

TEXTBOOK SOLUTIONS

Exercise 1.1	1	Exercise 14.1	36
Exercise 2.1	2	Exercise 14.2	36
Exercise 3.1	2	Exercise 15.1	36
Exercise 3.2	4	Exercise 15.2	37
Exercise 4.1	5	Exercise 16.1	39
Exercise 4.2	5	Exercise 16.2	40
Exercise 4.3	6	Exercise 16.3	40
Exercise 4.4	6	Exercise 17.1	41
Exercise 5.1	7	Exercise 17.2	42
Exercise 5.2	9	Exercise 18.1	42
Exercise 5.3	10	Exercise 18.2	43
Exercise 6.1	11	Exercise 18.3	44
Exercise 6.2	11	Exercise 19.1	44
Exercise 6.3	12	Exercise 19.2	45
Exercise 7.1	12	Exercise 20.1	47
Exercise 7.2	13	Exercise 20.2	48
Exercise 7.4	14	Exercise 20.3	49
Exercise 7.5	15	Exercise 21.1	50
Exercise 8.1	17	Exercise 22.1	51
Exercise 8.2	17	Exercise 23.1	51
Exercise 8.3	18	Exercise 23.2	53
Exercise 9.1	19	Exercise 23.3	54
Exercise 9.2	20	Exercise 24.1	54
Exercise 9.3	20	Exercise 24.2	55
Exercise 10.1	22	Exercise 27.1	56
Exercise 10.2	23	Exercise 27.2	56
Exercise 10.3	23	Exercise 28.1	57
Exercise 10.4	24	Exercise 28.2	57
Exercise 10.5	24	Exercise 28.3	59
Exercise 10.6	25	Exercise 28.4	59
Exercise 10.7	26	Exercise 28.5	60
Exercise 10.8	28	Exercise 28.6	60
Exercise 11.1	28	Exercise 29.1	61
Exercise 11.2	29	Exercise 29.2	62
Exercise 11.3	30	Exercise 30.1	64
Exercise 11.4	31	Exercise 30.2	64
Exercise 11.5	31	Exercise 30.3	65
Exercise 12.1	32	Exercise 31.1	66
Exercise 12.2	32	Exercise 32.1	67
Exercise 12.3	33	Exercise 32.2	68
Exercise 12.4	33	Exercise 32.3	68
Exercise 13.1	34	Exercise 32.4	69
Exercise 13.2	35	Exercise 33.1	69
Exercise 13.3	35		

TEXTBOOK SOLUTIONS

Exercise 1.1

Q1 Area = length \times length \Rightarrow Unit of area
 = (m)(m) = $\mathbf{m^2}$ = **the square metre**

Q2 $P = mv \Rightarrow$ Unit of p = (Unit of m)(Unit of v)
 = (kg)(m s⁻¹) = $\mathbf{kg\ m\ s^{-1}}$ = **the kilogram metre per second**

Q3 Unit of $a = \frac{\text{Unit of } v}{\text{Unit of } t} = \frac{\text{m s}^{-1}}{\text{s}} = \mathbf{m\ s^{-2}}$
 = **the metre per second squared**

Q4 kg m⁻³, density = $\frac{\text{Mass}}{\text{Volume}}$
 \Rightarrow Unit of density = $\frac{\text{kg}}{\text{m}^3} = \mathbf{kg\ m^{-3}}$

Q5 $P = \frac{F}{A} \Rightarrow$ Unit of $P = \frac{\text{Unit of Force}}{\text{Unit of Area}}$
 = $\frac{\text{Newton}}{\text{Metre squared}} = \text{Newton per square metre}$
 = $\mathbf{N\ m^{-2}}$

Q6 (a) **10 000** (i.e. 100×100)

(b) **1 000 000** (i.e. $100 \times 100 \times 100$)

(c) **1000**

Q7 (i) $5\ \text{cm}^2 = \mathbf{5 \times 10^{-4}\ m^2}$

(ii) $40\ \text{cm}^2 = 40 \times 10^{-4}\ \text{m}^2 = \mathbf{4 \times 10^{-3}\ m^2}$

(iii) $1\ \text{cm}^3 = \mathbf{1 \times 10^{-6}\ m^3}$

(iv) $456\ \text{cm}^3 = 456 \times 10^{-6}\ \text{m}^3$
 = $\mathbf{4.56 \times 10^{-4}\ m^3}$

(v) $1\ 000\ 000\ 000 = (1 \times 10^9) \times 10^{-6}$
 = $10^3\ \text{m}^3 = \mathbf{1000\ m^3}$

Q8 (i) $105\ \text{km} = 105 \times 10^3\ \text{m} = \mathbf{1.05 \times 10^5\ m}$

(ii) $57\ \text{mm} = 57 \times 10^{-3}\ \text{m} = \mathbf{5.7 \times 10^{-2}\ m}$

(iii) $6.67 \times 10^{-11}\ \text{cm} = (6.67 \times 10^{-11})(\times 10^{-2})$
 = $\mathbf{6.67 \times 10^{-13}\ m}$

(iv) $6 \times 10^{27}\ \text{grams} = (6 \times 10^{27})(10^{-3})\ \text{kg}$
 = $\mathbf{6 \times 10^{24}\ kg}$

(v) $9 \frac{\text{g}}{\text{cm}^3} = \frac{9 \times 10^{-3}\ \text{kg}}{\text{cm}^3} = \frac{9 \times 10^{-3}\ \text{kg}}{1 \times 10^{-6}\ \text{m}^3}$
 = $\mathbf{9 \times 10^3\ kg\ m^{-3}}$

(vi) $100\ \text{km h}^{-1} = 100\ 000\ \text{m h}^{-1}$

= $\frac{100\ 000}{60 \times 60}\ \text{m s}^{-1} = \mathbf{27.78\ m\ s^{-1}}$

(vii) $5\ \text{nN} = \mathbf{5 \times 10^{-9}\ N}$

(viii) $10\ \mu\text{W} = 10 \times 10^{-6}\ \text{W} = \mathbf{1 \times 10^{-5}\ W}$

(ix) $5\ \text{Gm} = \mathbf{5 \times 10^9\ m}$

Q9 $F = ma \Rightarrow$ Unit of force = (kg)(m s⁻²)
 $\Rightarrow \mathbf{1\ N = 1\ kg\ m\ s^{-2}}$

Q10 $W = Fs \Rightarrow 1\ \text{Joule} = \mathbf{1\ N\ m}$

Q11 $1\ \text{J} = 1\ \text{N m} = 1(\text{kg m s}^{-2})(\text{m}) = \mathbf{1\ kg\ m^2\ s^{-2}}$

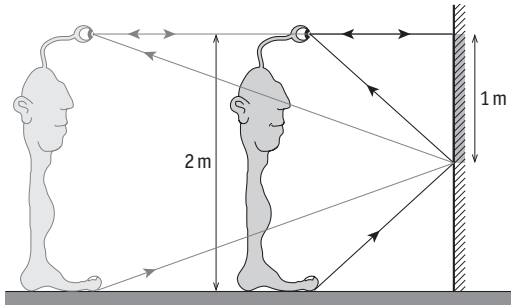
Q12 $1\ \text{W} = 1\ \text{J s}^{-1} = (1\ \text{kg m}^2\ \text{s}^{-2})\text{s}^{-1} = \mathbf{1\ kg\ m^2\ s^{-3}}$

Exercise 2.1

Q1 $t = \frac{\text{Distance}}{\text{Speed}} = \frac{3.8 \times 10^8}{3 \times 10^8} = 1.27 \text{ s}$

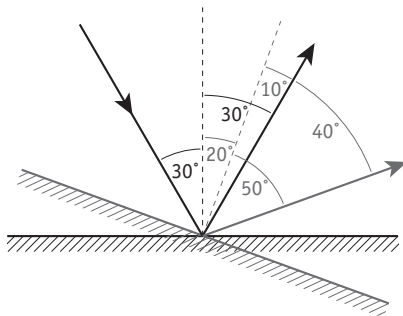
Q2 Incident ray, reflected ray, normal, angle of incidence, angle of reflection.

Q5 Answer = 1 m (see diagram)

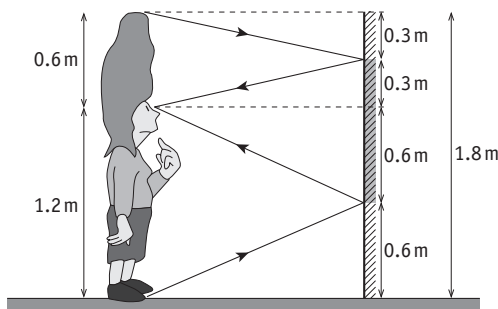


Q6 $t = \frac{\text{Distance}}{\text{Speed}} = \frac{3.97 \times 10^{16}}{3 \times 10^8} = 1.32 \times 10^8 \text{ s}$
 = **4.2 years**

Q7 From the diagram (i) 50° (ii) 50° (iii) 40°



Q9 From the diagram, length = 0.9 m



Exercise 3.1

Q1 $u = 30 \quad v = 50 \quad f = ?$

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

$$\Rightarrow \frac{1}{30} + \frac{1}{50} = \frac{1}{f}$$

$$\Rightarrow \frac{5+3}{150} = \frac{1}{f}$$

$$\Rightarrow f = \frac{150}{8} = 18.75$$

focal length = **18.75 cm**

Q2 $u = 20 \quad v = 30$
 Image virtual $\Rightarrow \frac{1}{u} - \frac{1}{v} = \frac{1}{f}$

$$\frac{1}{20} - \frac{1}{30} = \frac{1}{f}$$

$$\Rightarrow \frac{3-2}{60} = \frac{1}{f}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{60} \quad \Rightarrow f = \mathbf{60 \text{ cm}}$$

Q3 $u = 15 \quad f = 10 \quad v = ?$

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

$$\frac{1}{15} + \frac{1}{v} = \frac{1}{10}$$

$$\frac{1}{v} = \frac{1}{10} - \frac{1}{15}$$

$$\frac{1}{v} = \frac{3-2}{30}$$

$$\frac{1}{v} = \frac{1}{30} \quad \Rightarrow v = \mathbf{30 \text{ cm}}$$

Image is real ($v +$)

Magnification = $\frac{v}{u} = \frac{30}{15} = 2$

Image is twice the size of object
 \Rightarrow its height is 4 cm

Q4 $u = 10$ $f = 20$ $v = ?$

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

$$\frac{1}{10} + \frac{1}{v} = \frac{1}{20}$$

$$\frac{1}{v} = \frac{1}{20} - \frac{1}{10} \quad \Rightarrow \quad v = -20 \text{ cm}$$

\therefore Image is **20 cm** from mirror. It is **virtual**.

$$m = \frac{v}{u} = \frac{20}{10} = 2$$

Q5 $f = 40$

$$\text{Magnification} = 4 = \frac{v}{u}$$

$$\Rightarrow v = 4u.$$

Find u .

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

$$\frac{1}{u} + \frac{1}{4u} = \frac{1}{f}$$

$$\frac{4+1}{4u} = \frac{1}{f}$$

$$\frac{5}{4u} = \frac{1}{f} \Rightarrow f = \frac{4u}{5} \text{ i.e. } 40 = \frac{4u}{5}$$

$$\Rightarrow u = \frac{5 \times 40}{4}$$

$$u = \mathbf{50 \text{ cm}}$$

Q6 (i) Real image: $\frac{1}{u} + \frac{1}{v} = \frac{1}{20}$

$$\frac{v}{u} = 3 \Rightarrow v = 3u$$

$$\frac{1}{u} + \frac{1}{3u} = \frac{1}{20}$$

$$\frac{3+1}{3u} = \frac{1}{20}$$

$$\frac{4}{3u} = \frac{1}{20}$$

$$3u = 80 \quad \Rightarrow \quad u = \mathbf{26\frac{2}{3} \text{ cm}}$$

(ii) Virtual image

$$\frac{v}{u} = 3 \text{ and } \frac{1}{u} - \frac{1}{v} = \frac{1}{f}$$

$$v = +3u$$

$$\frac{1}{u} - \frac{1}{3u} = \frac{1}{20}$$

$$\frac{3-1}{3u} = \frac{1}{20}$$

$$\frac{2}{3u} = \frac{1}{20}$$

$$3u = 40$$

$$u = \frac{40}{3} = \mathbf{13\frac{1}{3} \text{ cm}}$$

Q7 Real image: $\frac{v}{u} = 2 \Rightarrow v = 2u$

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

$$\frac{1}{u} + \frac{1}{2u} = \frac{1}{50}$$

$$\frac{2+1}{2u} = \frac{1}{50}$$

$$2u = 150 \quad \Rightarrow \quad u = \mathbf{75 \text{ cm}}$$

Virtual image:

$$\frac{v}{u} = 2 \text{ and } \frac{1}{u} - \frac{1}{v} = \frac{1}{f}$$

$$v = 2u$$

$$\frac{1}{u} - \frac{1}{2u} = \frac{1}{50}$$

$$\frac{2-1}{2u} = \frac{1}{50}$$

$$\Rightarrow 2u = 50$$

$$u = \mathbf{25 \text{ cm}}$$

Q8 Image upright \Rightarrow Virtual image

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

$$\text{Magnification} = 3 = \frac{v}{u}$$

$$\Rightarrow v = 3u$$

$$\frac{1}{u} - \frac{1}{3u} = \frac{1}{100}$$

$$\frac{3-1}{3u} = \frac{1}{100}$$

$$\Rightarrow 200 = 3u$$

$$u = \frac{200}{3} = \mathbf{66\frac{2}{3} \text{ cm}}$$

Q9 Image is real and at the focus since light from a distant object arrives as parallel light.

Q10 Magnification = $\frac{1}{3}$

$$\Rightarrow \frac{v}{u} = \frac{1}{3} \quad \Rightarrow \quad u = 3v$$

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

$$\Rightarrow \frac{1}{3v} + \frac{1}{v} = \frac{1}{40}$$

$$\Rightarrow \frac{4}{3v} = \frac{1}{40}$$

$$\Rightarrow v = \frac{160}{3}$$

$$u = 3v = 3\left(\frac{160}{3}\right) = \mathbf{160 \text{ cm}}$$

Exercise 3.2

Q1 $\frac{1}{u} - \frac{1}{v} = -\frac{1}{f}$ $m = \frac{v}{u}$
 $u = 10, f = 12, v = ?$ $m = \frac{v}{u} = \frac{5.45}{10} = .545$
 $\frac{1}{10} - \frac{1}{v} = -\frac{1}{12}$ Image is **virtual** and
 5.45 cm behind mirror.
 $\frac{1}{10} + \frac{1}{12} = \frac{1}{v}$
 $\frac{6+5}{60} = \frac{1}{v} \Rightarrow \frac{1}{v} = \frac{11}{60}$
 $v = \frac{60}{11} = \mathbf{5.45 \text{ cm}}$

Q2 $u = 30, f = 12, v = ?$
 $\frac{1}{u} - \frac{1}{v} = -\frac{1}{f}$
 $\frac{1}{30} - \frac{1}{v} = -\frac{1}{12}$
 $\frac{1}{30} + \frac{1}{12} = \frac{1}{v} \Rightarrow v = \mathbf{8.57 \text{ cm}}$

Virtual

Magnification = $\frac{v}{u} = \frac{8.57}{30} = \mathbf{0.29}$

Q3 $f = 10, \text{Mag.} = \frac{v}{u} = \frac{1}{4} \Rightarrow 4v = u$
 $\frac{1}{u} - \frac{1}{v} = -\frac{1}{f}$ $\frac{+3}{4v} = \frac{+1}{10}$ $u = 4v \Rightarrow$
 $\frac{1}{4v} - \frac{1}{v} = -\frac{1}{10}$ $30 = 4v$ $u = \mathbf{30 \text{ cm}}$
 $\frac{1-4}{4v} = -\frac{1}{10}$ $v = \mathbf{7.5 \text{ cm}}$

Q4 $\frac{1}{u} - \frac{1}{v} = -\frac{1}{f}$ $m = \frac{v}{u} = \frac{\text{Height of image}}{\text{Height of object}}$
 $v = 10$ $m = \frac{2}{5} = \frac{v}{u}$
 $\therefore \begin{cases} 2u = 5v \\ 2u = 5(10) \\ u = 25 \end{cases}$ $\frac{1}{u} - \frac{1}{v} = -\frac{1}{f}$
 $\frac{1}{25} - \frac{1}{10} = -\frac{1}{f}$
 $\frac{2-5}{50} = -\frac{1}{f}$
 $\frac{-3}{50} = -\frac{1}{f}$
 $\Rightarrow f = \frac{50}{3} = \mathbf{16\frac{2}{3} \text{ cm}}$

Q5 $v = 4 \text{ cm}$
 $h_i = 4, h_o = 6$
 $m = \frac{h_i}{h_o} = \frac{v}{u} \Rightarrow \frac{4}{6} = \frac{v}{u}$
 $\frac{4}{6} = \frac{4}{u} \Rightarrow u = 6 \text{ cm}$
 $\frac{1}{u} - \frac{1}{v} = -\frac{1}{f}$
 $\frac{1}{6} - \frac{1}{4} = -\frac{1}{f}$
 $\frac{2-3}{12} = -\frac{1}{f}$
 $-\frac{1}{12} = -\frac{1}{f} \Rightarrow f = \mathbf{12 \text{ cm}}$

Q6 $m = \frac{v}{u} = \frac{1}{3}$
 $\frac{1}{u} - \frac{1}{v} = -\frac{1}{20}$ Find u .
 $v = \frac{u}{3}$

$\frac{1}{u} - \frac{1}{(\frac{u}{3})} = -\frac{1}{20}$

$\frac{1}{u} - \frac{3}{u} = -\frac{1}{20}$
 $\frac{-2}{u} = -\frac{1}{20} \Rightarrow u = \mathbf{40 \text{ cm}}$

Q7 $h_i = \frac{1}{2}h_o$
 $\frac{h_i}{h_o} = \frac{1}{2} = \frac{v}{u} \Rightarrow u = 2v$

$\frac{1}{2v} - \frac{1}{v} = -\frac{1}{40}$
 $\frac{1-2}{2v} = -\frac{1}{40}$
 $+\frac{1}{2v} = \frac{1}{40} \Rightarrow v = 20$
 $\therefore u = \mathbf{40 \text{ cm}}$

Q8 $m = \frac{1}{2} = \frac{v}{u}$
 $\frac{1}{u} - \frac{1}{v} = -\frac{1}{f}$
 $v = \frac{u}{2}$
 $\frac{1}{u} - \frac{1}{(\frac{u}{2})} = -\frac{1}{f}$

$-\frac{1}{u} = -\frac{1}{f} \therefore f = u$

\therefore Object must be a distance in front of mirror equal to its focal length.

Exercise 4.1

$$\text{Q1 } {}_a n_g = \frac{\sin 25^\circ}{\sin 16.4^\circ} = \frac{.4226}{.2823} = 1.496989 = \mathbf{1.5}$$

$$\text{Q2 } {}_a n_d = \frac{\sin 60^\circ}{\sin 21^\circ} = \mathbf{2.42}$$

$$\text{Q3 } {}_a n_w = \frac{\sin 30^\circ}{\sin r} = 1.33 \Rightarrow \sin r = \frac{\sin 30^\circ}{1.33} = .3759$$

$$\Rightarrow r = \mathbf{22.1^\circ}$$

$$\text{Q4 } {}_a n_g = 1.5 \quad {}_g n_a = \frac{1}{{}_a n_g} = \frac{1}{1.5} = \frac{2}{3}$$

$$\text{Q5 } {}_g n_w = \frac{1}{{}_w n_g} = \frac{1}{1.13} = \mathbf{0.88}$$

$$\text{Q6 } {}_g n_a = \frac{\sin 35^\circ}{\sin 69^\circ}$$

$${}_a n_g = \frac{1}{{}_g n_a} = \frac{1}{\frac{\sin 35^\circ}{\sin 69^\circ}} = \frac{\sin 69^\circ}{\sin 35^\circ} = \mathbf{1.63}$$

$$\text{Q7 } \frac{\sin i}{\sin 15^\circ} = {}_d n_a \quad \therefore \frac{\sin i}{\sin 15^\circ} = \frac{1}{2.42}$$

$$\Rightarrow \sin i = \frac{\sin 15^\circ}{2.42} = \frac{0.2588}{2.42} = 0.10695$$

$$i = \sin^{-1}(0.10695) = 6.1395, \text{ i.e. } i = \mathbf{6.1^\circ}$$

$$\text{Q8 } \frac{\sin r}{\sin 20^\circ} = 2.42 \Rightarrow \sin r = 0.8277$$

$$\Rightarrow r = \mathbf{55.9^\circ}$$

Exercise 4.2

$$\text{Q1 } {}_a n_g = \frac{\text{Real depth}}{\text{Apparent depth}} = \frac{5}{3.33} = \mathbf{1.5}$$

$$\text{Q2 } \frac{\text{Real depth}}{\text{Apparent depth}} = {}_a n_w$$

$$\therefore \frac{10}{\text{Apparent depth}} = 1.33$$

$$\Rightarrow \text{Apparent depth} = \frac{10}{1.33} = \mathbf{7.52 \text{ m}}$$

$$\text{Q3 } \frac{\text{Real depth}}{\text{Apparent depth}} = {}_a n_w \Rightarrow \frac{\text{Real depth}}{0.8} = \frac{4}{3}$$

$$\Rightarrow \text{Real depth} = \frac{4 \times 0.8}{3} = \mathbf{1.07 \text{ m}}$$

$$\text{Q4 } \text{Real depth} = 6$$

$$\text{Appears as cube} \Rightarrow \text{Apparent depth} = 5$$

$$\therefore \text{Refractive index} = \frac{6}{5} = \mathbf{1.2}$$

$$\text{Q5 } \text{Let } x = \text{the real depth} = \text{thickness of block, i.e.}$$

$$\text{Real depth} = x, \text{ Apparent depth} = x - 3.33$$

$${}_a n_g = \frac{\text{Real depth}}{\text{Apparent depth}} \Rightarrow 1.5 = \frac{x}{x - 3.33}$$

$$1.5x - 1.5(3.33) = x$$

$$1.5x - x = (1.5)(3.33)$$

$$0.5x = 4.995$$

$$x = \frac{4.995}{0.5} = \mathbf{9.99 \text{ cm}}$$

Exercise 4.3

$$\begin{aligned} \text{Q1 } n &= \frac{c_{\text{air}}}{c_{\text{medium}}} \Rightarrow c_{\text{medium}} = \frac{c_{\text{air}}}{n} \\ &= \frac{3 \times 10^8}{1.5} \\ &= 2 \times 10^8 \text{ ms}^{-1} \end{aligned}$$

$$\text{Q2 } c_d = \frac{c_{\text{air}}}{n} = \frac{3 \times 10^8}{2.42} = 1.24 \times 10^8 \text{ ms}^{-1}$$

$$\text{Q3 } n = \frac{c_{\text{air}}}{c_m} = \frac{3 \times 10^8}{2 \times 10^8} = \frac{3}{2} = 1.5$$

$$\text{Q4 } n = \frac{c_{\text{air}}}{c_m} = \frac{3 \times 10^8}{1.25 \times 10^8} = 2.4$$

Exercise 4.4

$$\text{Q1 } n = \frac{1}{\sin C} = \frac{1}{\sin 40^\circ} = 1.56$$

$$\text{Q2 } n = \frac{1}{\sin C} = \frac{1}{\sin 24.6^\circ} = 2.40$$

$$\begin{aligned} \text{Q3 } n &= \frac{1}{\sin C} \Rightarrow \sin C = \frac{1}{n} = \frac{1}{1.2} \\ &\Rightarrow \sin C = 0.8333 \\ &\Rightarrow C = 56.4^\circ \end{aligned}$$

$$\begin{aligned} \text{Q4 } \sin C &= \frac{1}{n} = \frac{1}{1.33} = 0.7518797 \\ &\Rightarrow C = 48.75^\circ \end{aligned}$$

$$\text{Q5 } \sin C = \frac{1}{n} = \frac{1}{1.66} \Rightarrow C = 37.04^\circ$$

$$\text{Q6 } n = \frac{1}{\sin C} = \frac{1}{\sin 40^\circ} = \frac{1}{0.6428} = 1.56$$

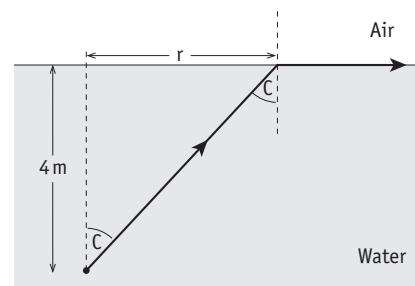
$$\begin{aligned} n &= \frac{\text{Real depth}}{\text{Apparent depth}} \Rightarrow 1.56 = \frac{12}{\text{Apparent depth}} \\ &\Rightarrow \text{Apparent depth} = 7.69 \text{ cm} \end{aligned}$$

$$\text{Q7 } n = 1.33$$

$$\Rightarrow \frac{1}{\sin C} = 1.33 \Rightarrow C = 48.75^\circ$$

$$\tan C = \frac{r}{4} \Rightarrow r = 4 \tan(48.75^\circ)$$

i.e. radius = 4.56 m



$$\text{Q8 } \tan C = \frac{2.3}{2} \Rightarrow C = 48.99^\circ$$

$$n = \frac{1}{\sin C} = \frac{1}{\sin 48.99^\circ} = 1.33$$

Q9 The angle of incidence of the ray on the glass air surface is 45° . In going from glass to air the angle of incidence must be greater than the critical angle if total internal reflection is to occur, i.e. for total internal reflection $45^\circ > C$ i.e. $C < 45^\circ$

$$\Rightarrow \sin C < \sin 45^\circ \Rightarrow \sin C < 0.707$$

$$\therefore \frac{1}{\sin C} > \frac{1}{0.707}$$

But $\frac{1}{\sin C} =$ refractive index of the glass

$$\text{and } \frac{1}{0.707} = 1.414$$

\therefore Refractive index must be greater than 1.414

Exercise 5.1

$$\begin{aligned} \text{Q1 } \frac{1}{u} + \frac{1}{v} &= \frac{1}{f} \Rightarrow \frac{1}{40} + \frac{1}{25} = \frac{1}{f} \\ &\Rightarrow f = \mathbf{15.38 \text{ cm, real.}} \end{aligned}$$

$$\begin{aligned} \text{Q2 } \frac{1}{u} + \frac{1}{v} &= \frac{1}{f} \Rightarrow \frac{1}{100} + \frac{1}{v} = \frac{1}{30} \Rightarrow \frac{1}{v} = \frac{1}{30} - \frac{1}{100} \\ &= \frac{100 - 30}{(30)(100)} \Rightarrow v = \mathbf{42.86 \text{ cm}} \end{aligned}$$

$$\frac{h_i}{h_o} = \frac{v}{u}$$

$$\frac{h_i}{4} = \frac{42.86}{100}$$

$$h_i = \frac{4(42.86)}{100} = 1.71 \text{ cm}$$

Image is **1.71 cm** high, **real**, and **42.86 cm** from lens.

$$\begin{aligned} \text{Q3 } \frac{1}{u} + \frac{1}{v} &= \frac{1}{f} \Rightarrow \frac{1}{20} + \frac{1}{v} = \frac{1}{30} \Rightarrow \frac{1}{v} = \frac{1}{30} - \frac{1}{20} \\ &= \frac{2 - 3}{60} = -\frac{1}{60} \Rightarrow v = \mathbf{-60} \end{aligned}$$

\Rightarrow Image is **virtual** and **60 cm** from lens.

$$\frac{h_i}{h_o} = \frac{v}{u} \Rightarrow h_i = \left(\frac{60}{20}\right)(2) = \mathbf{6 \text{ cm}}$$

Image is **6 cm** high.

$$\text{Q4 } \frac{v}{u} = 2, f = 50$$

Real image

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

$$\frac{1}{u} + \frac{1}{2u} = \frac{1}{50}$$

$$\frac{2+1}{2u} = \frac{1}{50}$$

$$\Rightarrow 2u = 150$$

$$u = \mathbf{75 \text{ cm}}$$

Virtual image

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

$$\frac{1}{u} - \frac{1}{2u} = \frac{1}{50}$$

$$\frac{1}{2u} = \frac{1}{50}$$

$$\Rightarrow u = \mathbf{25 \text{ cm}}$$

Q5 $f = 20$ $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Image is twice the height of object

$\Rightarrow m = 2 = \frac{v}{u} \Rightarrow v = 2u$

Real image

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

$\frac{1}{u} + \frac{1}{2u} = \frac{1}{20}$

$\frac{2+1}{2u} = \frac{1}{20}$

$\frac{3}{2u} = \frac{1}{20}$

$\Rightarrow 2u = 60$

$u = 30 \text{ cm}$

Virtual image

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

$\frac{1}{u} - \frac{1}{2u} = \frac{1}{20}$

$\frac{2-1}{2u} = \frac{1}{20}$

$\frac{1}{2u} = \frac{1}{20}$

$\Rightarrow u = 10 \text{ cm}$

Q6 Here $v = 10$ and magnification = $\frac{3}{0.08}$, i.e.

$m = \frac{3}{0.08} = \frac{v}{u}$

$\therefore 3u = 0.08v$

$u = \frac{(0.08)10}{3}$

$u = 0.2667$

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

$\frac{1}{0.2667} + \frac{1}{10} = \frac{1}{f}$

$3.75 + 0.1 = \frac{1}{f}$

$\Rightarrow \frac{1}{f} = 3.85$

$f = 0.2597 \text{ m}$

$f = 26.0 \text{ cm}$

Q7 Convex lens, since a concave lens does not form a real image.

$m = \frac{v}{u} = 15 \Rightarrow v = 15u \Rightarrow u = \frac{v}{15}$

$v = 4$

$\Rightarrow u = \frac{4}{15}$

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

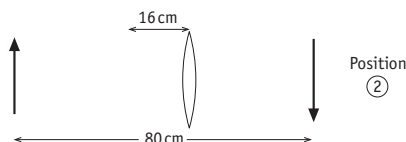
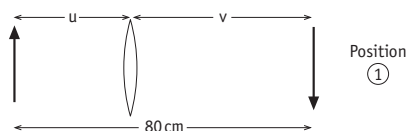
$\frac{1}{(\frac{4}{15})} + \frac{1}{4} = \frac{1}{f}$

$\frac{15}{4} + \frac{1}{4} = \frac{1}{f}$

$\frac{15+1}{4} = \frac{1}{f} \Rightarrow f = \frac{1}{4} \text{ m}$

i.e. $f = 25 \text{ cm}$

Q8



Let f be the focal length of lens.

