

A



A-level

Physics data and formulae

For use in exams from the June 2017 Series onwards

[Turn over]

DATA — FUNDAMENTAL CONSTANTS AND VALUES

QUANTITY	SYMBOL	VALUE	UNITS
speed of light in vacuo	C	3.00×10^8	m s^{-1}
permeability of free space	μ_0	$4\pi \times 10^{-7}$	H m^{-1}
permittivity of free space	ϵ_0	8.85×10^{-12}	F m^{-1}
magnitude of the charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\text{N m}^2 \text{kg}^{-2}$
the Avogadro constant	N_{A}	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$\text{J K}^{-1} \text{mol}^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}

QUANTITY	SYMBOL	VALUE	UNITS
the Stefan constant	σ	5.67×10^{-8}	$\text{Wm}^{-2} \text{K}^{-4}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to $5.5 \times 10^{-4} \text{ u}$)	m_e	9.11×10^{-31}	kg
magnitude of electron charge/mass ratio	$\frac{e}{m_e}$	1.76×10^{11}	C kg^{-1}
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67 (3) \times 10^{-27}$	kg
proton charge/mass ratio	$\frac{e}{m_p}$	9.58×10^7	C kg^{-1}
neutron rest mass (equivalent to 1.00867 u)	m_n	$1.67 (5) \times 10^{-27}$	kg

[Turn over]

QUANTITY	SYMBOL	VALUE	UNITS
gravitational field strength	g	9.81	N kg^{-1}
acceleration due to gravity	g	9.81	m s^{-2}
atomic mass unit (1u is equivalent to 931.5 MeV)	u	1.661×10^{-27}	kg

ALGEBRAIC EQUATION

quadratic equation $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

ASTRONOMICAL DATA

BODY	MASS/kg	MEAN RADIUS/m
Sun	1.99×10^{30}	6.96×10^8
Earth	5.97×10^{24}	6.37×10^6

GEOMETRICAL EQUATIONS

arc length $= r\theta$

circumference of circle $= 2\pi r$

area of circle $= \pi r^2$

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

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

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

[Turn over]

PARTICLE PHYSICS

CLASS	NAME	SYMBOL	REST ENERGY/MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^\pm$	0.510999
	muon	$\mu^\pm$	105.659
mesons	π meson	$\pi^\pm$	139.576
		π^0	134.972
	K meson	$K^\pm$	493.821
		K^0	497.762
baryons	proton	p	938.257
	neutron	n	939.551

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:	$e^-, \nu_e; \mu^-, \nu_\mu$	+ 1
Antiparticles:	$e^+, \bar{\nu}_e; \mu^+, \bar{\nu}_\mu$	- 1

[Turn over]

PHOTONS AND ENERGY LEVELS

photon energy $E = hf = \frac{hc}{\lambda}$

photoelectricity $hf = \phi + E_{\text{k (max)}}$

energy levels $hf = E_1 - E_2$

de Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$

WAVES

wave speed $c = f\lambda$
 period $f = \frac{1}{T}$

first harmonic $f = \frac{1}{2l} \sqrt{\frac{T}{\mu}}$

fringe spacing $w = \frac{\lambda D}{s}$
 diffraction grating $d \sin \theta = n\lambda$

refractive index of a substance s , $n = \frac{c}{c_s}$

for two different substances of refractive indices n_1 and n_2 ,

law of refraction $n_1 \sin \theta_1 = n_2 \sin \theta_2$

critical angle $\sin \theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$

[Turn over]

MECHANICS**moments**

$$\text{moment} = Fd$$

velocity and acceleration

$$v = \frac{\Delta s}{\Delta t}$$

$$a = \frac{\Delta v}{\Delta t}$$

equations of motion

$$v = u + at$$

$$s = \left(\frac{u + v}{2} \right) t$$

$$v^2 = u^2 + 2as$$

$$s = ut + \frac{at^2}{2}$$

force

$$F = ma$$

force

$$F = \frac{\Delta(mv)}{\Delta t}$$

impulse

$$F \Delta t = \Delta(mv)$$

work, energy and power

$$W = F s \cos \theta$$

$$E_k = \frac{1}{2} m v^2$$

$$\Delta E_p = mg \Delta h$$

$$P = \frac{\Delta W}{\Delta t}, P = Fv$$

$$\text{efficiency} = \frac{\text{useful output power}}{\text{input power}}$$

MATERIALS

density $\rho = \frac{m}{V}$

Hooke's law $F = k \Delta L$

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

tensile stress = $\frac{F}{A}$

tensile strain = $\frac{\Delta L}{L}$

energy stored $E = \frac{1}{2} F \Delta L$

[Turn over]

