

A



**AS**

## **Physics data and formulae**

**For use in exams from the June 2016 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 | $e$          | $1.60 \times 10^{-19}$ | C                                |
| the Planck constant                 | $h$          | $6.63 \times 10^{-34}$ | 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              | $k$          | $1.38 \times 10^{-23}$ | $\text{J K}^{-1}$                |

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

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

**ALGEBRAIC EQUATION**

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

**ASTRONOMICAL DATA**

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

**GEOMETRICAL EQUATIONS**

arc length  $= r\theta$

circumference of circle  $= 2\pi r$

area of circle  $= \pi r^2$

curved surface area of cylinder  $= 2\pi r h$

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

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

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## 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         |
|         | 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            |

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**PHOTONS AND ENERGY LEVELS**

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

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

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

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

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

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

**[Turn over]**

**ELECTRICITY**

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

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

**END OF DATA SHEET**

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