Then for position (i) we have $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ (1)

also $u + v = 80 \Rightarrow u = 80 - v$ (2)

In position (ii) Object distance = $u + 16$

Image distance = $v - 16$

$\therefore \frac{1}{u+16} + \frac{1}{v-16} = \frac{1}{f}$ (3)

From (1) and (3)

$\frac{1}{u} + \frac{1}{v} = \frac{1}{u+16} + \frac{1}{v-16}$

From (2) $u = 80 - v$

\therefore This becomes

$\frac{1}{80-v} + \frac{1}{v} = \frac{1}{80-v+16} + \frac{1}{v-16}$

$\frac{v+80-v}{v(80-v)} = \frac{v-16+96-v}{(v-16)(96-v)}$

$\frac{80}{v(80-v)} = \frac{80}{(v-16)(96-v)}$

$(v-16)(96-v) = v(80-v)$

$96v - (16)(96) - v^2 + 16v = 80v - v^2$

$32v = 1536 \Rightarrow v = 48$

$u = 80 - v \Rightarrow u = 32$

$\frac{1}{32} + \frac{1}{48} = \frac{1}{f} \Rightarrow \frac{1}{f} = \frac{48+32}{(32)(48)} = \frac{80}{1536}$

$\Rightarrow f = 19.2 \text{ cm}$

Position (i) $m = \frac{v}{u} = \frac{48}{32} = \frac{6}{4} = \frac{3}{2}$

Position (ii) $m = \frac{v}{u} = \frac{48-16}{32+16} = \frac{32}{48} = \frac{2}{3}$

Q9 (i) u and v are interchangeable.

\therefore Distance between lenses = $13.3 - 8.0 = 5.3 \text{ cm}$

(ii) $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{13.3} + \frac{1}{8.0} = \frac{1}{f}$

$\Rightarrow f = 4.995 \text{ cm}$

Exercise 5.2

Q1 Concave lens formula is $\Rightarrow \frac{1}{u} - \frac{1}{v} = -\frac{1}{f}$

$$u = 30, f = 20$$

$$\frac{1}{30} - \frac{1}{v} = -\frac{1}{20} \quad \Rightarrow \frac{1}{v} = \frac{5}{60}$$

$$-\frac{1}{v} = -\frac{1}{20} - \frac{1}{30} \quad 60 = 5v$$

$$-\frac{1}{v} = \frac{-3-2}{60} \quad v = \frac{60}{5}$$

$$-\frac{1}{v} = \frac{-5}{60} \quad v = \mathbf{12 \text{ cm}}$$

Concave lens image is always **virtual**.

Q2 $f = 20$; $u = 20$; $v = ?$

Concave lens \Rightarrow

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

$$\frac{1}{20} - \frac{1}{v} = -\frac{1}{20}$$

$$-\frac{1}{v} = -\frac{1}{20} - \frac{1}{20}$$

$$-\frac{1}{v} = -\frac{2}{20}$$

$$2v = 20$$

$$v = \mathbf{10 \text{ cm}}$$

$$\text{Mag.} = \frac{v}{u}$$

$$= \frac{10}{20} = \frac{1}{2}$$

$$\Rightarrow \frac{\text{Height of image}}{\text{Height of object}} = \frac{1}{2}$$

\therefore Height of image

$$= \frac{1}{2} \text{ Height of object} = \left(\frac{1}{2}\right)(5) = \mathbf{2.5 \text{ cm}}$$

Image is virtual; 10 cm from lens, of height 2.5 cm.

Q3 $m = \frac{1}{3} \Rightarrow \frac{v}{u} = \frac{1}{3} \Rightarrow u = 3v \quad f = 60$

$$\frac{1}{u} - \frac{1}{v} = -\frac{1}{f} \quad \Rightarrow 3v = 120$$

$$\frac{1}{3v} - \frac{1}{v} = -\frac{1}{60} \quad \Rightarrow v = 40 \text{ cm}$$

$$\frac{1-3}{3v} = -\frac{1}{60} \quad u = 3v$$

$$\frac{-2}{3v} = -\frac{1}{60} \quad \Rightarrow u = \mathbf{120 \text{ cm}}$$

Q4 $\text{Mag.} = \frac{1}{2} = \frac{v}{u}$. Let focal length be f .

$$u = 2v \Rightarrow v = \frac{u}{2}$$

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

$$\frac{1}{u} - \frac{1}{\frac{u}{2}} = -\frac{1}{f}$$

$$\frac{1}{u} - \frac{2}{u} = -\frac{1}{f}$$

$$\frac{1-2}{u} = -\frac{1}{f} \Rightarrow -\frac{1}{u} = -\frac{1}{f} \Rightarrow u = f$$

i.e. **the distance from the object to the lens is equal to the focal length of the lens.**

Exercise 5.3

Q1 (i) $p = \frac{1}{f} = \frac{1}{0.4} = +2.5 \text{ m}^{-1}$

(ii) $p = \frac{1}{f} = \frac{1}{0.6} = -1.67 \text{ m}^{-1}$

Q2 $f = \frac{1}{p} = \frac{1}{12} \text{ m} = 8.33 \text{ cm}$

Q3 $f = \frac{1}{p} = \frac{1}{0.025} = 40 \text{ m}$

Q4 (i) $p = p_1 + p_2 = 6 + 10 = 16 \text{ m}^{-1}$

(ii) $f = \frac{1}{p} = \frac{1}{16} = 0.0625 \text{ m} = 6.25 \text{ cm}$

Q5 (i) $p = p_1 + p_2 = -4 - 8 = -12 \text{ m}^{-1}$

(ii) $f = \frac{1}{p} = \frac{1}{-12} = 0.0833 \text{ m} = 8.33 \text{ cm}$

Q6 $p = p_1 + p_2 = -0.02 + 0.05 = 0.03 \text{ m}^{-1}$

Its sign is + \therefore **convex**.

Q7 For convex lens $f = 10 \text{ cm}$

$$\Rightarrow p_1 = \frac{1}{0.1} = 10 \text{ m}^{-1}$$

For concave lens $f = 15 \text{ cm}$

$$\Rightarrow p_2 = \frac{-1}{0.15} = -6.67$$

$$p = p_1 + p_2 = 10 - 6.67 = 3.33 \text{ m}^{-1}$$

\Rightarrow Focal length of combination

$$= \frac{1}{3.33} = 0.3 \text{ m} = +30 \text{ cm}$$

Sign + \Rightarrow combination is convex.

$$h_o = 2 \text{ cm}, \quad u = 20, \quad v = ?, \quad f = 30$$

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

$$\frac{1}{20} + \frac{1}{v} = \frac{1}{30} \Rightarrow v = -60 \text{ cm}$$

\Rightarrow Image is **virtual**.

$$\frac{h_i}{h_o} = \frac{v}{u} \Rightarrow h_i = \left(\frac{60}{20}\right)(2) = 6 \text{ cm}$$

Q8 $\frac{1}{20} = \frac{1}{f_1} + \frac{1}{60} \Rightarrow f_1 = 30 \text{ cm}$

Q9 Let $f_1 =$ focal length of convex lens.

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \Rightarrow \frac{1}{40} = \frac{1}{f_1} - \frac{1}{40}$$

$$\frac{1}{f_1} = \frac{1}{40} + \frac{1}{40} \Rightarrow f_1 = 20 \text{ cm}$$

Q10 Let $f_2 =$ focal length of concave lens.

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{-1}{40} = \frac{1}{20} - \frac{1}{f_2}$$

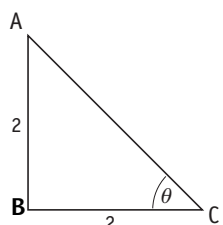
$$\frac{1}{f_2} = \frac{1}{20} + \frac{1}{40}$$

$$f_2 = 13.33 \text{ cm}$$

Exercise 6.1

- Q1** (i) $20 \times 10^{-3} \text{ s} = 2 \times 10^{-2} \text{ s}$
(ii) $500 \text{ ms} = 500 \times 10^{-3} = 0.5 \text{ s}$
(iii) $4000 \text{ ms} = 4000 \times 10^{-3} \text{ s} = 4 \text{ s}$
(iv) $1 \mu\text{s} = 1 \times 10^{-6} \text{ s}$
(v) $50 \mu\text{s} = 50 \times 10^{-6} \text{ s} = 5 \times 10^{-5} \text{ s}$
(vi) $\frac{1}{2} \text{ hr} = (\frac{1}{2})(60)(60) \text{ s} = 1800 \text{ s}$
(vii) Two days = $(2)(24)(60)(60) \text{ s} = 172\,800 \text{ s}$
(x) One year = $(365)(24)(60)(60) = 31\,536\,000 \text{ s}$
- Q2** $1 \times 10^6 \text{ s} = \frac{1 \times 10^6}{(24)(60)(60)} \text{ days} = 11.57 \text{ days}$
- Q3** no working out reqd.
- Q4** (i) $6.25 \text{ km} = 6.25 \times 10^3 \text{ m}$
(ii) $1 \text{ cm} = 1 \times 10^{-2} \text{ m}$
(iii) $20 \text{ mm} = 20 \times 10^{-3} = 2 \times 10^{-2} \text{ m}$
(iv) $4 \text{ nm} = 4 \times 10^{-9} \text{ m}$
- Q5** (a) Average speed = $\frac{\text{Distance}}{\text{Time}} = \frac{2000}{(4)(60)} = 8.33 \text{ ms}^{-1}$
(b) Average speed = $\frac{100}{10} = 10 \text{ ms}^{-1}$
- Q6** Time = $\frac{\text{Distance}}{\text{Average speed}} = \frac{200\,000}{25} = 8000 \text{ s}$
- Q7** Time = $\frac{\text{Distance}}{\text{Average speed}} = \frac{2\,000\,000}{200} = 10\,000 \text{ s}$
- Q8** Distance travelled = Circumference of circle
 $= 2\pi r = (2)(\pi)(30)$
Speed = $\frac{\text{Distance}}{\text{Time}} = \frac{(2)(\pi)(30)}{(90)} = \frac{2\pi}{3} = 2.09 \text{ m s}^{-1}$
- Q9** (i) $s = ut = (2)(25) = 50 \text{ m}$
(ii) $s = ut = (2)(\frac{1}{2})(60)(60) = 3600 \text{ m}$
(iii) $s = ut = (2)(1 \times 10^{-3}) = 2 \times 10^{-3} \text{ m}$
(iv) $s = ut = 2t \text{ metres}$

Exercise 6.2

- Q1** Average velocity = $\frac{\text{Displacement}}{\text{Time}} = \frac{2000 \text{ m South East}}{5 \times 60 \text{ s}} = 6.67 \text{ m s}^{-1} \text{ South East}$
- Q2** $s = ut = (30)(10) = 300 \text{ m South}$
- Q3** (i) $s = ut = 10 \times 1 = 10 \text{ m}$
(ii) $s = ut = 10 \times 10 = 100 \text{ m}$
(iii) $s = ut = (10)(t) = 10t \text{ metres}$
(iv) $s = ut = (10)(2 \times 10^{-6}) = 2 \times 10^{-5} \text{ m}$
- Q4** (i) **2 m North**
(ii) **2 m South**
(iii) **2 m West**
(iv) **2 m East**
- 
- $|AC|^2 = 2^2 + 2^2 \Rightarrow |AC| = \sqrt{8} = 2.83$
 $\tan \theta = \frac{2}{2} = 1 \Rightarrow \theta = 45^\circ$
- (v) 2.83 m W 45° N (North West)
(vi) 2.83 m E 45° S (South East)
- Q5** Distance = perimeter of semi-circle = $\frac{1}{2}(2\pi r) = \pi r = 5\pi = 15.71 \text{ m}$
Displacement of B from A = **10 m East**
(i) Average speed = $\frac{\text{Distance}}{\text{Time}} = \frac{15.71}{10} = 1.571 \text{ m s}^{-1}$
(ii) Average velocity = $\frac{\text{Displacement}}{\text{Time}} = \frac{10}{10} = 1 \text{ m s}^{-1} \text{ East}$
- Q6** If the speed of the car is changing it means the car **would** travel 30 m in the next second **if** its speed stopped changing at that instant. If the speed of the car is constant then it will travel 30 m in the next second.
- Q7** No; Yes, an object moving in a circle at a steady speed. The velocity is changing since the direction of motion is changing but the speed is constant.

Q8 no working out reqd.

Q9 Magnitude of overall displacement

$$= \sqrt{3^2 + 4^2} = 5 \text{ m}$$

Direction of overall displacement is East θ°
North where $\text{Tan } \theta = \frac{4}{3} \Rightarrow \theta = 53.13^\circ$

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Time}}$$

$$= \frac{5 \text{ m}}{5} = 1 \text{ m s}^{-1}$$

E 53.13° N

Exercise 6.3

Q1 No calculations required.

Q2 No calculations required.

Q3 No calculations required.

Exercise 7.1

$$\text{Q1 } a = \frac{v-u}{t} = \frac{30-10}{3} = \frac{20}{3} = 6\frac{2}{3} \text{ m s}^{-2} \text{ North}$$

$$\text{Q2 } a = \frac{v-u}{t} = \frac{10-0}{2} = 5 \text{ m s}^{-2} \text{ West}$$

$$\text{Q3 } \frac{25-40}{10} = -1.5 \text{ m s}^{-2} = 1.5 \text{ m s}^{-2} \text{ in opposite direction to the initial motion.}$$

$$\text{Q4 (i) Velocity gained} = \text{Acceleration} \times \text{Time}$$

$$= (3)(1) = 3 \text{ m s}^{-1}$$

$$\text{(ii) } (3)(4) = 12 \text{ m s}^{-1}$$

$$\text{(iii) } (3)(13.5) = 40.5 \text{ m s}^{-1}$$

$$\text{(iv) } 3t \text{ m s}^{-1}$$

$$\text{Q5 } a = \frac{v-u}{t} = \frac{10-0}{6} = 1.667 \text{ m s}^{-2}$$

$$\text{Q6 } a = \frac{v-u}{t} = \frac{9 \text{ West} - 5 \text{ East}}{2.5} = \frac{9 - (-5)}{2.5}$$

$$= 5.6 \text{ m s}^{-2} \text{ West}$$

Exercise 7.2

Q1 $u = 10, a = 2, t = 12, v = ?, s = ?$

$$\begin{array}{l} v = u + at \\ = 10 + 2(12) \\ = \mathbf{34 \text{ m s}^{-1}} \end{array} \quad \left| \quad \begin{array}{l} s = ut + \frac{1}{2}at^2 \\ = (10)(12) + \frac{1}{2}(2)(12)^2 \\ = 120 + 144 \\ = \mathbf{264 \text{ m}} \end{array} \right.$$

Q2 $u = 14, v = 30, t = 20, a = ?, s = ?$

$$\begin{array}{l} v = u + at \\ 30 = 14 + a(20) \\ 16 = 20a \\ a = \frac{16}{20} \\ = \mathbf{0.8 \text{ m s}^{-2}} \end{array} \quad \left| \quad \begin{array}{l} s = ut + \frac{1}{2}at^2 \\ s = (14)(20) + \frac{1}{2}(0.8)(20)^2 \\ s = 280 + 160 \\ s = \mathbf{440 \text{ m}} \end{array} \right.$$

Q3 $u = 2, v = 12, s = 50, a = ?, t = ?$

$$\begin{array}{l} v^2 = u^2 + 2as \\ 12^2 = 2^2 + 2a(50) \\ 144 - 4 = 1000a \\ a = \mathbf{1.4 \text{ m s}^{-2}} \end{array} \quad \left| \quad \begin{array}{l} v = u + at \\ 12 = 2 + 1.4t \\ t = \frac{10}{1.4} = \mathbf{7.14 \text{ s}} \end{array} \right.$$

Q4 $u = 60, v = 20, t = 4, a = ?, s = ?$

$$\begin{array}{l} v = u + at \\ 20 = 60 + a4 \\ -40 = 4a \\ a = \mathbf{-10 \text{ m s}^{-2}} \end{array} \quad \left| \quad \begin{array}{l} s = ut + \frac{1}{2}at^2 \\ s = (60)(4) + \frac{1}{2}(-10)(4)^2 \\ s = \mathbf{160 \text{ m}} \end{array} \right.$$

Q5 $u = 6, t = 60, s = 3000, a = ?, v = ?$

$$\begin{array}{l} s = ut + \frac{1}{2}at^2 \\ 3000 = 6(60) + \frac{1}{2}a(60)^2 \\ 3000 - 360 = 1800a \\ a = \mathbf{1.467 \text{ m s}^{-2}} \end{array} \quad \left| \quad \begin{array}{l} v = u + at \\ v = 6 + (1.467)(60) \\ v = \mathbf{94.02 \text{ m s}^{-1}} \end{array} \right.$$

Q6 $u = 30, v = 10, s = 200, a = ?$

$$\begin{array}{l} v^2 = u^2 + 2as \\ 100 = 30^2 + 2a(200) \\ a = \mathbf{-2 \text{ m s}^{-2}} \end{array}$$

Q7 $u = 20, a = -3, v = 0, t = ?$

$$\begin{array}{l} v = u + at \\ 0 = 20 - 3(t) \\ t = \frac{20}{3} = \mathbf{6.667 \text{ s}} \end{array}$$

Q8 (i) $u = 120, a = 10, t = 12, v = ?$

$$\begin{array}{l} v = u + at \\ v = 120 + (10)(12) \\ v = \mathbf{240 \text{ m s}^{-1}} \text{ in original direction} \\ \text{of motion.} \end{array}$$

(ii) $u = 120, a = -10, t = 12, v = ?$

$$\begin{array}{l} v = u + at \\ v = 120 - 10(12) \\ v = \mathbf{0 \text{ m s}^{-1}} \end{array}$$

Q9 (i) $u = 5, a = 4, v = ?, t = 5$

$$\begin{array}{l} v = u + at \\ v = 5 + 4(5) \\ v = \mathbf{25 \text{ m s}^{-1}} \text{ in original direction} \\ \text{of motion} \end{array}$$

(ii) $u = 5, a = -4, v = ?, t = 5$

$$\begin{array}{l} v = u + at \\ v = 5 + (-4)(5) \\ v = \mathbf{-15 \text{ m s}^{-1}} \end{array} \quad \begin{array}{l} \text{i.e. } 15 \text{ m s}^{-1} \text{ in} \\ \text{opposite direction of} \\ \text{original motion } v. \end{array}$$

Q10 Distance S_1 of rear of bike from P after t seconds.

$$S_1 = 12t$$

Distance S_2 of front of car from P after t seconds.

$$s = ut + \frac{1}{2}at^2$$

$$S_2 = (0)(t) + \frac{1}{2}(2)t^2 = t^2$$

Car meets bike when $S_2 = S_1$ i.e. $t^2 = 12t$

$$t^2 - 12t = 0, \text{ i.e. } t(t - 12) = 0$$

$$\Rightarrow t = 0 \text{ or } t = 12$$

\Rightarrow Car meets bike after **12 seconds**

Distance of bike from P at this instant

$$= S_1 = (12)(12)$$

$$= \mathbf{144 \text{ m from P.}}$$

Exercise 7.4

$$\mathbf{Q1} \quad a = \frac{v-u}{t} = \frac{\left(\frac{4.3}{0.04}\right) - \left(\frac{1.45}{0.04}\right)}{8\left(\frac{1}{50}\right)}$$

$$= 445.3 \text{ cm s}^{-2} = \mathbf{4.453 \text{ m s}^{-2}}$$

$$\mathbf{Q2} \quad u = \frac{4 \times 10^{-2}}{0.1333} = 0.3 \text{ m s}^{-1}$$

$$v = \frac{4 \times 10^{-2}}{0.0167} = 2.4 \text{ m s}^{-1}$$

$$s = 1.4 \quad \therefore \quad a = \frac{v^2 - u^2}{2s} = \frac{(2.4)^2 - (0.3)^2}{2(1.4)} = \mathbf{2.025 \text{ m s}^{-2}}$$

Exercise 7.5

Q1 $u = 0, s = 60, a = 9.8, t = ?, v = ?$

$$\begin{array}{l} v^2 = u^2 + 2as \\ v^2 = 0^2 + 2(9.8)(60) \\ v = \sqrt{1176} \\ v = \mathbf{34.29 \text{ m s}^{-1}} \end{array} \quad \left| \begin{array}{l} v = u + at \\ 34.29 = 9.8t \\ t = \mathbf{3.5 \text{ s}} \end{array} \right.$$

Q2 $u = 200, a = -9.8, v = 0, s = ?, t = ?$

$$\begin{array}{l} v^2 = u^2 + 2as \\ 0 = (200)^2 + 2(-9.8)s \\ s = \frac{200^2}{19.6} = \mathbf{2040.8 \text{ m}} \end{array} \quad \left| \begin{array}{l} v = u + at \\ 0 = 200 - 9.8t \\ t = \mathbf{20.41 \text{ s}} \end{array} \right.$$

Q3 $u = 0, a = 9.8, t = 3, s = ?$

$$\begin{aligned} s &= ut + \frac{1}{2}at^2 \\ s &= (0)(3) + \frac{1}{2}(9.8)(3)^2 \\ s &= \mathbf{44.1 \text{ m}} \end{aligned}$$

Q4 $u = 0, v = 22, s = 30, a = ?, t = ?$

$$\begin{array}{l} v^2 = u^2 + 2as \\ 22^2 = 0 + 2a(30) \\ a = \mathbf{8.067 \text{ m s}^{-2}} \end{array} \quad \left| \begin{array}{l} v = u + at \\ 22 = 0 + 8.067t \\ t = \mathbf{2.73 \text{ s}} \end{array} \right.$$

Q5 (i) $u = 80, v = 0, a = -9.8, s = ?$

$$\begin{array}{l} v^2 = u^2 + 2as \\ 0 = 80^2 + 2(-9.8)(s) \\ s = \frac{80^2}{19.6} = \mathbf{326.5 \text{ m}} \end{array} \quad \left| \begin{array}{l} v = u + at \\ 0 = 80 - 9.8t \\ t = \frac{80}{9.8} \\ t = \mathbf{8.16 \text{ s}} \end{array} \right.$$

(ii) $s = 96, t = ?$

$$\begin{aligned} s &= ut + \frac{1}{2}at^2 \\ 96 &= 80t - \frac{1}{2}(9.8)t^2 \\ 4.9t^2 - 80t + 96 &= 0 \\ t &= \frac{80 \pm \sqrt{80^2 - 4(4.9)(96)}}{(2)(4.9)} \\ \Rightarrow t &= \mathbf{15.02 \text{ or } 1.304 \text{ s}} \end{aligned}$$

(ii) *Alternative Solution*

$$\begin{aligned} v^2 &= u^2 + 2as \\ v^2 &= 80^2 + 2(-9.8)(96) \\ v &= \pm 67.22 \text{ m s}^{-1} \\ v &= u + at \\ 67.22 &= 80 - 9.8t \\ t &= \mathbf{1.30 \text{ s}} \\ -67.22 &= 80 - 9.8t \\ t &= \mathbf{15.02 \text{ s}} \end{aligned}$$

Q6 (i) $u = ?, s = 100, t = 2, a = -9.8$

$$\begin{aligned} s &= ut + \frac{1}{2}at^2 \\ 100 &= u(2) + \frac{1}{2}(-9.8)(2)^2 \\ 100 &= 2u - 19.6 \\ \Rightarrow u &= \mathbf{59.8 \text{ m s}^{-1}} \end{aligned}$$

(ii) $u = 59.8, v = 0, s = ?, a = -9.8$

$$\begin{aligned} v^2 &= u^2 + 2as \\ 0 &= (59.8)^2 + 2(-9.8)s \\ s &= \mathbf{182.45 \text{ m}} \end{aligned}$$

(iii) First find the two times at which it is 100 m above ground.

$u = 59.8, a = -9.8, s = 100, t = ?$

$$\begin{aligned} s &= ut + \frac{1}{2}at^2 \\ 100 &= (59.8)t - (\frac{1}{2})9.8t^2 \\ 4.9t^2 - 59.8t + 100 &= 0 \\ t &= \frac{59.8 \pm \sqrt{(59.8)^2 - 4(4.9)(100)}}{(2)(4.9)} \\ t &= 10.204 \text{ s or } t = 2 \end{aligned}$$

Time difference $10.204 - 2 = \mathbf{8.204 \text{ s}}$

Q7 (i) $u = 24, v = 0, s = ?, a = -9.8$

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

$$0 = 24^2 - 2(9.8)s$$

$$s = 29.39 \text{ m}$$

\Rightarrow Total height above ground:

$$= 29.39 + 16$$

$$= \mathbf{45.39 \text{ m}}$$

(ii) Time t_1 from point of projection to greatest height:

$$u = 24, v = 0, a = -9.8, t_1 = ?$$

$$v = u + at_1$$

$$0 = 24 - 9.8t_1$$

$$t_1 = 2.449 \text{ s}$$

Time t_2 from greatest height to ground:

$$u = 0, a = 9.8, s = 45.39, t_2 = ?$$

$$s = ut_2 + \frac{1}{2}at_2^2$$

$$45.39 = 0 + \frac{1}{2}9.8t_2^2$$

$$t_2 = \sqrt{\frac{(2)(45.39)}{9.8}} = 3.044 \text{ s}$$

$$\text{Total time} = t_1 + t_2$$

$$= 2.449 + 3.044$$

$$= \mathbf{5.493 \text{ s}}$$

(ii) *Alternative solution*

$$u = 24, a = -9.8, t = ?, s = -16$$

$$s = ut + \frac{1}{2}at^2$$

$$-16 = 24t - \frac{1}{2}9.8t^2$$

$$4.9t^2 - 24t - 16 = 0$$

[Solve: $t = 5.49 \text{ s}$ or a negative solution]

(iii) From greatest height to ground:

$$u = 0, a = 9.8, t = 3.044, v = ?$$

$$v = u + at$$

$$v = 0 + (9.8)(3.044)$$

$$v = \mathbf{29.83 \text{ m s}^{-1}}$$

Q8 On Earth:

$$u = ?, s = 2, a = -9.8, v = 0$$

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

$$0 = u^2 + 2(-9.8)(2) \Rightarrow u = \sqrt{39.2}$$

$$u = \mathbf{6.26099 \text{ m s}^{-1}}$$

On Moon:

$$u = 6.26099 = \sqrt{39.2}, a = \frac{-9.8}{6}, s = ?, v = 0$$

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

$$0 = 39.2 + 2\left(\frac{-9.8}{6}\right)s$$

$$\Rightarrow s = \mathbf{12 \text{ m}}$$

Q9 First body: after t seconds of motion it will be a distance S_1 from A where $S_1 = 40t$

If body 1 moves for t seconds, body 2 moves for $t - 10$ seconds. Distance of body 2 from A:

$$S_2 = (0)(t - 10) + \frac{1}{2}2(t - 10)^2$$

Bodies meet when: $S_1 = S_2$

$$40t = (t - 10)^2$$

$$40t = t^2 - 20t + 100 \Rightarrow t^2 - 60t + 100 = 0$$

$$t = \frac{60 \pm \sqrt{60^2 - 4(1)(100)}}{2}$$

$$= \frac{60 \pm 56.57}{2}$$

$$t = 58.28 \text{ s} \text{ or } t = 1.715 \text{ s}$$

t must be greater than 10 $\therefore t = 58.28 \text{ s}$

It takes the second body $58.28 - 10 = \mathbf{48.28 \text{ s}}$ to catch up.

$$\text{Distance from A} = S_1 = ut$$

$$= (40)(58.28)$$

$$= \mathbf{2331.2 \text{ m}}$$

Q10 $u = u, a = -9.8, t = 6, v = -8$

$$v = u + at$$

$$-8 = u + (-9.8)(6)$$

$$u = \mathbf{50.8 \text{ m s}^{-1}}$$

$$s = ut + \frac{1}{2}at^2$$

$$s = (50.8)(6) - \left(\frac{1}{2}\right)(9.8)(6)^2 = 128.4 \text{ m}$$

$$\text{Height above ground} = 128.4 + 40$$

$$= \mathbf{168.4 \text{ m}}$$

Exercise 8.1

Q3 (iv) $R^2 = 3^2 + 4^2 = 25 \Rightarrow R = 5 \text{ N}$
 $\tan \theta = \frac{3}{4} \Rightarrow \theta = 36.87^\circ$

(v) $R^2 = 2^2 + 2^2 = 8 \Rightarrow R = \sqrt{8} = 2.83 \text{ N}$
 $\tan \theta = \frac{2}{2} = 1 \Rightarrow \theta = 45^\circ$

(vi) $R^2 = 5^2 + 12^2 = 169$
 $\Rightarrow R = \sqrt{169} = 13$
 $\tan \theta = \frac{5}{12} \Rightarrow \theta = 22.62^\circ$

Exercise 8.2

- Q1** (a) $R_1 = \sqrt{2^2 + 2^2} = 2.83$
 \therefore Overall resultant = $2.83 + 5 = 7.83 \text{ N}$ in
direction of 5 N force
- (b) $R_1 = \sqrt{3^2 + 3^2} = 4.24 \text{ N}$
Resultant = $6 + 4.24 = 10.24 \text{ N}$ in
direction of 6 N force.
- (c) $R_1 = \sqrt{10^2 + 10^2} = 14.14 \text{ N}$
 $R = 14.14 - 10 = 4.14 \text{ N}$
at 45° to each of the perpendicular 10 N
forces.
- (d) $R_1 = \sqrt{4^2 + 4^2} = 5.66$
 $R = 5.66 - 2 = 3.66 \text{ N}$ (in opposite
direction to 2 N force.

Exercise 8.3

Q1 Horizontal component = $200 \cos 70^\circ = \mathbf{68.40 \text{ N}}$
 Vertical component = $200 \sin 70^\circ = \mathbf{187.94 \text{ N}}$

Q2 (i) Horizontal force on cart = Horizontal component = $3500 \cos 25^\circ = \mathbf{3172.1 \text{ N}}$

(ii) Vertical force on cart = Vertical component = $3500 \sin 25^\circ = \mathbf{1479.2 \text{ N}}$

Q3 Horizontal component = $100 \cos 60^\circ = \mathbf{50}$
 Vertical component = $100 \sin 60^\circ = \mathbf{86.6}$

Q4 Horizontal component = $200 \sin 40^\circ = \mathbf{128.6}$
 Vertical component = $200 \cos 40^\circ = \mathbf{153.2}$

Q5 Resolve velocity into components parallel to and perpendicular to bank.