ELECTRICITY

current and pd $I = \frac{\Delta Q}{\Delta t} \quad V = \frac{W}{Q} \quad R = \frac{V}{I}$

resistivity $\rho = \frac{RA}{L}$

resistors in series $R_T = R_1 + R_2 + R_3 + \dots$

resistors in parallel $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$

power $P = VI = I^2 R = \frac{V^2}{R}$

emf $\mathcal{E} = \frac{E}{Q} \quad \mathcal{E} = I(R + r)$

CIRCULAR MOTION

magnitude of angular speed $\omega = \frac{v}{r}$

$$\omega = 2\pi f$$

centripetal acceleration $a = \frac{v^2}{r} = \omega^2 r$

centripetal force $F = \frac{mv^2}{r} = m\omega^2 r$

SIMPLE HARMONIC MOTION

acceleration $a = -\omega^2 x$

displacement $x = A \cos(\omega t)$

speed $v = \pm \omega \sqrt{(A^2 - x^2)}$

maximum speed $v_{\max} = \omega A$

maximum acceleration $a_{\max} = \omega^2 A$

for a mass-spring system $T = 2\pi \sqrt{\frac{m}{k}}$

for a simple pendulum $T = 2\pi \sqrt{\frac{l}{g}}$

[Turn over]

THERMAL PHYSICS**energy to change temperature**

$$Q = mc\Delta\theta$$

energy to change state

$$Q = ml$$

gas law

$$pV = nRT$$

$$pV = NkT$$

kinetic theory model

$$pV = \frac{1}{3}Nm(c_{\text{rms}})^2$$

kinetic energy of gas molecule

$$\frac{1}{2}m(c_{\text{rms}})^2 = \frac{3}{2}kT = \frac{3RT}{2N_A}$$

GRAVITATIONAL FIELDS

force between two masses

$$F = \frac{Gm_1 m_2}{r^2}$$

gravitational field strength

$$g = \frac{F}{m}$$

magnitude of gravitational field strength in a radial field

$$g = \frac{GM}{r^2}$$

work done

$$\Delta W = m\Delta V$$

gravitational potential

$$V = - \frac{GM}{r}$$

$$g = - \frac{\Delta V}{\Delta r}$$

[Turn over]

ELECTRIC FIELDS AND CAPACITORS**force between two point charges**

$$F = \frac{1}{4 \pi \epsilon_0} \frac{Q_1 Q_2}{r^2}$$

force on a charge

$$F = E Q$$

field strength for a uniform field

$$E = \frac{V}{d}$$

work done

$$\Delta W = Q \Delta V$$

field strength for a radial field

$$E = \frac{1}{4 \pi \epsilon_0} \frac{Q}{r^2}$$

electric potential

$$V = \frac{1}{4 \pi \epsilon_0} \frac{Q}{r}$$

field strength

$$E = \frac{\Delta V}{\Delta r}$$

capacitance

$$C = \frac{Q}{V}$$

$$C = \frac{A \epsilon_0 \epsilon_r}{d}$$

capacitor energy stored

$$E = \frac{1}{2} Q V = \frac{1}{2} C V^2 = \frac{1}{2} \frac{Q^2}{C}$$

capacitor charging

$$Q = Q_0 (1 - e^{-\frac{t}{RC}})$$

decay of charge

$$Q = Q_0 e^{-\frac{t}{RC}}$$

time constant

$$RC$$

MAGNETIC FIELDS

force on a current $F = BIl$

force on a moving charge $F = BQv$

magnetic flux $\Phi = BA$

magnetic flux linkage $N\Phi = BAN \cos \theta$

magnitude of induced emf $\varepsilon = N \frac{\Delta\Phi}{\Delta t}$

$N\Phi = BAN \cos \theta$

emf induced in a rotating coil $\varepsilon = BAN\omega \sin \omega t$

alternating current $I_{\text{rms}} = \frac{I_0}{\sqrt{2}} \quad V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$

transformer equations $\frac{N_s}{N_p} = \frac{V_s}{V_p}$

$$efficiency = \frac{I_s V_s}{I_p V_p}$$

[Turn over]

NUCLEAR PHYSICS

**inverse square law
for γ radiation**

$$I = \frac{k}{x^2}$$

radioactive decay

$$\frac{\Delta N}{\Delta t} = -\lambda N, N = N_0 e^{-\lambda t}$$

activity

$$A = \lambda N$$

half-life

$$T_{1/2} = \frac{\ln 2}{\lambda}$$

nuclear radius

$$R = R_0 A^{1/3}$$

**energy-mass
equation**

$$E = mc^2$$

OPTIONS**ASTROPHYSICS**

$$1 \text{ astronomical unit} = 1.50 \times 10^{11} \text{ m}$$

$$1 \text{ light year} = 9.46 \times 10^{15} \text{ m}$$

$$1 \text{ parsec} = 2.06 \times 10^5 \text{ AU} = 3.08 \times 10^{16} \text{ m} = 3.26 \text{ ly}$$

$$\text{Hubble constant, } H = 65 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

$$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$$

$$\text{telescope in normal adjustment} \quad M = \frac{f_o}{f_e}$$

$$\text{Rayleigh criterion} \quad \theta \approx \frac{\lambda}{D}$$

$$\text{magnitude equation} \quad m - M = 5 \log \frac{d}{10}$$

$$\text{Wien's law} \quad \lambda_{\text{max}} T = 2.9 \times 10^{-3} \text{ m K}$$

$$\text{Stefan's law} \quad P = \sigma A T^4$$

[Turn over]

