Test yourself (page 2)

1 a) $\text{Av. speed} = \frac{\text{total distance}}{\text{time}}$

$= \frac{800}{40}$

$= 20$ m/s

b) The car may have been accelerating, decelerating or stationary during its journey.

2 a) $\text{Speed} = \frac{\text{distance}}{\text{time}}$

$10 = \frac{\text{distance}}{9}$

Distance = 90 m

b) $\text{Speed} = \frac{\text{distance}}{\text{time}}$

$10 = \frac{220}{\text{time}}$

$\text{Time} = \frac{220}{10}$

Time = 22 s

3 a) $\text{Av. speed} = \frac{\text{total distance}}{\text{time}}$

$= \frac{400}{44}$

$= 9.1$ m/s

b) $\text{Av. speed} = \frac{\text{total distance}}{\text{time}}$

$= \frac{210\,000}{(3 \times 60 \times 60)}$

$= 19.4$ m/s

c) $\text{Av. speed} = \frac{\text{total distance}}{\text{time}}$

$= \frac{43\,750\,000}{(25 \times 60 \times 60)}$

$= 4860$ m/s (3 significant figures)

Show you can (page 2)

a) Distance does not have a direction, displacement does.

b) Speed does not have a direction, velocity does.

Show you can (page 4)

Speed of 72 km/h = $\frac{72\,000\text{ m}}{(60 \times 60)\text{s}}$ = 20 m/s

Show you can (page 5)

a) The train's velocity increases by 3 m/s in each and every subsequent second.

b) The bus's velocity decreases by 2 m/s in each and every subsequent second.

Test yourself (page 6)

4 $a = \frac{(v - u)}{t}$

$= \frac{(30 - 3)}{8}$

$= 3.375\text{ m/s}^2$

5 $a = \frac{(v - u)}{t}$

$= \frac{(0 - 25)}{5}$

$= -5\text{ m/s}^2$

6 **a)** $a = \frac{(v - u)}{t}$

$4 = \frac{(v - 0)}{5}$

Hence $v = 4 \times 5$

$= 20$ m/s

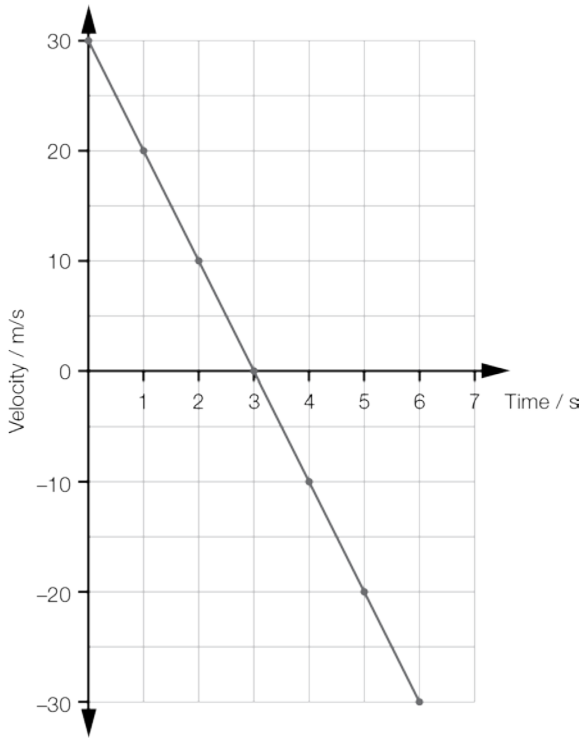
b) $a = \frac{(v - u)}{t}$

$4 = \frac{(v - 28)}{8}$

$32 = v - 28$

$v = 60$ m/s

7



Show you can (page 7)

Area of triangle = $\frac{1}{2}$ × base × perpendicular height

= $\frac{1}{2}$ × 4 × 8

= 16 m

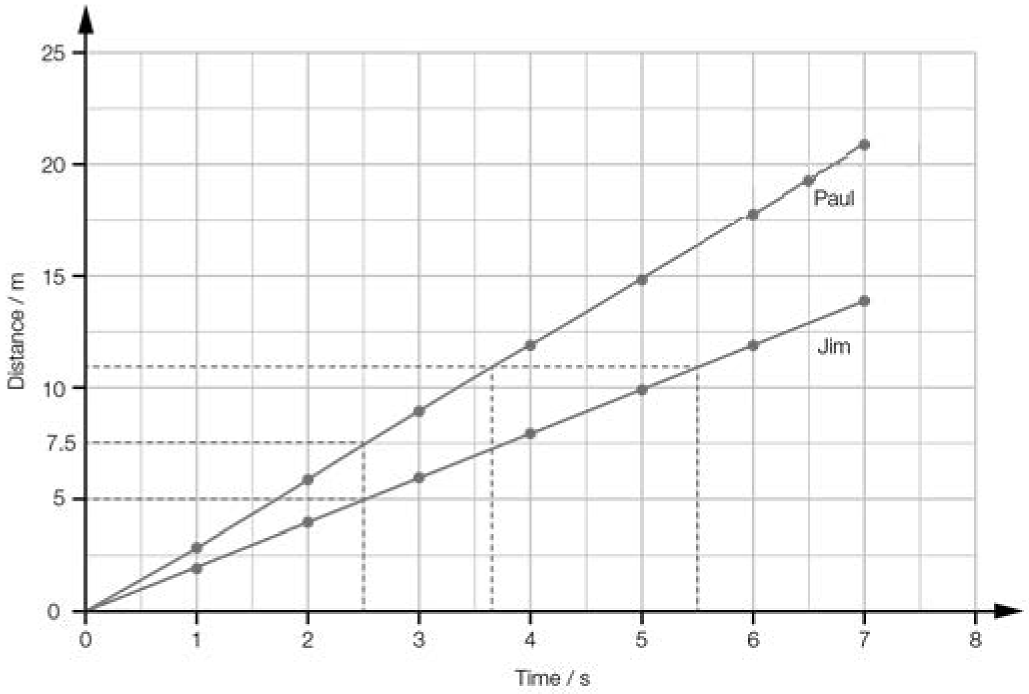
Test yourself (page 9)

Name of Quantity	Formula/Definition	Scalar or Vector
Distance	**Separation between two points**	scalar
Displacement	**Separation between two points, in a given direction**	**vector**
Speed	Rate of change of distance with respect to time	scalar
Velocity	**Rate of change of displacement with respect to time**	vector
Acceleration	Rate of change of velocity with respect to time	**vector**

8

Practice questions (pages 10–11)

1 a) and b)



a) (3 marks)

b) (3 marks)

c) i) Paul (1 mark)

ii) Paul 3.7 s, Jim 5.5 s (1 mark)

iii) 7.5 – 5 = 2.5 m (2 marks)

iv) Yes (1 mark)

v) Jim's average speed = $\frac{14}{7}$

= 2 m/s (3 marks)

2 At time = 0 s, (1 mark) the object has an initial speed. (1 mark)

As time increases, the object's speed increases (1 mark) non-uniformly. (1 mark)

It then reaches a larger (1 mark) steady speed. (1 mark)

3 a) Acceleration = gradient (1 mark)

$= \frac{(25-0)}{(5-0)}$ (1 mark)

$= 5\ m/s^2$ (1 mark)

b) Total displacement = area under graph (1 mark)

= area of triangle + area of rectangle

$= \frac{(5 \times 25)}{2} + 10 \times 25$

= 62.5 + 250 (2 marks)

= 312.5 m (also accept 313 m) (1 mark)

4 a) i) Uniform acceleration (1 mark)

ii) Constant velocity (1 mark)

iii) Uniform deceleration (1 mark)

b) i) Acceleration = gradient (1 mark)

$= \frac{(5-0)}{(2-0)}$ (1 mark)

$= 2.5\ \text{m/s}^2$ (1 mark)

ii) Total displacement = area under graph (1 mark)

= area of triangle + area of rectangle + area of triangle

$= \frac{(5\times2)}{2} + (5\times1) + \frac{(5\times4)}{2}$ (1 mark)

= 5 + 5 + 10 (1 mark)

= 20 m (1 mark)

iii) Av. speed = $\frac{\text{total distance}}{\text{time}}$ (1 mark)

$= \frac{20}{7}$ (1 mark)

= 2.86 m/s (1 mark)

5 u = 20 m/s

v = ? m/s

t = 10 s

$a = 3\ \text{m/s}^2$

$v = u + a\,t$ (1 mark)

= 20 + (3 × 10) (1 mark)

= 50 m/s (1 mark)

6 $u = 0$ m/s, $v = ?$ m/s, $t = 10$ s, $a = 0.3$ m/s^2, $s = ?$

$v = u + a t$ (1 mark)

$= 0 + (0.3 \times 10)$ (1 mark)

$= 3$ m/s

$s = (v + u) \times \frac{t}{2}$ (1 mark)

$= (3 + 0) \times \frac{10}{2}$ (1 mark)

$= 15$ m (1 mark)

7 $u = 20$ m/s, $v = 0$ m/s, $t = ?$ s, $a = -10$ m/s^2, $s = ?$

$v = u + a t$ (1 mark)

$0 = 20 + (-10 \times t)$ (1 mark)

$10 t = 20$

$t = 2$ s (1 mark)

$s = (v + u) \times \frac{t}{2}$ (1 mark)

$= (20) \times \frac{2}{2}$ (1 mark)

$= 20$ m (1 mark)

8 $u = 0$ m/s, $v = ?$ m/s, $t = 3$ s, $v = ?$ m/s, $t = 3$ s, $a = 10$ m/s^2, $s = ?$

a) $v = u + a t$ (1 mark)

$? = 0 + (10 \times 3)$ (1 mark)

$v = 30$ m/s (1 mark)

b) Av. speed $= \frac{(v + u)}{2}$ (1 mark)

$= \frac{(30 + 0)}{2}$ (1 mark)

$= 15$ m/s (1 mark)

c) $s = (v + u) \times \frac{t}{2}$ (1 mark)

$= (30) \times \frac{3}{2}$ (1 mark)

$= 45$ m (1 mark)

9 $u = 0$ m/s, $v = ?$ m/s, $t = 10$ s, $a = 10$ m/s^2, $s = 500$ m

a) $v = u + a\,t$ (1 mark)

$? = 0 + (10 \times 10)$ (1 mark)

$v = 100$ m/s (1 mark)

b) Av. vel. $= \dfrac{(v+u)}{2}$ (1 mark)

$= \dfrac{(100+0)}{2}$ (1 mark)

$= 50$ m/s (1 mark)

OR Av. vel. $= \dfrac{\text{total distance}}{\text{time}}$

$= \dfrac{500}{10}$

$= 50$ m/s

10 $u = 50$ m/s, $v = 0$ m/s, $t = ?$ s, $a = -10$ m/s^2, $s = ?$

a) $v = u + a\,t$ (1 mark)

$0 = 50 + (-10 \times ?)$ (1 mark)

$t = \dfrac{50}{10}$ s

$t = 5$ s (1 mark)

b) $s = (v + u) \times \dfrac{t}{2}$ (1 mark)

$= (50 + 0) \times \dfrac{5}{2}$ (1 mark)

$= 125$ m (1 mark)

11 $u = 0$ m/s, $v = ?$ m/s, $t = 5$ s, $a = 3$ m/s^2

a) $v = u + at$ (1 mark)

$v = 0 + (3 \times 5)$ (1 mark)

$v = 15$ m/s (1 mark)

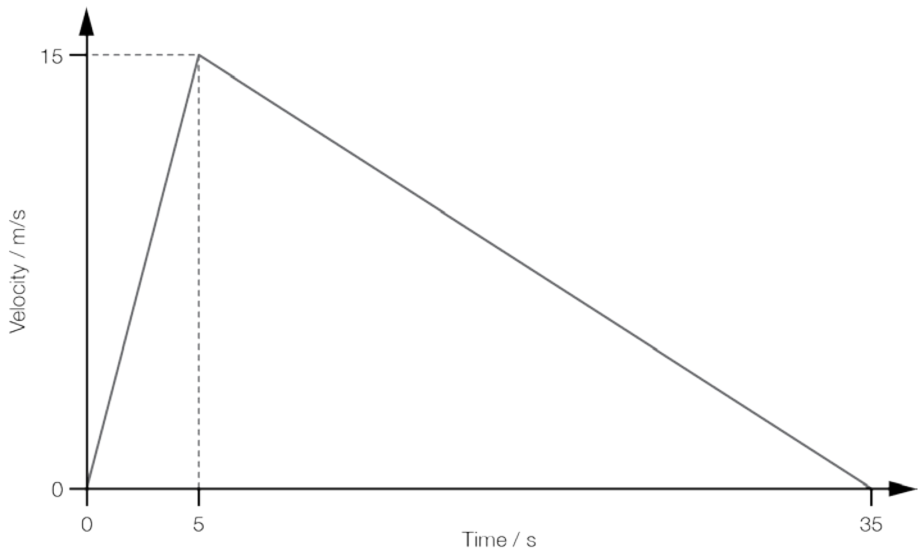
$u = 15$m/s, $v = 0$ m/s, $t = ?$ s, $a = -0.5$ m/s^2

b) $v = u + at$ (1 mark)

$0 = 15 + (-0.5 \times t)$ (1 mark)

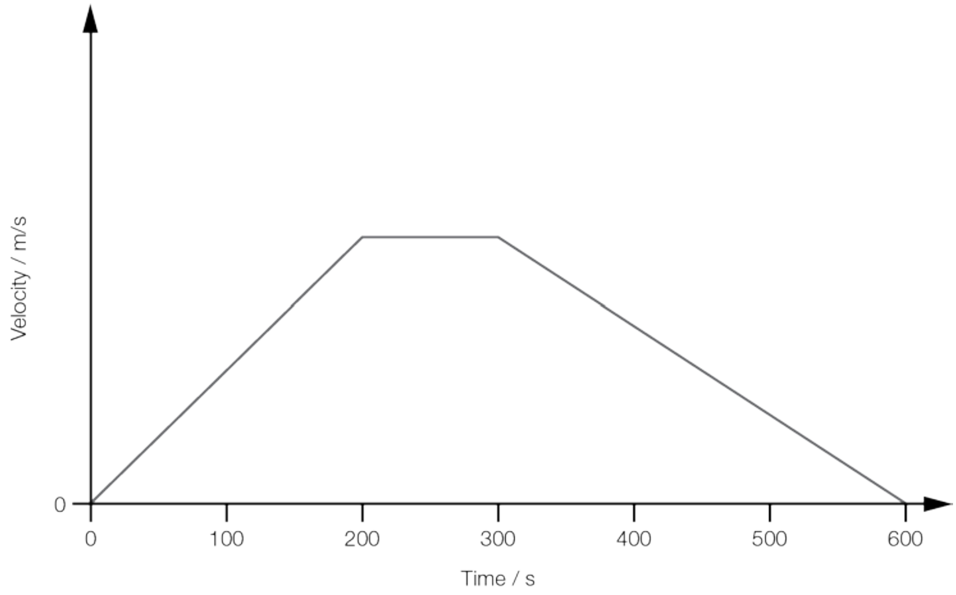
$t = 30$ s (1 mark)

c)



(3 marks)

12 a)



(1 mark)

b) Displacement = 0 m, hence average vel. = 0 m/s (1 mark)

13 a) Direction of motion has changed. (1 mark)

b) Area of smaller triangle = $\frac{1}{2}$ × base × perpendicular height (1 mark)

$= \frac{1}{2} \times 1.5 \times 16$ (1 mark)

= 12 m (1 mark)

c) Accel. of free fall = gradient of graph (1 mark)

$= \frac{30}{3}$ (1 mark)

= 10 m/s^2 (1 mark)

Test yourself (page 18)

1 a) "Steady speed" means there is no acceleration, so the forces on the cyclist must be balanced.

b) Resultant force = (70 – 40) = 30 N

Mass = 90 kg

Acceleration = ?

$F = m\,a$

$a = \frac{F}{m}$

$= \frac{30}{90}$

$a = 0.33\ \text{m/s}^2$

2 Resultant force = (F_{thrust} – 400)

m = 1200 kg

$a = 3.0\ \text{m/s}^2$

resultant force = $m\,a$

(F_{thrust} – 400) = 1200 × 3

(F_{thrust} – 400) = 3600

F_{thrust} = 4000 N

3 Resultant force = (F_{thrust} – $F_{friction}$)

m = 1200 kg

$a = 2.0\ \text{m/s}^2$

resultant force = $m\,a$

(3000 – $F_{friction}$) = 1200 × 2

(3000 – $F_{friction}$) = 2400

$F_{friction}$ = 600 N

4 a) To the right

b) Resultant force = $m\,a$

(2000 – 400) = 800 × a

$\frac{(1600)}{800} = a$

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

5 a) Weight = 20 000 N

b) Resultant force = $m\,a$

(25 000 – 20 000) = 2000 × a

$\frac{(5000)}{2000} = a$

$a = 2.5\ \text{m/s}^2$

6 Steady speed implies frictional force = forward thrust = 300 N

Resultant force = $m\,a$

(F_{thrust} – $F_{friction}$) = $m\,a$

(F_{thrust} – 300) = 500 × 2

F_{thrust} = 1000 + 300

F_{thrust} = 1300 N

7 a) $u = 24$ m/s

$v = 0$ m/s

$t = 8$ s

$a = ?$

$$a = \frac{(v-u)}{t} = \frac{(0-24)}{8} = -3 \text{ m/s}^2$$

b) $m = 1200$ kg

$a = 3$ m/s^2

$F = ?$

$$F = m\,a = 1200 \times 3$$

$F = 3600$ N

8 a) The force exerted by the cyclist must be equal to frictional force due to air resistance etc., so there are balanced forces on the cyclist, hence steady speed. But if the forward force increases to 240 N with a frictional force of 120 N, there must be a resultant forward force causing acceleration.

b) Resultant force = (300 – 120)

$m = 60$ kg

$a = ?$

Resultant force = $m\,a$

$180 = 60 \times a$

$a = 3$ m/s^2

9 a) $u = 50$ m/s

$v = 0$ m/s

$t = 5$ s

$a = ?$

$$a = \frac{v-u}{t} = \frac{0-50}{5} = -10 \text{ m/s}^2$$

b) Resultant force = 18 000 N

$m = ?$

$a = 10$ m/s^2

Resultant force = $m\,a$

$18\,000 = m \times 10$

$m = 1800$ kg

10 a) $u = 20$ m/s

$v = 0$ m/s

$t = 0.1$ s

$a = ?$

$$a = \frac{(v-u)}{t} = \frac{(0-20)}{0.1} = -200 \text{ m/s}^2$$

b) $F = m\,a$

$= 1000 \times 200$

$= 2 \times 10^5$ N

Show you can (page 19)

a)

	Mass	Weight
1	is an amount of material	**is the force of attraction between the mass of an object and mass of Earth**
2	**is constant**	varies from place to place
3	is measured in kg	is measured in **newtons (or 'N')**
4	mass = density × volume	**weight = mass × acceleration due to gravity**

b) i) $W = ?$, $m = 70$ kg, $g = 10$ N/kg

$W = m\,g$

$= 70 \times 10$

$= 700$ N

ii) $W = ?$, $m = 70$ kg, $g = 1.6$ N/kg

$W = m\,g$

$= 70 \times 1.6$

$= 112$ N

Show you can (page 21)

a) Weight is measured in newtons not kilograms. She should have said "My weight is 550 N" or "My mass is 55 kg".

b) It will accelerate then fall with a constant velocity (also known as terminal velocity).

c) Both hammer and feather will accelerate downwards at 1.6 m/s^2, since there is no air resistance on the Moon.

d) Opening the parachute increases the drag force, which will decelerate the parachutist.

e) The sky-diver falls initially with a large acceleration (from origin to A). As the velocity increases, the air resistance also increases and so the acceleration reduces (section AB). Eventually, at point B the upward force due to air resistance balances the downward force due to gravity, so the velocity stays constant (section BC). At point C, the parachute opens and this greatly increases the air resistance, so the force of air resistance is greater than the force due to gravity, and in section CD the sky-diver decelerates rapidly. Eventually, at point D, once again the force due to air resistance on the sky-diver + parachute balances the force due to gravity, the deceleration is zero and the sky-diver + parachute falls at constant velocity (section DE), until the skydiver reaches the ground at point E.

