b i bar chart
pie chart
One variable categoric; one variable discrete; can calculate percentage of total number at each speed. (5)
ii Time needs to be long enough to give a large sample ideally a morning/afternoon/day; a bar chart would need 'the number of vehicles per ....' (2)

4 a i acceleration
ii speed
iii velocity–time (3)
b X starts after Y (0.4 s); X completes race in a shorter time (X 9.6 s – Y 10.8 s); X wins the race; gradients of both graphs increase throughout; both X and Y accelerate throughout; X's acceleration > Y's; 100 m race (6)

2 Resultant forces

2.1

1 a The car decelerates
b The gravitational force (i.e. your weight), the support force on you from the cushion.
2 a i 50 N upwards ii 200 N
b i equal, opposite
ii downwards, upwards
iii upwards
3 a 500 N downwards
b 500 N upwards
c 500 N upwards

2.2

1 a The glider decelerates and stops. Without the air blower on, the glider is in contact with the track and friction acts on it so its velocity decreases to zero and it stops.
b They are equal and opposite.
2 a It is in the opposite direction to the velocity.
b It is zero.
3 a The force of the mud on the car is greater than the force on the car from the tractor.
b 50 N

2.3

1 a 10 N to the left.
b 50 N vertically upwards.
c 500 N up the slope.
2 a 5.0 N
b 6.1 N
c 6.5 N
3 5400 N (to 2 s.f.)

2.4

1 a 640 N
b 4.0 m/s^2
2 a 16 N
b 40 kg
c 12 m/s^2
d 2.4 N
e 25 000 kg
3 a 3000 N
b i 600 N
ii 2400 N

Answers to end of chapter summary questions

1 a i 1.6 N vertically downwards.
ii 1.6 N
b i 0.4 N vertically downwards.
ii 0.4 N vertically upwards.
2 a i It is zero.
ii The upthrust acting on the balloon is equal to the sum of the gravitational force on the balloon and the downward pull of the thread on the balloon. The upthrust is therefore greater than the gravitational force on the balloon.
b The balloon would move upwards because there is no downward pull on it from the thread. The upthrust is greater than the gravitational force on the balloon so the resultant force on the balloon is vertically upwards.
3 a increases, stays the same
b decreases
c stays the same
4 a 960 N
b i 1.1 m/s^2
ii 77 N
5 a i 7200 N
ii 0
b 13 300 N
6 b 9.57 kN

Answers to end of chapter examination-style questions

1 a acceleration; force; velocity (3)
b Acceleration is rate of change of velocity; velocity is a vector quantity – it has direction; train is changing direction; so although at constant speed, it is accelerating. (4)
c The tension in the towrope is the resultant force; it is the diagonal in a scaled parallelogram drawing; the component (part) of the force along the river will be longer (force larger) when the diagonal is longer. (3)
2 a 1600 N
b Resultant force is 4000 – 1600 = 2400 N
Acceleration = F/m = 2400/1200 = 2 m/s^2
(1 mark for answer; 1 mark for correct unit) (4)
c Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. As speed increases, so does force A; resultant force is less; acceleration is reduced; speed still increases but at a reducing rate; eventually, force A = 4000 N; resultant force then zero; acceleration is zero; speed then remains constant. (6)
d As fuel is used the mass of the car becomes less; for the same force, the acceleration is greater; average velocity will be higher; so the time taken for one lap will be less. (4)
3 a i To the right. (1)
ii To the left. (1)
b The force on Y causes it to move; its acceleration is 800/200; acceleration is 4 m/s^2; the force on X causes it to slow down; its deceleration is 800/1200; deceleration is 0.67 m/s^2. (6)
4 a Choose a scale for the force diagram; draw a line 100 units long; construct an angle of 30° to the line; draw a second line, at this angle, 100 units long; complete the parallelogram; measure the length of the diagonal; convert to size of force using the scale; measure the angle of the diagonal from one of the force vectors. (6)
b He would need to make the angle between his rope and the other rope larger; so that the diagonal of the force parallelogram is still in the same direction. (2)

3 Momentum and force

3.1

1 a Momentum = mass × velocity, kg m/s.
b 240 kg m/s
c 0.48 m/s
2 a 400 kg m/s
b 0.5 m/s
c 1000 m/s
3 a 5000 kg m/s
b 2.0 m/s

3.2

1 a They exert equal and opposite forces on each other.
b They have equal and opposite momentum just after they separate.
c Just after they separate, the velocity of the 80 kg skater is three-quarters the velocity of the 60 kg skater and in the opposite direction.
d Their total momentum is zero just after they separate.
2 a 120 kg m/s
b 1.5 m/s
3 a 25 m/s
b It would have been less.

3.3

1 a The seat belt increases the time taken to stop the person so the change of momentum per second is less, and therefore the force on the person is less.
b –7200 N
2 a i 4000 N
ii 800 N
b Force = change of momentum divided by time taken. The change of momentum would be the same but the time taken would be much less. So the force would be much greater.
3 a Initial momentum = 2000 kg × 12 m/s = 24 000 kg m/s = final momentum. This is equal to the total mass × the velocity after impact which is therefore equal to 24 000 kg m/s ÷ 12 000 kg = 2 m/s.
b i –33 m/s^2
ii –20 000 kg m/s
iii 67 000 N

3.4

1 In an accident where the car suddenly stopped, the child would press against the back of the car seat spreading out the force. This would prevent the chid from being thrown forwards.
2 The air bag increases the time taken to stop the person it acts on. This reduces the force of the impact. Also, the force is spread out across the chest by the air bag so its effect is lessened again.
3 **a** 26100 kg m/s **b** 35 m/s **c** Yes

Answers to end of chapter summary questions

1 **a** **i** 45000 kg m/s **ii** 3750 N
b It is reduced to zero.
c The car would probably have skidded as there is an upper limit on how much friction the road can exert on the tyres.
2 **a** **i** 115 N
ii The force acts horizontally backwards from the seat belt.
b The child would not have stopped when the car stops and would hit the back of the front seats or be thrown through the windscreen.
3 **a** The force of the student's foot on the boat pushes the boat away.
b **i** 37.5 kg m/s **ii** 0.75 m/s
4 **a** **i** 36000 kg m/s **ii** 20000 kg m/s
b **i** 16000 kg m/s **ii** 13.3 m/s
5 **a** **i** Acceleration = change in $\frac{\text{velocity}}{\text{time}}$, since weight starts at rest.

$$\text{Speed} = \frac{10}{0.63} = 6.3\,\text{m/s}.$$

ii 44 kg m/s
b 20000 N
c The impact force would probably have been the same because the increase of the speed and hence the momentum of the weight would have been over a longer impact time.
6 **a** 8.4 kg m/s
b Impact force $= \frac{\Delta p}{t} = \frac{8.4}{0.0384} = 218.75 = 220\,\text{N}$ (2 s.f.)

Answers to end of chapter examination-style questions

1 **a** Momentum is mass × velocity; velocity is speed in a given direction; so momentum has magnitude and direction. (3)
b **i** Momentum of P = mass × velocity OR 20 000 × 14
= 280 000 kgm/s
(1 mark for answer; 1 mark for correct unit) (3)
ii momentum of Q = 600 000 kgm/s (1)
iii total momentum before collision = 880 000 kgm/s
momentum after collision = 880 000 kgm/s
= 50 000 × v
v = 17.6 m/s (4)

2 **a** **i** kgm/s (1)
ii **Similarities:** both have same *magnitude* of momentum.
Differences: they have momentum in opposite directions and since the coach has a larger mass, he has a smaller velocity. (3)
b momentum of dancer = 50 × 1.5
momentum of coach = 75 kgm/s
= 90 × v
v = 0.83 m/s (3)

3 **a** Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Physics points: seatbelts they stop drivers/passengers continuing forward when car stops suddenly; preventing them hitting the windscreen/seat in front; time of impact is increased; so deceleration is reduced; therefore the force of impact is reduced; seatbelts also spread the force; airbags inflate on impact; spread the force; increase time of impact; reducing the deceleration; also reducing the force. (6)
b The batsman wants the impact force to be large; therefore the impact time should be as short as possible; the fielder wants the force on his hands to be as small as possible; therefore the impact time should be long. (4)
4 **a** The crumple zone 'gives'; making the impact time longer than it would be without the crumple zone; this reduces the deceleration; thus reducing the force and the damage to the car. (4)
b Acceleration = F/m OR 60/0.2
= 300 m/s²
= change in velocity/time OR change in velocity/0.008 s
change in velocity = 300 × 0.008 = 2.4 m/s (5)
5 **a** **i** 8 m/s; 9600 kg m/s (2)
ii Impact time = 2 milliseconds (1);

$$\text{Impact force} = \frac{1200 \times -8}{0.002} = -4\,800\,000\,\text{N} = -4800\,\text{kN}\ (3)$$

b The decrease in velocity does not take place at a constant rate; as shown by the graph being a curve/line has a changing gradient; so momentum is not lost at a steady rate; therefore the impact force is not constant and is least at the end of the impact. (4)

4 More about forces

4.1

1 **a** Braking distance
b Thinking distance
c Braking distance
2 **a** **i** 6.0 m **ii** 24.0 m **iii** 30.0 m
b 12 m
3 **a** **i** The thinking distance is proportional to the speed as the reaction time is constant.
ii When the speed is twice as large and the braking force is constant, the braking time is greater, so the braking distance more than doubles (think about the area under the velocity–time graph).
b Yes; the braking distance divided by the square of the speed is the same for all three speeds. So the braking distance is proportional to the square of the speed.

4.2

1 **a** The initial resultant force is equal to its weight.
b The frictional force is less than the weight.
c Zero
d Zero
2 **a** 500 N
b 80 N
c 48 N
3 **a** The frictional force due to the parachute increases with speed so the resultant force on the parachutist decreases. When the frictional force becomes equal to the weight, the resultant force becomes zero and the parachutist moves at terminal velocity.
b **i** 900 N
ii 900 N upwards

4.3

1 **a** **i** The extension of a spring is directly proportional to the force applied, as long as its limit of proportionality is not exceeded.
ii 2.5 N
b **i** It does not return to its original length when it is released.
ii The rubber band does return to its original length when it is released whereas the polythene strip does not.
2 **a** The limit beyond which the tension is no longer proportional to the extension.
b The force per unit extension as long as the limit of proportionality is not reached.
c The increase of its length from its unstretched length.
3 **a** **i** 80 mm
ii 54 mm
iii 10 mm
b **i** 60 mm
ii 50 N/m
iii 1/the spring constant

Answers to end of chapter summary questions

1 **a** 25.5 m
b **i** −4.0 m/s² **ii** 94.5 m
2 **a** **i** The braking distance is increased because friction between the tyres and the road is reduced
ii The reaction time is increased so the distance travelled in this time (the thinking distance) is increased.
b **i** 12.6 m
ii 3.4 m
iii Stopping distance $= \frac{\text{distance}}{\text{speed}} = \frac{24}{18} = 1.33\,\text{s}$

$$\text{Deceleration} = \frac{0 - 18}{1.33} = -13.5\,\text{m/s}^2$$

Braking force = 1200 × −13.5 = 16200 N
3 **a** 320 N **b** 80 N
4 **a** For an object of mass m, the gravitational force on it = m × g. Since this is the only force acting on the object, the resultant force on the object = m × g. The acceleration of the object = resultant force/mass = m × g/m = g.
b 17 m/s
c **i** The acceleration of X is constant and equal to 10 m/s²
ii Object accelerates at first. The frictional force on it increases with speed so the resultant force on it and its acceleration decreases. When the frictional force is equal to the weight of the object, the resultant force is zero. The acceleration is then zero so the velocity is constant.
5 **a** **i** 225 N
ii 450 N

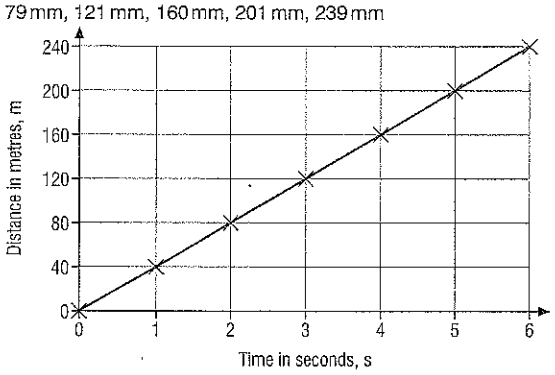
b The cyclist exerts a constant force driving her forward. Crouching reduces the force of air resistance (the frictional force). The frictional force increases with speed. So the cyclist can get to a higher speed before the frictional force becomes equal to the driving force.

6 a i 0.048 m **ii** 25 N/m

b 1.0 N

7 a 79 mm, 121 mm, 160 mm, 201 mm, 239 mm

b



c 280 mm

d i 25 N/m **ii** 3.5 N

Answers to end of chapter examination-style questions

1 a The distance travelled during the reaction/thinking time. (1)

b i Alcohol slows reactions; this increases the reaction time; which increases the thinking distance. (3)

ii The thinking distance increases with increasing speed; they are directly proportional. (2)

c i Deceleration = change in velocity/time
= 30/4.8
= 6.25 m/s² (2)

ii Braking force = 900 × 6.25
= 5825 N (2)

iii distance = area
= ½ × 4.8 × 30
= 72 m (3)

d Speed of vehicle; braking force; mass of vehicle; condition of road; condition of brakes/tyres. (5)

2 a i C (1)

ii zero error (1)

b i Gravity (1)

ii Drag of oil/viscosity of oil (1)

c i Speed increasing; but with decreasing acceleration; force Y increases with speed; so resultant force decreases. (4)

ii Steady/constant speed; eventually force Y = force X; resultant force zero; acceleration zero. (4)

3 a Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Measure the initial length of spring with only weight hanger attached; add one weight and measure new length; subtract initial length to find the extension; repeat with further weights; each time removing weight to check spring returns to previous length. (6)

b i Plot extension against stretching force; straight line through origin indicates that they are directly proportional. (2)

ii Calculate the extension for each force; then doubling force from 1 N to 2 N doubles extension from 0.5 to 1.0 cm; doubling again from 2 N to 4 N doubles 1.0 cm to 2.0 cm. Therefore, extension is directly proportional to stretching force. (3)

c When the stretching force is removed; the material returns to original shape/size. (2)

5 Forces and energy

5.1

1 a i Energy is transferred into kinetic energy of the boat and the water and thermal energy of the surroundings.

ii Energy is transferred into gravitational potential energy of the barrier and thermal energy due to friction and sound energy.

b 80 000 J

2 a The kinetic energy of the car is transferred by heating to the disc pads by friction.

b 140 000 J

3 a i 96 J

ii 96 J

b 200 N

5.2

1 a i A mains-connected filament lamp.

ii 10 000 W electric cooker

b 600 000 kW (= 600 MW)

2 a 800 J

b 800 J

c 160 W

3 a i 1800 m

ii 9.0 MJ

b Force = $\frac{\text{work done}}{\text{distance}} = \frac{9\,000\,000}{1800} = 500\,\text{N}$

5.3

1 a On descent, gravitational potential energy of the ball is transferred to kinetic energy of the ball. On impact, the kinetic energy of the ball is transferred into elastic energy of the ball and some of the elastic energy is transferred back to kinetic energy as it rebounds. After the impact, the kinetic energy of the ball is transferred to gravitational potential energy of the ball as it rises.

b i 1.1 J

ii Energy transfer to the surroundings due to air resistance as the ball moves through the air; energy transfer by heating to the ball when the ball is deformed.

2 a 90 J

b 4500 J

3 a 450 J

b 375 J

4 Energy must be supplied to keep the biceps muscle in the arm contracted. No work is done on the object, because it doesn't move. The energy supplied heats the muscles and is transferred by heating to the surroundings.

5.4

1 a i 36 kJ

ii 88 J

b 17 m/s

2 a i Work done by the muscles transfer chemical energy from the muscles to elastic potential energy of the catapult.

ii Elastic potential energy of the catapult is transferred to kinetic energy of the object.

b i 10 J

ii 10 m/s

3 a 3600 N

b 800 kg

Answers to end of chapter summary questions

1 a i 210 MJ

ii 6900 m

iii Resistive force = $\frac{\text{work done}}{\text{distance}} = \frac{210\,000\,000}{6900} = 30345 = 30000\,\text{N}$ (2 s.f.)

iv The acceleration of the train is zero so the resultant force on it is zero. Therefore, the driving force and the resistive force must be equal and opposite to each other.

b The train gains gravitational energy as it travels up the incline. The rate at which it transfer energy to the surroundings is unchanged as its speed is the same and the resistive forces acting on it are unchanged. So the output power of the engine needs to be greater as energy must be transferred to the train as gravitational potential energy as well as to the surroundings.