Schwarzschild radius $R_s \approx \frac{2GM}{c^2}$

Doppler shift for $v \ll c$ $\frac{\Delta f}{f} = -\frac{\Delta \lambda}{\lambda} = \frac{v}{c}$

red shift $z = -\frac{v}{c}$

Hubble's law $v = Hd$

MEDICAL PHYSICS**lens equations**

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

$$m = \frac{v}{u}$$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

threshold of hearing

$$I_0 = 1.0 \times 10^{-12} \text{ W m}^{-2}$$

intensity level

$$\text{intensity level} = 10 \log \frac{I}{I_0}$$

absorption

$$I = I_0 e^{-\mu x}$$

$$\mu_m = \frac{\mu}{\rho}$$

ultrasound imaging

$$Z = p c$$

$$\frac{I_r}{I_i} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1} \right)^2$$

half-lives

$$\frac{1}{T_E} = \frac{1}{T_B} + \frac{1}{T_P}$$

[Turn over]

ENGINEERING PHYSICS

moment of inertia $I = \Sigma mr^2$

angular kinetic energy $E_k = \frac{1}{2} I \omega^2$

equations of angular motion $\omega_2 = \omega_1 + \alpha t$
 $\omega_2^2 = \omega_1^2 + 2\alpha\theta$

$$\theta = \omega_1 t + \frac{\alpha t^2}{2}$$

$$\theta = \frac{(\omega_1 + \omega_2) t}{2}$$

torque $T = I \alpha$

$$T = F r$$

angular momentum angular momentum = $I \omega$

angular impulse $T \Delta t = \Delta(I \omega)$

work done $W = T \theta$

power $P = T \omega$

thermodynamics $Q = \Delta U + W$

$$W = p \Delta V$$

adiabatic change $p V^\gamma = \text{constant}$

isothermal change $p V = \text{constant}$

heat engines

$$\text{efficiency} = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$$

$$\text{maximum theoretical efficiency} = \frac{T_H - T_C}{T_H}$$

work done per cycle = area of loop

input power = calorific value $\times$ fuel flow rate

indicated power = (area of $p - V$ loop)
 $\times$ (number of cycles per second)
 $\times$ (number of cylinders)

output or brake power $P = T \omega$

friction power = indicated power $-$ brake power

heat pumps and refrigerators

$$\text{refrigerator: } COP_{\text{ref}} = \frac{Q_C}{W} = \frac{Q_C}{Q_H - Q_C}$$

$$\text{heat pump: } COP_{\text{hp}} = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_C}$$

[Turn over]

TURNING POINTS IN PHYSICS

electrons in fields

$$F = \frac{eV}{d}$$

$$F = Bev$$

$$r = \frac{mv}{Be}$$

$$\frac{1}{2}mv^2 = eV$$

Millikan's
experiment

$$\frac{QV}{d} = mg$$

$$F = 6\pi\eta rv$$

Maxwell's formula

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$$

special relativity

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$I = I_0 \sqrt{1 - \frac{v^2}{c^2}}$$

$$E = m c^2 = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

ELECTRONICS

resonant
frequency

$$f_0 = \frac{1}{2\pi \sqrt{LC}}$$

Q-factor

$$Q = \frac{f_0}{f_B}$$

operational
amplifiers: open
loop

$$V_{\text{out}} = A_{\text{OL}} (V_+ - V_-)$$

inverting amplifier

$$\frac{V_{\text{out}}}{V_{\text{in}}} = - \frac{R_f}{R_{\text{in}}}$$

non-inverting
amplifier

$$\frac{V_{\text{out}}}{V_{\text{in}}} = 1 + \frac{R_f}{R_1}$$

[Turn over]

**summing
amplifier**

$$V_{\text{out}} = -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \dots \right)$$

**difference
amplifier**

$$V_{\text{out}} = (V_+ - V_-) \frac{R_f}{R_1}$$

Bandwidth requirement:

for AM *bandwidth = 2 f_M*

for FM *bandwidth = 2(Δf + f_M)*

END OF DATA SHEET

BLANK PAGE

BLANK PAGE

Copyright Information

For confidentiality purposes, from the November 2015 examination series, acknowledgements of third party copyright material will be published in a separate booklet rather than including them on the examination paper or support materials. This booklet is published after each examination series and is available for free download from www.aqa.org.uk after the live examination series.

Permission to reproduce all copyright material has been applied for. In some cases, efforts to contact copyright-holders may have been unsuccessful and AQA will be happy to rectify any omissions of acknowledgements. If you have any queries please contact the Copyright Team, AQA, Stag Hill House, Guildford, GU2 7XJ.

Copyright © 2019 AQA and its licensors. All rights reserved.