Answers to Workbook

1A Measurement, motion, mass, weight and density

Core

1 **a** 20
b 4
c 120
d 500
e 1400

2 **a** 15.00 m
b 1.50 m
c 0.15 m
d 0.015 m

3 **a** 1×10^3
b 2.25×10^5
c 6.5×10^2
d 1.5×10^4

4 **a** 10 000
b 250
c 1 500 000
d 350 000 000

5 **a** 1×10^{-3}
b 2×10^{-2}
c 1.2×10^{-3}
d 1.02×10^{-2}

6 **a** **i** 1×10^{-2}
ii 0.01
b **i** 2×10^{-3}
ii 0.002
c **i** 3×10^{-4}
ii 0.0003
d **i** 8×10^{-4}
ii 0.0008

7 **a** 5×10^{-3} m

b 5×10^{-1} m

c 5×10^{3} m

8 **a** 3

b 2

c 3

9 **a** 1 m

b 1.3 m

c 1.26 m

10 27 cm^2 (do not accept 27.0 cm^2)

11 Area of triangle = $\frac{1}{2}$ × base × height = $\frac{1}{2}$ × 30 cm × 40 cm = 600 cm^2

12 Number of bricks = (15 cm × 15 cm × 10 cm) / (5 cm × 2 cm × 3 cm) = 75

13 32 s / 20 = 1.6 s

14 **a** B

b C

c Average speed = 1000 m / 200 s = 5 m/s

15 **a** **i** 270 m

ii No distance

iii 270 m

b 270 m / (3 × 60 s) = 1.5 m/s

16 **a** mg_{Earth} = 918 kg × 9.8 N/kg = 9.0×10^3 N

b mg_{Mars} = 918 kg × 3.9 N/kg = 3.6×10^3 N

17 **a** mg = 0.015 kg × 9.8 N/kg = 0.15 N

b mg = 0.051 kg × 9.8 N/kg = 0.50 N

c mg = 0.3 kg × 9.8 N/kg = 3 N

d mg = 3.1 kg × 9.8 N/kg = 30 N

18 **a** m = weight/g = 784 N / 9.8 N/kg = 80 kg

b Weight on Moon = mg_{Moon} = 80 kg × 1.6 m/s^2 = 128 N

19 C

20 $\rho = m/V$ = 7.36 g / (2.0 cm × 2.0 cm × 2.0 cm) = 0.92 g/cm^3 or 920 kg/m^3

21 **a** V = (75 − 50) cm^3 = 25 cm^3

b $\rho = m/V$ = 200 g / 25 cm^3 = 8 g/cm^3 = 8×10^3 kg/m^3

22 $m = \rho V$ = 1.3 kg/m^3 × (3 m × 4 m × 2.5 m) = 39 kg

Supplement

23 **a** $a = \Delta v/\Delta t$ = (8 − 0) m/s / 10 s = 0.8 m/s^2

b $\Delta t = \Delta v/a$ = (0 − 8) m/s / (−2 m/s^2) = 4 s

24 $\Delta v = a\,\Delta t$ = 1.5 m/s^2 × 4 s = 6 m/s

$v_2 = v_1 + a\,\Delta t$ = 6 m/s + 6 m/s = 12 m/s

25 **a** Average speed = $(v_1 + v_2) / 2$ = (8 m/s + 20 m/s) / 2 = 14 m/s

b Average speed = total distance travelled/total time taken,

so distance travelled = average speed × total time taken = 14 m/s × 60 s = 840 m

c $a = \Delta v/\Delta t$ = (20 m/s − 8 m/s) / 60 s = 0.2 m/s^2

26 **a** 3.0 m/s

b $a = \Delta v/\Delta t$ = 3.0 m/s / 20 s = 0.15 m/s^2

c Distance = average speed × total time taken (or area under graph in time interval AB)

= 3 m/s × 16 s = 48 m

d Distance = average speed × total time taken (or area under graph in time interval BC)

= (base × height of triangle)/2) = (3/2) m/s × 14 s = 21 m

27 **a** **i** $\Delta v = a\,\Delta t$ = 9.8 m/s^2 × 2 s = 20 m/s downwards

ii Distance = average speed × total time taken = (20/2) m/s × 2 s = 20 m

b Linear with gradient = 9.8 m/s^2

Exam-style questions

Core

1 **a** B: volume of liquid = 500 cm^3 ***[1]***

Volume of tank = 10 cm × 10 cm × 10 cm = 1000 cm^3 ***[1]***

Fraction of tank filled = 500 cm^3/1000 cm^3 = $\frac{1}{2}$ ***[1]***

b A: volume of brick = 4 cm × 3 cm × 5 cm = 60 cm^3 ***[1]***

= volume of liquid displaced = 10 cm × 10 cm × Δh ***[1]***

Δh = rise in liquid level = 60 cm^3 / 10 cm × 10 cm = 0.6 cm ***[1]***

c Thickness of 120 pages = thickness of book − thickness of each cover ***[1]***

= (8.2 mm − 2 × 0.5) mm = 7.2 mm ***[1]***

Thickness of 1 page = 7.2 mm / 120 = 0.06 mm ***[1]***

2 **a** **i** Increasing ***[1]***

ii Constant ***[1]***

b **i** Constant ***[1]***

ii Zero ***[1]***

c **i** Increasing ***[1]***

ii Constant ***[1]***

d OA (graph has greatest gradient) ***[1]***

Supplement

3 **a** $\rho = m/V$ ***[1]*** = 46 g / 50 cm^3 = 0.92 g/cm^3 ***[1]***

b Sink; ***[1]*** vinegar has a higher density than the oil ***[1]***

4 B ***[1]***

5 **a** $a = \Delta v_{OA}/\Delta t_{OA}$ ***[1]***

= 30 m/s / 200 s = 0.15 m/s^2 ***[1]***

b $a = \Delta v_{BC}/\Delta t_{BC}$ ***[1]***

= −30 m/s / 300 s = −0.1 m/s^2 ***[1]***

c Average speed = $(v_1 + v_2) / 2$ ***[1]*** = (30 m/s + 0 m/s) / 2 = 15 m/s ***[1]***

d Distance = average speed × total time taken (or area under slope)

= (base × height of triangle)/2) ***[1]*** = 30/2 m/s × 5 × 60 s = 4500 m = 4.5 km ***[1]***

e AB ***[1]***

1B Forces and momentum

Core

1 a Horizontal forces are equal; resultant force = 10 N − 5 N = 5 N downwards

b 5 N upwards

2 Force, rest, constant, straight

3 a mg = 80 kg × 9.8 m/s^2 = 784 N

b 784 N

c 784 N − 300 N = 484 N

d 784 N

4 a When ruler is balanced, $L \times X$ = 50 cm × W so X = 50 cm × W/L

X = 50 cm × $W/2W$ = 25 cm

b X = 50 cm × W/L = 50 cm × $W/5W$ = 10 cm

c X = 50 cm × W/L = 50 cm × $W/10W$ = 5 cm

5 Forces, equilibrium, sum, equals, direction, clockwise, point, moments, no, resultant

6 a (weight of board acts at its centre, i.e. 45 cm from hinge)

When board is level, anticlockwise moment = clockwise moment

so T × 90 cm = 6 N × 45 cm

and T = 6 N × 45 cm / 90 cm = 3 N

b When board is level, upward force = downward force so $F + T$ = 6 N

and F = 6 N − T = 6 N − 3 N = 3 N

7 Suspend card from one corner and use a plumb line to draw the vertical line on the card from the point of suspension; repeat with a different point of suspension.

The centre of gravity is located where the two lines intersect.