Parallel comp = $6 \cos 40^\circ = 4.596 \text{ m s}^{-1}$

Perpendicular comp = $6 \sin 40^\circ = 3.857 \text{ m s}^{-1}$

Time to cross lake = $\frac{\text{Width of lake}}{\text{Perp comp}}$
 $= \frac{2000}{3.857} = \mathbf{518.5 \text{ s}}$

Distance travelled parallel to side in this time
 $= (\text{Parallel comp}) \times \text{Time}$
 $= (4.596)(518.5) = \mathbf{2383 \text{ m}}$

Distance from start = $\sqrt{(2000)^2 + (2383)^2}$
 $= \mathbf{3111.1 \text{ m}}$

Q6 Comp parallel to roof = $40 \sin 30^\circ = \mathbf{20 \text{ N}}$
 Comp perp to roof = $40 \cos 30^\circ = \mathbf{34.64 \text{ N}}$

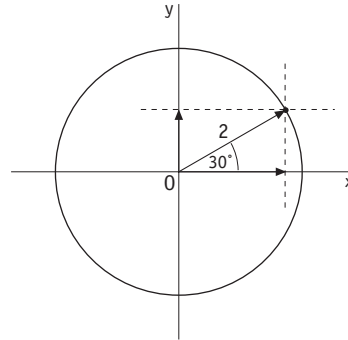
Q7 Horizontal component = $4 \cos 30^\circ = \mathbf{3.46 \text{ m s}^{-1}}$
 Vertical component = $4 \sin 30^\circ = \mathbf{2 \text{ m s}^{-2}}$

Q8 Parallel component = $30 \cos 20^\circ = \mathbf{28.19 \text{ N}}$
 Perpendicular component = $30 \sin 20^\circ = \mathbf{10.26 \text{ N}}$

Q9 Parallel component = $\mathbf{W \cos \theta}$
 Perpendicular component = $\mathbf{W \sin \theta}$

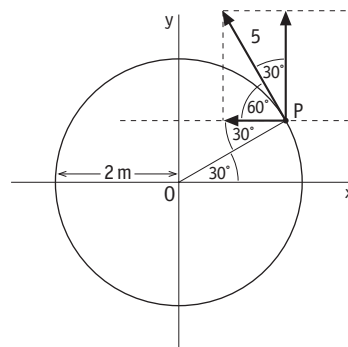
Q10 (i) Displacement: Comp along $ox = 2 \cos 30^\circ = \mathbf{1.732 \text{ m}}$

Comp along $oy = 2 \sin 30 = \mathbf{1.0 \text{ m}}$



(ii) Velocity: Comp along $ox = -5 \sin 30 = \mathbf{-2.5 \text{ m s}^{-1}}$

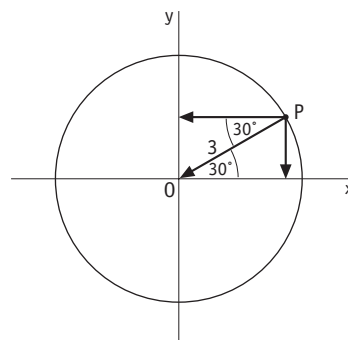
Comp along $oy = 5 \cos 30 = \mathbf{4.33 \text{ m s}^{-1}}$



(iii) Acceleration:

Comp along $ox = -3 \cos 30 = \mathbf{-2.60 \text{ m s}^{-2}}$

Comp along $oy = -3 \sin 30 = \mathbf{-1.5 \text{ m s}^{-2}}$



Exercise 9.1

Q1 $F = ma = (20)(5) = 100 \text{ N}$

Q2 $a = \frac{F}{m} = \frac{4}{10} = 0.4 \text{ m s}^{-2}$

Q3 $F = ma = (100)(2) = 200 \text{ N}$

Q4 $m = \frac{F}{a} = \frac{4000}{3} = 1333.3 \text{ kg}$

Q5 $u = 6, F = 40, m = 10, t = 12$

(i) $a = \frac{F}{m} = \frac{40}{10} = 4 \text{ m s}^{-2}$

(ii) $v = u + at$

$$v = 6 + (4)(12)$$

$$v = 54 \text{ m s}^{-1}$$

(iii) $s = ut + \frac{1}{2}at^2$
 $= (6)(12) + \frac{1}{2}(4)(12)^2$
 $= 72 + 288$
 $= 360 \text{ m}$

Q6 $u = 2, v = 10, t = 4$

$$v = u + at$$

$$10 = 2 + a4$$

$$a = 2 \text{ m s}^{-2}$$

$$F = ma = (20)(2) = 40 \text{ N}$$

Q7 $w = mg$

(i) $w = (1)(9.8) = 9.8 \text{ N}$

(ii) $w = (1 \times 10^{-3})(9.8) = 9.8 \times 10^{-3} \text{ N}$

(iii) $w = (105)(9.8) = 1029 \text{ N}$

(iv) $w = (m)9.8 = 9.8 \text{ m newtons}$

Q8 $F = ma$

$$m = \frac{F}{a} = \frac{2000}{4} = 500 \text{ kg}$$

$$u = 0, t = 20, a = 4, v = ?$$

(i) $v = u + at$

$$v = 0 + (4)(20)$$

$$v = 80 \text{ m s}^{-1}$$

(ii) $s = ut + \frac{1}{2}at^2$

$$s = 0 + \left(\frac{1}{2}\right)(4)(20^2)$$

$$s = 800 \text{ m}$$

$$u = 80, v = 0, a = ?, t = 0.1$$

$$v = u + at$$

$$0 = 80 + a(0.1)$$

$$a = \frac{-80}{0.1} = 800 \text{ m s}^{-2}$$

$$F = ma = (800)(500) = 4 \times 10^5 \text{ N}$$

Q9 (a) $a = \frac{F}{m} = \frac{40-10}{20} = 1.5 \text{ m s}^{-2}$

(b) $a = \frac{F}{m} = \frac{100-20}{20} = 4 \text{ m s}^{-2}$

(c) $a = \frac{F}{m} = \frac{600-600}{20} = 0 \text{ m s}^{-2}$

$$v = u + at$$

$$v = 20 + (1.5)(2) = 23 \text{ m s}^{-1}$$

$$v = 20 + (4)(2) = 28 \text{ m s}^{-1}$$

$$v = 20 + 0 = 20 \text{ m s}^{-1}$$

Q10 $a = \frac{F}{m} = \frac{500-400}{6} = 16.67 \text{ m s}^{-2}$

Q11 Car $100 \text{ km h}^{-1} = \frac{100 \times 1000}{60 \times 60} = 27.78 \text{ m s}^{-1}$

$$u = 27.78, v = 0, s = 100, a = ?$$

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

$$0 = (27.78)^2 + 2(a)(100)$$

$$a = \frac{(27.78)^2}{200}$$

$$a = 3.859 \text{ N}$$

$F = ma = (1200)(3.859) = 4630 \text{ N}$ = the force needed to stop the car in 100 m

Force available = 2000 N

Answer = **No**

Force = **4630 N**

Exercise 9.2

- Q1** Driving force = **600 N**, because if car is moving at uniform speed, resultant force is zero.

$$a = \frac{F}{m} = \frac{1000 - 600}{725} = 0.5517 \text{ m s}^{-2}$$

$$u = 0, v = 100 \text{ km h}^{-1} = 27.778 \text{ m s}^{-1}, \\ a = 0.55, t = ?$$

$$v = u + at$$

$$27.778 = 0 + 0.5517t \Rightarrow t = \mathbf{50.35 \text{ s}}$$

- Q2** Deceleration of bullet = $\frac{v-u}{t}$
 $= \frac{50 - 200}{0.005} = 3 \times 10^4 \text{ ms}^{-2}$

$$\text{Force} = ma = (0.002)(3 \times 10^4) = \mathbf{60 \text{ N}}$$

- Q3** (i) Object moving at constant speed
 $\Rightarrow a = 0 \Rightarrow T = \mathbf{19\ 600 \text{ N}}$
- (ii) Accelerating down $F = ma$
 $\Rightarrow 19\ 600 - T = (2000)(2)$
 $T = \mathbf{15\ 600 \text{ N}}$

- Q4** Reading on balance = Tension
 Net force = Mass \times Acceleration

$$(i) T - 98 = 10(0) \Rightarrow T = \mathbf{98 \text{ N}}$$

$$(ii) T - 98 = 10(2) \Rightarrow T = \mathbf{118 \text{ N}}$$

$$(iii) 10g - T = 10(2) \Rightarrow T = \mathbf{78 \text{ N}}$$

$$(iv) 10g - T = 10(0) \Rightarrow T = \mathbf{98 \text{ N}}$$

$$(v) 10g - T = 10(9.8) \Rightarrow T = \mathbf{0 \text{ N}}$$

- Q5** Reading on scales = Normal reaction N
 Net force = Mass \times Acceleration

$$(i) N - 980 = 100(0) \Rightarrow N = \mathbf{980 \text{ N}}$$

$$(ii) N - 980 = 100(0) \Rightarrow N = \mathbf{980 \text{ N}}$$

$$(iii) 980 - N = 100(0) \Rightarrow N = \mathbf{980 \text{ N}}$$

$$(iv) N - 980 = 100(3) \Rightarrow N = \mathbf{1280 \text{ N}}$$

$$(v) 980 - N = 100(3) \Rightarrow N = \mathbf{680 \text{ N}}$$

$$(vi) 980 - N = 100(9.8) \Rightarrow N = \mathbf{0 \text{ N}}$$

- Q6** Force = Rate of change of momentum
 $= \frac{2.25}{0.05} = \mathbf{45 \text{ N}}$

Exercise 9.3

Q1 $P = mv = (800)(20) = \mathbf{16\ 000 \text{ kg m s}^{-1}}$

Q2 (a) $P = mv = (1200)(30) = \mathbf{36\ 000 \text{ kg m s}^{-1}}$

(b) $P = mv = (1200)(0) = \mathbf{0 \text{ kg m s}^{-1}}$

(c) $100 \text{ km/hr} = \frac{100 \times 1000}{60 \times 60} = 27.78 \text{ m s}^{-1}$

$$P = mv = (1200)(27.78) \\ = \mathbf{33\ 333.3 \text{ kg m s}^{-1}}$$

(d) $500 \text{ cm s}^{-1} = \mathbf{5 \text{ m s}^{-1}}$

$$P = mv = (1200)(5) = \mathbf{6000 \text{ kg m s}^{-1}}$$

Q3 $P = mv \Rightarrow v = \frac{P}{m} = \frac{40\ 000}{1200} = \mathbf{33\frac{1}{3} \text{ m s}^{-1}}$

$$v = \frac{P}{m} = \frac{40\ 000}{2} = \mathbf{20\ 000 \text{ m s}^{-1}}$$

- Q4** Total momentum = $(20)(40) + (50)(-20)$
 $= -200$
 $= \mathbf{200 \text{ kg m s}^{-1}}$ in the direction in which the **50 kg mass moves.**

- Q5** Momentum before = Momentum after
 $(800 \times 20) + (1500)(0) = 2300v \Rightarrow v = \frac{16\ 000}{2300}$
 $= \mathbf{6.96 \text{ m s}^{-1}}$

- Q6** P before = P after $\Rightarrow (6000)(10) + (2000)(2)$
 $= 8000v \Rightarrow v = \mathbf{8 \text{ m s}^{-1}}$ in original direction of motion.

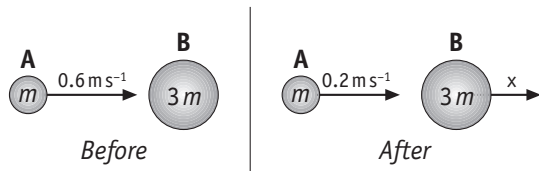
- Q7** P before = P after $\Rightarrow (6000)(10) + (2000)(-20)$
 $= 8000v$
 $60\ 000 - 4000 = 8000v \Rightarrow v = \mathbf{7 \text{ m s}^{-1}}$ in original direction of motion.

- Q8** P before = P after
 $0 = (10 \times 10^{-3})(400) + 2v \Rightarrow v = -2 \text{ m s}^{-1}$
 i.e. gun recoils backwards at $\mathbf{2 \text{ m s}^{-1}}$

- Q9** P before = P after
 $(100)(10) + (60)(-15) = 100v + (60)(8)$
 $\Rightarrow 1000 - 900 = 100v + 480 \Rightarrow 100v = -380$
 $\Rightarrow v = -3.8 \text{ m s}^{-1}$ i.e. 100 kg block moves with $\mathbf{3.8 \text{ m s}^{-1}}$ in opposite direction to its initial velocity.

Q10 P.C.M.

$$\begin{aligned}
 (m)(0.6) + (3m)(0) &= (m)(0.2) + (3m)x \\
 0.6 &= 0.2 + 3x \\
 3x &= 0.4 \Rightarrow x = \mathbf{0.133 \text{ m s}^{-1}}
 \end{aligned}$$



Q11 (i) $0 = 500v + 2 \times 500 \Rightarrow v = -2 \text{ m s}^{-1}$
i.e. recoil velocity is **2 m s⁻¹**

(ii) For gun: $u = 2, v = 0, a = ?, s = 0.25$

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

$$0 = 2^2 + 2(a)(0.25)$$

$$a = -\frac{4}{0.5} = -8 \text{ m s}^{-2}$$

$$F = ma \quad (500)(8) = \mathbf{4000 \text{ N}}$$

Q12 $P \text{ before} = P \text{ after} \Rightarrow (12 \times 10^{-3})(200) + (10)(0) = 10v + (12 \times 10^{-3})(50)$

$$2.4 + 0 = 10v + 0.6 \Rightarrow 10v = 1.8$$

$$\Rightarrow v = 0.18 \text{ m s}^{-1}$$

Force exerted on block

$$= \frac{\text{Change in momentum of block}}{\text{Time taken}}$$

$$= \frac{(10)(0.18) - (10)(0)}{0.002} = \mathbf{900 \text{ N}}$$

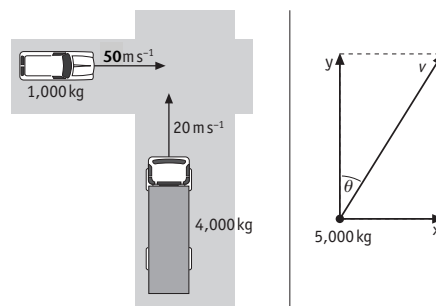
Force exerted on bullet

$$= \frac{\text{Change in momentum of bullet}}{\text{Time taken}}$$

$$= \frac{(12 \times 10^{-3})(50) - (12 \times 10^{-3})(200)}{0.002} = \mathbf{-900 \text{ N}}$$

\therefore Forces have the same magnitudes *QED*

Q13



$$(1000)(50) = 5000x \Rightarrow x = 10$$

$$(4000)(20) = 5000y \Rightarrow y = 16$$

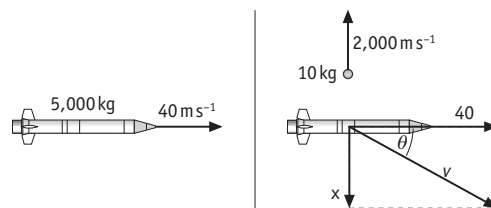
$$v = \sqrt{10^2 + 16^2} = 18.87 \text{ m s}^{-1}$$

$$\text{Tan } \theta = \frac{x}{y} = \frac{10}{16} \Rightarrow \theta = 32^\circ$$

Velocity of wreck = **18.87 m s⁻¹ at 32° with direction of lorry's initial velocity.**

Q14 Apply P.C.M. in direction of emission of mass
 $P \text{ before} = P \text{ after}$

$$0 = (10)(2000) + (5000)(-x) \Rightarrow x = 4 \text{ m s}^{-1}$$



Thus rocket recoils at 4 m s^{-1} . It still keeps its 40 m s^{-1} :

$$\begin{aligned}
 \text{Resultant velocity: } v &= \sqrt{40^2 + 4^2} \\
 &= \mathbf{40.1995 \text{ m s}^{-1}}
 \end{aligned}$$

$$\theta = \text{Tan}^{-1} \left(\frac{x}{40} \right) = \text{Tan}^{-1} \left(\frac{4}{40} \right) \Rightarrow \theta = 5.7^\circ$$

Velocity of rocket = **40.1995 m s⁻¹ at 5.7° with original direction of motion.**

Q15 $(0.08)(5) + 0 = 0.280v$
 $v = \mathbf{1.43 \text{ m s}^{-1}}$

$$\begin{aligned}
 \text{Change in momentum for 80 g mass} &= (\text{final momentum} - \text{initial momentum}) \\
 &= (0.08)(1.43 - 5) = \mathbf{-0.286 \text{ kg m s}^{-1}}
 \end{aligned}$$

$$\begin{aligned}
 \text{Change in momentum for 200 g mass} &= (.2)(1.43) = \mathbf{0.286 \text{ kg m s}^{-1}}
 \end{aligned}$$

$$\text{Force} = \frac{\text{Change in momentum}}{\text{Time}} = \frac{0.286}{0.1} = \mathbf{2.86 \text{ N}}$$

Exercise 10.1

Q1 (i) $200 \text{ g} = \frac{200}{1000} \text{ kg} = \mathbf{0.2 \text{ kg}}$

(ii) $4 \text{ g} = \mathbf{0.004 \text{ kg}}$

(iii) $2 \times 10^5 \text{ g} = \frac{2 \times 10^5}{1000} = \mathbf{200 \text{ kg}}$

(iv) $24 \text{ mg} = 24 \times 10^{-3} \text{ g} = \frac{24 \times 10^{-3}}{1000} \text{ kg}$
 $= \mathbf{2.4 \times 10^{-5} \text{ kg}}$

Q2 (i) $1 \text{ cm}^3 = \mathbf{1 \times 10^{-6} \text{ m}^3}$

(ii) $120 \text{ cm}^3 = 120 \times 10^{-6} \text{ m}^3$
 $= \mathbf{1.2 \times 10^{-4} \text{ m}^3}$

(iii) $4 \text{ litres} = 4000 \text{ cm}^3 = 4000 \times 10^{-6} \text{ m}^3$
 $= \mathbf{4 \times 10^{-3} \text{ m}^3}$

(iv) $2 \times 10^6 \text{ cm}^3 = (2 \times 10^6)(1 \times 10^{-6}) = \mathbf{2 \text{ m}^3}$

Q3 (i) $1 \text{ cm}^2 = \mathbf{1 \times 10^{-4} \text{ m}^2}$

(ii) $220 \text{ cm}^2 = 220 \times 10^{-4} \text{ m}^2$
 $= \mathbf{2.2 \times 10^{-2} \text{ m}^2}$

(iii) $4 \text{ mm}^2 = \mathbf{4 \times 10^{-6} \text{ m}^2}$

(iv) $3 \times 10^4 \text{ cm}^2 = \mathbf{3 \text{ m}^2}$

Q4 $\rho = \frac{m}{V} = \frac{4}{0.012} = \mathbf{333.33 \text{ kg m}^{-3}}$

Q5 $\rho = \frac{m}{V} = \frac{1.8 \times 10^4}{1.61} = \mathbf{11\ 180 \text{ kg m}^{-3}}$

Q6 $\rho = \frac{m}{V}$

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

$$= \frac{4}{1.05 \times 10^4}$$

$$= \mathbf{3.8 \times 10^{-4} \text{ m}^3}$$

$$3 \text{ cm}^3 = 3 \times 10^{-6} \text{ m}^3$$

$$\therefore m = \rho v$$

$$= (1.05 \times 10^4)(3 \times 10^{-6})$$

$$\Rightarrow m = \mathbf{0.0315 \text{ kg}}$$

Q7 $m = \rho V = (1.36 \times 10^4)(1 \times 10^{-6}) = \mathbf{0.0136 \text{ kg}}$

Q8 $\rho = \frac{m}{V} \Rightarrow V = \frac{m}{\rho} = \frac{(20 \times 10^{-3})}{7.3 \times 10^3}$
 $= \mathbf{2.74 \times 10^{-6} \text{ m}^3}$

Volume = Area \times Thickness

$$2.74 \times 10^{-6} = A \times 2 \times 10^{-6}$$

$$\Rightarrow A = \mathbf{1.37 \text{ m}^2}$$

Exercise 10.2

$$\text{Q1 } P = \frac{F}{A} = \frac{100}{5} = \mathbf{20 \text{ Pa}}$$

$$\text{Q2 } P = \frac{F}{A} = \frac{60}{25 \times 10^{-4}} = \mathbf{24\,000 \text{ Pa}}$$

$$\text{Q3 (i) Area of side A} \\ = (3 \times 10^{-2})(5 \times 10^{-2}) = 1.5 \times 10^{-3} \text{ m}^2$$

$$\text{(ii) Area of side B} \\ = (3 \times 10^{-2})(9 \times 10^{-2}) = 2.7 \times 10^{-3} \text{ m}^2$$

$$\text{(iii) Area of side C} \\ = (5 \times 10^{-2})(9 \times 10^{-2}) = 4.5 \times 10^{-3} \text{ m}^2$$

$$\text{Force} = \text{Weight of block} = (4)(9.8) = \mathbf{39.2 \text{ N}}$$

$$\text{(i) } P = \frac{F}{A} = \frac{39.2}{1.5 \times 10^{-3}} = \mathbf{2.613 \times 10^4 \text{ Pa}}$$

$$\text{(ii) } P = \frac{39.2}{2.7 \times 10^{-3}} = \mathbf{1.452 \times 10^4 \text{ Pa}}$$

$$\text{(iii) } P = \frac{39.2}{4.5 \times 10^{-3}} = \mathbf{8.711 \times 10^3 \text{ Pa}}$$

$$\text{Q4 } P = \frac{F}{A} \therefore F = PA = (400)(0.06) = \mathbf{24 \text{ N}}$$

$$\text{Q5 } F = PA = (1 \times 10^5)(621 \times 10^{-4}) = \mathbf{6210 \text{ N}}$$

$$\text{Q6 } F = PA = (500)(\pi(0.1)^2) = \mathbf{15.7 \text{ N}}$$

$$\text{Q7 } P = \frac{F}{A} \Rightarrow F = PA = (556)(2.2)(2.2) = \mathbf{2691 \text{ N}}$$

= weight of oil

$$W = mg \Rightarrow m = \frac{W}{g} \therefore \rho = \frac{m}{V} = \frac{W}{gV} \\ = \frac{2691}{(9.8)(2.2)^3} = \mathbf{25.79 \text{ kg m}^{-3}}$$

$$\text{Q8 } P = \frac{F}{A} = \frac{(32)(9.8)}{\pi(0.04)^2} = \mathbf{62\,388.7 \text{ Pa}}$$

Exercise 10.3

$$\text{Q1 } P = \frac{F}{A} = \frac{100 \times 9.8}{0.5} = \frac{980}{0.5} = \mathbf{1960 \text{ Pa}}$$

$$\text{Q2 } P = \rho gh = (1000)(9.8)(33) = \mathbf{323\,400 \text{ Pa}}$$

$$\text{Q3 (i) } P = \rho gh = (10^3)(9.8)(0.2) = \mathbf{1960 \text{ Pa}}$$

$$\text{(ii) } P = \rho gh = (13.6 \times 10^3)(9.8)(0.2) \\ = \mathbf{26\,656 \text{ Pa}}$$

$$\text{Q4 (i) } P = \rho gh = (1000)(9.8)(1) = \mathbf{9800 \text{ Pa}}$$

$$\text{(ii) } P = \rho gh = (1000)(9.8)(1.1) = \mathbf{10\,780 \text{ Pa}}$$

$$\text{(iii) } P = \frac{F}{A} \Rightarrow F = PA = (9800)(0.2)(0.3) \\ = \mathbf{588 \text{ N}}$$

$$\text{(iv) } P = \frac{F}{A} \Rightarrow F = PA = (10\,780)(0.2)(0.3) \\ = \mathbf{646.8 \text{ N}}$$

$$\text{Resultant upward force on block} \\ = 646.8 - 588 = 58.8 \text{ N}$$

$$\text{Weight of block} = 70 \text{ N} \Rightarrow \text{it will sink.}$$

Exercise 10.4

Q1 $P_1 = 1 \times 10^5$, $V_1 = 3 \text{ m}^3$

$$P_2 = 3 \times 10^5, V_2 = ?$$

$$P_1 V_1 = P_2 V_2$$

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{1 \times 10^5 \times 3}{3 \times 10^5}$$

$$V_2 = 1 \text{ m}^3$$

Q2 (i) $P_1 V_1 = P_2 V_2$

$$(1 \times 10^5)(40 \times 10^{-6}) = (160 \times 10^{-6})P_2$$

$$P_2 = \frac{(1 \times 10^5)(40 \times 10^{-6})}{160 \times 10^{-6}} = 25 \text{ 000 Pa}$$

(ii) $P_1 V_1 = P_2 V_2$

$$(1 \times 10^5)(40 \times 10^{-6}) = (80 \times 10^{-6})P_2$$

$$P_2 = \frac{(1 \times 10^5)(40 \times 10^{-6})}{80 \times 10^{-6}} = 50 \text{ 000 Pa}$$

(iii) $P_1 V_1 = P_2 V_2$

$$(1 \times 10^5)(40 \times 10^{-6}) = (1 \times 10^{-6})P_2$$

$$P_2 = \frac{(1 \times 10^5)(40 \times 10^{-6})}{1 \times 10^{-6}} = 4 \text{ 000 000 Pa} = 4 \times 10^6 \text{ Pa}$$

Q3 No calculations required.

Q4 (i) $P_1 V_1 = P_2 V_2$

$$(1 \times 10^5)(700 \times 10^{-6}) = (2 \times 10^5)V_2$$

$$V_2 = \frac{(1 \times 10^5)(700 \times 10^{-6})}{2 \times 10^5} = 3.5 \times 10^{-4} \text{ m}^3 = 350 \text{ cm}^3$$

(ii) $(1 \times 10^5)(700 \times 10^{-6}) = (7 \times 10^5)V_2$

$$V_2 = \frac{(1 \times 10^5)(700 \times 10^{-6})}{7 \times 10^5} = 1 \times 10^{-4} \text{ m}^3 = 100 \text{ cm}^3$$

(iii) $V_2 = \frac{(1 \times 10^5)(700 \times 10^{-6})}{5 \times 10^4} = 1.4 \times 10^{-3} \text{ m}^3 = 1400 \text{ cm}^3$

Q5 20 Pa m^3 since at a fixed temperature PV is a constant by Boyle's Law.

Exercise 10.5

Gravity solutions

Q1 $F = \frac{Gm_1 m_2}{d^2} = \frac{(6.7 \times 10^{-11})(1)(1)}{1} = 6.7 \times 10^{-11} \text{ N}$

Q2 $F = \frac{Gm_1 m_2}{d^2} = \frac{(6.7 \times 10^{-11})(76)(6 \times 10^{24})}{(6.4 \times 10^6)^2} = 745.9 \text{ N}$

Q3 $F = \frac{Gm_1 m_2}{d^2} = \frac{(6.7 \times 10^{-11})(90)(1000)}{2^2} = 1.508 \times 10^{-6} \text{ N}$

Q4 $F = \frac{Gm_1 m_2}{d^2} = \frac{(6.7 \times 10^{-11})(76)(7 \times 10^{22})}{(1.7 \times 10^6)^2} = 123.34 \text{ N}$

Q5 $F = \frac{Gm_1 m_2}{d^2} = \frac{(6.7 \times 10^{-11})(6 \times 10^{24})(7 \times 10^{22})}{(3.8 \times 10^8)^2} = 1.95 \times 10^{20} \text{ N}$

Q6 $F = \frac{Gm_1 m_2}{d^2} = \frac{(6.7 \times 10^{-11})(6 \times 10^{24})(1.9 \times 10^{30})}{(1.5 \times 10^{11})^2} = 3.39 \times 10^{22} \text{ N}$

Exercise 10.6

$$\begin{aligned} \text{Q1 } g &= \frac{GM}{R^2} = \frac{(6.7 \times 10^{-11})(1.9 \times 10^{27})}{(7 \times 10^7)^2} \\ &= 25.98 \text{ m s}^{-2} \\ &= \mathbf{26 \text{ m s}^{-2}} \end{aligned}$$

$$W = mg = (90)(26) = \mathbf{2340 \text{ N}}$$

$$\begin{aligned} \text{Q2 } g &= \frac{GM}{R^2} = \frac{(6.7 \times 10^{-11})(1.9 \times 10^{22})}{(1.7 \times 10^6)^2} \\ &= \mathbf{1.62 \text{ m s}^{-2}} \end{aligned}$$

$$W = mg = (60)(1.62) = \mathbf{97.2 \text{ N}}$$

$$\begin{aligned} \text{Q3 } g_s &= \frac{GM_s}{R_s^2} = \frac{(6.7 \times 10^{-11})(1.9 \times 10^{30})}{(6.956 \times 10^8)^2} \\ &= \mathbf{263 \text{ m s}^{-2}} \end{aligned}$$

$$\begin{aligned} \text{Q4 } \text{Weight} &= \text{force of gravity} \\ \Rightarrow mg &= \frac{GMm}{R^2} \Rightarrow g = \frac{GM}{R^2} \end{aligned}$$

Q5 If g_d = acceleration at distance d , then weight of object of mass $m = mg_d$ = grav force of attraction.

$$\therefore mg_d = \frac{GMm}{d^2} \Rightarrow g_d = \frac{GM}{d^2}$$

At height h above surface of planet of radius R , distance from centre $d = R + h$

$$\therefore g_h = \frac{GM}{(R+h)^2}$$

$$\begin{aligned} \text{Q6 } g &= \frac{GM}{(R+h)^2}, \text{ by previous question} \\ &= \frac{(6.7 \times 10^{-11})(6 \times 10^{24})}{(6.4 \times 10^6 + 100 \times 10^3)^2} = \mathbf{9.51 \text{ m s}^{-2}} \end{aligned}$$

Q7 Value on surface = 9.8

Half value on surface = 4.9

Let d = distance from centre of Earth to object.

$$(i) \quad 4.9 = \frac{GM}{d^2} \Rightarrow d^2 = \frac{GM}{4.9}$$

$$= \frac{(6.7 \times 10^{-11})(6 \times 10^{24})}{4.9}$$

$$\Rightarrow d = 9.058 \times 10^6 \text{ m}$$

Radius of Earth = 6.4×10^6

\therefore Height above surface =

$$9.058 \times 10^6 - 6.4 \times 10^6 = 2.7 \times 10^6 \text{ m}$$

i.e. $h = \mathbf{2.7 \times 10^6 \text{ m}}$

$$(ii) \quad \text{Acceleration} = \frac{g}{10} = \frac{9.8}{10} = 0.98 = \frac{GM}{d^2}$$

$$\begin{aligned} \Rightarrow d &= \sqrt{\frac{GM}{0.98}} = \sqrt{\frac{((6.7 \times 10^{-11})(6 \times 10^{24}))}{0.98}} \\ &= 2.03 \times 10^7 \end{aligned}$$

$$\begin{aligned} \text{Height} &= d - R = 2.03 \times 10^7 - 6.4 \times 10^6 \\ &= \mathbf{1.39 \times 10^7} \end{aligned}$$

$$\begin{aligned} \text{Q8 } g &= \frac{GM}{R^2} \Rightarrow M = \frac{gR^2}{G} = \frac{(9.8)(6.4 \times 10^6)^2}{6.7 \times 10^{-11}} \\ &= \mathbf{5.99 \times 10^{24} \text{ kg}} \end{aligned}$$

$$\text{Q9 } g = \frac{GM}{R^2} \Rightarrow 9.8 = \frac{GM}{R^2}$$

Distance from centre of Earth is $3R$.

$$g_h = \frac{GM}{(3R)^2} = \frac{1}{9} \left(\frac{GM}{R^2} \right) = \frac{1}{9} (9.8) = \mathbf{1.089 \text{ m s}^{-2}}$$

Q10 No calculation required.

$$\text{Q11 } g_m = \frac{GM_m}{R_m^2} \text{ and } g_e = \frac{GM_e}{R_e^2}$$

$$\Rightarrow \frac{g_m}{g_e} = \left(\frac{M_m}{M_e} \right) \left(\frac{R_e}{R_m} \right)^2 = (0.04) \left(\frac{1}{0.37} \right)^2$$

$$\therefore g_m = g_e (1.081) = (9.8)(0.292) = \mathbf{2.86 \text{ m s}^{-2}}$$

Q12 Let P be the point where resultant force = 0
Suppose P is a distance y from the Earth and a distance x from the moon:

$$\Rightarrow \frac{GM_e m}{y^2} = \frac{GM_m m}{x^2}$$

Where m = mass of object placed at P

$$\Rightarrow \frac{M_e}{y^2} = \frac{M_m}{x^2} \Rightarrow \frac{x^2}{y^2} = \frac{M_m}{M_e} \Rightarrow \frac{x}{y} = \sqrt{\frac{M_m}{M_e}}$$

$$\text{Also } x + y = 3.8 \times 10^8$$

$$y = 3.8 \times 10^8 - x$$

$$x = \sqrt{\frac{M_m}{M_e}} (3.8 \times 10^8 - x)$$

$$x = \sqrt{\frac{1}{81}} (3.8 \times 10^8 - x)$$

$$\Rightarrow 9x = 3.8 \times 10^8 - x$$

$$\Rightarrow 10x = 3.8 \times 10^8$$

$$x = \mathbf{3.8 \times 10^7 \text{ m}}$$

Resultant gravity force is zero when
 3.8×10^7 m from Moon.

