TEXTBOOK SOLUTIONS

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

TEXTBOOK SOLUTIONS

Exercise 1.1

Q1 Area = length × 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}) = **kg m $\mathbf{s^{-1}}$ = 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 $P = \frac{\text{Unit of Force}}{\text{Unit of Area}}$

$= \frac{\text{Newton}}{\text{Metre squared}}$ = 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 cm^2 = $\mathbf{5 \times 10^{-4}\ m^2}$

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

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

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

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

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

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

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

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

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

(vi) 100 km h^{-1} = 100 000 m h^{-1}
$= \frac{100\,000}{60 \times 60}$ m s^{-1} = $\mathbf{27.78\ m\ s^{-1}}$

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

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

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

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

Q10 $W = Fs \Rightarrow$ 1 Joule = **1 N m**

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

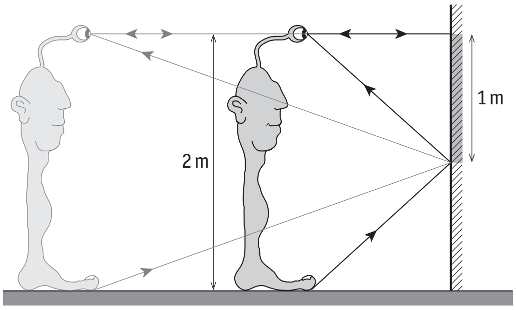
Q12 1 W = 1 J s^{-1} = (1 kg m^2 s^{-2})s^{-1} = $\mathbf{1\ kg\ m^2\ s^{-3}}$

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.

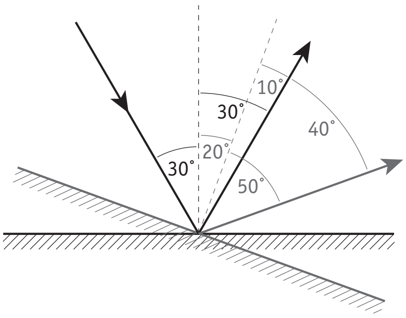
Q5 Answer = 1 m (see diagram)



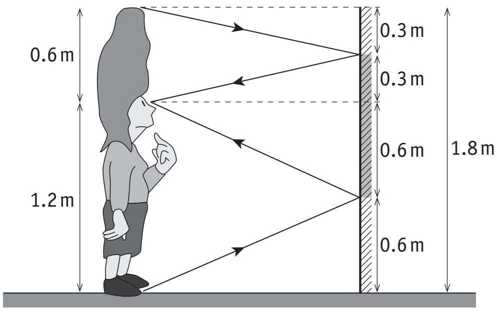
Q6 $t = \frac{\text{Distance}}{\text{Speed}} = \frac{3.97 \times 10^{16}}{3 \times 10^8} = 1.32 \times 10^8\text{s}$

$= \mathbf{4.2\ years}$

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



Q9 From the diagram, length = 0.9 m



Exercise 3.1

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

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

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

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

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

focal length = **18.75 cm**

Q2 $u = 20$ $v = 30$

Image virtual $\Rightarrow \frac{1}{u} - \frac{1}{v} = \frac{1}{f}$

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

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

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

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

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

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

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

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

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

Image is real (v +)

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

Image is twice the size of object

⇒ its height is 4 cm

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

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

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

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

∴ Image is **20 cm** from mirror. It is **virtual**.

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

Q5 $f = 40$

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

$\Rightarrow \quad v = 4u.$

Find u.

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

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

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

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

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

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

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

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

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

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

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

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

(ii) Virtual image

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

$$v = +3u$$

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

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

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

$$3u = 40$$

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

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

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

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

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

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

Virtual image:

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

$$v = 2u$$

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

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

$$\Rightarrow \quad 2u = 50$$

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

Q8 Image upright $\Rightarrow$ Virtual image

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

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

$\Rightarrow \ v = 3u$

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

$$\frac{3-1}{3u} = \frac{1}{100} \quad \Rightarrow \quad 200 = 3u$$

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

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

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

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

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

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

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

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

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

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.

$\frac{1}{10} + \frac{1}{12} = \frac{1}{v}$

$\frac{6+5}{60} = \frac{1}{v} \Rightarrow \frac{1}{v} = \frac{11}{60}$

$v = \frac{60}{11}$ = **5.45 cm**

Q2 $u = 30, f = 12, v = ?$

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

$\frac{1}{30} - \frac{1}{v} = -\frac{1}{12}$

$\frac{1}{30} + \frac{1}{12} = \frac{1}{v}$ $\Rightarrow v =$ **8.57 cm**

Virtual

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

Q3 $f = 10$, Mag. $= \frac{v}{u} = \frac{1}{4} \Rightarrow 4v = u$

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

$\frac{1}{4v} - \frac{1}{v} = -\frac{1}{10}$

$\frac{1-4}{4v} = -\frac{1}{10}$

$\frac{+3}{4v} = \frac{+1}{10}$

$30 = 4v$

$v =$ **7.5 cm**

$u = 4v \Rightarrow$

$u =$ **30 cm**

Q4 $\frac{1}{u} - \frac{1}{v} = -\frac{1}{f}$ $m = \frac{v}{u} = \frac{\text{Height of image}}{\text{Height of object}}$

$v = 10$ $m = \frac{2}{5} = \frac{v}{u}$

$\therefore$ $2u = 5v$

$2u = 5(10)$

$u = 25$

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

$\frac{1}{25} - \frac{1}{10} = -\frac{1}{f}$

$\frac{2-5}{50} = -\frac{1}{f}$

$\frac{-3}{50} = -\frac{1}{f}$

$\Rightarrow f = \frac{50}{3}$ = **16⅔ cm**

Q5 $v = 4$ cm

$h_i = 4, h_o = 6$

$m = \frac{h_i}{h_o} = \frac{v}{u} \Rightarrow \frac{4}{6} = \frac{v}{u}$

$\frac{4}{6} = \frac{4}{u} \Rightarrow u = 6$ 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* = 12 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* = 40 cm**

Q7 $h_i = ½h_o$

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

$\frac{1}{2v} - \frac{1}{v} = -\frac{1}{40}$

$\frac{1-2}{2v} = -\frac{1}{40}$

$+\frac{1}{2v} = \frac{1}{40}$ $\Rightarrow v = 20$

$\therefore$ *u* = **40 cm**

Q8 $m = \frac{1}{2} = \frac{v}{u}$

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

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

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

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

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

Exercise 4.1

Q1 $_an_g = \frac{\text{Sin } 25°}{\text{Sin } 16.4°} = \frac{.4226}{.2823} = 1.496989 = \mathbf{1.5}$

Q2 $_an_d = \frac{\text{Sin } 60°}{\text{Sin } 21°} = \mathbf{2.42}$

Q3 $_an_w = \frac{\text{Sin } 30°}{\text{Sin } r} = 1.33 \Rightarrow \text{Sin } r = \frac{\text{Sin } 30°}{1.33} = .3759$

$\Rightarrow r = \mathbf{22.1°}$

Q4 $_an_g = 1.5 \qquad {}_gn_a = \frac{1}{_an_g} = \frac{1}{1.5} = \mathbf{\frac{2}{3}}$

Q5 $_gn_w = \frac{1}{_wn_g} = \frac{1}{1.13} = \mathbf{0.88}$

Q6 $_gn_a = \frac{\text{Sin } 35°}{\text{Sin } 69°}$

$_an_g = \frac{1}{_gn_a} = \frac{1}{\frac{\text{Sin } 35°}{\text{Sin } 69°}} = \frac{\text{Sin } 69°}{\text{Sin } 35°} = \mathbf{1.63}$

Q7 $\frac{\text{Sin } i}{\text{Sin } 15°} = {}_dn_a \qquad \therefore \qquad \frac{\text{Sin } i}{\text{Sin } 15°} = \frac{1}{2.42}$

$\Rightarrow \text{Sin } i = \frac{\text{Sin } 15°}{2.42} = \frac{0.2588}{2.42} = 0.10695$

$i = \text{Sin}^{-1}(.10695) = 6.1395$, i.e. $i = \mathbf{6.1°}$

Q8 $\frac{\text{Sin } r}{\text{Sin } 20°} = 2.42 \Rightarrow \text{Sin } r = 0.8277$

$\Rightarrow r = \mathbf{55.9°}$

Exercise 4.2

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

Q2 $\frac{\text{Real depth}}{\text{Apparent depth}} = {}_an_w$

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

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

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

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

Q4 Real depth = 6

Appears as cube $\Rightarrow$ Apparent depth = 5

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

Q5 Let x = the real depth = thickness of block, i.e.

Real depth = x, Apparent depth = $x - 3.33$

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

$1.5x - 1.5(3.33) = x$

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

$0.5x = 4.995$

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

Exercise 4.3

Q1 $n = \frac{c_{air}}{c_{medium}}$ $\Rightarrow c_{mediun} = \frac{c_{air}}{n}$

$= \frac{3 \times 10^8}{1.5}$

$= \mathbf{2 \times 10^8\ ms^{-1}}$

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

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

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

Exercise 4.4

Q1 $n = \frac{1}{\text{Sin } C} = \frac{1}{\text{Sin } 40°} = \mathbf{1.56}$

Q2 $n = \frac{1}{\text{Sin } C} = \frac{1}{\text{Sin } 24.6°} = \mathbf{2.40}$

Q3 $n = \frac{1}{\text{Sin } C}$ $\Rightarrow$ $\text{Sin } C = \frac{1}{n} = \frac{1}{1.2}$

$\Rightarrow$ $\text{Sin } C = 0.8333$

$\Rightarrow$ $C = \mathbf{56.4°}$

Q4 $\text{Sin } C = \frac{1}{n} = \frac{1}{1.33} = 0.7518797$

$\Rightarrow$ $C = \mathbf{48.75°}$

Q5 $\text{Sin } C = \frac{1}{n} = \frac{1}{1.66}$ $\Rightarrow$ $C = \mathbf{37.04°}$

Q6 $n = \frac{1}{\text{Sin } C} = \frac{1}{\text{Sin } 40°} = \frac{1}{0.6428} = 1.56$

$n = \frac{\text{Real depth}}{\text{Apparent depth}}$ $\Rightarrow 1.56 = \frac{12}{\text{Apparent depth}}$

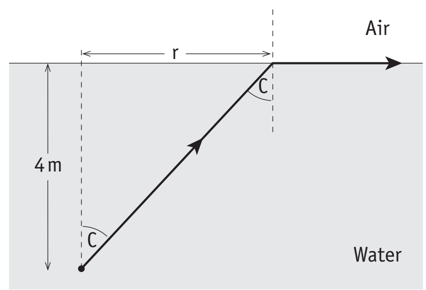
$\Rightarrow$ Apparent depth = **7.69 cm**

Q7 $n = 1.33$

$\Rightarrow$ $\frac{1}{\text{Sin } C} = 1.33$ $\Rightarrow$ $C = 48.75°$

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

i.e. radius = **4.56 m**



Q8 $\text{Tan C} = \frac{2.3}{2} \Rightarrow \text{C} = 48.99°$

$n = \frac{1}{\text{Sin C}} = \frac{1}{\text{Sin } 48.99°} = \mathbf{1.33}$

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 $45° > C$ i.e. $C < 45°$

$\Rightarrow \text{Sin } C < \text{Sin } 45° \Rightarrow \text{Sin } C < 0.707$

$\therefore \frac{1}{\text{Sin } C} > \frac{1}{0.707}$

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

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

$\therefore$ Refractive index must be greater than 1.414

Exercise 5.1

Q1 $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{40} + \frac{1}{25} = \frac{1}{f}$

$\Rightarrow$ f = **15.38 cm, real**.

Q2 $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{100} + \frac{1}{v} = \frac{1}{30} \Rightarrow \frac{1}{v} = \frac{1}{30} - \frac{1}{100}$

$= \frac{100 - 33}{(30)(100)} \Rightarrow v =$ **42.86 cm**

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

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

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

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

Q3 $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{20} + \frac{1}{v} = \frac{1}{30} \Rightarrow \frac{1}{v} = \frac{1}{30} - \frac{1}{20}$

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

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

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

Image is **6 cm** high.

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

Real image	Virtual image
$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$	$\frac{1}{u} - \frac{1}{v} = \frac{1}{f}$
$\frac{1}{u} + \frac{1}{2u} = \frac{1}{50}$	$\frac{1}{u} - \frac{1}{2u} = \frac{1}{50}$
$\frac{2+1}{2u} = \frac{1}{50}$	$\frac{1}{2u} = \frac{1}{50}$
$\Rightarrow 2u = 150$	$\Rightarrow u =$ **25 cm**
$u =$ **75 cm**	

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

Image is twice the height of object

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

Real image	Virtual image
$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$	$\frac{1}{u} - \frac{1}{v} = \frac{1}{f}$
$\frac{1}{u} + \frac{1}{2u} = \frac{1}{20}$	$\frac{1}{u} - \frac{1}{2u} = \frac{1}{20}$
$\frac{2+1}{2u} = \frac{1}{20}$	$\frac{2-1}{2u} = \frac{1}{20}$
$\frac{3}{2u} = \frac{1}{20}$	$\frac{1}{2u} = \frac{1}{20}$
$\Rightarrow \quad 2u = 60$	
$u =$ **30 cm**	$\Rightarrow \quad u =$ **10 cm**

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

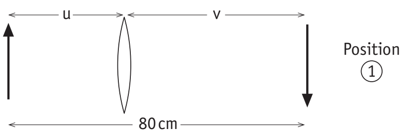
$m = \frac{3}{0.08} = \frac{v}{u}$	$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$
$\therefore \quad 3u = 0.08v$	$\frac{1}{0.2667} + \frac{1}{10} = \frac{1}{f}$
$u = \frac{(0.08)10}{3}$	$3.75 + 0.1 = \frac{1}{f}$
$u = 0.2667$	$\Rightarrow \quad \frac{1}{f} = 3.85$
	$f = 0.2597$ m
	$f =$ **26.0 cm**

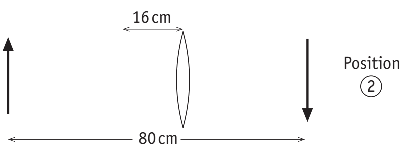
Q7 **Convex lens**, since a concave lens does not form a real image.

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

$v = 4$	$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$
$\Rightarrow u = \frac{4}{15}$	$\frac{1}{(\frac{4}{15})} + \frac{1}{4} = \frac{1}{f}$
	$\frac{15}{4} + \frac{1}{4} = \frac{1}{f}$
	$\frac{15+1}{4} = \frac{1}{f} \Rightarrow f = \frac{1}{4}$ m
	i.e. $f =$ **25 cm**

Q8





Let f be the focal length of lens.

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

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

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

Image distance $= v - 16$

$\therefore \quad \frac{1}{u+16} + \frac{1}{v-16} = \frac{1}{f}$ **(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**

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

$\Rightarrow f =$ **19.2cm**

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

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

Q9 (i) u and v are interchangable.

$\therefore$ Distance between lenses $= 13.3 - 8.0$

$=$ **5.3 cm**

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

$\Rightarrow f =$ **4.995 cm**

Exercise 5.2

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

$u = 30,\ f = 20$

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

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

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

$-\frac{1}{v} = \frac{-5}{60}$

$\Rightarrow \frac{1}{v} = \frac{5}{60}$

$60 = 5v$

$v = \frac{60}{5}$

$v = \mathbf{12\ cm}$

Concave lens image is always **virtual**.

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

Concave lens $\Rightarrow$

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

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

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

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

$2v = 20$

$v = \mathbf{10\ cm}$

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

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

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

$\therefore$ Height of image

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

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

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

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

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

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

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

$\Rightarrow 3v = 120$

$\Rightarrow v = 40$ cm

$u = 3v$

$\Rightarrow u = \mathbf{120\ cm}$

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

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

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

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

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

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

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

Exercise 5.3

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

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

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

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

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

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

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

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

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

Its sign is + ∴ **convex**.

Q7 For convex lens $f = 10$ cm

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

For concave lens $f = 15$ cm

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

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

⇒ Focal length of combination

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

Sign + ⇒ combination is convex.

$h_o = 2$ cm, $u = 20$, $v = ?$, $f = 30$

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

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

⇒ Image is **virtual**.

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

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

Q9 Let f_1 = focal length of convex lens.

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

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

Q10 Let f_2 = focal length of concave lens.

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

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

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

$f_2 = \mathbf{13.33\ cm}$

Exercise 6.1

Q1 (i) 20×10^{-3} s = $\mathbf{2 \times 10^{-2}}$ **s**

(ii) 500 ms = 500×10^{-3} = **0.5 s**

(iii) 4000 ms = 4000×10^{-3} s = **4 s**

(iv) 1 µs = $\mathbf{1 \times 10^{-6}}$ **s**

(v) 50 µs = 50×10^{-6} s = $\mathbf{5 \times 10^{-5}}$ **s**

(vi) ½ hr = (½)(60)(60) s = **1800 s**

(vii) Two days = (2)(24)(60)(60) s = **172 800 s**

(x) One year = (365)(24)(60)(60)
= **31 536 000 s**

Q2 1×10^6 s = $\frac{1 \times 10^6}{(24)(60)(60)}$ days = **11.57 days**

Q3 no working out reqd.