Supplement

8 Spring constant, $k = F/x = m_1g/x_1 = m_2g/x_2$ so $m_2 = m_1x_2/x_1$

so $M = m_1x_2/x_1$ = 0.5 kg × 15 cm / 10 cm = 0.75 kg

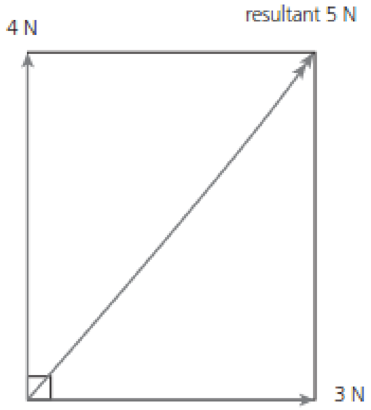
9 D; spring constant, $k = F/x = m_1g/x_1 = m_2g/x_2$ so $x_2 = m_2x_1/m_1$

extension = 0.3 kg × 3 cm/1.0 kg = 0.90 cm = 9.0 mm

10 Scalars have magnitude only, e.g. mass; vectors have magnitude and direction, e.g. force.

11 Magnitude of resultant $= \sqrt{(3\times3)+(4\times4)} = \sqrt{9+16} = \sqrt{25} = 5\,\text{N}$

tan $\theta = F_Y/F_X = 4/3 = 1.3$; direction of resultant $\theta = 53°$ to 3 N force



12 a i $F = F_1 - F_2$ = 100 N − 80 N = 20 N to the right

ii $F = ma$, so $a = F/m$ = 20 N/ 50 kg = 0.4 m/s^2

b i Forces are equal and opposite so resultant force F = 0 N

ii and acceleration = F/m = 0 m/s^2

13 $F = ma$ = 15 kg × 4 m/s^2 = 60 N

14 a Speed is a scalar and has magnitude only; velocity is a vector and has magnitude and direction.

b Tension in the string acts towards the centre of the circle, continuously changing the ball's direction and so its velocity.

c Along the tangent to the circle at its lowest point

15 a Momentum $p = mv$ = 5 kg × 3 m/s = 15 (kg m/s)

b mv = 5 kg × 40 m/s = 200 (kg m/s)

16 Total momentum before collision is (m × 5 m/s) + (m × 0 m/s) = 5m

Total momentum after collision is (m × 4 m/s) + (m × v) = 4m + mv

If momentum is conserved: 5m = 4m +mv, so v = (5m − 4m) / m = 1 m/s

17 a $p = mv$ = 50 ×10^{-3} kg × 20 m/s = 1 kg m/s

b Impulse = Δ(mv) = 1 kg m/s

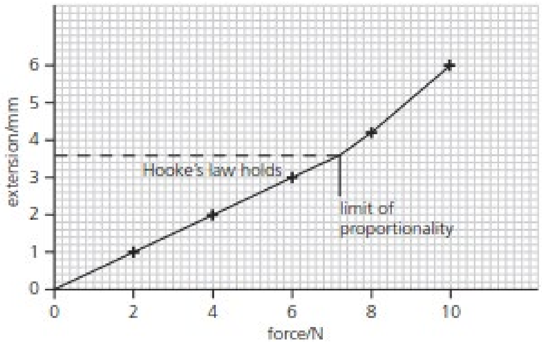
c $F = \Delta p/\Delta t$ = 1 kg m/s / 0.002 s = 500 N

Exam-style questions

Core

1 a Graph: axes labelled correctly ***[1]***; easy-to-read scales chosen and at least half of graph paper used ***[1]***; points clearly and correctly plotted to half a small square ***[1]***; well judged best-fit curve, thin continuous line joining all points. ***[1]***

b Linear region of graph correctly marked ***[1]***



c Gradient calculated by triangle method using at least half of linear portion of graph ***[1]***; gradient = rise/run = 2 × 10^3 N/m ***[1]***

Supplement

2 a Spring constant, $k = F/x = mg/x$ ***[1]*** = (2 kg × 10 N/kg) / (10 × 10^{-2}) m = 200 N/m ***[1]***

b Extension of spring, x = 30 cm − 20 cm = 10 cm ***[1]***
Spring constant, $k = F/x$ = 0.5 N / (10 × 10^{-2}) m = 5 N/m ***[1]***

c i extension, x = 40 cm − 20 cm = 20 cm ***[1]***

ii $F = kx$ = 5 N/m × 20 × 10^{-2} m = 1 N ***[1]***

3 a Taking moments about left hand support: 80 N × 3 m = Q × 5 m ***[1]***
Q = 240 N m / 5 m = 48 N ***[1]***

b $P + Q$ = 80 N ***[1]*** so P = 80 N − 48 N = 32 N ***[1]***

4 a $F = ma$, so $a = F/m$ ***[1]*** = 1350 N / (45 × 10^{-3}) kg = 30 000 m/s^2 ***[1]***

b $a = \Delta v/\Delta t$ so $\Delta v = a\,\Delta t$ ***[1]*** = 30000 m/s^2 × 0.001s = 30 m/s ***[1]***

c 1 Follow through longer to extend collision time ***[1]*** **2** strike harder ***[1]***

1C Energy, work, power and pressure

Core

1 a Mechanical work

b Electrical work

2 a Gravitational potential energy → kinetic energy

b Electrical energy → thermal energy

3 $W = Fd$ = 120 N × 500 m = 60 kJ

4 a $W = Fd$ = 150 N × (10 × 10^{-2} m) = 15 J

b $W = Fd$, so $d = W/F$ = 15 J / 750 N = 0.02 m (= 2 cm)

5 a It cannot be used up; two from: solar, wind, hydroelectric, tidal, geothermal

b It cannot be replaced once used; two from: coal, oil, gas, nuclear

6 a $W = Fd$ = 9000 N × 20 m = 1.8 × 10^5 J

b Power = W/t = 1.8 × 10^5 J / 15 s = 12 kW

7 a $p = F/A$= 40 N / 4.0 m^2 = 10 Pa

b $p = F/A$= 40 N / 0.5 m^2 = 80 Pa

c $p = F/A = 40\ \text{N} / 0.1\ \text{m}^2 = 400\ \text{Pa}$

d $p = F/A = 40\ \text{N} / 4.0\ \text{cm}^2 = 40\ \text{N} / (4.0 \times 10^{-4})\ \text{m}^2 = 1.0 \times 10^5\ \text{Pa}$

8 a $F = pA = 20\ \text{N/m}^2 \times 2\ \text{m}^2 = 40\ \text{N}$

b $F = pA = 20\ \text{N/m}^2 \times 1\ \text{m}^2 = 20\ \text{N}$

c $F = pA = 20\ \text{N/m}^2 \times 1 \times 10^{-4}\ \text{m}^2 = 2 \times 10^{-3}\ \text{N}$

d $F = pA = 20\ \text{N/m}^2 \times 0.1 \times 10^{-4}\ \text{m}^2 = 2 \times 10^{-4}\ \text{N}$

9 B; $p = F/A$ so larger contact area less pressure

10 a $p = F/A = 100\ \text{N} / (4.0 \times 10^{-4})\ \text{m}^2 = 2.5 \times 10^5\ \text{Pa}$

b i $F = pA = 2.5 \times 10^5\ \text{N/m}^2 \times 20 \times 10^{-4}\ \text{m}^2 = 500\ \text{N}$

ii 500 N

Supplement

11 a $E_k = \frac{1}{2}mv^2 = 5\ \text{kg} \times \frac{1}{2}(6\ \text{m/s})^2 = 90\ \text{J}$

b $E_k = \frac{1}{2}mv^2 = 5\ \text{kg} \times \frac{1}{2}(12\ \text{m/s})^2 = 360\ \text{J}$

12 a $\Delta E_P = mg\Delta h = 5\ \text{kg} \times 10\ \text{N/kg} \times 10\ \text{m} = 500\ \text{J}$

b $\Delta E_P = mg\Delta h = 5\ \text{kg} \times 10\ \text{N/kg} \times 25\ \text{m} = 1250\ \text{J}$

13 Rearranging $E_k = \frac{1}{2}mv^2$, gives $v = \sqrt{2E_k / m} = \sqrt{2 \times 2.7 \times 10^3\ \text{J} / 600\ \text{kg}} = 3\ \text{m/s}$

14 a i $E_P = mgh = 3\ \text{kg} \times 9.8\ \text{N/kg} \times 5.1\ \text{m} = 150\ \text{J}$

ii 150 J

iii Rearranging $E_k = \frac{1}{2}mv^2$, gives $v = \sqrt{2E_k / m} = \sqrt{2 \times 150\ \text{J} / 3\ \text{kg}} = 10\ \text{m/s}$

b Transferred to thermal energy and sound

15 $P = \Delta E/t = mg\Delta h/t = 2000\ \text{kg/s} \times 9.8\ \text{N/kg} \times 10\ \text{m} = 2.0 \times 10^5\ \text{W}$

90% efficient, so power generated $= 2.0 \times 10^5 \times 90/100 = 1.8 \times 10^5\ \text{W}$

16 a efficiency $= \dfrac{\text{useful power output}}{\text{total power output}} \times 100\% = (350\ \text{W}/500\ \text{W}) \times 100\% = 70\%$

b It is transferred to thermal energy

17 $\Delta p = \rho g \Delta h = 1.0 \times 10^3\ \text{kg/m}^3 \times 10\ \text{m/s}^2 \times 3.05\ \text{m} = 3.0 \times 10^4\ \text{Pa}$