2 a 180 J

b work done = force × distance in the direction of the force = 11 N × 20 m = 220 J.

c The trolley did not gain kinetic energy as its speed was constant. The trolley gained 180 J of gravitational potential energy. Resistive forces such as friction at the trolley wheels must have transferred 40 J of energy to the surroundings as waste energy.

3 a i 530 kJ

ii 7100 kN

iii The car would skid.

b No; the kinetic energy of cars moving at 80 mph is much greater than that of cars moving at 70 mph. Impact forces would therefore be much greater and so injuries would be more severe. In addition, motorists have less time to act to avoid an impact at high speed.

4 a 2.0 m/s

b i 9.6 kJ

ii 4.0 kJ

iii 2.2 kJ

c i The change of momentum of each wagon occurs over a longer time so the change of momentum per second and hence the impact force is less.

ii Energy is transferred to the surroundings as sound and heat in the impact and energy is stored in the compressed spring.

5 a Energy is initially stored in the stretched cord as elastic potential energy. This energy is transferred to the arrow as kinetic energy when the cord is released. As the arrow gains height, its kinetic energy decreases and its gravitational potential energy increases. At maximum height, the arrow has maximum gravitational potential energy and minimum kinetic energy. As it travels through the air, some of its energy is transferred to the air due to air resistance.
b i 4.7J
ii 3.0J
iii 15m/s
6 a 135kJ
b i 940J
ii 675kJ
c 810kJ

Answers to end of chapter examination-style questions

1 a joule; kilojoule; kilowatt-hour (3)
b i $W = m \times g$ OR $W = 58 \times 10$ (1)
$= 580$N (1)
ii Work = weight × height OR work = 580 × 12 (1)
= 6960J (1)
iii Power = work done/time taken OR power = 6960/120 (1)
= 58W (1 mark for 58, 1 mark for the unit)
2 a i chemical energy from food (1); transferred to kinetic as the jumper runs (1); to gravitational potential as he rises above ground (1)
ii Gravitational potential energy = $m \times g \times h = 65 \times 10 \times 1.25$ (1)
$= 812.5$ J (1)
b i Kinetic energy = $812.5 = \frac{1}{2} \times m \times v^2$ (1)
$v^2 = 2 \times 812.5/65$ (1)
$= 25$ (1)
$v = 5$m/s (1)
ii Energy is lost (1); due to drag along the track (1); and in rising (1)
3 a Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Equipment needed: stopwatch; scales/balance; tape measure. They need to measure: their mass; the vertical height of the stairs (they may measure the rise and number of steps and multiply together – in which case a tape measure would not be needed, just a ruler); and the time taken to climb the stairs – this would need co-operation and some form of signalling to indicate starting and stopping of the stopwatch. (6)
b Work done = 450 × 4 (1)
power = work/time = 1800/2.5 (1)
= 720W (1)
4 a i gravitational potential (1)
ii Loss in height = 0.5m (1)
percentage loss = 0.5/2.0 × 100 (1)
= 25% (1)
iii Transferred to thermal; warms the ground; spreads out. (3)
b i Equal to GPE = $m \times g \times h$ (1)
$= 0.2 \times 10 \times 2$ (1)
$= 4$J (1)
ii $\frac{1}{2} \times m \times v^2 = 4$ (1)
$= 8/0.2$ (1)
$= 40$ (1)
$v = 6.3$m/s (1)
iii Reaction force of the floor changes the motion (1); speed changes (1); direction is reversed (1); acceleration is the rate of change of the vector velocity. (1)

6 Forces in action

6.1

1 a and c The centre of mass is where the two diagonal lines from the corners cross.
b The centre of mass is found by drawing two diametric lines at right angles. The centre of mass is where the two line cross.
2 The centre of mass of the child is then directly below the midpoint M of the points of suspension of the swing. At this position, the moment of the child about M is zero.
3 See the practical instructions and Figure 4 on p 51.

6.2

1 a i It decreases. ii It is unchanged.
b i 1.4s ii 0.71Hz
2 a 37.93s
b 0.53Hz
3 a Similarity: They both move repeatedly along a line or they both move repeatedly through the equilibrium position.
Difference: Their time period differs or the amplitude of the swing decreases faster than the amplitude of the simple pendulum.
b The relevant length that determines the time period is from the point o suspension to the centre of mass. This is shorter in the swing than in the pendulum as the effect of the child sitting on the swing raises the centre of mass, so the swing time period is less.

6.3

1 a i Increased
ii Unchanged
iii Reduced to a quarter
b 18Nm
2 a Anticlockwise
b i Increased
ii Decreased
3 a The moment of the applied force about the pivot is greater the longer the handle is, so a greater force can be exerted on the nail.
b The rust on the hinge increases the frictional forces in the hinge, so a greater moment and hence a greater force must be applied to the door to overcome the moment of the frictional forces at the hinge.
4 72N

6.4

1 a i 3N
ii 1.2N
b In both examples, the line of action of the effort is at a greater perpendicular distance from the pivot than the corresponding distance for the load. A smaller effort therefore gives an equal and opposite moment about the pivot to the load's moment.
2 a Dawn
b 340N, 1.84m
c Dawn needs to move 0.66m towards the pivot so she is 1.84m from the pivot.
3 1.5N

6.5

1 a i It would be less stable as its centre of mass would be higher.
ii Without stabilisers, when the child leans to one side, the moment of the rider's weight (about the line between the points where the cycle wheels are on the ground) makes the bicycle fall over. The stabiliser wheel on that side touches to ground and an upward force from the ground acts on it. This upward force provides a moment (about the line between the points where the cycle wheels are on the ground) which counterbalances the moment of the rider's weight and stops the bicycle falling over.
b A supermarket trolley, a tall electric kettle, etc.
2 a The chair would topple over if the baby in the chair leans too far sideways.
b The lower the centre of mass, the harder it is to topple it over.
3 a When it is empty, its centre of mass is approximately halfway up the bottle. When it is standing upright and is less than half full, its centre of mass is approximately halfway between its base and the water level. This position of the centre of mass will always be lower than the position when it is empty.
b The cone has a wide base which is attached to a heavy square board The centre of mass of the cone is therefore much lower than it would be if the base was narrow, and therefore more stable.

6.6

1 a B, C
b C, D
2 a friction
b pull (tension)
c gravity
d electrostatic force
3 a i The car would skid off the bend because the centripetal force needed would be greater at a higher speed and the friction on the tyres providing the centripetal force would be unchanged.
ii The car would skid off the bend as the centripetal force needed increases as the radius of the circle is decreased.
b If the track was not banked, the track would not be able to exert enough centripetal force on the train to make it stay on the track wher it travels round the curve. With a banked track, the weight of the train would contribute towards the necessary centripetal force in addition t the force of the track on the train.

6.7

1 a The area of your hands in contact with the ground when you do a handstand is smaller than the area of your feet on the ground when you are upright. Since the force (i.e. your weight) is the same in both cases and pressure = force divided by area, the pressure on your hands in a handstand is greater than the pressure on your feet when you are upright.

b When in use, a sharp knife has a smaller contact area than a blunt knife has. For the same force, the pressure of a sharp knife is greater so it cuts more easily than a blunt knife does.

2 **a** A crane, a digger, vehicle brakes, etc.
b **i** The pressure of the compressed air forces the piston in X upwards, making the two outer parts of the arm move up.
ii The bucket moves in a downward scoop towards the cab.

3 **a** 18000N **b** 8800N

Answers to end of chapter summary questions

1 **a** The effort acts further from the fulcrum than does the force of the bottle opener on the top. So the force of the bottle opener on the top is greater than the effort.
b 75N; the effort is 3 times further from the fulcrum than edge of the cap is. So an effort of 25N causes three times as much force to be exerted on the edge of the cap.

2 **a** It would be less stable as it would be easier to disturb.
b 0.06N

3 **a** The distance from the wheel axle to force *F* is much greater than the distance from the axle to the centre of mass. The weight of the sand and the wheelbarrow causes a certain moment about the wheel axle. To lift the wheelbarrow legs off the ground, force *F* must create a greater moment about the wheel axle. Because the distance from the wheel axle to force *F* is much greater than the distance from the axle to the centre of mass, force *F* can be much smaller than the weight to give an greater moment than that of the weight.
b **i** 149N **ii** 84N

4 Friction between the footwear and the floor provides the necessary centripetal force to enable the person to revolve with the floor. The floor is too slippy to provide such friction so anyone stepping on the floor would probably slide towards the edge and be thrown off it as it revolves.

5 **a** The centre of the brake pedal is about 4 times further from the pivot that the piston rod. A force of 20N on the piston could therefore be achieved by applying a force of 5N to the brake pedal. This would give a moment sufficient to cause a force of 20N on the piston.
b **i** 33kPa
ii The pressure in the master cylinder is transmitted without loss to each brake cylinder. The force on each brake cylinder is equal to the pressure x its cross-sectional area. As each brake cylinder has a much greater cross-sectional area than the master cylinder has, the force exerted by the brake cylinder is much greater than 20N.

6 **a** The time period is the time for the pendulum bob to swing from one extreme to the opposite extreme and back (or the time between successive passes through the centre in the same direction).
b **i** 3.03s
ii The time period would become less and the frequency would increase.
c Displace the pendulum by a measured distance from the centre and measure the time for 10 complete oscillations. Repeat the procedure several times for the same initial displacement to obtain an average time for 10 oscillations and hence calculate the mean value of the time period. Repeat the test for different measured amplitudes. Plot a graph of the time period on the y-axis against the amplitude on the x-axis to see if the time period varies with amplitude.

Answers to end of chapter examination-style questions

1 **a** Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: put a pin through one hole; suspend the sheet from the pin; hang a plumb-line from the pin; draw a vertical line along the plumb-line; repeat hanging the sheet from the other hole; where the two lines cross is the centre of mass. (6)
b **i** Moment = force × (perpendicular) distance from pivot OR = 2.5 × 30 (1) = 75Ncm (1)
ii Anticlockwise moment less (1); since perpendicular distance is less (1); therefore clockwise moment is less (1); so tension in spring is less. (1)

2 **a** **i** Two from: track; wheel base; position of centre of mass (2)
ii The government test should be unbiased/manufacturers' test could be biased. (1)
b **i** Weight = 12000N (1) moment = weight × distance from pivot OR = 12000 × 0.5 (1) = 6000Nm (1 for answer; 1 for the unit).
ii Low centre of mass (1); clockwise moment returns vehicle to the horizontal (1); line of action of weight passes through base. (1)
iii Centre of mass raised (1); vehicle tilts less (1); before line of action of weight passes outside base. (1)

3 **a** centripetal (1)
b Electrostatic attraction (1); gravity. (1)
c Towards the centre of the circle. (1)
d Mass (1); velocity (1); radius of circle. (1)

4 **a** Liquids are almost incompressible (1); pressure transmitted equally in all directions. (1)
b Pressure acts equally on both sides of rim (1); brake blocks have same area. (1)
c Force = pressure × area OR = 250 × 2 (1) = 500N (1) Two blocks, so total force = 1000N. (1)
d Master piston has small area (1); large pressure transmitted (1); slave piston has larger area so F (P × A) is larger. (1)

7 General properties of waves

7.1

1 **a** The oscillations in a transverse wave are perpendicular to the direction of energy transfer. The oscillations of a longitudinal wave are parallel to the direction of energy transfer.
b **i** An electromagnetic wave or waves on a stretched string or wire.
ii Sound waves.
c The particles are displaced so they are closer together.

2 **a** Transverse
b **i** Along the rope from one end to the other.
ii It oscillates in a direction perpendicular to the energy transfer.

3 **a** Stretch the slinky out with each person holding one end. To send transverse waves along the slinky, move one end so it oscillates at right angles to the slinky. To send longitudinal waves along the slinky, move one end so it oscillates parallel to the slinky.
b The red coil moves to and fro in a direction parallel to the slinky axis about a fixed point along the axis.

7.2

1 **a** amplitude = 9 mm, wavelength = 37 mm
b The number of wavecrests passing a point in one second or the number of cycles of the waves that pass a point in one second.

2 **a** **i** and **iii** see 7.2 Figure 1.
b Point P will oscillate at right angles to the wave moving from a maximum as the wave peak passes down to a minimum as the wave trough passes.

3 **a** 6.0m/s
b **i** 6.0m
ii 360m

7.3

1 **a** They are equal.
b The angle of each refracted wavefront to the boundary becomes greater than the angle of each incident wave front to the boundary.

2 See 7.3 Figure 3

3 **a** The slopes prevent reflection of the waves at the sides of the tank.
b Reflection of waves from the sides would occur and these reflected waves would spoil the pattern of the waves in the tank.

7.4

1 **a** The wavelength is unchanged.
b **i** The waves spread out (or diffract) more.
ii The waves spread out (or diffract) less.

2 **a** Diffraction is the spreading of waves when and after they pass through a gap or pass by an obstacle.
b **i** The radio waves carrying the TV signal from the transmitter are short compared with obstacles such as the hills so the waves do not diffracted much. Therefore, fewer radio waves would reach a TV receiver on the other side of a hill to the transmitter.
ii The longer wavelength radio waves are diffracted more than the waves carrying the TV signal and so they spread out more when the pass over a hill and can reach radio receivers at some locations which TV signals cannot reach.

3 The sound waves from the radio diffract when they reach the doorway so they spread out and travel along the corridor.

7.5

1 The tea tray reflects some of the radio waves carrying the TV signal. The reflected waves and waves directly from the transmitter produce an interference pattern. If the aerial is at a point where the waves cancel each other out, the TV signal becomes very weak.

2 The waves from each slit arrive at the same time at this point because they travel equal distances. Therefore they always reinforce each other at this point and the detector signal is stronger.

3 **a** The interference fringes would be further apart.
b The interference fringes would be green and their spacing would be less than the spacing of red fringes and more than the spacing of blue fringes.

Answers to end of chapter summary questions

1 a See 7.2 Figure 1
b In a transverse wave, the particles oscillate at right angles to the direction in which the wave travels. In a longitudinal wave, the particles oscillate along the direction in which the wave travels.
c Transverse wave; waves on a string or a rope, electromagnetic waves
Longitudinal waves; sound waves
2 a 0.05 Hz
b 0.40 m/s
c 8.0 m
3 a i Decreases
ii Unchanged
b i Unchanged
ii Unchanged
iii Unchanged
4 a See Figure 1a
b See Figure 1b

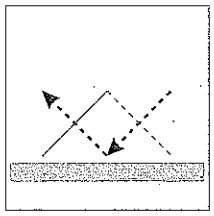


Figure 1a

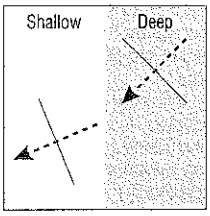
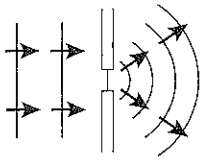


Figure 1b

5 a 100 MHz
b The waves would travel across the top of a hill without diffracting if their wavelength is much less than the height of the hill. As a result, no waves would spread down the hill so a receiver on the far side of the hill would not receive a signal.
6 a



i Diffraction
ii The waves would be shorter (at the same distance apart), diffracted less.
8 a i Diffraction
ii Interference
iii Cancellation
iv and v reinforcement
b i The points of cancellation and reinforcement would be closer together.
ii The waves would be further apart. The points of cancellation and reinforcement would be further apart.