Q4 (i) 6.25 km = $\mathbf{6.25 \times 10^{3}}$ **m**

(ii) 1 cm = $\mathbf{1 \times 10^{-2}}$ **m**

(iii) 20 mm = 20×10^{-3} = $\mathbf{2 \times 10^{-2}}$ **m**

(iv) 4 nm = $\mathbf{4 \times 10^{-9}}$ **m**

Q5 (a) Average speed = $\frac{\text{Distance}}{\text{Time}}$

= $\frac{2000}{(4)(60)}$ = **8.33 ms^{-1}**

(b) Average speed = $\frac{100}{10}$ = **10 ms^{-1}**

Q6 Time = $\frac{\text{Distance}}{\text{Average speed}} = \frac{200\,000}{25}$ = **8000 s**

Q7 Time = $\frac{\text{Distance}}{\text{Average speed}} = \frac{2\,000\,000}{200}$ = **10 000 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 m s^{-1}**

Q9 (i) $s = ut = (2)(25)$ = **50 m**

(ii) $s = ut$ = (2) (½)(60)(60) = **3600 m**

(iii) $s = ut = (2)(1 \times 10^{-3})$ = $\mathbf{2 \times 10^{-3}}$ **m**

(iv) $s = ut$ = **2*t* metres**

Exercise 6.2

Q1 Average velocity = $\frac{\text{Displacement}}{\text{Time}}$
= $\frac{\text{2000 m South East}}{5 \times 60 \text{ s}}$ = **6.67 m s^{-1} South East**

Q2 $s = ut = (30)(10)$ = **300 m South**

Q3 (i) $s = ut = 10 \times 1$ = **10 m**

(ii) $s = ut = 10 \times 10$ = **100 m**

(iii) $s = ut = (10)(t)$ = **10*t* metres**

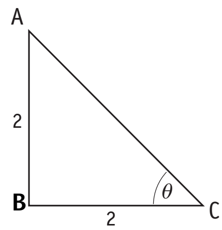
(iv) $s = ut = (10)(2 \times 10^{-6})$ = $\mathbf{2 \times 10^{-5}}$ **m**

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°**

(v) 2.83 m W 45° N (North West)

(vi) 2.83 m E 45° S (South East)

Q5 Distance = perimeter of semi-circle = ½$(2\pi r)$
= $\pi r = 5\pi$ = **15.71 m**

Displacement of B from A = **10 m East**

(i) Average speed = $\frac{\text{Distance}}{\text{Time}} = \frac{15.71}{10}$
= **1.571 m s^{-1}**

(ii) Average velocity = $\frac{\text{Displacement}}{\text{Time}} = \frac{10}{10}$
= **1 m s^{-1} 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

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

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

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

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

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

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

Q4 (i) Velocity gained = Acceleration × Time = (3)(1) = $\mathbf{3\ m\ s^{-1}}$

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

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

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

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

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

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

Exercise 7.2

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

$$v = u + at = 10 + 2(12) = \mathbf{34\ m\ s^{-1}}$$

$$s = ut + \tfrac{1}{2}at^2 = (10)(12) + \tfrac{1}{2}(2)(12)^2 = 120 + 144 = \mathbf{264\ m}$$

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

$$v = u + at$$
$$30 = 14 + a(20)$$
$$16 = 20a$$
$$a = \tfrac{16}{20} = \mathbf{0.8\ m\ s^{-2}}$$

$$s = ut + \tfrac{1}{2}at^2$$
$$s = (14)(20) + \tfrac{1}{2}(0.8)(20)^2$$
$$s = 280 + 160$$
$$\mathbf{s = 440\ m}$$

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

$$v^2 = u^2 + 2as$$
$$12^2 = 2^2 + 2a(50)$$
$$144 - 4 = 1000$$
$$a = \mathbf{1.4\ m\ s^{-2}}$$

$$v = u + at$$
$$12 = 2 + 1.4t$$
$$t = \tfrac{10}{1.4} = \mathbf{7.14\ s}$$

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

$$v = u + at$$
$$20 = 60 + a4$$
$$-40 = 4a$$
$$a = \mathbf{-10\ m\ s^{-2}}$$

$$s = ut + \tfrac{1}{2}at^2$$
$$s = (60)(4) + \tfrac{1}{2}(-10)(4)^2$$
$$s = \mathbf{160\ m}$$

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

$$s = ut + \tfrac{1}{2}at^2$$
$$3000 = 6(60) + \tfrac{1}{2}a(60)^2$$
$$3000 - 360 = 1800a$$
$$a = \mathbf{1.467\ m\ s^{-2}}$$

$$v = u + at$$
$$v = 6 + (1.467)(60)$$
$$v = \mathbf{94.02\ m\ s^{-1}}$$

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

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

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

$$v = u + at$$
$$0 = 20 - 3(t)$$
$$t = \tfrac{20}{3} = \mathbf{6.667\ s}$$

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

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

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

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

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

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

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

$$v = u + at$$
$$v = 5 + (-4)(5)$$
$$v = \mathbf{-15\ m\ s^{-1}}$$

i.e. 15 m s^{-1} in opposite direction of original motion v.

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. $t^2 = 12t$

$t^2 - 12t = 0$, i.e. $t(t - 12) = 0$

$\Rightarrow t = 0$ or $t = 12$

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

Distance of bike from P at this instant

$= S_1 = (12)(12)$

= 144 m from P.

Exercise 7.4

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

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

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

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

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

= 2.025 m s^{-2}

Exercise 7.5

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

$$v^2 = u^2 + 2as$$
$$v^2 = 0^2 + 2(9.8)(60)$$
$$v = \sqrt{1176}$$
$$v = \mathbf{34.29\ m\ s^{-1}}$$

$$v = u + at$$
$$34.29 = 9.8t$$
$$t = \mathbf{3.5\ s}$$

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

$$v^2 = u^2 + 2as$$
$$0 = (200)^2 + 2(-9.8)\ s$$
$$s = \frac{200^2}{19.6} = \mathbf{2040.8\ m}$$

$$v = u + at$$
$$0 = 200 - 9.8t$$
$$t = \mathbf{20.41\ s}$$

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

$$s = ut + \tfrac{1}{2}at^2$$
$$s = (0)(3) + \tfrac{1}{2}9.8(3)^2$$
$$s = \mathbf{44.1\ m}$$

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

$$v^2 = u^2 + 2as$$
$$22^2 = 0 + 2a(30)$$
$$a = \mathbf{8.067\ m\ s^{-2}}$$

$$v = u + at$$
$$22 = 0 + 8.067t$$
$$t = \mathbf{2.73\ s}$$

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

$$v^2 = u^2 + 2as$$
$$0 = 80^2 + 2(-9.8)(s)$$
$$s = \frac{80^2}{19.6} = \mathbf{326.5\ m}$$

$$v = u + at$$
$$0 = 80 - 9.8t$$
$$t = \frac{80}{9.8}$$
$$t = \mathbf{8.16\ s}$$

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

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

(ii) *Alternative Solution*

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

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

$$s = ut + \tfrac{1}{2}at^2$$
$$100 = u(2) + \tfrac{1}{2}(-9.8)(2)^2$$
$$100 = 2u - 19.6$$
$$\Rightarrow u = \mathbf{59.8\ m\ s^{-1}}$$

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

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

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

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

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

Time difference 10.204 –2 = **8.204 s**

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

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

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

$s = 29.39$ m

$\Rightarrow$ Total height above ground:

$= 29.39 + 16$

$=$ **45.39 m**

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

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

$v = u + at_1$

$o = 24 - 9.8t_1$

$t_1 = 2.449$ s

Time t_2 from greatest height to ground:

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

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

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

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

Total time $= t_1 + t_2$

$= 2.449 + 3.044$

$=$ **5.493 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: $t = 5.49$ s or a negative solution]

(iii) From greatest height to ground:

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

$v = u + at$

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

$v =$ **29.83 m s^{-1}**

Q8 On Earth:

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

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

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

$u =$ **6.26099 m s^{-1}**

On Moon:

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

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

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

$\Rightarrow s =$ **12 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: $S_1 = S_2$

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

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

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

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

$t = 58.28$ s or $t = 1.715$ s

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

It takes the second body $58.28 - 10 =$ **48.28 s** to catch up.

Distance from A $= S_1 = ut$

$= (40)(58.28)$

$=$ **2331.2 m**

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

$v = u + at$

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

$u =$ **50.8 m s^{-1}**

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

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

Height above ground $= 128.4 + 40$

$=$ **168.4 m**

Exercise 8.1

Q3 (iv) $R^2 = 3^2 + 4^2 = 25 \Rightarrow R = \mathbf{5\ N}$

$\tan\theta = \frac{3}{4} \Rightarrow \theta = \mathbf{36.87°}$

(v) $R^2 = 2^2 + 2^2 = 8 \Rightarrow R = \sqrt{8} = \mathbf{2.83\ N}$

$\tan\theta = \frac{2}{2} = 1 \Rightarrow \theta = \mathbf{45°}$

(vi) $R^2 = 5^2 + 12^2 = 169$

$\Rightarrow R = \sqrt{169} = \mathbf{13}$

$\tan\theta = \frac{5}{12} \Rightarrow \theta = \mathbf{22.62°}$

Exercise 8.2

Q1 (a) $R_1 = \sqrt{2^2 + 2^2} = 2.83$

$\therefore$ Overall resultant = 2.83 +5 = 7.83 N in direction of 5 N force

(b) $R_1 = \sqrt{3^2 + 3^2} = 4.24$ N

Resultant = 6 + 4.24 = 10.24 N in direction of 6 N force.

(c) $R_1 = \sqrt{10^2 + 10^2} = 14.14$ N

$R = 14.14 - 10 = 4.14$ N

at 45° to each of the perpendicular 10 N forces.

(d) $R_1 = \sqrt{4^2 + 4^2} = 5.66$

$R = 5.66 - 2 = 3.66$ N (in opposite direction to 2 N force.

Exercise 8.3

Q1 Horizontal component = 200 Cos 70° = **68.40 N**
Vertical component = 200 Sin 70° = **187.94 N**

Q2 (i) Horizontal force on cart = Horizontal component = 3500 Cos 25° = **3172.1 N**

(ii) Vertical force on cart = Vertical component = 3500 Sin 25° = **1479.2 N**

Q3 Horizontal component = 100 Cos 60° = **50**
Vertical component = 100 Sin 60° = **86.6**

Q4 Horizontal component = 200 Sin 40° = **128.6**
Vertical component = 200 Cos 40° = **153.2**

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

Parallel comp = 6 Cos 40° = 4.596 m s^{-1}

Perpendicular comp = 6 Sin 40° = 3.857 m s^{-1}

Time to cross lake $= \dfrac{\text{Width of lake}}{\text{Perp comp}}$

$= \dfrac{2000}{3.857}$ = **518.5 s**

Distance travelled parallel to side in this time
= (Parallel comp) × Time
= (4.596)(518.5) = **2383 m**

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

Q6 Comp parallel to roof = 40 Sin 30° = **20 N**
Comp perp to roof = 40 Cos 30° = **34.64 N**

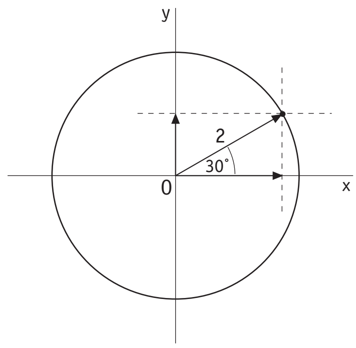
Q7 Horizontal component = 4 Cos 30° = **3.46 $\mathbf{m\ s^{-1}}$**
Vertical component = 4 Sin 30° = **2 $\mathbf{m\ s^{-2}}$**

Q8 Parallel component = 30 Cos 20° = **28.19 N**
Perpendicular component = 30 Sin 20° = **10.26 N**

Q9 Parallel component = **W Cos θ**
Perpendicular component = **W Sin θ**

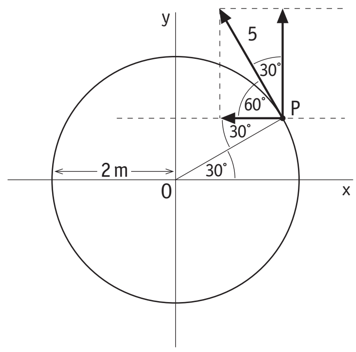
Q10 (i) Displacement: Comp along *ox* = 2 Cos 30°
= **1.732 m**

Comp along *oy* = 2 Sin 30 = **1.0 m**



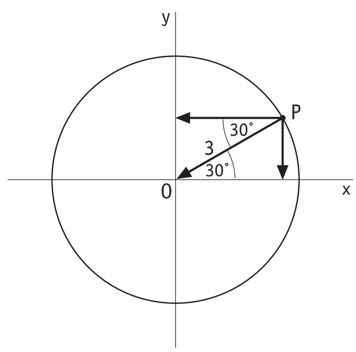
(ii) Velocity: Comp along *ox* = –5 Sin 30
= **–2.5 $\mathbf{m\ s^{-1}}$**

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



(iii) Acceleration:
Comp along *ox* = –3 Cos 30
= **–2.60 $\mathbf{m\ s^{-2}}$**

Comp along *oy* = –3 Sin 30 = **–1.5 $\mathbf{m\ s^{-2}}$**



Exercise 9.1

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

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

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

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

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

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

(ii) $v = u + at$

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

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

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

$= (6)(12) + \frac{1}{2}(4)(12)^2$

$= 72 + 288$

$= \mathbf{360\ m}$

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

$v = u + at$

$10 = 2 + a4$

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

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

Q7 $w = mg$

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

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

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

(iv) $w = (m)9.8 = \mathbf{9.8\ \mathit{m}}$ **newtons**

Q8 $F = ma$

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

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

(i) $v = u + at$

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

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

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

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

$s = \mathbf{800\ m}$

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

$v = u + at$

$0 = 80 + a(0.1)$

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

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

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

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

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

$v = u + at$

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

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

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

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

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

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

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

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

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

$a = 3.859$ N

$F = ma = (1200)(3.859) = 4630$ 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.

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

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

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

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

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 $F = ma$
$\Rightarrow 19\,600 - T = (2000)(2)$
$\mathbf{T = 15\,600 \text{ N}}$

Q4 Reading on balance = Tension
Net force = Mass × 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 × 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
= **200 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 ⇒ (6000)(10) + (2000)(2) = $8000v \Rightarrow v =$ **8 m s^{-1} in original direction of motion**.

Q7 P before = P after ⇒ (6000)(10) + (2000)(–20)
$= 8000v$
$60\,000 - 4000 = 8000v \Rightarrow v =$ **7 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 **2 m s^{-1}**

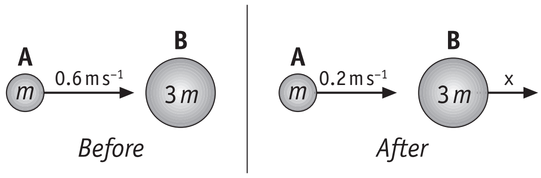
Q9 P before = P after
$(100)(10) + (60)(-15) = 100v + (60)(8)$
$\Rightarrow 1000 - 900 = 100v + 480 \Rightarrow 100v = -380$
$\Rightarrow v = -3.8 \text{ m s}^{-1}$ i.e. 100 kg block moves with **3.8 m s^{-1}** in opposite direction to its initial velocity.

Q10 P.C.M.

$(\cancel{m})(0.6) + (\cancel{3m})(0) = (\cancel{m})(0.2) + (\cancel{3m})x$

$0.6 = 0.2 + 3x$

$3x = 0.4 \Rightarrow x = \mathbf{0.133\ m\ s^{-1}}$



Q11 (i) $0 = 500v + 2 \times 500 \Rightarrow v = -2\,\text{m s}^{-1}$

i.e. recoil velocity is $\mathbf{2\ m\ s^{-1}}$

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

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

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

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

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

Q12 P before = P 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

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

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

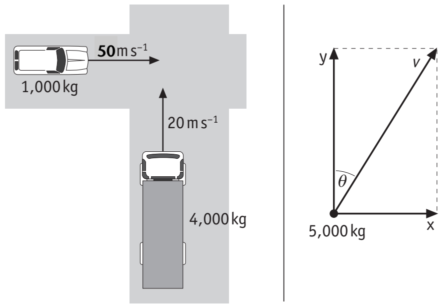
Force exerted on bullet

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

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

$\therefore$ **Forces have the same magnitudes** *QED*

Q13



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

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

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

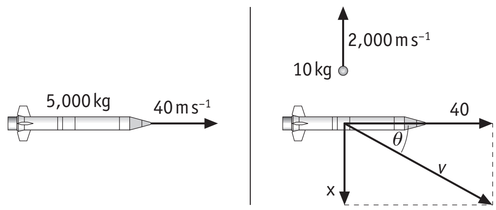
$\text{Tan}\,\theta = \dfrac{x}{y} = \dfrac{10}{16} \Rightarrow \theta = 32°$

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 before = P after

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



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

Resultant velocity: $v = \sqrt{40^2 + 4^2}$

$= 40.1995\ \text{m s}^{-1}$

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

Velocity of rocket = **40.1995 m s^{-1} at 5.7° with original direction of motion**.

Q15 $(0.08)(5) + 0 = 0.280v$

$v = \mathbf{1.43\ m\ s^{-1}}$

Change in momentum for 80 g mass

= (final momentum – initial momentum)

$= (0.08)(1.43 - 5) = -\,0.286\ \text{kg m s}^{-1}$

Change in momentum for 200 g mass

$= (.2)(1.43) = 0.286\ \text{kg m s}^{-1}$

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

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

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

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

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

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

$\therefore \quad m = \rho v$

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

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

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

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

Volume = Area $\times$ Thickness
$2.74 \times 10^{-6} = A \times 2 \times 10^{-6}$
$\Rightarrow \mathbf{A = 1.37 \text{ m}^2}$

Exercise 10.2

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

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

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

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

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

Force = Weight of block = (4)(9.8) = **39.2 N**

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

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

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

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

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

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

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

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

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

Exercise 10.3

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

Q2 $P = \rho g h = (1000)(9.8)(33) = \mathbf{323\ 400\ Pa}$

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

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

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

(ii) $P = \rho g h = (1000)(9.8)(1.1) = \mathbf{10\ 780\ Pa}$

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

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

Resultant upward force on block
= 646.8 – 588 = 58.8 N
Weight of block = 70 N ⇒ it will sink.

Exercise 10.4

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

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

$P_1V_1 = P_2V_2$

$V_2 = \frac{P_1V_1}{P_2} = \frac{1 \times 10^5 \times 3}{3 \times 10^5}$

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

Q2 (i) $P_1V_1 = P_2V_2$

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

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

(ii) $P_1V_1 = P_2V_2$

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

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

(iii) $P_1V_1 = P_2V_2$

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

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

= 4 000 000 Pa = $\mathbf{4 \times 10^6}$ **Pa**

Q3 No calculations required.

Q4 (i) $P_1V_1 = P_2V_2$

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

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

$= 3.5 \times 10^{-4} \text{ m}^3$ = **350 cm³**

(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 cm³**

(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 cm³**

Q5 **20 Pa m³** since at a fixed temperature *PV* is a constant by Boyle's Law.

Exercise 10.5

Gravity solutions

Q1 $F = \frac{Gm_1m_2}{d^2} = \frac{(6.7 \times 10^{-11})(1)(1)}{1}$

$= \mathbf{6.7 \times 10^{-11}}$ **N**

Q2 $F = \frac{Gm_1m_2}{d^2} = \frac{(6.7 \times 10^{-11})(76)(6 \times 10^{24})}{(6.4 \times 10^6)^2}$

= **745.9 N**

Q3 $F = \frac{Gm_1m_2}{d^2} = \frac{(6.7 \times 10^{-11})(90)(1000)}{2^2}$

$= \mathbf{1.508 \times 10^{-6}}$ **N**

Q4 $F = \frac{Gm_1m_2}{d^2} = \frac{(6.7 \times 10^{-11})(76)(7 \times 10^{22})}{(1.7 \times 10^6)^2}$

= **123.34 N**

Q5 $F = \frac{Gm_1m_2}{d^2} = \frac{(6.7 \times 10^{-11})(6 \times 10^{24})(7 \times 10^{22})}{(3.8 \times 10^8)^2}$

$= \mathbf{1.95 \times 10^{20}}$ **N**

Q6 $F = \frac{Gm_1m_2}{d^2} = \frac{(6.7 \times 10^{-11})(6 \times 10^{24})(1.9 \times 10^{30})}{(1.5 \times 10^{11})^2}$

$= \mathbf{3.39 \times 10^{22}}$ **N**

Exercise 10.6

Q1 $g = \frac{GM}{R^2} = \frac{(6.7\times10^{-11})(1.9\times10^{27})}{(7\times10^7)^2}$

$= 25.98\ \text{m s}^{-2}$

$= \mathbf{26\ m\ s^{-2}}$

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

Q2 $g = \frac{GM}{R^2} = \frac{(6.7\times10^{-11})(1.9\times10^{22})}{(1.7\times10^6)^2}$

$= \mathbf{1.62\ m\ s^{-2}}$

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

Q3 $g_s = \frac{GM_s}{R_s^2} = \frac{(6.7\times10^{-11})(1.9\times10^{30})}{(6.956\times10^8)^2}$

$= \mathbf{263\ m\ s^{-2}}$

Q4 Weight = force of gravity

$\Rightarrow mg = \frac{GMm}{R^2} \Rightarrow g = \frac{GM}{R^2}$

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 $d = R + h$

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

Q6 $g = \frac{GM}{(R+h)^2}$, by previous question

$= \frac{(6.7\times10^{-11})(6\times10^{24})}{(6.4\times10^6+100\times10^3)^2} = \mathbf{9.51\ m\ s^{-2}}$

Q7 Value on surface = 9.8

Half value on surface = 4.9

Let d = distance from centre of Earth to object.