Exam-style questions

Core

1 a $T = 600\ \text{N}/2 = 300\ \text{N}$ ***[1]***

b $W = Fd = 600\ \text{N} \times 1.5\ \text{m}$ ***[1]*** $= 900\ \text{J}$ ***[1]***

c $P = W/t = 900\ \text{J} / 3\ \text{s}$ ***[1]*** $= 300\ \text{W}$ ***[1]***

2 a i Renewable ***[1]*** clean ***[1]***

ii The Sun does not always shine ***[1]*** expensive to manufacture ***[1]***

b i High energy density ***[1]*** readily available ***[1]***

ii Radiation risks ***[1]*** safe disposal of radioactive waste required ***[1]***

c i Renewable ***[1]*** clean ***[1]***

ii Wind not always available ***[1]*** environmental objections ***[1]***

d **i** High energy density***[1]*** readily available ***[1]***

ii Non-renewable***[1]*** release carbon dioxide and sulfur dioxide into atmosphere ***[1]***

Supplement

3 **a** Gravitational potential energy ***[1]*** transferred to kinetic energy ***[1]*** and thermal energy (resulting from resistive forces) ***[1]***

b Distance travelled/s = 12 m ***[1]***

$E = W = Fd = 5\text{ N} \times 12\text{ m} = 60\text{ J}$ ***[1]***

c **i** 60 J/s = 60 W ***[1]***

ii $d = E/F = 60\text{ J} / 7.5\text{ N} = 8\text{ m}$ ***[1]***

$v = d/t = 8\text{ m/s}$ ***[1]***

4 **a** $E_k = \frac{1}{2}mv^2$ ***[1]*** $= 60 \times 10^{-3}\text{ kg} \times (30\text{ m/s})^2 / 2$ ***[1]*** = 27 J ***[1]***

b 0 J ***[1]***

c 27 J ***[1]***

d Rearrange $\Delta E_P = mg\Delta h$ to give $\Delta h = \Delta E_P/mg$ ***[1]*** $= 27\text{ J}/((60 \times 10^{-3})\text{ kg} \times 9.8\text{ N/kg}) = 46\text{ m}$ ***[1]***

2 Thermal physics

Core

1 **a** Gas

b Solid

c Gas

d liquid

e Solid

2 **a** Gas

b Solid

c Liquid

3 **a** Fast-moving air molecules collide with the smoke particles. A smoke particle is much more massive than an air molecule, but when there are more high-speed molecules striking one side of it than the other at a particular instant, a net force results and the smoke particle will move in the direction of the force. The imbalance and the resulting force cause the smoke particles to change direction rapidly in a random manner.

b They will move faster.

4 Very large numbers of fast-moving molecules rebounding from the walls of the container produce a force and hence a pressure on the walls.

5 **a** It increases.

b The air molecules move faster and so have more frequent and more violent collisions with the walls: the average force on the walls increases.

6 B

7 B

8 **a** 0°C

b 100°C

9 **a** $T = \theta + 273$

b $T = (30 + 273) = 303$ K

c $\theta = (T - 273) = (150 - 273) = -123$℃

10 **a** The temperature at which the substance changes from a solid to a liquid.

b The temperature at which the substance changes from a liquid to a vapour.

11 **a** C

b A

c E

d D

12 For example: melt the same amount of wax onto one end of each rod; place the rods on a tripod with the waxed ends separated and the other ends close together. Heat the unwaxed ends with a flame. The wax will begin to drip first from the metal rod because it is a good conductor and transfers thermal energy quickly.

13 Metal transfers thermal energy faster than plastic away from the hand, because it is a better conductor, so the metal feels colder.

14 C

15 D

16 **a** B

b C

17 Thermal, higher, lower, energy, temperature, fluid, radiation, electromagnetic

Supplement

18 **a** $p_1V_1 = p_2V_2$ so $V_2 = p_1V_1/p_2 = p_1 \times 200\ \text{cm}^3 / (p_1/2) = 400\ \text{cm}^3$

b $p_1V_1 = p_2V_2$ so $V_2 = p_1V_1/p_2 = p_1 \times 200\ \text{cm}^3 / (2p_1) = 100\ \text{cm}^3$

19 **a** $p_1V_1 = p_2V_2$ so $p_2 = p_1V_1/V_2 = 2 \times 10^5\ \text{Pa} \times V_1/2V_1 = 1 \times 10^5\ \text{Pa}$

b $p_1V_1 = p_2V_2$ so $p_2 = p_1V_1/V_2 = 2 \times 10^5\ \text{Pa} \times V_1/(V_1/2) = 4 \times 10^5\ \text{Pa}$

20 **a** A

b Energy required per unit mass per unit temperature increase

21 The wall is used to store energy; brick and concrete have high specific heat capacities.

22 Rearrange equation $c = \dfrac{\Delta E}{m\Delta\theta}$ to give the equation

$\Delta E = m\,c\,\Delta\theta = (70 \times 10^{-3})$ kg × 4000 J/kg ºC × 60ºC = 16 800 J

23 $c = \dfrac{\Delta E}{m\Delta\theta}$

$t = (9 \times 60 + 20)$ s = 560 s

$\Delta E = P\,t$ = 150 W × 560 s so c = 150 J/s × 560 s / (0.5 kg × (60 − 20)ºC) = 4200 J/(kg °C)

24 **a** B

b A

25 a Faster-moving particles escape from the surface of the liquid. This results in the average speed, and therefore the average kinetic energy of the remaining particles being lowered, so that the temperature of the liquid falls.

b Two from: large surface area, high temperature, draught/vacuum above liquid

26 a Block A; a black surface is a better emitter of radiation than a shiny one.

b i The shiny foil reflects the radiation back into the room.

ii The white colour reflects radiation.

Exam-style questions

Core

1 a i Temperature remains constant ***[1]***

ii Temperature remains constant ***[1]***

b i Increases ***[1]***

ii Decreases ***[1]***

c More energetic particles escape from the liquid surface. ***[1]*** This leads to the average kinetic energy of the liquid falling ***[1]*** and so the temperature of the liquid decreases. ***[1]***

2 a Three from: double-glazed windows, cavity walls, fur or fleece jackets, string vests, fibreglass roof insulation ***[3]***

b Transfer of thermal energy by convection is restricted. ***[1]***

Supplement

3 Insert an immersion heater of power P into the centre of a cylinder of metal and place a thermometer into another hole in the cylinder. Switch on the heater for a measured time, t. ***[1]*** Work out the energy supplied by heater, $P \times t$. ***[1]*** Record the temperature of the metal before the heater is switched on and the highest temperature reached by the metal just after the heater is switched off. ***[1]*** Work out the temperature rise of the metal, ΔT. ***[1]*** Measure the mass of the metal, m. ***[1]*** Equate energy supplied by heater to energy gained by metal, $Pt = mc\Delta T$. ***[1]*** Hence evaluate specific heat capacity, c. ***[1]*** Error in value obtained is due to loss of heat to the environment. ***[1]***

4 a Atoms in hot regions pass on their vigorous vibrations ***[1]*** to neighbouring atoms in colder regions. ***[1]*** Also, in metals, 'free' electrons move faster and further in the hot regions ***[1]*** and can transfer that energy to atoms in cooler regions very quickly***[1]***.

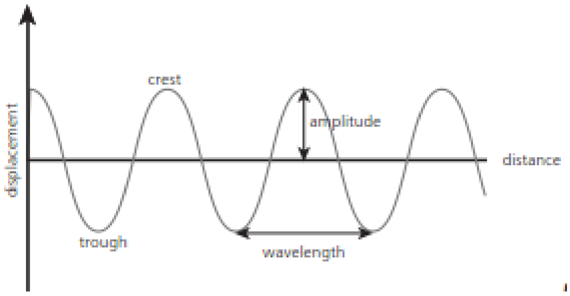
b There are no 'free' electrons available to move rapidly through the material, transferring energy. ***[1]***

3 Waves

Core

1 Vibrations are perpendicular to direction of travel for transverse wave, parallel to/in line with direction of travel for longitudinal wave.

2



Crest, trough**,** amplitude, and wavelength correctly labelled

3 f = number of wave crests passing a point per second = $1/T$ = 1/0.1 s = 10 Hz

4 T = 60 s / 72

$f = 1/T$ = 72 / 60 s^{-1} = 1.2 Hz

5 **a** 36 cm / 6 = 6 cm

b 5 Hz

c $v = f\lambda$ = 5 Hz × 6 cm = 30 cm/s

d Rearrange $v = s/t$ to give $t = s/v$ then t = 960 cm / 30 cm/s = 32 s

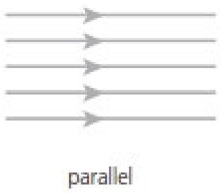
6 **a** No change

b Halved

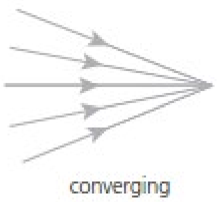
c The direction of travel bends towards normal to boundary.