Exercise 10.7

Q1 (i) $M = Fd = (10)(0.4) = \mathbf{4 \text{ N m}}$

(ii) $M = Fd = (10)(0) = \mathbf{0 \text{ N m}}$

(iii) $M = Fd = (10)(0.9) = \mathbf{9 \text{ N m}}$

Q2 (i) $-(10)(0.4) - (1)(0.5) - (12)(0.7) + (28)(0.5) = \mathbf{+1.1}$

(ii) $-(12)(0.2) + (10)(0.1) + 5(0.5) + (5)(0.7) + (10)(0.3) + 1(0.2) - (28)(0.2) = \mathbf{+1.1}$

(iii) (a) $(12)(0.4) + (60)(0.2) = X(0.4) \Rightarrow X = \mathbf{42 \text{ N}}$

(b) $(30)(X) = (10)(0.25) \Rightarrow X = 0.0833 \text{ m} = \mathbf{8.33 \text{ cm}}$

(c) $(20)(0.35) + (40)(0.15) = (10)(0.15) + 30(X) \Rightarrow X = 0.3833 \text{ m} = \mathbf{38.33 \text{ cm}}$

(d) $(20)(0.4) + (40)(0.2) = (60)(0.1) + (10)(0.3) + X(0.2) \Rightarrow X = \mathbf{35}$

Q4 Weight W acts vertically down through 50 cm mark.

Take moments about 45 cm mark:

$$W(0.05) = (60)(0.35) \Rightarrow W = \mathbf{420 \text{ N}}$$

Q5 Weight of stick = $(20 + 40) - (10 + 20 + 28) \Rightarrow W = \mathbf{2 \text{ N}}$

Moments about A:

Clockwise:

$$(10)(10) + (20)(30) + (2)(50) + (28)(100) = \mathbf{3600 \text{ N cm}}$$

Anti-clockwise:

$$(20)(20) + (40)(80) = \mathbf{3600 \text{ N cm}}$$

$$\therefore \text{Sum of moments} = 3600 - 3600 = \mathbf{0}$$

Moments about B:

Clockwise:

$$(20)(10) + (2)(20) + (28)(70) = \mathbf{2200 \text{ N cm}}$$

Anti-clockwise:

$$(10)(20) + (40)(50) = \mathbf{2200 \text{ N cm}}$$

$$\therefore \text{Sum of moments} = \mathbf{0}$$

Moments about C:

Clockwise:

$$(20)(30) + (28)(50) = 2000 \text{ N cm}$$

Anti-clockwise:

$$(40)(30) + (20)(20) + (10)(40) = 2000 \text{ N cm}$$

$$\therefore \text{Sum of moments} = 0$$

Moments about D:

Clockwise:

$$(40)(20) + (20)(80) = 2400 \text{ N cm}$$

Anti-clockwise:

$$(10)(90) + (20)(70) + (2)(50) = 2400 \text{ N cm}$$

$$\therefore \text{Sum of moments} = 0$$

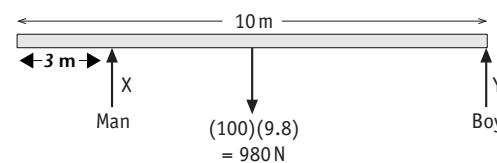
- Q6** Let R_1 = force at 10 cm and R_2 = force at 70 cm.

Let W = weight of beam. It acts at 50 cm (i.e. in middle). Take moments about 10 cm mark:

$$(R_2)(0.6) = W(0.4) \Rightarrow R_2 = \frac{2}{3}W$$

$$R_1 + R_2 = W \Rightarrow R_1 = \frac{1}{3}W$$

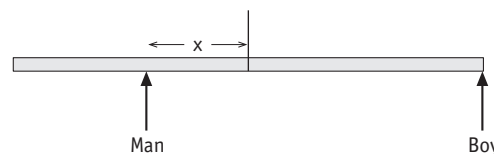
Q7



Take moments about boy:

$$X(7) = (980)(5) \Rightarrow X = 700 \text{ N}$$

$$\therefore \text{Man exerts } \mathbf{700 \text{ N}} \text{ and boy } (980 - 100) = \mathbf{280 \text{ N}}$$



Man supports three times weight of boy

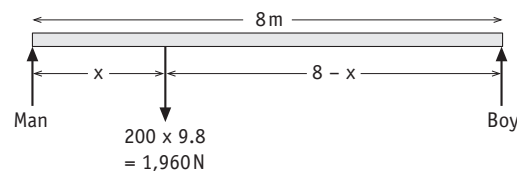
$$\Rightarrow \text{Man exerts } \frac{3}{4}(980) \text{ N} = 735 \text{ N}$$

$$\text{Boy exerts } \frac{1}{4}(980) \text{ N} = 245 \text{ N}$$

Take moments about centre:

$$(735)(X) = (245)(5) \Rightarrow X = \mathbf{1.667 \text{ m}}$$

Q8



$$\text{Man exerts } \frac{4}{5} \text{ of } 1960 = 1568 \text{ N}$$

$$\text{Boy exerts } \frac{1}{5} \text{ of } 1960 = 392 \text{ N}$$

$$\text{Moments about weight: } (1568)x = (392)(8 - x) \\ \Rightarrow 1568x + 392x = 3136 \Rightarrow x = \mathbf{1.6 \text{ m}}$$

Exercise 10.8

Q1 $F(0.05) = (300)(1.5) \Rightarrow F = \mathbf{9000\ N}$

Q2 $T = Fd = (40)(0.5) = \mathbf{20\ N\ m}$

Q3 $T = Fd \Rightarrow 85 = F(0.4) \Rightarrow F = \mathbf{212.5\ N}$

Q4 $T = Fd \Rightarrow 600 = F(0.1) \Rightarrow F = \mathbf{6000\ N}$

Exercise 11.1

Q1 $W = Fs = (10)(30) = \mathbf{300\ J}$

Q2 $W = Fs = (400)(30) = \mathbf{12\ 000\ J}$

Q3 $W = Fs \Rightarrow s = \frac{W}{F} = \frac{20\ 000}{340} = \mathbf{58.82\ m}$

Q4 $W = mg = (100)(9.8) = \mathbf{980\ N}$
 $W = Fs = (980)(60) = \mathbf{58\ 800\ J}$

Q5 $W = Fs = (20)(9.8)(1) = \mathbf{196\ J}$

Q6 $W = Fs = (60)(9.8)(8) = \mathbf{4704\ J}$

Q7 $u = 0, v = 30, t = 10, a = ?, s = ?$

Find a : $v = u + at$
 $30 = 0 + a(10)$
 $\Rightarrow a = \mathbf{3\ m\ s^{-2}}$

Find s : $s = ut + \frac{1}{2}at^2$
 $s = \frac{1}{2}(3)(10^2)$
 $s = \mathbf{150\ m}$

$F = ma \Rightarrow F = (800)(3) = \mathbf{2400\ N}$
 $W = Fs = (2400)(150) = \mathbf{360\ 000\ J}$

Q8 $u = 0$
 $v = 80\ \text{km h}^{-1} = \frac{80\ 000}{(60)(60)}\ \text{m s}^{-1} = \mathbf{22.22\ m\ s^{-1}}$

$t = 20, a = ?, s = ?$

Find a :
 $v = u + at \Rightarrow 22.22 = a(20) \Rightarrow a = \mathbf{1.11\ m\ s^{-2}}$

Find F :
 $F = ma \Rightarrow F = (1000)(1.11) = \mathbf{1110\ N}$

Find s :
 $s = ut + \frac{1}{2}at^2 \Rightarrow s = \frac{1}{2}(1.11)(20)^2 \Rightarrow s = \mathbf{222\ m}$

Find W :
 $W = Fs = (1110)(222) = \mathbf{246\ 420\ J}$

The answer is **246 914 J** if you retain all decimal places throughout the calculation.

Q9 Let h = Vertical height

$\text{Sin } 40^\circ = \frac{h}{10} \Rightarrow h = 10 \text{ Sin } 40^\circ$

$W = Fs = (105)(9.8) 10 \text{ Sin } 40^\circ = \mathbf{6614.28\ J}$

If ladder was vertical:

$W = Fs = (105)(9.8)(10) = \mathbf{10\ 290\ J}$

Exercise 11.2

Q1 $E_k = \frac{1}{2}mv^2 = \left(\frac{1}{2}\right)(20)(12)^2 = \mathbf{1440\ J}$

Q2 $E_k = \frac{1}{2}(1000)(28)^2 = \mathbf{392\ 000\ J}$

Q3 $E_k = \frac{1}{2}(9.1 \times 10^{-31})(1.5 \times 10^7)^2$
 $= \mathbf{1.024 \times 10^{-16}\ J}$

Q4 $E_k = \frac{1}{2}mv^2 \Rightarrow m = \frac{2E_k}{v^2}$
 $= \frac{(2)(160\ 000)}{(20)^2} = \mathbf{800\ kg}$

Q5 $E_k = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2E_k}{m}}$
 $= \sqrt{\frac{(2)(4000)}{200}} = \mathbf{6.32\ m\ s^{-1}}$

Q6 (i) $\frac{1}{2}(4 \times 10^{-3})(400)^2 = \mathbf{320\ J}$

(ii) $\frac{1}{2}(800)(28)^2 = \mathbf{313\ 600\ J}$

(iii) $\frac{1}{2}(10\ 000)\left(\frac{100\ 000}{(60)(60)}\right)^2 = \mathbf{3.9 \times 10^6\ J}$

(iv) $\frac{1}{2}(30 \times 10^{-3})\left(\frac{150\ 000}{(60)(60)}\right)^2 = \mathbf{26\ J}$

Q7 (i) $\frac{1}{2}(20)(3)^2 = \mathbf{90\ J}$

(ii) $\frac{1}{2}(20)(30)^2 = \mathbf{9000\ J}$

(iii) Change in $E_k = 9000 - 90 = \mathbf{8910\ J}$

(iv) Work done = change in E_k
 $= \text{Force} \times \text{distance}$
 $\therefore 8910 = (12)\ s \Rightarrow s = \mathbf{742.5\ m}$

(v) From above: $\mathbf{8910\ J}$

Q8 Work done on bullet = loss in E_k
 $= (0.5)(4 \times 10^{-3})(200)^2 = 80\ \text{J}$

$W = Fs \Rightarrow F = \frac{W}{s} = \frac{80}{0.5} = \mathbf{160\ N}$

Work done = $Fs = (160)(0.25)$
 $= 40\ \text{J} = \text{loss in } E_k$

Remaining $E_k = 80\ \text{J} - 40\ \text{J} = 40\ \text{J}$

$\therefore 40 = \frac{1}{2}(4 \times 10^{-3})v^2 \Rightarrow v = \mathbf{141.4\ m\ s^{-1}}$

Q9 $E_k = \frac{1}{2}mv^2$

Double speed to $2v$

$E_k = \frac{1}{2}m(2v)^2 = 4\left(\frac{1}{2}mv^2\right)$

$\Rightarrow E_k$ has quadrupled.

Q10 $\frac{1}{2}m_1v_1^2 = \frac{1}{2}m_2v_2^2$

$m_1(4v_2)^2 = m_2v_2^2$

$\therefore \frac{m_1}{m_2} = \frac{1}{16} \Rightarrow m_1 : m_2 = \mathbf{1 : 16}$

Exercise 11.3

Q1 $E_p = mgh = (20)(9.8)(600)$
 $= \mathbf{117\ 600\ J}$

Q2 $E_p = mgh \therefore 4000 = (4)(9.8)h$
 $\therefore 4000 = 39.2h$

$h = \frac{4000}{39.2} = \mathbf{102\ m}$

Q3 $E_p = mgh = (3)(9.8)(60)$
 $= E_k = \mathbf{1764\ J}$

$1764 = \frac{1}{2}(3)v^2 \Rightarrow v = \mathbf{34.3\ m\ s^{-1}}$

Q4 Loss in kinetic energy = gain in potential energy.

$\frac{1}{2}(m)(100)^2 = m(9.8)(h)$

$h = \mathbf{510.2\ m}$

Q5 $E_p = mgh = (100)(9.8)(50) = \mathbf{49\ 000\ J}$
 E_p at 30 m = $(100)(9.8)(30) = 29\ 400\ J$
 Kinetic Energy = Loss in potential energy
 $= \mathbf{19\ 600\ J}$

Q6 Loss in $E_p =$ Gain in E_k

$m(9.8)(0.5) = \frac{1}{2}mv^2$

$v = \sqrt{(2)(9.8)(0.5)} = \mathbf{3.13\ m\ s^{-1}}$

Q7 Loss in Potential Energy = Gain in Kinetic energy

$mg(2 - 2 \cos 40^\circ) = \frac{1}{2}mv^2$

$v = \sqrt{4g(1 - \cos 40^\circ)} = \mathbf{3.028\ m\ s^{-1}}$

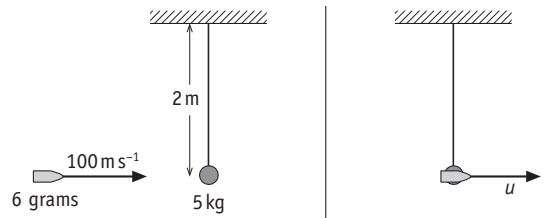
Q8 $(10)(30) + 0 = 25v \Rightarrow v = \mathbf{12\ m\ s^{-1}}$

Initial $E_k = \frac{1}{2}(10)(30)^2 = 4500\ J$

Final $E_k = \frac{1}{2}(25)12^2 = 1800\ J$

Loss in $E_k = \mathbf{2700\ J}$

Q9



Conservation of momentum:

$\Rightarrow \left(\frac{6}{1000}\right)(100) = 5.006u \Rightarrow u = 0.1199\ m\ s^{-1}$

Gain in $E_p =$ Loss in E_k

$(\underline{5.006})(9.8)h = \frac{1}{2}(\underline{5.006})(0.1199)^2$

$\Rightarrow h = \mathbf{0.073\ cm}$

Exercise 11.4

$$\text{Q1 } P = \frac{W}{t} = \frac{600\,000}{12} = \mathbf{50\,kw}$$

$$\text{Q2 } P = \frac{E}{t} = \frac{18\,000}{(30)(60)} = \mathbf{10\,W}$$

$$\text{Q3 } P = \frac{E}{t} = \frac{60\,000}{60} = \mathbf{1000\,W}$$

$$\text{Q4 } P = \frac{W}{t} = \frac{2 \times 10^7}{(2)(60)(60)} = \mathbf{2778\,W}$$

$$\text{Q5 } E = Pt = (60)(5)(60)(60) = \mathbf{1.08 \times 10^6\,J}$$

$$\text{Q6 } E = Pt = (130 \times 10^3)(5)(60) = \mathbf{3.9 \times 10^7\,J}$$

$$\text{Q7 } P = \frac{W}{t} = \frac{(50)(9.8)(50)}{12} = \mathbf{2042\,W}$$

$$\text{Q8 } P = \frac{W}{t} = \frac{(50)(9.8)(2)(25)}{60} = \mathbf{408\,W}$$

$$\text{Q9 } P = \frac{W}{t} = \frac{(40)(9.8)(50)(0.16)}{40} = \mathbf{78.4\,W}$$

$$\text{Q10 } t = \frac{W}{P} = \frac{1 \times 10^6}{77 \times 10^3} = \mathbf{12.987\,s}$$

$$\text{Q11 } W = Pt = (1000)(60)(60) = \mathbf{3.6\,MJ}$$

Exercise 11.5

$$\text{Q1 } \% \text{ efficiency} = \frac{P_O}{P_I} \times 100 = \frac{4000}{5000} \times 100 = \mathbf{80\%}$$

$$\text{Q2 } \text{Power out} = \frac{\text{Work}}{\text{Time}} = \frac{mgh}{t} = \frac{(2000)(9.8)(20)}{10} \\ = \mathbf{39\,200\,W}$$

$$\% \text{ efficiency} = \frac{P_O}{P_I} \times 100 = \frac{39\,200}{60\,000} \times 100 \\ = \mathbf{65.3\%}$$

$$\text{Q3 } 25\% \text{ of input power} = \mathbf{130\,kW}$$

$$75\% \text{ of power becomes heat } \therefore \text{ amount} \\ \text{converted to heat} = \left(\frac{130}{25}\right) 75\,kW = \mathbf{390\,kW}$$

Exercise 12.1

$$\text{Q1 } 180^\circ = \pi \text{ rad} \Rightarrow 1^\circ = \frac{\pi}{180} \text{ rad}$$

$$\Rightarrow 10^\circ = \frac{10\pi}{180} \text{ rad} = \frac{\pi}{18} \text{ rad}$$

$$48^\circ = \frac{48\pi}{180} = \mathbf{0.878 \text{ rad}}$$

$$\text{Q2 } \frac{\pi}{5} \text{ rad} = \frac{180^\circ}{5} = \mathbf{36^\circ}$$

$$\frac{\pi}{7} \text{ rad} = \frac{180}{7} = \mathbf{25.7^\circ}$$

$$1 \text{ rad} = \frac{180}{\pi} = \mathbf{57.296^\circ}$$

$$4.2 \text{ rad} = \frac{(4.2)(180)}{\pi} = \mathbf{240.64^\circ}$$

$$\text{Q3 } \theta = \frac{s}{r} \Rightarrow s = r\theta$$

$$(i) s = (3)(1) = \mathbf{3 \text{ m}}$$

$$(ii) s = (3)(\pi) = \mathbf{9.42 \text{ m}}$$

$$(iii) s = (3)\left(\frac{\pi}{4}\right) = \mathbf{2.36 \text{ m}}$$

$$(iv) s = (3)\left(\frac{(123)\pi}{180}\right) = \mathbf{6.44 \text{ m}}$$

$$\text{Q4 } \theta = \frac{s}{r} \Rightarrow r = \frac{s}{\theta} = \frac{3}{3.5} = \mathbf{0.857 \text{ cm}}$$

$$\text{Q5 } \theta = \frac{s}{r} \Rightarrow s = r\theta = (93 \times 10^6)(0.00932) \\ = \mathbf{8.67 \times 10^5 \text{ miles}}$$

$$\text{Q6 } s = r\theta = (2.2)\left(\frac{10\pi}{180}\right) = \mathbf{0.384 \text{ m}}$$

Exercise 12.2

$$\text{Q1 (i) } v = \frac{s}{t} = \frac{40}{(2)(60)} = \mathbf{0.333 \text{ m s}^{-1}}$$

$$(ii) \omega = \frac{v}{r} = \frac{0.333}{3} = \mathbf{0.111 \text{ rad s}^{-1}}$$

$$(i) \omega = \frac{\theta}{t} \Rightarrow t = \frac{\theta}{\omega} = \frac{\frac{\pi}{2}}{0.111} = \mathbf{14.15 \text{ s}}$$

$$(ii) t = \frac{\theta}{\omega} = \left(\frac{\frac{\pi}{3}}{0.111}\right) = \mathbf{9.43 \text{ s}}$$

$$\text{Q2 } r = 10 \text{ m}, \omega = 4 \text{ rad s}^{-1}$$

$$v = \omega r = (4)(10) = 40 \text{ m s}^{-1}$$

$$v = \frac{s}{t} \Rightarrow t = \frac{s}{v} = \frac{1000}{40} = \mathbf{25 \text{ s}}$$

$$\text{Q3 } \omega = \frac{v}{r} = \frac{3}{0.4} = \mathbf{7.5 \text{ rad s}^{-1}}$$

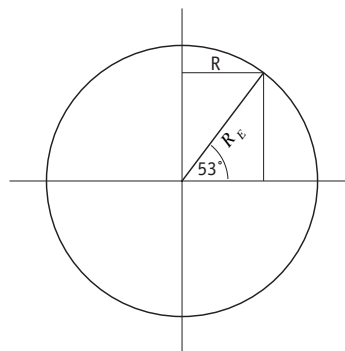
$$\text{Q4 (i) } v = \omega r = (6)(0) = \mathbf{0 \text{ m s}^{-1}}$$

$$(ii) v = \omega r = (6)(0.3) = \mathbf{1.8 \text{ m s}^{-1}}$$

$$\text{Q5 } \omega = \frac{(400)(2\pi)}{60} \text{ rad s}^{-1}$$

$$v = \omega r = \left(\frac{(400)(2\pi)}{60}\right)(2) = \mathbf{83.78 \text{ m s}^{-1}}$$

Q6



$$(i) \omega = \frac{\theta}{t} = \frac{2\pi}{(24)(60)(60)}$$

$$= \mathbf{7.27 \times 10^{-5} \text{ rad s}^{-1}}$$

$$(ii) v = \omega R = (7.27 \times 10^{-5}) \times (6.4 \times 10^6)$$

$$= \mathbf{465 \text{ m s}^{-1}}$$

$$(iii) v = \omega R = \omega(R_E \cos 53)$$

$$= (7.27 \times 10^{-5})(6.4 \times 10^6) \cos 53$$

$$= \mathbf{280 \text{ m s}^{-1}}$$

Exercise 12.3

$$\text{Q1 } F = \frac{mv^2}{r} = \frac{(1200)(25)^2}{200} = \mathbf{3750 \text{ N}}$$

$$\text{Q2 } F = m\omega^2 r = (4)(4.5)^2(0.2) = \mathbf{16.2 \text{ N}}$$

$$\text{Q3 (i) } a = \frac{v^2}{r} = \frac{(12)^2}{1} = \mathbf{144 \text{ m s}^{-2}}$$

$$F = ma = (5)(144) = \mathbf{720 \text{ N}}$$

$$\text{(ii) } a = \frac{v^2}{r} = \frac{(12)^2}{(0.3)} = \mathbf{480 \text{ m s}^{-2}}$$

$$F = ma = (5)(480) = \mathbf{2400 \text{ N}}$$

$$\text{Q4 (i) } \omega = \frac{v}{r} = \frac{4}{0.4} = \mathbf{10 \text{ rad s}^{-1}}$$

$$\text{(ii) } a = \frac{v^2}{r} = \frac{4^2}{0.4} = \mathbf{40 \text{ m s}^{-2}}$$

$$\text{(iii) } F = ma = (10)(40) = \mathbf{400 \text{ N}}$$

$$\text{Q5 } F = \frac{mv^2}{r} = \frac{(950)\left(\frac{100\,000}{(60)(60)}\right)^2}{100} = \mathbf{7330 \text{ N}}$$

$$\text{Q6 } v = r\omega = (0.5)(20) = \mathbf{10 \text{ m s}^{-1}}$$

$$\text{Q7 } a = \frac{v^2}{r} \Rightarrow r = \frac{v^2}{a} = \frac{(500^2)}{(9)(9.8)} = \mathbf{2834 \text{ m}}$$

$$\text{Q8 Loss in } E_k = \text{Gain in } E_p$$

$$\frac{1}{2}m5^2 - \frac{1}{2}mv^2 = mgh$$

$$\left(\frac{1}{2}\right)(5^2) - \left(\frac{1}{2}\right)v^2 = (9.8)(0.8)$$

$$12.5 - 7.84 = \frac{v^2}{2} \Rightarrow v = \mathbf{3.05 \text{ m s}^{-1}}$$

$$a = \frac{v^2}{r} = \frac{(3.05)^2}{0.8} = \mathbf{11.63 \text{ m s}^{-2}}$$

$$F = ma = (0.24)(11.63) = \mathbf{2.79 \text{ N}}$$

Exercise 12.4

$$\text{Q1 } v^2 = \frac{GM}{R} = \frac{(6.7 \times 10^{-11})(6 \times 10^{24})}{(6.4 \times 10^6) + (50 \times 10^6)}$$

$$\Rightarrow v = \mathbf{2669.8 \text{ m s}^{-1}}$$

$$T = \frac{2\pi R}{v} = \frac{(2)(\pi)[(6.4 \times 10^6) + (50 \times 10^6)]}{2669.8}$$

$$= 132733.41 \text{ s} = \mathbf{36.87 \text{ hours}}$$

$$\text{Q2 } T^2 = \frac{4\pi^2 R^3}{GM} \Rightarrow R = \sqrt[3]{\frac{T^2 GM}{4\pi^2}}$$

$$30 \text{ min} = (30)(60) \text{ s}$$

$$R = \sqrt[3]{\frac{[(30)(60)]^2 (6.7 \times 10^{-11})(6 \times 10^{24})}{4\pi^2}}$$

$$= \mathbf{3.2 \times 10^6 \text{ m}}$$

$$v = \sqrt{\frac{GM}{R}} = \sqrt{\frac{(6.7 \times 10^{-11})(6 \times 10^{24})}{(3.2 \times 10^6)}}$$

$$= \sqrt{1.2562 \times 10^8} = \mathbf{11\,208 \text{ m s}^{-1}}$$

$$\text{Q3 } T^2 = \frac{4\pi^2 R^3}{GM} \Rightarrow T^2 = \frac{4\pi^2 (7.8 \times 10^{11})^3}{(6.7 \times 10^{-11})(2.0 \times 10^{30})}$$

$$= 1.3981 \times 10^{17}$$

$$\Rightarrow T = 3.739 \times 10^8 \text{ s} = \mathbf{11.9 \text{ years}}$$

$$\text{Q4 } T^2 \propto R^3$$

$$\frac{T_S^2}{T_E^2} = \frac{R_S^3}{R_E^3} \Rightarrow T_S^2 = T_E^2 \left(\frac{R_S}{R_E}\right)^3 = T_E^2 (9.5)^3$$

$$T_S = T_E \sqrt{(9.5)^3} = T_E \mathbf{(29.28) \text{ years}}$$

Since period of Earth's orbit = 1 year

$$\text{Q5 } \left[v^2 = \frac{GM}{R} \right]$$

$$\frac{v_s^2}{v_e^2} = \frac{\frac{GM_s}{R_s}}{\frac{GM_E}{R_E}}$$

$$\left(\frac{v_s}{v_e} \right)^2 = \left(\frac{R_E}{R_s} \right) \left(\frac{M_s}{M_E} \right)$$

$$R_E = R_s \text{ and } v_s = 10v_e$$

$$\begin{aligned} \Rightarrow (10)^2 &= \frac{M_s}{M_E} \Rightarrow M_s = M_E(100) \\ &= 6 \times 10^{24} \times 100 \\ &= \mathbf{6 \times 10^{26} \text{ kg}} \end{aligned}$$

$$\text{Q6 } T^2 = \frac{4\pi^2 R^3}{GM} \Rightarrow R = \sqrt[3]{\frac{T^2 GM}{4\pi^2}}$$

$$\begin{aligned} R &= \sqrt[3]{\frac{(86\,400)^2 (6.7 \times 10^{-11})(6 \times 10^{24})}{4\pi^2}} \\ &= \mathbf{4.24 \times 10^7 \text{ m}} \end{aligned}$$

$$\begin{aligned} v^2 &= \frac{GM}{R} \Rightarrow v = \sqrt{\frac{GM}{R}} = \sqrt{\frac{(6.7 \times 10^{-11})(6 \times 10^{24})}{4.24 \times 10^7}} \\ &= \mathbf{3079 \text{ m s}^{-1}} \end{aligned}$$

$$\text{Q7 } \omega = \frac{\theta}{t} = \frac{2\pi}{(24)(60)(60)} = (7.27 \times 10^{-5}) \text{ rad s}^{-1}$$

$$\begin{aligned} \text{(i) } v &= \omega r = (7.27 \times 10^{-5})(6.4 \times 10^6) \\ &= \mathbf{465 \text{ m s}^{-1}} \end{aligned}$$

$$\begin{aligned} \text{(ii) } a &= \omega^2 r = (7.27 \times 10^{-5})^2 (6.4 \times 10^6) \\ &= \mathbf{0.0338 \text{ m s}^{-2}} \\ &\text{(0.03385 if you don't round off } \omega) \end{aligned}$$

Exercise 13.1

$$\text{Q1 } F = ks \Rightarrow F = 4000 \text{ s}$$

$$\begin{aligned} \text{(i) } s &= 2 \text{ cm} = 2 \times 10^{-2} \text{ m} \\ \therefore F &= (4000)(2 \times 10^{-2}) = \mathbf{80 \text{ N}} \end{aligned}$$

$$\text{(ii) } 1000 = 4000 \text{ s} \Rightarrow s = \mathbf{0.25 \text{ m}}$$

$$\text{Q2 } F = ks \Rightarrow 8 = k(0.06) \Rightarrow k = 133.3$$

$$\text{(i) } F = (133.3)(0.02) = \mathbf{2.67 \text{ N}}$$

$$\text{(ii) } 15 = (133.3)(s) \Rightarrow s = \mathbf{11.25 \text{ cm}}$$

Exercise 13.2

Q1 (i) $T = \text{Time for one oscillation} = \frac{4}{20} = \mathbf{0.2 \text{ s}}$

(ii) $f = \frac{1}{T} = \frac{1}{0.2} = \mathbf{5 \text{ Hz}}$

Q2 $T = \frac{20}{50} = \mathbf{0.4 \text{ s}}$

Q3

$a = \omega^2 s$	$a = 4s$
$2 = \omega^2(0.5)$	$a = 4(0.1) = \mathbf{0.4 \text{ m s}^{-2}}$
$\Rightarrow \omega^2 = 4$	$a = 4s \Rightarrow s = \frac{a}{4}$
	$= \frac{0.5}{4}$
	$= \mathbf{0.125 \text{ m}}$

Q4 Force is max when accel is max and when displacement is max, i.e. force is max at amplitude.

$$a = \omega^2 s$$

$$1 = \omega^2(0.1) \Rightarrow \omega^2 = 10$$

$$a_{\max} = \frac{F_{\max}}{m} = \frac{60}{12} = 5 \text{ m s}^{-2}$$

$$a = \omega^2 s$$

$$5 = 10s_{\max} \Rightarrow s_{\max} = \mathbf{0.5 \text{ m}}$$

Q5 $T = \frac{2\pi}{\omega} \Rightarrow \omega = \frac{2\pi}{T}$

$$\therefore \omega = \frac{2\pi}{0.5} \Rightarrow \omega^2 = 157.914$$

$$a = \omega^2 s \Rightarrow a = (157.914)(0.04)$$

$$a = 6.3165 \text{ m s}^{-2}$$

$$F = ma = (4)(6.3165) = \mathbf{25.27 \text{ N}}$$

Q6 $a = \omega^2 s \Rightarrow 3 = \omega^2(0.5) \Rightarrow \omega = \sqrt{6}$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{6}} = \mathbf{2.565 \text{ s}}$$

Q7 $a = \omega^2 s \Rightarrow 2.5 = \omega^2(0.14) \Rightarrow \omega = 4.226$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{4.226} = 1.487 \Rightarrow f = \mathbf{0.673 \text{ Hz}}$$

Q8 $T = \frac{2\pi}{\omega} \Rightarrow \omega = \frac{2\pi}{T} = \frac{2\pi}{1.5} = 4.189$

$$a = \omega^2 s = (4.189)^2(0.25) = \mathbf{4.39 \text{ m s}^{-2}}$$

Exercise 13.3

Q1 $T = 2\pi \sqrt{\frac{l}{g}} \Rightarrow T = 2\pi \sqrt{\frac{2}{9.81}} = \mathbf{2.84 \text{ s}}$

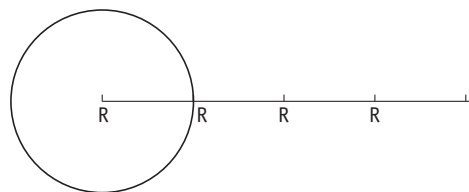
Q2 $T = \frac{90}{50} = 1.8 \text{ s}$

$$g = 4\pi^2 \frac{l}{T^2} = \frac{(4\pi^2)(0.8)}{(1.8)^2} = \mathbf{9.75 \text{ m s}^{-2}}$$

Q3 $T = 2\pi \sqrt{\frac{l}{g}} \Rightarrow l = \frac{gT^2}{4\pi^2}$

$$\therefore l = \frac{(9.8)(2)^2}{4\pi^2} = 0.9929 \text{ m} = \mathbf{99.29 \text{ cm}}$$

Q4



$$g = \frac{GM}{R^2} \quad g \propto \frac{1}{R^2}$$

R is four times bigger $\Rightarrow g$ is 16 times smaller

$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$T_{\text{height}} = 2\pi \sqrt{\frac{l}{\left(\frac{g}{16}\right)}} = \sqrt{16} \left(2\pi \sqrt{\frac{l}{g}}\right)$$

$$= 4 \text{ (Period on surface)} = 4(0.4) = \mathbf{1.6 \text{ s}}$$

Exercise 14.1

Q1 $T/K = t/^{\circ}\text{C} + 273.15$

(i) $= 0 + 273.15 = \mathbf{273.15\text{ K}}$

(ii) $= -100 + 273.15 = \mathbf{173.15\text{ K}}$

(iii) $= 20 + 273.15 = \mathbf{293.15\text{ K}}$

(iv) $= 100 + 273.15 = \mathbf{373.15\text{ K}}$

Q2 $t/^{\circ}\text{C} = T/K - 273.15$

(i) $= 100 - 273.15 = \mathbf{-173.15\text{ }^{\circ}\text{C}}$

(ii) $= 273 - 273.15 = \mathbf{-0.15\text{ }^{\circ}\text{C}}$

(iii) $= 373 - 273.15 = \mathbf{99.85\text{ }^{\circ}\text{C}}$

(iv) $= 500 - 273.15 = \mathbf{226.85\text{ }^{\circ}\text{C}}$

Exercise 14.2

Q1 No calculations required.