Test yourself (page 21)

11 a) 10 s

b) −50 m/s

c) Total distance = 2 × height

= 2 × area of triangle

$= 2 \times \frac{1}{2} \times 5 \times 50$

= 125 m

d) 0 m (it is thrown vertically upwards and comes back to rest on the ground where it started)

Practice questions (pages 22–23)

1 a) The acceleration of a body is directly proportional to the force applied to it (if its mass is constant), and the direction of the acceleration is parallel to the direction of the force. (2 marks)

b) $u = 0$ m/s, $v = 50$ m/s, $t = 25$ s, $a = ?$

$a = \frac{(v - u)}{t}$ (1 mark)

$= \frac{(50 - 0)}{25}$ (1 mark)

$= 2$ m/s^2 (1 mark)

c) Resultant force = 60 000 – 1500 = 58 500 N, $m = ?$, $a = 2$ m/s^2

resultant force = $m\,a$ (1 mark)

58 500 = $m \times 2$ (1 mark)

m = 29 250 kg (1 mark)

2 a) A body remains at rest or travels with uniform velocity, unless there is a resulting force acting on it. (2 marks)

b) $F = 90\,000$, $m = 3000$ kg, $a = ?$

$F = m\,a$ (1 mark)

90 000 = 3000 × a (1 mark)

a = 90 000/3000

a = 30 m/s^2 (1 mark)

c) $u = ?$ m/s, $v = 0$ m/s, $t = 2$ s, $a = -30$ m/s^2

$a = \frac{v - u}{t}$ (1 mark)

$-30 = \frac{0 - u}{2}$ (1 mark)

$-u = 2 \times (-30)$

$u = 60$ m/s (1 mark)

3 a) See experiment 'Investigating Newton's second law' on page 15. Include:

- a list of apparatus (1 mark)
- a diagram of apparatus (1 mark)
- a method (2 marks)
- an outlined table of results. (2 marks)

b) Since $F = m\,a$

then $m = \frac{F}{a}$ (1 mark)

$= \frac{1}{\text{(gradient of graph)}}$ (1 mark)

$= \frac{1}{(3/4500)}$

$= \frac{4500}{3}$

= 1500 kg (1 mark)

c) u = 6 m/s, v = 18 m/s, t = 4 s, a = ?

$a = \frac{(v-u)}{t}$ (1 mark)

$= \frac{(18-6)}{4}$ (1 mark)

$a = 3\ \text{m/s}^2$ (1 mark)

4 a) u = 0 m/s, v = 75 m/s, t = 1.5 s, a = ?

$a = \frac{(v-u)}{t}$ (1 mark)

$= \frac{(75-0)}{1.5}$ (1 mark)

$a = 50\ \text{m/s}^2$ (1 mark)

b) Resultant force = ? N, m = 22 000 kg, $a = 50\ \text{m/s}^2$

resultant force = $m\,a$ (1 mark)

= 22 000 × 5 (1 mark)

= 1.1×10^6 N (1 mark)

5 a) Resultant force = 210 N, m = ? kg, $a = 2\ \text{m/s}^2$

resultant force = $m\,a$ (1 mark)

210 = m × 2 (1 mark)

m = 105 kg

= mass of bicycle + mass of Tim

mass of bicycle = 105 – 65

= 40 kg (1 mark)

b) $F = 1.5 \times 10^4$ N; m = 2500 kg; a = ? m/s^2

$F = m\,a$ (1 mark)

$1.5 \times 10^4 = 2500 \times a$ (1 mark)

$a = 6.0$ m/s^2 (1 mark)

6 a) $W = m\,g$ (1 mark)

$= 70 \times 10$

$= 700$ N (1 mark)

b) m = 70 kg; g = 1.6 m/s^2; W = ?

$W = m\,g$ (1 mark)

$= 70 \times 1.6$ (1 mark)

$= 112$ N (1 mark)

c) W = 105.6 N; m = 12 kg; g = ? m/s^2

$W = m\,g$ (1 mark)

$105.6 = 12 \times g$

$g = \frac{105.6}{12}$

$= 8.8$ N/kg (1 mark)

d) N/kg $= \frac{\text{kg m/s}^2}{\text{kg}}$ (1 mark)

$=$ m/s^2 (1 mark)

So there are two equivalent sets of units for "*g*"!

7 a) Av. velocity = total displacement/time (1 mark)

$= \frac{1875}{25}$ (1 mark)

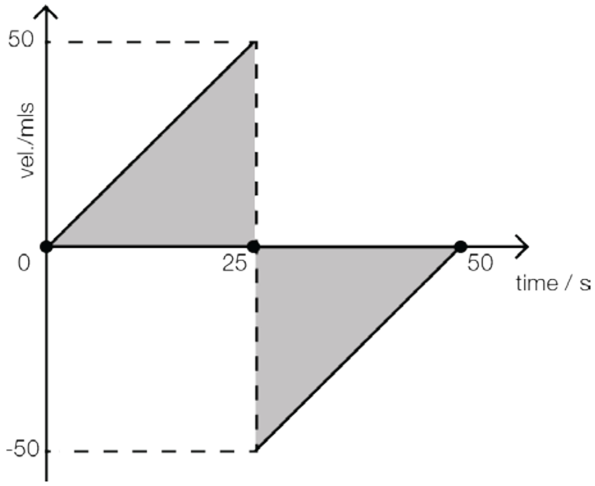
$= 75$ m/s (1 mark)

b) Av. velocity $= \frac{(v+u)}{2}$ (1 mark)

$75 = \frac{(0+u)}{2}$ (1 mark)

So max. velocity u = 150 m/s (1 mark)

c)



Axes labelled and scaled correctly (2)

Positive and negative triangles (1) each (4 marks)

d) Average velocity = 0 m/s (1 mark)

e) The bullet returns to the point where it originally left the surface, so its displacement is zero.

$$\text{velocity} = \frac{\text{displacement}}{\text{time}}$$

= 0 m/s (1 mark)

f) s = 1875 m, u = 150 m/s, t = 25 s, a = ? m/s^2

$a = \frac{(v-u)}{t}$ (1 mark)

$= \frac{(0-150)}{25}$ (1 mark)

= −6.0 m/s^2 (minus sign indicates downwards) (1 mark)

8 a) Resultant force = $m\,a$

= 15 000 × 2

= 30 000 N (1 mark)

b) Resultant force = forward force − force of friction (1 mark)

So forward force = resultant force + force of friction

= 30 000 + 12 000 (1 mark)

= 42 000 N (1 mark)

9 a) u = 0 m/s, v = ?, t = 1.5 s, a = 10 m/s^2

$a = \frac{(v-u)}{t}$ (1 mark)

$10 = \frac{(v-0)}{1.5}$ (1 mark)

v = 15 m/s (1 mark)

b) i)

$u = 24$ m/s, $v = 0$, $t = ?$ s, $a = -10$ m/s^2

$a = \frac{(v - u)}{t}$ (1 mark)

$-10 = \frac{(0 - 24)}{t}$ (1 mark)

$t = 2.4$ s (1 mark)

ii) $s = (v + u)\ \frac{t}{2}$ (1 mark)

$= (24) \times \frac{2.4}{2}$ (1 mark)

$= 12 \times 2.4$ s

$s = 28.8$ m (1 mark)

10 a) Forward force = 100 000 N

b) Resultant force = $m\ a$ (1 mark)

175 000 – 100 000 = 25 000 × a (1 mark)

75 000 = 25 000 × a (1 mark)

$a = \frac{75\,000}{25\,000}$

$a = 3$ m/s^2 (1 mark)

Test yourself (page 26)

1 **a)** 1 N => 15 – 12

= 3 cm

b) Total length = 9 cm, when 1 N has been added

So orig. length = 9 – 3

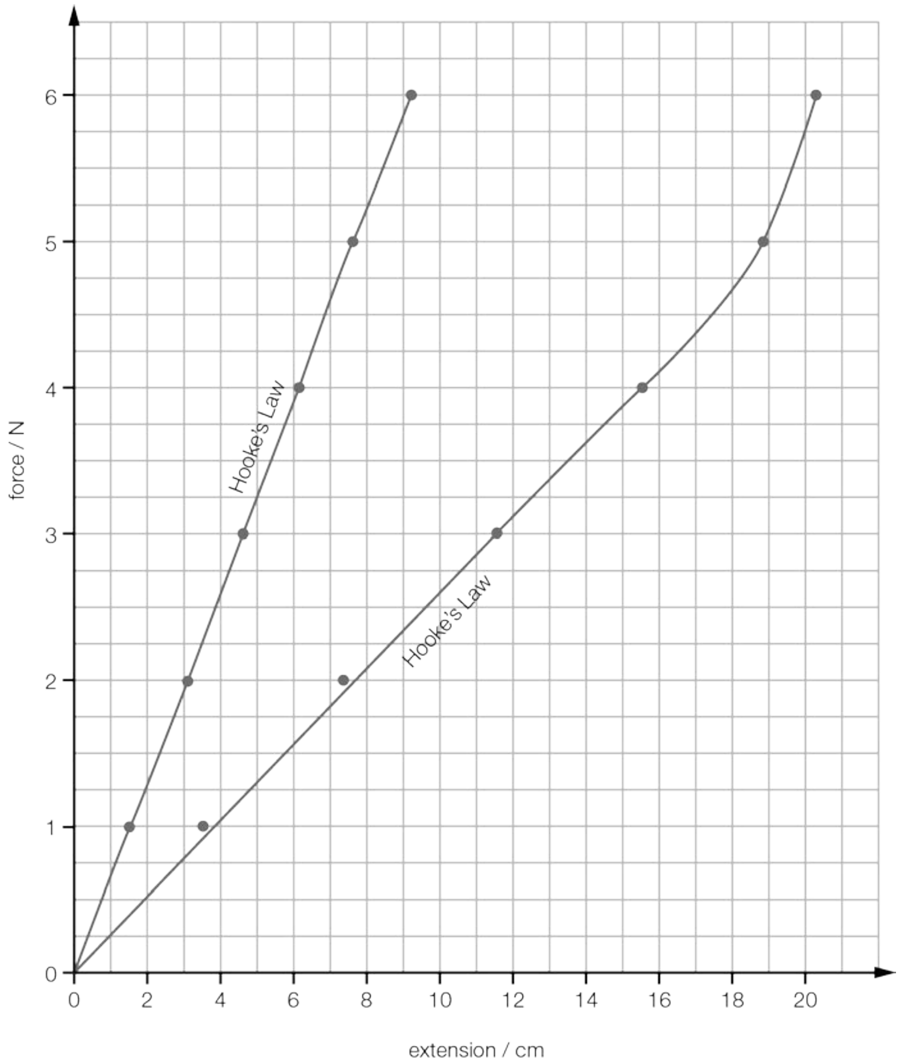
= 6 cm

2 Total extension is 60 – 24 = 36 cm

But 1 N produces an extension of 0.4 cm.

Hence $\frac{36}{0.4}$ = 90 N of force must be applied to the chest expander.

3



Show you can (page 26)

a) i)

Load in N	0	3	6	9	12
Length of spring in cm	6	8	10	12	14
Extension in cm	**0**	**2**	**4**	**6**	**8**

ii) Each additional 3 N, produces an extra extension of 2 cm. In other words, the extension is directly proportional to the load. So yes, Hooke's law is obeyed.

Show you can (page 27)

a) The area of the pinpoint is tiny so the ratio of force to the area, i.e. the pressure, is very large.

b) The ladder has a very large surface area in contact with the ice. The firefighter's weight and the weight of the ladder itself therefore produce a small pressure on the ice, so the ice is less likely to break.

c) The total area of the tracks of the tank is very large, so that the weight of the tank is spread out and the pressure on the soft ground is small. So the tank will not sink into the soft ground.

d) The sharpened chisel will have a smaller area of contact with the wood than a blunt chisel. So the pressure exerted by the carpenter will be larger and will penetrate the wood easily.

Test yourself (page 28)

4 Force = 600 N

Area = 300 cm^2

Pressure = ?

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{600}{300} = 2\ \text{N/cm}^2$$

5 Force = 56 000 N

Area = 0.005 m^2

Pressure = ? N/m^2

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{56\ 000}{0.005} = 1.12 \times 10^7\ \text{Pa}$$

6 Force = 320 N

Area of face 1 = 0.8 × 0.5 = 0.4 m^2

Pressure = ? N/m^2

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{320}{0.4} = 800\ \text{Pa}$$

Force = 320 N

Area of face 2 = 0.8 × 0.4 = 0.32 m^2

Pressure = ? N/m^2

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{320}{0.32} = 1000 \text{ Pa}$$

Force = 320 N

Area of face 1 = 0.5 × 0.4 = 0.2 m^2

Pressure = ? N/m^2

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{320}{0.2} = 1600 \text{ Pa}$$

Maximum pressure produced by the smallest area (1600 Pa)

Minimum pressure produced by the largest area (800 Pa)

7 Force = 400 N

Area = 2 cm^2

= 0.0002 m^2

Pressure = ?

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{400}{0.0002} = 2.0 \times 10^6 \text{ Pa}$$

8 Force = ? N

Area = 0.5 m^2

Pressure = 1 000 Pa

Force = pressure × area

= 1000 × 0.5

= 500 N

9 **a)** Force = 750 N

Area = ? cm^2

Pressure = 3 N/cm^2

$$\text{Area} = \frac{\text{force}}{\text{pressure}} = \frac{750}{3} = 250 \text{ cm}^2$$

B) The area of contact will be doubled, so the pressure will be halved.

10 Force = 30 000 N

Area = 0.75 m^2

Pressure = ? N/m^2

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{30000}{0.75} = 40\,000 \text{ N/m}^2$$

Test yourself (pages 30–31)

11 a) Moment = force × distance to pivot

= 150 × 0.9

= 135 N m

b) $F_1 \times d_1 = F_2 \times d_2$

$F_1 \times 1.35 = 135$

$$F_1 = \frac{135}{1.35}$$

= 100 N, so a force just greater than 100 N is required

12 $F_1 \times d_1 = F_2 \times d_2$

$3 \times x = 4 \times 36$

$x = 48$ cm

13 a) Moment = 100 N × 4 m = 400 N m clockwise

b) 400 N m anti-clockwise, because the gate does not move

c) Moments are balanced

Man's moment = $F \times (4 - 3) = 400$

Hence, $F = 400$ N

14 a) Moment = 5 N × 40 cm

= 200 N cm

= 2.0 N m clockwise

b) $W \times 25 = 200$

$$W = \frac{200}{25}$$

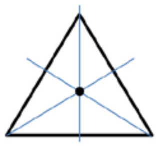
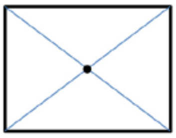
$W = 8$ N

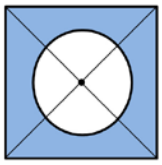
15 $F_1 \times d_1 = F_2 \times d_2$

$F \times 0.6 = 100 \times 0.3$

$F = 50$ N

Test yourself (page 34)

16 a)  

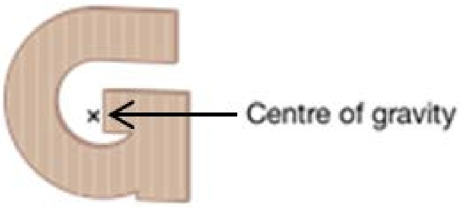
b) 

17 a) The centre of gravity is a point through which the whole weight of the body appears to act.

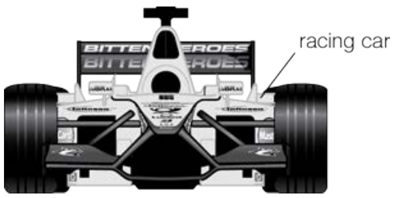
b) i) If the compass is wide enough, the centre of gravity of the pair of compasses and pencil could be below the table and exactly below the pencil point. In this condition, there is no moment about the point of suspension, so the pencil remains upright.

ii) If the compass is too wide (or not wide enough), there will be a resultant moment about the pencil point and the pencil will fall.

c)

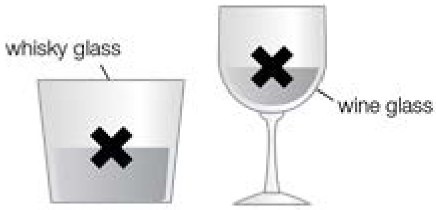


18 a)



b) Low centre of gravity and wide wheelbase.

19 a)



b) The whisky glass

c) Its centre of gravity is lower and the base of the whisky glass is wider.

Practice questions (pages 35–38)

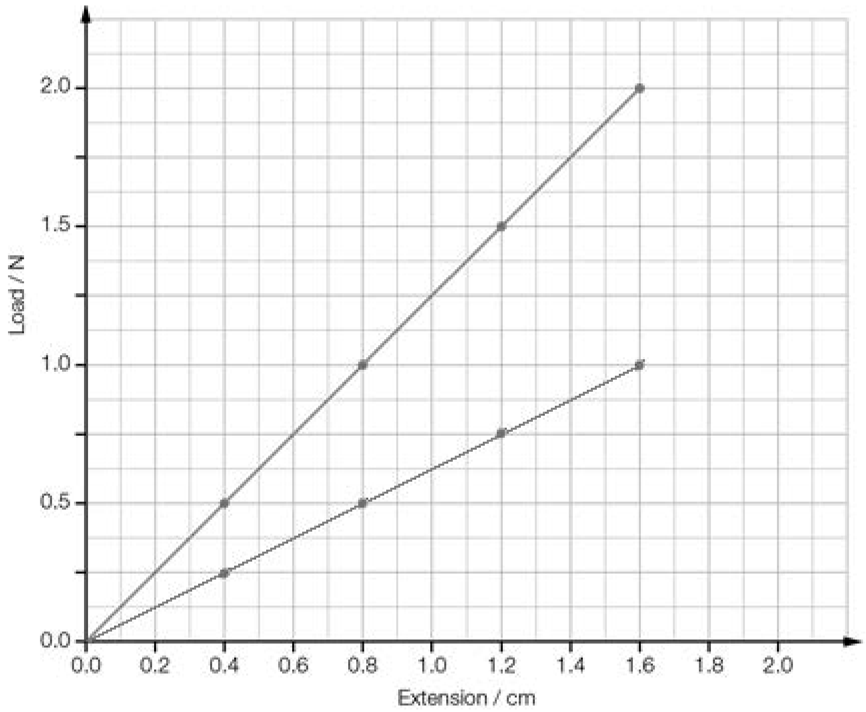
1 a)	The extension of a spring is directly proportional to the load,	(2 marks)
	provided the proportional limit is not exceeded.	(1 mark)
b) i)	120.5 – 0.5	(1 mark)
	= 120 cm	(1 mark)
ii)	2.0 kN	(1 mark)
	Extension increases by more	(1 mark)
	than 1.5 cm for equal increases in force.	(1 mark)

iii) For a load of 5 kN, the length of the seatbelt would be permanently changed/deformed. (1 mark)

For a load of 1 kN, the length of the seatbelt would return to its original length. (1 mark)

iv) The large forces involved in a major accident are likely to permanently deform seatbelts, so afterwards they behave in a plastic way rather than elastically. (1 mark)

2 a)



b) 1.25 N (1 mark)

c) Grad = $\frac{1.6}{2}$ (1 mark)

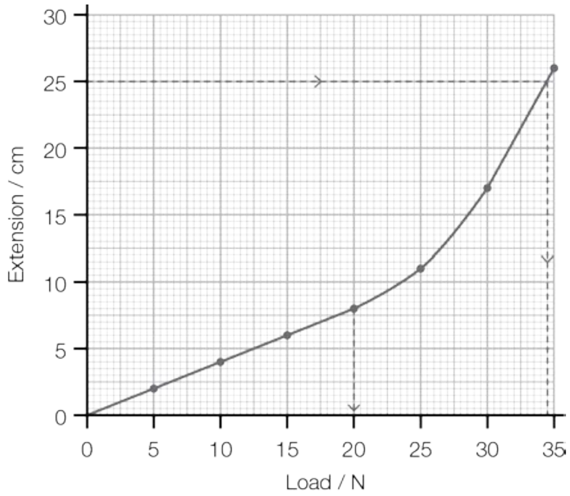
= 0.8 cm/N

$k = \frac{1}{\text{grad}}$ (1 mark)

= 1.25 N/cm (1 mark)

d) See graph in question 2 a) (2 marks)

3 a)



(2 marks)

b) 20 N (1 mark)

c) 34.5 N, (1 mark)

but this is in the region of the graph beyond that where Hooke's Law applies, (1 mark)

so is only an estimate. (1 mark)

4 a) Pressure is how force is distributed normally (at right angles) over an area. (1 mark)

b) Area = πr^2

$= \pi (0.08)^2$ (1 mark)

$= 0.02$ mm^2 (1 mark)

Area = πr^2

$= \pi (0.08 \times 10^{-3})^2$ (1 mark)

$= 2.0 \times 10^{-8}$ m^2 (1 mark)

c) 180 MPa = 180 000 000 Pa

$= 1.8 \times 10^8$ Pa (1 mark)

d) Force = pressure × area (1 mark)

$= 1.8 \times 10^8 \times 2.0 \times 10^{-8}$ (1 mark)

= 3.6 N (1 mark)

5 a) Area = 2 × 15 = 30 m^2 (1 mark)

b) Pressure = $\frac{\text{force}}{\text{area}}$ (1 mark)

$= \frac{150\,000}{30}$ (1 mark)

= 5000 Pa (1 mark)

c) Higher forces, (1 mark)

greater turning effect, (1 mark)

so trailer may topple over side of bridge.