7 Lines, direction, ray, beam, diverging, narrower, faster, before

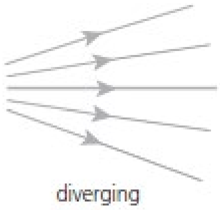
8 **a**



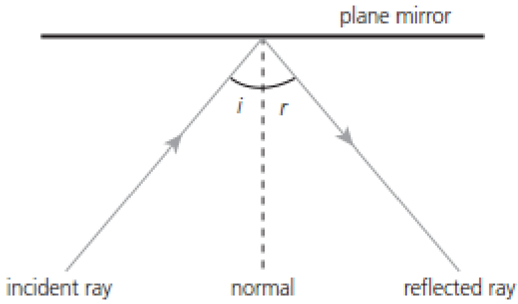
b



c



9 a



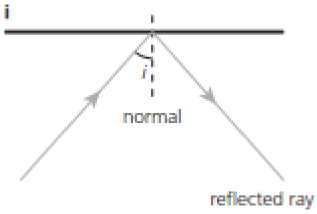
The plane mirror, the incident ray, the normal to the mirror, the reflected ray, the angle of incidence, *i*, and the angle of reflection, *r*, correctly labelled

b i 40°

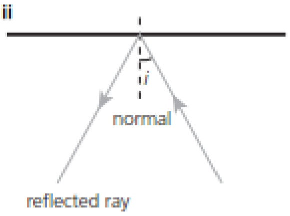
ii 40°

10 a, b, c

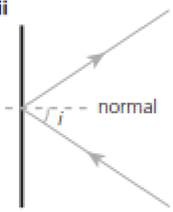
i



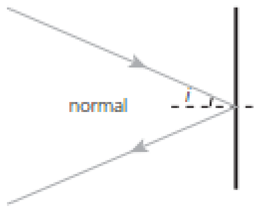
ii



iii

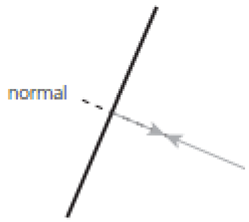


iv



v

vi

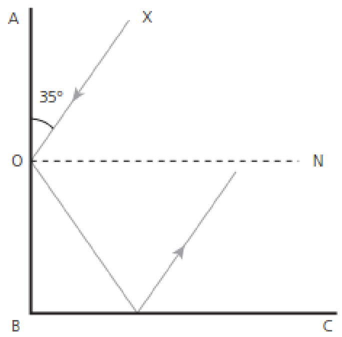


a Normal drawn correctly in: (i) and (ii), (iii) and (iv), (v) and (vi)

b Angle of incidence, *i*, drawn correctly in: (i) and (ii), (iii) and (iv), (v) and (vi)

c Reflected ray drawn correctly in: (i) and (ii), (iii) and (iv), (v) and (vi)

11 a



Ray reflected from AB and BC correctly drawn

b **i** 55°

ii 55°

iii 35°

iv 35°

c It is turned through 180° from the incident ray

12 B

13 A real image can be formed on a screen and the light rays pass through the image.

14 a 1 m

b 1 m

15 The ray is refracted towards the normal.

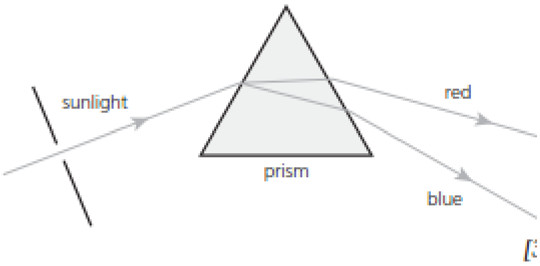
16 Towards, denser, away from, normal, optically, normally

17 B

18 **a** Dispersion occurs because the prism has different refractive indices for different colours of light.

b Red, orange, yellow, green, blue, indigo, violet

c



Dispersion in prism, red ray and blue ray correctly drawn

19 When light is incident on a boundary of lesser optical density at an angle of incidence greater than a critical angle, *c,* all of the light is reflected inside the denser medium.

20 Thin, two, parallel, focus, undeviated, centre, top, F, refracted, principal

21 D

22 Use the lens to focus an image of a distant object onto a piece of paper; the lens–image distance is equal to the focal length.

23 Parallel beam

24 **a** Four from: obey wave equation $v = f\lambda$; transverse; undergo reflection, refraction, diffraction; travel at 3×10^8 m/s in a vacuum

b **i** Infrared

ii Microwaves or infrared

iii X-rays

iv Infrared

v X-rays

vi Microwaves

25 **a** Radio

b X-rays

c X-rays

26 **a** Rearrange $v = f\lambda$ to give $\lambda = v/f = 3 \times 10^8$ m/s / 7.5×10^{14} Hz = 0.4 µm

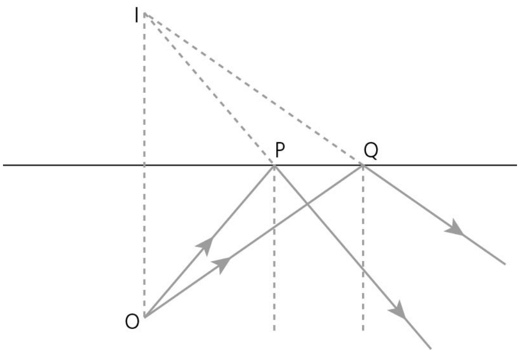
b Rearrange $v = f\lambda$ to give $\lambda = v/f = 3 \times 10^8$ m/s / 4.3×10^{14} Hz = 0.7 µm

27 **a** Risk: microwaves may harm living cells; precaution: use hands-free devices.

b Risk: X-rays can kill or damage living cells and cause cancer; precaution: protect by use of lead shielding

Supplement

28 a



Normals to mirror at P and Q, reflected rays at P and Q, extrapolated rays at P and Q correctly drawn, image position correctly located

b Virtual, upright, same size as object

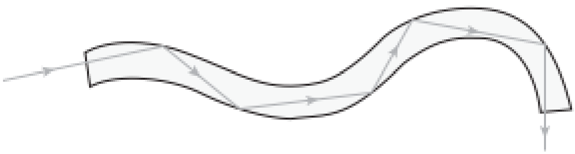
c The same distance behind mirror as the object is in front

29 a n = speed of light in air/speed of light in medium = c/v; rearrange to give

$v = c/n = 3 \times 10^8$ m/s / (3/2) = 2×10^8 m/s

b $v = c/n = 3 \times 10^8$ m/s / (4/3) = 2.25×10^8 m/s

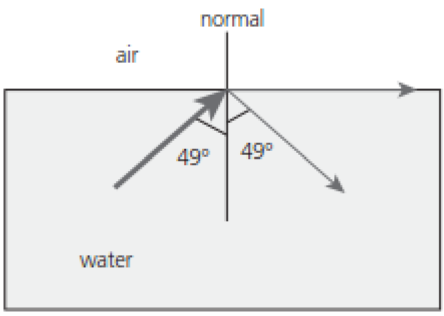
30 a



Path of ray shown for at least 3 reflections shown in fibre; ray shown exiting fibre

b Digital

31 a



Normal, incident and reflected rays drawn correctly at boundary

critical angle (49º) marked

b sin 49º = 0.7547

$n = 1/\sin c = 1/0.7547 = 1.33$

32 sin 52º = 0.7880

$n = 1/\sin c = 1/0.7880 = 1.27$

33 a B

b Light of one colour (or frequency)

34 **a** Rearrange $v = f\lambda$ to give $f = v/\lambda$ = 330 m/s / 20 × 10^{-2} m = 1650 Hz

b **i** 20–20 000 Hz

ii Greater than 20 kHz

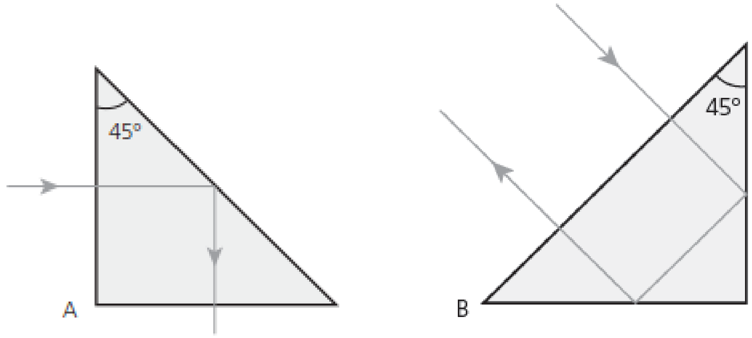
35 Rearrange $v = s/t$ to give $s = vt$ then s = 330 m/s × 8 s = 2640 m = 2.64 km