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

$= \frac{(6.7\times10^{-11})(6\times10^{24})}{4.9}$

$\Rightarrow d = 9.058\times10^6\ \text{m}$

Radius of Earth $= 6.4\times10^6$

$\therefore$ Height above surface =

$9.058\times10^6 - 6.4\times10^6 = 2.7\times10^6\ \text{m}$

i.e. $h = \mathbf{2.7\times10^6\ m}$

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

$\Rightarrow d = \sqrt{\frac{GM}{0.98}} = \sqrt{\frac{((6.7\times10^{-11})(6\times10^{24}))}{0.98}}$

$= 2.03\times10^7$

Height $= d - R = 2.03\times10^7 - 6.4\times10^6$

$= \mathbf{1.39\times10^7}$

Q8 $g = \frac{GM}{R^2} \Rightarrow M = \frac{gR^2}{G} = \frac{(9.8)(6.4\times10^6)}{6.7\times10^{-11}}$

$= \mathbf{5.99\times10^{24}\ kg}$

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

Distance from centre of Earth is $3R$.

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

Q10 No calculation required.

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

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

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

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

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

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

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

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

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

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

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

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

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

Exercise 10.7

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

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

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

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

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

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

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

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

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

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

Moments about A:
Clockwise:
(10)(10) +(20)(30) + (2)(50) + (28)(100)
= 3600 N cm
Anti-clockwise:
(20)(20) +(40)(80) = 3600 N cm
∴ Sum of moments = 3600 – 3600 = 0

Moments about B:
Clockwise:
(20)(10) +(2)(20) + (28)(70) = 2200 N cm
Anti-clockwise:
(10)(20) +(40)(50) = 2200 N cm
∴ Sum of moments = 0

Moments about C:
Clockwise:
(20)(30) + (28)(50) = 2000 N cm
Anti-clockwise:
(40)(30) +(20)(20) + (10)(40) = 2000 N cm
∴ Sum of moments = 0

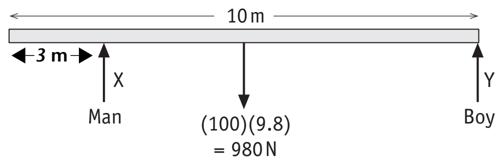
Moments about D:
Clockwise:
(40)(20) + (20)(80) = 2400 N cm
Anti-clockwise:
(10)(90) +(20)(70) + (2)(50) = 2400 N cm
∴ Sum of moments = 0

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:

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

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

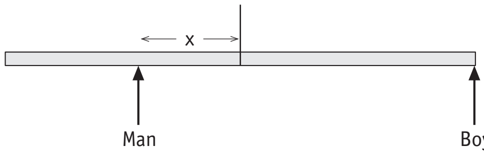
Q7



Take moments about boy:

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

∴ Man exerts **700 N** and boy (980 – 100) = **280 N**



Man supports three times weight of boy

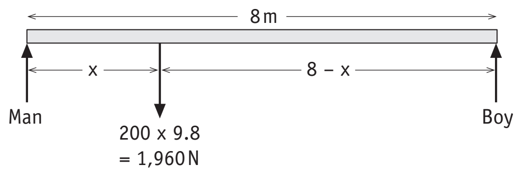
⇒ Man exerts $\frac{3}{4}(980)$ N = 735 N

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

Take moments about centre:

(735)(X) = (245) (5) ⇒ X = **1.667 m**

Q8



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

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

Moments about weight: $(1568)x = (392)(8 - x)$
$\Rightarrow 1568x + 392x = 3136 \Rightarrow x =$ **1.6 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*:
$$v = u + at$$
$$30 = 0 + a(10)$$
$$\Rightarrow a = 3\ \text{m s}^{-2}$$

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

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

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

$t = 20, a = ?, s = ?$
Find *a*:
$v = u + at \Rightarrow 22.22 = a(20) \Rightarrow a = 1.11\ \text{m s}^{-2}$
Find *F*:
$F = ma \Rightarrow F = (1000)(1.11) = 1110\ \text{N}$
Find *s*:
$s = ut + \frac{1}{2}at^2 \Rightarrow s = \frac{1}{2}(1.11)(20)^2 \Rightarrow s = 222\ \text{m}$

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

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

Q9 Let h = Vertical height
$\text{Sin } 40° = \frac{h}{10} \Rightarrow h = 10 \text{ Sin } 40°$

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

= Force × distance

$\therefore 8910 = (12)\ s \Rightarrow s = \mathbf{742.5\ m}$

(v) From above: **8910 J**

Q8 Work done on bullet = loss in E_k

$= (0.5)(4 \times 10^{-3})(200)^2 = 80\ J$

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

Work done = Fs = (160)(0.25)

= 40 J = loss in E_k

Remaining E_k = 80 J – 40 J = 40 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 $2v$

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

$\Rightarrow$ **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
= **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

$mg(2 - 2\ \text{Cos}\ 40°) = \frac{1}{2}mv^2$

$v = \sqrt{4g(1 - \text{Cos}\ 40°)} = \mathbf{3.028\ m\ s^{-1}}$

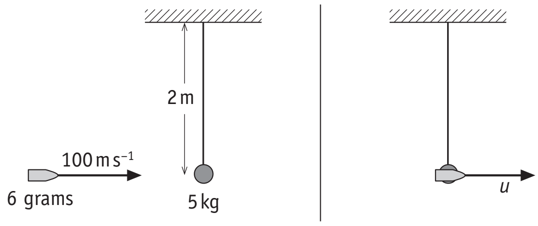
Q8 $(10)(30) + 0 = 25v \Rightarrow v = \mathbf{12\ m\ s^{-1}}$

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 = **2700 J**

Q9



Conservation of momentum:

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

Gain in E_p = Loss in E_k

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

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

Exercise 11.4

Q1 $P = \frac{W}{t} = \frac{600\ 000}{12}$ = **50 kw**

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

Q3 $P = \frac{E}{t} = \frac{60\ 000}{60}$ = **1000 W**

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

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

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

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

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

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

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

Q11 $W = Pt = (1000)(60)(60) =$ **3.6 MJ**

Exercise 11.5

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

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

= 39 200 W

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

= **65.3%**

Q3 25% of input power = 130 kW

75% of power becomes heat ∴ amount converted to heat = $\left(\frac{130}{25}\right)$75 kW = **390 kW**

Exercise 12.1

Q1 $180° = \pi$ rad $\Rightarrow 1° = \frac{\pi}{180}$ rad

$\Rightarrow 10° = \frac{10\pi}{180}$ rad $= \frac{\pi}{18}$ rad

$48° = \frac{48\pi}{180}$ $=$ **0.878 rad**

Q2 $\frac{\pi}{5}$ rad $= \frac{180°}{5}$ $=$ **36°**

$\frac{\pi}{7}$ rad $= \frac{180}{7}$ $=$ **25.7°**

1 rad $= \frac{180}{\pi}$ $=$ **57.296°**

4.2 rad $= \frac{(4.2)(180)}{\pi}$ $=$ **240.64°**

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

(i) $s = (3)(1) =$ **3 m**

(ii) $s = (3)(\pi) =$ **9.42 m**

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

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

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

Q5 $\theta = \frac{s}{r} \Rightarrow s = r\theta = (93 \times 10^6)(0.00932)$

$=$ **8.67×10^5 miles**

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

Exercise 12.2

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

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

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

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

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

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

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

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

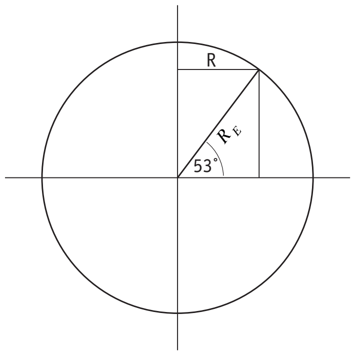
Q4 (i) $v = \omega r = (6)(0) =$ **0 m s^{-1}**

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

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

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

Q6



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

$=$ **7.27×10^{-5} rad s^{-1}**

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

$=$ **465 m s^{-1}**

(iii) $v = \omega R = \omega(R_E \text{ Cos } 53)$

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

$=$ **280 m s^{-1}**

Exercise 12.3

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

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

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

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

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

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

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

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

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

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

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

Q7 $a = \frac{v^2}{r} \Rightarrow r = \frac{v^2}{a} = \frac{(500^2)}{(9)(9.8)} = \mathbf{2834\ m}$

Q8 Loss in E_k = Gain in E_p

$\frac{1}{2}m\,5^2 - \frac{1}{2}mv^2 = mgh$

$\left(\frac{1}{2}\right)(5^2) - \left(\frac{1}{2}\right)v^2 = (9.8)(0.8)$

$12.5 - 7.84 = \frac{v^2}{2} \Rightarrow v = \mathbf{3.05\ m\ s^{-1}}$

$a = \frac{v^2}{r} = \frac{(3.05)^2}{0.8} = \mathbf{11.63\ m\ s^{-2}}$

$F = ma = (0.24)(11.63) = \mathbf{2.79\ N}$

Exercise 12.4

Q1 $v^2 = \frac{GM}{R} = \frac{(6.7\times10^{-11})(6\times10^{24})}{(6.4\times10^6)+(50\times10^6)}$

$\Rightarrow v = \mathbf{2669.8\ m\ s^{-1}}$

$T = \frac{2\pi R}{v} = \frac{(2)(\pi)[(6.4\times10^6)+(50\times10^6)]}{2669.8}$

$= 132733.41\ \text{s} = \mathbf{36.87\ hours}$

Q2 $T^2 = \frac{4\pi^2R^3}{GM} \Rightarrow R = \sqrt[3]{\frac{T^2GM}{4\pi^2}}$

30 min = (30)(60) s

$R = \sqrt[3]{\frac{[(30)(60)]^2(6.7\times10^{-11})(6\times10^{24})}{4\pi^2}}$

$= \mathbf{3.2\times10^6\ m}$

$v = \sqrt{\frac{GM}{R}} = \sqrt{\frac{(6.7\times10^{-11})(6\times10^{24})}{(3.2\times10^6)}}$

$= \sqrt{1.2562\times10^8} = \mathbf{11\ 208\ m\ s^{-1}}$

Q3 $T^2 = \frac{4\pi^2R^3}{GM} \Rightarrow T^2 = \frac{4\pi^2(7.8\times10^{11})^3}{(6.7\times10^{-11})(2.0\times10^{30})}$

$= 1.3981\times10^{17}$

$\Rightarrow T = 3.739\times10^8\ \text{s} = \mathbf{11.9\ years}$

Q4 $T^2 \propto R^3$

$\frac{T_S^{\,2}}{T_E^{\,2}} = \frac{R_S^{\,3}}{R_E^{\,3}} \Rightarrow T_S^{\,2} = T_E^{\,2}\left(\frac{R_S}{R_E}\right)^3 = T_E^{\,2}(9.5)^3$

$T_S = T_E\sqrt{(9.5)^3} = \boldsymbol{T_E}\mathbf{(29.28)\ years}$

Since period of Earth's orbit = 1 year

Q5 $\left[v^2 = \frac{GM}{R}\right]$

$$\frac{v_s^{\ 2}}{v_e^{\ 2}} = \frac{\frac{GM_s}{R_s}}{\frac{GM_E}{R_E}}$$

$$\left(\frac{v_s}{v_e}\right)^2 = \left(\frac{R_E}{R_s}\right)\left(\frac{M_s}{M_E}\right)$$

$R_E = R_s$ and $v_s = 10v_e$

$$\Rightarrow (10)^2 = \frac{M_s}{M_E} \Rightarrow M_s = M_E(100)$$

$$= 6 \times 10^{24} \times 100$$

$$= \mathbf{6 \times 10^{26}\ kg}$$

Q6 $T^2 = \frac{4\pi^2 R^3}{GM} \Rightarrow R = \sqrt[3]{\frac{T^2 GM}{4\pi^2}}$

$$R = \sqrt[3]{\frac{(86\ 400)^2(6.7 \times 10^{-11})(6 \times 10^{24})}{4\pi^2}}$$

$= \mathbf{4.24 \times 10^7\ m}$

$$v^2 = \frac{GM}{R} \Rightarrow v = \sqrt{\frac{GM}{R}} = \sqrt{\frac{(6.7 \times 10^{-11})(6 \times 10^{24})}{4.24 \times 10^7}}$$

$= \mathbf{3079\ m\ s^{-1}}$

Q7 $\omega = \frac{\theta}{t} = \frac{2\pi}{(24)(60)(60)} = (7.27 \times 10^{-5})$ rad s^{-1}

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

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

(ii) $a = \omega^2 r = (7.27 \times 10^{-5})^2(6.4 \times 10^6)$

$= \mathbf{0.0338\ m\ s^{-2}}$

(0.03385 if you don't round off ω)

Exercise 13.1

Q1 $F = ks \Rightarrow F = 4000$ s

(i) $s = 2\,\text{cm} = 2 \times 10^{-2}$ m

$\therefore F = (4000)(2 \times 10^{-2})$ **= 80 N**

(ii) $1000 = 4000$ s $\Rightarrow$ ***s* = 0.25 m**

Q2 $F = ks \Rightarrow 8 = k(0.06) \Rightarrow k = 133.3$

(i) $F = (133.3)(0.02) =$ **2.67 N**

(ii) $15 = (133.3)(s) \Rightarrow s =$ **11.25 cm**

Exercise 13.2

Q1 (i) T = Time for one oscillation = $\frac{4}{20}$ = **0.2 s**

(ii) $f = \frac{1}{T} = \frac{1}{0.2} =$ **5 Hz**

Q2 $T = \frac{20}{50} =$ **0.4 s**

Q3

$$a = \omega^2 s$$
$$2 = \omega^2(0.5)$$
$$\Rightarrow \omega^2 = 4$$

$$a = 4s$$
$$a = 4(0.1) = \mathbf{0.4\ m\ s^{-2}}$$
$$a = 4s \Rightarrow s = \frac{a}{4} = \frac{0.5}{4} = \mathbf{0.125\ m}$$

Q4 Force is max when accel is max and when displacement is max, i.e. force is max at amplitude.

$$a = \omega^2 s$$
$$1 = \omega^2(0.1) \Rightarrow \omega^2 = 10$$
$$a_{max} = \frac{F_{max}}{m} = \frac{60}{12} = 5\ \text{m s}^{-2}$$
$$a = \omega^2 s$$
$$5 = 10 s_{max} \Rightarrow s_{max} = \mathbf{0.5\ m}$$

Q5 $T = \frac{2\pi}{\omega} \Rightarrow \omega = \frac{2\pi}{T}$

$$\therefore \omega = \frac{2\pi}{0.5} \Rightarrow \omega^2 = 157.914$$
$$a = \omega^2 s \Rightarrow a = (157.914)(0.04)$$
$$a = 6.3165\ \text{m s}^{-2}$$
$$F = ma = (4)(6.3165) = \mathbf{25.27\ N}$$

Q6 $a = \omega^2 s \Rightarrow 3 = \omega^2(0.5) \Rightarrow \omega = \sqrt{6}$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{6}} = \mathbf{2.565\ s}$$

Q7 $a = \omega^2 s \Rightarrow 2.5 = \omega^2(0.14) \Rightarrow \omega = 4.226$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{4.226} = 1.487 \Rightarrow f = \mathbf{0.673\ Hz}$$

Q8 $T = \frac{2\pi}{\omega} \Rightarrow \omega = \frac{2\pi}{T} = \frac{2\pi}{1.5} = 4.189$

$$a = \omega^2 s = (4.189)^2(0.25) = \mathbf{4.39\ m\ s^{-2}}$$

Exercise 13.3

Q1 $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T = 2\pi\sqrt{\frac{2}{9.81}} =$ **2.84 s**

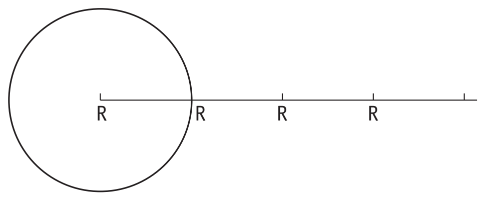
Q2 $T = \frac{90}{50} = 1.8$ s

$$g = 4\pi^2\sqrt{\frac{l}{T^2}} = \frac{(4\pi^2)(0.8)}{(1.8)^2} = \mathbf{9.75\ m\ s^{-2}}$$

Q3 $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow l = \frac{gT^2}{4\pi^2}$

$$\therefore l = \frac{(9.8)(2)^2}{4\pi^2} = 0.9929\ \text{m} = \mathbf{99.29\ cm}$$

Q4



$$g = \frac{GM}{R^2} \qquad g \propto \frac{1}{R^2}$$

R is four times bigger $\Rightarrow g$ is 16 times smaller

$$T = 2\pi\sqrt{\frac{l}{g}}$$
$$T_{height} = 2\pi\sqrt{\frac{l}{\left(\frac{g}{16}\right)}} = \sqrt{16}\left(2\pi\sqrt{\frac{l}{g}}\right)$$

= 4 (Period on surface) = 4(0.4) = **1.6 s**

Exercise 14.1

Q1 $T/K = t/°C + 273.15$

(i) $= 0 + 273.15 =$ **273.15 K**

(ii) $= -100 + 273.15 =$ **173.15 K**

(iii) $= 20 + 273.15 =$ **293.15 K**

(iv) $= 100 + 273.15 =$ **373.15 K**

Q2 $t/°C = T/K - 273.15$

(i) $= 100 - 273.15 =$ **–173.15 °C**

(ii) $= 273 - 273.15 =$ **–0.15 °C**

(iii) $= 373 - 273.15 =$ **99.85 °C**

(iv) $= 500 - 273.15 =$ **226.85 °C**

Exercise 14.2

Q1 No calculations required.

Q2 No calculations required.