6 $W \times d_1 = F \times d_2$ (1 mark)

600 × 75 = F × 225

$F = \frac{(600 \times 75)}{225}$ (1 mark)

= 200 N (1 mark)

7 a) The centre of gravity is a point through which the whole weight of the body appears to act. (1 mark)

b) Moment = force × distance to pivot (1 mark)

= 1500 × 0.4 (1 mark)

= 600 N m (1 mark)

c) 600 = effort × (0.4 + 0.7) (1 mark)

effort = $\frac{600}{1.1}$ (1 mark)

= 546 N (1 mark)

d) Upward force at pivot = weight – effort (1 mark)

= 1500 – 546

= 954 N (1 mark)

8 a) When a body is in equilibrium, the sum of the clockwise moments about any point equals the sum of the anticlockwise moments about the same point. (2 marks)

b) i) $W \times d_1 = F_2 \times d_2$ (1 mark)

$W \times (40 - 30) = 5 \times (40 - 8)$ (1 mark)

$$W = 5 \times \frac{32}{10}$$

$W = 16$ N (1 mark)

ii) Reaction force = total weight of wood + 5 N weight

= 16 + 5

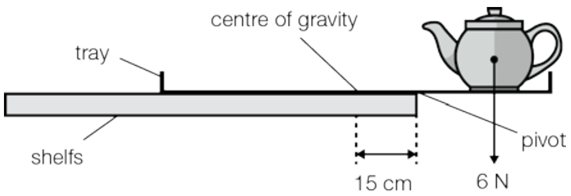
= 21 N (1 mark)

9 a) Moment = force × perpendicular distance to pivot (1 mark)

= 20 × 45 (1 mark)

= 900 N cm (= 9.0 N m) (1 mark)

b) i) (1 mark)



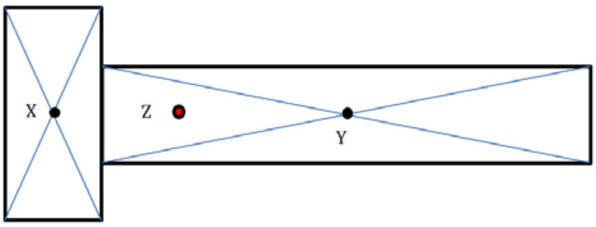
ii) $W \times d_1 = F_2 \times d_2$ (1 mark)

10 × 15 = 6 × distance from pivot (1 mark)

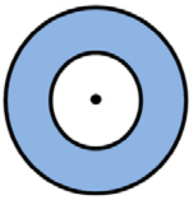
$$\text{distance from pivot} = \frac{150}{6}$$ (1 mark)

= 25 cm (1 mark)

10 a) i) ii) iii) (1 mark) for each point

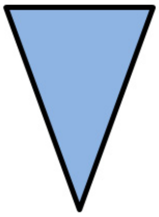


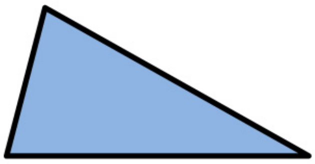
b) For example:



(3 marks)

11 a)





i) Unstable equilibrium **ii)** Neutral equilibrium (2 marks)

b) i)

A

B

(2 marks)

ii) Lamp B (1 mark)

iii) Its centre of gravity is lower (1 mark)

and its base is wider. (1 mark)

12 a) Position 1: The line of action of the weight is within the base of the bus, (1 mark)

there is no turning effect so the bus will be stable. (1 mark)

Position 2: The line of action of the weight is outside the base of the bus, (1 mark)

there is a turning effect so the bus will be unstable, i.e. it will topple. (1 mark)

b) The perpendicular distance (1 mark) from the line of action of the effort force to the pivot (1 mark) is much larger (1 mark) than the perpendicular distance from the line of action of the weight (1 mark) to the pivot. Hence the turning effect of the man's effort is bigger (1 mark) than the turning effect of the weight of the block. Consequently, the man can lift the block. (1 mark) (total 6 marks)

13 a) See experiment 'Investigating the Principle of Moments' on pages 29–30.

Description should include:

- apparatus (1 mark)
- diagram (2 marks)
- method (2 marks)
- formula used. (1 mark)

b) i) The turning effect of a force depends on both the size of the force and its perpendicular distance to the pivot. The wheel-brace when extended is longer, so it's turning effect will be larger, if the force is constant. (1 mark)

ii) Moment = force × perpendicular distance to pivot (1 mark)

= 20×0.4 (1 mark)

= 8 N m (1 mark)

Show you can (page 39)

$$1000\text{ kg} = 1\,000\,000\text{ g}$$

$$1\text{ m}^3 = 100 \times 100 \times 100\text{ cm}^3$$

$$\text{hence } \frac{1000\text{ kg}}{1\text{ m}^3} = \frac{1\,000\,000}{1\,000\,000}$$

$$= 1\text{ g/cm}^3$$

Test yourself (page 42)

1 $\rho = \frac{m}{V}$

$= \frac{57.9}{3}$

$= 19.3\text{ g/cm}^3$ => GOLD

2 a) $m = ?$

$\rho = 2.7\text{ g/cm}^3$

$V = 20\text{ cm}^3$

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

$2.7 = \frac{m}{20}$

Hence $m = 2.7 \times 20$

$= 54\text{ g}$

b) $m = 54\text{ g}$

$\rho = 2.7\text{ g/cm}^3$

$V = ?\text{ cm}^3$

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

$2.7 = \frac{54}{V}$

$V = \frac{54}{2.7}$

Hence $V = 20\text{ cm}^3$

3 $m = 120\text{ g}$

$\rho = ?\text{ g/cm}^3$

$V = 15\text{ cm}^3$

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

$= \frac{120}{15}$

$\rho = 8.0\text{ g/cm}^3$

4 $m = ?\text{ kg}$

$\rho = 1.26\text{ kg/m}^3$

$V = 10 \times 5 \times 3$

$= 150\text{ m}^3$

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

$1.26 = \frac{m}{150}$

$m = 1.26 \times 150\text{ kg}$

$m = 189\text{ kg}$

5 $m = 60$ g

$\rho = ?$ g/cm^3

$V = 35 - 15$

$= 20$ cm^3

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

$$= \frac{60}{20}$$

$$\rho = 3 \text{ g/cm}^3$$

6 $m = ?$ kg

$\rho = 800$ kg/m^3

$V = 0.08$ m^3

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

$$800 = \frac{m}{0.08}$$

$$m = 800 \times 0.08 \text{ kg}$$

$$m = 64 \text{ kg}$$

7 $m = 351.2 - 350$

$= 1.2$ g

$\rho = ?$ g/cm^3

$V = 1000$ cm^3

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

$$= \frac{1.2}{1000}$$

$$\rho = 1.2 \times 10^{-3} \text{ g/cm}^3$$

Show you can (page 43)

Solids	Liquids	Gases
Molecules vibrate about fixed positions. Molecules have strong **forces of attraction**. Molecules are packed very close together, so: Solids have a **high** density.	Molecules **are not in fixed positions but can move around**. Forces of attraction between molecules are still quite strong, but not as strong as in solids. Molecules **are close** together but not as close as in solids, so: Liquids have a medium density.	Molecules are very, very far apart. There are **weak** forces of attraction between molecules, so: Gases have a **low** density.

Practice questions (pages 44–45)

1 **a)** Density is the ratio (1 mark)

of a body's mass to its volume. (1 mark)

b) Use a displacement method. (1 mark)

Find the mass of the bracelet using a top-pan balance. (1 mark)

Record the volume of water in the measuring cylinder, then place the bracelet into the water and record the new volume of water + bracelet. (1 mark)

Volume of bracelet = (volume of water + bracelet) − (original volume of water) (1 mark)

c) $m = 46$ g; $\rho = ?$ g/cm^3; $V = 2.4$ cm^3

$\rho = \frac{m}{V}$ (1 mark)

$= \frac{46}{2.4}$ (1 mark)

$\rho = 19.2$ g/cm^3 (1 mark)

d) Gold (1 mark)

2 **a)** $V = 1.8 \times 1.2 \times 0.1$

$= 0.216$ m^3

$m = 520$ kg

$\rho = ?$

$\rho = \frac{m}{V}$ (1 mark)

$= \frac{520}{0.216}$ (2 marks)

$\rho = 2400$ kg/m^3 (to 2 significant figures) (1 mark)

b) According to the data, yes (1 mark)

because the density is greater than 2350. (1 mark)

3 **a)** $V = 0.5 \times 0.6 \times 0.2$ (1 mark)

$= 0.06$ m^3 (1 mark)

b) $m = ?$ kg; $\rho = 8400$ kg/m^3; $V = 0.06$ m^3

$\rho = \frac{m}{V}$ (1 mark)

$8400 = \frac{m}{0.06}$ (1 mark)

$m = 504$ kg (1 mark)

4 **a)** **i)** 1000 000 g ($= 1.0 \times 10^6$ g) (1 mark)

ii) 1 000 kg ($= 1.0 \times 10^3$ kg) (1 mark)

iii) 1 000 kg/m^3 ($= 1.0 \times 10^3$ kg/m^3) (1 mark)

b) $m = ?$ kg; $\rho = 0.18$ kg/m^3; $V = 500$ m^3

$\rho = \frac{m}{V}$ (1 mark)

$0.18 = \frac{m}{500}$ (1 mark)

$m = 90$ kg (1 mark)

total mass = 90 + 150 = 240 kg (1 mark)

5 a) i) Each 1 cm^3 of aluminium has a mass of 2.7 g. (1 mark)

ii) 1 m^3 = 100 × 100 × 100 = 1 000 000 cm^3 (= 1.0×10^6 cm^3) (1 mark)

iii) Mass in g = 2.7 × 1 000 000 = 2 700 000 g (= 2.7×10^6 g) (1 mark)

iv) Density = $\frac{2.7\times10^6\ \text{g}}{1.0\ \text{m}^3}$ (1 mark)

= 2700 kg/m^3 (= 2.7×10^3 kg/m^3) (1 mark)

b) i) Volume of liquid = 26 cm^3 (1 mark)

ii) Volume of liquid + stopper = 42 cm^3 (1 mark)

iii) Volume of stopper = 42 − 26 = 16 cm^3 (1 mark)

iv) Density = $\frac{m}{V}$ (1 mark)

= $\frac{40}{16}$ (1 mark)

= 2.5 g/cm^3 (1 mark)

6 a) i) Volume of 100 rivets = 70 − 50

= 20 cm^3 (1 mark)

ii) Volume of 1 rivet = $\frac{20}{100}$

= 0.20 cm^3 (1 mark)

b) Density = $\frac{m}{V}$ (1 mark)

= $\frac{180}{20}$ (1 mark)

= 9.0 g/cm^3 (1 mark)

7 D, C, A (1 mark)

8 Volume of Earth = $\frac{4}{3}\ \pi\ (6.4 \times 10^6)^3\ \text{m}^3$ (1 mark)

Mass of the Earth = 6.0×10^{24} kg

Density of Earth = $\frac{6.0\times10^{24}}{\left(\frac{4}{3}\pi\left(6.4\times10^{6}\right)^{3}\right)}$ (1 mark)

= $\frac{6.0\times10^{24}}{\left(\frac{4}{3}\pi\left(2.62\times10^{20}\right)\right)}$ (1 mark)

= $\frac{(6.0\times10^{24})}{(1.1\times10^{21})}$ (1 mark)

= 5.5×10^3 kg/m^3 (1 mark)

(Award full marks if correct answer provided along with other, correct, calculation steps.)

Test yourself (page 50)

1 Any three from: coal, oil, (natural) gas, lignite, peat (turf)

2

Quantity	Tick if the quantity is a form of energy
Sound	✓
Pressure	
Force	
Weight	
Electricity	✓
Heat	✓

3

Energy source	Renewable?	Non-renewable?
Gas		✓
Hydroelectricity	✓	
Oil		✓
Coal		✓
Wind	✓	
Tides	✓	

4 The solar cells change **light** energy into **electrical** energy. The battery stores **chemical** energy. As the propellers turn, they change **electrical** energy into useful **kinetic** energy. As the model aircraft gains height, it gains **gravitational potential** energy. If the model aircraft crashes into the ground, it produces wasted heat and **sound** energy.

5 Renewable resources are those that are replaced by nature in less than a human lifetime.

6 Both use heat to turn water into steam, which is transferred to kinetic energy of a turbine. This turns a generator that transfers kinetic energy to electrical energy.

A nuclear power station uses fission of uranium to produce heat and the waste products are dangerously radioactive.

A fossil fuel power station burns fossil fuels to produce heat. One of the waste products, carbon dioxide, is a major contributor to global warming.

7 The waste will be dangerously radioactive for a very long time and there can be no guarantee that it will not leak. There is also the possibility of seismic activity (earthquakes), which might bring it to the surface.

8 Carbon dioxide

9 Prevailing winds blow sulfur dioxide from the UK to Norway. The sulfur dioxide dissolves in water in the atmosphere, which then falls as acid rain.

10 Probably not. Wind, tidal and solar are the renewables that could be used. But all of these are not concentrated energy resources. Put solar panels on roofs.

11 Conserve fossil fuels, wind is renewable, less pollution

12 Depending on which types of power stations are used to provide electricity, some of the original materials used to generate electricity (fossil fuels and uranium) themselves produce very polluting waste products.

13

Device/situation	Input energy form		Useful output energy form
Microphone	sound energy	→	electrical energy
Electric smoothing iron	**electrical** energy	→	**heat** energy
Loudspeaker	**electrical** energy	→	**sound** energy
Coal burning in an open fire	**chemical** energy	→	**heat** energy
A weight falling towards the ground	**gravitational potential** energy	→	**kinetic** energy
A candle flame	**chemical** energy	→	**heat** energy and **light** energy

Show you can (page 51)

a) Arguments for: Nuclear power stations do not emit carbon dioxide, so do not contribute to global warming. They do not emit gases such as sulfur dioxide, which cause acid rain. Nuclear fuel is relatively cheap. Nuclear power stations produce a large amount of energy from a relatively small site.
Arguments against: Waste products remain dangerously radioactive for tens of thousands of years. These waste products are expensive to store safely and securely. Nuclear fuel is non-renewable. An accident could release dangerous radioactive material. Nuclear power stations are expensive to build initially, due to safety precautions. Decommissioning nuclear power stations takes a long time and is expensive.

b) Example answer: A nuclear power station, once built, does not require continuous supply from coal mines or gas wells. A nuclear power station produces no carbon dioxide or sulfur dioxide, so makes no contribution to global warming or acid rain, unlike a fossil fuel power station. Very large amounts of electricity can be produced by a single, relatively small site; to generate the same amounts of electricity, several large fossil fuel power stations would be needed. Economically, the output from and cost of running a nuclear power station are predictable and stable, whereas fossil fuel prices can change quickly and significantly. *(Accept other answers clearly expressed and supported by logical arguments.)*

c) Mining the lignite would spoil the beauty of a naturally very attractive area. Lignite is a fossil fuel that produces carbon dioxide and sulfur dioxide, known pollutants.

Test yourself (page 52)

14 a) $\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$

$= \frac{750\text{ kJ}}{1000\text{ kJ}}$

$= 0.75$

b) Heat is lost to the metal of the boiler, to the surroundings and in the hot smoke through the chimney. Sound is lost to the environment.

15 $\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$. Since, by the Law of Conservation of Energy, energy is neither created nor destroyed, the useful energy output can never be greater than the total energy input, so efficiency can never be greater than 1.00.

16 $\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$

$0.28 = \frac{140\,000\text{ kJ}}{\text{total energy input}}$

$\text{total (chemical) energy input} = \frac{140\,000\text{ kJ}}{0.28}$

$= 500\,000\text{ kJ } (= 5.0 \times 10^5\text{ kJ} = 500\text{ MJ})$

17 a) $\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$

$= \frac{(25 - 20)\text{ J}}{25\text{ J}}$

$= 0.20$

b) The Principle of Conservation of Energy

18 a) $\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$

$0.3 = \frac{?}{2000}$

Useful output energy = 2000 × 0.3

= 600 J

b) Wasted energy = 2000 – 600

= 1400 J

Hence heat energy = 90% of 1400 J

= 1260 J

Test yourself (page 54)

19 Work in J = force in N × distance in m

= (100 × 10) N × 5.5 m

= 5500 J

20 Work in J = force in N × distance in m

= 60 N × 20 m

= 1200 J

21 Work in J = force in N × distance in m

= 550 N × 3.0 m

= 1650 J

Test yourself (page 55)

22 $\text{Power} = \dfrac{\text{work done}}{\text{time taken}}$

$= \dfrac{(\text{weight} \times \text{height})}{\text{time taken}}$

$= \dfrac{(550 \times 15 \times 0.14)}{3}$

= 385 J

23 **a)** Work done = force × distance

1.8 = 45 × distance

$\text{distance} = \dfrac{1.8}{45}$

= 0.04 m (= 4 cm)

b) $\text{Power} = \dfrac{\text{work done}}{\text{time taken}}$

$= \dfrac{1.8}{0.3}$

= 6.0 W

Test yourself (page 58)

24 Kinetic energy, $\text{KE} = \dfrac{1}{2}mv^2$

$= \dfrac{1}{2} \times 120 \times 3000^2$

= 540 000 000 J (= 540 MJ)

25 Gravitational potential energy, GPE of rubber = *mgh*

= 0.050 kg × 10 N/kg × 280 m

= 140 J

KE of shell = $\frac{1}{2}mv^2$

= $0.5 \times 0.010 \times 150^2$

= 112.5 J

Comment: KE of shell is less than that of rubber as it hits the ground.

26 KE of tanker = $\frac{1}{2}mv^2$

$200\,000\,000 = 0.5 \times 100\,000\,000 \times v^2$

$v^2 = 4$

$v = 2$ m/s

27 KE of car = $\frac{1}{2}mv^2$

$160\,000 = 0.5 \times 800 \text{ x } v^2$

$v^2 = 400$

$v = 20$ m/s

= (20 × 60) metres/minute

= 1.2 km/minute

= 1.2 × 60 km/hour

= 72 km/hour

Test yourself (page 59)

28 Answers are in **bold** and **underlined**

Height above ground in m	Gravitational potential energy in J	Kinetic energy in J	Total energy in J	Speed in m/s
5.0	**100**	0	100	0
4.0	**80**	**20**	**100**	4.47
3.2	64	**36**	**100**	**6.0**
1.8	**36**	64	**100**	**8.0**
0.0	0	**100**	**100**	**10.0**

29 Energy in J = power in W × time in seconds

= 3600 W × (5 × 60) seconds

= 1 080 000 J (= 1.08 MJ)

30 a) i) Weight = mg

= 1500 kg × 10 N/kg

= 15 000 N (= 15 kN)

ii) Work = force × distance

= 15 000 N × 12 m

= 180 000 J (= 180 kJ)

b) Time in seconds $= \frac{\text{work in J}}{\text{power in W}}$

$= \frac{180\,000\text{ J}}{3000\text{ W}}$

= 60 seconds

c) Speed in m/s = $\frac{\text{distance in m}}{\text{time in seconds}}$

$= \frac{12\text{ m}}{60\text{ s}}$

= 0.2 m/s

31 a) Work in J = force in N × distance in m

= 1000 N × 0.4 m

= 400 J

b) Efficiency = $\frac{\text{useful energy output}}{\text{total energy input}}$

$= \frac{400\text{ J}}{1200\text{ J}}$

= 0.33

32 GPE = mass × gravitational field strength × height

176 = 2 × g × 10

$g = \frac{176}{20}$

= 8.8 N/kg

By inspection of the table, the planet was Venus.

33 a) KE in J as ball rises from ground = GPE of ball at its maximum height

10 J = 0.20 kg × 10 N/kg × height in metres

height = $\frac{10}{2.0}$

= 5.0 metres

b) In practice, energy is lost as heat against air resistance as the ball rises.

So, not all of the KE of the ball is converted into GPE.