Answers to end of chapter examination-style questions

1 a i C ii D
iii A iv B (4)
b i There are two sets of radio waves; travelling in opposite directions; they overlap/interfere at the car; where crest meets trough it is soft; where crest meets crest/trough meets trough it is loud. (5)
ii Only sound waves from speakers; conditions not right for interference. (2)
2 a i X – transverse (1)
ii Y – longitudinal (1)
iii Perpendicular to the direction of energy transfer. (1)
iv Parallel to the direction of energy transfer. (1)
b Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response.
Similarities: all travel in the form of waves; all transfer energy; light & radio have the same wave speed.
Differences: light & radio are transverse waves/sound is longitudinal; wavelength of radio longer than that of light for same frequency; sound has a much lower wave speed than light and radio; sound cannot travel through a vacuum/needs a medium. (6 – for full marks, there must be at least 2 similarities)
3 a i R
ii Q (2)
b $\lambda = 0.03$ m (1)
$f = c/\lambda$ OR $f = 3 \times 10^8/0.03$ (1)
$= 1 \times 10^{10}$ (1) Hz/hertz (1)
c i Waves from the two slits come together; crest to trough; cancel/subtract. (3)
ii Waves come together crest to crest/trough to trough; add/reinforce. (2)
iii higher than N (1)
4 a Diffraction increases with decreasing gap width; greatest diffraction when gap width = wavelength. (2)
b Sound waves diffract through doorway; door width similar to wavelength; light waves have much shorter wavelengths and so do not diffract significantly through doorway. (3)
c i Radio 4 carrier wave has a much greater wavelength than BBC1 television carrier wave; it is 3000 times as great. (2)
ii Radio 4 carrier waves diffract round the hill; they have a similar wavelength to the width of the hill. (2)
iii BBC1 television carrier wave has a much smaller wavelength; the carrier wave does not diffract round the hill. (2)

8 Electromagnetic waves

8.1

1 a Radio waves
b The speed is the same for all electromagnetic waves.
c X-rays
d Microwaves
2 radio microwaves infrared visible light ultraviolet X-rays gamma rays
3 a 0.50 m
b 1000 MHz
4 a Gamma radiation
b All electromagnetic waves travel at the same speed in space. Since both types of waves travel the same distance and they are emitted at the same time, they reach the Earth at the same time.

8.2

1 a i Radio waves
ii Light waves
b i Microwaves
ii Radio waves
2 a Mobile phone calls would not be clear as the phones would detect handset signals as well as mobile phone signals.
b If other radio wave users operated in the same wavelength range as the emergency services, their signals would be detected by the emergency services and might 'mask' the emergency services signals making conversations carried by the emergency services signals difficult to listen to.
3 a i Radio waves
ii Microwaves
iii Infrared radiation
iv Light
b 0.125 m

8.3

1 a i Radio waves or microwaves
ii Infrared radiation
b i The two signals would interfere where they cross and there would be points where they cancel each other
ii The signals cannot escape from the fibre so they cannot be detected except by the detector at the receiver end. Radio signals travel through the air so can be detected by any radio detector in the path of the waves.
2 a The skull of a child is thinner than that of an adult which means that mobile phone radiation can pass more easily through the skull of a child into the brain and cause a greater heating effect
b Light waves have a much higher frequency and a much smaller wavelength in air than radio waves so can carry many more pulses per second than radio waves can.
3 a Microwaves are absorbed less by the atmosphere than radio waves and are not diffracted as much so they spread out less making them suitable for satellite TV. Terrestrial TV uses radio waves as diffraction as it helps to prevent signal problems.
b Microwaves from such a transmitter dish are directed in a beam at the other dish so they travel in a straight line towards the other dish. If the other dish is visible from the first transmitter, it can detect the microwaves directed at it. The atmosphere does not absorb the beam much so the received signal is strong enough to be detected.

8.4

1 a X-rays pass through the crack but not through the surrounding metal. On the X-ray picture, the crack appears as a break in the shadow of the metal object.
b Yes
c A metal case would stop the X-rays so the X-rays would not reach the film inside the case.

2 a It harms the skin and can cause skin cancer. It damages the eyes and can cause blindness.
b i It absorbs most of the ultraviolet radiation from the Sun.
ii Ultraviolet radiation causes sunburn. Suncreams stop UV radiation reaching the skin. Suncreams absorbs the UV radiation that passes through the ozone layer.
3 a X-rays and gamma rays
b Lead
c i X-rays and gamma rays
ii Ultraviolet radiation, X-rays and gamma rays

8.5

1 a The contrast medium absorbs X-rays. Without it, the X-rays would pass through the stomach so no image of the stomach will be seen on the X-ray photograph.
b X-ray therapy can be used to destroy cancerous tissue.
2 a Dense material such as bone in the patient absorb X-rays from the tube and stop them reaching the film cassette. X rays that reach the film cassette blacken the film and do not pass through such absorbing materials. When the film is developed, clear images of the bones and other absorbing materials in the patient are seen on the film because X-rays did not reach these areas.
b If the film was not in a lightproof cassette, light from the room would blacken the entire film.
c X-rays ionise substances they pass through. Ionisation in healthy cells can damage or kill the cells or cause cell mutation and cancerous growth. The shielding prevents X-rays from reaching and damaging cells in parts of the patient not under investigation.
3 a X-rays
b Advantage = higher dose; disadvantage = higher cost.

Answers to end of chapter summary questions

1 a D E A B C
b i Microwaves
ii Gamma rays
iii Infrared rays
2 a i speed = wavelength × frequency
ii 103 MHz
b As the radio waves travel away from the transmitter, their amplitude is gradually reduced due to absorption by the air. At a certain distance *d*, the amplitude is just large enough for the waves to be detected. Reducing the power of the transmitter reduces the amplitude at that distance so the range is reduced.
3 a Mobile phones signals are carried by microwaves. Microwaves can heat substances which absorb them. If a mobile phone emits too much microwave radiation, the radiation absorbed by tissues in the head (e.g. brain tissue) may be adversely damaged by the heating effect of the microwaves.
b A; it emits less microwave energy per second so it would not affect the organs in the head (e.g. the brain or the ear) as much.
c Microwave radiation penetrates their skulls more than older skills because their skulls are thinner. Also, smaller heads heat up more easily than bigger heads.
4 a i Bone absorbs X-rays so a 'shadow' image is formed on the film.
ii X-rays pass through the fracture but not through the bones.
b i Barium absorbs X-rays so an image of the stomach is formed on the film.
ii The stomach movements would blur the images.
iii X-rays ionise substances they pass through. The amount of ionising radiation the patient is exposed to is reduced by stopping the X-rays reaching the patient. The quality of the image is unaffected because the low energy X-rays would not reach the film anyway.
c Ultrasound waves from a scanner do not harm the baby because they are non-ionising. X-rays are ionising and would harm the baby.
5 a Ionisation is the process of creating ions, which are charged atoms from uncharged atoms.
b X rays, gamma rays
c Ionising radiation can damage or kill living cells and can cause cell mutation and cancerous growth.
6 a When ultraviolet radiation is directed at invisible ink, the radiation is absorbed by atoms in the ink which then emit light so the ink glows and becomes visible.
b The further infrared radiation travels through air, the more it is absorbed by air molecules so a beam of infrared radiation would be too weak to detect after more than a few metres.
c Local radio signals are carried by electromagnetic waves of a much longer wavelength than microwaves so they spread out much more from a transmitter and the amplitude decreases with distance more than for microwaves which spread out enough to reach a wide area but not so much as to become too weak to detect. In addition, radio waves are absorbed more by the atmosphere than microwaves because microwaves are much higher in frequency and are not affected as much by air molecules.

Answers to end of chapter examination-style questions

1 a i X-rays (1)
ii radio waves (1)
iii X-rays (1)
iv ultraviolet (1)
b i They penetrate tissue (1); and clothing (1); but not bone (1); or metal. (1)
ii They carry a lot of energy (1); they cause ionisation (1); can cause cancer (1); and kill cells. (1)
2 a Gamma: Prolonging the shelf-life of fruit (1);
Infrared: In a TV remote control (1);
Radio: Carrying TV programmes (1);
Ultraviolet: Security marking of TV sets. (1)
b i They can pass through the atmosphere. (1)
ii Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: phones use microwaves; microwaves deliver energy to cells; can heat them up; phones are held near the brain; skull is thinner in young children; brain cells may be damaged. (6)
3 a i Can distinguish between different types of tissue (1); produce 3D images. (1)
ii Larger doses of radiation are used (1); much more expensive. (1)
b X-rays can damage cells (1); fetus has developing cells which can mutate. (1)
c Any six from: the overall dose has more than doubled (1); dose from background radiation is unchanged (1) dose from medical uses has increased by a large amount (1); other man-made radiation has also increased (1) more medical procedures involving radiation in 2010 (1); some, such as CT scans, deliver large doses (1); other man-made due to nuclear accidents (1); and weapons testing. (1)
4 a Infrared (1); light. (1)
b i Any wavelength greater than 100 m. (1)
ii Any wavelength between 1m and 100m. (1)
iii Any wavelength less than 1m. (1)
c Frequency = 2.4×10^9 Hz (1)
$\lambda = c/f$ OR = $3 \times 10^8 / 2.4 \times 10^9$ (1) = 0.125 m (1)

9 Sound and ultrasound

9.1

1 a Thick felt or a similar material.
b The bushes absorb some sound and also scatter it. Sound from traffic that reaches the fence panels is reflected back towards the motorway by the panels.
2 a 20 000 Hz
b When the whistle is blown, the ball inside the whistle revolves at high speed pushing the air in and out of the gaps in the case of the whistle. The vibrations of the air at the gaps causes sound waves to spread out from the whistle. The frequency of the sound is constant because the ball revolves at constant speed inside the whistle.
3 a i The cliff face would reflect sound from the horn and create an echo.
ii distance = 340 m/s × 5.0 s/2 = 850 m
b The person creates a sound which spreads out in all directions. The echoes are due to sound reflected from different parts of the cavern walls.

9.2

1 a The amplitude decreases; the frequency does not change.
b The loudness of the sound decreases because the amplitude of the sound waves decreases. This happens because the amplitude of the vibrations of the wire decreases.
2 a The amplitude of the waves would be taller but the horizontal spacing between the peaks and troughs would be unchanged.
b The horizontal spacing between the peaks and troughs would be greater but the amplitude of the waves would be unchanged.
3 a i and ii The pitch or frequency is raised.
iii The pitch is lowered.
b The sound of a violin (played correctly) lasts as long as the violin bow is in contact with a string. The sound of a drum dies away after the drum skin has been struck. A drum note is less rhythmical than a violin note.
c The vibrating tuning fork makes the table surface vibrate. The vibrating table surface creates sound waves in a much greater volume of air than the tips of the vibrating tuning fork does.

9.3

1 a The organs have a different density to the surrounding tissue. So ultrasound is reflected at the tissue/organ boundaries.
b Ultrasound is not ionising radiation whereas X-rays are. Ionising radiation is harmful to living tissue. Ultrasound is reflected at the boundaries between different types of tissue whereas X-rays are not.
c The reflected pulses would be weaker if there is more diffraction because the waves would spread out more and become weaker. Also, the pulses would be reflected from a wider area of each boundary so the position of the boundary would be more difficult to locate.
2 a 3 if the last pulse is due to the other side of the body.
b i 96 millionths of a second
ii 0.144 m
3 a 12 mm
b +2–3 mm

Answers to end of chapter summary questions

1 a i As the surface of the object vibrates, it alternately pushes air particles away as it moves into the air then allows them to return as it retreats from the air, in effect pulling them back. The air particles pushed away from the surface push on other air particles further away then allow them to retreat as they retreat. These further particles in turn alternately push and pull on particles further away. In this way, waves of compressions and rarefactions pass through the air.
ii The sound waves spread out as they travel away from the loudspeaker so the sound becomes fainter and the amplitude becomes smaller.
b i The waves on the screen become taller (higher amplitude).
ii The waves on the screen become more stretched out across the screen so fewer waves appear on the screen.
c The signal generator is connected to the loudspeaker and to the oscilloscope. The signal generator should be adjusted so the subject can hear the sound from the loudspeaker comfortably. The frequency of the signal generator should then be increased gradually until the subject can no longer hear the sound. The frequency at this point can then be determined by measuring the time period of the waveform on the oscilloscope screen. The upper limit frequency is equal to 1/the measured time period.
2 a reflected, smooth
b rough, scattered
c soft, absorbed
d The speed of sound in air increases with increasing air temperature. Refraction takes place at the boundaries between layers of air at different temperatures. At night the air near the ground is colder than air higher up so you can hear sound a long way from its source because sound waves refract back to the ground.
3 a Approximately 20 000 Hz.
b Keep the frequency and the loudness of the sound from the loudspeaker the same throughout. Keep the loudspeaker, the board or cushion and the sound meter in the same positions throughout. With the board in position, measure the sound meter reading. Replace the board with the cushion and measure the sound meter reading again. If the reading for the board is higher than the reading for the cushion, the board reflects more sound than the cushion.
4 a Sound waves created by clapping her hands together travel through the air to the wall where they reflect from it. Some of the reflected waves travel back to the person who hears the echo when the reflected sound waves reach her.
b 51 m
5 270 m
6 a 8.5 mm
b If the bat detects echoes directly ahead, the time delay between each pulse being emitted and being detected enables the bat to sense the distance to the reflecting object. The difference in the intensity of the echo at each ear enables the bat to sense the direction of the reflecting object.
7 a 0.75 mm
b i They could not be detected because they would be absorbed by the tissue.
ii The reflected pulses would be much weaker. Also, if the pulses spread out, it is difficult to tell which boundary a reflected pulse is from.
c Ultrasound as it is non-ionising unlike X-rays. Ionising radiation can damage or kill cells in living tissue.

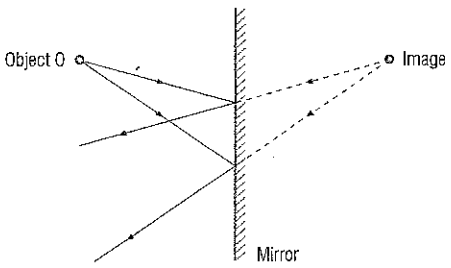
Answers to end of chapter examination-style questions

1 a i Signal generator (1); loudspeaker (1); microphone (1); cathode ray oscilloscope. (1)
ii A is louder than B (1); A is lower in pitch than B. (1)
b i An echo. (1)
ii Measure the distance to the wall (1); start a stopwatch when they hear the first sound (1); stop the stopwatch when they hear the echo (1); double the distance to the wall to find total distance travelled(1); divide the total distance by the time. (1)
iii Each student should measure the time and then find the average. (1)
2 a i longitudinal; transverse (1) (both correct for mark)
ii slower (1)
iii cannot; can (1) (both correct for mark)
b i 1 cm (1)
ii $f = 1/T = 1/0.002$ (1) = 500 Hz (1)
iii $\lambda = c/f = 340/500$ (1) = 0.68 m (1)
iv Diffraction most marked when gap width similar to wavelength (1); 0.68 m is of the same order as a doorway (1); so waves would be diffracted. (1)
3 a i Longitudinal wave (1); series of compressions in water (1); and rarefactions. (1)
ii There is nothing to be compressed. (1)
iii $\lambda = c/f = 1400/2000$ (1) = 0.7 m (1)
b i Sound/longitudinal waves (1); frequency above the range of the human ear. (1)
ii Distance = speed × time = 1400 × 0.1 (1) = 140 m (1)
This is twice the depth – answer 70 m (1)
iii One from: pre-natal scans; dispersing kidney stones; detecting flaws in metals; removing plaque; cleaning surgical instruments (1)
4 a 30 000 Hz (1)
b Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: transducer transmits ultrasound pulses into body; ultrasound can travel through solids and liquids; ultrasound travels through the body; partially reflected at boundaries between different types of tissue/baby/foetus; reflected ultrasound returns to the transducer; where it is detected; the computer processes the information to give a visual image on the screen. (6)

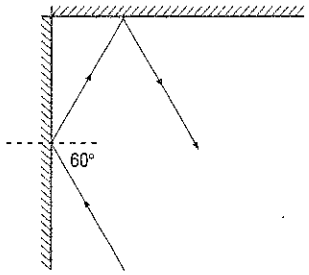
10 Reflection and refraction of light

10.1

1 a i 20° ii 40°
b 42°
2 a, b i



ii Use a millimetre ruler to measure the perpendicular distance from O to the mirror and from the image to the mirror.
3 a

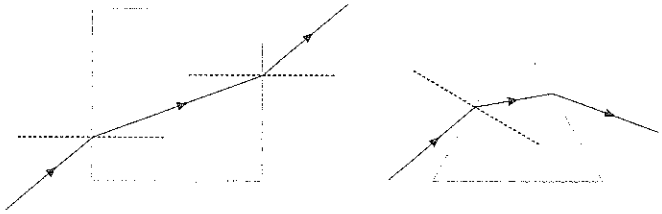


b i 180°
ii As the two mirrors are perpendicular to each other, the angle of incidence for the second reflection is always 90° – first angle of incidence. Therefore, adding both angles of incidences always equals 90° and therefore both reflected rays also equal 90° giving a total of 180°.

