SP1a Vectors and scalars

Student Book

1 Sketch of jet ski with up and down arrows, labelled upthrust and weight. Up and down arrows of equal size.

2 Mass measures the amount of material, weight is a force; mass is a scalar quantity, weight is a vector quantity; mass is measured in kilograms, weight is measured in newtons.

3 It is a distance in a particular direction.

4 Their displacement is zero, as they end up at the same point from which they started.

5 They are going around a bend, so their direction is changing.

6 The down arrow should be labelled 'weight', as 1000 N is a measurement of force. The 'speed' label should read velocity, as a direction is indicated as well as the speed.

S1 Answers could include: 15 minutes is a time, not a speed/velocity; unless she can walk in a straight line from home to school, she is referring to speed, not velocity.

S2 Displacement is a vector, and includes a direction. Distance is a scalar. Any suitable example, such as you could cover 3 miles in distance during a walk but if you end up back at your start point your final displacement is zero.

Speed is a scalar, velocity is a vector. Any suitable example, such as a car travelling at 30 km/h on a winding road has a constant speed but its velocity changes as it changes direction.

E1 Acceleration is a change in velocity with time. Velocity includes direction as well as speed, so if the direction of a vehicle is changing then its velocity is changing, and so it is accelerating.

Exam-style question

a any from velocity, displacement, acceleration, momentum (1)

b weight always acts downwards (1)

Activity and Assessment Pack

SP1a.1 Marble run

2 **a** The distance and displacement should be the same.

b The distance should be larger than the displacement. The displacement should be the same as for path X.

4 This may depend on whether the curves in path Y slow the marble down.

5 **a** The displacement is the same for both paths, so the marble that took the shortest time is the fastest.

b The marble travelled in a straight line for X, so the direction did not change. For path Y, the direction changed so the velocity changes even if the speed does not.

SP1a.2 Athletic event

2 Possible label placements are:

- distance the athletes will run – line drawn from the starting blocks to the finish line, following the curve of the track
- displacement of the runners at the end of the race – straight line drawn from starting blocks to finish line
- the athletes accelerate here. – near the starting blocks and/or on the curve of the track
- the runners have a constant speed here. – any part of the track other than the initial acceleration section
- the runners have a constant velocity here. – on a straight part of the track
- the runners' velocity is changing here. – near the starting blocks and/or on the curve of the track
- distance the hammer travels during one swing – distance marked around the circle the hammer swings
- displacement of hammer after one swing = 0 m – on the hammer
- weight = 400 N – force arrow shown pointing down from hammer or box being carried
- mass = 4 kg – on hammer or box being carried.

SP1a.3 Vectors and scalars Strengthen

1 **a** scalar
b vector
c scalar
d scalar
e vector
f scalar
g scalar
h vector
i vector

2 a 1.0 km
b speed, velocity
c 15 minutes
d 0.8 km

3 a magnitude, scalar, vector
distance, distance, displacement, displacement, map
speed, velocity, speed, velocity
momentum, acceleration, vectors

SP1a.4 Vectors and scalars – Extend

1 a a quantity that has both a magnitude/size and direction
b a quantity that has a magnitude/size but no direction
c the distance something travels in a certain time
d the speed in a particular direction
e how fast a velocity is changing

2 a Speed is not changing if it stays at 30 km/h. Velocity is changing because the car is continually changing direction.
b The car is accelerating because the velocity is changing.

3 a i distance, to know if she has enough fuel to get there/to work out how long it will take to get there
ii displacement, because the tunnel can go in a straight line
b i displacement, as the pilot can move in a straight line between them and the displacement also gives information about which way to go
ii distance, to work out how long/how much effort it will take to get there
iii displacement, as mobile phone signals go in straight lines
c i displacement, so he can work out when the pigeons might be returning
ii distance, to work out if there is enough fuel for the trip/how long it will take

4 Weight is a force, and so is a vector. Mass is a scalar, as it has no direction.

5 Vectors: momentum depends on mass and velocity, acceleration is a change of velocity over time, forces are pushes or pulls and have direction.
Scalar: energy is a scalar.