Practice questions (pages 60–62)

1 Kinetic energy (1 mark)

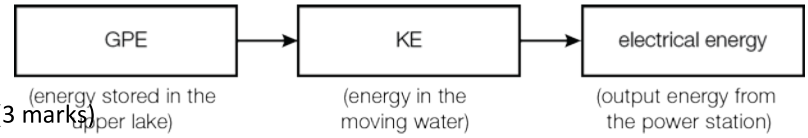
and gravitational potential energy (1 mark)

2 **a)** **<u>Kinetic</u>** energy of the wind is transferred to **<u>electrical</u>** energy. (2 marks)

b) Limitless supply of energy (1 mark)

c) Any two from: solar, tidal, geothermal, wave etc. (1 mark each, up to maximum of 2 marks)

3



(3 marks)

4 **a)** No greenhouse gases are produced (1 mark)

when fossil fuels are burnt. (1 mark)

b) Advantage, any one from: it is a renewable resource; it can also act as a bridge; it is ideal for an island such as Ireland. (1 mark)

Disadvantage, any one from: maintenance/far removed from cities; changes the ecology of estuaries and mudflats, affecting wildlife; expensive to build. (1 mark)

5 **a)** **i)** Any one from: nuclear energy, oil, natural gas, coal (1 mark)

Reason: limited resources/cannot be replaced (1 mark)

ii) Any one from: hydroelectric, wind energy (1 mark)

Reason: hydroelectric = part of water cycle; wind = depends only on weather (1 mark)

iii) Any one from: concentrated form of energy; often cheaper than renewable energy, although this is changing (1 mark)

b) **i)** GPE = $m \times g \times h$ (1 mark)

$= 1 \times 10^8 \times 10 \times 50$ (1 mark)

= 50 000 000 000 J/s or 5×10^{10} J/s (1 mark)

ii) Power output = efficiency × power input (1 mark)

$= 0.008 \times 5 \times 10^{10}$ (1 mark)

= 400 000 000 W (= 400 MW) (1 mark)

iii) Sun's energy evaporates the water from the oceans to form clouds, (1 mark)

so precipitation occurs over mountains and the water dropped forms streams and rivers that drive hydroelectric power stations. (1 mark)

c) i) Power output = efficiency × power input (1 mark)

= 0.6 × 500 (1 mark)

= 300 W (1 mark)

ii) 300 J (1 mark)

iii) Power = force × $\left(\frac{\text{distance}}{\text{time}}\right)$

300 = 1200 × speed (1 mark)

Speed = $\frac{300}{1200}$ (1 mark)

= 0.25 m/s (1 mark)

6 a) Work done = force × distance moved (1 mark)

= 8000 × 1.8 (1 mark)

= 14 400 J (1 mark)

b) Time = $\frac{\text{energy}}{\text{power}}$ (1 mark)

= $\frac{26\,000}{5200}$ (1 mark)

= 5.0 s (1 mark)

c) Input power = $\frac{\text{output power}}{\text{efficiency}}$ (1 mark)

= $\frac{5200}{0.26}$ (1 mark)

= 20 000 W (= 20 kW) (1 mark)

7 a) Work done = weight × height (1 mark)

= 24 000 × 40 (1 mark)

= 960 000

= 960 kJ (1 mark)

b) Power = $\frac{\text{work}}{\text{time}}$ (1 mark)

= $\frac{960\,000}{20}$ (1 mark)

= 48 000 W (= 48 kW) (1 mark)

c) Efficiency = $\frac{\text{useful power output}}{\text{total power input}}$ (1 mark)

$= \frac{960 \text{ kJ}}{1200 \text{ kJ}}$ (1 mark)

= 0.8 (1 mark)

d)

Energy	Increases/decreases/unchanged
Potential energy of the top tramcar	**Decreases**
Kinetic energy of the top tramcar	**Unchanged**
Kinetic energy of the bottom tramcar	**Unchanged**
Potential energy of the bottom tramcar	**Increases**
Heat energy	**Increases**

(1 mark each)

8 a)

Quantity	Increases	Decreases	Remains constant
Speed of ball		✓	
Potential energy of ball	✓		
Total energy of ball			✓
Kinetic energy of ball		✓	

(1 mark each)

b) i) GPE = $m \times g \times h$ (1 mark)

= 10 × 10 × 5 (1 mark)

= 500 J (1 mark)

ii) KE at the bottom = GPE at the top (1 mark)

so GPE = $\frac{1}{2}mv^2$ (1 mark)

$500 = \frac{1}{2} \times 10 \times v^2$ (1 mark)

$v^2 = 100$

$v = 10$ m/s (1 mark)

9 a) GPE = total energy

= 600 + 60

= 660 J (1 mark)

b) GPE = $m \times g \times h$ (1 mark)

$660 = 3 \times 10 \times h$ (1 mark)

$h = 22$ m (1 mark)

c) KE = $\frac{1}{2}mv^2$ (1 mark)

$600 = \frac{1}{2} \times 3 \times v^2$ (1 mark)

$v^2 = 400$

v = 20 m/s (1 mark)

10 a) GPE = $m \times g \times h$ (1 mark)

$52\,800 = 440 \times 10 \times h$ (1 mark)

h = 12 m (1 mark)

b) Kinetic energy at water surface = GPE + KE at start

= 52 800 + 3520

= 56 320 J (1 mark)

c) KE = $\frac{1}{2}mv^2$ (1 mark)

$56\,320 = \frac{1}{2} \times 440 \times v^2$ (1 mark)

$v^2 = 256$ (1 mark)

v = 16 m/s (1 mark)

11 a) Work done = weight × height (1 mark)

= 8 000 × (6.0 – 4.5) (1 mark)

= 12 000 J (1 mark)

b) Change in GPE = 12 000 J (1 mark)

c) KE = $\frac{1}{2}mv^2$ (1 mark)

$4900 = \frac{1}{2} \times 800 \times v^2$ (1 mark)

$v^2 = \frac{4900}{400}$ (1 mark)

v = 3.5 m/s (1 mark)

12 a) Difference in PE = $m \times g$ × difference in height (1 mark)

= 1.2 × 10 × (0.8 – 0.6) (2 marks)

= 2.4 J (1 mark)

b) KE = $\frac{1}{2}mv^2$

$4.2 = \frac{1}{2} \times 1.2 \times v^2$ (1 mark)

$v^2 = \frac{4.2}{0.6}$

v = 2.6 m/s (1 mark)

13 a) i) 6000 – 4800 = 1200 J (1 mark)

ii) Efficiency = $\frac{1200}{6000}$ (1 mark)

= 0.2 (1 mark)

iii) Energy = power × time (1 mark)

= 1200 × (10 × 60 × 60)

= 4.32×10^4 kJ (1 mark)

iv) Advantage: reduces domestic electricity bill. (1 mark)

Disadvantage: not much use in dark cloudy days. (1 mark)

v) 1. Be more energy efficient so as to use less total energy. (1 mark)

2. Minimise the use of electrical devices at night. (1 mark)

b) i) 100 N 3.0 m (1 mark)

200 N 1.5 m (1 mark)

300 N 1.0 m (1 mark)

ii) Power = $\frac{\text{work done}}{\text{time}}$ (1 mark)

= $\frac{(300 \times 10)}{30}$ (1 mark)

= 100 W (1 mark)

Show you can (page 65)

a) To prevent heat passing through the hull by conduction.

b) Polystyrene (also accept 'insulating foam' or 'expanding foam').

c) Polystyrene contains many pockets of stationary air, which is an excellent insulator.

Show you can (page 67)

a) It takes 40 years of use before savings in heating bills would equal the initial cost of double glazing.

b) Cavity wall insulation and loft insulation, the payback time is less.

Show you can (page 69)

a) Some of the infrared radiation from the Sun that arrives at the Earth reaches the surface. Part of this energy is radiated back into the Earth's atmosphere, but the re-radiated energy has a longer wavelength than the waves that come from the Sun. This radiation is absorbed by greenhouse gases such as carbon dioxide, keeping the Earth warm. As the amounts of greenhouse gases are increased, more energy is absorbed and the Earth becomes warmer. This is global warming.

b) Harmful effect, any one of: sea levels could rise, reducing farming area and crop production or flooding coastal villages; more energy in the Earth's atmosphere could lead to more frequent extreme weather events.
Beneficial effect, any one of: the summers and winters may be warmer; crops that grow in warmer conditions/milder winters could become more widespread.

Test yourself (page 70)

1 **a)** To radiate heat from the food inside the fridge to the kitchen.

b) Heat loss by radiation is increased if there is a larger surface area of metal, so thin fins are added to the pipes.

2 Top of oven, because hot air is less dense and rises. A fan circulates the air and keeps the entire volume of air in the oven at the same temperature, so that food in the oven is cooked uniformly.

3 To reflect the radiant heat from the Sun, keeping the inside of the house cooler.

4 **i)** Painted black – black surfaces radiate more heat.

ii) Metallic – metals conduct more heat.

iii) Large surface area – larger areas radiate heat more effectively.

iv) Adhered to the chip with a conducting glue – improves conduction of heat from chip to heat sink.

Practice questions (pages 71–73)

1 a)

Substance	Method of heat transfer
Water	**Convection**
Copper	**Conduction**
Glass	**Conduction**

(1 mark for each correct answer)

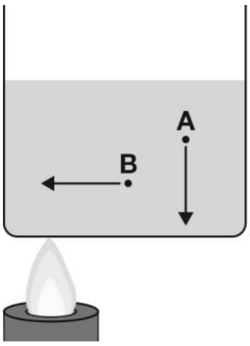
b) Heat is passed by conduction (1 mark) when the particles vibrate in the hotplate causing the particles in the glass to vibrate more. (1 mark)

2

This rod has no free electrons.	**G – Glass**
Atoms are mainly responsible for heat conduction.	**G – Glass**
Atoms vibrate more quickly when heat is added.	**GI – Both**
Heat is transferred when electrons collide with neighbouring atoms.	**I – Iron**

(1 mark for two or three correct, 2 marks for all four correct)

3 a)



(1 mark each)

b) Black surfaces are better radiators (1 mark) of heat than shiny silver surfaces, which reflect heat. (1 mark)

4 a) Conduction (1 mark)

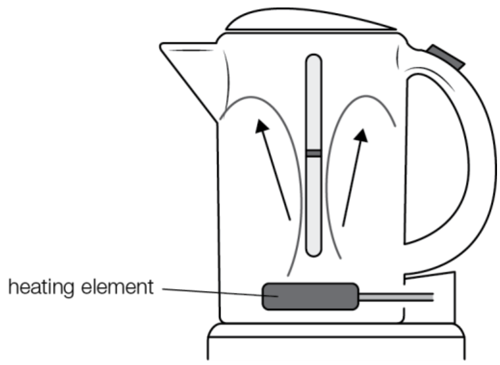
b) Heat transfer in mercury (1 mark) is much better (1 mark) than water.

c) Radiation (1 mark)

d) Black surface is a better absorber of heat (1 mark) so cork falls off this surface first. (1 mark)

5 a) i) Convection (1 mark)

ii)



(1 mark)

b) Conduction (1 mark)

c) i) Steel is a good conductor of heat. (1 mark)

ii) Wood is a good insulator. (1 mark)

6 a) Steel (1 mark)

b) The steel will conduct the heat away from your fingers, better than the plastic spoon. (1 mark)

7 a) i) There is no room for convection currents. (1 mark)

ii) Water is a poor conductor of heat. (1 mark)

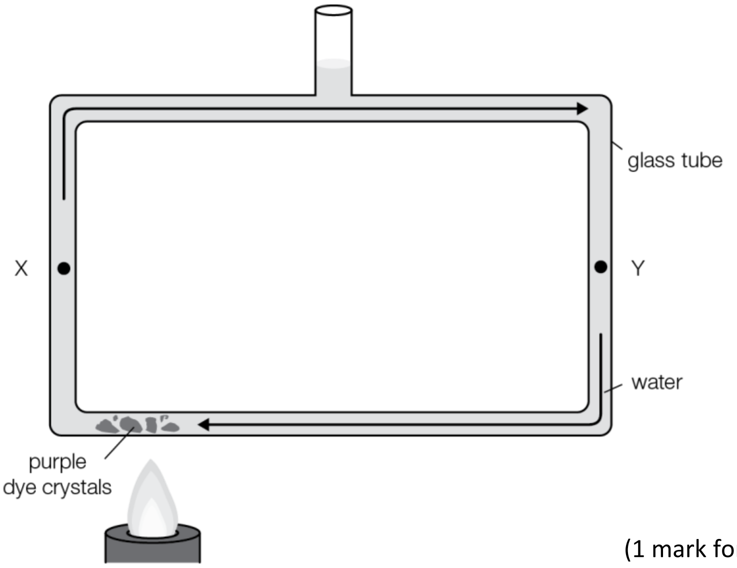
b) i) The blackened surface of thermometers will absorb radiant heat much better. (1 mark)

ii) Makes it a fair test (1 mark)

iii) Matt black (1 mark)

iv) Highest temperature reading (1 mark)

8 a) i)



(1 mark for each correct arrow)

ii) Convection (1 mark)

b) Radiation (1 mark)

Test yourself (page 77)

1 **a)** Electrons

b) Neutrons

c) Electrons

d) Protons and neutrons

e) Electrons

2 6 protons, 8 neutrons, zero electrons.

3 $^{23}_{11}Na$

4 Isotopes are nuclei of the same element which have the **same** number of protons but **different** numbers of neutrons.

Test yourself (page 80)

5 Carbon-14

6

Property	Alpha particles (α)	Beta particles (β)	Gamma rays (γ)
Nature	each particle is 2 protons + 2 neutrons (it is identical to a nucleus of helium-4)	**fast moving electrons**	very high energy electromagnetic waves
Relative charge compared with charge of a proton	**+2**	−1	0
Mass	High compared to betas	low	0
Speed	Up to 0.1 × speed of light	**0.9 × speed of light**	speed of light
Ionising effect	strong	weak	very weak
Penetrating effect	**penetrates a few cm of air and can easily be stopped by a sheet of paper**	penetrating, but stopped by a few millimetres of aluminium or other metal	very penetrating: never completely stopped, though lead and thick concrete will reduce intensity

Show you can (page 80)

a) Gamma rays

b) Alpha particles

c) Beta particles

d) Gamma rays

e) Alpha particles

f) Gamma rays

g) Alpha particles

Test yourself (page 82)

7

Radiation	Atomic number (*Z*)	Mass number (*A*)
α-emission	decreases by 2	**decreases by 4**
β-emission	**increases by 1**	unchanged
γ-emission	**unchanged**	**unchanged**

8 a) ${}^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$

b) ${}^{242}_{94}\mathrm{Pu} \rightarrow {}^{238}_{92}\mathrm{U} + {}^{4}_{2}\mathrm{He}$

c) ${}^{251}_{98}\mathrm{Cf} \rightarrow {}^{247}_{96}\mathrm{Cm} + {}^{4}_{2}\mathrm{He}$

d) ${}^{174}_{72}\mathrm{Hf} \rightarrow {}^{170}_{70}\mathrm{Yb} + {}^{4}_{2}\mathrm{He}$

e) ${}^{211}_{83}\mathrm{Bi} \rightarrow {}^{207}_{81}\mathrm{Tl} + {}^{4}_{2}\mathrm{He}$

f) ${}^{190}_{78}\mathrm{Pt} \rightarrow {}^{186}_{76}\mathrm{Os} + {}^{4}_{2}\mathrm{He}$

9 a) ${}^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}\mathrm{e}$

b) ${}^{3}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{0}_{-1}\mathrm{e}$

c) ${}^{137}_{55}\mathrm{Cs} \rightarrow {}^{137}_{56}\mathrm{Ba} + {}^{0}_{-1}\mathrm{e}$

d) ${}^{40}_{19}\mathrm{K} \rightarrow {}^{40}_{20}\mathrm{Ca} + {}^{0}_{-1}\mathrm{e}$

e) ${}^{60}_{27}\mathrm{Co} \rightarrow {}^{60}_{28}\mathrm{Ni} + {}^{0}_{-1}\mathrm{e}$

f) ${}^{32}_{15}\mathrm{P} \rightarrow {}^{32}_{16}\mathrm{S} + {}^{0}_{-1}\mathrm{e}$

10 a) Beta decay

b) Alpha decay

c) Alpha decay

11 a) Decreases by 4

b) Decreases by 2

c) Unchanged

d) Increases by 1

Test yourself (page 85)

12 a) 1000 to 500 to 250 => two half-lives = 14.4 hr

hence 1 half-life = 7.2 hr

b) 200 to 100 to 50 to 25 => three half-lives = 18 hr

hence 1 half-life = 6 hr

c) 500 to 250 to 125 to 62.5 => three half-lives = 86.4 years

hence 1 half-life = 28.8 years

13 a) 64 to 32 to 16 to 8 to 4 to 2 to 1 => six half-lives

1 half-life = 5.27 years

Hence total time = 31.62 years

b) 128 to 64 to 32 to 16 to 8 to 4 to 2 to 1 => seven half-lives

1 half-life = 8 days

Hence total time = 56 days

c) 32 to 16 to 8 to 4 to 2 to 1 => five half-lives

1 half-life = 138 days

Hence total time = 690 days

14 20 g to 10 g to 5 g => two half-lives

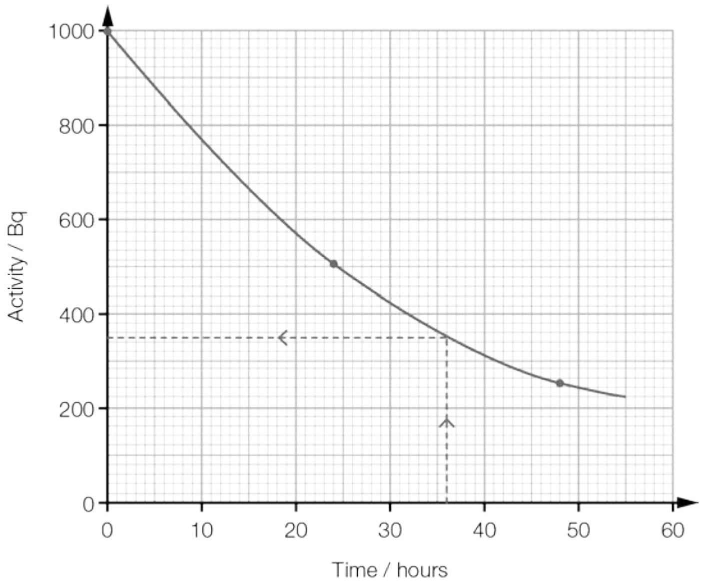
1 half-life = 5.26 years

Hence total time = 10.52 years

15

Activity in Bq	Time in half-lives	Time in hours
2000	–1	–24
1000 (start from here)	0	0
500	1	24
250	**2**	**48**

16



Activity after 36 hours = 350 Bq

Practice questions (pages 94–96)

1 a)

Particle	Mass	Charge	Number	Location
electron	**1/1840**	–1	**6**	**orbiting the nucleus**
neutron	1	**0**	6	in the nucleus
proton	**1**	**+1**	6	**in the nucleus**

(1 mark for each correct answer)

b) and emit radiation(s). (1 mark)

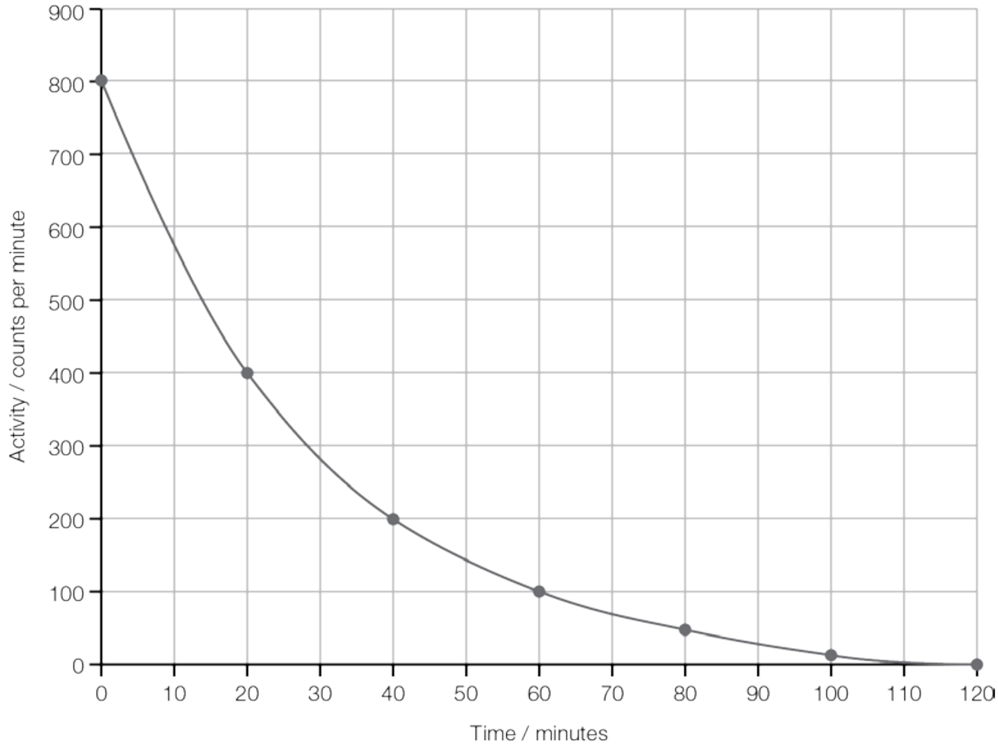
ii) Could remain in lungs (1 mark)

and cause mutations in nuclei in cells of lungs (1 mark)

iii) Isotopes are nuclei of the same element which have the same number of protons (1 mark)

but different numbers of neutrons. (1 mark)

