
charge on electron	e	$-1.60 \times 10^{-19}\,\mathrm{C}$
mass of electron	m_e	$9.11 \times 10^{-31}\,\mathrm{kg} = 0.000\,55\,\mathrm{u}$
mass of proton	m_p	$1.673 \times 10^{-27}\,\mathrm{kg} = 1.007\,3\,\mathrm{u}$
mass of neutron	m_n	$1.675 \times 10^{-27}\,\mathrm{kg} = 1.008\,7\,\mathrm{u}$
mass of alpha particle	m_α	$6.646 \times 10^{-27}\,\mathrm{kg} = 4.001\,5\,\mathrm{u}$
Avogadro constant	L, N_A	$6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
Planck constant	h	$6.63 \times 10^{-34}\,\mathrm{J\,s}$
Boltzmann constant	k	$1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
molar gas constant	R	$8.31\,\mathrm{J\,mol^{-1}\,K^{-1}}$
gravitational force constant	G	$6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$

Other data

standard temperature and pressure (stp)		273 K (0°C), 1.01×10^5 Pa (1 atmosphere)
molar volume of a gas at stp	V_m	2.24×10^{-2} m^3
gravitational field strength at the Earth's surface in the UK	g	9.81 N kg^{-1}

Conversion factors

unified atomic mass unit	1u	$= 1.661 \times 10^{-27}$ kg
	1 day	$= 8.64 \times 10^4$ s
	1 year	$\approx 3.16 \times 10^7$ s
	1 light year	$\approx 10^{16}$ m

Mathematical constants and equations

e = 2.72

$\pi = 3.14$

1 radian = 57.3°

arc = $r\theta$

circumference of circle = $2\pi r$

$\sin\theta \approx \tan\theta \approx \theta$
and $\cos\theta \approx 1$ for small θ

area of circle = πr^2

curved surface area of cylinder = $2\pi rh$

$\ln(x^n) = n \ln x$

volume of cylinder = $\pi r^2 h$

$\ln(e^{kx}) = kx$

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

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

Prefixes

10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^3	10^6	10^9
p	n	µ	m	k	M	G

Formulae and relationships

Imaging and Signalling

focal length	$\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$	Cartesian convention (object distance u, image distance v, focal length f)
refractive index	$n = \frac{\text{speed of light in vacuo}}{\text{speed of light in medium}}$	(refractive index n)
Noise limitation on maximum bits per sample	$b = \log_2 \frac{V_{total}}{V_{noise}}$ or $2^b = \frac{V_{total}}{V_{noise}}$	(maximum bits per sample b, total voltage variation V_{total}, noise voltage V_{noise})

Electricity

current	$I = \frac{\Delta Q}{\Delta t}$	(current I, charge flow ΔQ, time interval Δt)
potential difference	$V = \frac{E}{Q}$	(potential difference V, energy E, charge Q)
power	$P = IV = I^2R$	(power P, potential difference V, current I)
	$V_{load} = \varepsilon - Ir$	(emf ε, internal resistance r)
resistance and conductance	$R = \frac{V}{I} \quad G = \frac{I}{V}$	(resistance R, conductance G, potential difference V, current I)
	$G = G_1 + G_2 + ...$	(conductors in parallel)
resistance	$R = R_1 + R_2 + ...$	(resistors in series)
conductivity and resistivity	$G = \frac{\sigma A}{l}, R = \frac{\rho l}{A}$	(conductivity σ, resistivity ρ, cross section A, length l)
capacitance	$C = \frac{Q}{V}$ energy stored $= \frac{1}{2} QV = \frac{1}{2} CV^2$	(potential difference V, charge Q, capacitance C)
discharge of capacitor	$Q = Q_0 e^{-t/RC}$	(initial charge Q_0, time constant RC)
	$\tau = RC$	(time constant τ)

Materials

density	$\rho = \frac{M}{V}$	(density ρ, mass M, volume V)
Hooke's law	$F = kx$	(tension F, spring constant k, extension x)
stress, strain and the Young modulus	$\text{stress} = \frac{\text{tension}}{\text{cross-sectional area}}$	
	$\text{strain} = \frac{\text{extension}}{\text{original length}}$	
	$\text{Young modulus} = \frac{\text{stress}}{\text{strain}}$	
	$\text{elastic strain energy} = \frac{1}{2} kx^2$	

Gases

ideal gas equation	$pV = nRT$	(pressure p, volume V, number of moles n, molar gas constant R)
	$pV = NkT$	(number of molecules N, Boltzmann constant k)
kinetic theory of gases	$pV = \frac{1}{3}Nm\overline{c^2}$	(pressure p, volume V, number of molecules N, mass of molecule m, mean square speed $\overline{c^2}$)