SP1a.5 Vectors and scalars Homework 1

1 a 300, 300
b 700, 500
c 1000, 400, east
d 1400, 0

2 3 m/s north
1.5 m/s east, 3 m/s east
1.5 m/s south, 3 m/s south
1.5 m/s west

3 a vector
b vector
c scalar
d vector
e vector
f scalar
g scalar
h scalar

SP1a.6 Vectors and scalars Homework 2

1 a distance = 300 m, displacement = 300 m north
b distance = 700 m, displacement = 500 m north west (approximately), or on a bearing of 53º
c distance = 1000 m, displacement = 300 m east
d distance = 1400 m, displacement = 0

2 a Al's velocity is 1.5 m/s east from B to C, 1.5 m/s south from C to D, and 1.5 m/s west from D to A.
b Ben's velocity is 3 m/s east from B to C, 3 m/s south from C to D, and 3 m/s west from D to A.

3 Both are moving at 30 km/h, so their **speed** is the same.
Their **velocity** is different because they are moving in different directions.
They have both travelled the same **distance**, because they have been moving at the same speed for the same time.
Their **displacement** is different because they have moved in different directions from their starting point.

4 a 6 m north
b 3 m east
c 15 m
d 6.7 m, in a direction 26º east of north (bearing of 26º)

5 a vector – because it is a change in velocity
b scalar – this is the property of an object/ volumes do not act in particular directions
d vector – friction is a force, and forces are vectors
e scalar – an area does not have a direction

SP1b Distance/time graphs

Student Book

7th 1 speed = 3000 m / 120 s = 25 m/s

5th 2 distance = 90 m/s × 600 s = 54 000 km

8th 3 a speed = 80 m / 100 s = 0.8 m/s

8th b speed = 0

7th 4 distance = 0.8 m/s × 280 s = 224 m

S1 distance = 50 m/s × 7 s = 350 m

S2 The graph should have a rising line, then a horizontal line, then another rising line with a shallower slope than before.

E1 Distance/time graph drawn using this data:

Time from start of race (s)	Distance from start (m)
0	0
60	180
90	180
180	360

Exam-style question

substitution (1)
3 m/(4 × 60) s
evaluation (1)
= 0.0125 m/s
correct conversion of units (1)

Activity and Assessment Pack

SP1b.1 Measuring speeds

4 Description should include measuring the length of the pool and timing how long it takes to swim from one end to the other.

5 More accurate measurements are needed: the difference in times between different athletes is very short and human reaction time may introduce errors big enough to confuse the results of a race.

6 The method is not very accurate or not accurate enough. Reasons could include: human reaction time would be a much greater proportion of the time taken for a fast-moving object to cover a short distance; if a racing car's speed was measured over a whole lap, the exact distance will not be known because a car will not always follow the same line around bends; for an aeroplane, the difficulty of identifying exactly when it passes a particular point.

9 100 m (assuming students were 50 m from the wall)

13 Students should comment on the reaction time of the person using the stop clock.

14 Any error introduced by reaction time (or anything else) is effectively divided between the 10 claps, so the error in the time used for the calculation will be much smaller. Also, establishing the rhythm allows the person using the stop clock to anticipate when the echo will return, and so the error cause by reaction time may be less, in addition to it then being spread over a greater total distance that the sound has travelled.

15 The expected answer is that the time measurement obtained using a microphone and datalogger will be more accurate because there is no human reaction time involved in the measurement.

16 b Reasons could include the school being located above sea level, air pressure at the time being higher or lower than normal, air temperature being high/low, errors in measuring the distance, errors in measuring the time.

19 much faster (or over 10 times faster, depending on results)

20 The speed of sound is too fast/cannot react fast enough to measure the time between the sound being made and the sound being heard through the solid.

21 The greater the distance between the sensors, the longer the sound will take to travel. Any errors in measuring the times will be smaller in comparison to the actual time, and so will have a smaller effect on the accuracy of the results.