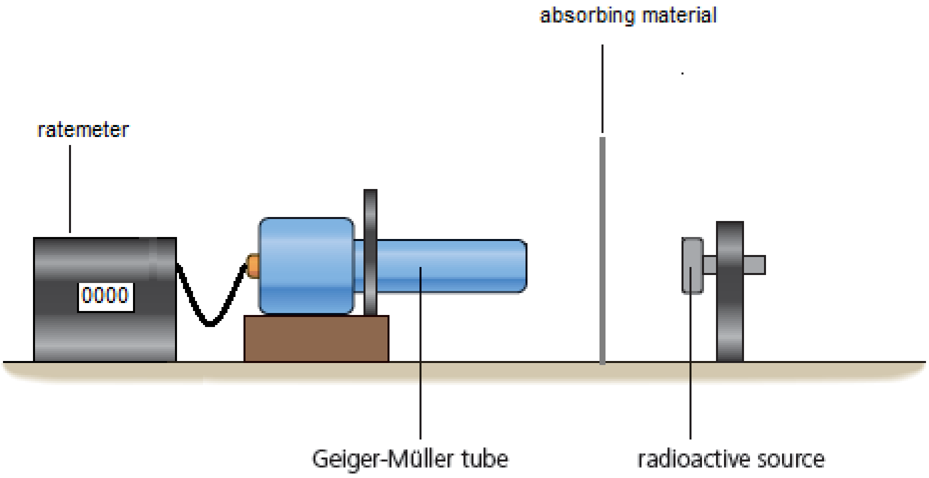
c) i) All points correctly plotted (1 mark)



ii) Smooth curve that joins all points (1 mark)

d) i) Most beta particles will be absorbed by several millimetres of aluminium. (1 mark)

ii) See diagram of apparatus below (3 marks)



iii) Thickness of aluminium tested, (1 mark)

count rate with no aluminium present (repeated before testing each different thickness of aluminium), (1 mark)

count rate after aluminium inserted between source and detector. (1 mark)

iv) Plot a graph of thickness of aluminium (*x*-axis) (1 mark)

against the ratio of count rate with aluminium present/count rate without aluminium present. (1 mark)

v) Graph of count rate against thickness should show a curve of negative gradient and have axes correctly labelled.. (1 mark)

Value of range obtained by finding thickness where graph crosses *x*-axis. (1 mark)

2 a) i) Each nucleus contains six protons. (1 mark)

ii) The first nucleus has six neutrons whereas the second nucleus has eight neutrons. (1 mark)

b) ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$ (1 mark for each correct value added)

c) i) In a time of 6000 years, (1 mark)

half of the original nuclei will decay (*or* the count rate will halve, *or* activity will halve). (1 mark)

ii) 80 to 40 to 20 to 10 => three half-lives (1 mark)

10 disintegrations per second would be the likely activity after 3 half-lives. (1 mark)

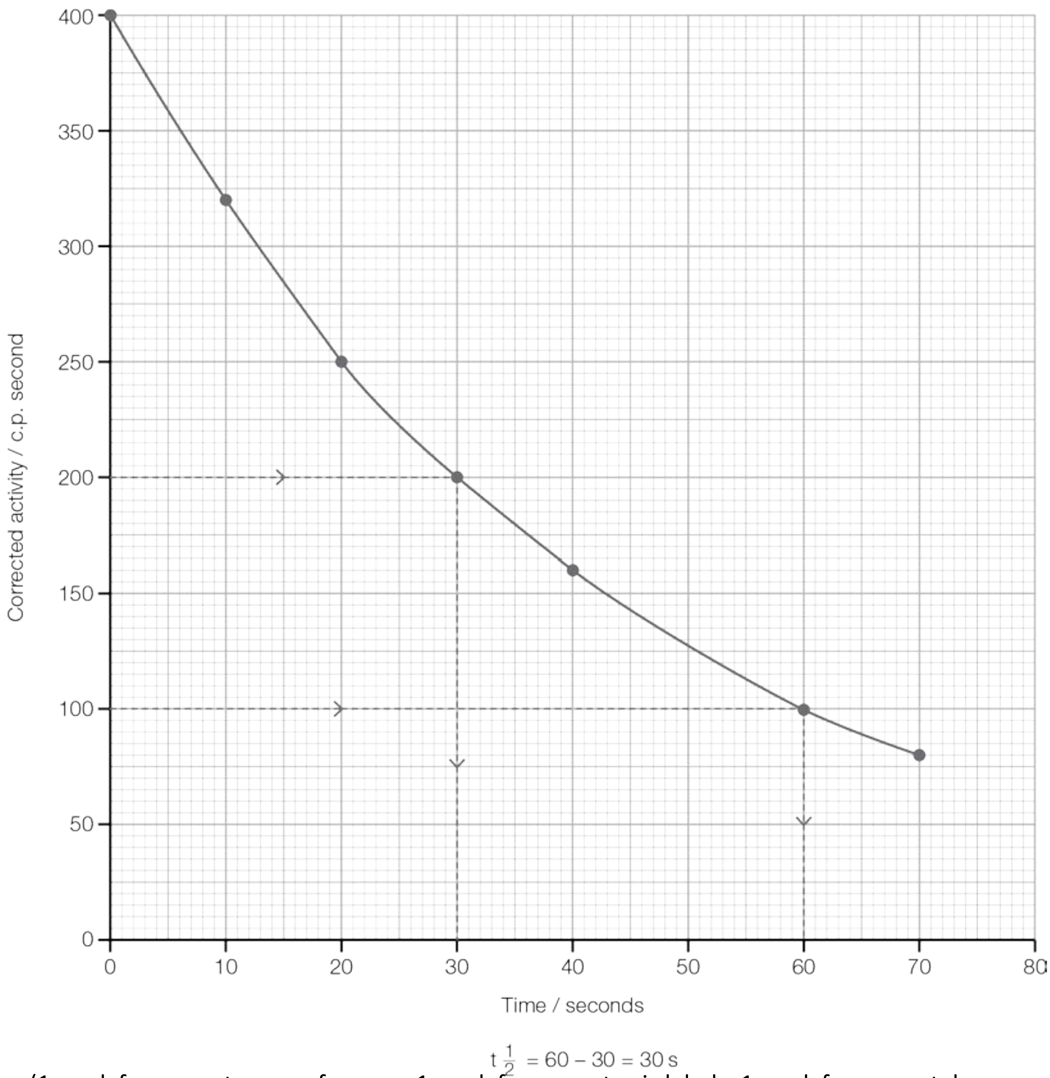
3 a) Alpha particles have a range of only a few cm in air (1 mark)

so such a source could not penetrate heart muscle, ribs etc. to be detected. (1 mark)

b) Background activity could come from the concrete walls of the building and from the radiographer himself. (1 mark)

Without the presence of the radioactive source, the radiographer would measure the count rate of a period of 30 minutes using a scalar counter, and then calculate the background count rate and then subtract this value from each of the subsequent readings. (1 mark)

c)



(1 mark for correct ranges for axes, 1 mark for correct axis labels, 1 mark for accurately plotted points and 2 marks for obtaining smooth curve of best fit)

d) Evidence from graph, (1 mark)

$t\frac{1}{2} = 60 - 30$

$= 30$ s (1 mark)

4 a) i) Alpha decay, mass number decreases by 4 (1 mark)

and atomic number decreases by 2. (1 mark)

ii) Beta decay, mass number does not change (1 mark)

but the atomic number increases by 1. (1 mark)

b)

Element (symbol)	Atomic number	Mass number	Decays by emitting	Leaving element
U	92	238	α	Th
Th	90	234	β	Pa
Pa	91	234	β	**U**
U	92	234	α	**Th**
Th	90	230	**α**	Ra
Ra	88	226	**α**	Rn
Rn	86	**222**	**α**	Po
Po	**84**	218	α	Pb
Pb	**82**	**214**	**β**	Bi
Bi	83	**214**	**β**	Po

($^1/_2$ mark each and round up total)

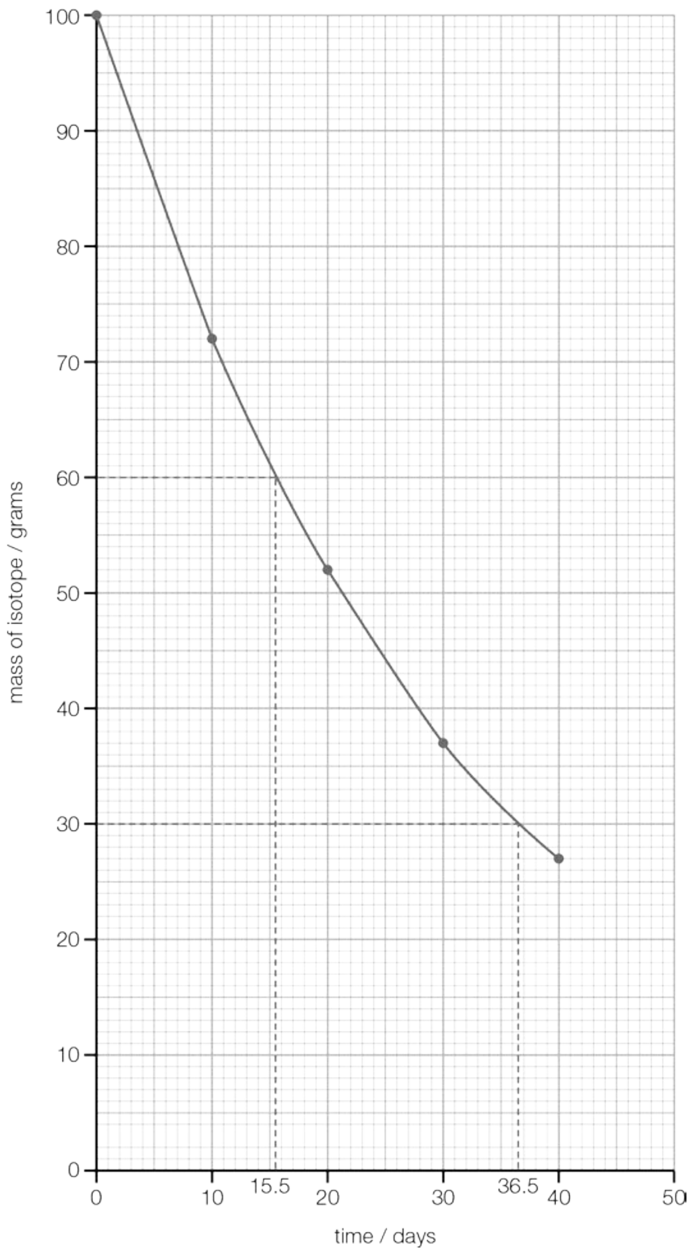
c) U-234 and U-238 (1 mark)

Th-234 and Th-230 (1 mark)

5 a) i) The half-life of a radioactive isotope is defined as the time taken for its activity to fall by half. (1 mark)

ii) Isotopes are nuclei of the same element which have the same number of protons but different numbers of neutrons. (1 mark)

b)



(1 mark for correct axes ranges, 1 mark for correct axis labels, 1 mark for correctly plotted points and 1 mark for smooth curve of best fit)

c) Half-life = 36.5 − 15 .5 (1 mark)

= 21 days (1 mark)

d) From graph, about 200 g (2 marks)

6 After 1 half-life (12 mins), one half would be present.

After 2 half-lives (24 mins), one quarter would be present. (1 mark)

After 3 half-lives (36 mins), one eighth would be present.

After 4 half-lives (48 mins), one sixteenth would be present. (1 mark)

After 5 half-lives (60 mins), $\frac{1}{32}$ would be present. (1 mark)

7 The decay process is a random (1 mark)

and spontaneous, 10 s is a very small fraction of time compared to the half-life, (1 mark)

hence the slightly different measurements.

8 a)

Particle	Quantity in the nucleus
proton	6
neutron	8

b) i) X2 and X4 (1 mark)

ii) They have the same atomic number but different mass numbers. (1 mark)

9

Nuclear reaction	Fusion	Fission
Where the process can be found happening	5	3
Fuel used	6	7
Description of the reaction	1	2
Conditions required to start	4	8

($^1/_2$ mark each and round up total)

10 a) ${}^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\text{e}$ (1 mark each)

b) 120 to 60 to 30 to 15 => three half-lives = 15 years (2 marks)

1 half-life = 5 years (1 mark)

c) 1. Sterilisation of hospital equipment (1 mark)

2. Detecting leaks in underground pipes (1 mark)

(also accept radiotherapy/treatment of cancer)

11 a) Alpha particles are stopped by thin sheets of paper, so thick gloves would certainly stop them. (1 mark)

b) 1. Use lead shielding. (1 mark)

2. Minimise contact time/keep your distance. (1 mark)

12 a) Two light (1 mark) hydrogen (1 mark) nuclei, join together (1 mark) to form a helium (1 mark) nucleus, releasing huge amounts of energy. (1 mark) This process occurs naturally in the stars. (1 mark) (total 6 marks)

b) i) Resolve future energy shortages/Limitless fuels sources. (1 mark)

ii) Any **two** from:

- extremely high temperatures are required; (1 mark)
- containment time needs to be large; (1 mark)
- large amounts of input energy are needed to initiate the fusion reaction, so more energy needs to be produced by a sustained reaction to justify the energy input. (1 mark)

c) i) ITER is the link between an experimental attempt and a full-scale power station to produce electricity using fusion. (1 mark)

Produces virtually no nuclear waste. (1 mark)

Fuel supplies virtually limitless. (1 mark)

ii) Financial and scientific research (1 mark) by many nations (1 mark) (total 2 marks)

13 a) i) 13 hours (1 mark)

ii) 220 counts per minute (1 mark)

b) i) 0.01 g (1 mark)

ii) Some may have been washed away with body fluids (1 mark)

c) Half-life is too long, could remain in body for 40 days, i.e. 5 half-lives. (1 mark)

Beta particles could not be detected outside the body, not penetrating enough. (1 mark)

14 a) Gamma rays (1 mark)

b) Will penetrate and destroy the DNA in the cancerous cells of the tumour (1 mark)

c) Other healthy tissues including the immune system could also be destroyed (1 mark)

d) The half-life of a radioactive isotope is defined as the time taken (1 mark)

for its activity to fall by half. (1 mark)

e) Its half-life should be short (1 mark)

otherwise it may cause further cancers. (1 mark)

Test yourself (page 99)

1 In transverse waves, the particles vibrate perpendicular to the direction of motion of the wave.

In longitudinal waves, the particles vibrate parallel to the direction of motion of the wave.

2 Two transverse waves: water waves, X-rays *(also accept any other form of electromagnetic radiation or S-waves)*

Two longitudinal waves: sound, ultrasound *(also accept P-waves)*

3 The wavelength of a wave is the distance between two consecutive crests or troughs.

Unit: metres

The frequency of a wave is the number of complete waves passing a fixed point in a second.

Unit: Hertz

The amplitude of a wave is the greatest displacement of the wave from its undisturbed position.

Unit: metres

Show you can (page 99)

a) A microwave oven converts microwave energy to heat energy.

b) Hold the slinky at one end. (i) To produce a longitudinal wave, move your hand back and forth parallel to the axis of the spring. (ii) To produce a transverse wave, move your hand back and forth perpendicular to the axis of the spring.

c) The compressions get further apart.

Test yourself (page 100)

4

Wavelength	Frequency	Speed
5 m	200 Hz	1000 m/s
12 m	50 Hz	**600** m/s
3 m	60 Hz	**180** m/s
0.05 m	4 Hz	20 cm/s
500 m	5 Hz	2.5 km/s
16 m	**0.05** Hz	80 cm/s
6×10^4 m	**5000** Hz	3×10^8 m/s

5 Amplitude = $\frac{1}{2}$ × the vertical distance between a crest and a trough

= 12 cm

frequency = number of waves passing per second

$= \frac{30}{60}$

= 0.5 Hz

wavelength = horizontal distance between successive crests

$= \frac{40}{4}$

= 10 cm

speed = frequency × wavelength

= 0.5 × 10

= 5 cm/s

Show you can (page 104)

a) $v = f\lambda$ where v (wave speed) is measured in m/s, f (frequency) is measured in Hz and λ (wavelength) is measured in metres

b) Use the graph to find the time, T, between successive peaks. Then $f = \frac{1}{T}$

c) Use the graph to find the distance, d, between successive peaks. This distance is the wavelength.

d) The reflection of light off a plane mirror is analogous to the reflection of water waves off a flat barrier. The angle of incidence = angle of reflection, and wave speed is unchanged. The refraction of light that takes place e.g. when light travels from air into a glass block is analogous to water waves moving from deep to shallow water. The waves slow down and change direction towards the normal.

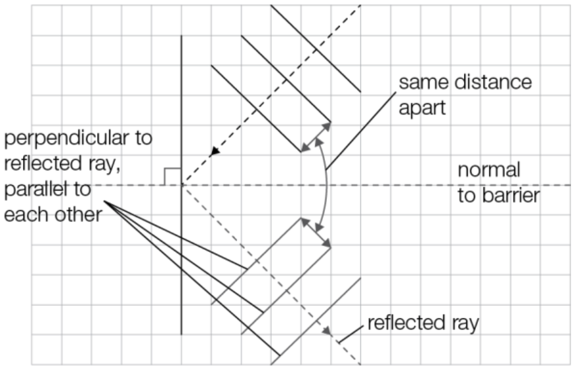
Test yourself (page 104)

6 a) Diagram should show:

Normal perpendicular to barrier at point of incidence.

Reflected ray from point of incidence so that angle *i* = angle *r*

Three wavefronts perpendicular to the reflected ray, which are parallel to each other and the same distance apart as the incident waves.



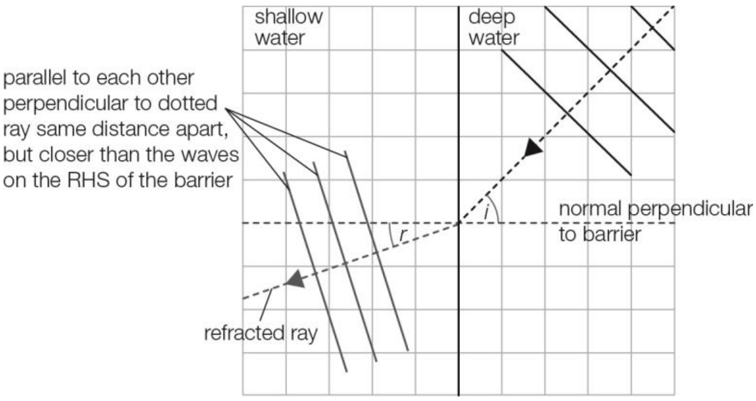
b) Frequency, wavelength and speed are all unchanged by reflection.

7 a) Diagram should show:

Normal perpendicular to barrier at point of incidence and on both sides of barrier.

Refracted ray bent towards normal at point of incidence so that angle *i* > angle *r*.

Three waves perpendicular to reflected ray, which are parallel to each other and closer together than the incident waves.



b) Frequency never changes on refraction. Wavelength and speed both decrease when water waves enter shallower water.

8 a) There are many similarities between the behaviour of water waves and the behaviour of light waves.

b) When water waves and light waves reflect, then angle of incidence = angle of reflection.

Reflected wavelength = incident wavelength.

There is no change in wavelength, frequency or speed.

(Also accept a statement that both are transverse waves.)

Test yourself (page 108)

9

radio waves	**microwaves**	**infrared light**	visible light	**ultraviolet light**	**X-rays**	**γ-rays**

increasing frequency →

10 Only electromagnetic waves can travel in a vacuum.

11 The missing waves are: X-rays, visible light, infrared light and microwaves.

These are entered in the table in order of increasing wavelength.

