Data, Formulae and Relationships Booklet

GCE Advanced Level and Advanced Subsidiary

Advancing Physics

Physics units (PILOT) 7730–7735
Physics units 2860–2865

These data, formulae and relationships are for the use of candidates following the Advancing Physics Pilot and Advancing Physics.

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.

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DATA, FORMULAE AND RELATIONSHIPS

Data

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

Physical constants

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

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	$2.24 \times 10^{-2}\ \mathrm{m^3}$
gravitational field strength at the Earth's surface in the UK	g	$9.81\ \mathrm{N\,kg^{-1}}$

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

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

Optics

focal length	$\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$	Cartesian convention (object distance u, image distance v, focal length f)
refractive index	$n = \frac{\sin i}{\sin r} = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$	(angle of incidence i, angle of refraction r)

Electricity

power	$P = IV = I^2R$	(power P, potential difference V, current I)
	$V_{load} = E - IR_{internal}$	(emf E, internal resistance $R_{internal}$)
conductance	$G = \frac{I}{V}$	(conductance G)
	$G = G_1 + G_2 + ...$	(conductors in parallel)
resistance	$R = R_1 + R_2 + ...$	(resistors in series)
conductivity	$G = \frac{\sigma A}{l}$	(conductivity σ, cross section A, length l)
capacitance	energy stored $= \frac{1}{2} QV = \frac{1}{2} CV^2$	(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

for a material in tension

Hooke's law	$F = kx$	(tension F, spring constant k, extension x)

$$\text{stress} = \frac{\text{tension}}{\text{cross-sectional area}}$$

$$\text{strain} = \frac{\text{extension}}{\text{original length}}$$

$$\text{Young modulus} = \frac{\text{stress}}{\text{strain}}$$

$$\text{Elastic strain energy} = \tfrac{1}{2} kx^2$$

Gases

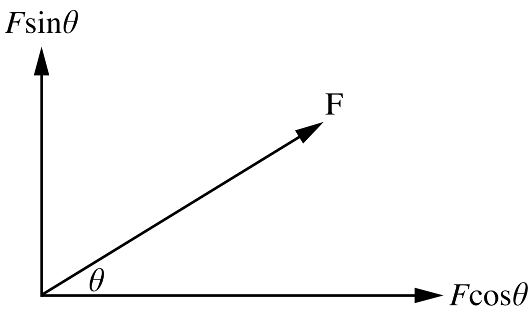
kinetic theory of gases	$pV = \frac{1}{3} Nm\overline{c^2}$	(pressure p, volume V, number of molecules N, mass of molecule m, mean square speed $\overline{c^2}$)

Motion and forces

force = rate of change of momentum

	impulse = $F\Delta t$	(force F)
	power = Fv	(velocity v)

components of a vector in two perpendicular directions



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	$a = \frac{v^2}{r}$	(radius of circle r)

Energy and thermal effects

efficiency	$\text{efficiency} = \frac{\text{useful energy output}}{\text{energy input}}$	
energy	$\Delta E = mc\Delta\theta$	(change in energy ΔE, mass m, specific thermal capacity c, temperature change $\Delta\theta$)
Boltzmann factor	$e^{(-\varepsilon/kT)}$	(ratio of numbers of particles in states differing in energy by ε, at temperature T)

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)

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)

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

$x = A \sin 2\pi f t$

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

risk = probability $\times$ 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)

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 $= -\dfrac{dV}{dr} \approx -\dfrac{\Delta V}{\Delta r}$	(potential gradient dV/dr)
gravitational fields	$g = \dfrac{F}{m}$	(gravitational field strength g, gravitational force F, mass m)
	$V_{grav} = -\dfrac{GM}{r}$	(gravitational potential V_{grav}, gravitational constant G, mass M, distance r)
electric fields	$V_{elec} = -\dfrac{kQ}{r}$	(electric potential V_{elec}, electric force constant k, charge Q, distance r)

Electromagnetism

force on a current carrying conductor	$F = I\,l\,B$	(flux density B, current I, length l)
force on a moving charge	$F = Q\,v\,B$	(charge Q, velocity perpendicular to field v)
	$\varepsilon = -\dfrac{d(N\Phi)}{dt}$	(induced emf ε, flux Φ, number of turns linked N)