Exam-style questions

Core

1 A ***[1]***

2 **a**



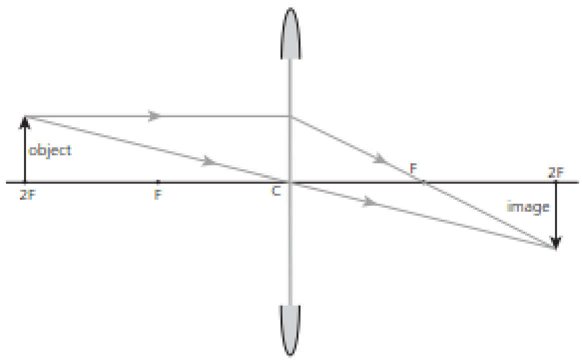
Prism A: reflection of ray at sloping surface ***[1]*** transmission of ray at exit ***[1]*** correctly drawn

Prism B: reflection of ray at vertical surface ***[1]*** reflection of ray at horizontal surface ***[1]*** transmission of ray at exit ***[1]*** correctly drawn.

b **i** A Periscope ***[1]***

ii B Binoculars ***[1]***

3 **a**



Principal foci (F) and optical centre (C) marked ***[1]*** construction rays ***[1]*** object ***[1]*** and image ***[1]*** correctly drawn

b 10 cm ***[1]***

c The same ***[1]***

4 **a** $v = s/t = 2d/t$ where d is the distance of ship from cliff ***[1]***

Rearranging equation gives $d = vt/2$ ***[1]*** = 330 m/s × 3 s /2 = 495 m ***[1]***

b Rearranging $v = 2d/t$ gives $t = 2d/v$ ***[1]***

$d = (495 - 165)$ m = 330 m ***[1]*** so $t = 2d/v = 2 \times 330$ m / 330 m/s = 2 s ***[1]***

5 **a** Rearranging $v = s/t$ gives $s = vt$ ***[1]*** = 330 m/s × 3 × 10^{-3}s = 0.99 m ***[1]***

b $v = s/t$ ***[1]*** = 0.9 m / (0.15 × 10^{-3}s) = 6000 m/s ***[1]***

c Use a digital timer to measure the time, *t*, that a sharp sound (e.g. a hammer blow on a metal plate) takes to travel between a 'start' and a 'stop' microphone. ***[1]*** Measure the distance between the microphones, *d*. ***[1]*** Repeat measurements of *t* several times and work out an average value. ***[1]*** Speed of sound = *d/t*. ***[1]***

6 **a** Longitudinal ***[1]***

b Transverse ***[1]***

c Transverse ***[1]***

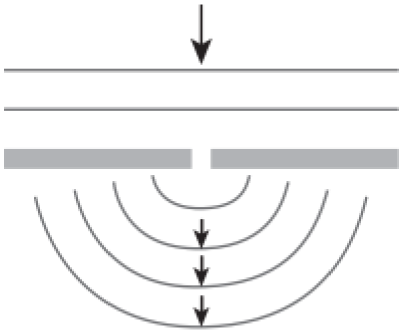
d Transverse ***[1]***

e Transverse ***[1]***

f Longitudinal ***[1]***

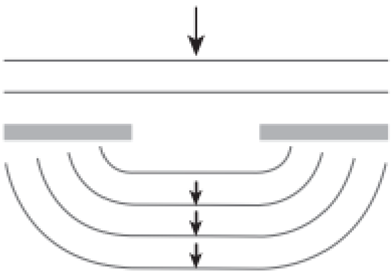
Supplement

1 **a**



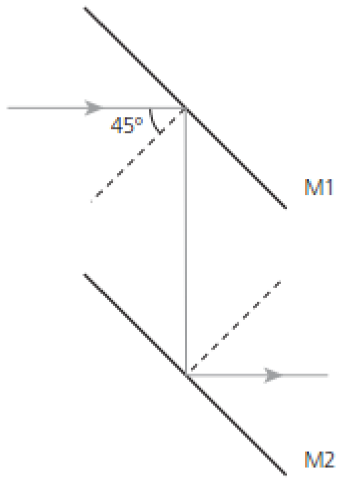
Curved waves ***[1]*** extending into region behind barrier ***[1]*** with same spacing as incident waves ***[1]***

b



Straight waves passing through gap ***[1]*** curving into region behind barrier ***[1]*** same spacing as incident waves ***[1]***

8 a



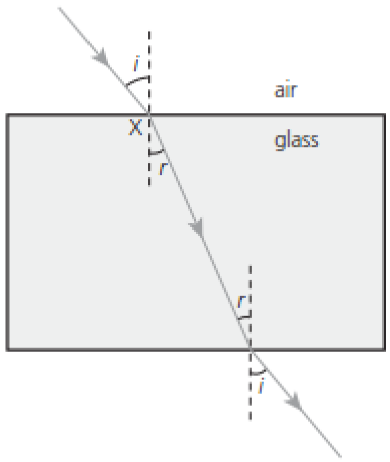
Reflected ray at M1 ***[1]*** normal at M2 ***[1]*** and reflected ray at M2 ***[1]*** drawn with incident and exit rays parallel ***[1]***

b **i** 45° ***[1]***

ii Periscope ***[1]***

iii It could be used to see over higher obstacles ***[1]***

9 a

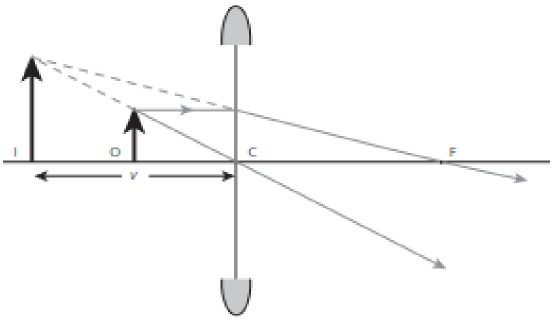


Normal at X, ***[1]*** ray through block, ***[1]*** *i*, ***[1]*** and *r* ***[1]*** marked correctly

b Exit ray is parallel to the ray entering the block ***[1]*** but is displaced sideways. ***[1]***

c $n = \sin i / \sin r$ ***[1]*** so $\sin r = \sin i / n$ ***[1]*** $= \sin 30°/1.5 = 0.3333$ ***[1]***; $r = \sin^{-1}(0.3333) = 19.5°$ ***[1]***

10 a



F and C marked ***[1]*** construction rays ***[1]*** back extrapolation ***[1]*** object ***[1]*** and image ***[1]*** correctly drawn

b 4 cm ***[1]***

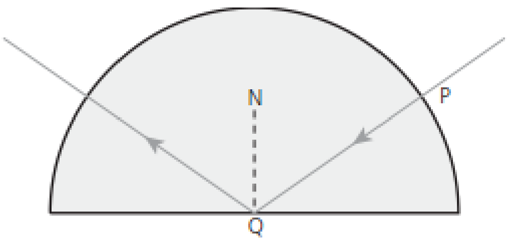
c Upright, enlarged, virtual ***[3]***

11 a The beam strikes the glass normally. ***[1]***

b Normal drawn correctly ***[1]*** $i = 55°$ ***[1]***

c $\sin c = \sin 90° / n = 1/n$ ***[1]*** = 1/1.5 = 0.6666 ***[1]***; $c = \sin^{-1}(0.6666) = 42°$ ***[1]***

d



Ray reflected from Q ***[1]*** and exiting glass normally ***[1]*** correctly drawn

12 a i Y ***[1]***

ii X ***[1]***

iii Y ***[1]***

b Molecules in the air vibrate back and forth in the direction of travel of the sound wave; ***[1]*** when the molecules are moving towards each other a compression (region of higher pressure) results; ***[1]*** when they are moving apart a rarefaction (region of lower pressure) occurs. ***[1]***

c i 0.85 m ***[1]***

ii Rearrange $v = f\lambda$ to give $f = v/\lambda$ ***[1]*** = 340 m/s / 0.85 m = 400 Hz ***[1]***