Wave	**X-rays**	**visible light**	**infrared light**	**microwaves**
Typical Wavelength / m	1×10^{-10}	6×10^{-7}	1×10^{-5}	1×10^{-3}

12 d = speed × time from emitter to wall

$= 340 \text{ m/s} \times (\frac{1}{2} \times 0.0025 \text{ s})$

$= 0.425 \text{ m}$

Practice questions (page 109)

1 In transverse waves the particles vibrate perpendicular to the direction of motion of the wave. (1 mark)

Example: X-rays (or any electromagnetic waves, or water waves, or S-waves) (1 mark)

In longitudinal waves the particles vibrate parallel to the direction of motion of the wave. (1 mark)

Example: sound waves (or P-waves) (1 mark)

2 Wavelength: distance between the centre of one compression and the next. (1 mark)

Frequency: the number of compressions that pass a point in one second. (1 mark)

Amplitude: the maximum distance a particle moves from the centre of the motion. (1 mark)

3 **a)** Frequency (or wavelength or speed) (1 mark)

b) Frequency (1 mark)

4 Amplitude = $\frac{1}{2} \times 16$

= 8 m (2 marks)

Frequency = $\frac{12}{60}$

= 0.2 hz (2 marks)

Wavelength = $\frac{80}{4}$

= 20 m (2 marks)

Speed of the waves = $f\lambda$

= 0.2 × 20

= 4 m/s (2 marks)

5 Amplitude = $\frac{25}{2}$ (1 mark)

= 12.5 cm (1 mark)

Frequency = $\frac{1}{T}$ (1 mark)

= $\frac{1}{0.25}$

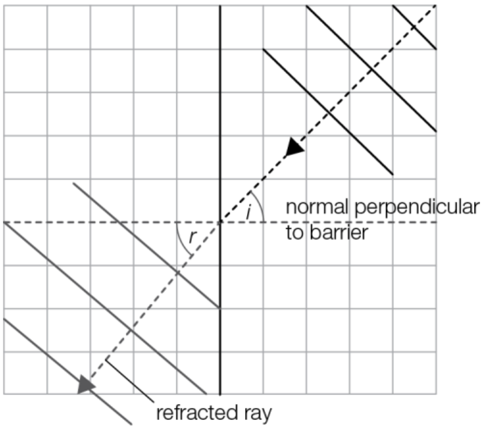
= 4 hz (1 mark)

Speed = frequency × wavelength (1 mark)

= 4 × 1.2

= 4.8 m/s (1 mark)

6 **a)** Diagram should show:



Normal perpendicular to barrier at point of incidence and at both sides of barrier. (1 mark)

Refracted ray bent away from the normal at point of incidence so that

angle *i* < angle *r*. (1 mark)

Three waves perpendicular to reflected ray which are parallel to each other, the same distance apart and further apart than the incident waves. (1 mark)

b) Frequency never changes on refraction (1 mark). Wavelength and speed both increase when water waves enter deeper water (2 marks).

7 **a)** Ultrasound is sound at a frequency greater than 20 kHz. (1 mark)

b) Ultrasound has a much higher frequency than human speech. (1 mark)

8 *Differences:*

1. Ultrasound cannot travel through a vacuum, all electromagnetic waves can travel in a vacuum. (1 mark)

2. Ultrasound is a longitudinal wave, all electromagnetic waves are transverse. (1 mark)

(also accept statement about difference in speed)

9 **a)** Radio waves, microwaves, infrared, visible, ultraviolet, X-rays, γ-rays. (2 marks)

b) Ultraviolet, X-rays and γ-rays are all known to produce cancer. (1 mark each)

10 In a longitudinal wave, the particles of the medium vibrate parallel to the direction in which the wave is travelling. (1 mark)

In a transverse wave, the particles vibrate perpendicular to the direction in which the wave is travelling. (1 mark)

Sound and P-type earthquake waves are examples of longitudinal waves. (1 mark)

Water waves and visible light (or any type of electromagnetic radiation, or S-waves) are examples of transverse waves. (1 mark)

11 **a)**

Wavelength, λ / m	0.7	1.0	1.5	2.5	4.0
Frequency, f / Hz	460	320	210	130	80
1/λ / 1/m	**1.43**	**1.0**	**0.67**	0.40	0.25

(1 mark each)

b) Vertical axis labelled f / Hz, Horizontal axis labelled 1 / λ / 1/m (1 mark)

scale chosen to use at least half the graph paper (1 mark)

points plotted to within 1 small square (1 mark)

line of best fit drawn with a ruler (1 mark)

c) Gradient is approx. 320–330 m/s (depends on line of best fit). (3 marks)

d) Gradient is the speed of sound. (1 mark)

e) At 250 Hz, graph shows 1/λ has a value of about 0.76–0.78, giving a wavelength of about 1.28 to 1.20 m (depends on line of best fit). (2 marks)

Test yourself (page 112)

1 0° (A common mistake is to say the angle is 90°)

2 Angle of reflection = angle of incidence (to normal)

= 90° – angle of incidence to mirror

= 90° – 40°

= 50°

3 Angle of incidence = $\frac{1}{2} \times 130°$

= 65°

4 

The laterally inverted image of AMBULANCE is painted on real ambulances so that a driver in front will see the real word AMBULANCE in the rear-view mirror.

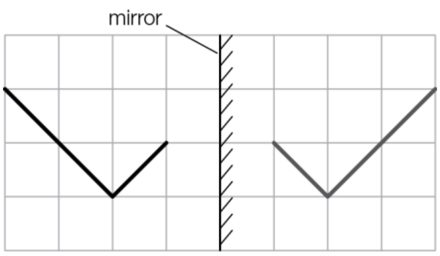
5 Angle of incidence on M^1 is 30°, so angle of reflection on M^1 is 30°.

Since mirrors are at right angles, angle of incidence on M^2 is 60°, so angle of reflection on M^2 is 60°.

Total change in direction of incident ray is 30° + 30° + 60° + 60° = 180°. In other words the ray reflected from M_2 is parallel to the ray incident on M_1, but in the opposite direction.

6 Student is 20 cm further from mirror AND image appears 20 cm further 'behind' mirror.

So distance between student and image has increased by 40 cm.

7 

8 Angle of incidence on A is 65°, so angle of reflection on A is 65°.

Since mirrors are at 120° to each other, then since the angle sum in a triangle is 180°, the acute angle between the incident ray on B and mirror B is 35°. So the angles of incidence and reflection on B are both 55°.

Show you can (page 116)

a) Refraction is the bending of light as it passes from one material into another and changes its speed.

b) Light refracts towards the normal when it slows down; it refracts away from the normal when it speeds up.

c) See 'Practical activity' description on pages 114 and 115.

d) Dispersion is the splitting up of white light into its coloured components. It occurs because each colour bends by a slightly different amount on refraction. It requires white light to pass from a material such as air into a more optically dense material such as glass, at a particular angle of incidence and then back out into air.

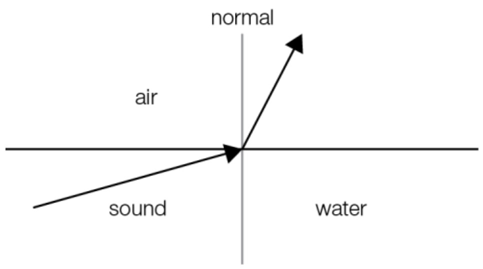
Test yourself (page 116)

9 a) i) Angle of incidence = 34°, angle of refraction = 24°

ii) Fastest in air

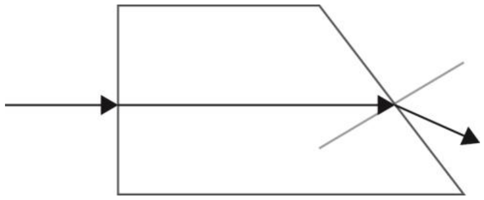
b) Red light bends less than blue when refracted in glass, so red light is faster than blue light in glass.

10



Sound bends towards from the normal because it is faster in water than in air.

11



12 a) Between air and diamond

b) Between air and diamond

c) Light slows down, so it bends towards the normal in diamond.

Show you can (page 120)

a) The critical angle is that angle of incidence in the first medium which results in an angle of refraction of 90° at the boundary between the first medium (e.g. glass) and the second medium (e.g. air).

b) i) The light is travelling in an optically dense material (like glass) towards a boundary with an optically rare material (like air).

ii) The angle of incidence at the boundary is greater than the critical angle for the two media.

c) See 'Practical activity – Experiment to find the critical angle' on pages 118 to 119.

d) Answers should draw upon the text on page 120 and, as appropriate, evidence gathered online for some applications of optical fibres.

Test yourself (page 121)

13 See 'Practical activity – Experiment to find the critical angle' on pages 118 to 119.

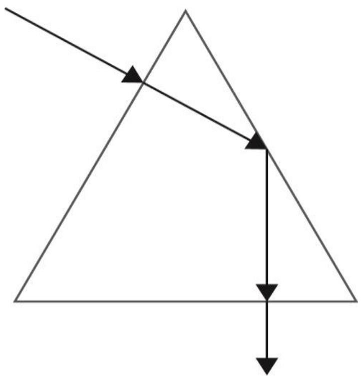
14 a) 0°

b) Since triangle is equilateral, angle at A is 60°. Therefore the angle of incidence at AC is 60°.

c) Angle of incidence at AC is 60°, which is greater than the critical angle, so the light is totally internally reflected at AC.

d) Angle of incidence on BC is 0°. So angle of refraction at glass/air boundary along BC is also 0°.

e)



15 For upper diagram (Figure 9.23): all statements are TRUE.

For lower diagram (Figure 9.24): all statements are FALSE.

16 Light in core is slower than in cladding, otherwise total internal reflection could not occur at the core-cladding boundary.

17 If it is bent too much, the angle of incidence at the core-cladding boundary may be less than the critical angle, resulting in refraction into the cladding.

Show you can (page 126)

See text for all of these questions:

a) See Figure 9.29 on page 124.

b) See the rules stated on page 124.

c) i) See diagram C on page 126.

ii) See diagram E on page 126.

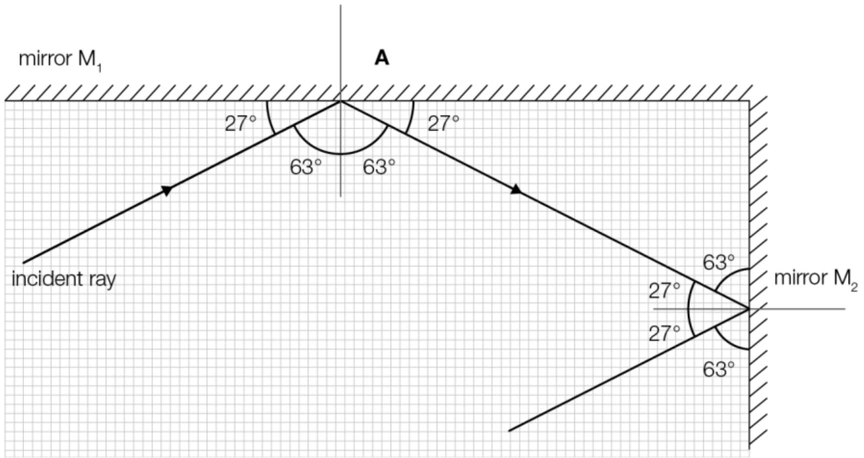
iii) See diagram A on page 126.

d) See the table directly opposite the "Show you can" on page 126.

Practice questions (pages 129–131)

1	Virtual,	(1 mark)
	laterally inverted,	(1 mark)
	same size as object,	(1 mark)
	same distance behind mirror as object is in front of mirror.	(1 mark)

2

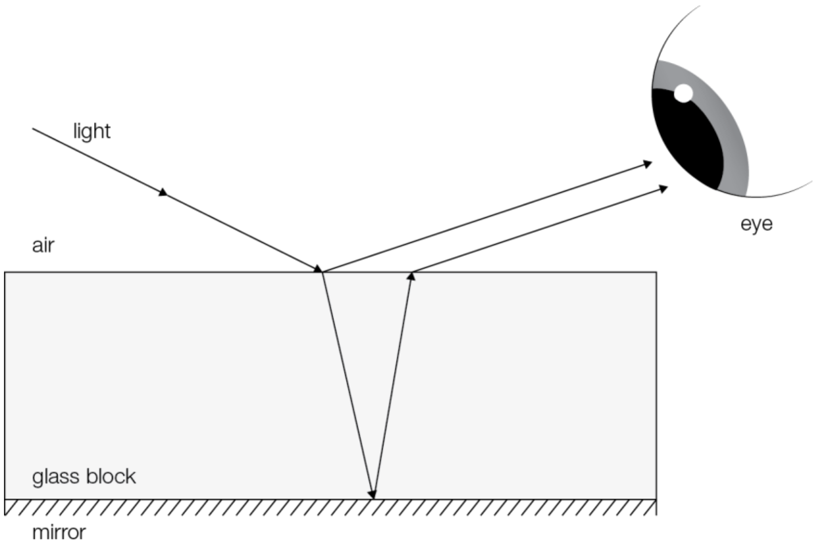


a) See diagram (normal at A correctly drawn for mark) (1 mark)

b) See diagram (all angles at A correct for the marks) (2 marks)

c) See diagram (reflected ray at A and reflected ray at M_2, mark for each) (2 marks)

3



(Air/glass refracted ray for 1 mark, glass/mirror reflected ray for 1 mark, glass/air refracted ray for 1 mark)

4 a) In both cases the light bends because it changes speed as it leaves the air. (2 marks)

b) Light bends by different amounts in glass and water, so the speed in each medium is different. (1 mark)

c) Light bends most as it enters glass – so light is slower in glass than in water. (2 marks)

5 a) Real (1 mark)

Diminished (1 mark)

Inverted (1 mark)

b) Convex lens (1 mark)

c) Principal focus is point where the lower ray on LHS of diagram crosses the principal axis (horizontal line). (1 mark)

d) Principal focus is 10 small squares from centre of lens,

so focal length is 10 × 2 mm = 20 mm

= 2.0 cm (1 mark)

e) Height of object is 25 small squares or 5.0 cm

height of image is 5 small squares or 1.0 cm

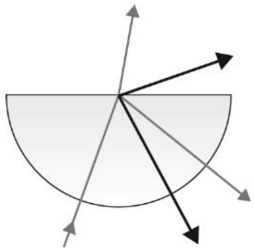
magnification = $\frac{1.0}{5.0}$

= 0.20 (1 mark)

6 1. The light is travelling in an optically dense material (like glass) towards a boundary with an optically rare material (like air). (1 mark)

2. The angle of incidence at the boundary is greater than the critical angle for the two media. (1 mark)

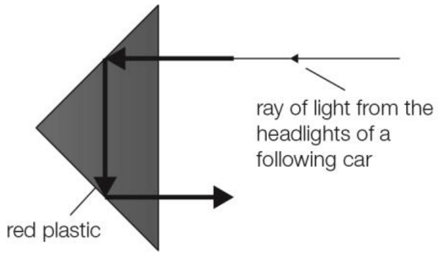
7 The student made two mistakes: the internally reflected ray at the straight edge does not obey the law of reflection and the refracted ray at the straight edge should bend away from (and not towards) the normal. (The corrections to the diagram are shown as bold arrows). (2 marks)



8 **a)** When the angle of incidence in plastic is 42°, the angle of refraction at the plastic/air boundary (1 mark)

is 90°. (1 mark)

b)



(1 mark for extending incident ray to far plastic edge without changing direction, 1 mark for correct first reflection with angle of incidence/reflection of 45°, 1 mark for correct second reflection with angle of incidence/reflection of 45°, 1 mark for crossing final plastic/air boundary without changing direction)

9 **a)** Dispersion (1 mark)

b) All colours in sunlight are refracted by the raindrop, (1 mark)

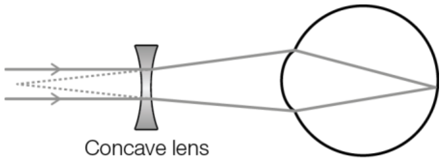
but each colour bends by a slightly different amount. (1 mark)

So the result is that the colours in the sunlight are all separated.

10 a) Short sight (myopia) (1 mark)

b) Diverging (concave) lens (1 mark)

c)



Rays diverge after passing through concave lens. (1 mark)

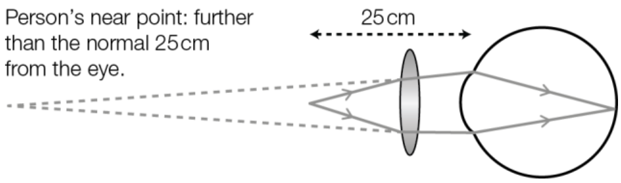
Rays converging within the eye. (1 mark)

Rays brought to focus on retina. (1 mark)

11 a) Long sight (hypermetropia) (1 mark)

b) Converging (convex) lens (1 mark)

c)



Rays diverging after passing through convex lens but appear to come from distant object. (1 mark)

Within eye rays converge on retina. (1 mark)

Rays come from point 25 cm in front of eye. (1 mark)

12 a) Graph with the following:

- suitable graph labels with units on each axis (1 mark)
- suitable linear scale on each axis covering at least 50% of the available paper (1 mark)
- points plotted to within a small square (1 mark)
- a suitable line of fit (in this case a curve). (2 marks)

b) Angle of refraction is NOT proportional to the angle of incidence because the graph does not show a straight line of best fit through the origin – it is a curve through the origin. (1 mark)

c) i) Angle of incidence is approximately 49°. (1 mark)

ii) Critical angle is angle of incidence in water that gives an angle of refraction in air of 90°. But light is reversible. So numerical value of critical angle is also equal to angle of refraction in water for which the angle of incidence in air is 90°. (1 mark)

Show you can (page 136)

a) Conductors have free electrons, insulators do not.

b) Electrons flow from the negative terminal of the battery to the positive terminal.

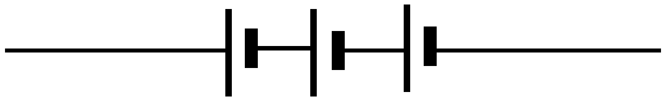
Conventional current flows in the opposite direction.

c) See table 10.2 on page 134.

d) Produce combinations of cells and check against the examples explained on page 135.

Test yourself (page 136)

1 **a)** Two of the cells cancel. So the voltage of each cell is the battery voltage or 1.6 V.

b) 

c) 3 × 1.6 V = 4.8 V

2 **a)** 3000 mA

b) 200 mA

c) 0.2 mA

3 **a)** 0.4 A

b) 1.5 A

c) 0.5 A

4 **a)** $Q = It$

$= 6\text{ A} \times 10\text{ s}$

$= 60\text{ C}$

b) $Q = It$

$= 0.3\text{ A} \times 60\text{ s}$

$= 18\text{ C}$

c) $Q = It$

$= 500 \times 10^{-6}\text{ A} \times (60 \times 60)\text{ s}$

$= 1.8\text{ C}$

5 **a)** $I = \frac{Q}{t}$

$= \frac{100\text{ C}}{5\text{ s}}$

$= 20\text{ A}$

b) $I = \frac{Q}{t}$

$= \frac{0.5\ \text{C}}{50\ \text{s}}$

$= 0.01$ A

c) $I = \frac{Q}{t}$

$= \frac{0.06\text{C}}{200\text{s}}$

$= 3 \times 10^{-4}$ A

$= 300\ \mu$A

Show you can (page 140)

a) In the Ohm's Law experiment we are investigating how current depends on voltage. If the temperature changed, the resistance would also change and the test would not be fair. We can ensure the temperature change is kept to a minimum by switching off the power supply immediately after the reading is obtained, and by allowing the test circuit to cool for two minutes between each measurement.

b) To find out how current depends on voltage we need a range of values, not just a single *V–I* pair. We can change the voltage across the wire by adjusting the power supply unit or by using a rheostat (variable resistor).

c) The *V–I* characteristic is a straight line through the origin showing that the current is directly proportional to the voltage across the conductor at constant temperature.

d) The current in a metallic conductor is directly proportional to the voltage across its ends, provided the temperature remains constant.