Q2 No calculations required.

Exercise 15.1

Q1 $Q = C\Delta\theta = (1500)(80 - 10) = \mathbf{105\ 000\text{ J}}$

Q2 $Q = C\Delta\theta \Rightarrow \Delta\theta = \frac{Q}{C} = \frac{1\ 000\ 000}{600} = \mathbf{1667\text{ }^{\circ}\text{C}}$

Q3 $Q = C\Delta\theta \Rightarrow C = \frac{Q}{\Delta\theta} = \frac{4000}{10} = \mathbf{400\text{ J K}^{-1}}$

Q4 $Q = mc\Delta\theta = (2)(4180)(80 - 12) = \mathbf{568\ 480\text{ J}}$

Q5 $Q = mc\Delta\theta = (12)(390)(120 - 10) = \mathbf{514\ 800\text{ J}}$

Q6 $Q = mc\Delta\theta \Rightarrow C = \frac{Q}{m\Delta\theta} = \frac{11\ 088}{(1.6)(25 - 7)} = \mathbf{385\text{ J kg}^{-1}\text{K}^{-1}}$

Q7 $Q = mc\Delta\theta \Rightarrow m = \frac{Q}{c\Delta\theta} = \frac{1\ 000\ 000}{(451)(100 - 20)} = \mathbf{12.32\text{ kg}}$

Q8 $Q = mc\Delta\theta \Rightarrow \Delta\theta = \frac{Q}{mc} = \frac{4000}{(0.4)(4180)} = 2.39$

\therefore Find temperature of water

$= 20\text{ }^{\circ}\text{C} + 2.39\text{ }^{\circ}\text{C} = \mathbf{22.39\text{ }^{\circ}\text{C}}$

$= 20\text{ }^{\circ}$

Q9 $Q = mc\Delta\theta \Rightarrow \Delta\theta = \frac{Q}{mc}$

For copper $\Delta\theta_1 = \frac{40\ 000}{(2)(390)} = 51.3\text{ }^{\circ}\text{C}$

For aluminium $\Delta\theta_2 = \frac{40\ 000}{(2)(910)} = 22\text{ }^{\circ}\text{C}$

Find temperature of copper

$= 0 + 51.3 = 51.3\text{ }^{\circ}\text{C}$

Find temperature of aluminium

$= 20 + 22\text{ }^{\circ}\text{C} = 42\text{ }^{\circ}\text{C}$

\Rightarrow Copper reaches the higher temperature

Q10 Heat added = heat to copper + heat to water

$= m_c c_c \Delta\theta \uparrow + m_w c_w \Delta\theta \uparrow$

$= (0.08)(390)(60 - 18)$

$+ (0.120)(4180)(60 - 18)$

$= 1310.4 + 21067.2$

$= \mathbf{22\ 377.6\text{ J}}$

Q11 Heat supplied $Q = mc\Delta\theta$

$= (5)(4180)(90) = 1\ 881\ 000\text{ J}$

Time = $\frac{\text{Energy supplied}}{\text{Power}} = \frac{1\ 881\ 000}{1000} = \mathbf{1881\text{ s}}$

Q12 Let θ = final temperature

Heat lost = Heat gained

$$(0.03)(4180)(100 - \theta) = (0.1)(4180)(\theta - 20)$$

$$3(100 - \theta) = 10(\theta - 20)$$

$$300 - 3\theta = 10\theta - 200$$

$$500 = 13\theta$$

$$\Rightarrow \theta = 38.5^\circ \text{C}$$

Final Temp = **38.5° C**

Q13 Heat lost by Copper = Heat gained by water + Heat gained by Calorimeter

$$m_c c_c \Delta\theta \downarrow = m_w c_w \Delta\theta \uparrow + m_{cal} c_c \Delta\theta \uparrow$$

$$(0.12)(390)(100 - \theta) = (0.08)(4180)(\theta - 20) + (0.06)(390)(\theta - 20)$$

$$46.8(100 - \theta) = 334.4(\theta - 20) + 23.4(\theta - 20)$$

$$\theta(-46.8 - 334.4 - 23.4) = (-46.8)(100) - 20(334.4) - 20(23.4)$$

$$\Rightarrow 404.6\theta = 11836$$

$$\theta = \mathbf{29.25^\circ \text{C}}$$

Exercise 15.2

Q1 $Q = ml$

$$Q = (10)(3.3 \times 10^5) = \mathbf{3.3 \times 10^6 \text{ J}}$$

Q2 $Q = ml = (0.5)(3.3 \times 10^5) = 1.65 \times 10^5 \text{ J}$
= **165 kJ**

Q3 $Q = ml \Rightarrow m = \frac{Q}{l} = \frac{1 \times 10^6}{3.3 \times 10^5} = \mathbf{3.03 \text{ kg}}$

Q4 $Q = ml = (0.4)(2.3 \times 10^6) = \mathbf{9.2 \times 10^5 \text{ J}}$

Q5 $Q = ml = (0.08)(2.3 \times 10^6) = \mathbf{1.84 \times 10^5 \text{ J}}$

Q6 Heat needed = Heat to melt ice + Heat to raise melted ice from 0° to 99°

$$= ml + mc\Delta\theta$$

$$= (3)(3.3 \times 10^5) + (3)(4180)(99)$$

$$= \mathbf{2.23 \text{ MJ}}$$

Q7 Heat needed = Heat to melt ice + Heat to raise water to 100° + Heat to vaporise water at 100°

$$= ml_f + mc\Delta\theta \uparrow + ml_v$$

$$= (1)(3.3 \times 10^5) + (1)(4180)(100)$$

$$+ (1)(2.3 \times 10^6) = \mathbf{3.05 \text{ MJ}}$$

Q8 $Q = mc\Delta\theta + ml$

$$Q = (0.06)(4180)(100 - 15)$$

$$+ (0.06)(2.3 \times 10^6)$$

$$Q = 21\,318 + 138\,000 = \mathbf{159\,318 \text{ J}}$$

Q9 $\left(\begin{array}{c} \text{Heat} \\ \text{needed} \end{array} \right) = \left(\begin{array}{c} \text{Heat to} \\ \text{melt ice} \end{array} \right) + \left(\begin{array}{c} \text{Heat to bring melted} \\ \text{ice from } 0^\circ \text{ to } 100^\circ \end{array} \right)$

$$= ml_f + mc\Delta\theta \uparrow$$

$$= (0.06)(3.3 \times 10^5) + (0.06)(4180)(100)$$

$$= \mathbf{44\,880 \text{ J}}$$

$$\text{Heat lost by steam} = m_s l_v$$

$$\therefore m_s(2.3 \times 10^6) = 44\,880$$

$$\therefore m_s = \mathbf{19.5 \text{ grams}}$$

Q10 Let θ = final temp reached
 Heat lost by water = Heat gained by ice
 Heat lost by water = Heat to melt ice + Heat to bring melted ice to final temp.
 $m_w c_w$ fall in temp = $m_{ice} l_f + m_{ice} c_w$ rise in temp
 $(0.5)(4180)(80 - \theta) = (0.2)(3.3 \times 10^5) + (0.2)(4180)(\theta - 0)$
 $167\,200 - 2090\theta = 66\,000 + 836\theta$
 $167\,200 - 66\,000 = (836 + 2090)\theta$
 $\theta = 34.6^\circ \text{C}$

Q11 Let θ = final temp reached

(i) Heat lost by steam = Heat gained by water
 $m_s l_v + m_s c_w$ (fall in temp) = $m_w c_w$ (rise in temp)
 $(0.002)(2.3 \times 10^6) + (0.002)(4180)(100 - \theta) = (0.08)(4180)(\theta - 10)$
 $4600 + 8.36(100 - \theta) = 334.4(\theta - 10)$
 $4600 + 836 - 8.36\theta = 334.4\theta - 3344$
 $4600 + 836 + 3344 = (334.4 + 8.36)\theta$
 $\theta = 25.6^\circ \text{C}$

(ii) Heat lost by steam = Heat gained by water + Heat gained by Cal
 i.e. Heat lost by steam
 $= m_w c_w \Delta\theta \uparrow + m_c c_c \Delta\theta \uparrow$
 $\Rightarrow 4600 + 8.36(100 - \theta)$
 $= 334.4(\theta - 10) + 27.3(\theta - 10)$
 $4600 + 836 - 8.36\theta$
 $= 334.4\theta - 3344 + 27.3\theta - 273$
 $4600 + 836 + 3344 + 273$
 $= (334.4 + 8.36 + 27.3)\theta$
 $\theta = 24.5^\circ \text{C}$

Q12 Heat lost by water + Heat lost by calorimeter = Heat needed to melt ice at 0°C to water at 0°C + Heat needed to raise temperature of melted ice from 0°C to 5.1°C
 i.e. $m_w c_w$ (fall in temp) + $m_c c_c$ (fall in temp)
 $= M_{ice} L + M_{ice} C_w (5.1)$
 $\Rightarrow (0.08)(4180)(25 - 5.1) + (0.05)(390)(25 - 5.1) = (0.02) L + (0.02)(4180)(5.1)$
 \Rightarrow Latent heat of fusion of ice L
 $3.3 \times 10^5 \text{ J kg}^{-1}$

Q13 1 litre = 1000 cm^3
 $Q = mc \Delta\theta$
 Heat needed = Heat to bring kettle from $10^\circ \rightarrow 100^\circ$ + Heat water $10^\circ \rightarrow 100^\circ$
 $= m_{al} c_{al} (90) + m_w c_w (90)$
 $= (0.5)(910)(90) + (1.7)(4180)(90)$
 $= 40\,950 + 639\,540$
 $= 680\,490 \text{ J}$

Time taken = $\frac{\text{Energy}}{\text{Power}} = \frac{680\,490}{2.5 \times 10^3} = 272 \text{ s} = 4.54 \text{ min}$

$Q = ml = \left(\frac{1.7}{2}\right) (2.3 \times 10^6) = 1.955 \times 10^6 \text{ J}$

Time = $\frac{1.955 \times 10^6}{2.5 \times 10^3} = 782 \text{ s} = 13.03 \text{ min}$

Q14 $E_p = mgh = (3.5 \times 10^{-3})(9.8)(3000) = 102.9 \text{ J}$

Let mass melted = m

$Q = ml_f \Rightarrow m = \frac{Q}{l_f} = \frac{102.9}{3.3 \times 10^5}$
 $= 3.1181 \times 10^{-4} \text{ kg} = 0.31 \text{ grams}$

Residual mass of hailstones = $3.5 - 0.31 = 3.19 \text{ grams}$

Exercise 16.1

Q1 10 Hz = **10 cycles** passing per second
Duration of 1 cycle = $\frac{1}{10}$ s = **0.1 s**

Q2 Wavelength = 2×2 m = **4 m**

Q3 Amplitude = max. disp from undisturbed position = $\frac{1}{2}$ (2 m) = **1 m**

Q4 $c = \lambda f = (1.5)(5) = \mathbf{7.5 \text{ m s}^{-1}}$

Q5 $c = \lambda f = (3.125)(96 \times 10^6) = \mathbf{3 \times 10^8 \text{ m s}^{-1}}$

Q6 $c = \lambda f = (6)(50 \times 10^6) = 3 \times 10^8 \text{ m s}^{-1}$
(for station 1)

All radio waves travel at the same speed in air (\approx vacuum)

$$\therefore \text{For station 2: } c = \lambda f \Rightarrow \lambda = \frac{c}{f} = \frac{3 \times 10^8}{25 \times 10^6} = \mathbf{12 \text{ m}}$$

Q7 $\lambda = 5 \times 10^{-9} \Rightarrow f = \frac{c}{\lambda} = \frac{3 \times 10^8}{5 \times 10^{-9}} = \mathbf{6 \times 10^{16} \text{ Hz}}$

$$\lambda = 1 \times 10^{-11} \Rightarrow f = \frac{c}{\lambda} = \frac{3 \times 10^8}{1 \times 10^{-11}} = \mathbf{3 \times 10^{19} \text{ Hz}}$$

Frequency range = $\mathbf{6 \times 10^{16} \text{ Hz} - 3 \times 10^{19} \text{ Hz}}$

Q8 $c = \lambda f = 12 \times 40 = \mathbf{480 \text{ m s}^{-1}}$

(i) f remains the same;

(ii) $c = \lambda f$, if f remains the same and c doubles then λ **doubles**.

Q9 15 min = $\frac{1}{2}$ period

$$\therefore \text{Period} = 30 \text{ min} = 30 \times 60 \text{ sec} = 1800 \text{ s}$$

$$\Rightarrow f = \frac{1}{T} = \frac{1}{1800}$$

$$v = 400 \text{ km hr}^{-1} = \frac{400 \times 1000}{60 \times 60} \text{ m s}^{-1} = 111.11 \text{ m s}^{-1}$$

$$\therefore c = \lambda f \Rightarrow \lambda = \frac{c}{f} = \frac{111.11}{\left(\frac{1}{1800}\right)} = \mathbf{199\,998 \text{ m}}$$

Q10 In air $c = \lambda f \Rightarrow f = \frac{c}{\lambda} = \frac{340}{0.40} = 850 \text{ Hz}$

In other medium $\lambda = \frac{c}{f} = \frac{500}{850} = \mathbf{58.82 \text{ cm}}$

Exercise 16.2**Q1** No calculations required.**Q2** No calculations required.**Q3** Distance from node to antinode = 5 m

$$\therefore \frac{\lambda}{4} = 5 \Rightarrow \lambda = 20 \text{ m}$$

$$c = f\lambda \Rightarrow f = \frac{c}{\lambda} = \frac{4}{20} = \mathbf{0.2 \text{ Hz}}$$

Q4 $c = f\lambda \Rightarrow \lambda = \frac{c}{f} = \frac{60 \times 10^{-2}}{6} = 0.1 \text{ m}$

$$\text{Distance between adjacent nodes} = \frac{\lambda}{2} = 0.05 \text{ m} \\ = \mathbf{5 \text{ cm}}$$

Q5 $c = 340 \text{ m s}^{-1}$, $f = ?$

$$8\left(\frac{\lambda}{2}\right) = 2 \text{ m} \Rightarrow \lambda = \frac{4}{8} = 0.5 \text{ m}$$

$$f = \frac{c}{\lambda} = \frac{340}{0.5} = \mathbf{680 \text{ Hz}}$$

Exercise 16.3

Q1 $f' = \frac{fc}{c-u} = \frac{(2000)(336)}{336-50} = \mathbf{2349.7 \text{ Hz}}$

Q2 $f' = \frac{fc}{c+u} = \frac{(2000)(336)}{336+50} = \mathbf{1740.9 \text{ Hz}}$

Q3 $f' = \frac{fc}{c-u} \Rightarrow 720 = \frac{(600)(340)}{340-u}$
 $\Rightarrow 340 - u = \frac{(600)(340)}{720}$
 $\Rightarrow u = \mathbf{56.67 \text{ m s}^{-1}}$

Q4 $f = 1000 \text{ Hz}$, $u = 40 \text{ m s}^{-1}$, $c = 336 \text{ m s}^{-1}$

$$\text{While approaching: } f' = \frac{fc}{c-u} = \frac{(1000)(336)}{(336-40)} \\ = 1135.1 \text{ Hz}$$

$$\text{While going away: } f' = \frac{fc}{c+u} = \frac{(1000)(336)}{(336+40)} \\ = 893.6 \text{ Hz}$$

$$\text{Change in frequency} = 1135.1 - 893.6 \\ = \mathbf{241.5 \text{ Hz}}$$

Q5 Approaching $f' = \frac{fc}{c-u} = \frac{(2000)(336)}{(336-20)}$
 $= 2126.58 \text{ Hz}$

$$\text{Going away: } f' = \frac{fc}{c+u} = \frac{(2000)(336)}{(336+20)} \\ = 1887.64 \text{ Hz}$$

 \therefore Change in frequency

$$= 2126.58 - 1887.64 = \mathbf{238.9 \text{ Hz}}$$

Q6 $f = 4000 \text{ Hz}$

Highest note is heard when at A

$$f' = 4200, c = 340, u = ?$$

$$(i) f' = \frac{fc}{c-u}$$

$$\Rightarrow 4200$$

$$= \frac{(4000)(340)}{(340-u)}$$

$$\Rightarrow u = \mathbf{16.19 \text{ m s}^{-1}}$$

$$(ii) \text{ Lowest note occurs at B: } f' = \frac{fc}{c+u}$$

$$= \frac{(4000)(340)}{(340+16.19)} = \mathbf{3818.2 \text{ Hz}}$$

$$(iii) \text{ Time} = \frac{\text{Distance}}{\text{Speed}} = \frac{2\pi(1)}{16.19} = \mathbf{0.388 \text{ s}}$$

$$(iv) \text{ Time} = \frac{0.388}{2} = \mathbf{0.194 \text{ s}}$$

Q7 Train approaching:

$$f' = \frac{fc}{c-u}$$

$$1000 = \frac{(f)(340)}{340-u}$$

$$\Rightarrow (1000)(340-u) = 340f$$

$$\therefore 1000(340-u) = 800(340+u)$$

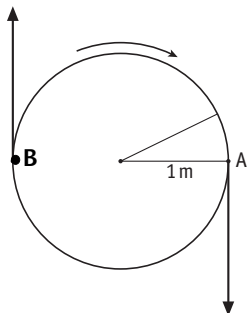
$$\Rightarrow u = \mathbf{37.78 \text{ m s}^{-1}}$$

$$\therefore f = \frac{(1000)(340-37.78)}{340} = \mathbf{888.9 \text{ Hz}}$$

$$\mathbf{Q8} \quad f' = \frac{fc}{c-u} \Rightarrow 208 = \frac{(200)(336)}{(336-u)}$$

$$\Rightarrow 336-u = \frac{(200)(336)}{(208)}$$

$$\Rightarrow u = \mathbf{12.92 \text{ m s}^{-1}}$$



Exercise 17.1

Q1 If we assume the time taken for the sound to travel up from the bottom of the well is negligible compared with time for stone to fall, we have:

For downward journey of stone:

$$u = 0, a = 9.8, t = 2, s = ?$$

$$s = ut + \frac{1}{2}at^2$$

$$s = \left(\frac{1}{2}\right)(9.8)(2)^2$$

$$\Rightarrow s = \mathbf{19.6 \text{ m}}$$

The problem becomes much more difficult if we do not make this simplifying assumption.

For stone falling down:

$$u = 0, a = 9.8, s = ?, t_1 = ?$$

$$s = \frac{1}{2}9.8t_1^2$$

$$s = 4.9t_1^2$$

1

For sound travelling up:

Time for sound to travel up

$$= t_2 = \frac{s}{340} \Rightarrow s = 340t_2$$

2

$$\text{Now } t_1 + t_2 = 2 \therefore t_2 = 2 - t_1$$

Equating **1** and **2**:

$$4.9t_1^2 = 340t_2$$

$$4.9t_1^2 = 340(2 - t_1)$$

$$4.9t_1^2 + 340t_1 - 680 = 0$$

Solving for t_1 :

$$t_1 = \frac{-340 \pm \sqrt{(340)^2 - 4(4.9)(-680)}}{2(4.9)}$$

$$t_1 = 1.945 \text{ s}$$

$$\mathbf{1} \Rightarrow s = \frac{1}{2}(9.8)(1.945)^2$$

$$= \mathbf{18.5 \text{ m} = \text{depth of well}}$$

$$\mathbf{Q2} \quad \text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

$$\Rightarrow \text{Distance} = (\text{Speed}) \times (\text{Time}) = (340)(4)$$

$$= \mathbf{1360 \text{ m}}$$

Exercise 17.2

$$\text{Q1 } f = \frac{1}{2l} \sqrt{\frac{T}{\mu}} = \frac{1}{(2)(0.8)} \sqrt{\frac{200}{0.04}} = \mathbf{44.2 \text{ Hz}}$$

$$\begin{aligned} \text{Q2 } f &= \frac{1}{2l} \sqrt{\frac{T}{\mu}} \Rightarrow 4f^2 l^2 = \frac{T}{\mu} \\ \Rightarrow T &= 4f^2 l^2 \mu = (4)(500)^2 (0.6)^2 (0.02) \\ &= \mathbf{7200 \text{ N}} \end{aligned}$$

$$\text{Q3 } \mu = \frac{\text{Mass}}{\text{Length}} = \frac{0.05}{0.8} = \mathbf{0.0625 \text{ kg m}^{-1}}$$

$$f = \frac{1}{2l} \sqrt{\frac{T}{\mu}} = \frac{1}{(2)(0.8)} \sqrt{\frac{100}{0.0625}} = \mathbf{25 \text{ Hz}}$$

$$\begin{aligned} \text{Q4 } \mu &= \frac{\text{Mass}}{\text{Length}} = \frac{0.04}{4} = 0.01 \text{ kg m}^{-1} \\ f &= \frac{1}{2l} \sqrt{\frac{T}{\mu}} = \frac{1}{(2)(4)} \sqrt{\frac{400}{0.01}} = \mathbf{25 \text{ Hz}} \end{aligned}$$

$$\text{Q5 } f = \infty \sqrt{T} \Rightarrow f = k \sqrt{T}$$

If tension is increased **four times** to $4T$.

$$f_{\text{new}} = k \sqrt{T_{\text{new}}} = k \sqrt{4T} = 2k \sqrt{T} = 2f$$

i.e frequency is doubled

$$\text{Q6 } f \propto \sqrt{T} \Rightarrow f = k \sqrt{T}$$

$$260 = k \sqrt{40} \Rightarrow k = \frac{260}{\sqrt{40}}$$

$$\therefore f = \left(\frac{260}{\sqrt{40}} \right) \sqrt{T}$$

$$\text{(i) When } T \text{ is } 160, f = \frac{260}{\sqrt{40}} \sqrt{160} = \mathbf{520 \text{ Hz}}$$

$$\text{(ii) When } T \text{ is } 200, f = \frac{260 \sqrt{200}}{\sqrt{40}} = \mathbf{581 \text{ Hz}}$$

$$\text{Q7 (i) } f \propto \frac{1}{l} \text{ If length is doubled } f \text{ is halved}$$

$$\therefore f = \mathbf{230 \text{ Hz}}$$

$$\text{(ii) } f \propto \frac{1}{l} \Rightarrow fl = k$$

$$\therefore k = (460)(0.6) = 276$$

$$\therefore f = \frac{276}{l}$$

$$\therefore f = \frac{276}{1.5} = \mathbf{184 \text{ Hz}}$$

Exercise 18.1

$$\text{Q1 } d = 2.8 \times 10^{-6} \text{ m}, n = 2, \theta = 65^\circ, \lambda$$

$$n\lambda = d \sin \theta \Rightarrow \lambda = \frac{d \sin \theta}{n}$$

$$= \frac{(2.8 \times 10^{-6})(\sin 65^\circ)}{2}$$

$$\lambda = \mathbf{1.269 \times 10^{-6} \text{ m}}$$

$$\text{Q2 } \lambda = \frac{d \sin \theta}{n} = \frac{(2.5 \times 10^{-6})(\sin 40^\circ)}{1}$$

$$= \mathbf{1.607 \times 10^{-6} \text{ m}}$$

$$\text{Q3 } d = \frac{1}{200} \text{ mm} = 0.005 \text{ mm} = \mathbf{5 \times 10^{-6} \text{ m}}$$

$$\text{Q4 } d = \frac{1}{500} \text{ mm} = 0.002 \text{ mm} = \mathbf{2 \times 10^{-6} \text{ m}}$$

$$\text{Q5 } d = \frac{1}{800} \text{ mm} = 0.00125 \text{ mm} = 1.25 \times 10^{-6} \text{ m}$$

$$n\lambda = d \sin \theta \Rightarrow \lambda = \frac{d \sin \theta}{n}$$

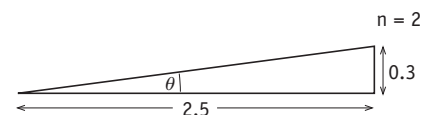
$$\therefore \lambda = \frac{(1.25 \times 10^{-6}) \sin 30^\circ}{1} = \mathbf{6.25 \times 10^{-7} \text{ m}}$$

$$\text{Q6 } d = \frac{1}{400} \text{ mm} = 0.0025 \text{ mm} = 2.5 \times 10^{-6} \text{ m}$$

$$n\lambda = d \sin \theta \Rightarrow \lambda = \frac{d \sin \theta}{n}$$

$$\therefore \lambda = \frac{(2.5 \times 10^{-6}) \sin 31^\circ}{2} = \mathbf{6.44 \times 10^{-7} \text{ m}}$$

Q7



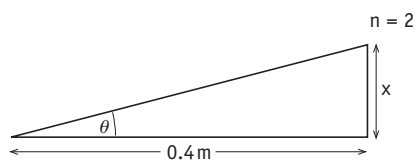
$$d = \frac{1}{200} = 5 \times 10^{-6} \text{ m}$$

$$\tan \theta = \frac{0.3}{2.5} = 0.12 \Rightarrow \sin \theta = 0.1191$$

$$\lambda = \frac{d \sin \theta}{n} \Rightarrow \lambda = \frac{(5 \times 10^{-6})(0.1191)}{2}$$

$$= \mathbf{2.978 \times 10^{-7} \text{ m}}$$

Q8



$$\lambda = 5 \times 10^{-7} \text{ m} \quad d = \frac{1}{600} = 1.667 \times 10^{-6} \text{ m}$$

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

$$\Rightarrow \sin \theta = \frac{n\lambda}{d} = \frac{(2)(5 \times 10^{-7})}{1.667 \times 10^{-6}} = 0.5999$$

$$\Rightarrow \theta = 36.86^\circ$$

$$\tan \theta = \frac{x}{0.4} \Rightarrow x = (0.4) \tan \theta$$

$$= (0.4) \tan 36.86^\circ \Rightarrow x = \mathbf{0.2999 \text{ m}}$$

$$\text{Q9} \quad d = \frac{1}{400} = 2.5 \times 10^{-6} \text{ m}$$

$$\lambda = 6.2 \times 10^{-7} \text{ m}$$

$$n = \frac{d \sin \theta}{\lambda}$$

$$n_{\max} = \frac{d}{\lambda} = \frac{2.5 \times 10^{-6}}{6.2 \times 10^{-7}} = 4.03$$

Fourth order is highest.

$$\text{Q10} \quad n_{\max} = \frac{d}{\lambda} = \frac{5 \times 10^{-6}}{6.2 \times 10^{-7}} = 8.06$$

Eight order is highest.

Exercise 18.2

Q1 No calculations required.

$$\text{Q2} \quad d = \frac{1}{5 \times 10^5} = 2 \times 10^{-6} \text{ m}$$

$$\theta = \left| \frac{\theta_R - \theta_L}{2} \right|$$

$$\theta = \frac{217.2 - 182.8}{2}$$

$$\Rightarrow \theta = 17.2^\circ$$

$$n\lambda = d \sin \theta \Rightarrow \lambda = \frac{d \sin \theta}{n}$$

$$= \frac{(2 \times 10^{-6}) \sin 17.2^\circ}{1}$$

$$\lambda = \mathbf{5.914 \times 10^{-7} \text{ m}}$$

$$\text{Q3} \quad \begin{array}{cccccc} 163^\circ 30' & 182^\circ 45' & 200 & 217^\circ 15' & 243^\circ 30' \\ 36.5^\circ & 17.25 & & 17.25 & 43.5 \end{array}$$

$$d = \frac{1}{500} \text{ mm} = \mathbf{2 \times 10^{-6} \text{ m}}$$

Both 1st order images give

$$\lambda = d \sin \theta = (2 \times 10^{-6}) \sin (17.25)$$

$$= 5.931 \times 10^{-7} \text{ m}$$

$$\text{2nd order: } \lambda = \frac{(2 \times 10^{-6}) \sin 36.5^\circ}{2}$$

$$= 5.948 \times 10^{-7} \text{ m}$$

$$\text{or } \lambda = \frac{(2 \times 10^{-6}) \sin (43.5)}{2} = 6.884 \times 10^{-7} \text{ m}$$

Average value of correct $\lambda = \mathbf{5.94 \times 10^{-7} \text{ m}}$

$6.884 \times 10^{-7} \text{ m}$ is different, therefore $243^\circ 30'$ is wrong.