Exercise 15.1

Q1 $Q = C\Delta\theta = (1500)(80 - 10) =$ **105 000 J**

Q2 $Q = C\Delta\theta \Rightarrow \Delta\theta = \frac{Q}{C} = \frac{1\,000\,000}{600} =$ **1667° C**

Q3 $Q = C\Delta\theta \Rightarrow C = \frac{Q}{\Delta\theta} = \frac{4000}{10} =$ **400 J K^{-1}**

Q4 $Q = mc\Delta\theta = (2)(4180)(80 - 12) =$ **568 480 J**

Q5 $Q = mc\Delta\theta = (12)(390)(120 - 10) =$ **514 800 J**

Q6 $Q = mc\Delta\theta \Rightarrow C = \frac{Q}{m\Delta\theta} = \frac{11\,088}{(1.6)(25 - 7)}$

$=$ **385 J kg^{-1}K^{-1}**

Q7 $Q = mc\Delta\theta \Rightarrow m = \frac{Q}{c\Delta\theta} = \frac{1\,000\,000}{(451)(100 - 20)}$

$=$ **12.32 kg**

Q8 $Q = mc\Delta\theta \Rightarrow \Delta\theta = \frac{Q}{mc} = \frac{4000}{(0.4)(4180)} = 2.39$

∴ Find temperature of water
$= 20°\,C + 2.39°\,C =$ **22.39° C**

$= 20°$

Q9 $Q = mc\Delta\theta \Rightarrow \Delta\theta = \frac{Q}{mc}$

For copper $\Delta\theta_1 = \frac{40\,000}{(2)(390)} = 51.3°\,C$

For aluminium $\Delta\theta_2 = \frac{40\,000}{(2)(910)} = 22°\,C$

Find temperature of copper
$= 0 + 51.3 = 51.3°\,C$

Find temperature of aluminium
$= 20 + 22°\,C = 42°\,C$
⇒ Copper reaches the higher temperature

Q10 Heat added = heat to copper + heat to water
$= m_c c_c \Delta\theta\uparrow + m_w c_w \Delta\theta\uparrow$
$= (0.08)(390)(60 - 18)$
$+ (0.120))(4180)(60 - 18)$
$= 1310.4 + 21067.2$
= **22 377.6 J**

Q11 Heat supplied $Q = mc\Delta\theta$

$= (5)(4180)(90) = 1\,881\,000$ J

Time $= \frac{\text{Energy supplied}}{\text{Power}} = \frac{1\,881\,000}{1000} =$ **1881 s**

Q12 Let θ = final temperature

Heat lost = Heat gained

$$(0.03)(4180)(100 - \theta) = (0.1)(4180)(\theta - 20)$$

$$3(100 - \theta) = 10(\theta - 20)$$

$$300 - 3\theta = 10\theta - 200$$

$$500 = 13\theta$$

$$\Rightarrow \theta = 38.5° \text{ C}$$

Final Temp = **38.5° C**

Q13 Heat lost by Copper = Heat gained by water + Heat gained by Calorimeter

$$m_c c_c \Delta\theta\downarrow = m_w c_w \Delta\theta\uparrow + m_{cal} c_c \Delta\theta\uparrow$$

$$(0.12)(390)(100 - \theta) = (0.08)(4180)(\theta - 20) + (0.06)(390)(\theta - 20)$$

$$46.8(100 - \theta) = 334.4(\theta - 20) + 23.4(\theta - 20)$$

$$\theta(-46.8 - 334.4 - 23.4) = (-46.8)(100) - 20(334.4) - 20(23.4)$$

$$\Rightarrow 404.6\theta = 11836$$

θ = **29.25° C**

Exercise 15.2

Q1 $Q = ml$

$Q = (10)(3.3 \times 10^5) = \mathbf{3.3 \times 10^6 \text{ J}}$

Q2 $Q = ml = (0.5)(3.3 \times 10^5) = 1.65 \times 10^5$ J $= \mathbf{165 \text{ kJ}}$

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°

$= ml + mc\Delta\theta$

$= (3)(3.3 \times 10^5) + (3)(4180)(99)$

= **2.23 MJ**

Q7 Heat needed = Heat to melt ice + Heat to raise water to 100° + Heat to vaporise water at 100°

$= ml_f + mc\Delta\theta\uparrow + ml_v$

$= (1)(3.3 \times 10^5) + (1)(4180)(100) + (1)(2.3 \times 10^6)$ = **3.05 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 = **159 318 J**

Q9 $\begin{pmatrix}\text{Heat} \\ \text{needed}\end{pmatrix} = \begin{pmatrix}\text{Heat to} \\ \text{melt ice}\end{pmatrix} + \begin{pmatrix}\text{Heat to bring melted} \\ \text{ice from 0° to 100°}\end{pmatrix}$

$= ml_f + mc\Delta\theta\uparrow$

$= (0.06)(3.3 \times 10^5) + (0.06)(4180)(100)$

= **44 880 J**

Heat lost by steam = $m_s l_v$

$\therefore m_s(2.3 \times 10^6) = 44\ 880$

$\therefore m_s$ = **19.5 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

$(0.5)(4180)(80-\theta) = (0.2)(3.3\times10^5) + (0.2)(4180)(\theta-0)$

$167\,200 - 2090\theta = 66\,000 + 836\theta$

$167\,200 - 66\,000 = (836+2090)\theta$

$\theta = \mathbf{34.6° \ C}$

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)

$(0.002)(2.3\times10^6) + (0.002)(4180)(100-\theta) = (0.08)(4180)(\theta-10)$

$4600 + 8.36(100-\theta) = 334.4(\theta-10)$

$4600 + 836 - 8.36\theta = 334.4\theta - 3344$

$4600 + 836 + 3344 = (334.4 + 8.36)\theta$

$\theta = \mathbf{25.6° \ C}$

(ii) Heat lost by steam = Heat gained by water + Heat gained by Cal

i.e. Heat lost by steam $= m_w c_w \Delta\theta\uparrow + m_c c_c \Delta\theta\uparrow$

$\Rightarrow 4600 + 8.36(100-\theta)$

$= 334.4(\theta-10) + 27.3(\theta-10)$

$4600 + 836 - 8.36\theta$
$= 334.4\theta - 3344 + 27.3\theta - 273$

$4600 + 836 + 3344 + 273$
$= (334.4 + 8.36 + 27.3)\theta$

$\theta = \mathbf{24.5° \ C}$

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
$\mathbf{3.3\times10^5\ J\ kg^{-1}}$

Q13 1 litre = 1000 cm^3
$Q = mc\Delta\theta$
Heat needed = Heat to bring kettle from $10° \to 100°$ + Heat water $10° \to 100°$

$= m_{al}c_{al}(90) + m_w c_w(90)$

$= (0.5)(910)(90) + (1.7)(4180)(90)$

$= 40\,950 + 639\,540$
$= 680\,490$ J

Time taken $= \frac{\text{Energy}}{\text{Power}} = \frac{680\,490}{2.5\times10^3} = 272$ s $= \mathbf{4.54\ min}$

$Q = ml = \left(\frac{1.7}{2}\right)(2.3\times10^6) = 1.955\times10^6$ J

Time $= \frac{1.955\times10^6}{2.5\times10^3} = 782$ s = **13.03 min**

Q14 $E_p = mgh = (3.5\times10^{-3})(9.8)(3000) = \mathbf{102.9\ J}$

Let mass melted = m

$Q = ml_f \Rightarrow m = \frac{Q}{l_f} = \frac{102.9}{3.3\times10^5}$
$= 3.1181\times10^{-4}$ kg = 0.31 grams

Residual mass of hailstones = 3.5 – 0.31
= **3.19 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 postion = $\frac{1}{2}$(2 m) = **1 m**

Q4 $c = \lambda f = (1.5)(5) = \mathbf{7.5\ m\ s^{-1}}$

Q5 $c = \lambda f = (3.125)(96 \times 10^6) = \mathbf{3 \times 10^8\ m\ s^{-1}}$

Q6 $c = \lambda f = (6)(50 \times 10^6) = 3 \times 10^8$ m s^{-1} (for station 1)
All radio waves travel at the same speed in air ($\approx$ vacuum)

$\therefore$ For station 2: $c = \lambda f \Rightarrow \lambda = \frac{c}{f} = \frac{3 \times 10^8}{25 \times 10^6}$

$= \mathbf{12\ m}$

Q7 $\lambda = 5 \times 10^{-9} \Rightarrow f = \frac{c}{\lambda} = \frac{3 \times 10^8}{5 \times 10^{-9}} = \mathbf{6 \times 10^{16}\ Hz}$

$\lambda = 1 \times 10^{-11} \Rightarrow f = \frac{c}{\lambda} = \frac{3 \times 10^8}{1 \times 10^{-11}}$

$= \mathbf{3 \times 10^{19}\ Hz}$

Frequency range = $\mathbf{6 \times 10^{16}\ Hz - 3 \times 10^{19}\ Hz}$

Q8 $c = \lambda f = 12 \times 40 = \mathbf{480\ m\ s^{-1}}$

(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

$\therefore$ Period = 30 min = 30×60 sec = 1800 s
$\Rightarrow f = \frac{1}{T} = \frac{1}{1800}$
v = 400 km hr^{-1} = $\frac{400 \times 1000}{60 \times 60}$ m s^{-1}
= 111.11 m s^{-1}

$\therefore c = \lambda f \Rightarrow \lambda = \frac{c}{f} = \frac{111.11}{(\frac{1}{1800})} = \mathbf{199\ 998\ m}$

Q10 In air $c = \lambda f \Rightarrow f = \frac{c}{\lambda} = \frac{340}{0.40} = 850$ Hz
In other medium $\lambda = \frac{c}{f} = \frac{500}{850} = \mathbf{58.82\ cm}$

Exercise 16.2

Q1 No calculations required.

Q2 No calculations required.

Q3 Distance from node to antinode = 5 m

$\therefore \frac{\lambda}{4} = 5 \Rightarrow \lambda = 20$ m

$c = f\lambda \Rightarrow \quad f = \frac{c}{\lambda} = \frac{4}{20} =$ **0.2 Hz**

Q4 $c = f\lambda \Rightarrow \lambda = \frac{c}{f} = \frac{60 \times 10^{-2}}{6} = 0.1$ m

Distance between adjacent nodes = $\frac{\lambda}{2} = 0.05$ m

= **5 cm**

Q5 $c = 340$ m s^{-1}, $f = ?$

$8\left(\frac{\lambda}{2}\right) = 2 \text{ m} \Rightarrow \lambda = \frac{4}{8} = 0.5$ m

$f = \frac{c}{\lambda} = \frac{340}{0.5} =$ **680 Hz**

Exercise 16.3

Q1 $f' = \frac{fc}{c-u} = \frac{(2000)(336)}{336-50} =$ **2349.7 Hz**

Q2 $f' = \frac{fc}{c+u} = \frac{(2000)(336)}{336+50} =$ **1740.9 Hz**

Q3 $f' = \frac{fc}{c-u} \Rightarrow 720 = \frac{(600)(340)}{340-u}$

$\Rightarrow 340 - u = \frac{(600)(340)}{720}$

$\Rightarrow u =$ **56.67 m s^{-1}**

Q4 $f = 1000$ Hz, $u = 40$ m s^{-1}, $c = 336$ m s^{-1}

While approaching: $f' = \frac{fc}{c-u} = \frac{(1000)(336)}{(336-40)}$

= 1135.1 Hz

While going away: $f' = \frac{fc}{c+u} = \frac{(1000)(336)}{(336+40)}$

= 893.6 Hz

Change in frequency = 1135.1 – 893.6

= **241.5 Hz**

Q5 Approaching $f' = \frac{fc}{c-u} = \frac{(2000)(336)}{(336-20)}$

= 2126.58 Hz

Going away: $f' = \frac{fc}{c+u} = \frac{(2000)(336)}{(336+20)}$

= 1887.64 Hz

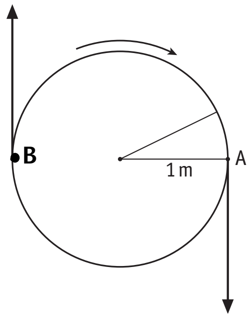
$\therefore$ Change in frequency

= 2126.58 – 1887.64 = **238.9 Hz**

Q6 $f = 4000$ Hz

Highest note is heard when at A

$f' = 4200$, $c = 340$, $u = ?$



(i) $f' = \frac{fc}{c-u}$

$\Rightarrow 4200$

$= \frac{(4000)(340)}{(340-u)}$

$\Rightarrow u = \mathbf{16.19\ m\ s^{-1}}$

(ii) Lowest note occurs at B: $f' = \frac{fc}{c+u}$

$= \frac{(4000)(340)}{(340+16.19)} = \mathbf{3818.2\ Hz}$

(iii) Time $= \frac{\text{Distance}}{\text{Speed}} = \frac{2\pi(1)}{16.19} = \mathbf{0.388\ s}$

(iv) Time $= \frac{0.388}{2} = \mathbf{0.194\ s}$

Q7 Train approaching:

$f' = \frac{fc}{c-u}$

$1000 = \frac{(f)(340)}{340-u}$

$\Rightarrow (1000)(340-u) = 340f$

Train receding:

$f' = \frac{fc}{c+u}$

$800 = \frac{(f)(340)}{340+u}$

$(800)(340+u) = 340f$

$\therefore\ 1000(340-u) = 800(340+u)$

$\Rightarrow u = \mathbf{37.78\ m\ s^{-1}}$

$\therefore f = \frac{(1000)(340-37.78)}{340} = \mathbf{888.9\ Hz}$

Q8 $f' = \frac{fc}{c-u} \Rightarrow 208 = \frac{(200)(336)}{(336-u)}$

$\Rightarrow 336 - u = \frac{(200)(336)}{(208)}$

$\Rightarrow u = \mathbf{12.92\ m\ s^{-1}}$

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:

$u = 0,\ a = 9.8,\ t = 2,\ s = ?$

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

$s = \left(\frac{1}{2}\right)(9.8)(2)^2$

$\Rightarrow s = \mathbf{19.6\ m}$

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**

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:

$t_1 = \frac{-(340 \pm \sqrt{(340)^2 - 4(4.9)(-680)})}{2(4.9)}$

$t_1 = 1.945$ s

1 $\Rightarrow s = \frac{1}{2}(9.8)(1.945)^2$

= 18.5 m = depth of well

Q2 Speed $= \frac{\text{Distance}}{\text{Time}}$

$\Rightarrow$ Distance = (Speed) × (Time) = (340)(4)

= **1360 m**

Exercise 17.2

Q1 $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}} = \frac{1}{(2)(0.8)}\sqrt{\frac{200}{0.04}}$ = **44.2 Hz**

Q2 $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}} \Rightarrow 4f^2l^2 = \frac{T}{\mu}$

$\Rightarrow T = 4f^2l^2\mu = (4)(500)^2(0.6)^2(0.02)$

= **7200 N**

Q3 $\mu = \frac{\text{Mass}}{\text{Length}} = \frac{0.05}{0.8}$ = **0.0625 kg m^{-1}**

$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}} = \frac{1}{(2)(0.8)}\sqrt{\frac{100}{0.0625}}$ = **25 Hz**

Q4 $\mu = \frac{\text{Mass}}{\text{Length}} = \frac{0.04}{4} = 0.01$ kg m^{-1}

$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}} = \frac{1}{(2)(4)}\sqrt{\frac{400}{0.01}}$ = **25 Hz**

Q5 $f = \propto \sqrt{T} \Rightarrow f = k\sqrt{T}$

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

Q6 $f \propto \sqrt{T} \Rightarrow f = k\sqrt{T}$

$260 = k\sqrt{40} \Rightarrow k = \frac{260}{\sqrt{40}}$

$\therefore f = \left(\frac{260}{\sqrt{40}}\right)\sqrt{T}$

(i) When T is 160, $f = \frac{260}{\sqrt{40}}\sqrt{160}$ = **520 Hz**

(ii) When T is 200, $f = \frac{260\sqrt{200}}{\sqrt{40}}$ = **581 Hz**

Q7 (i) $f \propto \frac{1}{l}$ If length is doubled f is halved

$\therefore f$ = **230 Hz**

(ii) $f \propto \frac{1}{l} \Rightarrow fl = k$

$\therefore k = (460)(0.6) = 276$

$\therefore f = \frac{276}{l}$

$\therefore f = \frac{276}{1.5}$ = **184 Hz**

Exercise 18.1

Q1 $d = 2.8 \times 10^{-6}$ m, $n = 2$, $\theta = 65$, λ

$n\lambda = d \text{ Sin } \theta \Rightarrow \lambda = \frac{d \text{ Sin } \theta}{n}$

$= \frac{(2.8 \times 10^{-6})(\text{Sin } 65°)}{2}$

λ = **1.269 × 10^{-6} m**

Q2 $\lambda = \frac{d \text{ Sin } \theta}{n} = \frac{(2.5 \times 10^{-6})(\text{Sin } 40°)}{1}$

= **1.607 × 10^{-6} m**

Q3 $d = \frac{1}{200}$ mm = 0.005 mm = **5 × 10^{-6} m**

Q4 $d = \frac{1}{500}$ mm = 0.002 mm = **2 × 10^{-6} m**

Q5 $d = \frac{1}{800}$ mm = 0.00125 mm = 1.25×10^{-6} m

$n\lambda = d \text{ Sin } \theta \Rightarrow \lambda = \frac{d \text{ Sin } \theta}{n}$

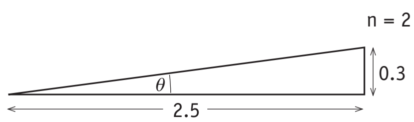
$\therefore \lambda = \frac{(1.25 \times 10^{-6}) \text{ Sin } 30°}{1}$ = **6.25 × 10^{-7} m**

Q6 $d = \frac{1}{400}$ mm = 0.0025 mm = 2.5×10^{-6} m

$n\lambda = d \text{ Sin } \theta \Rightarrow \lambda = \frac{d \text{ Sin } \theta}{n}$

$\therefore \lambda = \frac{(2.5 \times 10^{-6}) \text{ Sin } 31°}{2}$ = **6.44 × 10^{-7} m**

Q7



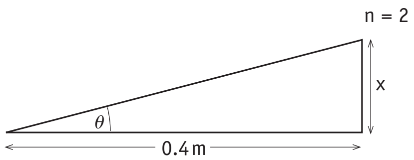
$d = \frac{1}{200} = 5 \times 10^{-6}$ m

$\text{Tan } \theta = \frac{0.3}{2.5} = 0.12 \Rightarrow \quad \text{Sin } \theta = 0.1191$

$\lambda = \frac{d \text{ Sin } \theta}{n} \Rightarrow \lambda = \frac{(5 \times 10^{-6})(0.1191)}{2}$

= **2.978 × 10^{-7} m**

Q8



$\lambda = 5 \times 10^{-7}$ m $\quad d = \frac{1}{600} = 1.667 \times 10^{-6}$ m

$n\lambda = d \text{ Sin } \theta$

$\Rightarrow \text{Sin } \theta = \frac{n\lambda}{d} = \frac{(2)(5 \times 10^{-7})}{1.667 \times 10^{-6}} = 0.5999$

$\Rightarrow \theta = 36.86°$

$\text{Tan } \theta = \frac{x}{0.4} \Rightarrow x = (0.4)\text{Tan } \theta$

$= (0.4) \text{ Tan } 36.86° \Rightarrow x =$ **0.2999 m**

Q9 $d = \frac{1}{400} = 2.5 \times 10^{-6}$ m

$\lambda = 6.2 \times 10^{-7}$ m

$n = \frac{d \text{ Sin } \theta}{\lambda}$

$n_{max} = \frac{d}{\lambda} = \frac{2.5 \times 10^{-6}}{6.2 \times 10^{-7}} = 4.03$

Fourth order is highest.

Q10 $n_{max} = \frac{d}{\lambda} = \frac{5 \times 10^{-6}}{6.2 \times 10^{-7}} = 8.06$

Eight order is highest.

Exercise 18.2

Q1 No calculations required.

Q2 $d = \frac{1}{5 \times 10^5} = 2 \times 10^{-6}$ m

$\theta = \left|\frac{\theta_R - \theta_L}{2}\right|$

$\theta = \frac{217.2 - 182.8}{2}$

$\Rightarrow \theta = 17.2°$

$n\lambda = d \text{ Sin } \theta \Rightarrow \lambda = \frac{d \text{ Sin } \theta}{n}$

$= \frac{(2 \times 10^{-6})\text{Sin } 17.2°}{1}$

$\lambda =$ **5.914×10^{-7} m**

Q3

163°30′	182°45′	200	217°15′	243°30′
36.5°	17.25		17.25	43.5

$d = \frac{1}{500}$ mm = **2×10^{-6} m**

Both 1st order images give
$\lambda = d \text{ Sin}\theta = (2 \times 10^{-6}) \text{ Sin } (17.25)$

$= 5.931 \times 10^{-7}$ m

2nd order: $\lambda = \frac{(2 \times 10^{-6}) \text{ Sin } 36.5°}{2}$

$= 5.948 \times 10^{-7}$ m

or $\lambda = \frac{(2 \times 10^{-6}) \text{ Sin } (43.5)}{2} = 6.884 \times 10^{-7}$ m

Average value of correct $\lambda =$ **5.94×10^{-7} m**

6.884×10^{-7} m is different, therefore 243°30′ is wrong.

