

For use in exams from the June 2016 Series onwards

## 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                      | $\text{J K}^{-1} \text{mol}^{-1}$ |
| the Boltzmann constant                                       | $k$             | $1.38 \times 10^{-23}$    | $\text{J K}^{-1}$                 |
| the Stefan constant  | $\sigma$        | $5.67 \times 10^{-8}$     | $\text{W m}^{-2} \text{K}^{-4}$   |
| 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                                |
| 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>(1u 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

| Body  | Mass/kg               | Mean radius/m      |
|-------|-----------------------|--------------------|
| Sun   | $1.99 \times 10^{30}$ | $6.96 \times 10^8$ |
| Earth | $5.97 \times 10^{24}$ | $6.37 \times 10^6$ |

### GEOMETRICAL EQUATIONS

arc length =  $r\theta$

circumference of circle =  $2\pi r$

area of circle =  $\pi r^2$

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

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

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

## 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 |
|----------|-----------------|----------------|-------------|
| <b>u</b> | $+\frac{2}{3}e$ | $+\frac{1}{3}$ | 0           |
| <b>d</b> | $-\frac{1}{3}e$ | $+\frac{1}{3}$ | 0           |
| <b>s</b> | $-\frac{1}{3}e$ | $+\frac{1}{3}$ | -1          |

## Properties of Leptons

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

## Photons and energy levels

*photon energy*  $E = hf = \frac{hc}{\lambda}$   
*photoelectricity*  $hf = \phi + E_{k(\max)}$   
*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  $n_1 > n_2$

## Mechanics

*moments*     *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*  $W = F s \cos \theta$   
 $E_k = \frac{1}{2} m v^2$       $\Delta E_p = mg \Delta h$   
 $P = \frac{\Delta W}{\Delta t}$ ,  $P = Fv$   
*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*  $E = \frac{1}{2} F \Delta L$

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