Exercise 18.3

$$\text{Q1 } d = \frac{1}{400} \text{ mm} = 0.0025 \text{ mm} = 2.5 \times 10^{-6} \text{ m}$$

$$n\lambda = d \sin \theta \Rightarrow \sin \theta = \frac{n\lambda}{d}$$

$$\text{For red light: } \sin \theta = \frac{(2)(710 \times 10^{-9})}{2.5 \times 10^{-6}}$$

$$\Rightarrow \theta = 34.61^\circ$$

$$\text{For blue light: } \sin \theta = \frac{(2)(410 \times 10^{-9})}{2.5 \times 10^{-6}}$$

$$\Rightarrow \theta = 19.15^\circ$$

\therefore Angular separation

$$= 34.61 - 19.15 = \mathbf{15.46^\circ}$$

Q2 (i) Because of the bigger n factor, calculate the angle between red and violet when $n = 1$ and when $n = 3$ to see exactly.

(ii) Red has a longer λ , the bigger the λ , the bigger θ

$$\text{(iii) } n\lambda = d \sin \theta \Rightarrow \lambda = \frac{d \sin \theta}{n}$$

$$[n = 1, \lambda_{\max} = d;$$

$$n = 2, \lambda_{\max} = \frac{d}{2}]$$

(iv) $n_{\max} = \frac{d}{\lambda}$, bigger d , the more orders visible.

(v) In a grating, red is diffracted most, violet least; in the prism it is the other way around.

Exercise 19.1

$$\text{Q1 } \epsilon = \epsilon_r \epsilon_0 = (2.2)(8.9 \times 10^{-12})$$

$$= \mathbf{1.958 \times 10^{-11} \text{ F m}^{-1}}$$

$$\text{Q2 } \epsilon = \epsilon_r \epsilon_0 \Rightarrow \epsilon_r = \frac{\epsilon}{\epsilon_0} = \frac{4 \times 10^{-11}}{8.9 \times 10^{-12}} = \mathbf{4.49}$$

$$\text{Q3 } F = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r^2} = \frac{1}{4\pi(8.9 \times 10^{-12})} \frac{(1)(3)}{1^2}$$

$$= \mathbf{2.682 \times 10^{10} \text{ N}}$$

The force is the same on each

$$\text{Q4 } F = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r^2}$$

$$= \frac{1}{4\pi(8.9 \times 10^{-12})} \frac{(3 \times 10^{-6})(6 \times 10^{-6})}{(4)^2}$$

$$= \mathbf{1.0058 \times 10^{-2} \text{ N}}$$

The force is attraction since the charges have opposite sign.

$$\text{Q5 } F = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r^2}$$

$$= \frac{1}{4\pi(8.9 \times 10^{-12})} \frac{(2 \times 10^{-6})(2 \times 10^{-6})}{(0.3)^2}$$

$$= \mathbf{0.397 \text{ N}} \text{ towards the } -2\mu\text{C} \text{ charge}$$

$$\text{Q6 } F_1 = \frac{1}{4\pi\epsilon} \frac{Q_1 Q_2}{r^2}$$

$$= \frac{1}{4\pi(7.2 \times 10^{-10})} \frac{(2 \times 10^{-6})(4 \times 10^{-6})}{(0.4)^2}$$

$$= \mathbf{5.526 \times 10^{-3} \text{ N}} \text{ towards the } -4\mu\text{C} \text{ charge}$$

$$\text{Q7 } F = \frac{1}{4\pi\epsilon_0} \frac{(1.6 \times 10^{-19})(1.6 \times 10^{-19})}{(4 \times 10^{-15})^2} = \mathbf{14.306 \text{ N}}$$

$$F = \frac{GM_1 M_2}{r^2}$$

$$= \frac{(6.7 \times 10^{-11})(1.67 \times 10^{-27})(1.67 \times 10^{-27})}{(4 \times 10^{-15})^2}$$

$$= \mathbf{1.17 \times 10^{-35} \text{ N}}$$

Q8 Let the size of each charge be Q

$$F = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{d^2} \Rightarrow 0.2 = \frac{1}{4\pi(8.9 \times 10^{-12})} \frac{Q^2}{(0.02)^2}$$

$$\Rightarrow Q^2 = (0.2)(4\pi)(8.9 \times 10^{-12})(0.02)^2$$

$$= 8.9472 \times 10^{-15}$$

$$\Rightarrow Q = \sqrt{8.9472 \times 10^{-15}} = 9.4589 \times 10^{-8} \text{ C}$$

$$= \mathbf{9.46 \times 10^{-8} \text{ C}}$$

Q9 $F_1 = \frac{1}{4\pi\epsilon} \frac{Q_1 Q_2}{x^2}$

$$F_2 = \frac{1}{4\pi\epsilon} \frac{Q_1 Q_2}{(3x)^2}$$

$$= \frac{1}{4\pi\epsilon} \frac{Q_1 Q_2}{x^2} \left(\frac{1}{9}\right)$$

$$= F_1 \left(\frac{1}{9}\right)$$

i.e. F_2 is $\left(\frac{1}{9}\right)F_1$

Q10 Let the charge at C be Q coulombs

Force on $10\mu\text{C}$ due to Q = Force on $10\mu\text{C}$ due to $8\mu\text{C}$.

$$\frac{1}{4\pi\epsilon_0} \frac{(10 \times 10^{-6})Q}{(0.05)^2} = \frac{1}{4\pi\epsilon_0} \frac{(8 \times 10^{-6})(10 \times 10^{-6})}{(0.1)^2}$$

$$\Rightarrow \frac{Q}{(0.05)^2} = \frac{8 \times 10^{-6}}{(0.1)^2}$$

$$\Rightarrow Q = 2 \times 10^{-6} \text{ C} = \mathbf{+2\mu\text{C}}$$

Exercise 19.2

Q1 $E = \frac{F}{Q} = \frac{12}{4 \times 10^{-6}} = \mathbf{3 \times 10^6 \text{ N C}^{-1}}$

Q2 $F = EQ = (3 \times 10^3)(2 \times 10^{-6}) = \mathbf{6 \times 10^{-3} \text{ N}}$

Q3 $E = \frac{F}{Q} \Rightarrow Q = \frac{F}{E} = \frac{7 \times 10^{-6}}{2 \times 10^3} = 3.5 \times 10^{-9} \text{ C}$

$$= \mathbf{3.5 \text{ nC}}$$

Q4 $E = \frac{Q}{4\pi\epsilon_0 r^2} = \frac{4 \times 10^{-6}}{4\pi(8.9 \times 10^{-12})(2)^2}$

$$= \mathbf{8.94 \times 10^3 \text{ V m}^{-1}}$$

The direction is always from the $4\mu\text{C}$ charge

Q5 $E = \frac{Q}{4\pi\epsilon_0 r^2}$

(i) $\frac{20 \times 10^{-6}}{4\pi(8.9 \times 10^{-12})(0.1 \times 10^{-3})^2}$

$$= \mathbf{1.7882 \times 10^{13} \text{ N C}^{-1}}$$

(ii) $\frac{20 \times 10^{-6}}{4\pi(8.9 \times 10^{-12})(1 \times 10^{-3})^2}$

$$= \mathbf{1.7882 \times 10^{11} \text{ N C}^{-1}}$$

(iii) $\frac{20 \times 10^{-6}}{4\pi(8.9 \times 10^{-12})(10 \times 10^{-2})^2}$

$$= \mathbf{1.7882 \times 10^7 \text{ N C}^{-1}}$$

In each case the direction of E is towards the charge.

Q6 (i) $E = \frac{Q}{4\pi\epsilon_0 r^2}$

Its direction is away from the charge Q

(ii) $E = \frac{Q}{4\pi\epsilon_0 r^2}$

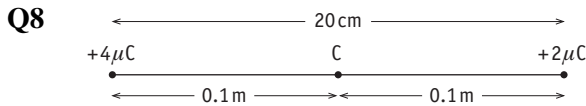
Its direction is towards the charge Q

Q7 $F = EQ = (3 \times 10^9)(1.6 \times 10^{-19})$

$$= \mathbf{4.8 \times 10^{-10} \text{ N}}$$

$$\text{Acceleration} = \frac{\text{Force}}{\text{Mass}} = \frac{F}{m} = \frac{4.8 \times 10^{-10}}{9 \times 10^{-31}}$$

$$= \mathbf{5.3333 \times 10^{20} \text{ m s}^{-2}}$$



E at

C due to $+4\mu\text{C}$

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

$$= \frac{4 \times 10^{-6}}{4\pi(8.9 \times 10^{-12})(0.1)^2}$$

$$= 3.5765 \times 10^6 \text{ N C}^{-1} \text{ to the right}$$

$$E \text{ at } C \text{ due to } +2\mu\text{C} = \frac{Q}{4\pi\epsilon_0 r^2}$$

$$= \frac{2 \times 10^{-6}}{4\pi(8.9 \times 10^{-12})(0.1)^2}$$

$$= 1.7883 \times 10^6 \text{ N C}^{-1} \text{ to the left}$$

Total field intensity at C

$$= 3.5765 \times 10^6 - 1.7883 \times 10^6$$

$$= \mathbf{1.7882 \times 10^6 \text{ N C}^{-1} \text{ towards the } +2\mu\text{C} \text{ charge}}$$

Force on $+5\mu\text{C}$, $F = E Q$

$$= (1.7882 \times 10^6)(5 \times 10^{-6})$$

$$= \mathbf{8.941 \text{ N towards the } +2\mu\text{C} \text{ charge}}$$

Q9 Electric field intensity at midpoint due to $+3\mu\text{C}$

$$= \frac{Q}{4\pi\epsilon_0 r^2} = \frac{3 \times 10^{-6}}{4\pi(8.9 \times 10^{-12})(0.2)^2}$$

$$= \mathbf{6.706 \times 10^5 \text{ N C}^{-1} \text{ towards the } -7\mu\text{C} \text{ charge}}$$

Electric field intensity at midpoint due to $-7\mu\text{C}$ charge

$$= \frac{Q}{4\pi\epsilon_0 r^2} = \frac{7 \times 10^{-6}}{4\pi(8.9 \times 10^{-12})(0.2)^2}$$

$$= 1.565 \times 10^6 \text{ N C}^{-1} \text{ towards the } -7\mu\text{C} \text{ charge}$$

Total field intensity =

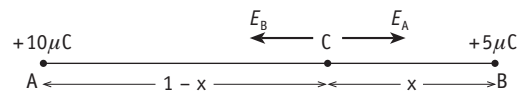
$$6.706 \times 10^5 + 1.565 \times 10^6$$

$$= 2.236 \times 10^6 \text{ N C}^{-1} \text{ towards the } -7\mu\text{C} \text{ charge}$$

$$F = EQ = (2.236 \times 10^6)(2 \times 10^{-6})$$

$$= \mathbf{4.47 \text{ N towards the } -7\mu\text{C} \text{ charge}}$$

Q10



Let C be the point at which $E = 0$

Let $x =$ distance from $+5\mu\text{C}$ at which E is zero

E at C due to $+10\mu\text{C} = E$ at C due to $+5\mu\text{C}$

i.e. $E_A = E_B$

$$\frac{1}{4\pi\epsilon_0} \frac{10 \times 10^{-6}}{(1-x)^2} = \frac{1}{4\pi\epsilon_0} \frac{5 \times 10^{-6}}{x^2}$$

$$\Rightarrow \frac{10}{(1-x)^2} = \frac{5}{x^2}$$

$$\Rightarrow \frac{(1-x)^2}{10} = \frac{x^2}{5}$$

$$(1-x)^2 = 2x^2$$

$$\therefore 1-x = \sqrt{2}x \quad \text{or} \quad \therefore 1-x = -\sqrt{2}x$$

$$1 = (1 + \sqrt{2})x$$

$$1 = x - \sqrt{2}x$$

$$\Rightarrow x = \frac{1}{1 + \sqrt{2}}$$

$$1 = x(1 - \sqrt{2})$$

$$\Rightarrow x = \frac{1}{1 - \sqrt{2}}$$

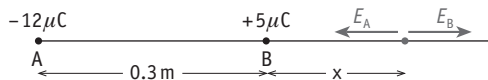
$$x = \mathbf{0.4142 \text{ m}}$$

$$x = \mathbf{-2.4}$$

Impossible

$\therefore E$ is zero at a distance of 0.4142 m from the $+5\mu\text{C}$ charge

Q11



To the right of the $+5\mu\text{C}$ the electric field strength due to $+5\mu\text{C}$ (E_B) is to the right and electric field strength E_A due to $-12\mu\text{C}$ is to the left.

Let x = distance at which these two forces cancel, i.e. $E_A = E_B$ (in magnitude)

$$\frac{12 \times 10^{-6}}{4\pi\epsilon_0(0.3+x)^2} = \frac{5 \times 10^{-6}}{4\pi\epsilon_0(x)^2} \Rightarrow \frac{12}{(0.3+x)^2} = \frac{5}{x^2}$$

$$12x^2 = 5(0.3+x)^2$$

$$\sqrt{12}x = \sqrt{5}(0.3+x)$$

$$\Rightarrow x = 0.5463$$

$$\text{or } \sqrt{12}x = -\sqrt{5}(0.3+x)$$

$$\Rightarrow x \text{ is negative; impossible}$$

$\therefore E$ is zero **0.5463 m** from the **$+5\mu\text{C}$ charge** and not between the two charges

Exercise 20.1

$$\text{Q1 } W = QV \Rightarrow v = \frac{W}{Q} = \frac{6}{2} = \mathbf{3 \text{ V}}$$

$$\text{Q2 } W = QV \Rightarrow v = \frac{W}{Q} = \frac{6 \times 10^{-5}}{6 \times 10^{-6}} = \mathbf{10 \text{ V}}$$

$$\text{Q3 } W = QV = (4)(20) = \mathbf{80 \text{ J}}$$

$$\text{Q4 } W = QV = (8 \times 10^{-6})(12) = \mathbf{9.6 \times 10^{-5} \text{ J}}$$

$$\text{Q5 } W = QV \Rightarrow v = \frac{W}{Q} = \frac{4.8 \times 10^{-16}}{1.6 \times 10^{-19}} = \mathbf{3000 \text{ V}}$$

$$\begin{aligned} \text{Q6 (i) } W &= QV = (1.6 \times 10^{-19})(1) \\ &= \mathbf{1.6 \times 10^{-19} \text{ J}} \end{aligned}$$

$$\begin{aligned} \text{(ii) } W &= QV = (1.6 \times 10^{-19})(300) \\ &= \mathbf{4.8 \times 10^{-17} \text{ J}} \end{aligned}$$

$$\begin{aligned} \text{Q7 Work} &= \text{Force} \times \text{Distance} \\ E &= \text{Force on 1 C} = 2 \times 10^4 \text{ N} \end{aligned}$$

Work done in bringing 1 C from one plate to the other.

$$\begin{aligned} W &= (\text{Force on 1 C})(\text{Distance between plates}) \\ &= (2 \times 10^4)(0.2) = \mathbf{4000 \text{ J}} \end{aligned}$$

Work done in bringing 1 C from one plate to the other = p.d. between plates.

$$\Rightarrow \text{p.d.} = \mathbf{4000 \text{ V}}$$

- Q8** (i) p.d. between plates = 400 V
 \Rightarrow 400 J done in bringing +1 C from one plate to the other.

$$W = Fs \Rightarrow 400 = (F)(2 \times 10^{-2})$$

$$\Rightarrow F = \mathbf{20\,000\,N}$$

- (ii) E is the force on +1 C \Rightarrow
 $E = \mathbf{20\,000\,N\,C^{-1}}$

(iii) $F = EQ = (2 \times 10^4)(1.6 \times 10^{-19})$
 $= \mathbf{3.2 \times 10^{-15}\,N}$

(iv) $W = QV = (1.6 \times 10^{-19})(400)$
 $= \mathbf{6.4 \times 10^{-17}\,J}$

- (v) Since kinetic energy gained = potential energy lost.

$$E_k = \mathbf{6.4 \times 10^{-17}\,J}$$

(vi) $\frac{1}{2}mv^2 = 6.4 \times 10^{-17}$
 $\Rightarrow \frac{1}{2}(9.1 \times 10^{-31})v^2 = 6.4 \times 10^{-17}$
 $\Rightarrow v = \mathbf{1.19 \times 10^7\,m\,s^{-1}}$

Exercise 20.2

Q1 $C = \frac{Q}{V} = \frac{2 \times 10^{-6}}{1 \times 10^4} = \mathbf{2 \times 10^{-10}\,F}$

Q2 $C = \frac{Q}{V} = \frac{4 \times 10^{-6}}{12} = \mathbf{3.333 \times 10^{-7}\,F}$

Q3 $C = \frac{Q}{V} \Rightarrow Q = CV = (8 \times 10^{-12})(1\,000\,000)$
 $= 8 \times 10^{-6}\,C = \mathbf{8\,\mu C}$

Q4 $C = \frac{Q}{V} \Rightarrow Q = CV$
 $= (2 \times 10^{-11})(300 \times 10^3)$
 $= 6 \times 10^{-6}\,C = \mathbf{6\,\mu C}$

Q5 $C = \frac{Q}{V} \Rightarrow V = \frac{Q}{C} = \frac{4 \times 10^{-6}}{3 \times 10^{12}} = \mathbf{1.33 \times 10^6\,V}$

Q7 $C = \frac{Q}{V} = \frac{5 \times 10^{-6}}{12} = \mathbf{4.167 \times 10^{-7}\,F}$

Q8 $C = \frac{Q}{V} \Rightarrow Q = CV = (50 \times 10^{-6})(100)$
 $= \mathbf{5 \times 10^{-3}\,C}$

Exercise 20.3

$$\text{Q1 } C = \frac{\epsilon_0 A}{d} = \frac{(8.9 \times 10^{-12})(0.02)}{(0.001)} = \mathbf{1.78 \times 10^{-10} \text{ F}}$$

$$\text{Q2 } C = \frac{\epsilon_0 A}{d} = \frac{(8.9 \times 10^{-12})(150 \times 10^{-4})}{(1 \times 10^{-3})}$$

$$= \mathbf{1.335 \times 10^{-10} \text{ F}}$$

$$\text{Q3 } C = \frac{\epsilon_0 A}{d} \Rightarrow A = \frac{Cd}{\epsilon_0} = \frac{(1)(1 \times 10^{-3})}{(8.9 \times 10^{-12})}$$

$$= \mathbf{1.1235 \times 10^8 \text{ m}^2}$$

$$\text{Q4 } C = \frac{\epsilon_0 A}{d} = \frac{(8.9 \times 10^{-12})(100 \times 10^{-4})}{(2 \times 10^{-3})}$$

$$= \mathbf{4.45 \times 10^{-11} \text{ F}}$$

With perspex dielectric $\epsilon_r = 2.6$

$$C = (2.6)(4.45 \times 10^{-11}) = \mathbf{1.157 \times 10^{-10} \text{ F}}$$

$$\text{Q5 } C = \frac{\epsilon A}{d} = \frac{(7)(8.9 \times 10^{-12})(25 \times 10^{-4})}{(1 \times 10^{-3})}$$

$$\Rightarrow C = 1.5575 \times 10^{-10} \text{ F}$$

$$Q = CV = (1.5575 \times 10^{-10})(500)$$

$$= \mathbf{7.79 \times 10^{-8} \text{ C}}$$

$$\text{Q6 } W = \frac{1}{2}CV^2 = \frac{1}{2}(6 \times 10^{-3})(200)^2 = \mathbf{120 \text{ J}}$$

$$\text{Q7 } C = \frac{Q}{V} \Rightarrow V = \frac{Q}{C} = \frac{4 \times 10^{-6}}{2 \times 10^{-6}} = 2 \text{ V}$$

$$W = \frac{1}{2}CV^2 = \frac{1}{2}(2 \times 10^{-6})(2)^2 = \mathbf{4 \times 10^{-6} \text{ J}}$$

$$\text{Q8 } W = \frac{1}{2}CV^2 = \frac{1}{2}(4.6 \times 10^{-6})(8)^2 = \mathbf{1.472 \times 10^{-4} \text{ J}}$$

$$\text{Q9 } W = \frac{1}{2}QV = \frac{1}{2}(7 \times 10^{-6})(30) = \mathbf{1.05 \times 10^{-4} \text{ J}}$$

$$\text{Q10 } W = \frac{1}{2}CV^2 \Rightarrow W = \frac{1}{2}\left(\frac{Q^2}{C}\right)$$

$$\Rightarrow 23 \times 10^{-3} = \frac{(0.5)(Q^2)}{2.4 \times 10^{-6}}$$

$$\Rightarrow Q = \mathbf{3.32 \times 10^{-4} \text{ C}}$$

$$\text{Q11 } W = \frac{1}{2}CV^2 \Rightarrow (0.01) = \frac{1}{2}(C)(12)^2$$

$$\Rightarrow C = \mathbf{1.39 \times 10^{-4} \text{ F}}$$

Q12 P.d. across each is **40 V**

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

$$Q = (8 \times 10^{-6})(40) = \mathbf{3.2 \times 10^{-4} \text{ C}}$$

$$Q = (4 \times 10^{-6})(40) = \mathbf{1.6 \times 10^{-4} \text{ C}}$$

Q13 $V_1 + V_2 = 40$ and $V = \frac{Q}{C}$

$$\Rightarrow \frac{Q}{8 \times 10^{-6}} + \frac{Q}{4 \times 10^{-6}} = 40$$

$$\Rightarrow Q(375\,000) = 40 \Rightarrow Q = \mathbf{1.067 \times 10^{-4} \text{ C}}$$

$$V_1 = \frac{Q}{C} = \frac{1.067 \times 10^{-4}}{8 \times 10^{-6}} = \mathbf{13.33 \text{ V}}$$

$$V_2 = \frac{Q}{C} = \frac{1.067 \times 10^{-4}}{4 \times 10^{-6}} = \mathbf{26.67 \text{ V}}$$

Q14 (i) P.d. across the resistor:

$$V = IR = (0.2 \times 10^{-3})(20 \times 10^3) = 4 \text{ V}$$

$$\Rightarrow \text{p.d. across capacitor} = 40 - 4 = \mathbf{36 \text{ V}}$$

$$\text{(ii) } C = \frac{Q}{V} \Rightarrow Q = CV = (60 \times 10^{-6})(36)$$

$$= \mathbf{2.16 \times 10^{-3} \text{ C}}$$

(iii) Work done = Energy stored

$$W = \frac{1}{2}\left(\frac{Q^2}{C}\right) = \frac{(0.5)(2 \times 10^{-6})^2}{(60 \times 10^{-6})}$$

$$= \mathbf{3.33 \times 10^{-8} \text{ J}}$$

Exercise 21.1

Q1 (i) $1 \text{ mA} = 1 \times 10^{-3} \text{ A}$

(ii) $0.05 \text{ mA} = 0.05 \times 10^{-3} = 5 \times 10^{-5} \text{ A}$

(iii) $50 \mu\text{A} = 50 \times 10^{-6} \text{ A} = 5 \times 10^{-5} \text{ A}$

(iv) $1000 \text{ mA} = 1 \text{ A}$

(v) $0.2 \mu\text{A} = 0.2 \times 10^{-6} = 2 \times 10^{-7} \text{ A}$

Q2 (i) $1 \text{ A} = 1000 \text{ mA}$

(ii) $100 \text{ A} = 100 \times 10^3 \text{ mA} = 10^5 \text{ mA}$

(iii) $0.025 \text{ A} = 0.025 \times 10^3 = 25 \text{ mA}$

(iv) $1 \mu\text{A} = 1 \times 10^{-3} \text{ mA}$

(v) $0.0006 \text{ A} = 0.0006 \times 10^3 \text{ mA} = 0.6 \text{ mA}$

Q3 (i) $10 = 7 + x \Rightarrow x = 3 \text{ A}$

(ii) $2 + 3 = 1 + x \Rightarrow x = 4 \text{ A}$

(iii) $x + 8 + 2 = 9 + 3 \Rightarrow x = 2 \text{ A}$

(iv) $x + x + 4 = 2 + 3 + 5 \Rightarrow x = 3 \text{ A}$

Q4 (i) $Q = It = (3)(1) = 3 \text{ C}$

(ii) $Q = It = (3)(60) = 180 \text{ C}$

(iii) $Q = It = (30)(60)(60) = 10\,800 \text{ C}$

Q5 (i) $I = \frac{Q}{t} = \frac{10}{10} = 1 \text{ A}$

(ii) $I = \frac{Q}{t} = \frac{1}{60} = 0.01667 \text{ A}$

(iii) $I = \frac{Q}{t} = \frac{10}{1} = 10 \text{ A}$

Q6 $Q = It = (6)(4)(60)(60) = 86\,400 \text{ C}$

Q7 Number of electrons = $\frac{1 \text{ coulomb}}{\text{Charge on one electron}}$
 $\frac{1}{1.6 \times 10^{-19}} = 6.25 \times 10^{18} \text{ electrons}$

Q8 $Q = It = (20)(6) = 120 \text{ C}$

1 C has 6.25×10^{18} electrons

$\Rightarrow 120 \text{ C has } (120)(6.25 \times 10^{18})$

$= 7.5 \times 10^{20} \text{ electrons}$

Q9 Charge gone past

= (Nr. of electrons)(charge on one electron)

= $(2 \times 10^{20})(1.6 \times 10^{-19}) = 32 \text{ C}$

$I = \frac{Q}{t} = \frac{32}{1} = 32 \text{ A}$

Q10 $Q = It \Rightarrow t = \frac{Q}{I} = \frac{36000}{5} = 7200 \text{ s}$

Q11 Charge hitting screen in one hour

= $Q = It = (1 \times 10^{-3})(60)(60) = 3.6 \text{ C}$

Number of electrons = $\frac{\text{Charge}}{\text{Charge on one electron}}$

= $\frac{3.6}{1.6 \times 10^{-19}} = 2.25 \times 10^{19} \text{ electrons}$

Q12 No calculations required.

Exercise 22.1

- Q1** Total emf = Sum of individual emfs
 $= 4 + 6 + 3 = 13 \text{ V}$
- Q2** (a) $W = QV = (1)(10) = 10 \text{ J}$
 (b) $W = QV = (6)(10) = 60 \text{ J}$
 (c) $W = QV = (1 \times 10^{-6})(10) = 1 \times 10^{-5} \text{ J}$
- Q3** $W = QV \Rightarrow V = \frac{W}{Q} = \frac{200}{50} = 4 \text{ V}$
- Q4** $W = QV = (20)(60) = 1200 \text{ J}$
- Q5** $W = QV \Rightarrow V = \frac{W}{Q} = \frac{4000}{80} = 50 \text{ V}$
- Q6** $P = VI \Rightarrow I = \frac{P}{V} = \frac{100}{230} = 0.435 \text{ A}$
- Q7** $P = VI = (12)(6.67) = 80 \text{ W}$
- Q8** (i) $P = VI = (220)(4) = 880 \text{ W}$
 (ii) $W = Pt = (880)(1)(60)(60)$
 $= 316800 \text{ J} = 3.168 \text{ MJ}$
- Q9** $P = VI \Rightarrow I = \frac{P}{V} = \frac{100}{230} = 0.435 \text{ A}$
- Q10** Total power = $(50)(5) = 250 \text{ W}$
 $I = \frac{P}{V} = \frac{250}{220} = 1.136 \text{ A}$
- Q11** (i) $P = VI = (10)(5) = 50 \text{ W}$
 Energy = Power \times time = $(50)(5)(60)$
 $= 15000 \text{ J} = 15 \text{ kJ}$
 (ii) $W = QV = (1)(10) = 10 \text{ J}$
- Q12** Total emf = $2 + 3 + 12 = 17 \text{ V}$
 $P = VI = (17)(2) = 34 \text{ W}$
- Q13** $V_1 = 6 \Rightarrow V_2 = 20 - 6 = 14 \text{ V}$
 Power in bulb 2, $P = VI = (3)(14) = 42 \text{ W}$
 Energy = Power \times Time = $(42)(2)(60)(60)$
 $= 302400 \text{ J} = 3.024 \times 10^5 \text{ J}$
- Q14** No calculations required.
- Q15** Since both bulbs are identical and current is everywhere the same in a series circuit, they shine equally brightly.