13 a $v = s/t = 2d/t$ where d is the depth of reflecting organ ***[1]***

Rearranging equation gives $d = vt/2$ ***[1]*** = 1400 m/s × (40 × 10^{-6})s / 2 ***[1]***

= 2.8 × 10^{-2} m (= 28 mm) ***[1]***

b speed = frequency × wavelength ***[1]***

c Rearrange $v = f\lambda$ to give $\lambda = v/f$ ***[1]*** = 1400 m/s / 10^6 Hz = 1.4 × 10^{-3} m (= 1.4 mm) ***[1]***

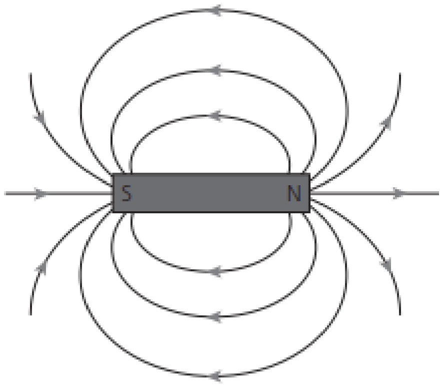
4A Electricity and magnetism

Core

1 Pole, south, repel, attract, soft, steel, permanent

2 **a** Using a plotting compass: lay bar magnet on a piece of paper and place plotting compass near the N pole. Mark the position of the N and S poles of the compass on the paper; then move the compass so that the S pole is at the point where the N pole was previously and mark the new position of the N pole. Continue until compass is near S pole then join up the points to give a field line. Plot other field lines by repeating the process with the compass at different starting points.

b



Field lines correctly shaped, N and S poles marked, arrows showing direction of field correctly

3 B, D

4 Two from: stroking with another magnet, hammering in a magnetic field, inserting in a solenoid and increasing d.c. current through the solenoid

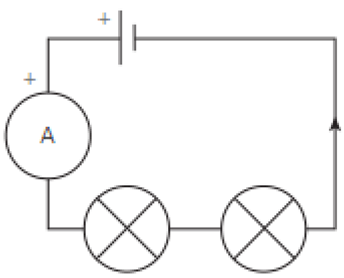
5 **a** Repel

b Repel

c Attract

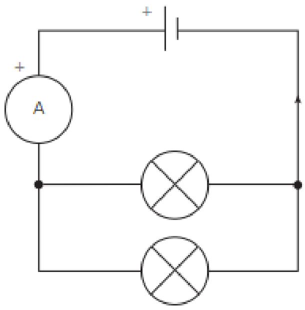
6 Electrons are transferred from the Perspex to the cloth, leaving the Perspex positively charged .

7 **a**



Correct symbols used for: battery, ammeter and two lamps
lamps connected in series, current direction marked correctly with arrow

b



Correct symbols used for: battery, ammeter and two lamps

lamps connected in parallel, current direction marked correctly with arrow

8 With a.c. the direction in which current flows reverses regularly;
with d.c. the current flows in one direction only.

9 **a** It is dimmer.

b It has the same (full) brightness.

c It is dimmer.

10 **a** potential difference = current × resistance

b Connect a battery, ammeter, variable resistor and the wire whose resistance is to be measured, in series. Connect a voltmeter across the wire. Measure V and I with different settings of the variable resistor. Evaluate the resistance of the wire $R = V/I$ for each setting.

11 Rearrange $R = V/I$ to give $V = IR$ = 0.3 A × 4 Ω = 1.2 V

12 $R = V/I$ = 12 V/2 A = 6 Ω

13 Rearrange $R = V/I$ to give $I = V/R$ = 1.5 V / 5 Ω = 0.3 A

14 **a** $R = R_1 + R_2$ = 6 Ω + 9 Ω = 15 Ω

b Rearrange $R = V/I$ to give $I = V/R$ = 1.5 V / 15 Ω = 0.1 A

c Rearrange $R_1 = V_1/I$ to give $V_1 = IR_1$ = 0.1 A × 6 Ω = 0.6 V

d $V_2 = IR_2$ = 0.1 A × 9 Ω = 0.9 V

15 C

16 C

17 **a** $P = IV$ = 10 A × 240 V = 2400 W (= 2.4 kW)

b $E = IVt = Pt$ = 2400 W × 40 × 60 s = 5.76 ×10^6 J (5760 kJ or 1.6 kWh)

c 16 cents

18 $P = IV$ so $I = P/V$ = 600 W / 240 V = 2.5 A
Use a 3 A fuse

19 C; $P = IV$ so $I = P/V$;
I_1 = 1500 W/240 V = 6.25A, I_2 = 1000 W / 240 V = 4.17 A,
I_3 = 500 W/240 V = 2.08 A and I_4 = 300 W / 240 V = 1.25A
$I_1 + I_2 + I_3 + I_4$ = 6.25 + 4.17 + 2.08 + 1.25 = 13.75 A
So only 3 appliances can be connected at once

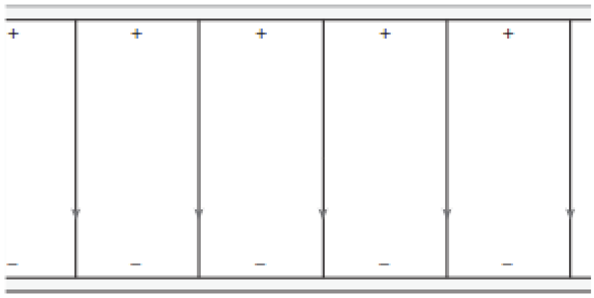
Supplement

20 a Some electrons can move easily from atom to atom and can be considered to be 'free' electrons.

b All electrons are firmly bound to atoms and there are no 'free' electrons available to produce a current.

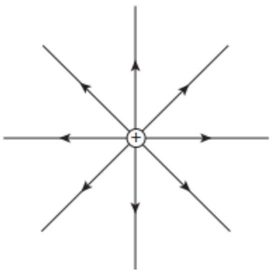
21 D

22 a



Parallel plates with opposite charges perpendicular field lines, direction of field marked correctly

b



Positive point charge radiating field lines, direction of field marked correctly

23 a Rearrange $I = Q/t$ to give $Q = It$ = 5 A × 4 s = 20 C

b $Q = It$ = 5 A × 2 × 60 s = 600 C

24 a $I = Q/t$ = 30 C / 15 s = 2 A

b $I = Q/t$ = 60 C / 60 s = 1 A

25 C

26 a B

b i $V_1/V_2 = R_1/R_2 = 5/15 = \frac{1}{3}$

$V = V_1 + V_2 = 10$ V so $V_1 = 10 \text{ V} \times \frac{1}{4} = 2.5$ V

ii $V_2 = 10 \text{ V} \times \frac{3}{4} = 7.5$ V

27 a $E = IVt = QV$ = 0.5 C × 6 V = 3 J

b $E = IVt$ = 3 A × 6 V × 20 s = 360 J

28 a $E = IVt = QV$ so $Q = E/V$ = 48 J / 12 V = 4 C

b $I = Q/t$ = 4 C / 10 s = 0.4 A

29 **a** Connect four cells in series

b $E = IVt = QV = 2\ \text{C} \times 6\ \text{V} = 12\ \text{J}$

30- **a** coulomb C

b ampere A

c volt V

d volt V

e ohm Ω

31 **a** Resistors in parallel: $1/R = 1/R_1 + 1/R_2 = 1/4 + 1/12 = 4/12\ \Omega^{-1}$

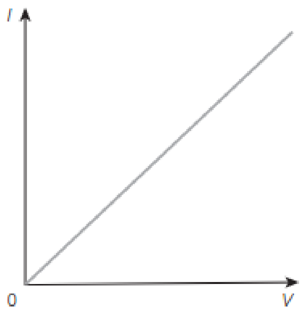
so $R = 12/4 = 3\ \Omega$

b Rearrange $R = V/I$ to give $I = V/R = 6\ \text{V} / 3\ \Omega = 2\ \text{A}$

c $I_1 = V/R_1 = 6\ \text{V} / 4\ \Omega = 1.5\ \text{A}$

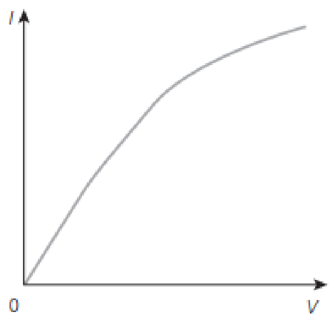
d $I_2 = V/R_2 = 6\ \text{V} / 12\ \Omega = 0.5\ \text{A}$

32 **a**



Axes labelled, straight line with positive gradient through origin

b



Axes labelled, straight line curving at high current with decreasing gradient

33 **a** High resistance when p.d. applied in one direction (reverse bias); low resistance when p.d. applied in the opposite direction (forward bias)

b Resistance increases as lamp heats up.