10.2

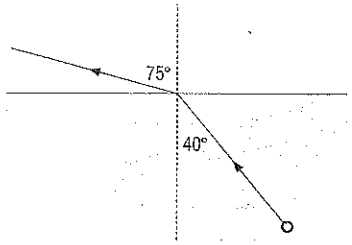
1 a Decrease
b Zero
c Smaller

2 a



b i Blue
ii In glass, blue light travels slower than red light.

3 a



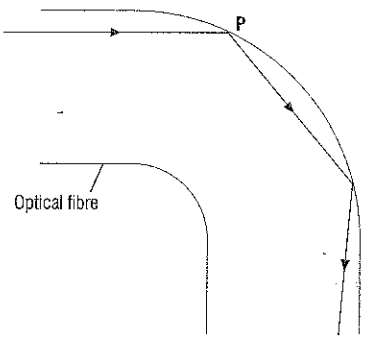
b All the light rays from a point on the bottom of the pool that refract at the surface appear to travel straight from a point above the bottom.

10.3

1 a 1.54
b 1.53
2 a 1.47
b The measurement in Q2 was a single pair of measurements and three pairs of measurements were made in Q1 so the result in Q2 is less reliable than that in Q1; the refractive index of glass of the second block might have been different.
3 a 25.5°
b 70.1°
c 1.52

10.4

1 a The angle of incidence must be greater than the critical angle.
b 90°
c 1.47
2 a

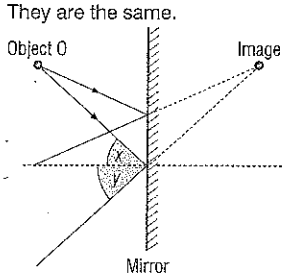


b Any two advantages:
1. The endoscope uses light which is non-ionising (unlike X-rays).
2. Movement of the fragments can be seen with an endoscope.
3. Fragments may be hidden by other fragments on an X-ray picture.

3 a 48.8°
b i 1.49
ii Range of critical angle = 41.5° – 42.5°. At 41.5°, the refractive index = 1.51. At 42.5°, the refractive index = 1.48. Therefore, the largest difference to the answer in part i is 0.02.

Answers to end of chapter summary questions

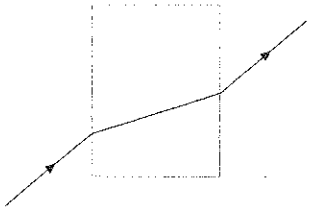
1 a i They are the same.
ii



iii They are the same.

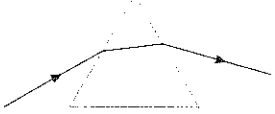
b Draw a straight line XY on a sheet of white paper and use a protractor to draw a 'normal' line perpendicular to XY. Place the mirror exactly on XY and use the ray box to direct a light ray at the point P where the normal intersects XY. Adjust the direction of the light ray so the angle of incidence is about 10°. Use a pencil to mark the direction of the incident and reflected rays. Remove the mirror and use a protractor to measure the angles of incidence and reflection. Repeat the text for several different angles of incidence. Record all your results in a table. Plot a straight line graph of the angle of reflection against the angle of incidence. The line should show that the angles of incidence and reflection are always equal to one another.

2 a i



ii The change of direction at the second refraction is exactly equal and opposite to the change at the first refraction. Since the opposite sides of the block are parallel, the light ray that emerges is therefore exactly parallel to the incidence light ray.

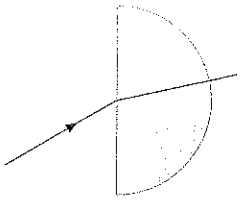
b i



ii A continuous spectrum of colour is seen on the screen with blue light refracted most and red light least. This happens because the refractive index of the glass varies with the wavelength of the light and is greatest for blue light and least for red light.

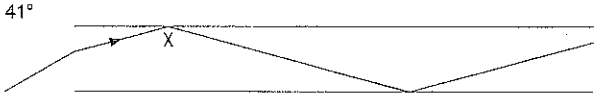
3 a i 1.53
ii 196 000 km/s
b i 19.5°
ii 80°

4 a



b Draw an outline of the block on a sheet of white paper and use a ruler to locate the centre C of the flat side of the outline. Mark point C on the sheet and use a protractor to draw the normal to the flat side at C. Place the block exactly on the outline and direct a light ray at C so the light ray passes into the block at C. Mark the path of the light ray before it enters the block and where it leave the block as point D. Remove the block and draw the path of the incident light ray and the path of the light ray from C to D. Use a protractor to measure the angle of incidence and the angle of refraction at C.
Calculate the refractive index n using the formula $n = \sin i / \sin c$ from C to D. Repeat the test for different angles of incidence and calculate a mean value for the refractive index from the individual values.

5 a i Total internal reflection is the total reflection of a light ray in a transparent medium at a boundary between the medium and a less refractive medium.
ii The angle of incidence at the boundary should be greater than the critical angle of the boundary.
iii 1.56
b i 41°
ii



iii One bundle takes light into the cavity. The other bundle is used to observe an image formed by a lens near the end of this bundle in the cavity.

6 a $\sin r = \frac{\sin i}{n}$; $\sin r = \frac{\sin 40}{1.59} = 0.404$; r = 24°
b i 39°
ii The angles in the triangle formed by the two normals at P and Q and the line PQ add up to 180°. The angle between the two normals is 90°. If x is the angle of incidence at Q, $x + 25° + 90° = 180°$ so $x = 65°$.
iii As angle x is greater than the critical angle of the block, the light ray undergoes total internal reflection at Q so it does not enter the air at Q.

Answers to end of chapter examination-style questions

1 a i Rays only appear to come from it/rays do not pass through it (1); cannot be formed on a screen. (1)
ii It is 'the wrong way round' or words to that effect BUT NOT upside down. (1)
b i Image 1 is 1 m behind mirror A (1); image 1 is 2 m behind mirror B (1); distance = 6 m. (1)
ii Image 1 in mirror B acts as virtual object for mirror A (1); image 1 in mirror A acts as virtual object for mirror B, whose image acts as object for mirror A etc. (1)

2 a i Light waves slow down on entering the other medium (1); the end X of the wavefront reaches the boundary first and so slows down first (1); this changes the direction of the wavefront downwards/towards the normal. (1)
ii If the wavefront is parallel to the interface. (1)
b i Normal correctly drawn (1); angle between normal and incident ray marked angle of incidence (1); angle between normal and refracted ray marked angle of refraction. (1)
ii A protractor (1)
iii Calculate the sines of all the angles (1); divide sin(i) by sin(r) for each pair of values (1); take the average of sin(i)/sin(r). (1)
iv Refractive index = sin 35/sin 22 (1)
= 1.53 (1)
sin C = 1/1.53 (1)
C = 41 degrees (1)

3 a i total internal (1); reflection (1)
ii endoscope; in phone cables; etc. (2)
b i The normal (1)
ii Ray bends away from the normal (1); with arrow to show direction. (1)
iii Critical angle (1)
iv Total internal reflection with angle of reflection equal to angle of incidence, judged by eye. (1)

4 a i Correct refraction at the first surface – towards the normal (1); correct refraction at the second surface – away from the normal. (1)
ii Orange is refracted/slowed down more than red (1); violet refracted most (1); so you would see a spectrum/dispersion. (1)
b Light must be travelling into a less dense medium (1); and the angle of incidence must be greater than the critical angle. (1)
c Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: two bundles of optical fibres; inserted through the throat; one bundle to shine light into the stomach; the other to carry light back to the observer; the lens forms an image on the end of the fibres; the process involved is total internal reflection; surgery is invasive; X-rays pose health risks. (6)

11 Lenses and the eye

11.1

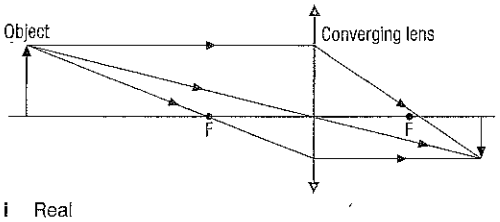
1 a A real image is formed where light rays from an object meet. A virtual image is formed where light rays from an object appear to originate from.
b i A real image
ii A virtual image
iii A virtual image

2 a Upright, enlarged and virtual.
b i Inverted, magnified and real.
ii The slide must be moved towards the screen.
c i ×3
ii The magnification would increase until the flower is at the focal point of the lens when no image is seen.

3 a The image is real, inverted and enlarged. Magnification ×3.
b The image would be smaller than it was and would still be upside down.

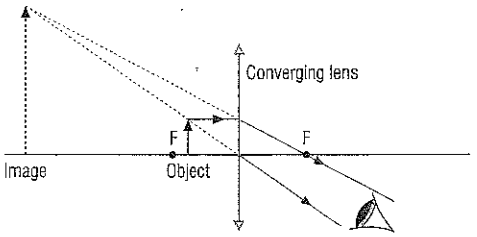
11.2

1 a



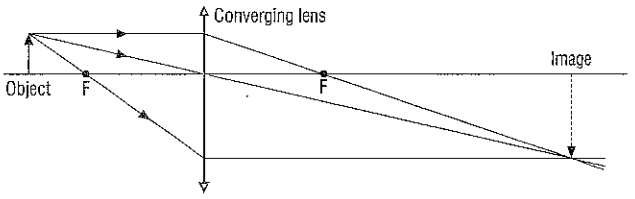
b i Real
ii Diminished
iii Inverted

2 a



b i Virtual
ii Magnified
iii Upright
c A diverging lens produces images smaller than the object.

3 a



b f = 1.8 cm
c The nearer the object is to the focal point, the further the image would be from the lens and the larger it would be. At the focal point, no image would be formed (because the rays from it that pass through the lens would be parallel).

11.3

1 a +0.220 m
b i +0.033 m
ii Real

2 –0.204 m

3 a –0.017 m
b Virtual

11.4

1 a i Alters the thickness of the eye lens to alter its power.
ii Focuses light onto the retina.
iii Allows light to enter the eye after passing through the cornea.
iv Joins the eye lens to the ciliary muscles.
v Protects the front of the eye and refracts light.
vi Controls the width of the pupil so controlling the amount of light passing through the eye lens.
vii Layer of light-sensitive cells on which the image is formed.
b It widens in darkness to allow as much light as possible to pass through the eye lens.

2 a Each eye lens becomes thinner.
b The power of each eye lens decreases.

3 a The iris becomes narrower so the pupil is not as wide and less light passes through to the retina.
b The aperture stop is made narrow so less light passes through it to the camera film or CCD.

11.5

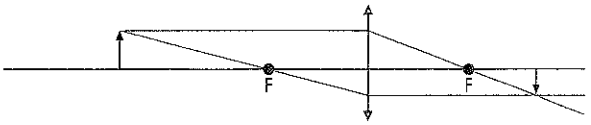
1 a Short sight.
b A diverging lens.

2 a The lens is a converging lens with a focal length of 50 cm.
b The sight defect is long sight. It may be caused by an eyeball that is too short or an eye lens that is not strong enough.
c The eye lens does not have enough focusing power to focus a near object on the retina. Making the cornea flatter would decrease the effective focusing power of the lens. This would worsen the sight defect.

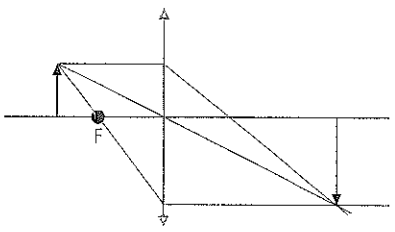
3 a The lens with the higher refractive index would be flatter.
b i +2.0 D
ii –2.5 D

Answers to end of chapter summary questions

1 a i converging
ii

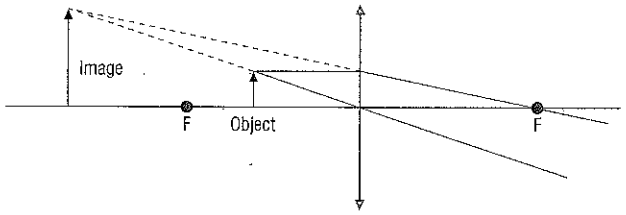


b Real, inverted and smaller than the object; camera.

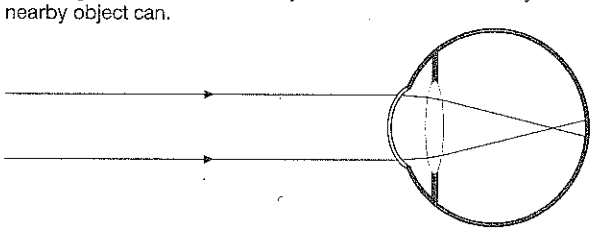
2 a 

b i Real
ii Inverted
c 2.0
d 300 mm

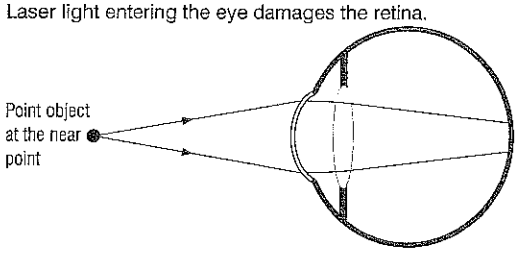
3 a See 10.2 Figure 4
b i Virtual
ii Inverted
c 53 mm

4 a 

b i 12.5 cm
ii 0.50 m from the lens on the same side as the object.
c i Virtual
ii Upright

5 a i Short-sight is where a distant object can not be seen clearly but a nearby object can.
ii 

b i Diverging
ii –1.25 D
c i The cornea. It is made slightly thinner so it becomes flatter at the front surface.
ii Laser light entering the eye damages the retina.

6 a i 

ii When a long-sighted eye views a near object, the eye lens is unable to focus the light rays on the retina. The image would be formed behind the retina. The eye lens is too weak to focus light from the object onto the retina. A blurred image is therefore seen.
b i A converging lens is needed
ii +0.50 D

Answers to end of chapter examination-style questions

1 a i Diagram showing rays parallel to the principal axis (1); brought to a point on the axis (1); distance from point to the lens marked 'focal length'. (1)
ii Diagram showing rays parallel to the principal axis (1); diverging from a point behind the lens (1); distance from point to lens marked 'focal length'. (1)
b i The ray parallel to principal axis passing through F (1); ray from top of object to centre of lens going straight on (1); both rays dotted back to where they meet (1); line from this point vertically down to axis labelled 'image'. (1)
ii M = height of image/height of object OR = image distance/object distance (1) = 2 OR their height of image/10 OR their image distance/5 (1)
iii magnified (1); upright (1); virtual (1)
c i Two (1 mark each) from: both have light-sensitive detectors; both form real images; both can focus objects at different distances; both form diminished images; both have inverted images.
ii Camera moves the lens (1) away from the film for near objects (1); eye changes the curvature/focal length/power of lens (1); more curved/shorter focal length/more powerful for near objects. (1)
iii Two (1 mark each) from: camera has a film or CCD ; eye has light sensitive retina; camera has an adjustable aperture; eye has an iris.

2 a

Device	Nature of image
Camera	real; magnified; inverted
Magnifying glass	virtual; magnified; upright
Projector	real; diminished; inverted

(3)

b i 0.1 cm (1)
ii mean v = 13.3 cm (1)
1/f = 1/u + 1/v OR 1/f = 1/40 + 1/13.5 (1)
= 0.099 (1)
f = 10.1 cm (1)
iii Calculate f for each pair of u and v values (1); take the average. (1)
iv Object inside F (1); virtual image formed (1); cannot be formed on a screen/rays do not pass through the image. (1)

3 a A = iris (1); B = retina (1); C = optic nerve (1); D = cornea (1); E = pupil (1)
b Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: iris controls the size of the pupil; in dark conditions, pupil has larger diameter OR the converse for light conditions; ciliary muscles alter the shape of the lens; making it more curved for nearer objects; increasing the power of the lens; making the focal length shorter; so that diverging rays from object are brought to a focus on the retina; eye at rest/muscles relaxed the eye lens can focus parallel light on the retina; i.e. light from a distant object. (6)
c i Short sight (1)
ii Concave/diverging (1)
iii f = 1/D OR f = 1/–2.5 (1)
= [100/2.5] cm (1)
= 40 cm (1)

12 Red-shift

12.1

1 a i Receding
ii Approaching
b The light from Andromeda shows a blue-shift which means Andromeda must be moving towards us.

2 a Earth, Sun, Andromeda galaxy, universe.
b i Their red-shift is of the same order of magnitude as that of the distant galaxies. Since red-shift depends on distance, this means that quasars can be as far away as the distant galaxies.
ii The power of a quasar is the same as that of billions of stars in a galaxy but a quasar is much smaller object than a galaxy so the power of a quasar is much greater.