Exercise 18.3

Q1 $d = \frac{1}{400}$ mm = 0.0025 mm = 2.5×10^{-6} m

$n\lambda = d \text{ Sin } \theta \Rightarrow \text{Sin } \theta = \frac{n\lambda}{d}$

For red light: $\text{Sin } \theta = \frac{(2)(710 \times 10^{-9})}{2.5 \times 10^{-6}}$

$\Rightarrow \theta = 34.61°$

For blue light: $\text{Sin } \theta = \frac{(2)(410 \times 10^{-9})}{2.5 \times 10^{-6}}$

$\Rightarrow \theta = 19.15°$

$\therefore$ Angular separation

= 34.61 – 19.15 **= 15.46°**

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

(iii) $n\lambda = d \text{ Sin } \theta \Rightarrow \lambda = \frac{d \text{ Sin } \theta}{n}$

[$n = 1$, $\lambda_{max} = d$;

$n = 2$, $\lambda_{max} = \frac{d}{2}$]

(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

Q1 $\varepsilon = \varepsilon_r \varepsilon_o = (2.2)(8.9 \times 10^{-12})$

$= \mathbf{1.958 \times 10^{-11}}$ **F m^{-1}**

Q2 $\varepsilon = \varepsilon_r \varepsilon_o \Rightarrow \varepsilon_r = \frac{\varepsilon}{\varepsilon_o} = \frac{4 \times 10^{-11}}{8.9 \times 10^{-12}} = \mathbf{4.49}$

Q3 $F = \frac{1}{4\pi\varepsilon_o} \frac{Q_1 Q_2}{r^2} = \frac{1}{4\pi(8.9 \times 10^{-12})} \frac{(1)(3)}{1^2}$

$= \mathbf{2.682 \times 10^{10}}$ **N**

The force is the same on each

Q4 $F = \frac{1}{4\pi\varepsilon_o} \frac{Q_1 Q_2}{r^2}$

$= \frac{1}{4\pi(8.9 \times 10^{-12})} \frac{(3 \times 10^{-6})(6 \times 10^{-6})}{(4)^2}$

$= \mathbf{1.0058 \times 10^{-2}}$ **N**

The force is attraction since the charges have opposite sign.

Q5 $F = \frac{1}{4\pi\varepsilon_o} \frac{Q_1 Q_2}{r^2}$

$= \frac{1}{4\pi(8.9 \times 10^{-12})} \frac{(2 \times 10^{-6})(2 \times 10^{-6})}{(0.3)^2}$

= **0.397 N** towards the $-2\mu C$ charge

Q6 $F_1 = \frac{1}{4\pi\varepsilon} \frac{Q_1 Q_2}{r^2}$

$= \frac{1}{4\pi(7.2 \times 10^{-10})} \frac{(2 \times 10^{-6})(4 \times 10^{-6})}{(0.4)^2}$

$= \mathbf{5.526 \times 10^{-3}}$ **N** towards the $-4\mu C$ charge

Q7 $F = \frac{1}{4\pi\varepsilon_o} \frac{(1.6 \times 10^{-19})(1.6 \times 10^{-19})}{(4 \times 10^{-15})^2} = \mathbf{14.306}$ **N**

$F = \frac{G M_1 M_2}{r^2}$

$= \frac{(6.7 \times 10^{-11})(1.67 \times 10^{-27})(1.67 \times 10^{-27})}{(4 \times 10^{-15})^2}$

$= \mathbf{1.17 \times 10^{-35}}$ **N**

Q8 Let the size of each charge be Q

$$F = \frac{1}{4\pi\varepsilon_o}\frac{Q_1Q_2}{d^2} \Rightarrow 0.2 = \frac{1}{4\pi(8.9\times10^{-12})}\frac{Q^2}{(0.02)^2}$$

$$\Rightarrow Q^2 = (0.2)(4\pi)(8.9\times10^{-12})(0.02)^2$$
$$= 8.9472\times10^{-15}$$

$$\Rightarrow Q = \sqrt{8.9472\times10^{-15}} = 9.4589\times10^{-8}\text{ C}$$
$$= \mathbf{9.46\times10^{-8}\ C}$$

Q9 $F_1 = \frac{1}{4\pi\varepsilon}\frac{Q_1Q_2}{x^2}$

$$F_2 = \frac{1}{4\pi\varepsilon}\frac{Q_1Q_2}{(3x)^2}$$

$$= \frac{1}{4\pi\varepsilon}\frac{Q_1Q_2}{x^2}\left(\frac{1}{9}\right)$$

$$= \boldsymbol{F_1\left(\frac{1}{9}\right)}$$

i.e. $\boldsymbol{F_2}$ **is** $\boldsymbol{\left(\frac{1}{9}\right)F_1}$

Q10 Let the charge at C be Q coulombs
Force on 10μC due to Q = Force on 10μC due to 8μC.

$$\frac{1}{4\pi\varepsilon_o}\frac{(10\times10^{-6})Q}{(0.05)^2} = \frac{1}{4\pi\varepsilon_o}\frac{(8\times10^{-6})(10\times10^{-6})}{(0.1)^2}$$

$$\Rightarrow \frac{Q}{(0.05)^2} = \frac{8\times10^{-6}}{(0.1)^2}$$

$$\Rightarrow Q = 2\times10^{-6}\text{ C} = +\mathbf{2}\mu\text{C}$$

Exercise 19.2

Q1 $E = \frac{F}{Q} = \frac{12}{4\times10^{-6}} = \mathbf{3\times10^{6}\ N\ C^{-1}}$

Q2 $F = EQ = (3\times10^3)(2\times10^{-6}) = \mathbf{6\times10^{-3}\ N}$

Q3 $E = \frac{F}{Q} \Rightarrow Q = \frac{F}{E} = \frac{7\times10^{-6}}{2\times10^3} = 3.5\times10^{-9}$ C

$= \mathbf{3.5\ N\ C}$

Q4 $E = \frac{Q}{4\pi\varepsilon_o r^2} = \frac{4\times10^{-6}}{4\pi(8.9\times10^{-12})(2)^2}$

$= \mathbf{8.94\times10^{3}\ V\ m^{-1}}$

The direction is always from the 4μC charge

Q5 $E = \frac{Q}{4\pi\varepsilon_o r^2}$

(i) $\frac{20\times10^{-6}}{4\pi(8.9\times10^{-12})(0.1\times10^{-3})^2}$

$= \mathbf{1.7882\times10^{13}\ N\ C^{-1}}$

(ii) $\frac{20\times10^{-6}}{4\pi(8.9\times10^{-12})(1\times10^{-3})^2}$

$= \mathbf{1.7882\times10^{11}\ N\ C^{-1}}$

(iii) $\frac{20\times10^{-6}}{4\pi(8.9\times10^{-12})(10\times10^{-2})^2}$

$= \mathbf{1.7882\times10^{7}\ N\ C^{-1}}$

In each case the direction of E is towards the charge.

Q6 (i) $\boldsymbol{E = \frac{Q}{4\pi\varepsilon_o r^2}}$

Its direction is away from the charge Q

(ii) $\boldsymbol{E = \frac{Q}{4\pi\varepsilon_o r^2}}$

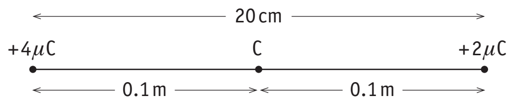
Its direction is towards the charge Q

Q7 $F = EQ = (3\times10^9)(1.6\times10^{-19})$
$= 4.8\times10^{-10}$ N

Acceleration = $\frac{\text{Force}}{\text{Mass}} = \frac{F}{m} = \frac{4.8\times10^{-10}}{9\times10^{-31}}$

$= \mathbf{5.3333\times10^{20}\ m\ s^{-2}}$

Q8



E at

C due to $+4\mu\text{C}$

$= \dfrac{Q}{4\pi\varepsilon_o r^2}$

$= \dfrac{4\times10^{-6}}{4\pi(8.9\times10^{-12})(0.1)^2}$

$= 3.5765\times10^{6}\ \text{N C}^{-1}$ to the right

E at *C* due to $+2\mu\text{C} = \dfrac{Q}{4\pi\varepsilon_o r^2}$

$= \dfrac{2\times10^{-6}}{4\pi(8.9\times10^{-12})(0.1)^2}$

$= 1.7883\times10^{6}\ \text{N C}^{-1}$ to the left

Total field intensity at *C*

$= 3.5765\times10^{6} - 1.7883\times10^{6}$

= 1.7882×10^{6} N C^{-1} towards the +2μC charge

Force on $+5\mu\text{C}$, $F = EQ$

$= (1.7882\times10^{6})(5\times10^{-6})$

= 8.941 N towards the +2μC charge

Q9 Electric field intensity at midpoint due to $+3\mu\text{C}$

$= \dfrac{Q}{4\pi\varepsilon_o r^2} = \dfrac{3\times10^{-6}}{4\pi(8.9\times10^{-12})(0.2)^2}$

= 6.706×10^{5} N C^{-1} towards the –7μC charge

Electric field intensity at midpoint due to $-7\mu\text{C}$ charge

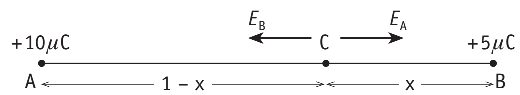
$= \dfrac{Q}{4\pi\varepsilon_o r^2} = \dfrac{7\times10^{-6}}{4\pi(8.9\times10^{-12})(0.2)^2}$

$= 1.565\times10^{6}\ \text{N C}^{-1}$ towards the $-7\mu\text{C}$ charge

Total field intensity =
$6.706\times10^{5} + 1.565\times10^{6}$
$= 2.236\times10^{6}\ \text{N C}^{-1}$ towards the $-7\mu\text{C}$ charge

$F = EQ = (2.236\times10^{6})(2\times10^{-6})$
= 4.47 N towards the – 7μC 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. $E_A = E_B$

$$\frac{1}{4\pi\varepsilon_o}\frac{10\times10^{-6}}{(1-x)^2} = \frac{1}{4\pi\varepsilon_o}\frac{5\times10^{-6}}{x^2}$$

$$\Rightarrow \frac{10}{(1-x)^2} = \frac{5}{x^2}$$

$$\Rightarrow \frac{(1-x)^2}{10} = \frac{x^2}{5}$$

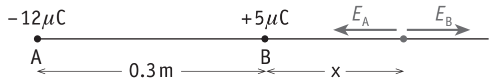
$$(1-x)^2 = 2x^2$$

$\therefore 1 - x = \sqrt{2}x$ or $\therefore 1 - x = -\sqrt{2}x$

$1 = (1+\sqrt{2})x$	$1 = x - \sqrt{2}x$
$\Rightarrow x = \dfrac{1}{1+\sqrt{2}}$	$1 = x(1-\sqrt{2})$
	$\Rightarrow x = \dfrac{1}{1-\sqrt{2}}$
x = 0.4142 m	**x = –2.4**
	Impossible

∴ *E* is zero at a distance of 0.4142 m from the +5μC charge

Q11



To the right of the $+5\mu C$ the electric field strength due to $+5\mu C$ (E_B) is to the right and electric field strength E_A due to $-12\mu C$ is to the left.

Let x = distance at which these two forces cancel, i.e. $E_A = E_B$ (in magnitude)

$$\frac{12\times10^{-6}}{4\pi\varepsilon_o(0.3+x)^2} = \frac{5\times10^{-6}}{4\pi\varepsilon_o(x)^2} \Rightarrow \frac{12}{(0.3+x)^2} = \frac{5}{x^2}$$

$12x^2 = 5(0.3+x)^2$

$\sqrt{12}x = \sqrt{5}(0.3+x)$

$\Rightarrow x = 0.5463$

or $\sqrt{12}x = -\sqrt{5}(0.3+x)$

$\Rightarrow$ x is negative; impossible

$\therefore$ ***E* is zero 0.5463 m from the $+5\mu C$ charge and not between the two charges**

Exercise 20.1

Q1 $W = QV \Rightarrow V = \frac{W}{Q} = \frac{6}{2} =$ **3 V**

Q2 $W = QV \Rightarrow V = \frac{W}{Q} = \frac{6\times10^{-5}}{6\times10^{-6}} =$ **10 V**

Q3 $W = QV = (4)(20) =$ **80 J**

Q4 $W = QV = (8\times10^{-6})(12) =$ $\mathbf{9.6\times10^{-5}}$ **J**

Q5 $W = QV \Rightarrow V = \frac{W}{Q} = \frac{4.8\times10^{-16}}{1.6\times10^{-19}} =$ **3000 V**

Q6 (i) $W = QV = (1.6\times10^{-19})(1)$

$= \mathbf{1.6\times10^{-19}}$ **J**

(ii) $W = QV = (1.6\times10^{-19})(300)$

$= \mathbf{4.8\times10^{-17}}$ **J**

Q7 Work = Force × Distance

E = Force on 1 C = 2×10^4 N

Work done in bringing 1 C from one plate to the other.

W = (Force on 1 C)(Distance between plates)

$= (2\times10^4)(0.2) = 4000$ J

Work done in bringing 1 C from one plate to the other = p.d. between plates.

$\Rightarrow$ p.d. = **4000 V**

Q8 (i) p.d. between plates = 400 V

$\Rightarrow$ 400 J done in bringing +1 C from one plate to the other.

$W = Fs \quad \Rightarrow \quad 400 = (F)(2 \times 10^{-2})$

$\Rightarrow$ F = **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

Q1 $C = \frac{\varepsilon_0 A}{d} = \frac{(8.9\times10^{-12})(0.02)}{(0.001)} = \mathbf{1.78\times10^{-10}\,F}$

Q2 $C = \frac{\varepsilon_0 A}{d} = \frac{(8.9\times10^{-12})(150\times10^{-4})}{(1\times10^{-3})}$

$= \mathbf{1.335\times10^{-10}\,F}$

Q3 $C = \frac{\varepsilon_0 A}{d} \Rightarrow A = \frac{Cd}{\varepsilon_0} = \frac{(1)(1\times10^{-3})}{(8.9\times10^{-12})}$

$= \mathbf{1.1235\times10^{8}\,m^2}$

Q4 $C = \frac{\varepsilon_0 A}{d} = \frac{(8.9\times10^{-12})(100\times10^{-4})}{(2\times10^{-3})}$

$= \mathbf{4.45\times10^{-11}\;F}$

With perspex dielectric $\varepsilon_r = 2.6$

$C = (2.6)(4.45\times10^{-11}) = \mathbf{1.157\times10^{-10}\,F}$

Q5 $C = \frac{\varepsilon A}{d} = \frac{(7)(8.9\times10^{-12})(25\times10^{-4})}{(1\times10^{-3})}$

$\Rightarrow C = 1.5575\times10^{-10}\,\text{F}$

$Q = CV = (1.5575\times10^{-10})(500)$

$= \mathbf{7.79\times10^{-8}\,C}$

Q6 $W = \frac{1}{2}CV^2 = \frac{1}{2}(6\times10^{-3})(200)^2 = \mathbf{120\;J}$

Q7 $C = \frac{Q}{V} \Rightarrow V = \frac{Q}{C} = \frac{4\times10^{-6}}{2\times10^{-6}} = 2\;\text{V}$

$W = \frac{1}{2}CV^2 = \frac{1}{2}(2\times10^{-6})(2)^2 = \mathbf{4\times10^{-6}\;J}$

Q8 $W = \frac{1}{2}CV^2 = \frac{1}{2}(4.6\times10^{-6})(8)^2 = \mathbf{1.472\times10^{-4}\;J}$

Q9 $W = \frac{1}{2}QV = \frac{1}{2}(7\times10^{-6})(30) = \mathbf{1.05\times10^{-4}\;J}$

Q10 $W = \frac{1}{2}CV^2 \Rightarrow W = \frac{1}{2}\left(\frac{Q^2}{C}\right)$

$\Rightarrow 23\times10^{-3} = \frac{(0.5)(Q^2)}{2.4\times10^{-6}}$

$\Rightarrow Q = \mathbf{3.32\times10^{-4}\,C}$

Q11 $W = \frac{1}{2}CV^2 \Rightarrow (0.01) = \frac{1}{2}(C)(12)^2$

$\Rightarrow C = \mathbf{1.39\times10^{-4}\,F}$

Q12 P.d. across each is **40 V**

$C = \frac{Q}{V} \Rightarrow Q = CV$

$Q = (8\times10^{-6})(40) = \mathbf{3.2\times10^{-4}\,C}$

$Q = (4\times10^{-6})(40) = \mathbf{1.6\times10^{-4}\,C}$

Q13 $V_1 + V_2 = 40$ and $V = \frac{Q}{C}$

$\Rightarrow \frac{Q}{8\times10^{-6}} + \frac{Q}{4\times10^{-6}} = 40$

$\Rightarrow Q(375\,000) = 40 \Rightarrow Q = \mathbf{1.067\times10^{-4}\;C}$

$V_1 = \frac{Q}{C} = \frac{1.067\times10^{-4}}{8\times10^{-6}} = \mathbf{13.33\;V}$

$V_2 = \frac{Q}{C} = \frac{1.067\times10^{-4}}{4\times10^{-6}} = \mathbf{26.67\;V}$

Q14 (i) P.d. across the resistor:
$V = IR = (0.2\times10^{-3})(20\times10^{3}) = 4\,\text{V}$

$\Rightarrow$ p.d. across capacitor $= 40 - 4 =$ **36 V**

(ii) $C = \frac{Q}{V} \Rightarrow Q = CV = (60\times10^{-6})(36)$

$= \mathbf{2.16\times10^{-3}\,C}$

(iii) Work done = Energy stored

$W = \frac{1}{2}\left(\frac{Q^2}{C}\right) = \frac{(0.5)(2\times10^{-6})^2}{(60\times10^{-6})}$

$= \mathbf{3.33\times10^{-8}\,J}$

Exercise 21.1

Q1 (i) 1 mA = $\mathbf{1 \times 10^{-3}\ A}$

(ii) 0.05 mA = 0.05×10^{-3} = $\mathbf{5 \times 10^{-5}\ A}$

(iii) 50 μA = 50×10^{-6} A = $\mathbf{5 \times 10^{-5}\ A}$

(iv) 1000 mA = **1 A**

(v) 0.2 μA = 0.2×10^{-6} = $\mathbf{2 \times 10^{-7}\ A}$

Q2 (i) 1 A = **1000 mA**

(ii) 100 A = 100×10^{3} mA = $\mathbf{10^{5}\ mA}$

(iii) 0.025 A = 0.025×10^{3} = **25 mA**

(iv) 1 μA = $\mathbf{1 \times 10^{-3}\ mA}$

(v) 0.0006 A = 0.0006×10^{3} mA = **0.6 mA**

Q3 (i) $10 = 7 + x \Rightarrow x = \mathbf{3\ A}$

(ii) $2 + 3 = 1 + x \Rightarrow x = \mathbf{4\ A}$

(iii) $x + 8 + 2 = 9 + 3 \Rightarrow x = \mathbf{2\ A}$

(iv) $x + x + 4 = 2 + 3 + 5 \Rightarrow x = \mathbf{3\ A}$

Q4 (i) $Q = It = (3)(1) = \mathbf{3\ C}$

(ii) $Q = It = (3)(60) = \mathbf{180\ C}$

(iii) $Q = It = (30)(60)(60) = \mathbf{10\ 800\ C}$

Q5 (i) $I = \frac{Q}{t} = \frac{10}{10} = \mathbf{1\ A}$

(ii) $I = \frac{Q}{t} = \frac{1}{60} = \mathbf{0.01667\ A}$

(iii) $I = \frac{Q}{t} = \frac{10}{1} = \mathbf{10\ A}$

Q6 $Q = It = (6)(4)(60)(60) = \mathbf{86\ 400\ C}$

Q7 Number of electrons = $\frac{1 \text{ coulomb}}{\text{Charge on one electron}}$

$\frac{1}{1.6 \times 10^{-19}} = \mathbf{6.25 \times 10^{18}}$ **electrons**

Q8 $Q = It = (20)(6) = 120$ C

1 C has 6.25×10^{18} electrons

$\Rightarrow$ 120 C has $(120)(6.25 \times 10^{18})$

$= \mathbf{7.5 \times 10^{20}}$ **electrons**

Q9 Charge gone past

= (Nr. of electrons)(charge on one electron)

= $(2 \times 10^{20})(1.6 \times 10^{-19})$ = 32 C

$I = \frac{Q}{t} = \frac{32}{1} = \mathbf{32\ A}$

Q10 $Q = It \Rightarrow t = \frac{Q}{I} = \frac{36000}{5} = \mathbf{7200\ s}$

Q11 Charge hitting screen in one hour

= $Q = It = (1 \times 10^{-3})(60)(60) = 3.6$ C

Number of electrons = $\frac{\text{Charge}}{\text{Charge on one electron}}$

$= \frac{3.6}{1.6 \times 10^{-19}} = \mathbf{2.25 \times 10^{19}}$ **electrons**

Q12 No calculations required.