Exercise 23.1

- Q1** $R = \frac{V}{I} = \frac{20}{4} = 5 \Omega$
- Q2** $V = IR = (5)(12) = 60 \text{ V}$
- Q3** $I = \frac{V}{R} = \frac{230}{10} = 2.3 \text{ A}$
- Q4** $R = \frac{V}{I} = \frac{12}{4} = 3 \Omega$
- Q5** $V = IR = (5)(6) = 30 \text{ V}$
- Q6** $R = \frac{V}{I} = \frac{24}{3} = 8 \Omega$
 $R = \frac{V}{I} = \frac{24}{2} = 12 \Omega$
 \therefore Increase in resistance = $12 - 8 = 4 \Omega$
- Q7** $R = \frac{V}{I} = \frac{10}{2} = 5 \Omega$
- Q8** $R = R_1 + R_2 = 2 + 3 = 5 \Omega$
 $I = \frac{V}{R} = \frac{12}{2} = 6 \text{ A}$
 $V = IR = (6)(5) = 30 \text{ V}$
- Q9** $R = \frac{V}{I} = \frac{10}{1} = 10 \Omega$
 \therefore Resistance of bulb = $10 - 4 = 6 \Omega$
- Q10** $V_1 = IR_1 = (5)(2) = 10 \text{ V}$
 $V_2 = IR_2 = (5)(4) = 20 \text{ V}$
 $V_3 = IR_3 = (5)(8) = 40 \text{ V}$
 Total $V = V_1 + V_2 + V_3 = 70 \text{ V}$
- Q11** (a) $\frac{1}{R} = \frac{1}{4} + \frac{1}{4} \Rightarrow R = 2 \Omega$
 (b) $\frac{1}{R} = \frac{1}{4} + \frac{1}{1} \Rightarrow R = 0.8 \Omega$
 (c) $\frac{1}{R} = \frac{1}{30} + \frac{1}{30} + \frac{1}{30} \Rightarrow R = 10 \Omega$
 (d) $\frac{1}{R} = \frac{1}{30} + \frac{1}{60} + \frac{1}{90} \Rightarrow R = 16.36 \Omega$
 (e) $\frac{1}{R} = \frac{1}{8} + \frac{1}{8} \Rightarrow R = 4 \Omega$
 (f) $\frac{1}{R_p} = \frac{1}{2} + \frac{1}{4} \Rightarrow R_p = 1.33 \Omega$
 $R = 1.33 + 6 = 7.33 \Omega$
- Q12** (i) $\frac{1}{R} = \frac{1}{20} + \frac{1}{20} \Rightarrow R = 10 \Omega$
 (ii) $R = R_1 + R_2 = 20 + 20 = 40 \Omega$
 (iii) $\frac{1}{R} = \frac{1}{2} + \frac{1}{3} \Rightarrow R = 1.2 \Omega$

Q13 $\frac{1}{R_p} = \frac{1}{2} + \frac{1}{3} \Rightarrow R_p = 1.2 \Omega$

Total resistance = $1.2 + 4 = 5.2 \Omega$

Current in 4Ω resistor:

$$I = \frac{V}{R} = \frac{20}{5.2} = \mathbf{3.846 \text{ A}}$$

P.d. across 4Ω resistor:

$$V = IR = (3.846)(4) = 15.38 \text{ V}$$

\Rightarrow p.d. across parallel combination

$$= 20 - 15.38 = 4.615 \text{ V}$$

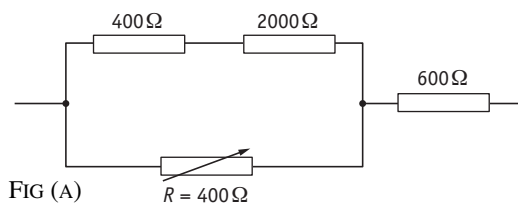
Current in 2Ω resistor:

$$I_1 = \frac{V}{R} = \frac{4.615}{2} = \mathbf{2.31 \text{ A}}$$

Current in 3Ω resistor:

$$I_2 = \frac{V}{R} = \frac{4.615}{3} = \mathbf{1.538 \text{ A}}$$

Q14 FIG (A) shows the circuit in a more intuitive manner:



(i) Resistance of parallel combination:

$$\frac{1}{R_p} = \frac{1}{400} + \frac{1}{2400} \Rightarrow R_p = 342.9 \Omega$$

$$\begin{aligned} \text{Total resistance} &= 600 + 342.9 \\ &= \mathbf{942.9 \Omega} \end{aligned}$$

(ii) Current from battery,

$$I = \frac{V}{R} = \frac{10}{942.9} = 0.01061 \text{ A}$$

P.d. across 600Ω resistor = IR

$$= (0.01061)(600) = 6.36 \text{ V}$$

\therefore p.d. across parallel combination

$$= 10 - 6.36 = 3.64 \text{ V}$$

\therefore Current in $2 \text{ k}\Omega$ resistor,

$$I = \frac{V}{R} = \frac{3.64}{2400} = \mathbf{0.0015 \text{ A}}$$

(i) If R is reduced, total resistance of circuit decreases, therefore current in the 600Ω resistor increases

(ii) Current in 600Ω resistor increases
 \Rightarrow p.d. across it increases,
 \Rightarrow the potential at A decreases.

(iii) p.d. across the parallel combination has decreased,
 \Rightarrow current through $2 \text{ k}\Omega$ resistor decreases.

Exercise 23.2

$$\begin{aligned} \text{Q1 } A &= \pi r^2 = \pi \left(\frac{d}{2}\right)^2 = \pi \left(\frac{0.22 \times 10^{-2}}{2}\right)^2 \\ &= 3.80 \times 10^{-8} \text{ m}^2 \\ \rho &= \frac{RA}{l} = \frac{(28.2)(3.8 \times 10^{-8})}{(0.892)} = \mathbf{1.2 \times 10^{-6} \Omega \text{ m}} \end{aligned}$$

$$\begin{aligned} \text{Q2 } \rho &= \frac{R\pi d^2}{4l} = \frac{(27.9)\pi(0.22 \times 10^{-3})^2}{(4)(0.856)} \\ &= \mathbf{1.24 \times 10^{-6} \Omega \text{ m}} \end{aligned}$$

$$\begin{aligned} \text{Q3 } R &= \frac{\rho l}{A} \Rightarrow l = \frac{RA}{\rho} \\ \therefore l &= \frac{(4)(0.16 \times 10^{-6})}{4.2 \times 10^{-7}} = \mathbf{1.524 \text{ m}} \end{aligned}$$

$$\begin{aligned} \text{Q4 } R &= \frac{\rho l}{A} \Rightarrow l = \frac{RA}{\rho} \\ \therefore l &= \frac{(12)\pi(0.25 \times 10^{-3})^2}{1.7 \times 10^{-8}} = \mathbf{138.6 \text{ m}} \end{aligned}$$

Q5 No calculations required.

$$\text{Q6 } \rho = \frac{R\pi d^2}{4l} \Rightarrow 1.2 \times 10^{-6} = \frac{(400)\pi d^2}{(4)(1.5)}$$

$$\Rightarrow d = \sqrt{\frac{(4)(1.5)(1.2 \times 10^{-6})}{(400)(\pi)}}$$

$$= \mathbf{7.569 \times 10^{-5} \text{ m}}$$

$$\begin{aligned} \text{Q7 } \rho &= \frac{R\pi d^2}{4l} \Rightarrow d = \sqrt{\frac{4\rho l}{\pi R}} \\ &= \sqrt{\frac{(1.3 \times 10^{-6})(4)(1.3)}{(20)(\pi)}} = \mathbf{3.28 \times 10^{-4} \text{ m}} \end{aligned}$$

Q8 $R \propto l$ and l is 6 times bigger

$\Rightarrow R$ is 6 times bigger

$$\Rightarrow R = (6)(4) = \mathbf{24 \Omega}$$

$R \propto l$ and R is 10 times bigger

$\Rightarrow l$ is 10 times bigger

$$\Rightarrow l = (10)(1.2) = \mathbf{12 \text{ m}}$$

Q9 $R \propto \frac{l}{A}$ and A is 4 times bigger

$\Rightarrow R$ is 4 times smaller

$$\Rightarrow R = \frac{2.6}{4} = \mathbf{0.65 \Omega}$$

If the resistance of the wire is to again be six ohms (i.e. four times bigger), the length must be **four times longer**.

Q10 $\rho = \frac{RA}{l}$ and $A = \pi r^2 = \pi \left(\frac{d}{2}\right)^2$

$$\Rightarrow \rho = \frac{(R)\left(\pi\left(\frac{d}{2}\right)^2\right)}{l} = \frac{R\pi d^2}{4l}$$

Q11 Length halved \Rightarrow Resistance is halved to 5Ω

Cross-sectional area doubled \Rightarrow Resistance is again halved to $\mathbf{2.5 \Omega}$

Q12 Average diameter = $\mathbf{0.424 \text{ mm}}$

$$\begin{aligned} \rho &= \frac{R\pi d^2}{4l} = \frac{(6)\pi(0.424 \times 10^{-3})^2}{(4)(0.784)} \\ &= \mathbf{1.08 \times 10^{-6} \Omega \text{ m}} \end{aligned}$$

Exercise 23.3

$$\text{Q1 } \frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow \frac{4}{6} = \frac{15}{R_4} \Rightarrow R_4 = 22.5 \Omega$$

$$\text{Q2 } \frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow \frac{10}{20} = \frac{R_3}{60} \Rightarrow R_3 = 30 \Omega$$

$$\text{Q3 } \frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow \frac{10R_2}{R_2} = \frac{4}{R_4} \Rightarrow R_4 = 0.4 \Omega$$

$$\text{Q4 (i) } \frac{R_1}{R_2} = \frac{R_3}{R_4} \text{ becomes } \frac{2R_1}{X} = \frac{R_3}{R_4}$$

$$\Rightarrow \frac{2R_1}{X} = \frac{R_1}{R_2} \Rightarrow X = 2 R_2$$

i.e. R_2 must be doubled

- (ii) The left hand side of $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ is doubled so if R_4 is halved the right hand side of the ratio is also doubled, and the bridge is balanced. Thus half the value of R_4

Exercise 24.1

$$\text{Q1 } W = I^2 R t = (5^2)(20)(3) = 1500 \text{ J}$$

$$\text{Q2 } W = I^2 R t$$

$$= ((12 \times 10^{-3})^2)(1 \times 10^3)(4 \times 60)$$

$$= 34.56 \text{ J}$$

$$\text{Q3 } W = I^2 R t = ((0.5)^2)(400)(60 \times 60)$$

$$= 360\,000 \text{ J}$$

$$\text{Q4 (i) } P = I^2 R = (1)^2(10) = 10 \text{ J}$$

$$\text{(ii) } P = I^2 R = (2)^2(10) = 40 \text{ J}$$

$$\text{(iii) } P = I^2 R = (3)^2(10) = 90 \text{ J}$$

$$\text{(iv) } P = I^2 R = (4)^2(10) = 160 \text{ J}$$

$$\text{Q5 (i) } P = I^2 R = (2)^2(1) = 4 \text{ J}$$

$$\text{(ii) } P = I^2 R = (2)^2(2) = 8 \text{ J}$$

$$\text{(iii) } P = I^2 R = (2)^2(10) = 40 \text{ J}$$

$$\text{(iv) } P = I^2 R = (2)^2(100) = 400 \text{ J}$$

$$\text{Q6 } P = I^2 R = (6)^2(40) = 1440 \text{ J}$$

$$\text{Energy} = \text{Power} \times \text{time}$$

$$= (1440)(60)(60) = 5\,184\,000 \text{ J}$$

$$\text{Q7 } P = I^2 R \Rightarrow 100 = (0.5)^2 R$$

$$\Rightarrow R = \frac{100}{0.25} = 400 \Omega$$

$$\text{Q8 } P = I^2 R \Rightarrow 3 \times 10^3 = (10)^2 R$$

$$\Rightarrow R = \frac{3 \times 10^3}{100} = 30 \Omega$$

$$\text{Q9 (a) } P = VI \Rightarrow I = \frac{P}{V} = \frac{2 \times 10^3}{230} = 8.7 \text{ A}$$

$$\text{(b) } P = I^2 R \Rightarrow R = \frac{P}{I^2} = \frac{2 \times 10^3}{(8.7)^2}$$

$$= 26.42 \Omega$$

$$\text{(c) } P = \frac{W}{t} \Rightarrow t = \frac{W}{P} = \frac{100 \times 10^6}{2000}$$

$$= 50\,000 \text{ s}$$

$$\text{Q10 } I = \frac{V}{R} = \frac{230}{40} = 5.75 \text{ A}$$

$$W = I^2 R t = (5.75)^2(40)(30) = 39\,675 \text{ J}$$

$$Q = It = (5.75)(30) = 172.5 \text{ C}$$

Q11 $P \propto I^2$ \therefore if the current doubles the power is four times greater.

OR

$$\text{Suppose } P_1 = R I_1^2$$

Now let current increase to $2I_1$

$$\therefore \text{ New power } P_2 = R(2I_1)^2 = 4 R I_1^2$$

$$\text{i.e. } P_2 = 4P_1$$

Q12 Energy supplied to the water:

$$Q = m c \Delta\theta = (500)(4180)(40)$$

$$= 8.36 \times 10^7 \text{ J}$$

= 80% of the electrical energy supplied

$$\Rightarrow \text{electrical energy supplied} = 1.045 \times 10^8 \text{ J}$$

$$W = I^2 R t$$

$$\Rightarrow 1.045 \times 10^8 = (20)^2 R(5)(60)(60)$$

$$\Rightarrow R = \mathbf{14.5 \Omega}$$

Q13 Power $P = VI = (230)(9) = 2070 \text{ W}$

Electrical energy needed:

$$Q = m c \Delta\theta = (2)(4180)(90) = 752\,400 \text{ J}$$

$$\text{Time} = \frac{\text{Energy}}{\text{Power}} = \frac{752400}{2070} = 363.5 \text{ s}$$

Energy needed to boil off 3/4 of the water

$$= (\text{Mass})(\text{Specific latent heat of vaporisation})$$

$$= m l$$

$$= (0.75)(2)(2.3 \times 10^6) = 3.45 \times 10^6 \text{ J}$$

$$\text{Time} = \frac{\text{Energy}}{\text{Power}} = \frac{3.45 \times 10^6}{2070} = \mathbf{1666.7 \text{ s}}$$

Exercise 24.2

$$\text{Q1 } P = VI \Rightarrow I = \frac{P}{V} = \frac{1000}{230} = 4.35 \text{ A}$$

\Rightarrow **The 13 A fuse is suitable.**

$$\text{Q2 Total power} = (2)(500) + 1000 + 2000 = 5000 \text{ W}$$

$$I = \frac{P}{V} = \frac{5000}{230} = 21.73 \text{ A}$$

\Rightarrow **The 30 A fuse is suitable.**

$$\text{Q3 (Nr. of kW h)} = (\text{Power in kW})(\text{Time in h}) = (2)(3) = \mathbf{6 \text{ kW h}}$$

$$\text{Q4 (Nr. of kW h)} = (\text{Power in kW})(\text{Time in h}) = (0.075)\left(\frac{40}{60}\right) = \mathbf{0.05 \text{ kW h}}$$

Exercise 27.1

- Q1** No calculations required.
- Q2** $F = BIL$
 $2 = B(3)(0.5) \Rightarrow B = \frac{2}{(3)(0.5)} = 1.33 \text{ T}$
- Q3** $F = BIL = (2.5)(4)(2) = 20 \text{ N}$
 \perp to both B and wire
- Q4** $F = BIL \Rightarrow B = \frac{F}{IL} = \frac{4}{3(1)} = \frac{4}{3} \text{ T}$
- Q5** No calculations required.
- Q6** No calculations required.
- Q7** No calculations required.
- Q8** $F = BIL = (0.4)(10)(0.3) = 1.2 \text{ N}$;
 $M = Fd = (1.2)(0.08) = 0.096 \text{ N m}$;
 Because \perp distance to axis decreases; yes;
 $(1.2)(0.16) = 0.192 \text{ N m}$
- Q9** $F = B_{\perp}IL = (2)(\sin 30)(3)(3) = 9 \text{ N}$
 zero degrees, i.e. when wire is parallel to magnetic field
- Q10** Parallel component = $3 \cos 60 = 1.5 \text{ T}$
 \perp component = $3 \sin 60 = 2.6 \text{ T}$
 The \perp component causes the force on the wire
 $F = (3 \sin 60)(2.5)(0.5) = 3.25 \text{ N}$
 perpendicular to wire and to the magnetic field.

Exercise 27.2

- Q1** $F = qvB = (2)(10)(2) = 40 \text{ N}$
- Q2** $F = qvB = (3 \times 10^{-6})(200)(4) = 2.4 \times 10^{-3} \text{ N}$
- Q3** $F = qvB = (1.6 \times 10^{-19})(6 \times 10^7)(4)$
 $= 3.84 \times 10^{-4} \text{ N}$
- Q4** $F = qvB \Rightarrow 2 \times 10^{-18} = (1.6 \times 10^{-19})(v)(2)$
 $\Rightarrow v = \frac{2 \times 10^{-18}}{(2)(1.6 \times 10^{-19})} = 6.25 \text{ m s}^{-1}$
- Q5** No calculations required.
- Q6** Force on moving charge = centripetal force
 $qvB = \frac{mv^2}{r}$
 $(1.6 \times 10^{-19})(2 \times 10^7)(0.03)$
 $= \frac{(1.67 \times 10^{-27})(2 \times 10^7)^2}{r}$
 $r = \frac{(1.67 \times 10^{-27})(2 \times 10^7)^2}{(1.67 \times 10^{-19})(2 \times 10^7)(0.03)} = 6.9583 \text{ m}$
- Q7** $r = \frac{mv^2}{qvB} = \frac{(9.1 \times 10^{-31})(2000)^2}{(1.6 \times 10^{-19})(2000)(3 \times 10^{-2})}$
 $= 3.7916 \times 10^{-7} \text{ m}$
- Q8** $\frac{mv^2}{r} = qvB \Rightarrow v = \frac{qBr}{m}$
 $v = \frac{(1.6 \times 10^{-19})(2 \times 10^{-3})(10 \times 10^{-2})}{(9.1 \times 10^{-31})}$
 $= 3.52 \times 10^7 \text{ m s}^{-1}$
- Q9** Time for one resolution = $\frac{\text{Distance}}{\text{Speed}} = \frac{2\pi r}{v} = T$
 $\frac{mv^2}{r} = Bev \Rightarrow \frac{v}{r} = \frac{Be}{m}$
 $\therefore T = 2\pi \left(\frac{r}{v}\right) = 2\pi \left(\frac{m}{Be}\right)$ i.e. $T = \frac{2\pi m}{Be}$
- Q10** (i) Number passing per second
 $= (0.1)(104) = 10.4 \text{ particles}$
 (ii) $(10.4)(2 \times 10^{-6}) = 2.08 \times 10^{-5} \text{ C}$
 (iii) $2.08 \times 10^{-5} \text{ A}$
- Q11** $I =$ charge passing per second
 $= \left(\frac{0.02}{100}\right) \times (10^{12}) \times (1.6 \times 10^{-19})$
 $= 3.2 \times 10^{-11} \text{ A}$

Exercise 28.1

$$\text{Q1 } \Phi = BA = (2)(0.3) = \mathbf{0.6 \text{ Wb}}$$

$$\text{Q2 } \Phi = BA \Rightarrow A = \frac{\Phi}{B} = \frac{0.4}{0.5} = \mathbf{0.8 \text{ m}^2}$$

$$\text{Q3 } \Phi = BA = (2)(100 \times 10^{-4}) = \mathbf{0.02 \text{ Wb}}$$

$$(1\text{m}^2 = 10^4\text{cm}^2 \Rightarrow 1\text{cm}^2 = 10^{-4}\text{m}^2)$$

$$\text{Q4 } \Phi = BA \Rightarrow B = \frac{\Phi}{A} = \left(\frac{2 \times 10^{-2}}{200 \times 10^{-4}} \right) = \mathbf{1 \text{ T}}$$

$$\text{Q5 } \Phi = BA \Rightarrow A = \frac{\Phi}{B} = \frac{2 \times 10^{-2}}{3 \times 10^{-3}} = 6.667 \text{ m}^2$$

$$A = \pi r^2 \Rightarrow r = \sqrt{\frac{A}{\pi}} = \sqrt{\frac{6.667}{\pi}} = \mathbf{1.46 \text{ m}}$$

$$\text{Q6 Change in } \Phi = \text{final } \Phi - \text{initial } \Phi$$

$$= (BA)_{\text{final}} - (BA)_{\text{initial}}$$

$$= (2.4)(10 \times 6 \times 10^{-4}) - (1.2)(10 \times 6 \times 10^{-4})$$

$$= 0.0144 - 0.0072$$

$$= \mathbf{7.2 \times 10^{-3} \text{ Wb}}$$

$$\text{Q7 } \Phi = B_{\perp}A = (4 \sin 30^\circ)(0.2) = \mathbf{0.4 \text{ Wb}}$$

$$\text{Q8 Comp of } B \text{ perpendicular to plane of coil}$$

$$= B \sin 40^\circ$$

$$= (2.5 \times 10^{-3})(\sin 40^\circ)$$

$$\Phi = B_{\perp}A$$

$$= (2.5 \times 10^{-3})(\sin 40^\circ)(\pi(20 \times 10^{-2})^2)$$

$$= \mathbf{2.02 \times 10^{-4} \text{ Wb}}$$

Exercise 28.2

$$\text{Q1 } E = \left(\frac{\text{final } \Phi - \text{initial } \Phi}{\text{time}} \right) = \frac{5-1}{2} = \mathbf{2 \text{ V}}$$

$$\text{Q2 } E = \left(\frac{\text{final } \Phi - \text{initial } \Phi}{\text{time taken}} \right) = \frac{0-0.4}{0.2} = \mathbf{-2 \text{ V}}$$

$$\text{Total induced emf} = (200)(2) = \mathbf{400 \text{ V}}$$

$$\text{Q3 } E = N \frac{d\Phi}{dt} = (600) \left(\frac{2.4-0}{0.6} \right) = \mathbf{2400 \text{ V}}$$

$$\text{Q4 } E = N \frac{d\Phi}{dt} = (200) \left(\frac{4-2}{0.3} \right) = \mathbf{1333.3 \text{ V}}$$

$$I = \frac{E}{R} = \frac{1333.3}{4} = \mathbf{333.3 \text{ A}}$$

$$\text{Q5 Change in flux} = \text{final } \Phi - \text{initial } \Phi$$

$$= [2.4][10 \times 6 \times 10^{-4}] - [1.2][10 \times 6 \times 10^{-4}]$$

$$= 0.0072 \text{ Wb}$$

$$= \mathbf{7.2 \times 10^{-3} \text{ Wb}}$$

$$\text{Q6 } E = N \frac{d\Phi}{dt}$$

$$= 100 \left(\frac{(6)(0.08) - (2)(0.08)}{0.5} \right) = \mathbf{64 \text{ V}}$$

$$\text{Q7 Final } \Phi = BA = (2)(8 \times 6 \times 10^{-4})$$

$$= 0.0096 \text{ Wb}$$

$$\text{Initial } \Phi = 0 \text{ Wb}$$

$$\text{Time taken for change} = \left(\frac{8 \times 10^{-2}}{3} \right)$$

$$= 2.667 \times 10^{-2} \text{ s}$$

$$E = \left(\frac{\text{final } \Phi - \text{initial } \Phi}{\text{time}} \right)$$

$$= \frac{0.0096 - 0}{2.667 \times 10^{-2}} = \mathbf{0.36 \text{ V}}$$

$$\text{Q8 Initial flux} = 0, \text{ Final flux} = BA$$

$$= (4)(4 \times 6 \times 10^{-4}) = 0.0096 \text{ T}$$

$$\Rightarrow 10 \text{ rotations per second}$$

$$1 \text{ rotation takes } \frac{1}{10} \text{ s}$$

$$\text{Time to go from A to B} = \left(\frac{1}{4} \right) \left(\frac{1}{10} \right) = \frac{1}{40} \text{ s}$$

$$E = N \frac{d\Phi}{dt} = (200) \left(\frac{0.0096 - 0}{\frac{1}{40}} \right) = \mathbf{76.8 \text{ V}}$$

$$\begin{aligned}
 \text{Q9 } E &= N \frac{d\Phi}{dt} = N \left(\frac{\text{final } \Phi - \text{initial } \Phi}{\text{time}} \right) \\
 &= 10\,000 \left(\frac{-(2 \times 10^{-2})(3 \times 10^{-2})^2 + 0}{0.1} \right) \\
 &= \frac{(1 \times 10^4)(2 \times 10^{-2})(9 \times 10^{-4})}{1 \times 10^{-1}} \\
 &= 18 \times 10^{-1} = \mathbf{1.8 \text{ V}}
 \end{aligned}$$

Q10 Time to go from position 1 to position 2

= time for $\frac{1}{4}$ rev

$$= \left(\frac{1}{4}\right) \frac{1}{40} \text{ sec}$$

$$= 6.25 \times 10^{-3} \text{ s}$$

$$E = N \left(\frac{\text{final } \Phi - \text{initial } \Phi}{\text{time}} \right)$$

$$4 = 200 \left(\frac{(B)(5 \times 10^{-2}) - 0}{6.25 \times 10^{-3}} \right)$$

$$\therefore B = \frac{(4)(6.25 \times 10^{-3})}{(200)(5 \times 10^{-2})} = 0.025 \times 10^{-1} \text{ T}$$

$$= \mathbf{2.5 \times 10^{-3} \text{ T}}$$

$$\text{Q11 } E = N \frac{d\Phi}{dt}; E = IR; I = \frac{Q}{t};$$

Let t be the time during which the flux density changes from 0 to 0.25 T

$$E = N \left(\frac{\Phi_{\text{final}} - \Phi_{\text{initial}}}{t} \right)$$

$$IR = 1 \left(\frac{B_1 A - B_2 A}{t} \right)$$

$$\frac{Q}{t} R = \frac{A}{t} (B_1 - B_2)$$

$$\therefore QR = A(B_1 - B_2)$$

$$(4 \times 10^{-3})(12) = A(0.25 - 0)$$

$$\Rightarrow A = 192 \times 10^{-3} \text{ m}^2$$

$$\Rightarrow A = \mathbf{1.92 \times 10^{-1} \text{ m}^2}$$

$$\text{Q12 From Q11: } IR = N \left(\frac{B_1 A - B_2 A}{t} \right) = \frac{Q}{t} R$$

$$\Rightarrow Q = NA \frac{(B_1 - B_2)}{R}$$

$$= \frac{(500)(400 \times 10^{-4})(0 - 1.8 \times 10^{-5})}{10}$$

$$= \frac{(5 \times 10^2)(4 \times 10^{-2})(1.8 \times 10^{-5})}{10} = \mathbf{3.6 \times 10^{-5} \text{ C}}$$

Exercise 28.3

Q1 In one second: Work done = Electrical power
 $F \times dist = I^2 R$

$$F(30) = (0.6)^2(20) \Rightarrow F = \mathbf{0.24 \text{ N}}$$

Q2 (i) $E = \frac{(2)(5 \times 12 \times 10^{-4}) - 0}{\left(\frac{12 \times 10^{-2}}{4}\right)} = \mathbf{0.4 \text{ V}}$

$$I = \frac{V}{R}$$

$$I = \frac{0.4}{5}$$

$$I = \mathbf{0.08 \text{ A}}$$

(ii) $Fd = I^2 R$

$$(F)(4) = (0.08)^2(5)$$

$$F = \mathbf{8 \times 10^{-3} \text{ N}}$$

Q3 $E = N \left(\frac{\text{final } \Phi - \text{initial } \Phi}{\text{time}} \right)$

$$= N \left(\frac{BL^2 - 0}{L/v} \right) = N(BLv) = NBLv$$

(i) $I = \frac{E}{R} = \frac{NBLv}{R}$

(ii) In one second

Work done = Electrical power

$$\Rightarrow Fv = I^2 R = \left(\frac{N^2 B^2 L^2 v^2}{R^2} \right) R$$

$$\Rightarrow F = \frac{N^2 B^2 L^2 v}{R}$$

Exercise 28.4

Q1 $V_{\text{rms}} = \frac{V_o}{\sqrt{2}} = \frac{20}{\sqrt{2}} = \mathbf{14.14 \text{ V}}$

Q2 $V_o = V_{\text{rms}} \sqrt{2} = (20) \sqrt{2} = \mathbf{28.28 \text{ V}}$

Q3 $V_o = V_{\text{rms}} \sqrt{2} = (230) \sqrt{2} = \mathbf{325.3 \text{ V}}$

Q4 $P = I_{\text{rms}} V_{\text{rms}} = (2)(110) = \mathbf{220 \text{ W}}$

Q5 $P = I_{\text{rms}}^2 R$

$$\Rightarrow 500 = I_{\text{rms}}^2 (20)$$

$$\Rightarrow I_{\text{rms}} = \mathbf{5 \text{ A}}$$

$$P = I_{\text{rms}} V_{\text{rms}}$$

$$\Rightarrow 500 = 5 V_{\text{rms}}$$

$$\Rightarrow V_{\text{rms}} = \mathbf{100 \text{ V}}$$

$$V_o = 100 \sqrt{2} = \mathbf{141.42 \text{ V}}$$

Q6 $I_o = 3$

(i) $I_{\text{rms}} = \frac{3}{\sqrt{2}} = \mathbf{2.12 \text{ A}}$

(ii) $P = I_{\text{rms}}^2 R = \left(\frac{3}{\sqrt{2}} \right)^2 (200) = \mathbf{900 \text{ W}}$

(iii) $P = I_{\text{rms}} V_{\text{rms}} \Rightarrow V_{\text{rms}} = \frac{900}{2.12}$
 $= \mathbf{424.53 \text{ V}}$

(iv) $V_o = V_{\text{rms}} \sqrt{2} = \mathbf{600.37 \text{ V}}$

Q7 Power = $V_{\text{rms}} I_{\text{rms}}$

$$= \left(\frac{520}{\sqrt{2}} \right) \left(\frac{3}{\sqrt{2}} \right) = 780 \text{ W}$$

$$P = \frac{W}{t} \Rightarrow t = \frac{W}{P} = \frac{2000}{780} = \mathbf{2.56 \text{ s}}$$

Q8 $E = N \frac{d\Phi}{dt} = \frac{(400)(5 \times 10^{-4})}{1 \times 10^{-3}} = \mathbf{200 \text{ V}}$

$$\text{nett emf} = 300 - 200 = 100 \text{ V}$$

$$I = \frac{E}{R}$$

$$I = \frac{100}{200}$$

$$I = \mathbf{0.5 \text{ A}}$$

Exercise 28.5

Q1 No calculations required.

Q2 $I = \frac{V}{R} = \frac{20}{10} = 2 \text{ A}$

Q3 No calculations required.

Q4 No calculations required.

Q5 No calculations required.

Q6 $E = IR$

$$12 - (\text{Induced emf}) = (100 \times 10^{-3})(40)$$

$$\Rightarrow \text{Induced emf} = 8 \text{ V}$$

Exercise 28.6

Q1 $\frac{V_i}{V_o} = \frac{N_p}{N_s}$

$$\Rightarrow V_o = V_i = V_i \left(\frac{N_s}{N_p} \right)$$

$$= 230 \left(\frac{100}{500} \right) = 46 \text{ V}$$

Q2 $\frac{V_i}{V_o} = \frac{N_p}{N_s} \Rightarrow V_i = V_o \left(\frac{N_p}{N_s} \right) = 4 \left(\frac{2000}{100} \right) = 80 \text{ V}$

Q3 $N_p = \left(\frac{V_i}{V_o} \right) N_s = \left(\frac{3000}{220} \right) (60) = 818 \text{ turns}$

Q4 $N_s = N_p \left(\frac{V_o}{V_i} \right) = (10\,000) \left(\frac{220}{4000} \right) = 550 \text{ turns}$

$$V_i I_p = V_o I_s$$

$$(4000)(I_p) = (220)(5) \Rightarrow I_p = 0.275 \text{ A}$$

$$\text{Output power} = V_o I_s = (220)(5) = 1100 \text{ W}$$

$$\text{Input power} = 100 \left(\frac{1100}{90} \right) = 1222.22 \text{ W}$$

$$\therefore 4000 I_p = 1222.22 \text{ W} \Rightarrow I_p = 0.306 \text{ A}$$

Q5 No calculations required.