3 a The light from a light source (e.g. galaxy) that is moving away from us is increased in wavelength due to the motion of the source moving away from us. This increase in wavelength is called a red-shift.
b i Y
ii X

12.2

1 a The Big Bang theory holds that the universe was created in a massive explosion about 13 billion years ago.
b They had no evidence for a massive explosion and they could explain Hubble's finding that the universe is expanding by assuming that the universe has always existed and is expanding because matter is entering it and pushing the galaxies apart.
c Cosmic background microwave radiation provided evidence that the universe was created in a massive explosion.

2 C D A B

3 a The distant galaxies are accelerating away from each other.
b The universe would stop expanding and go into reverse, ending in a Big Crunch.

Answers to end of chapter summary questions

1 a galaxy, wavelengths
b away, universe
c wavelength, shorter

2 a i the Big Bang
ii away from each other
iii billion .

b i Electromagnetic radiation created as gamma radiation just after the Big Bang.
ii The expansion of the universe discovered by Hubble is due to the Big Bang, a massive explosion in which the universe was created.

3 a i An increase.
ii Red light has a longer wavelength than any other colour of light. The wavelength of the light is made longer by the motion of the galaxy and is shifted towards the red part of the spectrum.
iii The galaxy is moving away from us. The speed of the galaxy can be deduced from the amount of the red-shift.
b The galaxy is moving towards us.
c i The universe is expanding.
ii The discovery of cosmic microwave background radiation.

4 a i Galaxy **A**.
ii Galaxy **C** is further away than galaxy **A**.
b i It is expanding.
ii We are not in any special place.

5 a i **X**, because it appears smaller than **Y** as seen from the Earth.
ii **X**, because it is further away than **Y** so it is moving faster and has a larger red-shift than **Y**.
b **Z** is moving away faster than **X** is because **Z** has a larger red-shift. **Z** must be a larger galaxy than **X**.

6 a 0.05 metres per second.
b 0.50 metres per second.

Answers to end of chapter examination-style questions

1 a i Sound gets louder as car approaches (1); when car going away it gets softer (1); and lower pitch/frequency. (1)
ii Travelling at same speed as police car.(1); in same direction (1); no relative motion. (1)
b Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: source moving relative to observer; waves produced at constant rate/frequency; on approach, waves 'squashed'; wavelength reduced; frequency heard is higher than that emitted; velocity the same; opposite happens when receding; waves 'stretched'; wavelength increased; frequency heard is higher than that emitted; volume changes because waves spread out; less far when approaching; further when receding. (6)

2 a i Light waves stretched out so wavelength shifted to red part of spectrum. (1)
ii Doppler effect of galaxies moving away from our galaxy. (1)
iii M99 (1)
b i Three of (1 mark each): there was an explosion; from very small initial point; billions of years ago; universe has been expanding ever since.
ii Four of (1 mark each): red-shift means galaxies are moving away; the further away the bigger the red-shift; the bigger the red-shift the faster it is moving; most distant galaxies moving fastest; suggests universe is expanding; from a point.

3 a i blue-shift (1)
ii D (1)
iii B (1)
iv Speed: stayed the same (1); Frequency: decreased (1)
b The other astronomers used a larger range of distances/galaxies at a greater distance (1); and greater range of speeds/galaxies travelling at higher speeds (1); data revealed a clearer pattern/definite relationship(1); suggests that the speed is directly proportional to distance. (1)
c i Straight line drawn on graph passing through (0, 0) (1) gradient = $\Delta y/\Delta x$ OR substitution (1) = answer in the range 55 to 65 km/s per megaparsec. (1)
ii Points much closer to a straight line (1); bigger range of galaxies (1); more accurate value for the Hubble constant. (1)

13 Kinetic theory

13.1

1 a Vaporisation
b Freezing
c Melting

2 a Condensation
b Evaporation/vaporisation
c Melting
d Freezing

3 a The particles start to move about each other at random and are no longer in fixed positions.
b The particles in water vapour are not in contact with each other except when they collide and they move about at random. When water vapour condenses on a cold surface, the vapour particles lose energy when they collide with the surface and they stick to the surface as a film of liquid. The particles in film move about at random in contact with each other.

13.2

1 The small bucket warms up faster because the mass of water in it is much less than in the large bucket.

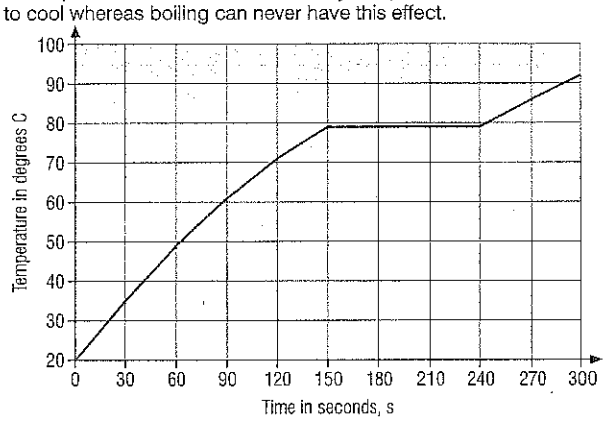
2 a Lead has a lower specific heat capacity than aluminium. Less energy is needed by lead for a given temperature rise.
b i 4500 J
ii 42 000 J
iii 46.5 kJ
c 25.6

3 A storage heater contains bricks or concrete that are heated by the heater element. A radiant heater does not contain bricks or concrete.
A storage heater transfers energy to the surroundings gradually. A radiant heater transfers heat instantly.

13.3

1 Boiling takes place at a certain temperature whereas evaporation occurs from a liquid at any temperature; boiling takes place throughout a liquid whereas evaporation is from the surface only; evaporation can cause a liquid to cool whereas boiling can never have this effect.

2 a i



ii 79 °C
b At 60 °C the substance is solid. Once it reachers 79 °C it begins to melt. After 90 seconds it has all melted and the liquid then increases in temperature to 90 °C.

3 Salt and water on the road forms a solution which will not freeze on the road unless the temperature drops below the freezing point of the solution. So no ice forms on the road unless the temperature drops below the freezing point of the solution. If the solution does freeze, grit helps to stop vehicles sliding as it provides friction between the tyres and the ice.

13.4

1 a 0.044 kg
b 340 kJ/kg

2 a 2.3 MJ/kg
b Energy was transferred from beaker to the surroundings. Therefore not all the energy supplied to the heater was used to boil the water as some was transferred by heating to the surroundings. The specific latent heat value obtained from the data would have been less as the energy needed to boil away the water was less than 18 400 J.

3 a 3020 J
b $E = \dot{m}C\theta = 0.008 \times 4200 \times 9 = 302.4$ J = 300 J (2 s.f.)
c 340 kg/kg

Answers to end of chapter summary questions

1 a i The substance was a solid from A to B and its temperature increased towards its melting point as it was supplied with energy.
ii The substance melted from B to C and its temperature did not changed until all of it had melted.
iii The substance was liquid from C to D and its temperature increased as it was supplied with energy.
b 78 °C
c From A to B the particles are in contact with each other and they vibrate about fixed positions. As the temperature increases the vibrations increase. From B to C, more and more of the particles break away from the fixed positions and move about at random. From C to D, the particles have all broken free and they move about at random in contact with each other.

2 a i 101 MJ
ii 2 MJ/s
b If the water was pumped at a slower rate, the temperature increase would be greater.

3 a 13 kJ

b The temperature of the air leaving the heater would decrease as the mass of air flowing through it each second would be greater and the energy supplied to it each second is unchanged.

4 **a** 6300 J
b 14 J/s

5 **a** 90 kJ
b 0.039 kg

6 **a** $E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 1200 \times (30)^2 = 540\,000$ J = 0.54 MJ
b 60 °C

Answers to end of chapter examination-style questions

1 **a** **i** Boiling point (1)
ii Any three (1 mark each) from: some escapes into the air; some is used to warm the gauze; some is used to warm the beaker; it spreads out.
iii Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: during OA the molecules gain energy; they vibrate more; some have sufficient energy to break free of the structure; the ice melts; during AB the molecules of liquid gain energy to move about faster; some gain enough energy to escape; the water evaporates; BC all the molecules have enough energy to escape; the water boils. (6)
iv Data is recorded continuously/frequently (1); greater resolution. (1)

2 **a** Energy needed depends on the mass (1); half the mass, half the energy needed/energy proportional to the mass. (1)
b $E = m \times c \times \theta$ OR $= 8 \times 4200 \times 20$ (1)
$= 672\,000$ (1)
$= 672$ kJ (1)

3 **a** **i** large mass per unit volume (1); large specific heat capacity. (1)
ii $E = m \times c \times \theta$ (1)
$\theta = E/(m \times c)$ OR $= 540\,000/(12 \times 900)$. (1)
$= 50$ °C (1)
iii It will be less (1); because some energy is not absorbed by the bricks (1); some is lost to the surroundings. (1)
b **i** It is lighter/portable (1)
ii It stores more energy (1)

4 **a** **i** Mass evaporated = 16 g (1)
= 0.016 kg (1)
$L = E/m$ OR $= 36\,800/0.016$ (1)
$= 230\,000$ J/kg (1)
ii Put lagging round the beaker. (1)

14 Energy transfer by heating

14.1

1 **a** Plastic and wood do not conduct by heating, so a plastic or wooden handle would not become hot when the pan was hot. A steel handle would become as hot as the pan as steel is a good conductor.
b Felt because it contains fibres that trap layers of air and dry air is a good insulator.

2 **a** Felt or synthetic fur could be used, because they are good insulators.
b Student's plan. Look for design of a fair test.

3 **a** The free electrons that gain kinetic energy diffuse through the metal quickly, passing on energy to other electrons and ions in the metal.
b When part of an insulator is heated, the atoms there vibrate more than elsewhere and they make atoms in adjacent parts vibrate so these parts become hot. The atoms in these parts make the atoms in adjacent colder parts vibrate so these colder parts become hot. Energy is therefore transferred through the non-metal.

14.2

1 Hot gases from the flame heat the base of the pan. Energy is transferred by conduction through the base of the pan to heat the water in contact with the base. The water at the base rises because it becomes less dense when it is heated. The rising water makes the water throughout the pan circulate through convection currents and colder water sinks to the base where the colder water is heated so it rises and causes the circulation to continue until the water throughout the pan is hot.

2 **a** It heats it reducing its density so it rises.
b The hot air passes through the grille into the room.
c Cold air flows into the heater at the bottom.

3 **a** Drop the crystal into a beaker of water through a tube. Heat gently under one corner. The colour rises above point of heating and travels across the top and falls at opposite side of beaker (where density of cooler water is greater). The colour then travels across the bottom of the beaker to replace lower density warmer water that rises above the Bunsen flame.
b Air in contact with the radiator is heated so it rises and circulates in the room. The air in the room becomes warmer as a result. The rising air against the radiator is replaced by cold air so the cold air is then warmed and it circulates. All parts of the room therefore become warm. If the radiator was elsewhere, warm air from the radiator that circulates and reaches the top of the window would become cold and move down the window, becoming colder as it transferred energy by heating to the cold window. People near the window would feel colder than elsewhere in the room.

14.3

1 **a** Water particles in the surrounding air collide with atoms on the cold surface and lose energy as a result. They are held on the surface by the surface atoms to form a film of liquid.
b The more energetic particles in the water escape from the liquid at the surface. The average energy of the remaining liquid particles becomes lower as a result. So the temperature of the liquid decreases.

2 **a** The air in the bus becomes damp as everyone breathes out warm water vapour. The water vapour condenses on the inside of the windows.
b When the door is opened, warm air carrying water vapour enters the refrigerator. The water vapour now in the refrigerator condenses on the cold walls of the inside of the refrigerator and runs down the walls to the drip tray. If the door is opened too often, water vapour keeps entering the refrigerator and condensing so filling the drip tray.

3 **a** Water evaporates faster from the wet clothes on a hot day than on a cold day because more energy is transferred to the clothes by the warmer air leading to a faster rate of evaporation.
b Evaporation of water from the wet clothes on a windy day transfers more energy from the skin, which makes the wearer colder than someone wearing dry clothes.

14.4

1 **a** Electromagnetic radiation emitted from the surface of objects due to their temperature.
b The city is hotter than the rural areas surrounding it because the hotter an area of a surface is the more infrared radiation it emits. This may be due to the greater amount of energy being used in urban areas.

2 **a**

Object	Infrared	Light
A hot iron	✓	✗
A light bulb	✓	✓
A TV screen	✗	✓
The Sun	✓	✓

b Put your hand near it and see if it gets warm due to radiation from the iron.

3 **a** They lose less heat through radiation when they huddle together because they radiate energy to each other.
b The wavelength is short enough to enable the radiation to pass through the prism and lies just below the red part of the visible spectrum.

14.5

1 **a** The sand grains provide a rougher and darker surface than ice and can therefore absorb more infrared radiation from the Sun. They therefore warm up and melt the surrounding ice.
b A matt black surface absorbs infrared radiation from the Sun better than any other type of surface.

2 **a** The black surface absorbs more infrared radiation from the Sun than the silver surface.
b As the cars are identical except for their colour, the black car would cool faster because it radiates more infrared radiation than the silver car. However, the temperature in both cars would probably decrease to the same value which would be the temperature of the surroundings.

3 **a** To make the test fair. The temperature recorded will differ at different distances from the cube as the radiation spreads out.
b **i** B
ii D
c Greater accuracy, collects multiple sets of data at whatever time intervals you choose.

14.6

1 Energy transfer from the hot water to the outer surface of the radiator takes place due to conduction. Air in contact with the radiator surface is heated by infrared radiation and conduction. The hot air near the radiator rises and circulates causing energy transfer to the air in the room by convection.

2 a i To prevent the component overheating.
ii Metal is a good conductor. The heat sink is plate-shaped to increase its surface area, so it transfers energy to the surrounding air as effectively as possible.
b Plan must have a fair system that compares a single plate of glass to a pair of plates, ideally with a sealed air gap between.
3 a Student's explanation to include the role played by the plastic cap, double-walled plastic container, silvered inside surfaces, vacuum layer.
b Water vapour from the warm water condenses on the frosted surfaces in the freezer and releases energy in the process which transfers by conduction to the frost and causes it to melt.

14.7

1 When the oven heats up, the brass tube expands more than the Invar rod. When the oven overheats, the difference in the expansion of the brass tube and the Invar rod is sufficient to move the valve so it closes the large opening between the two parts of the chamber.
2 a Without expansion gaps between sections of concrete, adjacent sections would make contact and push against each other and the concrete would crack.
b Rubber in the expansion gaps prevents rubble falling into the gap. If rubble fell into the gap, the concrete sections either side of the gap would be unable to expand and the sections would push via the rubble on each other.
3 a The bimetallic strip consists of two different metals fixed to each other. One of the metals expands more than the other when the temperature of the strip is increased. As a result the strip bends.
b The bimetallic strip should be reversed so it bends away from the contact screw when its temperature increases instead of bending towards it. The contact screw should be adjusted so it remains in contact with bimetallic strip until the required 'switch off' temperature is reached.