Test yourself (page 140)

6 $I = \frac{V}{R}$

$= \frac{20\ V}{10\ \Omega}$

$= 2$ A

7 $R = \frac{V}{I}$

$= \frac{15\text{ V}}{3\text{ A}}$

$= 5\ \Omega$

8 $V = I \times R$

$= 2\text{ A} \times 25\ \Omega$

$= 50\text{ V}$

9 **a)** $R = \frac{V}{I}$

$= \frac{15\ V}{2.5\ A}$

$= 6.0\ \Omega$

b) $V = I \times R$

$= 2.0\text{ A} \times 6.0\ \Omega$

$= 12\text{ V}$

10 **a)** $I = \frac{V}{R}$

$= \frac{6\text{ V}}{12\ \Omega}$

$= 0.5\text{ A}$

b) $V = I \times R$

$= 1.5\text{ A} \times 12\ \Omega$

$= 18\text{ V}$

11 $R = \frac{V}{I}$

$= \frac{6\text{ V}}{0.1\text{ A}}$

$= 60\ \Omega$

12 $R = \frac{V}{I}$

$= \frac{3\ \text{V}}{0.6\ \text{A}}$

$= 5\ \Omega$

$I = \frac{V}{R}$

$= \frac{2.5\ \text{V}}{5\ \Omega}$

$= 0.5\ \text{A}$

Test yourself (page 147)

13 a) First circuit: $R_{\text{Total}} = R_1 + R_2 + R_3$

$= 2 + 4 + 6$

$= 12\ \Omega$

So, current from cell $= \frac{V}{R}$

$= \frac{3\ \text{V}}{12\ \Omega}$

$= 0.25\ \text{A}$

Second circuit: since the resistors are both 8 Ω, $R_{\text{Total}} = \frac{R}{2}$

$= \frac{8}{2}$

$= 4\ \Omega$

So current from cell $= \frac{V}{R}$

$= \frac{8\ \text{V}}{4\ \Omega}$

$= 2\ \text{A}$

b) Voltage across 8 Ω in second circuit = cell voltage

$= 8\ \text{V}$

14 a) First circuit: total resistance = $\frac{12}{2}$

$= 6\ \Omega$

So ammeter A_1 reads $\frac{9\ V}{6\ \Omega}$ = 1.5 A

Current splits equally at junction with two identical resistors –

So A_2 reads 0.75 A and A_3 reads 0.75 A.

Second circuit: total resistance = $\frac{6}{2}+\frac{4}{2}$

$= 5\ \Omega$

So ammeter A_3 reads $\frac{10\ \text{V}}{5\ \Omega}$ = 2 A

Current splits equally since resistors in each parallel network are the same,

So A_1 reads 1 A and A_2 reads 1 A.

b) First circuit: voltage across each resistor = $I \times R$

$= 0.75 \times 12$

$= 9$ V

Second circuit: voltage across each 6 Ω resistor = $I \times R$

$= 1 \times 6$

$= 6$ V

Second circuit: voltage across each 4 Ω resistor = $I \times R$

$= 1 \times 4$

$= 4$ V

15 a)

Circuit	**V_1 / V**	**V_2 / V**	**I_1 / A**	**I_2 / A**
A	3	3	0.4	**0.2**
B	3	**1.5**	0.1	**0.1**

b) Circuit A: each lamp has resistance, $R = \frac{V}{I}$

$= \frac{3}{0.2}$

$= 15\ \Omega$

Circuit B: each lamp has resistance, $R = \frac{V}{I}$

$= \frac{1.5}{0.1}$

$= 15\ \Omega$

Show you can (page 153)

a) i) Resistance is directly proportional to length.

ii) Resistance is inversely proportional to the cross-sectional area.

iii) Resistance is bigger for materials that are insulators and smaller for conductors.

b) i) See 'Practical activity – Resistance and length' on pages 148-149.

ii) See 'Practical activity – Resistance and cross-sectional area' pages 150 to 152.

iii) See 'Practical activity – Investigating how the resistance of a metallic conductor at constant temperature depends on the medium it is made from' page 153.

Test yourself (page 153)

16 a) Length is $(\frac{2}{2.5}) \times 100$ cm = 80 cm

b) Resistance is $(\frac{120}{100}) \times 2.5\ \Omega = 3\ \Omega$

17 48 cm length has resistance, $R = \frac{V}{I}$

$= \frac{0.90}{0.15}$

$= 6\ \Omega$

New length has resistance, $R = \frac{V}{I}$

$= \frac{1.44}{0.36}$

$= 4\ \Omega$

New length is $(\frac{4}{6}) \times 48$ cm = 32 cm

18 a) 30 cm of wire A has resistance $(\frac{30}{80}) \times 2.4 = 0.90\ \Omega$

40 cm of wire B has resistance $(\frac{40}{50}) \times 1.2 = 0.96\ \Omega$

so the 40 cm length of wire B has the greater resistance.

b) Both graphs are straight lines through the (0, 0) origin.

Wire A passes through (100, 3) and Wire B passes through (100, 2.4), so A has the larger gradient.

19 a) The 80 cm length has a resistance of $(\frac{80}{100}) \times 3.0 = 2.4\ \Omega$

Making the loop and connecting it in this way creates two sections, each of 1.2 Ω, in parallel.

Two 1.2 Ω resistors in parallel have a combined resistance of 0.6 Ω.

b) As the crocodile clips are moved, one part of the loop is now longer and so it has a resistance greater than 0.6 Ω. The other part is now shorter and so it has a resistance less than 0.6 Ω. When resistors are in parallel their combined resistance is always less than the smallest resistance in the network. So the total resistance **decreases** as the clips move towards each other.

20 a) Resistance is $\left(\frac{75}{50}\right) \times 1.6 = 2.4\ \Omega$

b) Doubling the diameter quadruples the cross-sectional area and therefore reduces the resistance by a factor of 4. Resistance is $\frac{1.6}{4} = 0.4\ \Omega$.

The answer below relates to a 0.4 mm diameter wire.

c) Compared to part b) the length has increased by a factor of 1.5 so the new resistance is $1.5 \times 0.4 = 0.6\ \Omega$

21 Quadrupling the length from 20 cm to 80 cm would quadruple the resistance.

Doubling the diameter from 0.3 mm to 0.6 mm quadruples the cross-sectional area and would reduce the resistance by a factor of 4.

The combined effect is that resistance does not change – it remains 0.8 Ω.

Practice questions (pages 154–155)

1 a) Conventional current (1 mark)

b) Charged particles move from 10 Ω resistor towards 20 Ω resistor. (1 mark)

c) Electrons (1 mark)

d) 0.6 A (1 mark)

e) $Q = I \times t$ (1 mark)

$= 0.6\text{ A} \times 60\text{ s}$ (1 mark)

$= 36\text{ C}$ (1 mark)

2 Total resistance = 20 + 10

= 30 Ω (1 mark)

$V = I \times R$

$= 0.6 \times 30$ (1 mark)

$= 18\text{ V}$ (1 mark)

3 a) $R_{total} = \frac{R}{2}$ and in this case, $12 = \frac{R}{2}$, so $R = 24\ \Omega$ (1 mark)

b) To get two resistors in series to add to give 12 Ω, each must be 6 Ω. (1 mark)

4

Circuit A	Circuit B
$V_1 = 2 \times 1.5$ $= 3$ V $V_2 = 3$ V (lamps in parallel) Total resistance of circuit is $\frac{6}{2} = 3\ \Omega$ A_1 reads $\frac{3}{3} = 1$ A A_2 reads $\frac{3}{6} = 0.5$ A	$V_1 = 2 \times 1.5$ $= 3$ V $V_2 = 1.5$ V (lamps in series) Total resistance of circuit is $6 + 6 = 12\ \Omega$ A_1 reads $\frac{3}{12} = 0.25$ A A_2 reads $\frac{3}{12} = 0.25$ A (same as A_1)

($^1/_2$ mark for each correct meter reading)

5 **a)** Resistance = $\frac{\text{voltage}}{\text{current}}$ (1 mark)

$= \frac{0.012\text{ V}}{0.003\text{ A}}$ (1 mark)

$= 4\ \Omega$ (1 mark)

b) Current splits equally in parallel network since resistors are identical, so each of the three parallel resistors takes a current of 1 mA. (1 mark)

Current in the resistor nearest Y is 3 mA. (1 mark)

c) Combined resistance of parallel resistors is $\frac{1}{3}$ that of resistor nearest Y.

Voltage splits in proportion to resistance.

Voltage across each parallel resistor = $\frac{1}{4}$ of total voltage

$= \frac{1}{4} \times 12$ mV

$= 3$ mV (1 mark)

Voltage across resistor nearest Y = 12 – 3

= 9 mV (1 mark)

d) For resistance nearest Y: resistance = $\frac{\text{voltage}}{\text{current}}$

$= \frac{0.009\text{ V}}{0.003\text{ A}}$

$= 3\ \Omega$ (1 mark)

Resistors are all identical – each is $3\ \Omega$. (1 mark)

6 **a)** Total resistance = $R_1 + R_2$

= 40 + 20

= 60 Ω (1 mark)

Current = $\frac{\text{voltage}}{\text{resistance}}$

= $\frac{12\text{ V}}{60\ \Omega}$

= 0.2 A (1 mark)

Voltage across R_1 = current × resistance

= 0.2 A × 40 Ω

= 8 V (1 mark)

b) It is assumed the resistance of the voltmeter is so large that it draws negligible current from the circuit. (1 mark)

So the current in each resistor is the same. (1 mark)

7

Switch		**Effective resistance between X and Y/Ω**	**Comment**
A	**B**		
Open	Open	**9**	**Only 6 Ω and 3 Ω resistors are in series** (1 mark)
Open	Closed	**5.4**	**6 Ω and 4 Ω resistors in parallel give 2.4 Ω** **2.4 Ω in series with 3 Ω give a total of 5.4 Ω** (1 mark)
Closed	Open	**7**	**6 Ω and 12 Ω resistors in parallel give 4 Ω** **4 Ω in series with 3 Ω give a total of 7 Ω** (1 mark)
Closed	Closed	**5**	**Parallel resistors collectively give 2 Ω** **2 Ω in series with 3 Ω give 5 Ω** (1 mark)

8 **a)**

Area of cross section of wire/mm²	0.5	1.0	2.0	3.0	4.0
Resistance/Ω	t entry) 24.0	**12.0**	6.0	**4.0**	**3.0**

Note that resistance × area = a constant (in this case 12.0 Ω mm²)

b) $R \times A$ = 12 for a 100 cm length of wire. (1 mark)

For area 1.5 mm², $R = \frac{12}{1.5}$

= 8 Ω for 100 cm length (1 mark)

So for 50 cm of wire the resistance is $\frac{1}{2} \times 8 = 4\ \Omega$ (1 mark)

Show you can (page 157)

a) Electrons are accelerated towards the positive terminal of the battery. As they move through the metal lattice they collide with the metal ions, giving them some of their kinetic energy in every collision. This causes the ions to vibrate faster and with greater amplitude. We experience this as the metal becoming hotter.

b) $P = I \times V$

Test yourself (page 158)

1 $E = P \times t$

$= 1000\ \text{W} \times (60 \times 60)\ \text{s}$

$= 3\,600\,000\ \text{J}\ (= 3.6\ \text{MJ})$

2 **a)** $P = \frac{E}{t}$

$= \frac{15\,000\ \text{J}}{10\ \text{s}}$

$= 1\,500\ \text{W}$

b) 1 500 W = 1.5 kW

3 **a)** $P = I \times V$

$= 0.25\ \text{A} \times 240\ \text{V}$

$= 60\ \text{W}$

b) $E = P \times t$

$= 60\ \text{W} \times 60\ \text{s}$

$= 3\,600\ \text{J}$

4 **a)** $E = P \times t$

$= 960\ \text{W} \times 5\ \text{s}$

$= 4\,800\ \text{J}$

b) $I = \frac{P}{V}$

$= \frac{960\ \text{W}}{12\ \text{V}}$

$= 80\ \text{A}$

Test yourself (page 158)

5 $P = I \times V$

$= 4\text{ A} \times 240\text{ V}$

$= 960\text{ W}$

6 $I = \dfrac{P}{V}$

$= \dfrac{48\text{ W}}{12\text{ V}}$

$= 4.0\text{ A}$

7

Name of appliance	Power rating	Current drawn	Resistance
Bulb of study lamp	60 W	**0.25 A**	**960 Ω**
Television	80 W	**0.33 A**	**720 Ω**
Toaster	1200 W	**5.0 A**	**48 Ω**
Convector heater	2 kW	**8.33 A**	**28.8 Ω**
Shower	3 kW	**12.5 A**	**19.2 Ω**

8 $P = I \times V$

$= I^2 \times R$

$= \dfrac{V^2}{R}$

$P = \dfrac{240^2}{48}$

$= 1200\text{ W}$ (= 1.2 kW)

Practice questions (pages 163–164)

1 a) $I = \dfrac{P}{V}$ (1 mark)

$= \dfrac{2000}{230}$ (1 mark)

$= 8.7\text{ A}$ (1 mark)

So select the 13 A fuse as the smallest rated above the normal current. (1 mark)

b) Live wire: 8.7 A, neutral wire: 8.7 A, earth wire: 0 A (1 mark)

c) If the user then touches the metal body, they could be electrocuted. (1 mark)

d) The earth wire should be connected electrically to the metal frame. (1 mark)

e) The fuse should be inserted in the plug so that it is on the live side of the fire's element. (1 mark)

f) If the live wire touches the frame current will flow through the low resistance earth wire to earth. This current will be big enough to blow the fuse in the plug, so disconnecting the fire from further danger from a high voltage. (1 mark)

2 a) i) Units used = 12 107 – 11 897

= 210 kW h (1 mark)

ii) Cost = 210 × 15p (1 mark)

= 3150p

= £31.50 (1 mark)

b) i) A is the fuse. (1 mark)

ii) Wire 2 (earth wire) (2 marks)

iii) 1 – blue (1 mark), 2 – green/yellow stripes (1 mark), 3 – brown (1 mark)

3 a) i) The television works normally when connected to a 240 V supply. (1mark)

In normal operation it uses 80 joules of electrical energy per second. (1 mark)

ii) The TV is a double-insulated device. (1 mark)

It does not need an earth wire. (1 mark)

iii) Live (1 mark)

iv) To ensure the television is safe when the switch is open (1 mark)

v) All metal parts are enclosed in a plastic, insulating box so that no one can come into contact with a live wire. (1 mark)

b) i) Number of units = 8 × 2

= 16 kW h (1 mark)

16 kW h × 15 pence/kW h (1 mark)

= 240 pence

= £2.40 (1 mark)

ii) The cable is thicker than the element, so its resistance is much less. (1 mark)

This means less electrical energy is converted into heat in the cable than in the element.

4 a) Number of units = number of kW × number of hours

= 0.1 × 12 (1 mark)

= 1.2 kW h (1 mark)

b) Number of units = number of kW × number of hours

= 0.25 × 4 (1 mark)

= 1 kW h (1 mark)

c) Number of units = number of kW × number of hours

$= 2.4 \times \frac{5}{60}$ (1 mark)

= 0.2 kW h (1 mark)

5 a) $P = I \times V$

$= 15 \times 230$ (1 mark)

$= 3450$ W

$= 3.45$ kW (1 mark)

b) Number of units = 3.45 kW × $\left(\frac{10}{60}\right)$ hours

= 0.575 kW h (1 mark)

0.575 × 12 pence = 6.9 pence (1 mark)

6 a) Energy = power × time (1 mark)

= 1000 J/s × 3600 s (1 mark)

= 3 600 000 J (= 3.6 MJ) (1 mark)

b) Common name: kW h or "a unit" (1 mark)

7 a) The normal current is much greater than 3 A, so the fuse would blow immediately the fire was switched on. (1 mark)

b) The normal current for the lamp is around 0.25 A. So the fuse would probably never blow even when the current being drawn was much more than normal. (1 mark)

c) $I = \frac{P}{V}$

$= \frac{800}{230}$

= 3.5 A (1 mark)

So select the next highest fuse at 5 A (1 mark)

8 Maximum power available = $I \times V$

= 5 A × 230 V

= 1150 W (1 mark)

Maximum number of bulbs = $\frac{\text{maximum power}}{\text{power of 1 bulb}}$

$= \frac{1150}{60}$

= 19.2 (1 mark)

So, cannot use more than 19 bulbs (1 mark)

9 a) Kettle: $\frac{2400\text{ W}}{230\text{ V}}$ = 10.4 A (1 mark)

Dishwasher: $\frac{3000\text{ W}}{230\text{ V}}$ = 13.0 A (1 mark)

Television: $\frac{800\text{ W}}{230\text{ V}}$ = 3.5 A (1 mark)

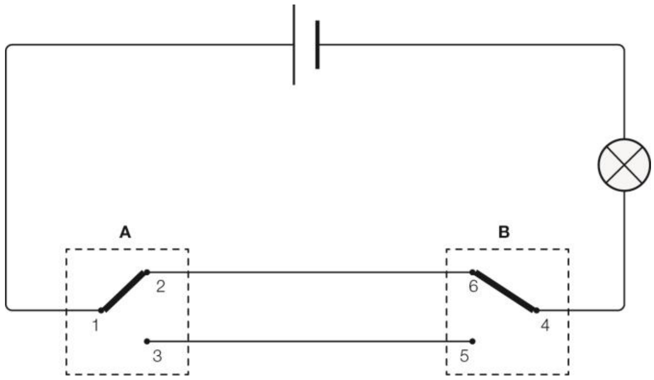
Toaster: $\frac{1300\text{ W}}{230\text{ V}}$ = 5.7 A (1 mark)

b) Total current drawn = 10.4 + 13.0 + 3.5 + 5.7

= 32.6 A

The current drawn would immediately blow the 13 A fuse. (1 mark)

10 a)



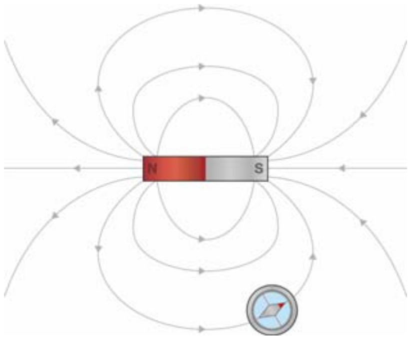
(Note that the bulb would also light if the switches were in positions 1 to 3 and 5 to 4.) (2 marks)

b) The current flows from the positive terminal to **1** to **2** to **6** to **4** to the lamp and to the negative terminal. (2 marks)

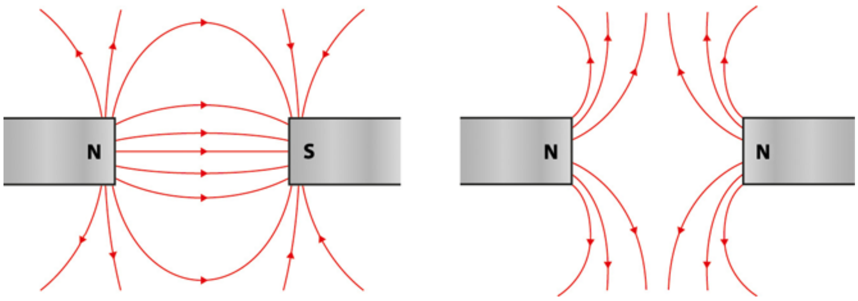
Test yourself (page 166)

1 There is a North pole and a South pole at the ends of a bar magnet and at the ends of a current-carrying solenoid. The field lines for both show closed loops, running from North to South. However, within a solenoid the field lines are parallel and equally spaced, indicating a constant magnetic field.

2



3



Show you can (page 167)

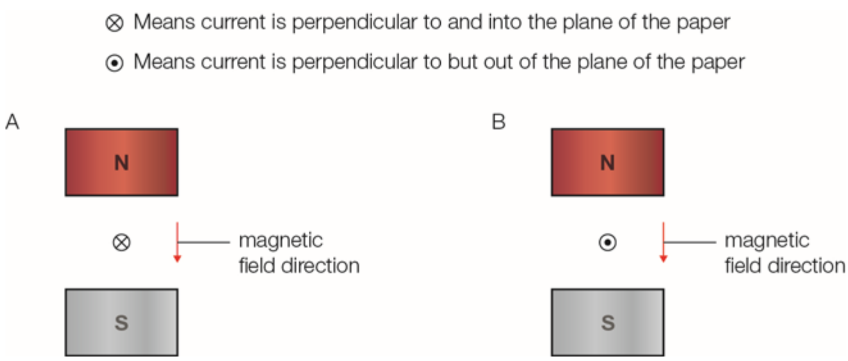
a) Practical activity

b) A neutral point is a point where there is no resultant magnetic field.

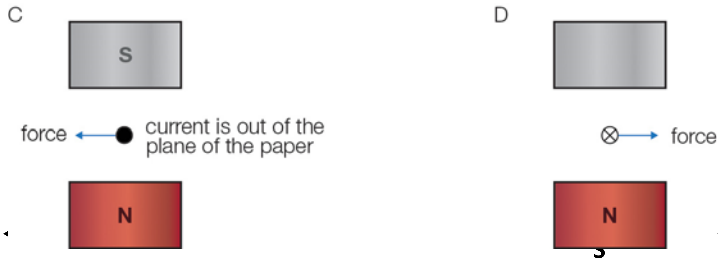
Test yourself (page 171)

4 Point the centre finger of the left hand in the direction of the current and the first finger in the direction of the magnetic field, the direction in which the thumb is pointing gives the direction of the force. (See Figure 12.11 on page 169.)

