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# PHYSICS DATA AND FORMULAE

**For use in exams from the June 2016 Series onwards**

**[Turn over]**

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## DATA - FUNDAMENTAL CONSTANTS AND VALUES

| Quantity | Symbol | Value | Units |
|---|---|---|---|
| speed of light in vacuo | $c$ | $3{\cdot}00 \times 10^{8}$ | $m\ s^{-1}$ |
| permeability of free space | $\mu_0$ | $4\pi \times 10^{-7}$ | $H\ m^{-1}$ |
| permittivity of free space | $\varepsilon_0$ | $8{\cdot}85 \times 10^{-12}$ | $F\ m^{-1}$ |
| magnitude of the charge of electron | $e$ | $1{\cdot}60 \times 10^{-19}$ | C |
| the Planck constant | $h$ | $6{\cdot}63 \times 10^{-34}$ | $J\ s$ |
| gravitational constant | $G$ | $6{\cdot}67 \times 10^{-11}$ | $N\ m^2\ kg^{-2}$ |
| the Avogadro constant | $N_A$ | $6{\cdot}02 \times 10^{23}$ | $mol^{-1}$ |
| molar gas constant | $R$ | $8{\cdot}31$ | $J\ K^{-1}\ mol^{-1}$ |
| the Boltzmann constant | $k$ | $1{\cdot}38 \times 10^{-23}$ | $J\ K^{-1}$ |
| the Stefan constant | $\sigma$ | $5{\cdot}67 \times 10^{-8}$ | $W\ m^{-2}\ K^{-4}$ |
| the Wien constant | $\alpha$ | $2{\cdot}90 \times 10^{-3}$ | $m\ K$ |
| electron rest mass (equivalent to $5{\cdot}5 \times 10^{-4}$ u) | $m_e$ | $9{\cdot}11 \times 10^{-31}$ | kg |
| electron charge / mass ratio | $\frac{e}{m_e}$ | $1{\cdot}76 \times 10^{11}$ | $C\ kg^{-1}$ |
| proton rest mass (equivalent to 1·00728 u) | $m_p$ | $1{\cdot}67(3) \times 10^{-27}$ | kg |
| proton charge/mass ratio | $\frac{e}{m_p}$ | $9{\cdot}58 \times 10^{7}$ | $C\ kg^{-1}$ |

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| | | | |
|---|---|---|---|
| neutron rest mass (equivalent to 1·00867 u) | $m_n$ | $1{\cdot}67(5) \times 10^{-27}$ | kg |
| 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 | $1{\cdot}661 \times 10^{-27}$ | kg |

## ALGEBRAIC EQUATION

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

## ASTRONOMICAL DATA

| Body | Mass / kg | Mean radius / m |
|---|---|---|
| Sun | $1{\cdot}99 \times 10^{30}$ | $6{\cdot}96 \times 10^{8}$ |
| Earth | $5{\cdot}97 \times 10^{24}$ | $6{\cdot}37 \times 10^{6}$ |

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

## 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 |

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## 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: | $e^+$, $\overline{\nu_e}$, $\mu^+$, $\overline{\nu_\mu}$ | –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 $\lambda = \frac{h}{p} = \frac{h}{mv}$

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## 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 $n_1 > n_2$

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## Mechanics

**moments**

moment = $Fd$

**velocity and acceleration**

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

**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**

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

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

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

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

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## Materials

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

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

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

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

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

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 $R_T = R_1 + R_2 + R_3 + \ldots$

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

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

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

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