Answers to end of chapter summary questions

1 a i The temperature variations causes the roofing material to expand and contract. If the temperature variations are great enough, this repeated expansion and contraction would cause small cracks to develop.
ii A smooth shiny surface is better because it would reflect sunlight and would therefore not get as hot in sunlight. It would also radiate less energy to the surroundings at night.
b The panel with the transparent cover would reflect sunlight and the fluid in the panel would absorb some radiation so not as much radiation would be absorbed by the matt black surface. However, the matt black surface would heat the fluid in the panel directly. The panel with the matt black cover would absorb sunlight very effectively so it would become warmer in sunlight than the base of the other panel. However, it would need to be an effective conductor to heat the fluid underneath effectively and it would also emit radiation into the surrounding air. The panel with the matt black cover would probably be more effective further form the equator as the Sun is lower in the sky.
2 a i By conduction through the plate.
ii By radiation and convection in the air.
b The fins increase the surface area of the heat sink. The larger the surface area, the greater the energy loss due to radiation and convection from the plate.
c The greater the density of the material, the larger the mass of the heat sink will be. The greater the mass and specific heat capacity of the material, the lower the increase of temperature will be for a given amount of energy transferred by heating to the heat sink.
3 a i Energy transfer from the hot water in the radiator takes place due to convection. Energy transfer through the radiator metal takes place due to conduction. Energy transfer from the outside of the radiator takes place due to convection in the air and radiation from the radiator surface.
ii Air between the panels becomes hotter than the air near the panels on the outside of the radiator. The hot air in the gap rises and is replaced by cooler air drawn in to the gap at the bottom of the panels. The hot air from the radiator circulates in the room.
b Radiation from the heater element rapidly heats the outer surface of the bricks. The inside of the bricks slowly become warmer due to conduction and therefore store energy by heating. When the heater is switched off, the outer surface of the bricks emits radiation to the surroundings so it becomes cooler than the interior. Conduction from the hot interior to the surface takes place gradually so the interior gradually cools down.
4 a Wool fibres is a good insulator as the fibres are made of insulating material and they trap dry air which is a good insulator. The inside of the clothing becomes warm due to radiation from the body. The body inside stays warm because the clothing does not conduct energy away from the inside.
b In cold weather, radiation from exposed skin causes energy transfer from the head. Hair is a insulator and it contains some trapped air so it does reduce some conduction. Wearing a hat cuts out radiation from exposed parts of the scalp and reduces conduction by providing extra insulation.
c The surface area of the ear is relatively large in relation to its mass. In normal conditions, radiation from your ears is balanced by radiation received from the surroundings by the ears. In very cold weather, energy received is significantly less so the ears radiate more energy than they receive. Because their surface area is so large in relation the their mass, they soon cool down.
5 a Their clothing becomes damp due to sweat and cooling by evaporation occurs so the clothing and hence the skin becomes cold.
b i Infrared radiation
ii The reflective coating traps infrared radiation in the space between the body and the blanket so the space becomes warmer. The warm air in the space keeps the body warm.
6 a i The water heated at the bottom rose to the top causing convection in the tube and melting the ice cube at the top.
ii The water was warmed at the top and stayed there as it is less dense than cold water. Conduction through the water eventually made the water at the bottom warm, and then the ice cube melted.
b 2 Energy transfer in water is mainly due to convection.

Answers to end of chapter examination-style questions

1 a i diameter of rods (1); length of rods. (1)
ii Energy makes the wax melt (1); the first pin to drop was on the best conductor. (1)
b i Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: heated water expands; becomes less dense; heated water rises; the colder water at the top is denser; colder water falls; setting up a convection current (6)
ii Any five of (1 mark each): metal is a good heat conductor; because there are free electrons in its structure; the free electrons near the inside surface gain KE; they move faster; and collide with electrons and ions nearer the outside; transferring some energy; outer surface warms up.
c i For example in bridges/roads (1); by leaving a small gap for expansion to take place safely. (1)
ii A fire causes the temperature of the strip to rise (1); the metals in the strip expand (1); brass expands more than steel (1); top of str bends to the right (1); making contact at the contact screw (1); completes circuit/bell rings. (1)
2 a absorbers (1)
b reflectors (1)
c Large surface area; facing south; angled at 45 degrees to horizontal (1)
3 a i nature of the surface of the mug (1); surface area of the mug (1); temperature of the water (1); temperature of the surroundings. (1
ii The mass of the water (1); the specific heat capacity of water. (1)
b The petrol evaporates (1); the most energetic molecules escape (1); the mean kinetic energy of the molecules is reduced (1); temperatur is proportional to the mean kinetic energy. (1)
c i Larger area (1); warmer temperature (1); both increase the rate o evaporation. (1)
ii Particles of water experience forces of attraction (1); closer together than in vapour (1); have less energy than in the vapour. (1)

15 Energy transfers and efficiency

15.1

1 a The brake pads becomes hot due to friction. Energy transfer from th brake pads to the surroundings by heating. Sound waves created b braking also transfers energy to the surroundings.
b Kinetic energy of the roller coaster is transferred to gravitational potential energy of the roller coaster and to kinetic energy of the air as the roller coaster goes up the hill. Gravitational potential energy is transferred to kinetic energy and the air as the roller coaster descends.
2 a **On descent:** Gravitational potential energy → kinetic energy + ene heating the surroundings due to air resistance.
On impact: Kinetic energy → elastic energy of trampoline + energy heating the surroundings due to impact + sound.

On ascent: Elastic energy of trampoline → kinetic energy → gravitational potential energy + energy heating the surroundings due to air resistance.

b The ball has less energy at the top of its bounce than at the point of release.

c Use a clamp to hold a metre ruler vertically over the middle of the trampoline surface. Hold the ball next to the metre ruler with its lowest point level with the top of the ruler. Release the ball so it rebounds vertically and observe the highest level of the bottom of the ball against the metre ruler after the rebound. Repeat the same test several times to obtain the average rebound position of the ball. Repeat the test with the same ball for the other two trampolines. The one with the highest rebound position is the bounciest.

3 Elastic energy of the rubber straps is transferred to kinetic energy of the capsule. This kinetic energy is transferred to gravitational potential energy as the capsule rises to the top of its flight etc.

15.2

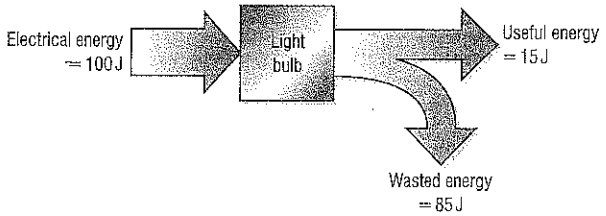
1 **a** Wasted: sound, kinetic energy of the air.
b Useful: light and sound. Wasted: heat.
c Useful: boils the water. Wasted: heat loss through surfaces, sound.
d Useful: sound. Wasted: heat loss.

2 **a** The gear box would heat up due to energy transfer through friction between the gears. The hotter the gear box gets, the less efficient the gears will work.
b The shoes would heat up due to energy transfer by conduction and infrared radiation from the feet. The feet would transfer less energy as the shoes warm up so the feet would become hotter.
c The drill would heat up and smoke if it burns the wood.
d The discs would heat up due to energy transfer by friction between the discs and the brake pads from the kinetic energy of the moving parts of the car.

3 **a** As the pendulum swings towards the middle, its gravitational potential energy decreases and its kinetic energy increases. As it moves from the middle to the highest position on the opposite side, its kinetic energy transfers back to gravitational potential energy. Air resistance acting causes some of its kinetic energy to be transferred to the surrounding as heat.
b Air resistance causes friction as the pendulum swings. This produces heat and so the pendulum transfers energy to the surroundings and stops.

15.3

1 **a** 85 J
b It is transferred by conduction to the surroundings
c



2 **a** 36 J
b 40%

3 **a** 800 J
b 50 W

15.4

1 **a** Cavity wall insulation conducts much less energy than air especially if the air is damp. It prevents energy transfer by radiation and convection across the cavity.
b The foil reflects infrared radiation from the radiator so preventing absorption of radiation by the surface of the wall behind the foil.

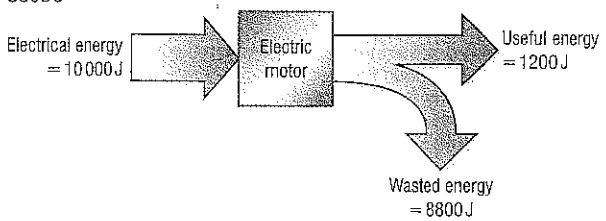
2 **a** Plastic is a poor conductor. Metal is a good conductor. Energy transfer through a metal frame would therefore be greater than through a plastic frame.
b Energy transfer due to conduction and convection takes place in the space between the panes if the space is filled with air but not if there is a vacuum there.
c The window which has the lower U-value is better because less energy per second passes through it for the same temperature difference.

3 **a** £180
b £60
c 3 years

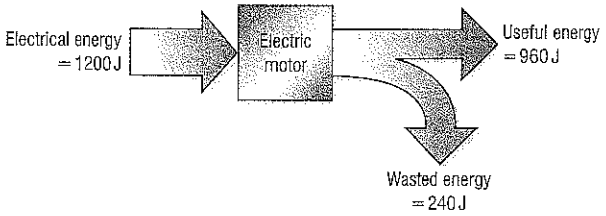
Answers to end of chapter summary questions

1 **a** electrical, light, useful, wasted
b **i** 18%
ii 369 kJ

2 **a** **i** 1200 J
ii 12%
b **i** 8800 J
ii



3 **a** **i** 960 J
ii 240 J
iii



b 5040 J

4 **a** Gravitational potential energy is transferred to kinetic energy of the block as the block falls. On impact, some of the energy of the block is transferred to kinetic energy of the girder and some is transferred to the surroundings as sound energy. In addition, some of the energy of the block is transformed in the block and the girder into energy by heating.
b **i** 9000 J
ii 1800 W

5 **a** **i** 1500 J
ii 13 500 J
iii 10%
b **i** Apply oil to the bearings of the motor and the pulley to reduce friction.
ii Friction or air resistance can never be completely eliminated from the motor. In addition, the motor becomes warm due to the heating effect of the electric current passing through it.

6 **a** U-value is the energy per second that passes through each square metre of material when the temperature difference across it is 1 °C.
b Energy transfer through each square metre is 6.4 times greater through the window than through the wall. The walls are better insulators than the windows due to a combination of the substances used, design and construction as well as the thickness. However the wall area is 7 times that of the window so more energy passes through the walls than through the window.
c **i** Cavity wall insulation is when the cavity between the two layers of bricks in an outer wall is filled with an insulating foam which traps air in small pockets reducing convection.
ii The payback time is the time taken for the cost of the cavity wall insulation to be repaid from the reduction of the heating costs.

Answers to end of chapter examination-style questions

1 **a** A = 4; B = 2; C = 3; D = 1 (4)
b Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: at the start, the ball has gravitational potential energy; as it falls, this transfers to kinetic; when it hits the table, some is transferred to sound; and by heating; warming the table; this energy spreads out/is dissipated; as the ball bounces up, kinetic is transferred back to gravitational potential; but since some has been lost in the impact; it does not regain its original height. (6)

2 **a** **i** light (1)
ii electrical (1)
iii kinetic (1)
b Energy cannot be created or destroyed/the total amount of energy before and after a transfer is the same. (1)
c **i** 38 J (1)
ii 2 J (1)
iii 60 J (1)
iv 0.38 or 38% (1)

3 **a** **i** Conduction (1)
ii (3000/7000) × 100 (1)
= 42.6% (1)
iii To maintain the temperature, energy must be supplied at the same rate at which it is being lost (1); 7000 W. (1)
b **i** Loft insulation (1)
ii Loft insulation (1)
iii Payback time = 1100/400 (1) = 2.75 years (1)

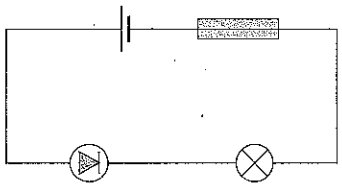
16 Electricity

16.1

1 a i Electrons transfer from the cloth to the polythene rod when the rod is rubbed with the cloth.
ii Electrons transfer from the perspex rod to the cloth when the rod is rubbed with the cloth.
b Glass loses electrons.
2 a Attraction
b Attraction
c Repulsion
3 a X and Y have the same type of charge.
b Suspend R horizontally on the end of a thread and then charge R by rubbing it with a dry cloth. Charge X and hold it near R. If it repels R, X is also positive. If X attracts R, X is negative. Y has the same type of charge to X.

16.2

1 1 = cell; 2 = switch; 3 = indicator; 4 = fuse
2 a



b A variable resistor.
c 15C
3 a A light-emitting diode is a diode that emits light when current passes through it.
b A variable resistor is used to change the current in a circuit.

16.3

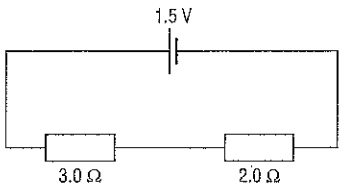
1 a 8.0Ω
b 10.0Ω
2 W: 6.0Ω; X: 80 V; Y: 2.0 A
3 a 50Ω
b i 18C
ii 54J

16.4

1 a i Thermistor
ii Diode
iii Filament bulb
b i 5Ω
ii 10Ω
2 a 15Ω
b The ammeter reading increases because the resistance of the thermistor decreases.
3 a When the LDR is covered, its resistance increases. The current decreases because the resistance of the LDR increases and the potential difference across the LDR is still 3.0 V.
b i The current is zero until the potential difference is about 0.7V then the current increases rapidly.
ii The resistance is very large until about 0.7V then it decreases rapidly.

16.5

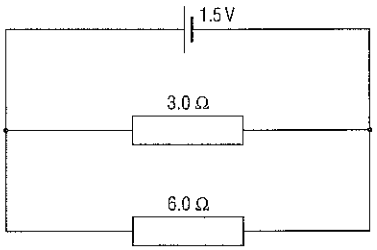
1 a 0.4V
b 0.20A, 0.5V
2 a



b i 5.0Ω
ii 0.3A
3 a i 12Ω
ii 3.0V
b $\frac{3V}{12\Omega} = 0.25A$
c P = 0.5 V, Q = 2.5 V
d i 15Ω
ii 0.20A
iii P 0.40V, Q 2.00V, R 0.60V

16.6

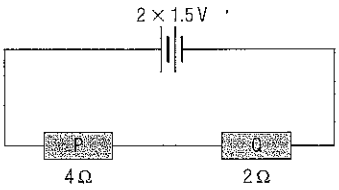
1 a 0.30A
b The 3Ω resistor.
c 0.60Ω
2 a



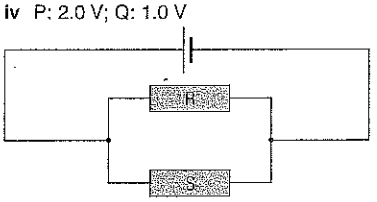
b i Current = 1.5 V/3Ω = 0.50A
ii Current = 1.5 V/6Ω = 0.25A
c Cell current = 0.5 + 0.25 = 0.75 A
3 a i I_1 = 3.0A; I_2 = 2.0A; I_3 = 1.0A
ii Current through the battery = 6.0A
b 6.5A

Answers to end of chapter summary questions

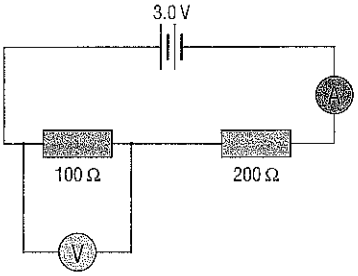
1 The resistance increases when the current is increased. This is because the increase of current makes the bulb hotter. As a result, the metal ions of the filament vibrate more, so they resist the passage of electrons through the filament more.
2 a Filament bulb
b Resistor
c Thermistor
d Diode
3 a



b i 3.0V
ii 6Ω
iii 0.5A
iv P: 2.0 V; Q: 1.0 V
4 a



b i 1.0A
ii 0.5A
iii 1.5A
5 a Different from, equal to
b Equal to, less than
6 a i 2.0V
ii Potential difference across LDR = 3.0 – 2.0 = 1.0V
iii 100Ω
b i Ammeter reading decreases when LDR is covered as resistance increases.
ii The potential difference across the LDR = $V - (I \times R)$ so the LDR resistance = potential difference across LDR ÷ current I
7 a



b i 300Ω
ii 0.01A
iii 1.0V
iv 100Ω 1.0V; 200Ω 2.0V

8 a i The battery pd of 3.0 V is shared between the LED and the resistor. Since the potential difference across the LED is 0.6 V when it emits light, the potential difference across the resistor is 3.0 – 0.6 = 2.4 V.
ii 0.0024 A
b 200 Ω
c The current would be (almost) zero as the 'reverse' resistance of the LED is very high. The total resistance of the LED and the resistor would therefore be much greater than it was when the LED was in its 'forward' direction so the current would be much less than 0.0024 A.