Exercise 22.1

Q1 Total emf = Sum of indiviadual emfs

$= 4 + 6 + 3 = \mathbf{13\ V}$

Q2 (a) $W = QV = (1)(10) = \mathbf{10\ J}$

(b) $W = QV = (6)(10) = \mathbf{60\ J}$

(c) $W = QV = (1 \times 10^{-6})(10) = \mathbf{1 \times 10^{-5}\ J}$

Q3 $W = QV \Rightarrow V = \frac{W}{Q} = \frac{200}{50} = \mathbf{4\ V}$

Q4 $W = QV = (20)(60) = \mathbf{1200\ J}$

Q5 $W = QV \Rightarrow V = \frac{W}{Q} = \frac{4000}{80} = \mathbf{50\ V}$

Q6 $P = VI \Rightarrow I = \frac{P}{V} = \frac{100}{230} = \mathbf{0.435\ A}$

Q7 $P = VI = (12)(6.67) = \mathbf{80\ W}$

Q8 (i) $P = VI = (220)(4) = \mathbf{880\ W}$

(ii) $W = Pt = (880)(1)(60)(60)$

$= 316800\ J = \mathbf{3.168\ MJ}$

Q9 $P = VI \Rightarrow I = \frac{P}{V} = \frac{100}{230} = \mathbf{0.435\ A}$

Q10 Total power = $(50)(5) = \mathbf{250\ W}$

$I = \frac{P}{V} = \frac{250}{220} = \mathbf{1.136\ A}$

Q11 (i) $P = VI = (10)(5) = 50\ W$

Energy = Power × time = $(50)(5)(60)$

$= 15\,000\ J = \mathbf{15\ kJ}$

(ii) $W = QV = (1)(10) = \mathbf{10\ J}$

Q12 Total emf = $2 + 3 + 12 = 17\ V$

$P = VI = (17)(2) = \mathbf{34\ W}$

Q13 $V_1 = 6 \Rightarrow V_2 = 20 - 6 = 14\ V$

Power in bulb 2, $P = VI = (3)(14) = 42\ W$

Energy = Power × Time = $(42)(2)(60)(60)$

$= 302\,400\ J = \mathbf{3.024 \times 10^5\ J}$

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 $R = \frac{V}{I} = \frac{20}{4} = \mathbf{5\ \Omega}$

Q2 $V = IR = (5)(12) = \mathbf{60\ V}$

Q3 $I = \frac{V}{R} = \frac{230}{10} = \mathbf{2.3\ A}$

Q4 $R = \frac{V}{I} = \frac{12}{4} = \mathbf{3\ \Omega}$

Q5 $V = IR = (5)(6) = \mathbf{30\ V}$

Q6 $R = \frac{V}{I} = \frac{24}{3} = 8\ \Omega$

$R = \frac{V}{I} = \frac{24}{2} = 12\ \Omega$

∴ Increase in resistance = $12 - 8 = \mathbf{4\ \Omega}$

Q7 $R = \frac{V}{I} = \frac{10}{2} = \mathbf{5\ \Omega}$

Q8 $R = R_1 + R_2 = 2 + 3 = 5\ \Omega$

$I = \frac{V}{R} = \frac{12}{2} = 6\ A$

$V = IR = (6)(5) = \mathbf{30\ V}$

Q9 $R = \frac{V}{I} = \frac{10}{1} = 10\ \Omega$

∴ Resistance of bulb = $10 - 4 = \mathbf{6\ \Omega}$

Q10 $V_1 = IR_1 = (5)(2) = \mathbf{10\ V}$

$V_2 = IR_2 = (5)(4) = \mathbf{20\ V}$

$V_3 = IR_3 = (5)(8) = \mathbf{40\ V}$

Total $V = V_1 + V_2 + V_3 = \mathbf{70\ V}$

Q11 (a) $\frac{1}{R} = \frac{1}{4} + \frac{1}{4} \Rightarrow R = \mathbf{2\ \Omega}$

(b) $\frac{1}{R} = \frac{1}{4} + \frac{1}{1} \Rightarrow R = \mathbf{0.8\ \Omega}$

(c) $\frac{1}{R} = \frac{1}{30} + \frac{1}{30} + \frac{1}{30} \Rightarrow R = \mathbf{10\ \Omega}$

(d) $\frac{1}{R} = \frac{1}{30} + \frac{1}{60} + \frac{1}{90} \Rightarrow R = \mathbf{16.36\ \Omega}$

(e) $\frac{1}{R} = \frac{1}{8} + \frac{1}{8} \Rightarrow R = \mathbf{4\ \Omega}$

(f) $\frac{1}{R_p} = \frac{1}{2} + \frac{1}{4} \Rightarrow R_p = 1.33\ \Omega$

$R = 1.33 + 6 = \mathbf{7.33\ \Omega}$

Q12 (i) $\frac{1}{R} = \frac{1}{20} + \frac{1}{20} \Rightarrow R = \mathbf{10\ \Omega}$

(ii) $R = R_1 + R_2 = 20 + 20 = \mathbf{40\ \Omega}$

(iii) $\frac{1}{R} = \frac{1}{2} + \frac{1}{3} \Rightarrow R = \mathbf{1.2\ \Omega}$

Q13 $\frac{1}{R_p} = \frac{1}{2}+\frac{1}{3} \Rightarrow R_p = 1.2\ \Omega$

Total resistance = 1.2 + 4 = 5.2 Ω

Current in 4 Ω resistor:

$I = \frac{V}{R} = \frac{20}{5.2} = \mathbf{3.846\ A}$

P.d. across 4 Ω resistor:

$V = IR = (3.846)(4) = 15.38\ V$

$\Rightarrow$ p.d. across parallel combination

$= 20 - 15.38 = 4.615\ V$

Current in 2 Ω resistor:

$I_1 = \frac{V}{R} = \frac{4.615}{2} = \mathbf{2.31\ A}$

Current in 3 Ω resistor:

$I_2 = \frac{V}{R} = \frac{4.615}{3} = \mathbf{1.538\ A}$

Q14 FIG (A) shows the circuit in a more intuitive manner:

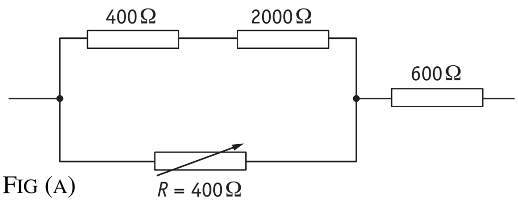


FIG (A)

(i) Resistance of parallel combination:

$\frac{1}{R_p} = \frac{1}{400}+\frac{1}{2400} \Rightarrow R_p = 342.9\ \Omega$

Total resistance = 600 + 342.9

= **942.9 Ω**

(ii) Current from battery,

$I = \frac{V}{R} = \frac{10}{942.9} = 0.01061\ A$

P.d. across 600 Ω resistor = IR

= (0.01061)(600) = 6.36 V

∴ p.d. across parallel combination

= 10 - 6.36 = 3.64 V

∴ Current in 2 kΩ resistor,

$I = \frac{V}{R} = \frac{3.64}{2400} = \mathbf{0.0015\ A}$

(i) If R is reduced, total resistance of circuit decreases, therefore current in the 600 Ω resistor increases

(ii) Current in 600 Ω 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 kΩ resistor decreases.

Exercise 23.2

Q1 $A = \pi r^2 = \pi\left(\frac{d}{2}\right)^2 = \pi\left(\frac{0.22 \times 10^{-2}}{2}\right)^2$

$= 3.80 \times 10^{-8}\ \text{m}^2$

$\rho = \frac{RA}{l} = \frac{(28.2)(3.8 \times 10^{-8})}{(0.892)} = \mathbf{1.2 \times 10^{-6}\ \Omega\ m}$

Q2 $\rho = \frac{R\pi d^2}{4l} = \frac{(27.9)\pi(0.22 \times 10^{-3})^2}{(4)(0.856)}$

$= \mathbf{1.24 \times 10^{-6}\ \Omega\ m}$

Q3 $R = \frac{\rho l}{A} \Rightarrow l = \frac{RA}{\rho}$

$\therefore\ l = \frac{(4)(0.16 \times 10^{-6})}{4.2 \times 10^{-7}} = \mathbf{1.524\ m}$

Q4 $R = \frac{\rho l}{A} \Rightarrow l = \frac{RA}{\rho}$

$\therefore\ l = \frac{(12)\pi(0.25 \times 10^{-3})^2}{1.7 \times 10^{-8}} = \mathbf{138.6\ m}$

Q5 No calculations required.

Q6 $\rho = \frac{R\pi d^2}{4l} \Rightarrow 1.2 \times 10^{-6} = \frac{(400)\pi d^2}{(4)(1.5)}$

$\Rightarrow d = \sqrt{\frac{(4)(1.5)(1.2 \times 10^{-6})}{(400)(\pi)}}$

$= \mathbf{7.569 \times 10^{-5}\ m}$

Q7 $\rho = \frac{R\pi d^2}{4l} \Rightarrow d = \sqrt{\frac{4\rho l}{\pi R}}$

$= \sqrt{\frac{(1.3 \times 10^{-6})(4)(1.3)}{(20)(\pi)}} = \mathbf{3.28 \times 10^{-4}\ m}$

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

$\Rightarrow$ $l = (10)(1.2) = \mathbf{12\ m}$

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 $A = \pi r^2 = \pi\left(\frac{d}{2}\right)^2$

$\Rightarrow \rho = \frac{(R)\left(\pi\left(\frac{d}{2}\right)^2\right)}{l} = \mathbf{\frac{R\pi d^2}{4l}}$

Q11 Length halved $\Rightarrow$ Resistance is halved to 5 Ω

Cross-sectional area doubled $\Rightarrow$ Resistance is again halved to **2.5 Ω**

Q12 Average diameter = **0.424 mm**

$\rho = \frac{R\pi d^2}{4l} = \frac{(6)\pi(0.424 \times 10^{-3})^2}{(4)(0.784)}$

$= \mathbf{1.08 \times 10^{-6}\ \Omega\ m}$

Exercise 23.3

Q1 $\frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow \frac{4}{6} = \frac{15}{R_4} \Rightarrow R_4 = \mathbf{22.5\ \Omega}$

Q2 $\frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow \frac{10}{20} = \frac{R_3}{60} \Rightarrow R_3 = \mathbf{30\ \Omega}$

Q3 $\frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow \frac{10R_2}{R_2} = \frac{4}{R_4} \Rightarrow R_4 = \mathbf{0.4\ \Omega}$

Q4 (i) $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ 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. $\boldsymbol{R_2}$ **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

Q1 $W = I^2Rt = (5^2)(20)(3) = \mathbf{1500\ J}$

Q2 $W = I^2Rt$
$= ((12 \times 10^{-3})^2)(1 \times 10^3)(4 \times 60)$
$= \mathbf{34.56\ J}$

Q3 $W = I^2Rt = ((0.5)^2)(400)(60 \times 60)$
$= \mathbf{360\ 000\ J}$

Q4 (i) $P = I^2R = (1)^2(10) = \mathbf{10\ J}$

(ii) $P = I^2\mathrm{R} = (2)^2(10) = \mathbf{40\ J}$

(iii) $P = I^2R = (3)^2(10) = \mathbf{90\ J}$

(iv) $P = I^2R = (4)^2(10) = \mathbf{160\ J}$

Q5 (i) $P = I^2R = (2)^2(1) = \mathbf{4\ J}$

(ii) $P = I^2R = (2)^2(2) = \mathbf{8\ J}$

(iii) $P = I^2R = (2)^2(10) = \mathbf{40\ J}$

(iv) $P = I^2R = (2)^2(100) = \mathbf{400\ J}$

Q6 $P = I^2\mathrm{R} = (6)^2(40) = 1440\ \mathrm{J}$
Energy = Power × time
$= (1440)(60)(60) = \mathbf{5\ 184\ 000\ J}$

Q7 $P = I^2R \Rightarrow 100 = (0.5)^2\mathrm{R}$

$\Rightarrow \mathrm{R} = \frac{100}{0.25} = \mathbf{400\ \Omega}$

Q8 $P = I^2R \Rightarrow 3 \times 10^3 = (10)^2\mathrm{R}$

$\Rightarrow \mathrm{R} = \frac{3 \times 10^3}{100} = \mathbf{30\ \Omega}$

Q9 (a) $P = VI \Rightarrow I = \frac{P}{V} = \frac{2 \times 10^3}{230} = \mathbf{8.7\ A}$

(b) $P = I^2\mathrm{R} \Rightarrow R = \frac{P}{I^2} = \frac{2 \times 10^3}{(8.7)^2}$
$= \mathbf{26.42\ \Omega}$

(c) $P = \frac{W}{t} \Rightarrow t = \frac{W}{P} = \frac{100 \times 10^6}{2000}$
$= \mathbf{50\ 000\ s}$

Q10 $I = \frac{V}{R} = \frac{230}{40} = 5.75\ \mathrm{A}$

$W = I^2Rt = (5.57)^2(40)(30) = 39\ 675\ \mathrm{J}$

$Q = It = (5.75)(30) = \mathbf{172.5\ C}$

Q11 $P \propto I^2$ $\therefore$ if the current doubles the power is four times greater.

OR

Suppose $P_1 = R\,I_1^2$

Now let current increase to $2I_1$

$\therefore$ New power $P_2 = R(2I_1)^2 = 4\,RI_1^2$

i.e. $\boldsymbol{P_2 = 4P_1}$

Q12 Energy supplied to the water:

$Q = m\,c\,\Delta\theta = (500)(4180(40)$

$= 8.36 \times 10^7$ J

= 80% of the electrical energy supplied

$\Rightarrow$ electrical energy supplied $= 1.045 \times 10^8$ J

$W = I^2\,R\,t$

$\Rightarrow 1.045 \times 10^8 = (20)^2\,R(5)(60)(60)$

$\Rightarrow$ R = **14.5 Ω**

Q13 Power $P = V\,I = (230)(9) = 2070$ W

Electrical energy needed:

$Q = m\,c\,\Delta\theta = (2)(4180)(90) = 752\,400$ J

Time $= \frac{\text{Energy}}{\text{Power}} = \frac{(752400)}{2070} = 363.5$ s

Energy needed to boil off 3/4 of the water

= (Mass)(Specific latent heat of vaporisation)

$= m\,l$

$= (0.75)(2)(2.3 \times 10^6) = 3.45 \times 10^6$ J

Time $= \frac{\text{Energy}}{\text{Power}} = \frac{3.45 \times 10^6}{2070} =$ **1666.7 s**

Exercise 24.2

Q1 $P = V\,I \Rightarrow I = \frac{P}{V} = \frac{1000}{230} = 4.35$ A

$\Rightarrow$ **The 13 A fuse is suitable.**

Q2 Total power $= (2)(500) + 1000 + 2000$

$= 5000\,W$

$I = \frac{P}{V} = \frac{5000}{230} = 21.73$ A

$\Rightarrow$ **The 30 A fuse is suitable.**

Q3 (Nr. of kW h) = (Power in kW)(Time in h)

= (2)(3) = **6 kW h**

Q4 (Nr. of kW h) = (Power in kW)(Time in h)

$= (0.075)(\frac{40}{60}) =$ **0.05 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 T**

Q3 $F = BIL = (2.5)(4)(2) =$ **20 N**

$\perp$ to both B and wire

Q4 $F = BIL \Rightarrow B = \frac{F}{IL} = \frac{4}{3(1)} = \mathbf{\frac{4}{3}}$ **T**

Q5 No calculations required.

Q6 No calculations required.

Q7 No calculations required.

Q8 $F = BIL = (0.4)(10)(0.3) =$ **1.2 N**;

$M = Fd = (1.2)(0.08) =$ **0.096 N m**;

Because $\perp$ distance to axis decreases; yes;

$(1.2)(0.16) =$ **0.192 N m**

Q9 $F = B_{\perp}IL = (2)(\text{Sin } 30)(3)(3) =$ **9 N**

zero degrees, i.e. when wire is parallel to magnetic field

Q10 Parallel component = 3 Cos 60 = 1.5 T

$\perp$ component = 3 Sin 60 = 2.6 T

The $\perp$ component causes the force on the wire

$F = (3 \text{ Sin } 60)(2.5)(0.5) =$ **3.25 N**

perpendicular to wire and to the magnetic field.