5 a)



b)



6 **a)** i, ii, iii (because the lines do not cross the time axis)

b) iv, v

N

Test yourself (page 174)

7 As described on page 172 of the text, connect the coil to the ammeter. Plunge a bar magnet into the coil and observe the momentary deflection of the ammeter needle, showing that a current has been induced. Notice that when the magnet is stationary, the needle returns to zero. This effect is electromagnetic induction.

8 The direction of the induced current is always such as to produce a magnetic field to oppose the motion that is causing the electromagnetic induction.

Show you can (page 174)

a) If both coil and magnet are stationary there is no kinetic energy which can be converted into electrical energy. So there is no induced current.

b) Connect a coil to a cathode ray oscilloscope (CRO). Insert a magnet into the coil and start to rotate it. Observe the a.c. signal displayed on the CRO. (It is fiddly to do this experiment – it works better if the magnet is rotated at the end of a variable speed electric screwdriver.)

Test yourself (page 175)

9 **a)** **i)** Electromagnetic induction

ii) When the magnet is stationary there is no change in the magnetic flux linked with the coil, so there is no electromagnetic induction. So no current flows.

When the North pole moves into the coil, the magnetic flux linked with the coil is changing, so electromagnetic induction occurs and there is an induced current.

b) When the North pole is pulled out of the coil, the magnetic flux linked with the coil is changing, but this time in the opposite sense, so electromagnetic induction occurs and there is an induced current in the opposite direction.

c) Kinetic energy provided by the person moving the magnet

10 a) When the switch is closed there is a sudden increase in the current in the primary coil. This causes a sudden increase in the magnetic field linked to the secondary coil. So there is electromagnetic induction in the secondary coil and a current is detected. The effect is momentary because the current in the primary coil does not increase indefinitely.

b) When the switch is opened there is a sudden decrease in the current in the primary coil. This causes a sudden decrease in the magnetic field linked to the secondary coil. So there is electromagnetic induction in the secondary coil and a current is detected.

c) Because the magnetic field linked to the secondary coil in a) is increasing, while in b) it is collapsing, the directions of the current in the two situations are opposite to each other.

d) Switch the current in the primary coil on and off repeatedly OR replace the battery and switch with a source of a.c.

11 The faster the magnet, the greater the size of the induced current.

12 The direction of the induced current is always such as to set up a magnetic field that opposes the motion causing the induction.

13 Connect the ends of the coil to an ammeter. Plunge the North pole of the magnet into the coil and observe the momentary deflection on the ammeter. Pull the North pole of the magnet out of the coil and notice the momentary deflection of the ammeter in the opposite direction. Repeating these movements creates an alternating current.

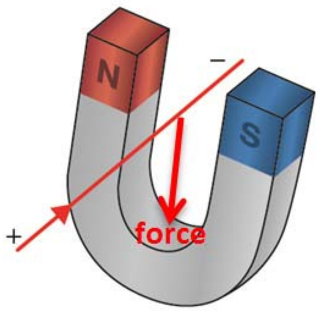
Show you can (page 176)

a) Connect the ends of the coil to a centre-zero ammeter. Plunge the magnet into the coil.

b) An alternating current is induced in that coil.

Test yourself (page 179)

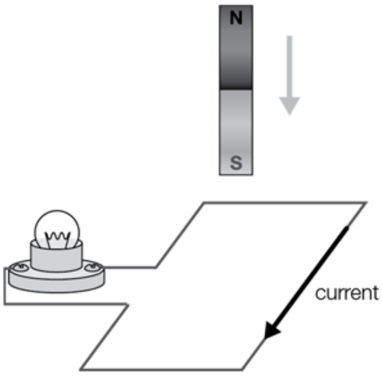
14



15 a) Yes – the magnetic field/flux linked with the wire is changing.

b) No – the circuit is incomplete (not closed), so no current can flow.

c)



16 a) There is a momentary deflection on the centre-zero ammeter. The needle then returns to zero. When the switch is closed there is a sudden increase in the current in the primary coil. This causes a sudden increase in the magnetic field linked to the secondary coil. So there is electromagnetic induction in the secondary coil and a current is detected.

b) There is a momentary deflection on the centre-zero ammeter, but in the opposite direction to that observed in (i). When the switch is opened there is a sudden decrease in the current in the primary coil. This causes a sudden decrease in the magnetic field linked to the secondary coil. So there is electromagnetic induction in the secondary coil and a current is detected. The needle then returns to zero.

17 The first pulse shows the induced e.m.f. as the flux linked with the coil is increasing. The second pulse is in the opposite direction because it shows the induced e.m.f. as the magnet leaves the coil and the flux linked with the coil is decreasing.

18 a) The wind causes the cups to turn. This causes the magnet to spin. The spinning magnet produces a changing flux in the coil, inducing an alternating current, which is detected on the voltmeter.

b) The greater the speed of the wind, the faster the cups turn, the faster the magnet spins and the greater the induced voltage.

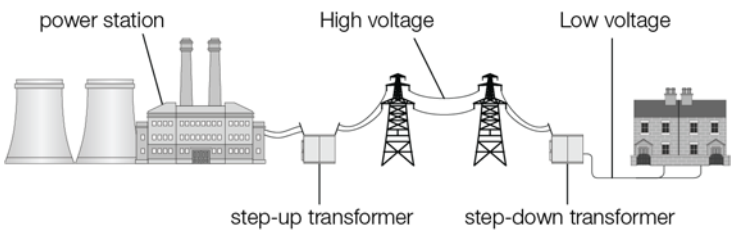
c) Using a stronger magnet (or using a coil of more turns per unit of length) would make the anemometer more sensitive.

19 a) Current flows in the coil because the moving magnet produce a changing flux in the coil and so induces a voltage across the coil.

b) Alternating. The magnet oscillates at the end of a spring. As it enters the coil, current flows in one direction. As it leaves the coil, current flows in the opposite direction.

c) The graph is a sine wave of decreasing amplitude.

20 a)



b) Voltage is low in the power station, then high in the distribution network between the two transformers, then low in the homes.

c) High voltages mean that to deliver a given amount of power, the current is low (from $P = I \times V$). A low current means less heat is given out from the power cables.

21 a) 25 kJ

b) Increasing the voltage means that to deliver a given amount of power, the current is reduced (from $P = I \times V$). A lower current means less heat is given out from the power cables.

c) At the consumer distribution system (between the distribution network and homes).

d) To reduce the voltage to a value that is suitable for (safer) electrical appliances.

22 a) i) There is an induced current detected on the meter while the first coil is moving and is not too far from the neighbouring coil.

ii) The induced current is now in the opposite direction.

b) A 1 Hz a.c. is induced in the second coil. This causes the needle on the meter to flick back and forth about the zero mark once every second.

23 a) Since the turns ratio is 0.1, the voltage at the secondary is 0.1 × 8 kV = 800 V

b) $I = \frac{P}{V}$

$= \frac{7200}{800}$

$= 9$ A

24 a) To increase an a.c. voltage

b) To reduce an a.c. voltage

25 At the power station: a step-up transformer is used to increase the a.c. voltage, thus reducing the current and so reducing heat loss in the overhead transmission lines.
At the user substation the a.c. voltage is reduced to make it safer and suitable for use in domestic electrical appliances.

26

$$\frac{\text{number of turns in secondary coil}}{\text{number of turns in primary coil}} = \frac{\text{voltage across secondary coil}}{\text{voltage across primary coil}}$$

$$\frac{Ns}{Np} = \frac{Vs}{Vp}$$

Show you can (page 181)

a) An a.c. generator consists of a rectangular coil of wire, which is mounted on an axle and placed between the opposite poles of a magnet. As the axle rotates the coil turns, ‘cutting’ the magnetic field lines and inducing a voltage in the coil. (You do not need to know about the slip rings and how the current in the coil is taken to an external circuit.)

b) A simple transformer consists of an iron core on which are mounted a primary coil and a secondary coil. Both coils are made of insulated copper wire. The primary coil is connected to an input a.c. voltage supply. The secondary coil is connected to the external circuit.

Practice questions (pages 182–183)

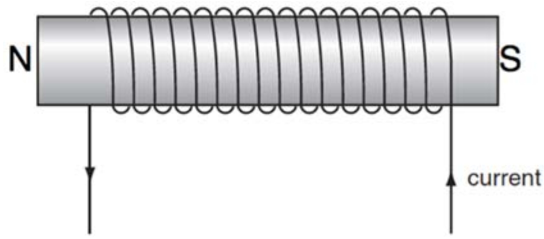
1 **a)** Increase the current, (1 mark)

increase the number of turns per unit length of coil; (1 mark)

insert a soft iron rod into the coil. (1 mark)

b) In a ferrous metal (iron) scrap yard, an electromagnet is attached to the end of a cable attached to a crane. When the current is switched on the electromagnet can lift ferrous metal. When it is switched off, the ferrous metal falls. (1 mark)

c) **i)** (1 mark for each correct pole)



ii) For shape of the field, refer to Figure 12.4 on page 166. (1 mark for correct shape of field outside coil, 1 mark for correct field inside coil, 1 mark for correct poles and 1 mark for correct arrows on field lines.)

2 **a)** Vertically from North to South (1 mark)

b) Rod moves to the right. (1 mark)

c) Rod will now move to the left. (1 mark)

d) Rod will now move to the left. (1 mark)

3 **a)** 'd.c.' means 'direct current'. (1 mark)

b) Force on AB is vertically downwards (1 mark)

c) Force on CD is vertically upwards (1 mark)

d) There is an unbalanced moment about the central axis through the coil.

This moment causes the coil to turn. (1 mark)

e) At the instant shown there is no force on side BC. (2 marks)

4 **a)** The moving bicycle wheel causes the ridged knob to turn.

This causes the magnet to spin. (1 mark)

The spinning magnet produces a changing flux in the coil, (1 mark)

inducing an electric current to light the lamp. (1 mark)

b) The faster the bicycle moves, the faster the ridged knob turns and the faster the magnet spins. (1 mark)

This causes a much greater rate of change of magnetic flux with the coil and a bigger induced e.m.f. (1 mark)

The bigger the induced e.m.f., the bigger is the current in the coil and the brighter the lamp (1 mark)

c) When the bicycle stops, the magnet stops spinning and there is no longer an induced e.m.f. (1 mark)

5 a) a.c. (1 mark)

b) At the instant the plane of the coil is vertical, the magnetic flux linked with the coil is at a maximum, but it is not changing. (1 mark)

A changing flux is required to induce an e.m.f. (1 mark)

c) At the instant the plane of the coil is horizontal, the magnetic flux linked with the coil is zero, but it is changing at its maximum rate. (1 mark)

A flux changing at maximum rate induces a maximum e.m.f. (1 mark)

d) To increase the electrical output: turn the coil faster, (1 mark)

use a stronger magnet, (1 mark)

use a coil containing more turns of wire. (1 mark)

6 a) When the switch is closed there is a momentary deflection on the needle on the ammeter before it returns once more to zero. (1 mark)

The sudden increase in the current in the primary circuit causes a changing magnetic flux in the iron ring, which induces a current in the secondary circuit. (1 mark)

b) When the switch in re-opened, there is once more a momentary deflection on the needle on the ammeter, (1 mark)

but this time in the opposite direction, before it returns once more to zero. (1 mark)

The sudden change in current to zero in the primary circuit causes the magnetic field in the iron ring to collapse, changing the magnetic flux and inducing a current in the opposite direction in the secondary circuit. (1 mark)

7 a) $\frac{V_{out}}{V_{in}} = \frac{N_s}{N_p}$ (1 mark)

$V_{\text{out}} = 230 \times \frac{5}{500}$ (1 mark)

$= \frac{230}{100}$

$= 2.3\ \text{V}$ (1 mark)

b) $P_{out} = P_{in}$ (1 mark)

$I_s \times V_s = I_p \times V_p$ (1 mark)

$$I_s = 1.15 \times \frac{230}{2.3}$$

$= 115$ A (1 mark)

c) The left-hand coil draws a current of only 1.15 A, so it need not be too thick. (1 mark)

The right-hand coil draws a current that is 100 times greater. A thin wire could melt, so the wire needs to be quite thick. (1 mark)

8 **a)** 'a.c.' stands for 'alternating current'. (1 mark)

In a d.c. circuit, the current flows in the same direction all the time. (1 mark)

An a.c. current reverses its direction regularly. (1 mark)

b) A transformer's core is made of soft iron. (1 mark)

c) $\frac{V_s}{V_p} = \frac{N_s}{N_p}$ (1 mark)

$V_s = V_p \times \frac{N_s}{N_p}$ (1 mark)

$= 16 \times \frac{100}{50}$ (1 mark)

$= 16 \times 2$

$= 32$ V (1 mark)

Show you can (page 186)

Asteroids are large rocks in outer space. Some are very large, while others are as small as a few metres in diameter. Many are found in the "Asteroid Belt", a giant ring-shaped area of space between the orbits of Mars and Jupiter.

Test yourself (page 186)

1 Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune.

2 The inner planets have rocky surfaces, the outer planets are gaseous. The inner planets are relatively small. The outer planets are much larger.

3 Artificial satellites are man-made objects that orbit a heavenly body (usually the Earth) and have been placed in orbit by humans. Natural satellites have been placed in position by nature and orbit planets or stars. Examples of artificial satellites orbiting the Earth include the two Telstars, the International Space Station, Global Positioning Satellites (GPS), television broadcasting satellites including Astra, and many more. The Moon is a natural satellite of the Earth (there are natural satellites of all the other planets in the Solar System except Mercury and Venus).

4 Any three from: communications, Earth observation (e.g. for mapping, monitoring rainforests and global temperatures), astronomy, orbiting laboratories.

5 Comets range from a few hundred metres to tens of kilometres in diameter. At their centres are rock, ice, silicates and some organic compounds. They orbit the Sun, some in very eccentric orbits (like a rugby ball).

Show you can (page 188)

a) A stellar nebula consists mainly of cold clouds of hydrogen gas and dust.

b) Gravity causes the hydrogen gas particles to come together. The gravitational force is greater than the outward pressure due to the particles' kinetic energy and the gas collapses inwards. During this collapse the material at the centre of the cloud heats up. The hot core at the centre of the cloud is called a protostar. As the protostar accumulates more and more gas and dust, its density and temperature continue to rise. Eventually the temperature is so high that nuclear fusion can begin. A star is born.

c) Nuclear fusion is the process by which two nuclei of hydrogen join together to form heavier nuclei, such as helium, with the release of vast quantities of energy.

d) The outward force caused by nuclear fusion (sometimes called radiation pressure) is exactly balanced by the inward force due to gravity.

e) The hydrogen in the core of the star is used up in nuclear fusion. However, surrounding the core is a layer of hydrogen. Gravitational contraction provides enough energy for nuclear fusion of the hydrogen in this layer. The outward pressure from the nuclear fusion reactions prevents the star from collapsing and makes it expand to several hundred times its former size. The surface temperature falls and the starlight is now predominantly orange. We refer to the star as a red giant.

Within the red giant, other higher order nuclear reactions can take place. Helium, for example, can fuse to become carbon and oxygen. Close to the end of the life of a red giant, the gravitational force can no longer hold the outer layers of gas. These outer layers flow out, cool and surround the core to form a nebula. This nebula may eventually contribute to the creation of another star. Over time the core that remains cools to become a white dwarf. Eventually, all fusion stops, and the star cools to become a black dwarf.

f) If a star is more massive than the Sun it goes through a slightly different process when the hydrogen fusion process ends. The huge amount of energy from helium fusion pushes the outer layers of the star outwards and it turns into a red supergiant. Red supergiants are among the largest stars in the universe by volume.

g) At the end of their lives, red supergiants explode to create a supernova. After the supernova explosion, what is left of the star collapses further. Some red supergiants become neutron stars of enormous density.

h) If the mass of the supernova is sufficient, what remains after gravitational collapse may have even greater density than a neutron star. This is a black hole, so-called because its gravitational field is so great that not even light can escape from it.

Show you can (page 193)

a) Red shift is the increase in wavelength of radiation due to the movement of the source of radiation away from the observer.

b) Red shift tells us that neighbouring galaxies are moving away from us.

c) The lines in the solar absorption spectrum match the lines in the hydrogen absorption spectrum on Earth.

d) Cosmic Microwave Background Radiation represents the signature or “afterglow” of the Big Bang that occurred 14 billion years ago. It consists of microwave radiation coming from all parts of the observable universe.

e) Following the Big Bang there was a rapid expansion (inflation) and cooling of the universe, followed by the formation of neutrons and protons. Further expansion and cooling allowed nuclei to form. Eventually after further expansion and cooling, the temperature had dropped sufficiently for electrons to combine with neutrons and protons to form atoms of hydrogen.

f) Nuclear fusion is the joining together of two light hydrogen nuclei to create a heavier helium nucleus with the release of vast quantities of energy. It occurs naturally in stars.

g) 14 billion years (or more precisely, 13.8 billion years)

Practice questions (page 194)

1 a) Gravity (1 mark)

b) Hydrogen and helium (1 mark)

c) Observing stars shows that the line absorption spectra contain the same lines as the spectra of hydrogen and helium as observed on Earth. (1 mark)

d) Nuclear fusion (1 mark)

e) Helium (1 mark)

2 a) Protostar, main sequence star, red giant, white dwarf, black dwarf (2 marks)

b) The outward force caused by nuclear fusion (sometimes called radiation pressure) (1 mark)
is exactly balanced by the inward force due to gravity. (1 mark)

c) A red supergiant (1 mark)
becomes a supernova when it has completed fusion reactions and collapses inwards under its own gravity. (1 mark)

d) Black holes are so-called because their enormous gravitational force prevents even light from escaping. (1 mark)

3 a) Axes labeled as in the table, (1 mark)
both scales chosen to cover at least half available paper, (1 mark)
all points plotted to within a small square, (1 mark)
appropriate line of best fit drawn. (2 marks)

b) The graph is a straight line through the origin, (1 mark)
showing that recession speed is directly proportional to distance. (1 mark)

c) Gradient = $\frac{\text{change in recession speed}}{\text{change in distance}}$ (1 mark)

$= \frac{1610 - 450}{(7-2)\times 10^{20}}$ (1 mark)

$= 2.3 \times 10^{-18}$ /s (answer will depend on line of best fit and interval chosen) (1 mark)

d) From graph, when distance = 2.4×10^{20} m,

recession speed ≈ 550 m/s

= 550 × 3600 m/hour

= 1 980 000 m/hour

≈ 2000 km/h

OR

From gradient, v = gradient × distance

= $2.3 \times 10^{-18} \times 2.4 \times 10^{20}$ m/s

= 550 m/s

= 550 × 3600 m/hour

= 1 980 000 m/hour

≈ 2000 km/h (3 marks for either route)

4 Observations of planetary transits (1 mark)

reveal the passage of a planet crossing a star; (1 mark)

the intensity of light observed from the star 'dips' as a planet passes in front of the star. (1 mark)

5 The major difficulties are:

flight time – the distance is so great that the flight would last for many generations (1 mark)

engineering – our spacecraft are just too slow (1 mark)

logistics – it is not clear how the spacecraft could carry enough fuel, oxygen and water (1 mark)

communications – even at the speed of light, signals would take years to reach the Earth from the spacecraft, or from Earth to the spacecraft (1 mark)

6 When the hydrogen fusion process ends, a very massive main sequence star fuses helium at a very fast rate. (1 mark)

The huge amount of energy released causes the star to become a red supergiant. (1 mark)

After the fusion of helium, progressively heavier nuclei are formed up to iron. (1 mark)

At this point, the gravitational forces overcome the radiation pressure and the star collapses, then explodes as a supernova. (1 mark)

The remaining mass of the star finally contracts to become a neutron star or a black hole. (1 mark)

7 **a)** A light year is the distance (1 mark)

travelled by a beam of light in a year. (1 mark)

b) The light year is used by astrophysicists because cosmological distances are so very large that the distances used on Earth are much too small. (1 mark)

8 Distance = speed × time (1 mark)

= $3 \times 10^{8} \times 3600 \times 24 \times 365 \times 2.5 \times 10^{6}$ (1 mark)

= 2.37×10^{22} m (1 mark)

= 2.37×10^{19} km (1 mark)

9 Red shift is the increase in wavelength of radiation (1 mark)

due to the movement of the source away from the observer. (1 mark)

Red shift tells us that most galaxies we can observe are moving away from us. (1 mark)

If the distances between nearly all galaxies are increasing, then the whole universe must be expanding. (1 mark)

10

Event sequence	**Order**
Neutrons and protons are formed	**2**
Rapid expansion and cooling occurs	**1**
Further expansion and cooling occurs, allowing hydrogen atoms to form	**4**
More expansion and cooling occurs, allowing hydrogen nuclei to form	**3**

(3 marks)