Answers to end of chapter examination-style questions

1 a i negative
ii uncharged
iii positive
b Electrons are transferred to surface atoms of ruler from the duster (1); ruler has an excess of negative charge (1); duster has a deficiency of electrons (1); so is positively charged. (1)
c Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: friction at the nozzle/connection to + terminal of a supply; causes paint molecules to lose electrons; paint droplets have the same type of charge; so repel each other; causing droplets to spread out forming a fine spray; the opposite charge on the car door; attracts the droplets; to give an even coating of paint. (6)

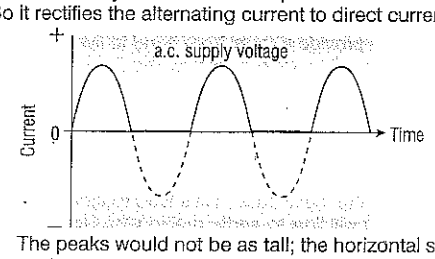
2 a i Correct symbols for battery, switch, variable resistor, resistor (piece of wire), ammeter (2); in series (1); with correct symbol for voltmeter in parallel with resistance wire. (1)
ii So that current only flows when readings are to be taken (1); if current flows all the time, the piece of wire will heat up (1); increasing its resistance. (1)
iii So that a series of results can be obtained (1); and a mean value for resistance calculated/graph plotted. (1)
b i 60 Ω (1)
ii 115 V (1)
c i 230 V (1)
ii 30 Ω (1)
iii 15.4 A (1)

3 a 3 kΩ (1)
b Total R = 5.5 kΩ (1)
I = V/R OR = 6/5500 (1)
= 1.09 mA (1)
c i V = I × R OR = 0.00109 × 2500 (1)
= 2.73 V (1)
ii R at 0 °C = 17.5 kΩ (1)
V = (2.5/20) × 6 (1)
= 0.75 V (1)
iii The potential difference across R increases with temperature (1) so could be used to switch on/off a system when temperature rises (1) thermostat (1); e.g. for cooling system. (1)

17 Household electricity

17.1

1 a 12 V
b 230 V
c 1.5 V
d 325 V
2 The number of cycles on the screen would: **a** increase **b** decrease.
3 25 Hz
4 a Direct current is in one direction only. Alternating current repeatedly reverses.
b The diode only allows current to pass in one direction, its direction. So it rectifies the alternating current to direct current.
c i



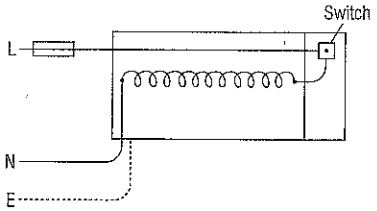
ii The peaks would not be as tall; the horizontal spacing would be unchanged

17.2

1 a i The neutral wire
ii Yellow/green
b i The sockets are in parallel so each of the appliances connected to the sockets can be switched on and off without affecting the other appliances.
ii Brass is a good conductor and doesn't oxidise like copper does. Brass is harder than copper and doesn't deform as easily as copper.
iii The live wire could be exposed where the cable is worn away or damaged.
2 a 1 C; 2 D; 3 A; 4 B
b 1 Rubber is flexible and is an insulator.
2 Stiff plastic is an insulator, it doesn't wear and it can't be squashed.
3 Brass is a good conductor and doesn't deteriorate.
4 Copper is an excellent conductor and copper wires bend easily.
3 a The three wires must be insulated from each other otherwise there would be a dangerously large current in the cable due to the very low resistance between the live wire and the other wires where they touch.
b The earth wire of the cable is connected to a terminal fixed to the metal case. The other end of the earth wire is connected to the earth pin in the three-pin plug attached to the cable. When the plug is connected to a three-pin wall socket, the metal case is therefore connected via the earth wire to the ground.
c The cables to the wall sockets need to be thicker so their resistance is lower and more current passes through them than through the lighting cables. If they were not thicker, the heating effect of the current would be greater and the cables would overheat.

17.3

1 a A fuse protects an appliance or a circuit.
b So it cuts off the live wire if too much current passes through it.
c It is faster than a fuse and doesn't need to be replaced after it 'trips'.
2 a Yes.
b The element is live.
c



3 a i An ordinary circuit-breaker switches the current in the live wire off if the current is greater than a certain value. An RCCB switches the current in the live wire if the current in the live wire and the neutral wire differ.
ii The current in the live wire might be too small to operate an ordinary circuit breaker. An RCCB would operate with a small current in current in the neutral wire and in the live wire differ.
b A RCCB acts faster than a circuit breaker and a fuse and can be used when there is no earth connection.

17.4

1 a 1 W
b 1150 W
c The current through the lamp in normal operation is 0.4 A. A 13 A fuse would not melt if a current greater than 0.4 A passed through it.
2 a i 36 W
ii 460 W
b i 3 A
ii 5 A
3 c i 6.5 V, 169 W
ii 2.8%

17.5

1 a 150 C
b 120 J
c 180 J
2 a i 80 C
ii 720 C
b i 120 J
ii 300 J
c i 150 C
ii 12 J/C from the battery; 8 J/C to the lamp; 4 J/C to the variable resistor.
iii 1800 J from the battery = 1200 J to the lamp + 600 J to the variable resistor.
3 a 12.0 Ω
b 0.50 A
c 30 C
d 4 Ω: 2.0 V; 8.0 Ω: 4.0 V
e 4 Ω: 60 J (= 30 C × 2.0 V); 8.0 Ω: 120 J (= 30 C × 4.0 V)
f 180 J

17.6

1 a 2.4 kWh
b 15 kJ
c £177.80

2 a i 1.5 kWh
ii 0.5 kWh
iii 0.8 kWh

3 a i 4 kW
ii 43.2 million joules (4000 × 3 × 60 × 60)
b i 390 W
ii 51 kWh
iii £6.10

17.7

1 An example of each possible electrical hazard is given in the table.

Appliance	Hazard
Electric drill	The drill might 'hit' a live wire in a cable in the wall.
Electric saw	The saw might cut the cable (or cut a limb).
Hairdryer	Anyone with wet hands using a hairdryer would be at risk.
Vacuum cleaner	The vacuum cleaner might run over and damage its cable.

2 a i The fault needs to be put right or the appliance replaced otherwise a new fuse will melt as soon as the appliance that caused the fault is switched on.
ii Three-core as an iron has a metal base.
b i 30
ii 11
iii 3000 kWh at 10p per kWh = £300
iv Cost of 30 bulbs + electricity = £315; cost of 11 LEDs + electricity = £83; saving = £232

3 a 4.8 A
b The metal case must be 'earthed'. The 3 core cable includes an earth wire for this purpose. A 2 core cable does not have an earth wire.
c i 5 A
ii If a fault develops and the current is much greater than 4.8 A, a higher current fuse such as a 13 A fuse would not blow if the current was less than the fuse rating. Too much current would pass through the appliance and the cables and either the appliance or the cables would overheat.

17.8

1 a i Step-up
ii Step-down
b The grid voltage would be lower than if a transformer was connected. The current through the grid cables would be much greater and a much greater percentage of the power supplied to the grid system would be wasted.

2 a To reduce the energy wasted in transmitting the electricity.
b To reduce the voltage to a safer level for cables inside towns and cities.

3 a i It increases the voltage.
ii It reduces the current.
b i 190 A
ii 10 kW
c Mains devices operate at 230 V. The grid voltage needs to be stepped down by transformers from 132 000 V to 230 V for safe use in our homes.

Answers to end of chapter summary questions

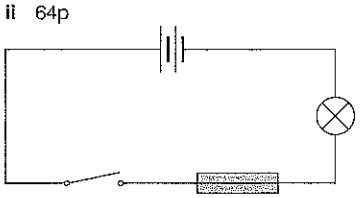
1 a i The neutral wire.
ii The live wire.
b i The waves would be taller as the amplitude would increase.
ii The waves would be closer together as the time for each cycle would be less.

2 a If a live wire touches the case, the case would become live. Anyone touching the case would be electrocuted as an electric current would pass through their body to earth.
b Live – brown, neutral – blue, earth – green/yellow

3 a i parallel
ii series, live
b i A fuse is a thin wire that overheats and melts if too much current passes through it; a circuit breaker is an electromagnetic switch that opens and stays open if too much current passes through it.
ii A circuit breaker works faster than a fuse and can be reset more quickly.

4 a i 11 A
ii 13 A fuse
iii 35 kWh
b i The kettle.
ii 64p

5 a



b i 432 J
ii 108 J
iii 324 J
c i 30 Ω
ii 0.4 A
iii battery 4.8 W; 5 Ω resistor 0.8 W; 25 Ω resistor 4.0 W.

6 a i 3.0 A
ii 600 C
b i $E = P \times t$ = 36 W × 200 s = 7200 J
ii 12 J/C
c i 3.0 A through each bulb; 6.0 A through the battery.
ii Energy supplied per second to each bulb = 36 W = 36 J/s; energy supplied per second by the battery = 12 V × 6.0 A = 72 J/s. Therefore energy supplied per second to the two bulbs = the energy supplied per second by the battery.

7 a 28.7 A
b i D because the maximum safe current through D is greater than the current that would pass through it when the oven operates at full power. So D would not overheat. E would not overheat either but it would be more expensive than D.
ii Cables A, B and C would overheat as their maximum safe current is less than the current that would pass through them when the oven is at full power. The overheated cable might cause a fire. Also, the cable insulation could melt and cause a short-circuit that may start a fire.

8 a i To change the voltage from the power station generator to a suitably high grid voltage and reducing the grid voltage to a suitable mains voltage for our homes.
ii A step-up transformer.
b i The grid voltage is much higher.
ii The current supplied to the grid is much smaller.
iii Power is wasted in the cables due to the heating effect of the current. The less the current, the less the power that is wasted.

Answers to end of chapter examination-style questions

1 a It needs an ac supply (1); needs a potential difference of 230V (1); frequency 50 Hz (1); so mains (1); When on hottest setting, with maximum fan speed it takes 1200 joules of energy per second. (1)
b i No. of kilowatt-hours used = 7198.5 – 6471.5 = 727.0 (1)
Cost = 727 × 0.15 (1)
= £109.05 (1)
ii 2000 W = 2 kW (1)
Cost = 2 × 3 × 0.15 (1)
= £0.90 (1)
c i P = V × I OR 60 = 230 × I
I = 60/230 (1)
= 0.26 A (1)
ii 30 hours = 30 × 3600 s (1)
Q = I × t OR = 0.26 × 30 × 3600 (1)
= 28 080 (1) coulomb/C (1)

2 a One lead (brown/live) is not connected (1); cable grip tightened on leads not outer cable (1) neutral (blue) lead connected to live pin. (1)
b Water conducts electricity/wet hands have lower resistance than dry hands (1); water can provide a route from hand to live pin. (1)
c Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: hairdryer has a plastic case; it is double insulated; if there is a fault and the live lead touches the metal case of the kettle, the case becomes live; anyone touching it will provide a route to earth; they will conduct current; will get an electric shock; the earth lead is connected to the metal case; if live lead touches the earthed kettle, a large current will flow to earth; melting the wire in the fuse; thus breaking the circuit; and rendering the kettle unusable until fault rectified. (6)

3 a LED (1)
b filament lamp (1)
c LED (1)

4 a Time period = 1 cm = 0.02 s (1)
F = 1/T = 1/0.02 (1)
= 50 Hz (1)
b peak potential difference = 1.5 cm (1)
= 3 V (1)

18 Motors, generators and transformers

18.1

1 a i N
ii S
b P is a N-pole; P repels X because it has like polarity and it attracts Y because it has unlike polarity.
2 a N
b S
c Unmagnetised
3 a See 18.1 Figure 4
b i X = N, Y = S
ii The needle of the compass would also rotate in the same direction as the bar magnet.

18.2

1 a See 18.2 Figure 2
b Although both iron and steel can be magnetised, steel does not lose its magnetism when the current is switched off. Iron does lose its magnetism when the current is switched off.
2 C; B; E; D; A
3 a The current through the electromagnet coil magnetises the core of the electromagnet. The armature is pulled on to the core. This opens the make-and-break switch which cuts the current. The electromagnet loses its magnetism and the make-and-break switch closes so the cycle repeats itself.
b The armature of the buzzer has a much lower mass so it moves faster than the bell's armature and it therefore has a higher frequency of vibration.

18.3

1 a When a current passes through the coil of the electric motor, a force acts on each side of the coil due to the magnetic field of the magnet in the motor. The force on each side has a turning effect on the coil and because the current on each side is in opposite directions, the forces on each side are always in opposite directions so the motor turns. Each time the coil passes the position where the coil is at right angles to the magnetic field, the split-ring commutator reverses the connections to the battery so the current round the coil reverses direction. Without the split-ring commutator, the forces would reverse and so the coil would turn back. The action of the split-ring commutator allows the forces to continue to turn the coil in the same direction.
b The force on the loudspeaker coil would be in one direction only with a direct current so the coil would not vibrate.
2 a The current is in the opposite direction to what it would have been so the force on each side is in the opposite direction to what it would have been. The coil therefore rotates in the opposite direction.
b i Faster because the coil is lighter.
ii Faster because the field is much stronger due to the presence of the iron.
3 a The force decreases gradually as the wire is turned and becomes zero when the wire is at right angles to the field lines.
b A force acts on the coil when a current passes through it because it is in a magnetic field. An alternating current causes an alternating force to act on the coil. The coil therefore vibrates because it is acted on by an alternating force. The vibration of the coil makes the diaphragm vibrate which produces sound waves.

18.4

1 a A potential difference is induced in a wire when it cuts across the magnetic field lines of the magnet. The induced potential difference causes a current to pass through the wire and the ammeter while the wire is cutting the field lines.
b The ammeter would show a smaller reading in the opposite direction because the wire cuts across the field lines more slowly and in the opposite direction so the induced potential difference is less and in the reverse direction.
2 a There would be no deflection of the pointer.
b The pointer deflection would be bigger.
3 a The current in X creates a magnetic field which passes through coil Y. The increase of the magnetic field in Y induced a potential difference in Y.
b The magnetic field does not change. A potential difference can only be induced when the magnetic field is changing.

18.5

1 a A potential difference is induced in the coil when the sides of the coil cut across the field lines. The potential difference reverses direction each time the coil is at the position where its sides are moving parallel to the field lines. This happens every half-turn of the coil so one full turn of the coil corresponds to one full cycle of the alternating voltage.
b The alternating voltage would have a greater peak value (i.e. amplitude) and its time period would be less (i.e. its frequency would be greater).
2 a The peak value would be smaller. The waves would be stretched more across the screen.
b The peak value is less because the sides of the coil cut more slowly across the field lines so the potential difference at any position of the coil is less than when the coil spins faster. The waves are more stretched out across the screen because the time for each cycle would be longer.
3 a The split-ring commutator reconnects the coil the opposite way round in the circuit every half-turn each time the coil is perpendicular to the magnetic field lines. As a result, the induced potential difference changes its polarity.
b See 18.5 Figure 4b

18.6

1 a An alternating current is passed through the primary coil. This coil creates an alternating magnetic field that passes through the secondary coil. As a result, an alternating potential difference is induced in the secondary coil.
b i The 4000-turn coil
ii A steel core would not be easily magnetised and demagnetised. When an alternating current passes through the primary coil, a steel core would not produce as strong a magnetic field as the iron core would, so the induced potential difference in the secondary coil would be much smaller.
2 a Direct current in the primary coil would not produce an alternating magnetic field so no potential difference would be induced in the secondary coil.
b The current would short-circuit across the wires instead of passing through them. This would cause the coil to overheat if it did not cause a fuse to blow.
c Iron is a magnetic material so it makes the magnetic field much stronger. It is easily magnetised and demagnetised when the current alternates.
3 a i If the mains supply fails, the battery takes over.
ii The transformer steps the potential difference down.
b It has a ferrite core, which is much lighter than an iron core of the same size.

18.7

1 a 1200 turns
b 1150 turns
c i 6.0 A
ii 0.26 A
2 a 2000 turns
b i 3 A
ii 0.15 A
3 a The current in A is less than the current in B.
b The cables have the same resistance and the current in A is less than in B. So the heating effect of the current in A is less than that in B.

Answers to end of chapter summary questions

1 a i See 18.1 Figure 6a
ii The compass points in a direction parallel to the axis of the magnets to the left or right according to whether the magnet with the N-pole at the gap is on the left or the right of the gap.
b i current, force
ii current, lines, field
2 a When a current passes through the coil of the electromagnet, the core of the electromagnet becomes magnetised and attracts the iron armature. The iron armature turns about the pivot and its lower end pushes against one side of the switch and makes the switch close.
b When the ignition switch is closed, the core of the relay coil becomes magnetised so the relay switch closes. The motor is switched on as a result of the relay switch closing.
3 a Upwards
b The force is zero.
c The force on the sides make the coil turn.
4 a i See 18.5 Figure 4
ii The split-ring commutator would need to be replaced by two separate slip rings with a connecting brush at each ring.

b Direct current through the primary coil does not produce an alternating magnetic field. No potential difference is induced in the secondary coil as the magnetic field through it does not change.

5 a i 10A
ii 100A
b The higher the potential difference, the less the current needed to transfer a certain amount of electric power. The smaller the current through the cables, the less power is wasted in the cables due to their resistance and the heating effect of the current.