Exercise 27.2

Q1 $F = qvB = (2)(10)(2) =$ **40 N**

Q2 $F = qvB = (3 \times 10^{-6})(200)(4) = \mathbf{2.4 \times 10^{-3}}$ **N**

Q3 $F = qvB = (1.6 \times 10^{-19})(6 \times 10^{7})(4)$

$= \mathbf{3.84 \times 10^{-4}}$ **N**

Q4 $F = qvB \Rightarrow 2 \times 10^{-18} = (1.6 \times 10^{-19})(v)(2)$

$\Rightarrow v = \frac{2 \times 10^{-18}}{(2)(1.6 \times 10^{-19})} = \mathbf{6.25 \text{ m s}^{-1}}$

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 m**

Q7 $r = \frac{mv^2}{qvB} = \frac{(9.1 \times 10^{-31})(2000)^2}{(1.6 \times 10^{-19})(2000)(3 \times 10^{-2})}$

$= \mathbf{3.7916 \times 10^{-7}}$ **m**

Q8 $\frac{mv^2}{r} = qvB \Rightarrow v = \frac{qBr}{m}$

$v = \frac{(1.6 \times 10^{-19})(2 \times 10^{-3})(10 \times 10^{-2})}{(9.1 \times 10^{-31})}$

$= \mathbf{3.52 \times 10^{7} \text{ m s}^{-1}}$

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. $\boldsymbol{T = \frac{2\pi m}{Be}}$

Q10 (i) Number passing per second

= (0.1)(104) = **10.4 particles**

(ii) $(10.4)(2 \times 10^{-6}) = \mathbf{2.08 \times 10^{-5}}$ **C**

(iii) $\mathbf{2.08 \times 10^{-5}}$ **A**

Q11 I = charge passing per second

$= \left(\frac{0.02}{100}\right) \times (10^{12}) \times (1.6 \times 10^{-19})$

$= \mathbf{3.2 \times 10^{-11}}$ **A**

Exercise 28.1

Q1 $\Phi = BA = (2)(0.3) = \mathbf{0.6\,Wb}$

Q2 $\Phi = BA \Rightarrow A = \frac{\Phi}{B} = \frac{0.4}{0.5} = \mathbf{0.8\,m^2}$

Q3 $\Phi = BA = (2)(100 \times 10^{-4}) = \mathbf{0.02\,Wb}$

$(1\text{m}^2 = 10^4\text{cm}^2 \Rightarrow 1\text{cm}^2 = 10^{-4}\text{m}^2)$

Q4 $\Phi = BA \Rightarrow B = \frac{\Phi}{A} = \left(\frac{2 \times 10^{-2}}{200 \times 10^{-4}}\right) = \mathbf{1\ T}$

Q5 $\Phi = BA \Rightarrow A = \frac{\Phi}{B} = \frac{2 \times 10^{-2}}{3 \times 10^{-3}} = 6.667\ \text{m}^2$

$A = \pi r^2 \Rightarrow r = \sqrt{\frac{A}{\pi}} = \sqrt{\frac{6.667}{\pi}} = \mathbf{1.46\ m}$

Q6 Change in Φ = final Φ – initial Φ

$= (BA)_{\text{final}} - (BA)_{\text{initial}}$

$= (2.4)(10 \times 6 \times 10^{-4}) - (1.2)(10 \times 6 \times 10^{-4})$

$= 0.0144 - 0.0072$

$= \mathbf{7.2 \times 10^{-3}\,Wb}$

Q7 $\Phi = B_\perp A = (4 \text{ Sin } 30°)(0.2) = \mathbf{0.4\ Wb}$

Q8 Comp of B perpendicular to plane of coil
$= B$ Sin 40°
$= (2.5 \times 10^{-3})(\text{Sin } 40°)$

$\Phi = B_\perp A$
$= (2.5 \times 10^{-3})(\text{Sin } 40°)(\pi(20 \times 10^{-2})^2)$

$= \mathbf{2.02 \times 10^{-4}\,Wb}$

Exercise 28.2

Q1 $E = \left(\frac{\text{final } \Phi - \text{initial } \Phi}{\text{time}}\right) = \frac{5-1}{2} = \mathbf{2\ V}$

Q2 $E = \left(\frac{\text{final } \Phi - \text{initial } \Phi}{\text{time taken}}\right) = \frac{0-0.4}{0.2} = \mathbf{-2\ V}$

Total induced emf $= (200)(2) = \mathbf{400}\,V$

Q3 $E = N\frac{d\Phi}{dt} = (600)\left(\frac{2.4-0}{0.6}\right) = \mathbf{2400\ V}$

Q4 $E = N\frac{d\Phi}{dt} = (200)\left(\frac{4-2}{0.3}\right) = \mathbf{1333.3\ V}$

$I = \frac{E}{R} = \frac{1333.3}{4} = \mathbf{333.3\ A}$

Q5 Change in flux = final Φ – initial Φ
$= [2.4][10 \times 6 \times 10^{-4}] - [1.2][10 \times 6 \times 10^{-4}]$

$= 0.0072\ \text{Wb}$

$= \mathbf{7.2 \times 10^{-3}\ Wb}$

Q6 $E = N\frac{d\Phi}{dt}$

$= 100\left(\frac{(6)(0.08) - (2)(0.08)}{0.5}\right) = \mathbf{64\ V}$

Q7 Final $\Phi = BA = (2)(8 \times 6 \times 10^{-4})$

$= 0.0096$ Wb

Initial $\Phi = 0$ Wb

Time taken for change $= \left(\frac{8 \times 10^{-2}}{3}\right)$

$= 2.667 \times 10^{-2}$ s

$E = \left(\frac{\text{final } \Phi - \text{initial } \Phi}{\text{time}}\right)$

$= \frac{0.0096 - 0}{2.667 \times 10^{-2}} = \mathbf{0.36\ V}$

Q8 Initial flux = 0, Final flux = BA
$= (4)(4 \times 6 \times 10^{-4}) = 0.0096$ T
$\Rightarrow$ 10 rotations per second
1 rotation takes $\frac{1}{10}$ s

Time to go from A to B $= \left(\frac{1}{4}\right)\left(\frac{1}{10}\right) = \frac{1}{40}$ s

$E = N\frac{d\Phi}{dt} = (200)\left(\frac{0.0096 - 0}{\frac{1}{40}}\right) = \mathbf{76.8\ V}$

Q9 $E = N\frac{d\Phi}{dt} = N\left(\frac{\text{final }\Phi - \text{initial }\Phi}{\text{time}}\right)$

$= 10\,000\left(\frac{-(2\times10^{-2})(3\times10^{-2})^2+0}{0.1}\right)$

$= \frac{(1\times10^{4})(2\times10^{-2})(9\times10^{-4})}{1\times10^{-1}}$

$= 18\times10^{-1} = \mathbf{1.8\ V}$

Q10 Time to go from position 1 to position 2
= time for $\frac{1}{4}$ rev

$= \left(\frac{1}{4}\right)\frac{1}{40}$ sec

$= 6.25\times10^{-3}$ s

$E = N\left(\frac{\text{final }\Phi - \text{initial }\Phi}{\text{time}}\right)$

$4 = 200\left(\frac{(B)(5\times10^{-2})-0}{6.25\times10^{-3}}\right)$

$\therefore B = \frac{(4)(6.25\times10^{-3})}{(200)(5\times10^{-2})} = 0.025\times10^{-1}$ T

$= \mathbf{2.5\times10^{-3}\ T}$

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

$E = N\left(\frac{\Phi_{\text{final}} - \Phi_{\text{initial}}}{t}\right)$

$IR = 1\left(\frac{B_1A - B_2A}{t}\right)$

$\frac{Q}{t}R = \frac{A}{t}(B_1 - B_2)$

$\therefore QR = A(B_1 - B_2)$

$(4\times10^{-3})(12) = A(0.25 - 0)$

$\Rightarrow A = 192\times10^{-3}\ \text{m}^2$

$\Rightarrow A = \mathbf{1.92\times10^{-1}\ m^2}$

Q12 From Q11: $IR = N\left(\frac{B_1A - B_2A}{t}\right) = \frac{Q}{t}R$

$\Rightarrow Q = NA\frac{(B_1 - B_2)}{R}$

$= \frac{(500)(400\times10^{-4})(0 - 1.8\times10^{-5})}{10}$

$= \frac{(5\times10^{2})(4\times10^{-2})(1.8\times10^{-5})}{10} = \mathbf{3.6\times10^{-5}\ C}$

Exercise 28.3

Q1 In one second: Work done = Electrical power

$F \times dist = I^2R$

$F(30) = (0.6)^2(20) \Rightarrow F = \mathbf{0.24\ N}$

Q2 (i) $E = \dfrac{(2)(5\times 12\times 10^{-4}) - 0}{\left(\frac{12\times 10^{-2}}{4}\right)} = \mathbf{0.4\ V}$

$I = \frac{V}{R}$

$I = \frac{0.4}{5}$

$I = \mathbf{0.08}\boldsymbol{A}$

(ii) $Fd = I^2R$

$(F)(4) = (0.08)^2(5)$

$F = \mathbf{8\times 10^{-3}\ N}$

Q3 $E = N\left(\dfrac{\text{final } \Phi - \text{initial } \Phi}{\text{time}}\right)$

$= N\left(\dfrac{BL^2 - 0}{L/v}\right) = N(BLv) = NBLv$

(i) $I = \frac{E}{R} = \boldsymbol{\frac{NBLv}{R}}$

(ii) In one second

Work done = Electrical power

$\Rightarrow Fv = I^2R = \left(\dfrac{N^2B^2L^2v^2}{R^2}\right)R$

$\Rightarrow F = \boldsymbol{\dfrac{N^2B^2L^2v}{R}}$

Exercise 28.4

Q1 $V_{rms} = \frac{V_o}{\sqrt{2}} = \frac{20}{\sqrt{2}} = \mathbf{14.14\ V}$

Q2 $V_o = V_{rms}\sqrt{2} = (20)\sqrt{2} = \mathbf{28.28\ V}$

Q3 $V_o = V_{rms}\sqrt{2} = (230)\sqrt{2} = \mathbf{325.3\ V}$

Q4 $P = I_{rms}V_{rms} = (2)(110) = \mathbf{220\ W}$

Q5 $P = I_{rms}^2R$

$\Rightarrow 500 = I_{rms}^2(20)$

$\Rightarrow I_{rms} = \mathbf{5\ A}$

$P = I_{rms}V_{rms}$

$\Rightarrow 500 = 5V_{rms}$

$\Rightarrow V_{rms} = \mathbf{100\ V}$

$V_o = 100\sqrt{2} = \mathbf{141.42\ V}$

Q6 $I_o = \mathbf{3}$

(i) $I_{rms} = \frac{3}{\sqrt{2}} = \mathbf{2.12\ A}$

(ii) $P = I_{rms}^2R = \left(\frac{3}{\sqrt{2}}\right)^2(200) = \mathbf{900\ W}$

(iii) $P = I_{rms}V_{rms} \Rightarrow V_{rms} = \frac{900}{2.12}$

$= \mathbf{424.53\ V}$

(iv) $V_o = V_{rms}\sqrt{2} = \mathbf{600.37\ V}$

Q7 Power = $V_{rms}I_{rms}$

$= \left(\frac{520}{\sqrt{2}}\right)\left(\frac{3}{\sqrt{2}}\right) = 780\ \text{W}$

$P = \frac{W}{t} \Rightarrow t = \frac{W}{P} = \frac{2000}{780} = \mathbf{2.56\ s}$

Q8 $E = N\dfrac{d\Phi}{dt} = \dfrac{(400)(5\times 10^{-4})}{1\times 10^{-3}} = \mathbf{200\ V}$

nett emf $= 300 - 200 = 100\ \text{V}$

$I = \frac{E}{R}$

$I = \frac{100}{200}$

$I = \mathbf{0.5\ A}$

Exercise 28.5

Q1 No calculations required.

Q2 $I = \frac{V}{R} = \frac{20}{10} = \mathbf{2\ A}$

Q3 No calculations required.

Q4 No calculations required.

Q5 No calculations required.

Q6 $E = IR$

12 – (Induced emf) = $(100 \times 10^{-3})(40)$
⇒ Induced emf = **8 V**

Exercise 28.6

Q1 $\frac{V_i}{V_o} = \frac{N_p}{N_s}$

$\Rightarrow V_o = V_i = V_i\left(\frac{N_s}{N_p}\right)$

$= 230\left(\frac{100}{500}\right) = \mathbf{46\ V}$

Q2 $\frac{V_i}{V_o} = \frac{N_p}{N_s} \Rightarrow V_i = V_o\left(\frac{N_p}{N_s}\right) = 4\left(\frac{2000}{100}\right) = \mathbf{80\ V}$

Q3 $N_p = \left(\frac{V_i}{V_o}\right)N_s = \left(\frac{3000}{220}\right)(60) = \mathbf{818\ turns}$

Q4 $N_s = N_p\left(\frac{V_o}{V_i}\right) = (10\,000)\left(\frac{220}{4000}\right) = \mathbf{550\ turns}$

$V_i I_p = V_o I_s$

$(4000)(I_p) = (220)(5) \Rightarrow I_p = \mathbf{0.275\ A}$

Output power = $V_o I_s = (220)(5) = 1100\ W$

Input power = $100(\frac{1100}{90}) = \mathbf{1222.22\ W}$

$\therefore 4000 I_p = 1222.22\ W \Rightarrow I_p = \mathbf{0.306\ A}$

Q5 No calculations required.

Exercise 29.1

Q1 (i) E_P lost, $W = QV = eV$
$= (1.6 \times 10^{-19})(8000) = \mathbf{1.28 \times 10^{-15}\ J}$

(ii) E_K gained $= E_P$ lost $= \mathbf{1.28 \times 10^{-15}\ J}$

(iii) $E_K = \frac{1}{2}mv^2 \Rightarrow (0.5)(9.1 \times 10^{-31})v^2$
$= 1.28 \times 10^{-15} \Rightarrow v = \sqrt{\frac{1.28 \times 10^{-15}}{(0.5)(9 \times 10^{-31})}}$

$= \mathbf{5.3 \times 10^7\ m\ s^{-1}}$

Q2 $\frac{1}{2}mv^2 = eV$
$v = \sqrt{\frac{2eV}{m}} = \mathbf{5.93 \times 10^7\ m\ s^{-1}}$

Q3 $\frac{1}{2}mv^2 = eV$
$V = \frac{mv^2}{2e} = \mathbf{639.8\ V}$

Q4 (i) 5 eV $= 5 \times 1.6 \times 10^{-19}$ J $= \mathbf{8 \times 10^{-19}\ J}$

(ii) 200 eV $= 200 \times 1.6 \times 10^{-19}$ **J**
$= \mathbf{3.2 \times 10^{-17}\ J}$

(iii) 40 keV $= (40 \times 10^3)(1.6 \times 10^{-19})$ J
$= \mathbf{6.4 \times 10^{-15}\ J}$

(iv) 5 MeV $= (5 \times 10^6)(1.6 \times 10^{-19})$ J
$= \mathbf{8 \times 10^{-13}\ J}$

(v) 40 GeV $= (40 \times 10^9)(1.6 \times 10^{-19})$ J
$= \mathbf{6.4 \times 10^{-9}\ J}$

(vi) 4.2 eV $= (4.2)(1.6 \times 10^{-19})$ J
$= \mathbf{6.72 \times 10^{-19}\ J}$

Q5 (i) 3 keV = **3000 eV**

(ii) 6 MeV = $\mathbf{6 \times 10^6\ eV}$

(iii) 2.5 GeV = $\mathbf{2.5 \times 10^9\ eV}$

(iv) 1 J $= \frac{1}{1.6 \times 10^{-19}}$ eV $= \mathbf{6.25 \times 10^{18}\ eV}$

(v) 2×10^{-15} J $= \frac{2 \times 10^{-15}}{1.6 \times 10^{-19}}$ eV = **12 500 eV**

(vi) 6.4×10^{-16} J $= \frac{6.4 \times 10^{-16}}{1.6 \times 10^{-19}}$ eV = **4000 eV**

(vii) 5.6×10^{-19} J $= \frac{5.6 \times 10^{-19}}{1.6 \times 10^{-19}}$ = **3.5 eV**

Q6 No calculations required.

Q7 $F = qvB = (1.6 \times 10^{-19})(2.1 \times 10^6)(4.2)$
$= \mathbf{1.41 \times 10^{-12}\ N}$

Q8 $F = qvB$
$v = \frac{F}{qB} = \frac{2 \times 10^{-12}}{(1.6 \times 10^{-19})(3)} = \mathbf{4.2 \times 10^6\ m\ s^{-1}}$

Q9 $\frac{mv^2}{r} = Bqv \Rightarrow r = \frac{mv^2}{Bqv} \Rightarrow r = \frac{mv}{Bq}$

$= \frac{(9.1 \times 10^{-31})(5.6 \times 10^7)}{(3 \times 10^{-2})(1.6 \times 10^{-19})} = \mathbf{1.06 \times 10^{-2}\ m}$

Q10 No calculations required.

Q11 $\frac{e}{m} = 1.76 \times 10^{11}$

$\frac{1.6 \times 10^{-19}}{m} = 1.76 \times 10^{11}$

$\Rightarrow m = \frac{1.6 \times 10^{-19}}{1.76 \times 10^{11}} = \mathbf{9.09 \times 10^{-31}\ kg}$

Exercise 29.2

Q1 Red light : $E = hf = (6.6\times10^{-34})(4\times10^{14})$

$= \mathbf{2.64\times10^{-19}\ J}$

$2.64\times10^{-19}\ \text{J} = \frac{2.64\times10^{-19}}{1.6\times10^{-19}}\ \text{eV} = \mathbf{1.65\ eV}$

Q2 Blue light : $E = hf = (6.6\times10^{-34})(8\times10^{14})$

$= \mathbf{5.28\times10^{-19}\ J}$

$= \frac{5.28\times10^{-19}}{1.6\times10^{-19}}\ \text{eV} = \mathbf{3.3\ eV}$

Q3 $c = f\lambda \Rightarrow f = \frac{c}{\lambda} = \frac{3\times10^{8}}{5\times10^{-7}} = 6\times10^{14}\ \text{Hz}$

$E = hf = (6.6\times10^{-34})(6\times10^{14})$

$= \mathbf{3.96\times10^{-19}\ J}$

Q4 $\lambda = 600\ \text{nm} = 600\times10^{-9}\ \text{m}$

$\lambda f = c \Rightarrow f = \frac{c}{\lambda}$

$E = hf = \frac{hc}{\lambda} = \frac{(6.6\times10^{-34})(3\times10^{8})}{600\times10^{-9}}$

$= \mathbf{3.3\times10^{-19}\ J}$

Q5 $\lambda = 590\ \text{nm} = 590\times10^{-9}\ \text{m}$

(i) $c = f\lambda \Rightarrow f = \frac{c}{\lambda}$

$\therefore$ frequency $= \frac{3\times10^{8}}{590\times10^{-9}}$

$= \mathbf{5.08\times10^{14}\ Hz}$

(ii) $E = hf = (6.6\times10^{-34})(5.08\times10^{14})$

$= \mathbf{3.3528\times10^{-19}\ J}$

(iii) Energy of source = 10 W = 10 joules per second

Number of Photons emitted per second

$= \frac{\text{Energy emitted per second}}{\text{Energy of one photon}} = \frac{10}{3.3528\times10^{-19}}$

$= \mathbf{2.98\times10^{19}\ Photons}$

Q6 $2.2\ \text{eV} = (2.2)(1.6\times10^{-19})\ \text{J} = 3.52\times10^{-19}\ \text{J}$

$E = hf \Rightarrow f = \frac{E}{h} = \frac{3.52\times10^{-19}}{6.6\times10^{-34}} = \mathbf{5.33\times10^{14}\ Hz}$

$\lambda = \frac{c}{f} = \frac{3\times10^{8}}{5.33\times10^{14}} = \mathbf{5.63\times10^{-7}\ m}$

Q7 Number of Photons striking per second
= Number of electrons emitted per second

Current = Charge passing per second
= Charge on one electron × Number of electrons passing per second

$\therefore\ 2\times10^{-6} = (1.6\times10^{-19})(x)$

$\Rightarrow x = \frac{2\times10^{-6}}{1.6\times10^{-19}} = \mathbf{1.25\times10^{13}\ Photons}$

Q8 $1\ \text{eV} = 1.6\times10^{-19}\ \text{J}$

$4\ \text{eV} = 4\times1.6\times10^{-19} = \mathbf{6.4\times10^{-19}\ J}$

$\Phi = hf_o \Rightarrow f_o = \frac{\Phi}{h} = \frac{6.4\times10^{-19}}{6.6\times10^{-34}}$

$= \mathbf{9.70\times10^{14}\ Hz}$

Q9 (a) $\Phi = hf_o = (6.6\times10^{-34})(2\times10^{15})$

$= \mathbf{1.32\times10^{-18}\ J}$

(b) Work function in eV $= \frac{1.32\times10^{-18}}{1.6\times10^{-19}}$

$= \mathbf{8.25\ eV}$

Q10 $\Phi = 1.2\ \text{eV} = 1.2\times1.6\times10^{-19}\ \text{J}$

$= \mathbf{1.92\times10^{-19}\ J}$

$\Phi = hf_o \Rightarrow f_o = \frac{\Phi}{h} = \frac{1.92\times10^{-19}}{6.6\times10^{-34}}$

$= \mathbf{2.91\times10^{14}\ Hz}$

$\lambda = \frac{c}{f} = \frac{3\times10^{8}}{2.91\times10^{14}} = \mathbf{1.03\times10^{-6}\ m}$