Exercise 29.1

Q1 (i) E_p lost, $W = QV = eV$
 $= (1.6 \times 10^{-19})(8000) = \mathbf{1.28 \times 10^{-15} \text{ J}}$

(ii) E_K gained = E_p lost = $\mathbf{1.28 \times 10^{-15} \text{ J}}$

(iii) $E_K = \frac{1}{2}mv^2 \Rightarrow (0.5)(9.1 \times 10^{-31})v^2$
 $= 1.28 \times 10^{-15} \Rightarrow v = \sqrt{\frac{1.28 \times 10^{-15}}{(0.5)(9 \times 10^{-31})}}$
 $= \mathbf{5.3 \times 10^7 \text{ m s}^{-1}}$

Q2 $\frac{1}{2}mv^2 = eV$
 $v = \sqrt{\frac{2eV}{m}} = \mathbf{5.93 \times 10^7 \text{ m s}^{-1}}$

Q3 $\frac{1}{2}mv^2 = eV$
 $V = \frac{mv^2}{2e} = \mathbf{639.8 \text{ V}}$

Q4 (i) $5 \text{ eV} = 5 \times 1.6 \times 10^{-19} \text{ J} = \mathbf{8 \times 10^{-19} \text{ J}}$

(ii) $200 \text{ eV} = 200 \times 1.6 \times 10^{-19} \text{ J}$
 $= \mathbf{3.2 \times 10^{-17} \text{ J}}$

(iii) $40 \text{ keV} = (40 \times 10^3)(1.6 \times 10^{-19}) \text{ J}$
 $= \mathbf{6.4 \times 10^{-15} \text{ J}}$

(iv) $5 \text{ MeV} = (5 \times 10^6)(1.6 \times 10^{-19}) \text{ J}$
 $= \mathbf{8 \times 10^{-13} \text{ J}}$

(v) $40 \text{ GeV} = (40 \times 10^9)(1.6 \times 10^{-19}) \text{ J}$
 $= \mathbf{6.4 \times 10^{-9} \text{ J}}$

(vi) $4.2 \text{ eV} = (4.2)(1.6 \times 10^{-19}) \text{ J}$
 $= \mathbf{6.72 \times 10^{-19} \text{ J}}$

Q5 (i) $3 \text{ keV} = \mathbf{3000 \text{ eV}}$

(ii) $6 \text{ MeV} = \mathbf{6 \times 10^6 \text{ eV}}$

(iii) $2.5 \text{ GeV} = \mathbf{2.5 \times 10^9 \text{ eV}}$

(iv) $1 \text{ J} = \frac{1}{1.6 \times 10^{-19}} \text{ eV} = \mathbf{6.25 \times 10^{18} \text{ eV}}$

(v) $2 \times 10^{-15} \text{ J} = \frac{2 \times 10^{-15}}{1.6 \times 10^{-19}} \text{ eV} = \mathbf{12\,500 \text{ eV}}$

(vi) $6.4 \times 10^{-16} \text{ J} = \frac{6.4 \times 10^{-16}}{1.6 \times 10^{-19}} \text{ eV} = \mathbf{4000 \text{ eV}}$

(vii) $5.6 \times 10^{-19} \text{ J} = \frac{5.6 \times 10^{-19}}{1.6 \times 10^{-19}} = \mathbf{3.5 \text{ eV}}$

Q6 No calculations required.

Q7 $F = qvB = (1.6 \times 10^{-19})(2.1 \times 10^6)(4.2)$
 $= \mathbf{1.41 \times 10^{-12} \text{ N}}$

Q8 $F = qvB$

$$v = \frac{F}{qB} = \frac{2 \times 10^{-12}}{(1.6 \times 10^{-19})(3)} = \mathbf{4.2 \times 10^6 \text{ m s}^{-1}}$$

Q9 $\frac{mv^2}{r} = Bqv \Rightarrow r = \frac{mv^2}{Bqv} \Rightarrow r = \frac{mv}{Bq}$
 $= \frac{(9.1 \times 10^{-31})(5.6 \times 10^7)}{(3 \times 10^{-2})(1.6 \times 10^{-19})} = \mathbf{1.06 \times 10^{-2} \text{ m}}$

Q10 No calculations required.

Q11 $\frac{e}{m} = 1.76 \times 10^{11}$

$$\frac{1.6 \times 10^{-19}}{m} = 1.76 \times 10^{11}$$

$$\Rightarrow m = \frac{1.6 \times 10^{-19}}{1.76 \times 10^{11}} = \mathbf{9.09 \times 10^{-31} \text{ kg}}$$

Exercise 29.2

Q1 Red light : $E = hf = (6.6 \times 10^{-34})(4 \times 10^{14})$
 $= 2.64 \times 10^{-19} \text{ J}$

$$2.64 \times 10^{-19} \text{ J} = \frac{2.64 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV} = 1.65 \text{ eV}$$

Q2 Blue light : $E = hf = (6.6 \times 10^{-34})(8 \times 10^{14})$
 $= 5.28 \times 10^{-19} \text{ J}$

$$= \frac{5.28 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV} = 3.3 \text{ eV}$$

Q3 $c = f\lambda \Rightarrow f = \frac{c}{\lambda} = \frac{3 \times 10^8}{5 \times 10^{-7}} = 6 \times 10^{14} \text{ Hz}$

$$E = hf = (6.6 \times 10^{-34})(6 \times 10^{14})$$

$$= 3.96 \times 10^{-19} \text{ J}$$

Q4 $\lambda = 600 \text{ nm} = 600 \times 10^{-9} \text{ m}$

$$\lambda f = c \Rightarrow f = \frac{c}{\lambda}$$

$$E = hf = \frac{hc}{\lambda} = \frac{(6.6 \times 10^{-34})(3 \times 10^8)}{600 \times 10^{-9}}$$

$$= 3.3 \times 10^{-19} \text{ J}$$

Q5 $\lambda = 590 \text{ nm} = 590 \times 10^{-9} \text{ m}$

(i) $c = f\lambda \Rightarrow f = \frac{c}{\lambda}$

$$\therefore \text{frequency} = \frac{3 \times 10^8}{590 \times 10^{-9}}$$

$$= 5.08 \times 10^{14} \text{ Hz}$$

(ii) $E = hf = (6.6 \times 10^{-34})(5.08 \times 10^{14})$

$$= 3.3528 \times 10^{-19} \text{ J}$$

(iii) Energy of source = 10 W = 10 joules per second

Number of Photons emitted per second

$$= \frac{\text{Energy emitted per second}}{\text{Energy of one photon}} = \frac{10}{3.3528 \times 10^{-19}}$$

$$= 2.98 \times 10^{19} \text{ Photons}$$

Q6 $2.2 \text{ eV} = (2.2)(1.6 \times 10^{-19}) \text{ J} = 3.52 \times 10^{-19} \text{ J}$

$$E = hf \Rightarrow f = \frac{E}{h} = \frac{3.52 \times 10^{-19}}{6.6 \times 10^{-34}} = 5.33 \times 10^{14} \text{ Hz}$$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{5.33 \times 10^{14}} = 5.63 \times 10^{-7} \text{ m}$$

Q7 Number of Photons striking per second
 = Number of electrons emitted per second

Current = Charge passing per second
 = Charge on one electron \times Number of electrons passing per second

$$\therefore 2 \times 10^{-6} = (1.6 \times 10^{-19})(x)$$

$$\Rightarrow x = \frac{2 \times 10^{-6}}{1.6 \times 10^{-19}} = 1.25 \times 10^{13} \text{ Photons}$$

Q8 $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$

$$4 \text{ eV} = 4 \times 1.6 \times 10^{-19} = 6.4 \times 10^{-19} \text{ J}$$

$$\Phi = hf_o \Rightarrow f_o = \frac{\Phi}{h} = \frac{6.4 \times 10^{-19}}{6.6 \times 10^{-34}}$$

$$= 9.70 \times 10^{14} \text{ Hz}$$

Q9 (a) $\Phi = hf_o = (6.6 \times 10^{-34})(2 \times 10^{15})$

$$= 1.32 \times 10^{-18} \text{ J}$$

(b) Work function in eV = $\frac{1.32 \times 10^{-18}}{1.6 \times 10^{-19}}$

$$= 8.25 \text{ eV}$$

Q10 $\Phi = 1.2 \text{ eV} = 1.2 \times 1.6 \times 10^{-19} \text{ J}$

$$= 1.92 \times 10^{-19} \text{ J}$$

$$\Phi = hf_o \Rightarrow f_o = \frac{\Phi}{h} = \frac{1.92 \times 10^{-19}}{6.6 \times 10^{-34}}$$

$$= 2.91 \times 10^{14} \text{ Hz}$$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{2.91 \times 10^{14}} = 1.03 \times 10^{-6} \text{ m}$$

Q11 $f_o = 8.8 \times 10^{14}$ Hz, $f = 9.2 \times 10^{14}$ Hz

$$\begin{aligned} \text{(i)} \quad \frac{1}{2} m v_{max}^2 &= hf - hf_o = h(f - f_o) \\ &= 6.6 \times 10^{-34} (9.2 \times 10^{14} - 8.8 \times 10^{14}) \\ &= \mathbf{2.64 \times 10^{-20} \text{ J}} \end{aligned}$$

$$\begin{aligned} \text{(ii)} \quad 2.64 \times 10^{-20} \text{ J} &= \frac{2.64 \times 10^{-20}}{1.6 \times 10^{-19}} \text{ eV} \\ &= \mathbf{0.165 \text{ eV}} \end{aligned}$$

Q12 $\lambda = 350 \text{ nm} = 350 \times 10^{-9} \text{ m}$

$$c = \lambda f \Rightarrow f = \frac{c}{\lambda} = \frac{3 \times 10^8}{350 \times 10^{-9}} = \mathbf{8.57 \times 10^{14} \text{ Hz}}$$

$$\begin{aligned} \text{Max } E_K &= 2 \text{ eV} = 2 \times 1.6 \times 10^{-19} \text{ J} \\ &= 3.2 \times 10^{-19} \text{ J} \end{aligned}$$

$$E_{K_{max}} = hf - \Phi$$

$$\begin{aligned} 3.2 \times 10^{-19} &= (6.6 \times 10^{-34})(8.57 \times 10^{14}) - \Phi \\ \Rightarrow \Phi &= 5.66 \times 10^{-19} - 3.2 \times 10^{-19} \\ &= \mathbf{2.46 \times 10^{-19} \text{ J}} \end{aligned}$$

Q13 $0.2 \text{ mA} = (0.2 \times 10^{-3}) \text{ A} = (0.2 \times 10^{-3}) \text{ C s}^{-1}$

$$\text{Number of electrons in 1 C} = \frac{1}{1.6 \times 10^{-19}}$$

\therefore Number of electrons leaving cathode

$$= \frac{0.2 \times 10^{-3}}{1.6 \times 10^{-19}} \Rightarrow \text{Number of photons}$$

$$= \frac{0.2 \times 10^{-3}}{1.6 \times 10^{-19}} = \mathbf{1.25 \times 10^{15}}$$

Energy of one photon $E = hf =$

$$(6.6 \times 10^{-34})(2 \times 10^{16}) = 1.32 \times 10^{-17} \text{ J}$$

\therefore Energy per second =

$$\left(\begin{array}{c} \text{Energy of one} \\ \text{Photon} \end{array} \right) \times \left(\begin{array}{c} \text{Number of Photons} \\ \text{per second} \end{array} \right)$$

$$= (1.32 \times 10^{-17})(1.25 \times 10^{15}) = 0.0165 \text{ J}$$

$$= \mathbf{1.65 \times 10^{-2} \text{ J}}$$

Q14 $\lambda = 250 \text{ nm} = 250 \times 10^{-9} \text{ m}$

$$f = \frac{c}{\lambda} = \frac{3 \times 10^8}{250 \times 10^{-9}} = 1.2 \times 10^{15} \text{ Hz}$$

$$\begin{aligned} \Phi &= 1.6 \text{ eV} = (1.6)(1.6 \times 10^{-19}) \text{ J} \\ &= 2.56 \times 10^{-19} \text{ J} \end{aligned}$$

Max kinetic energy = $hf - \Phi$

$$\Rightarrow E_{K_{max}}$$

$$\begin{aligned} &= (6.6 \times 10^{-34})(1.2 \times 10^{15}) - 2.56 \times 10^{-19} \\ &= 7.92 \times 10^{-19} - 2.56 \times 10^{-19} \\ &= \mathbf{5.36 \times 10^{-19} \text{ J}} \end{aligned}$$

$$\frac{1}{2} (9.1 \times 10^{-31}) v^2 = 5.36 \times 10^{-19}$$

$$\Rightarrow v = \mathbf{1.09 \times 10^6 \text{ m s}^{-1}}$$

Q15 $E = hf = (6.6 \times 10^{-34})(92 \times 10^6)$

$$= 6.072 \times 10^{-26} \text{ joules}$$

Number of Photons emitted per second

$$= \frac{2 \times 10^6}{6.072 \times 10^{-26}} = \mathbf{3.29 \times 10^{31} \text{ Photons}}$$

Exercise 30.1

- Q1** No calculations required.
- Q2** No calculations required.
- Q3** No calculations required.
- Q4** No calculations required.
- Q5** No calculations required.
- Q6** Decrease in mass number = $238 - 230 = 8$
 $\Rightarrow 2 \alpha$ -particles emitted \Rightarrow atomic number decreases by 4 (i.e. 2×2) to 88
 To get back up to 90, 2 β -particles must be emitted.
- Q7** Decrease in mass number = $238 - 226 = 12$
 $\Rightarrow 3 \alpha$ -particles \Rightarrow decrease in atomic number = $3(2) = 6$ to 86 \therefore 2 β must be emitted to get atomic number up to 88
- Q8** No calculations required.
- Q9** No calculations required.
- Q10** No calculations required.
- Q11** No calculations required.
- Q12** 4α -particles \Rightarrow Mass number decreases by $4 \times 4 = 16$ and atomic number decreases by $4 \times 2 = 8$
 3β -particles \Rightarrow atomic number increases by 3 \therefore overall decrease in atomic number = $8 - 3 = 5$

Exercise 30.2

- Q1** No calculations required.
- Q2** No calculations required.
- Q3** (i) $\frac{1}{2}$ remains
 (ii) 6 years = 2 half-lives $\Rightarrow \frac{1}{4}$ remains
 (iii) 9 years = 3 half-lives $\Rightarrow \frac{1}{8}$ remains
- Q4** 40 years = 4 half-lives
 $\Rightarrow \frac{1}{2^4} = \frac{1}{16}$ remains and $\frac{15}{16}$ has decayed.
- Q5** (i) Number of half-lives = $\frac{(5)(60)}{(20)} = 15$
 (ii) 3 hours = $\frac{(3)(60)}{20}$ half-lives = 9
 $\frac{1}{2^9}$ remains undecayed, i.e. $\frac{1}{512}$
 (iii) 40 mins = 2 half-lives $\Rightarrow \frac{1}{4}$ remains
 $\Rightarrow \frac{3}{4}$ has decayed
 (iv) $\frac{1}{2^n}$
- Q6** $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} \Rightarrow \lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \frac{\ln 2}{120} = 5.776 \times 10^{-3} \text{ s}^{-1}$
- Q7** $T_{\frac{1}{2}} = 5.5 \text{ minutes} = (5.5)(60) \text{ seconds}$
 $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \frac{0.693}{(5.5)(60)} = 0.0021 \text{ s}^{-1}$
 $= 2.1 \times 10^{-3} \text{ s}^{-1}$
- Q8** $\lambda = \frac{\ln 2}{(2.4)(365)(24)(60)(60)} = 9.158 \times 10^{-9} \text{ s}^{-1}$
- Q9** $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{5 \times 10^3} = 1.386 \times 10^{-4} \text{ s}$
- Q10** $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{2 \times 10^{-3}} = 346.57 \text{ s} = 5.776 \text{ min}$
- Q11** $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{0.693}{9.627 \times 10^{-5}} = 7200 \text{ s} = 2 \text{ hours}$
 6 hours = 3 half-lives $\Rightarrow \frac{1}{8}$ remains undecayed

Q12 Activity = λN

$$3 \times 10^3 = 8 \times 10^{-8} N$$

$$\Rightarrow N = \frac{3 \times 10^3}{8 \times 10^{-8}} = \mathbf{3.75 \times 10^{10}}$$

Q13 Activity = $\lambda N = (8 \times 10^{-3})(2 \times 10^{15})$
 $= \mathbf{1.6 \times 10^{13} \text{ Bq}}$

Q14 Activity = λN

$$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \left(\frac{\ln 2}{(4)(60)} \right) (6 \times 10^{20})$$

$$= \mathbf{1.73 \times 10^{18} \text{ Bq}}$$

Q15 $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} \Rightarrow \lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$

$$\lambda = \frac{\ln 2}{(8 \times 10^{18})(365)(24)(60)(60)}$$

$$= 2.747 \times 10^{-27} \text{ s}^{-1}$$

$$\text{Activity} = \lambda N = (2.747 \times 10^{-27})(6.2 \times 10^{16})$$

$$= \mathbf{1.7 \times 10^{-10} \text{ alpha particles per second}}$$

Q16 Activity = λN

$$3.5 \times 10^{10} = \lambda (2.6 \times 10^{21})$$

$$\Rightarrow \lambda = \mathbf{1.346 \times 10^{-11} \text{ s}^{-1}}$$

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{1.346 \times 10^{-11}} = 5.1496 \times 10^{10} \text{ s}$$

$$= \mathbf{1633 \text{ years}}$$

Exercise 30.3

Q1 $64 \text{ g} = 6.02 \times 10^{23} \text{ atoms}$

$$1 \text{ g} = \frac{6.02 \times 10^{23}}{64}$$

$$2000 \text{ g} = \frac{(2000)(6.02 \times 10^{23})}{64}$$

$$= \mathbf{1.88 \times 10^{25} \text{ atoms}}$$

Q2 $218 \text{ g} = 6.02 \times 10^{23} \text{ atoms}$

$$3.5 \mu\text{g} = \frac{6.02 \times 10^{23} \times 3.5 \times 10^{-6}}{218}$$

$$= \mathbf{9.665 \times 10^{15} \text{ atoms}}$$

Q3 218 g has $6.02 \times 10^{23} \text{ atoms}$

$$2.4 \mu\text{g} = \frac{6.02 \times 10^{23} \times 2.4 \times 10^{-6}}{218}$$

$$= 6.628 \times 10^{15} \text{ atoms}$$

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}} = \frac{0.693}{(3.1)(60)} = 3.73 \times 10^{-3} \text{ s}^{-1}$$

$$\text{Activity} = \lambda N = (3.73 \times 10^{-3})(6.628 \times 10^{15})$$

$$= \mathbf{2.47 \times 10^{13} \text{ Bq}}$$

Q4 $T_{\frac{1}{2}} = 22 \text{ hrs} = 79\,200 \text{ s}$

$$\lambda = \frac{0.693}{79\,200} = 8.75 \times 10^{-6} \text{ s}^{-1}$$

$$\text{Activity} = \lambda N$$

$$150 = 8.75 \times 10^{-6} N \Rightarrow N = 1.74 \times 10^7 \text{ atoms}$$

$$6.02 \times 10^{23} \text{ atoms} = 228 \text{ g} \Rightarrow 1.714 \times 10^7 \text{ atoms} = \mathbf{6.5 \times 10^{-15} \text{ grams}}$$

Exercise 31.1

$$\begin{aligned} \text{Q1 } E = mc^2 \Rightarrow m &= \frac{E}{c^2} = \frac{1.4 \times 10^9}{(3.00 \times 10^8)^2} \\ &= \mathbf{1.56 \times 10^{-8} \text{ kg}} \end{aligned}$$

$$\begin{aligned} \text{Q2 Mass lost} &= (4 \times 10^6)(60)(60) \\ E = mc^2 &= (4 \times 10^6)(60)(60) \times (3 \times 10^8)^2 \\ &= \mathbf{1.296 \times 10^{27} \text{ J}} \end{aligned}$$

$$\begin{aligned} \text{Q3 Energy emitted in 1 year} \\ &= (3.6 \times 10^{23})(60)(60)(24)(365) \\ &= 1.1352 \times 10^{31} \text{ J} \\ m &= \frac{E}{c^2} = \frac{1.1352 \times 10^{31}}{(3.00 \times 10^8)^2} = \mathbf{1.2614 \times 10^{14} \text{ kg}} \end{aligned}$$

$$\begin{aligned} \text{Q4 } E = mc^2 &= (8 \times 10^{-27})(3.00 \times 10^8)^2 \\ &= \mathbf{7.2 \times 10^{-10} \text{ J}} \end{aligned}$$

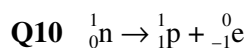
$$\begin{aligned} \text{Q5 Mass of reactants:} \\ 2.325210 \times 10^{-26} + 6.646322 \times 10^{-27} \text{ kg} \\ &= 2.9898 \times 10^{-26} \text{ kg} \\ \text{Mass of products} \\ &= 2.822706 \times 10^{-26} + 1.672623 \times 10^{-27} \text{ kg} \\ &= 2.9899 \times 10^{-26} \text{ kg} \\ \text{Gain in mass} &= 1.261 \times 10^{-30} \text{ kg} \\ \Rightarrow \text{Energy taken in} &= E = mc^2 \\ &= (1.261 \times 10^{-30})(3 \times 10^8)^2 \\ &= 1.1349 \times 10^{-13} \text{ J} \\ &= 709312.5 \text{ eV} = \mathbf{0.71 \text{ MeV}} \\ \text{Energy of } \alpha\text{-particle} &= 7.68 \text{ MeV} \\ \text{Energy available} &7.68 - 0.71 = 6.97 \text{ MeV} \\ \text{Kinetic energy of proton} &= \frac{17}{18} \text{ of } 6.97 \\ &= \mathbf{6.58 \text{ MeV}} \end{aligned}$$

$$\begin{aligned} \text{Q6 Mass lost} &= (3.344 \times 10^{-27})(2) \\ &- 6.646 \times 10^{-27} = 4.2 \times 10^{-29} \text{ kg} \\ E = mc^2 &= (4.2 \times 10^{-29})(3.00 \times 10^8)^2 \\ &= \mathbf{3.78 \times 10^{-12} \text{ J}} \end{aligned}$$

$$\begin{aligned} \text{Q7 } {}_{27}^{59}\text{Co} + {}_0^1\text{n} &\rightarrow {}_{27}^{60}\text{Co} + \gamma \\ \text{Loss in Mass} \\ &= (9.7859 \times 10^{-26} \text{ kg} + 1.6749 \times 10^{-27} \text{ kg}) \\ &- (9.9520 \times 10^{-26}) = 1.39 \times 10^{-29} \text{ kg} \\ E = mc^2 &= (1.39 \times 10^{-29})(3 \times 10^8)^2 \\ &= \mathbf{1.251 \times 10^{-12} \text{ J}} \end{aligned}$$

$$\begin{aligned} \text{Q8 } 200 \text{ MeV} &= 200 \times (1.6 \times 10^{-19}) \times 10^6 \text{ J} \\ &= 3.2 \times 10^{-11} \text{ J} \\ E = mc^2 \Rightarrow m &= \frac{E}{c^2} = \frac{3.2 \times 10^{-11}}{(3 \times 10^8)^2} \\ &= \mathbf{3.56 \times 10^{-28} \text{ kg}} \end{aligned}$$

$$\begin{aligned} \text{Q9 P.C.M.} &\Rightarrow (4.24 \times 10^{-25})U = (6.68 \times 10^{-27})V \\ &\Rightarrow \frac{V}{U} = \mathbf{63.5 : 1} \\ \text{Energy} = E = mc^2 &= (1.2 \times 10^{-29})(3 \times 10^8)^2 \\ &= \mathbf{1.08 \times 10^{-12} \text{ J}} \\ &= \text{Total initial energy} \\ \text{i.e. } E_\alpha + E_n &= 1.08 \times 10^{-12} \\ \Rightarrow \frac{1}{2}(4.24 \times 10^{-25})U^2 + \frac{1}{2}(6.68 \times 10^{-27})V^2 \\ &= 1.08 \times 10^{-12} \\ \text{Also } V &= 63.5U \\ \text{Solving simultaneously gives:} \\ V &= 1.78 \times 10^7 \text{ m s}^{-1} \text{ and} \\ U &= 2.81 \times 10^5 \text{ m s}^{-1} \\ &(\text{see Exercise 32.1 Q1 for an alternative method of solving a question like this.}) \end{aligned}$$



$$\text{Loss in mass} = 1.674\,929 \times 10^{-27}$$

$$- (1.672\,623 \times 10^{-27} + 9.109\,390 \times 10^{-31})$$

$$\text{i.e. Loss in mass} = 1.395 \times 10^{-30} \text{ kg}$$

$$E = mc^2 = (1.395 \times 10^{-30})(3 \times 10^8)^2$$

$$= 1.26 \times 10^{-13} \text{ J}$$

Exercise 32.1

Q1 Loss in Mass = $3.753\,152 \times 10^{-25}$

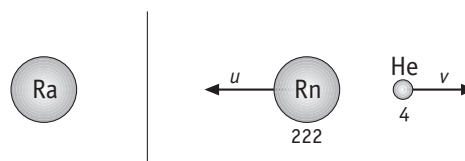
$$(- 3.686\,602 \times 10^{-25} + 6.646\,322 \times 10^{-27})$$

$$= 8.678 \times 10^{-30} \text{ kg}$$

$$E = mc^2 = (8.678 \times 10^{-30})(3 \times 10^8)^2$$

$$= 7.81 \times 10^{-13} \text{ J} = 4.88 \text{ MeV}$$

Q2 $M_R u = M_H v \Rightarrow \frac{v}{u} = \frac{M_R}{M_H} = \frac{222}{4} \Rightarrow \frac{v}{u} = 55.5$



Ratio of kinetic energies

$$= \frac{\frac{1}{2}M_R u^2}{\frac{1}{2}M_H v^2} = \left(\frac{M_R}{M_H}\right)\left(\frac{u}{v}\right)^2 = \left(\frac{v}{u}\right)\left(\frac{u^2}{v^2}\right) = \frac{u}{v}$$

$$= \frac{1}{55.5} \Rightarrow \text{Kinetic energy of } \alpha\text{-particle}$$

$$= 55.5 \text{ Kinetic energy of Radon}$$

$$\Rightarrow \text{Kinetic energy of } \alpha\text{-particle}$$

$$= \frac{\text{Total energy}}{56.5} \times 55.5$$

$$= 7.66 \times 10^{-13} \text{ J}$$

Q3 The β -particle is so light compared with a Nitrogen nucleus that it gets virtually all of the Kinetic energy (It is approximately 28 000 times lighter)

$$E = mc^2 = (2.77 \times 10^{-31})(3 \times 10^8)^2$$

$$= 2.493 \times 10^{-14} \text{ J} = \text{Kinetic energy of } \beta\text{-particle}$$

Exercise 32.2

Q1 $1 u = 1.66 \times 10^{-27} \text{ kg}$

$$E = mc^2$$

$$= (1.66 \times 10^{-27})(3.00 \times 10^8)^2$$

$$= 1.49 \times 10^{-10} \text{ J}$$

$$= \frac{1.49 \times 10^{-10}}{1.6 \times 10^{-19}} \text{ eV} = \mathbf{931 \text{ eV}}$$

Q2 Decrease in Mass

$$= 238.050\,784 - (234.043\,593 + 4.002\,603)$$

$$= 0.004\,588 \text{ u}$$

$$E = mc^2$$

$$= (0.004588)(1.66 \times 10^{-27})(3 \times 10^8)^2$$

$$= 6.854 \times 10^{-13} \text{ J}$$

$$= \frac{6.854 \times 10^{-13}}{1.6 \times 10^{-19}} \text{ eV}$$

$$= \mathbf{4.28 \text{ MeV}}$$

Exercise 32.3

Q1 Energy needed $E = mc^2$

$$= (2.5 \times 10^{-28})(3 \times 10^8)^2$$

$$= 2.25 \times 10^{-11} \text{ J}$$

$$\Rightarrow \text{Energy of each proton}$$

$$= 1.125 \times 10^{-11} \text{ J}$$

$$= \mathbf{70 \text{ MeV}}$$

Q2 $E = mc^2$

$$= (3)(2.5 \times 10^{-28})(3 \times 10^8)^2$$

$$= 6.75 \times 10^{-11} \text{ J}$$

$$\Rightarrow \text{Energy of proton} = 3.375 \times 10^{-11} \text{ J}$$

$$= \mathbf{211 \text{ MeV}}$$

Exercise 32.4

- Q1** (i) $u\bar{d} \quad \left(+\frac{2}{3}\right) + \left(\frac{1}{3}\right) = +1$
(ii) $\bar{u}d \quad \left(-\frac{2}{3}\right) + \left(-\frac{1}{3}\right) = -1$
(iii) $uud \quad \left(+\frac{2}{3}\right) + \left(+\frac{2}{3}\right) + \left(-\frac{1}{3}\right) = +1$
(iv) $udd \quad \left(+\frac{2}{3}\right) + \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right) = 0$
(v) $u\bar{s} \quad \left(+\frac{2}{3}\right) + \left(+\frac{1}{3}\right) = +1$
(vi) $\bar{u}s \quad \left(-\frac{2}{3}\right) + \left(-\frac{1}{3}\right) = -1$
(vii) $uds \quad \left(+\frac{2}{3}\right) + \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right) = 0$
(viii) $uus \quad \left(+\frac{2}{3}\right) + \left(+\frac{2}{3}\right) + \left(-\frac{1}{3}\right) = +1$
(ix) $dds \quad \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right) = -1$
(x) $dss \quad \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right) = -1$
(xi) $sss \quad \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right) = -1$

Exercise 33.1

Q1 $FSD = 15 \text{ mA}$

$$I_1 R_1 = I_2 R_2$$

$$(0.015)(5) = (0.985)(R)$$

$$\Rightarrow R = \frac{(0.015)(5)}{(0.985)} = \mathbf{0.07614 \Omega}$$

Q2 $FSD = 10 \text{ mA} = 0.01 \text{ A}$

$$V_1 + V_2 = 12$$

$$(0.01)(5) + (0.01)(R) = 12 \Rightarrow R = \mathbf{1195 \Omega}$$

Q3 (i) In parallel

$$FSD = 6 \text{ mA} = 0.006 \text{ A}$$

$$I_1 R_1 = I_2 R_2$$

$$\Rightarrow (0.006)(10)$$

$$= (11.994)(R)$$

$$\Rightarrow R = \mathbf{0.005 \Omega}$$

(ii) In series

$$20 = (0.006)(10) + (0.006)R$$

$$\Rightarrow R = \mathbf{3323.3 \Omega}$$

Q4 Voltages in parallel are equal

$$\Rightarrow (I)(4) = (20 - I)(0.02)$$

$$4I = 0.4 - 0.02I$$

$$4.02I = 0.4$$

$$I = \frac{0.4}{4.02} = \mathbf{0.0995 \text{ A}}$$

Q5 $I = \frac{V}{R} = \frac{40}{3005} = 0.01331 \text{ A}$

$$V_1 = I_1 R_1 = (0.01331)(5) = \mathbf{0.0666 \text{ V}}$$

Q6 $I = \frac{V}{R} = \frac{20}{20\,000} = 0.001 \text{ A}$

Need: 80 V across R

$$V = IR \Rightarrow R = \frac{V}{I} = \frac{80}{0.001} = 80\,000 \Omega$$

\therefore connect in series a resistor of **80 k Ω**

$$\mathbf{Q7} \quad A = \pi r^2 = \pi \left(\frac{d}{2}\right)^2 = \pi \left(\frac{0.085}{2000}\right)^2$$

$$R = \frac{\rho l}{A} = \frac{(1.7 \times 10^{-8})(18)}{\pi \left(\frac{0.085}{2000}\right)^2}$$

$$R = \mathbf{53.93 \, \Omega}$$

$$FSD = 2 \text{ mA} = 0.002 \text{ A}$$

$$(i) \quad V = IR$$

$$V_{max} = (0.002)(53.93) = \mathbf{0.1079 \text{ V}}$$

$$(ii) \quad 10 = I_1 R_1 + I_2 R_2$$

$$10 = (0.002)(53.93) + (0.002)R$$

$$R = \mathbf{4946 \, \Omega}$$