6 a 12V
b 0.5A
c 5A

7 a 150 turns
b 0.15A

Answers to end of chapter examination-style questions

1 a i strength of magnetic field (1)
ii If you double or treble the current, you double or treble the force (1); the force is directly proportional to the current. (1)
b i Force on AD is down (1); force on BC is up (1); so coil turns (1) anticlockwise. (1)
ii Force on BC is still up with force on AD is still down (1); so coil turns clockwise. (1)
iii Reverse the current (1)

2 a Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: the coil spins in a magnetic field; the coil cuts the magnetic field lines; the coil is effectively in a changing magnetic field; a potential difference is induced across the coil; since the coil is part of a circuit, a current flows; the slip rings carry the current to the brushes; which are connected to the external circuit. (6)
b i The current varies in magnitude (1); and reverses at regular intervals. (1)
ii One complete cycle in 0.04s (1); f = 1/t = 1/0.04 (1); f = 25Hz (1)

3 a iron (1)
b i 5000 (1)
ii $n_s/n_p = V_s/V_p$ OR $n_s/5000 = 110/230$ (1)
$n_s = (5000 \times 110)/230$ (1)
$n_s = 2391$ (1)
iii An alternating current passes through the primary coil (1); this produces an alternating magnetic field in the core (1); the secondary coil is therefore in a changing magnetic field (1); an alternating potential difference is induced across the secondary coil (1); this drives an alternating current through the shaver. (1)
c The car battery provides direct current (1); so there is no changing magnetic field. (1)
d $V_s \times I_s = V_p \times I_p$ OR $230 \times I_s = 48\,000$ (1)
$I_s = 48\,000/230$ (1)
$I_s = 209$A (1)

19 Radioactivity

19.1

1 a Radiation from uranium consists of particles whereas the radiation from a lamp is electromagnetic waves; radiation from uranium is ionising whereas radiation from a lamp is non-ionising.
b Radioactive atoms have unstable nuclei whereas the atoms in a lamp filament do not. The decay of a radioactive atom cannot be stopped whereas the atoms in a lamp filament stop emitting radiation when the filament current is switched off.

2 a Alpha radiation.
b Beta or gamma radiation.

3 a There are atoms in the substance that have nuclei that are unstable. These nuclei become stable by emitting radiation.
b Any two from radioactive isotopes in the air, the ground or in building materials; X ray machines; cosmic radiation.
c i The substance is radioactive.
ii The Geiger counter continues to detect background radiation.

19.2

1 a 6p + 6n
b 27p + 33n
c 92p + 143n
d 4 protons, 10 neutrons

2 a 92p + 146n
b 90p + 144n
c 91p + 143n

3 a i $^{235}_{92}X \rightarrow {}^{231}_{90}Th + {}^{4}_{2}\alpha$
ii $^{64}_{29}Cu \rightarrow 6_{30}{}^{4}Zn + {}^{0}_{-1}\beta$
b i $^{210}_{83}Bi \rightarrow {}^{210}_{84}Po + {}^{0}_{-1}\beta$
ii $^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}\alpha$

19.3

1 a To stop the radiation so it can't affect objects or people nearby.
b Charged particles are deflected by an electric or magnetic field. Gamma radiation is not deflected by an electric or a magnetic field so gamma radiation is not made up of charged particles.
c To keep the source out of range.
d α, β radiation

2 a i Gamma
ii Alpha
iii Beta
b i The magnetic field deflects charged particles and γ radiation is uncharged whereas α and β particles are charged.
ii α and β particles are oppositely charged so they are deflected in opposite directions.
iii The mass of an α particle is much greater than that of a β particle and so it is much harder to deflect an alpha particle than to deflect a beta particle.

3 a Radiation can knock electrons from atoms. This ionisation damages the genes in a cell which can be passed on if the cell generates more cells.
b Place the Geiger tube in a holder so the tube can be moved horizontally. Move the holder and tube so the end of the tube is close to the source and the Geiger counter detects radiation from the source. Move the tube and holder gradually away from the source until the count rate from the counter decreases significantly. The distance from the end of the tube to the source is the range of the α radiation from the source.

19.4

1 a The half-life is the average time it takes for the number of nuclei of the isotope in a sample to halve.
b 75cpm
c 6.5 hours

2 a i 4 milligrams
ii 1 milligram
b About 65 hours (= just over 4 half lives)

3 a i 160 million atoms
ii 10 million atoms
b Just less than 180 minutes (= just less than 4 half lives)

19.5

1 a β; thin metal stops α radiation completely and does not stop γ radiation. The amount of β radiation passing through a thin metal sheet depends on the thickness of the sheet.
b γ; α radiation would be wholly absorbed by the body so could not be used. β radiation would be partly absorbed but γ radiation is absorbed much less so γ radiation is more reliable.
c γ; α radiation would be wholly absorbed by the pipe wall so could not be used. β radiation would be partly absorbed by the ground but γ radiation would much less affected so γ radiation is more reliable.

2 a γ-radiation would hardly be absorbed by the foil as it would all pass straight through the foil.
b A stable isotope in the body (or elsewhere) would not be dangerous whereas an unstable isotope would be harmful as it is radioactive.

3 a It needs to be detectable outside the body, non-toxic, have a short half-life (1–24 hours) and decay into a stable product.
b 11200 years old.
c The count rate measurements would be due to background radiation as well as the wood. The count rate due to background radiation is measured by measuring the count rate without the wood present. This is then subtracted from the count rate with the wood present to give the count rate due to the wood only.

Answers to end of chapter summary questions

1 a i 6p + 8n
ii 90p + 138n
b i 7p + 7n
ii $^{14}_{7}N$
c i 88p + 136n
ii $^{224}_{88}Ra$

2

	α	β	γ
Identity	helium nuclei	electrons	electromagnetic radiation
Stopped by	paper	5 mm aluminium	thick lead
Electric field deflection	towards the positive plate	towards the negative plate	no deflection
Range in air	about 5 cm	about 1 m	unlimited
Relative ionisation	very strong	strong	weak

3 a 1 B, 2 D, 3 A, 4 C.
b i Smoke alarms use alpha radiation. However, californium-241 has too short a half-life to be useful in a smoke alarm.
ii 2nd column – alpha because α radiation creates enough ions in the air to give an ionisation current in the detector without smoke present. Smoke absorbs the ions and stops the ionisation current which triggers the alarm. 3rd column – 28 years – the longer the half-life, the longer the smoke alarm will continue to operate (provided the battery is changed when necessary).

4 a Student graph
b 1 hour 40 minutes

5 a 2 half-lives
b 11 200 years

6 a Background radioactivity.
b 356 cpm
c Beta radiation, because it penetrates thin foil and is stopped by an aluminium plate. Alpha radiation would be stopped by the foil. Gamma radiation would pass through the foil and the plate.

Answers to end of chapter examination-style questions

1 a i A: 1 B: 4 C: 3 D: 2 (4)
ii Atoms with the same number of protons/same atomic number (1); but with a different number of neutrons/different mass number. (1)
iii $^{7}_{3}Y$ (1)
b Their nuclei give out radiation (1); which is a random event occurring without anything being done. (1)

2 a Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. The radiation is alpha particles (1); it is relatively safe if the source is outside the body (1); because it has a range of only a few centimetres in air; (1); and it is stopped by clothing/skin (1); if the source is inside the body the radiation can affect living cells (1); the radiation cannot penetrate through the body to detectors outside (1)
b It has 2 fewer neutrons (1); and the same number of protons. (1)

3 a i Divide the initial count rate in two (2500 cpm) and find the x-axis figure at this point (1); 5 hours (1)
ii 10 hours = 2 × half-life (1); so count rate is 4 times as great (1); 20 000 cpm (1)
iii mass number = 234 (1); atomic number = 90 (1)
b It should emit gamma radiation (1); for the radiation to be detectable outside the body (1); the half-life should be a few hours (1); long enough to do the investigation (1); but short enough for the isotope not to remain in the body for long. (1)
c i Normally the alpha particles ionise the air (1); the air conducts a current (1); if smoke enters at P, the smoke absorbs ions (1); the drop in current triggers the alarm. (1)
ii It emits alpha particles which are highly ionising (1); the alpha particles have a short range so do not reach people in the room (1); the half-life is long enough for it not to need replacing. (1)

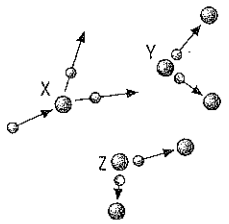
20 Energy from the nucleus

20.1

1 a The nucleus splits into two fragments and releases energy and several neutrons in the process.
b The nucleus absorbs a neutron without undergoing fission.

2 a (In order) B, A, C, D, B ...
b i The control rods absorb fission neutrons and keep the chain reaction under control, maintaining an even rate of fission.
ii More fission neutrons will be absorbed so the number of fission neutrons in the reactor core will decrease and the rate of release of energy due to fission will therefore decreases.

3 a i A and D
ii They have undergone fission and released neutrons and energy.
iii C and E
b i



ii Either, the third neutron released by X was absorbed by a control rod, or slowed by the moderator, or absorbed by a non-fissionable nucleus, or escaped from the reactor.

20.2

1 a Nuclear fusion is the formation of a nucleus when two smaller nuclei collide and fuse together.
b A helium nucleus with 2 protons and a single neutron is formed, $^{3}_{2}He$.

2 a i So the nuclei have enough kinetic energy to overcome the force of repulsion between them and fuse.
ii The energy output would be less than the energy input so it would not produce any energy overall.
b *Advantage* – the fuel is readily available or, the reaction products are less harmful than fission products or, the reactions would stop if the plasma touches the sides of the reactor.
Disadvantage – the reactions cannot be maintained for long periods of time or, strong magnetic fields are needed to control the plasma.

3 a 1 proton and 1 neutron.
b $^{2}_{1}H + {}^{1}_{1}p \rightarrow {}^{3}_{2}He$
c $^{3}_{2}He + {}^{3}_{2}He \rightarrow {}^{4}_{2}He + {}^{1}_{1}p + {}^{1}_{1}p$

20.3

1 a i It needs to be stored securely because it is hazardous and would be a danger to people and animals if it escaped.
ii It needs to be stored for a long time because it contains radioactive isotopes with long half-lives.
b The α-radiation from the source will be absorbed by the surrounding tissues and it could damage or kill cells in the body or cause cancer. Outside the body, it is less dangerous as α-radiation has no penetrating power, but it can damage skin cells if within range of them or retinal cells if near the eye.

2 a Radon gas in a house may be more concentrated than outdoors and people in the house would breathe it in. The lungs would be exposed to α-radiation from radon gas atoms that enter the lungs. The ionising effect of the α-particles in the tissue cells would damage or kill the cells or cause cancer.
b Install pipes under the house and connect them to a suction pump to draw radon gases out of the ground before it seeps into the house. The top of the outlet pipe from the pump would need to be high up outside the house.

3 Benefits to building either type of reactor should include no greenhouse gas emissions, reliable and secure electricity supplies, and large-scale generation from small sites compared with renewable supplies that would take up much larger areas etc. Drawbacks should include long-term storage of nuclear waste, possible escape of radioactive substances into the environment, impracticality of fusion reactors, etc.

20.4

1 a When we use a powerful telescope to see a distant galaxy, we are seeing the galaxy as it was billions of years ago because the light from it has taken billions of years to reach us.
b About 13 billion years.
c They are both positively charged, so they repel each other. The force of repulsion is much greater than the force of gravity between them.

2 a i We could not send a probe far enough to be outside the Milky Way.
ii As galaxies take millions of years to form, any sequence of photos would not span this timescale.
b i Gravitational forces hold the stars together.
ii The universe has expanded leaving these vast spaces.
3 a 3, 4, 1, 2
b i The force of gravity between them.
ii Gravitational potential energy is released and transferred into kinetic energy as dust and gas clouds pull together. As the clouds of gas and dust become denser and denser, the particles in the clouds move faster and faster and so the clouds heat up.
iii The force of gravitational attraction towards the centre of the galaxy acts as the centripetal force to keep the stars revolving about the centre of the galaxy.

20.5

1 a B, A, C, D.
b i A
ii It will fade out and go cold to become a black dwarf.
2 a i expand, collapse
ii collapse, explode
b i The neutron star must have enough mass.
ii The gravitational field is so strong that nothing can escape from it.
c i A supernova is the explosion of a supergiant star after it collapses on itself.
ii It becomes a neutron star.
3 a i The force of attraction due to its gravity acting on its own mass.
ii The force of the radiation flowing outwards to its surface from its core.
b i A white dwarf cools down and when it no longer emits light it has become a black dwarf because it can no longer be seen.
ii Infrared radiation.

20.6

1 a hydrogen
b uranium
c helium, iron
d hydrogen
e iron
2 a A star
b A supernova
c A supernova
d A galaxy
3 a i Nuclear fusion
ii A supernova event
b i The Sun and the rest of the Solar System formed from the debris of a supernova. Much of the uranium-238 formed from the debris of the supernova still exists because has it has a half-life which is comparable with the age of the Earth.
ii Some plutonium-239 would have been created in the supernova from which the Sun was formed. Since this event was at least 4500 million years ago, any plutonium-239 created then would have long since decayed into other elements.

Answers to end of chapter summary questions

1 a i stays the same
ii decreases
iii increases
iv stays the same
b i The reactor would overheat and the materials in it might melt. In the meltdown the reactor pressure might be high enough to cause an explosion releasing radioactive material into the atmosphere. The coolant fluid that leaked out would be radioactivity and would need to be contained in secure storage.
ii The excess neutrons would be absorbed and the reaction would slow down releasing less energy.
2 a i The process where two small nuclei fuse together to form a single larger nucleus.
ii Because they are both positively charged.
iii To overcome the force of repulsion between them due to their charge.
b The plasma needs to be very hot. The plasma is difficult to control.
3 a i fusion
ii fission
iii fission
iv fusion
b The fuel is readily available. The products of fusion are not radioactive.
4 a i Nuclear fusion
ii Hydrogen
b The Sun will cool down and swell out to become a red giant.
5 a planet
b galaxy
c stars
d stars, galaxy
6 A giant star collapses and becomes a white dwarf which is a star that is hotter, smaller and more dense. The white dwarf loses energy by radiation and eventually cools to become a black dwarf which is cold and invisible. A supergiant star collapses more rapidly than a giant star and then explodes throwing matter in all directions into the surrounding space and emitting so much radiation that is becomes much brighter than the supergiant. The core of the supergiant is compressed further in the explosion and forms a neutron star or, if its mass is large enough, it forms a black hole.
7 a **A, C, B, D, E.**
b i A red giant is much larger in diameter and cooler than the Sun. It is less dense than the Sun.
ii A white dwarf is much smaller in diameter and hotter than the Sun. It is more dense than the Sun.
c i It will fade out.
ii It will explode as a supernova, leaving a neutron star at its core. If the mass of the neutron star is large enough, it will be a black hole.
8 a i A large star that explodes.
ii A star that becomes a supernova suddenly becomes much brighter then it fades. A star like the Sun has a constant brightness.
b i A massive object, from which nothing can escape.
ii They would be pulled in by the force of gravity and then disappear.
iii A neutron star is composed entirely of neutrons. It is formed at the core of a supernova if there is not enough matter to form a black hole.
9 a i Helium
ii Helium
b i lead, uranium
ii The two elements would have been formed in a supernova explosion.
iii Heavy elements can only have formed in a supernova. The presence of heavy elements in the Earth tells us that the Solar System formed from the debris of a supernova.

Answers to end of chapter examination-style questions

1 a

Non-renewable	Renewable
coal-fired	solar-powered
gas-fired	tidal
nuclear	wind farm

(5)

b i Marks for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of scientific response. Points to be made: the neutron is absorbed by the nucleus; which makes the nucleus unstable; the nucleus splits into two fragments; releasing a lot of energy; and 2 or 3 neutrons; this is called nuclear fission; the neutrons can split further nuclei; setting up a chain reaction. (6)
ii To slow down the neutrons (1); so that they can cause fission. (1)
iii To absorb neutrons (1); stopping the fission process. (1)
2 a i fusion (1)
ii fission (1)
iii fission (1)
iv fission (1)
v fusion. (1)
b Nuclei (1); of smaller/hydrogen atoms (1); join together to form larger/helium atoms. (1)
c i mass number 4 (1); atomic number 2 (1)
ii 1 proton (1); 1 neutron (1)
iii Nuclei contain protons (1); protons have a positive electric charge (1); therefore protons repel each other (1); with a force that gets larger the closer they are. (1)