Q11 $f_o = 8.8 \times 10^{14}$ Hz, $f = 9.2 \times 10^{14}$ Hz

(i) $\frac{1}{2} mv_{max}^2 = hf - hf_o = h(f - f_o)$

$= 6.6 \times 10^{-34}(9.2 \times 10^{14} - 8.8 \times 10^{14})$

$= \mathbf{2.64 \times 10^{-20}}$ **J**

(ii) 2.64×10^{-20} J $= \frac{2.64 \times 10^{-20}}{1.6 \times 10^{-19}}$ eV

$=$ **0.165 eV**

Q12 $\lambda = 350$ nm $= 350 \times 10^{-9}$ m

$c = \lambda f \Rightarrow f = \frac{c}{\lambda} = \frac{3 \times 10^8}{350 \times 10^{-9}} = \mathbf{8.57 \times 10^{14}}$ **Hz**

Max $E_K = 2$ eV $= 2 \times 1.6 \times 10^{-19}$ J

$= 3.2 \times 10^{-19}$ J

$E_{K_{max}} = hf - \Phi$

$3.2 \times 10^{-19} = (6.6 \times 10^{-34})(8.57 \times 10^{-14}) - \Phi$

$\Rightarrow \Phi = 5.66 \times 10^{-19} - 3.2 \times 10^{-19}$

$= \mathbf{2.46 \times 10^{-19}}$ **J**

Q13 0.2 mA $= (0.2 \times 10^{-3})$ A $= (0.2 \times 10^{-3})$ C s^{-1}

Number of electrons in 1 C $= \frac{1}{1.6 \times 10^{-19}}$

$\therefore$ Number of electrons leaving cathode

$= \frac{0.2 \times 10^{-3}}{1.6 \times 10^{-19}} \Rightarrow$ Number of photons

$= \frac{0.2 \times 10^{-3}}{1.6 \times 10^{-19}} = \mathbf{1.25 \times 10^{15}}$

Energy of one photon $E = hf =$

$(6.6 \times 10^{-34})(2 \times 10^{16}) = 1.32 \times 10^{-17}$ J

$\therefore$ Energy per second =

$\begin{pmatrix}\text{Energy of one} \\ \text{Photon}\end{pmatrix} \times \begin{pmatrix}\text{Number of Photons} \\ \text{per second}\end{pmatrix}$

$= (1.32 \times 10^{-17})(1.25 \times 10^{15}) = 0.0165$ J

$= \mathbf{1.65 \times 10^{-2}}$ **J**

Q14 $\lambda = 250$ nm $= 250 \times 10^{-9}$ m

$f = \frac{c}{\lambda} = \frac{3 \times 10^8}{250 \times 10^{-9}} = 1.2 \times 10^{15}$ Hz

$\Phi = 1.6$ eV $= (1.6)(1.6 \times 10^{-19})$ J

$= 2.56 \times 10^{-19}$ J

Max kinetic energy $= hf - \Phi$

$\Rightarrow E_{K_{max}}$

$= (6.6 \times 10^{-34})(1.2 \times 10^{15}) - 2.56 \times 10^{-19}$

$= 7.92 \times 10^{-19} - 2.56 \times 10^{-19}$

$= \mathbf{5.36 \times 10^{-19}}$ **J**

$\frac{1}{2}(9.1 \times 10^{-31})v^2 = 5.36 \times 10^{-19}$

$\Rightarrow v = \mathbf{1.09 \times 10^{6}}$ **m s^{-1}**

Q15 $E = hf = (6.6 \times 10^{-34})(92 \times 10^6)$

$= 6.072 \times 10^{-26}$ joules

Number of Photons emitted per second

$= \frac{2 \times 10^6}{6.072 \times 10^{-26}} = \mathbf{3.29 \times 10^{31}}$ **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 $\Rightarrow 2 \propto$ –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 $\Rightarrow 3 \propto$ –particles $\Rightarrow$ decrease in atomic number = 3(2) = 6 to 86 $\therefore$ 2β 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 $4 \propto$ –particles $\Rightarrow$ Mass number decreases by 4×4 = **16** and atomic number decreases by 4×2 = 8

3 β–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) $\mathbf{\frac{1}{2}}$ remains

(ii) 6 years = 2 half-lives $\Rightarrow \mathbf{\frac{1}{4}}$ remains

(iii) 9 years = 3 half-lives $\Rightarrow \mathbf{\frac{1}{8}}$ remains

Q4 40 years = 4 half-lives

$\Rightarrow \frac{1}{2^4} = \mathbf{\frac{1}{16}}$ remains and $\mathbf{\frac{15}{16}}$ 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. $\mathbf{\frac{1}{512}}$

(iii) 40 mins = 2 half-lives $\Rightarrow \frac{1}{4}$ remains

$\Rightarrow \mathbf{\frac{3}{4}}$ has decayed

(iv) $\mathbf{\frac{1}{2^n}}$

Q6 $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} \Rightarrow \lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \frac{\ln 2}{120} = \mathbf{5.776 \times 10^{-3}\ s^{-1}}$

Q7 $T_{\frac{1}{2}}$ = 5.5 minutes = (5.5)(60) seconds

$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \frac{0.693}{(5.5)(60)} = 0.0021\ \mathrm{s}^{-1}$

$= \mathbf{2.1 \times 10^{-3}\ s^{-1}}$

Q8 $\lambda = \frac{\ln 2}{(2.4)(365)(24)(60)(60)} = \mathbf{9.158 \times 10^{-9}\ s^{-1}}$

Q9 $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{5 \times 10^3} = \mathbf{1.386 \times 10^{-4}\ s}$

Q10 $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{2 \times 10^{-3}}$ = 346.57 s = **5.776 min**

Q11 $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{0.693}{9.627 \times 10^{-5}}$ = 7200 s = 2 hours

6 hours = 3 half-lives $\Rightarrow \mathbf{\frac{1}{8}}$ 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 = $\lambda N = (8 \times 10^{-3})(2 \times 10^{15})$

$= \mathbf{1.6 \times 10^{13}}$ **Bq**

Q14 Activity = λN

$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \left(\frac{\ln 2}{(4)(60)}\right)(6 \times 10^{20})$

$= \mathbf{1.73 \times 10^{18}}$ **Bq**

Q15 $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} \Rightarrow \lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$

$\lambda = \frac{\ln 2}{(8 \times 10^{18})(365)(24)(60)(60)}$

$= 2.747 \times 10^{-27}\ \text{s}^{-1}$

Activity = $\lambda N = (2.747 \times 10^{-27})(6.2 \times 10^{16})$

$= \mathbf{1.7 \times 10^{-10}}$ alpha particles per second

Q16 Activity = λN

$3.5 \times 10^{10} = \lambda (2.6 \times 10^{21})$

$\Rightarrow \lambda = \mathbf{1.346 \times 10^{-11}\ s^{-1}}$

$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{1.346 \times 10^{-11}} = 5.1496 \times 10^{10}\text{s}$

$=$ **1633 years**

Exercise 30.3

Q1 64 g = 6.02×10^{23} atoms

1 g = $\frac{6.02 \times 10^{23}}{64}$

2000 g $= \frac{(2000)(6.02 \times 10^{23})}{64}$

$= \mathbf{1.88 \times 10^{25}}$ **atoms**

Q2 218 g = 6.02×10^{23} atoms

3.5 μg $= \frac{6.02 \times 10^{23} \times 3.5 \times 10^{-6}}{218}$

$= \mathbf{9.665 \times 10^{15}}$ **atoms**

Q3 218 g has 6.02×10^{23} atoms

2.4 μg $= \frac{6.02 \times 10^{23} \times 2.4 \times 10^{-6}}{218}$

$= 6.628 \times 10^{15}$ atoms

$\lambda = \frac{0.693}{t_{\frac{1}{2}}} = \frac{0.693}{(3.1)(60)} = 3.73 \times 10^{-3}\ \text{s}^{-1}$

Activity = $\lambda N = (3.73 \times 10^{-3})(6.628 \times 10^{15})$

$= \mathbf{2.47 \times 10^{13}}$ **Bq**

Q4 $T_{\frac{1}{2}}$ = 22 hrs = 79 200 s

$\lambda = \frac{0.693}{79\ 200} = 8.75 \times 10^{-6}\ \text{s}^{-1}$

Activity = λN

$150 = 8.75 \times 10^{-6} N \Rightarrow N = 1.74 \times 10^7$ atoms

6.02×10^{23} atoms = 228 g $\Rightarrow 1.714 \times 10^7$ atoms = $\mathbf{6.5 \times 10^{-15}}$ **grams**

Exercise 31.1

Q1 $E = mc^2 \Rightarrow m = \frac{E}{c^2} = \frac{1.4 \times 10^9}{(3.00 \times 10^8)^2}$

$= \mathbf{1.56 \times 10^{-8}\ kg}$

Q2 Mass lost = $(4 \times 10^6)(60)(60)$

$E = mc^2 = (4 \times 10^6)(60)(60) \times (3 \times 10^8)^2$

$= \mathbf{1.296 \times 10^{27}\ J}$

Q3 Energy emitted in 1 year

$= (3.6 \times 10^{23})(60)(60)(24)(365)$

$= 1.1352 \times 10^{31}$ J

$m = \frac{E}{c^2} = \frac{1.1352 \times 10^{31}}{(3.00 \times 10^8)^2} = \mathbf{1.2614 \times 10^{14}\ kg}$

Q4 $E = mc^2 = (8 \times 10^{-27})(3.00 \times 10^8)^2$

$= \mathbf{7.2 \times 10^{-10}\ J}$

Q5 Mass of reactants:
$2.325210 \times 10^{-26} + 6.646322 \times 10^{-27}$ kg

$= 2.9898 \times 10^{-26}$ kg

Mass of products

$= 2.822706 \times 10^{-26} + 1.672623 \times 10^{-27}$ kg

$= 2.9899 \times 10^{-26}$ kg

Gain in mass = 1.261×10^{-30} kg

$\Rightarrow$ Energy taken in = $E = mc^2$

$= (1.261 \times 10^{-30})(3 \times 10^8)^2$

$= 1.1349 \times 10^{-13}$ J

= 709312.5 eV = **0.71 MeV**

Energy of α-particle = 7.68 MeV

Energy available 7.68 – 0.71 = 6.97 MeV

Kinetic energy of proton = $\frac{17}{18}$ of 6.97

= **6.58 MeV**

Q6 Mass lost $= (3.344 \times 10^{-27})(2)$

$- 6.646 \times 10^{-27} = 4.2 \times 10^{-29}$ kg

$E = mc^2 = (4.2 \times 10^{-29})(3.00 \times 10^8)^2$

$= \mathbf{3.78 \times 10^{-12}\ J}$

Q7 ${}^{59}_{27}\text{Co} + {}^{1}_{0}\text{n} \rightarrow {}^{60}_{27}\text{Co} + \gamma$

Loss in Mass

$= (9.7859 \times 10^{-26}\text{ kg} + 1.6749 \times 10^{-27}\text{ kg})$

$- (9.9520 \times 10^{-26}) = 1.39 \times 10^{-29}$ kg

$E = mc^2 = (1.39 \times 10^{-29})(3 \times 10^8)^2$

$= \mathbf{1.251 \times 10^{-12}\ J}$

Q8 200 MeV = $200 \times (1.6 \times 10^{-19}) \times 10^6$ J

$= 3.2 \times 10^{-11}$ J

$E = mc^2 \Rightarrow m = \frac{E}{c^2} = \frac{3.2 \times 10^{-11}}{(3 \times 10^8)^2}$

$= \mathbf{3.56 \times 10^{-28}\ kg}$

Q9 P.C.M. $\Rightarrow (4.24 \times 10^{-25})U = (6.68 \times 10^{-27})V$
$\Rightarrow \frac{V}{U} = \mathbf{63.5 : 1}$

Energy = $E = mc^2 = (1.2 \times 10^{-29})(3 \times 10^8)^2$

$= \mathbf{1.08 \times 10^{-12}\ J}$

= Total initial energy

i.e. $E_\alpha + E_n = 1.08 \times 10^{-12}$

$\Rightarrow \frac{1}{2}(4.24 \times 10^{-25})\,U^2 + \frac{1}{2}(6.68 \times 10^{-27})\,V^2$

$= 1.08 \times 10^{-12}$

Also $V = 63.5U$

Solving simultaneously gives:

$V = 1.78 \times 10^7$ m s^{-1} and

$U = 2.81 \times 10^5$ m s^{-1}

(see Exercise 32.1 Q1 for an alternative method of solving a question like this.

Q10 ${}_0^1\text{n} \rightarrow {}_1^1\text{p} + {}_{-1}^{0}\text{e}$

Loss in mass = $1.674\ 929 \times 10^{-27}$

$-(1.672\ 623 \times 10^{-27} + 9.109\ 390 \times 10^{-31})$

i.e. Loss in mass = 1.395×10^{-30} kg

$E = mc^2 = (1.395 \times 10^{-30})(3 \times 10^8)^2$

$= \mathbf{1.26 \times 10^{-13}}$ **J**

Exercise 32.1

Q1 Loss in Mass = $3.753\ 152 \times 10^{-25}$

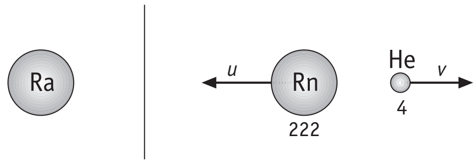
$(-\ 3.686\ 602 \times 10^{-25} + 6.646\ 322 \times 10^{-27})$

$= 8.678 \times 10^{-30}$ kg

$E = mc^2 = (8.678 \times 10^{-30})(3 \times 10^8)^2$

$= 7.81 \times 10^{-13}$ J = **4.88 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

$$= \frac{\frac{1}{2}M_R u^2}{\frac{1}{2}M_H v^2} = \left(\frac{M_R}{M_H}\right)\frac{u^2}{v^2} = \left(\frac{v}{u}\right)\left(\frac{u^2}{v^2}\right) = \frac{u}{v}$$

$= \frac{1}{55.5} \Rightarrow$ Kinetic energy of α-particle

= 55.5 Kinetic energy of Radon

$\Rightarrow$ Kinetic energy of α-particle

$= \frac{\text{Total energy}}{56.5} \times 55.5$

$= \mathbf{7.66 \times 10^{-13}}$ **J**

Q3 The β-particle is so light compared with a Nitrogen nucleus that it gets virtually all of the Kinetic energy (It is approximatley 28 000 times lighter)

$E = mc^2 = (2.77 \times 10^{-31})(3 \times 10^8)^2$

$= \mathbf{2.493 \times 10^{-14}}$ J = Kinetic energy of β-particle

Exercise 32.2

Q1 $1\ u = 1.66 \times 10^{-27}$ kg

$E = mc^2$

$= (1.66 \times 10^{-27})(3.00 \times 10^8)^2$

$= 1.49 \times 10^{-10}$ J

$= \frac{1.49 \times 10^{-10}}{1.6 \times 10^{-19}}$ eV = **931 eV**

Q2 Decrease in Mass

= 238.050 784 – (234.043 593 + 4.002 603)

= 0.004 588 u

$E = mc^2$

$= (0.004588)(1.66 \times 10^{-27})(3 \times 10^8)^2$

$= 6.854 \times 10^{-13}$ J

$= \frac{6.854 \times 10^{-13}}{1.6 \times 10^{-19}}$ eV

= **4.28 MeV**

Exercise 32.3

Q1 Energy needed $E = mc^2$

$= (2.5 \times 10^{-28})(3 \times 10^8)^2$

$= 2.25 \times 10^{-11}$ J

⇒ Energy of each proton

$= 1.125 \times 10^{-11}$ J

= **70 MeV**

Q2 $E = mc^2$

$= (3)(2.5 \times 10^{-28})(3 \times 10^8)^2$

$= 6.75 \times 10^{-11}$ J

⇒ Energy of proton = 3.375×10^{-11} J

= **211 MeV**

Exercise 32.4

Q1

(i) $u\bar{d}$ $\left(+\frac{2}{3}\right)+\left(\frac{1}{3}\right)$ = **+1**

(ii) $\bar{u}d$ $\left(-\frac{2}{3}\right)+\left(-\frac{1}{3}\right)$ = **– 1**

(iii) uud $\left(+\frac{2}{3}\right)+\left(+\frac{2}{3}\right)+\left(-\frac{1}{3}\right)$ = **+1**

(iv) udd $\left(+\frac{2}{3}\right)+\left(-\frac{1}{3}\right)+\left(-\frac{1}{3}\right)$ = **0**

(v) $u\bar{s}$ $\left(+\frac{2}{3}\right)+\left(+\frac{1}{3}\right)$ = **+1**

(vi) $\bar{u}s$ $\left(-\frac{2}{3}\right)+\left(-\frac{1}{3}\right)$ = **–1**

(vii) uds $\left(+\frac{2}{3}\right)+\left(-\frac{1}{3}\right)+\left(-\frac{1}{3}\right)$ = **0**

(viii) uus $\left(+\frac{2}{3}\right)+\left(+\frac{2}{3}\right)+\left(-\frac{1}{3}\right)$ = **+1**

(ix) dds $\left(-\frac{1}{3}\right)+\left(-\frac{1}{3}\right)+\left(-\frac{1}{3}\right)$ = **–1**

(x) dss $\left(-\frac{1}{3}\right)+\left(-\frac{1}{3}\right)+\left(-\frac{1}{3}\right)$ = **–1**

(xi) sss $\left(-\frac{1}{3}\right)+\left(-\frac{1}{3}\right)+\left(-\frac{1}{3}\right)$ = **–1**

Exercise 33.1

Q1 $FSD = 15$ mA

$I_1R_1 = I_2R_2$

(0.015)(5) = (0.985)(R)

$\Rightarrow R = \frac{(0.015)(5)}{(0.985)}$ = **0.07614 Ω**

Q2 $FSD = 10$ mA = 0.01 A

$V_1 + V_2 = 12$

(0.01)(5) + (0.01)(R) = 12 ⇒ R = **1195 Ω**

Q3 (i) In parallel

$FSD = 6$ mA = 0.006 A

$I_1R_1 = I_2R_2$

⇒ (0.006)(10)

= (11.994)(R)

⇒ ***R* = 0.005 Ω**

(ii) In series

20 = (0.006)(10) + (0.006)R

⇒ R = 3323.3 Ω

Q4 Voltages in parallel are equal

⇒ (I)(4) = (20 – I)(0.02)

4I = 0.4 – 0.02I

4.02I = 0.4

$I = \frac{0.4}{4.02}$ = **0.0995 A**

Q5 $I = \frac{V}{R} = \frac{40}{3005}$ = 0.01331 A

$V_1 = I_1R_1$ = (0.01331)(5) = **0.0666 V**

Q6 $I = \frac{V}{R} = \frac{20}{20\,000}$ = 0.001 A

Need: 80 V across R

$V = IR \Rightarrow R = \frac{V}{I} = \frac{80}{0.001}$ = 80 000 Ω

∴ connect in series a resistor of **80 kΩ**

Q7 $A = \pi r^2 = \pi\left(\frac{d}{2}\right)^2 = \pi\left(\frac{0.085}{2000}\right)^2$

$$R = \frac{\rho l}{A} = \frac{(1.7 \times 10^{-8})(18)}{\pi\left(\frac{0.085}{2000}\right)^2}$$

R = **53.93** Ω

FSD = 2 mA = 0.002 A

(i) $V = IR$

V_{max} = (0.002)(53.93) = **0.1079 V**

(ii) $10 = I_1R_1 + I_2R_2$

10 = (0.002)(53.93) + (0.002)R

***R* = 4946** Ω