

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	$c$	$3.00 \times 10^8$	$\text{m s}^{-1}$
permeability of free space	$\mu_0$	$4\pi \times 10^{-7}$	$\text{H m}^{-1}$
permittivity of free space	$\epsilon_0$	$8.85 \times 10^{-12}$	$\text{F m}^{-1}$
magnitude of the charge of electron	$e$	$1.60 \times 10^{-19}$	$\text{C}$
the Planck constant	$h$	$6.63 \times 10^{-34}$	$\text{J s}$

**gravitational constant**       $G$        $6.67 \times 10^{-11}$        $\text{N m}^2 \text{kg}^{-2}$

**the Avogadro constant**       $N_A$        $6.02 \times 10^{23}$        $\text{mol}^{-1}$

**molar gas constant**       $R$        $8.31$        $\text{JK}^{-1} \text{mol}^{-1}$

**the Boltzmann constant**       $k$        $1.38 \times 10^{-23}$        $\text{JK}^{-1}$        $\omega$

**the Stefan constant**       $\sigma$        $5.67 \times 10^{-8}$        $\text{Wm}^{-2} \text{K}^{-4}$

**the Wien constant**       $\alpha$        $2.90 \times 10^{-3}$        $\text{m K}$

**[Turn over]**

QUANTITY	SYMBOL	VALUE	UNITS
electron rest mass (equivalent to $5.5 \times 10^{-4}$ u)	$m_e$	$9.11 \times 10^{-31}$	kg
magnitude of electron charge/mass ratio	$\frac{e}{m_e}$	$1.76 \times 10^{11}$	C kg <sup>-1</sup>
proton rest mass (equivalent to 1.00728 u)	$m_p$	$1.67 (3) \times 10^{-27}$	kg
proton charge/mass ratio	$\frac{e}{m_p}$	$9.58 \times 10^7$	C kg <sup>-1</sup>

<b>neutron rest mass (equivalent to 1.008667 u)</b>	$m_n$	$1.67 (5) \times 10^{-27}$	<b>kg</b>
<b>gravitational field strength</b>	$g$	<b>9.81</b>	<b>N kg<sup>-1</sup></b>
<b>acceleration due to gravity</b>	$g$	<b>9.81</b>	<b>m s<sup>-2</sup></b>
<b>atomic mass unit (1 u is equivalent to 931.5 MeV)</b>	$u$	$1.661 \times 10^{-27}$	<b>kg</b>

**[Turn over]**

## ALGEBRAIC EQUATION

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

## ASTRONOMICAL DATA

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

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** =  $\frac{4}{3}\pi r^3$

7

**[Turn over]**

# PARTICLE PHYSICS

CLASS	NAME	SYMBOL	REST ENERGY/MeV
photon	photon	$\gamma$	0
lepton	neutrino	$\nu_e$	0
		$\nu_\mu$	0
	electron	$e^\pm$	0.510999
	muon	$\mu^\pm$	105.659
mesons	$\pi$ meson	$\pi^\pm$	139.576
		$\pi^0$	134.972

	<b>K meson</b>	<b><math>K^\pm</math></b>	<b>493.821</b>
		<b><math>K^0</math></b>	<b>497.762</b>
<b>baryons</b>	<b>proton</b>	<b>p</b>	<b>938.257</b>
	<b>neutron</b>	<b>n</b>	<b>939.551</b>

**[Turn over]**

# PROPERTIES OF QUARKS

antiquarks have opposite signs

TYPE	CHARGE	BARYON NUMBER	STRANGENESS
<b>u</b>	$+\frac{2}{3}e$	$+\frac{1}{3}$	<b>0</b>
<b>d</b>	$-\frac{1}{3}e$	$+\frac{1}{3}$	<b>0</b>
<b>s</b>	$-\frac{1}{3}e$	$+\frac{1}{3}$	<b>-1</b>

# 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  $hf = \phi + E_k (\text{max})$

energy levels  $hf = E_1 - E_2$

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

**BLANK PAGE**

**[Turn over]**

# 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

$$d \sin \theta = n\lambda$$

14

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**

$$\mathbf{moment} = Fd$$

**velocity and  
acceleration**

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

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

**equations of motion**

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

$$v^2 = u^2 + 2as \qquad s = ut + \frac{at^2}{2}$$

**force**

$$F = ma$$

**force**

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

**impulse**

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

**work, energy and  
power**

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

$$E_k = \frac{1}{2} m v^2 \quad \Delta E_p = mg \Delta h$$

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

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

**[Turn over]**

# MATERIALS

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

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

**Young modulus**  $= \frac{\textit{tensile stress}}{\textit{tensile strain}}$

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

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

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

# ELECTRICITY

**current and pd**

$$I = \frac{\Delta Q}{\Delta t} \qquad V = \frac{W}{Q} \qquad R = \frac{V}{I}$$

**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**

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

**emf**

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

**[Turn over]**

# CIRCULAR MOTION

$$\omega = \frac{v}{r}$$

magnitude of angular speed

$$\omega = 2\pi f$$

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

centripetal acceleration

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

centripetal force

## **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]**

# THEMAL 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

$$F = EQ$$

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**

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

**[Turn over]**

**capacitor charging**

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

**decay of charge**

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

**time constant**

$$RC$$

**BLANK PAGE**

**[Turn over]**

## 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

$$\varepsilon = N \frac{\Delta\Phi}{\Delta t}$$

emf induced in a rotating coil

$$N\Phi = BAN \cos \theta$$

$$\varepsilon = BAN\omega \sin \omega t$$

**alternating current**

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

**transformer equations**

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

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

**[Turn over]**

# NUCLEAR PHYSICS

inverse square law for  
 $\gamma$  radiation

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

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

radioactive decay

activity

$$A = \lambda N$$

30

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

half-life

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

nuclear radius

$$E = mc^2$$

energy-mass equation

## OPTIONS

## ASTROPHYSICS

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

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

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

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

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

[Turn over]

**telescope in normal adjustment**  $M = \frac{f_0}{f_e}$

**Rayleigh criterion**

$$\theta \approx \frac{\lambda}{D}$$

**magnitude equation**

$$m - M = 5 \log \frac{d}{10}$$

**Wien's law**

$$\lambda_{\max} T = 2.9 \times 10^{-3} \text{ m K}$$

**Stefan's law**

$$P = \sigma AT^4$$

**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**

$$v = Hd$$

**[Turn over]**

# 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**

$$\text{angular momentum} = I \omega$$

**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**

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

**[Turn over]**

## 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 × fuel flow rate**

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

**output or brake power**  $P = T \omega$

**friction power = indicated power – brake power**

**heat pumps and refrigerators**

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

**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**

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

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

**[Turn over]**

## special relativity

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

$$l = l_0 \sqrt{1 - \frac{v^2}{c^2}}$$

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

# ELECTRONICS

**resonant  
frequency**

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

**Q-factor**

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

**operational  
amplifiers: open  
loop**

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

**inverting amplifier**

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

**[Turn over]**

**non-inverting  
amplifier**

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

**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 =  $2f_M$*

*for FM      bandwidth =  $2(\Delta f + f_M)$*

**END OF DATA SHEET**

## BLANK PAGE

### Copyright information

For confidentiality purposes, all acknowledgements of third-party copyright material are published in a separate booklet. This booklet is published after each live examination series and is available for free download from [www.aqa.org.uk](http://www.aqa.org.uk).

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.

Copyright © 2023 AQA and its licensors. All rights reserved.

**WP/M/CH/Jun23/7408/INS/E1**