34 **a** Doubled

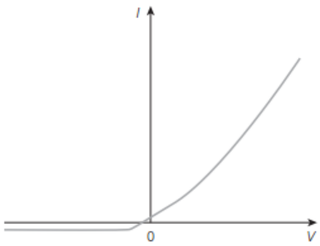
b Halved

c Doubled

d Halved

35 B

36



Axes labelled, very low current for negative voltages / increasing current for positive voltages

37 Analogue voltages vary continuously; digital voltages have discrete values, for example, high or low .

38 **a** Two from: LDR, thermistor, microphone, pressure switch

b Two from: lamp, LED, loudspeaker, relay, motor, heater

39 **a** **i** Increases

ii Switches on

iii Lamp lights

b As a light-operated intruder alarm

Exam-style questions

Core

1 **a** No damaged insulation, exposed wires, loose connections or short circuits ***[1]***; plug correctly wired ***[1]***

b Water lowers the resistance of the path to earth ***[1]*** so the current increases. ***[1]***

c The current through wire ***[1]*** is too high. ***[1]***

d It ensures the current-carrying capacity of the wiring ***[1]*** is not exceeded. (The fuse melts and breaks the circuit if the current becomes greater than the fuse rating.) ***[1]***

Supplement

2 **a** All at same brightness because they have the same voltage across them; ***[1]*** if one lamp fails, the rest remain lit. ***[1]***

b **i** $R = V/I$ *so* $I = V/R$ ***[1]*** = 24 V / 80 Ω = 0.3 A ***[1]***

ii I_{total} = 20 × 0.3 A ***[1]*** = 6.0 A ***[1]***

iii I_{drawn} = 6.0 A − 0.3 A ***[1]*** = 5.7 A ***[1]***

3 **a** **i** R_{total} = 18 Ω + 12 Ω = 30 Ω ***[1]***

$R = V/I$ so $I = V/R$ = 9 V / 30 Ω = 0.3 A ***[1]***

ii $V_1/V_2 = R_1/R_2$ = 18/12 = 3/2 ***[1]***

$V = V_1 + V_2$ = 9 V ***[1]*** so V_1 = 9 V × 3/5 = 5.4 V ***[1]***

iii V_2 = 9 V × 2/5 = 3.6 V ***[1]***

b **i** R_{total} = 33 Ω + 12 Ω = 45 Ω ***[1]***

$R = V/I$ so $I = V/R$ = 9 V / 45 Ω = 0.2 A ***[1]***

ii $V_1/V_2 = R_1/R_2$ = 33/12 = 11/4 ***[1]***

$V = V_1 + V_2$ = 9 V ***[1]*** so V_1 = 9 V × 11/15 = 6.6 V ***[1]***

iii $V_2 = 9\text{ V} \times 4/15 = 2.4\text{ V}$ ***[1]***

c Increases ***[1]***

4 **a** **i** Increases ***[1]***

ii Increases ***[1]***

iii Decreases ***[1]***

b $V = V_{LDR} + V_R = 6\text{ V}$ ***[1]***

so when $V_{LDR} = 3.5\text{ V}$, $V_R = (6 - 3.5)V = 2.5\text{ V}$ ***[1]***

For a potential divider, $V_1/V_2 = R_1/R_2$ so $V_{LDR}/V_R = R_{LDR}/R$

Rearranging gives $R_{LDR} = V_{LDR} \times R/V_R$ ***[1]*** $= 3.5\text{ V} \times 10\ \Omega / 2.5\text{ V} = 14\ \Omega$ ***[1]***

4B Electromagnetic effects

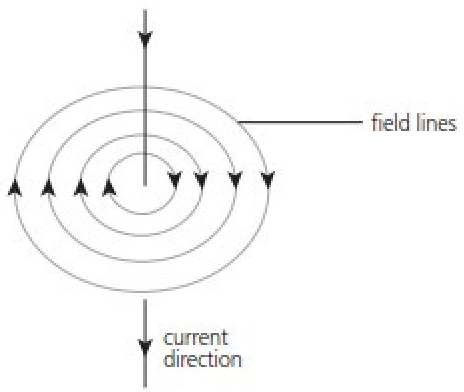
Core

1 B

2 Use a larger current, more turns on solenoid

3 Speed of rotation of the coil, number of turns on the coil, strength of the magnetic field

4



Circular field lines around wire, field direction and current direction marked correctly

5 **a** Upwards

b Upwards

6 a.c. voltages can be stepped up and down easily using transformers

7 C

8 **a** Rearrange $V_p/V_s = N_p/N_s$ to give $V_s = V_p \times N_s / N_p = 240\text{ V} \times 30/600 = 12\text{ V}$

b Step-down

Supplement

9 **a** It does not move

b It swings to right

c It swings further to left

d It swings to right

10 Current flows to the right

11 **a** N

b S

c N

12 a $P = IV$ so $I = P/V$ = 80 000 W / 400 000 V = 0.2 A

b Energy loss = I^2R = 0.2 A × 0.2 A × 15 Ω = 0.6 J/s

13 a i B

ii Reverse current direction

iii Left

b i Inside solenoid

ii Outside solenoid

14 a Rearrange $I_pV_p = I_sV_s$ to give $I_s = I_pV_p / V_s$ = 0.15 A × 240 V / 12 V = 3.0 A

b 90% efficiency gives I_s = 3.0 A× 90/100 = 2.7 A

15 Upwards (towards the positive plate)

16 Upwards

Exam-style questions

Core

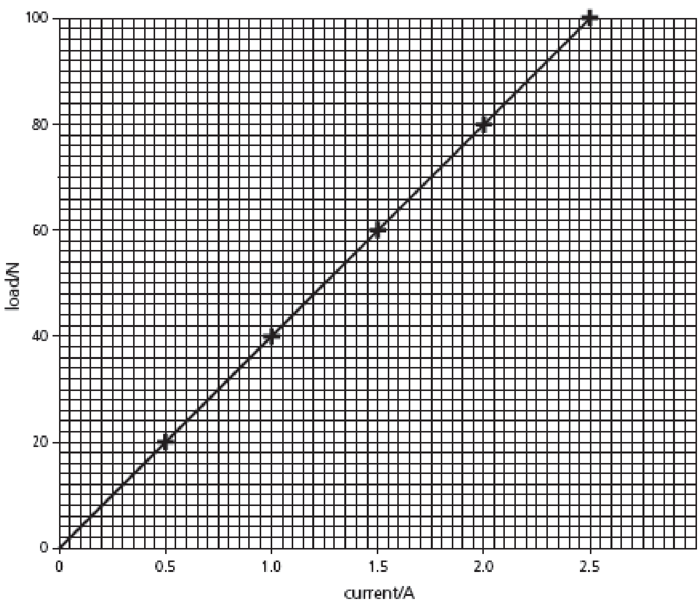
1 a The current through the coil reaching the 'pull-on' value. ***[1]***

b It becomes magnetised by current in coil ***[1]*** and attracts the iron armature. ***[1]***

c Contact is made at X ***[1]*** allowing current to flow in circuit PQ. ***[1]***

d It is used to control power in a second circuit; ***[1]*** especially useful if second circuit requires a larger current. ***[1]***

2 a Graph: axes labelled correctly ***[1]***; easy-to-read scales chosen and at least half of graph paper used ***[1]***; points clearly and correctly plotted to half a small square ***[1]***; well judged, best-fit, thin continuous line joining all points ***[1]***



b Linear/straight line, through origin ***[1]***

c 0.75 A ***[1]***

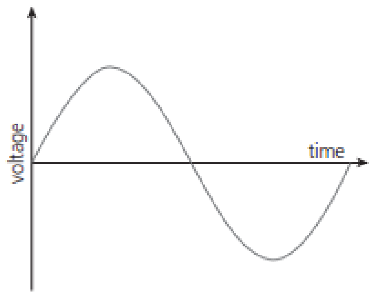
d 50 N ***[1]***

e Q could lift a heavier load with a given current. ***[1]***

Supplement

3 a They maintain contact with the brushes as the coil rotates. ***[1]***

b



Axes labelled correctly ***[1]***, one cycle ***[1]*** of sine wave sketched ***[1]***

c Horizontal ***[1]***

d a.c. ***[1]***

4 a It causes the coil to turn ***[1]***

b Increase current in coil ***[1]***; increase number of turns on coil ***[1]***; increase strength of magnet ***[1]***

c The coil would turn faster. ***[1]***

d It causes a change of direction of the current in the coil every half-turn ***[1]*** so that the direction of the couple on the coil stays constant ***[1]***.