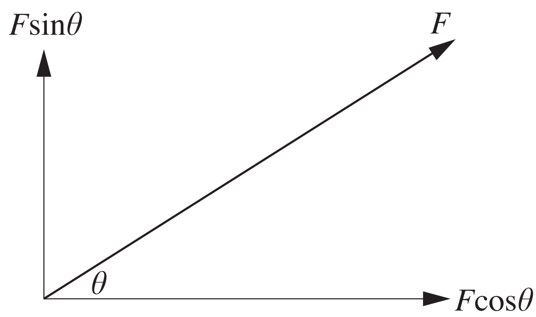
Motion and forces

momentum	$p = mv$	(momentum p, mass m, velocity v)

force = rate of change of momentum

impulse = $F\Delta t$ (force F)

components of a vector in two perpendicular directions



	work = Fx	(force F, component of displacement in the direction of the force x)
	power = Fv	(speed v)
equations for uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$	(initial speed u, final speed v, time taken t, acceleration a, distance travelled s)
	$v = u + at$	
	$v^2 = u^2 + 2as$	
for circular motion	$a = \frac{v^2}{r}, F = \frac{mv^2}{r}$	(radius of circle r)

Energy and thermal effects

efficiency	efficiency = $\frac{\text{useful energy output}}{\text{energy input}}$	
energy	$\Delta E = mc\Delta\theta$	(change in energy ΔE, mass m, specific thermal capacity c, temperature change $\Delta\theta$)
Boltzmann factor	$e^{(-E/kT)}$	

Waves

$n\lambda = d\sin\theta$ (on a distant screen from a diffraction grating or double slit; order n, wavelength λ, angles of maxima θ)

$v = f\lambda$ (wave speed v, frequency f, wavelength λ)

Oscillations

$$\frac{d^2x}{dt^2} = a = -\left[\frac{k}{m}\right]x = -(2\pi f)^2 x$$ (acceleration a, force per unit displacement k, mass m, displacement x, frequency f)

$x = A\cos 2\pi ft$ (amplitude A, time t)

$x = A\sin 2\pi ft$

$$T = 2\pi\sqrt{\frac{m}{k}}$$ (periodic time T)

$$f = \frac{1}{T}$$

total energy $E = \frac{1}{2}kA^2 = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$

Atomic and nuclear physics

radioactive decay $\frac{\Delta N}{\Delta t} = -\lambda N$ (number N, decay constant λ)

$N = N_0 e^{-\lambda t}$ (initial number N_0)

$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ (half-life $T_{\frac{1}{2}}$)

absorbed dose = energy deposited per unit mass

dose equivalent = absorbed dose × quality factor

risk = probability × consequence

expected random variation in N random counts is of the order $\sqrt{N}$

mass-energy relationship $E_{rest} = mc^2$ (energy E, mass m, speed of light c)

relativistic factor γ $\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$ (speed of object v, speed of light c)

relativistic energy $E_{total} = \gamma E_{rest}$ (total energy E_{total}, rest energy E_{rest}, relativistic factor γ)

energy-frequency relationship for photons $E = hf$ (photon energy E, Planck constant h, frequency f)

$\lambda = \frac{h}{p}$ (wavelength λ, Planck constant h, momentum p (= mv for slow moving particles))

Field and potential

for all fields	field strength $= -\frac{dV}{dr} \approx -\frac{\Delta V}{\Delta r}$	(potential gradient dV/dr)
gravitational fields	$g = \frac{F}{m}$	(gravitational field strength g, gravitational force F, mass m)
	$V_{grav} = -\frac{GM}{r}$, $F = -\frac{GMm}{r^2}$	(gravitational potential V_{grav}, force F, gravitational constant G, mass M, distance r)

Electric fields

	$E = \frac{F}{q}$	(electric field strength E, electric force F, charge q)
	$V_{elec} = \frac{kQ}{r}$ $F = \frac{kQq}{r^2}$	(electric potential V_{elec}, force F, electric force constant k, charge Q, distance r)

Electromagnetism

force on a current carrying conductor	$F = ILB$	(flux density B, current I, length L)
force on a moving charge	$F = qvB$	(charge q, velocity perpendicular to field v)
	$\varepsilon = -\frac{d(N\Phi)}{dt}$	(induced emf ε, flux Φ, number of turns linked N)
ideal transformer	$\frac{V_1}{V_2} = \frac{N_1}{N_2}$ $\frac{I_2}{I_1} = \frac{N_1}{N_2}$	

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