5 a Rearrange $V_p/V_s = N_p/N_s$ to give $N_s = V_s \times N_p/V_p$ ***[1]*** = 1000 V × 100/250 ***[1]*** = 400 ***[1]***

b $P = IV$ ***[1]*** = 0.8 A × 250 V = 200 W ***[1]***

c Rearrange $I_pV_p = I_sV_s$ to give $I_s = I_pV_p/V_s$ ***[1]*** = 0.8 A × 250 V / 1000 V ***[1]*** = 0.2 A ***[1]***

d It reduces the efficiency. ***[1]***

5 Nuclear physics

Core

1 G

2 a $A = Z + N$

b Z

c i ${}^{4}_{2}\text{He}$

ii ${}^{0}_{-1}\text{e}$

iii ${}^{1}_{0}\text{n}$

3 Nuclides that have the same proton number (Z) but different nucleon numbers (A)

4 a 14

b i 6

ii 6

iii 6

c Yes

5 **a** α-particles

b γ-rays

c γ-rays

d α-particles

e β-particles

f α-particles

6 **a** +1

b 0

c +2

d −1

e 0

f +2

7 **a** β-particles

b α-particles

c γ-rays

d β-particles

e γ-rays

f α-particles

g β-particles

8 **a** Electrons are removed from atoms/molecules; leaving behind positive ions

b Using a Geiger counter/GM tube or a charged electroscope

9 B

10 **a** Average time for half the nuclei in a sample to decay

b Radiation from the environment with example from cosmic rays, radioactive sources in the air (radon gas) and rocks around us, food and drink

11 Number of counts has fallen by half, so age is one half-life: 5700 years

Supplement

12 Downwards

13 **a** **i** Decreases

ii Increases

b β; the radiation will pass easily through the paper and be readily detected by a Geiger counter

14 Most of the incident α-particles passed straight through while some were deflected through an large angle and a few particles completely rebounded.

15 **a** **i** 131

ii 54

b 131 − 53 = 78

c 77

Exam-style questions

Core

1 **a** Two from: damage living cells and tissues leading to cancer; eye cataracts; radiation burns/sickness; death; cause gene mutation ***[2]***

b Two from: radioactive tracers in medicine or agriculture; thickness testing and flaw detection in industry; dating of materials; sterilization; radiotherapy; smoke detectors ***[2]***

c Two from: use lead or concrete shielding; handle sources with long forceps/remotely; keep away from the eyes; keep in lead boxes ***[2]***

Supplement

2 **a** The break-up of a large nucleus ***[1]*** into two smaller nuclei of nearly equal size ***[1]***

b **i** $A = 235 + 1 - 90 - 1 - 1$ ***[1]*** $= 144$ ***[1]***

ii $Z = 92 + 0 - 56 - 0 - 0$ ***[1]*** $= 36$ ***[1]***

c **i** Kinetic energy of emitted particles ***[1]***

ii Heats water to produce steam, which then drives a generator ***[1]***

3 **a** The union of two light nuclei ***[1]*** into one heavier nucleus ***[1]***

b **i** $A = 3 + 3 - 1 - 1$ ***[1]*** $= 4$ ***[1]***

ii $Z = 2 + 2 - 2 - 1$ ***[1]*** $= 1$ ***[1]***

c **i** He ***[1]***

ii H ***[1]***

d Electromagnetic radiation ***[1]***

4 **a** **i** $A = 241 - 237$ ***[1]*** $= 4$ ***[1]***

ii $Z = 95 - 93$ ***[1]*** $= 2$ ***[1]***

b α-particle ***[1]***

c It causes ionisation of the air ***[1]***

6 Space physics

Core

1 **C**

2 **B**

3 **a** The Earth orbits the Sun once in every 365 days; the Earth is tilted on its axis

b The northern hemisphere is tilted away from the Sun and the southern hemisphere is tilted towards the Sun

4 C

5 B

6 **a** C

b A

c D

d B

Supplement

7 **B**

8 **a** The orbital speed of Mercury is greater than that of the Earth and the circumference of its orbit is less, because it is nearer the Sun

b Mars is further from the Sun than the Earth and it does not have much atmosphere

c The mass, and hence the gravitational field of the Earth, is too low to be able to retain a light gas such as hydrogen.

9 T = distance/speed = $2 \times \pi \times 108 \times 10^6$ km / 35 km/s = 19.4×10^6 s

= 19.4×10^6 s / $60 \times 60 \times 24$ = 224 days

10 Stars are formed when a cloud of hydrogen collapses under gravitational attraction to form a protostar. As the mass of the protostar increases it becomes hotter, and when the core is hot enough nuclear fusion of hydrogen into helium begins. The protostar turns into a stable star when the inward force of gravity is balanced by outward force arising from the high temperature of the star.

11 Energy, fusion, collapse, expand, temperature, carbon, planetary, dwarf

12 High mass star → red giant → supernova → neutron star OR black hole

13 A planetary nebula, B white dwarf, C supernova , D neutron star, E black hole

14 **B**

15 **1** Cosmic microwave background radiation (CMBR)

2 Redshift in the light from distant galaxies shows the speed of recession increases with distance

16 $H_o = v/d$ so $d = v/H_o$ = 350 km/s / (2.2×10^{-18} s^{-1}) = 160×10^{18} km

= 160×10^{18} km / (10^{13} km/light year) = 16 million light years

17 1100 million light years = $1100 \times 10^6 \times 10^{13}$ km = 1.1×10^{22} km

$H_o = v/d$ = 24 000 km/s / (1.1×10^{22} km) = 2.2×10^{-18} s^{-1}

Exam-style questions

Core

1 **a** Because the Earth rotates ***[1]*** on its axis every 24 hours ***[1]***

b At noon, ***[1]*** on or about 21 June ***[1]***.

2 **a** The high temperature of the star ***[1]*** causes hydrogen gas in its surface layers to glow. ***[1]***

b It is redshifted (its wavelength increases) ***[1]*** in comparison with light from glowing hydrogen on Earth ***[1]***

c Measurement of the redshift of light from distant galaxies ***[1]*** shows that the further away a galaxy is ***[1]*** the greater is the redshift ***[1]*** and so the faster the galaxy is receding. ***[1]***

Supplement

3 **a** A protostar is formed from the gravitational collapse of interstellar clouds of gas and dust containing hydrogen. ***[1]***

b A star is powered by the release of energy during the nuclear fusion ***[1]*** of hydrogen into helium. ***[1]***

c When most of the hydrogen in the core is used up. ***[1]***

d When the star becomes unstable, the inward force of gravity is sufficient to cause the core to collapse. ***[1]*** The outer layers of gas expand and cool, ***[1]*** and the star becomes a red giant. ***[1]***

4 a $v = 2\pi r / T$ ***[1]***

so $v_N/v_E = (2\pi r_N/T_N) / (2\pi r_E/T_E)$ ***[1]*** $= (r_N \times T_E) / (r_E \times T_N)$ ***[1]*** = 30/165 = 0.18 ***[1]***

b Slower ***[1]***

5 a Light from glowing hydrogen and other gases in stars in distant galaxies ***[1]*** have a longer wavelength than they do on Earth, ***[1]*** that is, they are shifted towards the red end of the electromagnetic spectrum. ***[1]***

b $v = H_o d$ ***[1]*** where v is the speed of recession of a galaxy a distance d away and H_o is Hubble's constant ***[1]***

6 a $d = v/H_o$ ***[1]*** = 60000 km/s / $(2.2 \times 10^{-18}\ s^{-1})$ ***[1]*** $= 2.7 \times 10^{22}$ km ***[1]***

b $d = 2.7 \times 10^{22}$ km / (10^{13} km/light year) ***[1]*** $= 2.7 \times 10^{9}$ light years

Time to reach Earth $= 2.7 \times 10^{9}$ years ***[1]***

c Time $= d/v = 2.7 \times 10^{22}$ km / 60000 km/s ***[1]*** $= 43 \times 10^{16}$ s ***[1]***

Since 1 year = 365 × 24 × 60 × 60 s $= 3.2 \times 10^{7}$ s ***[1]***

Time $= 43 \times 10^{16} / 3.2 \times 10^{7}$ years ***[1]*** $= 14 \times 10^{9}$ years ***[1]***

d It is the approximate age of the universe. ***[1]***