SP1b.2 Distance/time graphs and speed – Strengthen

1 B

2 distance = 50 m/s × 7 s = 350 m

3 6 m/s, 2 m/s, 0 m/s, 4 m/s

4 Sketch graph should have a steep line, then a horizontal section, then finish with a line less steep than the first one.

5 speed = distance / time = 100 m / 20 s = 5 m/s

SP1b.3 Distance/time graphs and speed – Extend

1 a 3 m/s for 60 s
  b distance = 3 m/s × 60 s = 180 m

2 a 2 m/s for 90 s
  b distance = 2 m/s × 90 s = 180 m

3

Time from start of race (s)	Distance from start (m)
0	0
60	180
90	180
180	360

4 distance/time graph that correctly plots the points above

5 average speed = 360 m / 180 s = 2 m/s

6 a You need to know how far Matt is from David's end of the pool: this is Matt's displacement from that end, not the distance he has swum.
  b If following the hints, after 30 seconds:
  David's displacement is 0.5 m/s × 30 s = 15 m
  Matt's displacement is 25 m – (0.75 m/s × 30 s) = 25 m – 22.5 m = 2.5 m
  Displacement/time graph drawn with two lines (David's going up to the right, Matt's staring at 25 m and going down). The two lines should cross at 20 seconds, where the displacement is 10 m.
  c At 10 seconds David's displacement is 5 m. In the next 10 seconds he covers 7.5 m so his total displacement at 20 s is 12.5 m. The lines on the graph now cross at approximately 18.5 seconds, where the displacement is just over 11 m.

SP1b.4 Distance/time graphs Homework 1

1 a C
  b 10 seconds

2 a B
  b steepest line

3 a 200 m
  b speed = 200 m / 50 s = 4 m/s

4 D, this is the slowest part of the journey

5 distance = 31 m/s × 19 s = 589 m

6 time = 15 m / 0.2 m/s = 75 s

SP1b.5 Distance/time graphs Homework 2

1 100 m

2 0 m

3 speed = 100 m / 125 s = 0.8 m/s

4 a 0.8 m/s up the pool, or +0.8 m/s
  b 0.8 m/s down the pool, or –0.8 m/s
  Accept explanations that include a direction and/or positive/negative signs to indicate that although the speed is the same, he is swimming in opposite directions.

5 time = 100 m / 1.25 m/s = 80 s

6 a time = 100 m / 0.5 m/s = 200 s
  b distance/time graph with points (0, 0), (125 s, 100 m), (150 s, 100 m), (350 s, 200 m)

7 D to A; the line is the steepest

8 a speed = 300 m / 300 s = 1 m/s
  b speed = (700 m – 300 m) / (500 s – 300 s) = 400 m / 200 s = 2 m/s
  c speed = (1400 m – 1000 m) / (900 s – 800 s) = 400 m / 100 s = 4 m/s

9 speed = 1400 m / 400 s = 3.5 m/s

10 Journey A is 143 000 m long and takes 2 × 60 × 60 = 7200 seconds. Average speed = 143 000 m / 7200 s = 19.86 m/s
  Journey B is 160 000 m long and takes (3 × 60 × 60) + (15 × 60) = 11 700 seconds. Average speed = 160 000 m / 11 700 s = 13.68 m/s.

11 Journey B covers a greater distance; the coach will travel more slowly because of lower speed limits on the roads and more junctions in towns; the overall time will be increased (and the average speed decreased) because it will spend some time in each of the intermediate towns setting down and picking up passengers

12 Graph should have displacement on the vertical axis, and show straight lines joining (0, 0), (30 s, 25 m), (60 s, 0 m), (90 s, 25 m), (120 s, 0 m).

SP1b.6 Equation practice

1 speed = 100 m / 25 s = 4 m/s

2 distance = 3 m/s × 120 s = 360 m

3 a distance = 1.5 m/s × 300 s = 450 m
  b distance = 5 m/s × 300 s = 1500 m

4 a speed = 100 m / 12 s = 8.33 m/s
  b distance = 8 m/s × 25 s = 200 m
  c time = 400 m / 8 m/s = 50 s

d speed = 800 m / 125 s = 6.4 m/s

e speed = 1000 m / 160 s = 6.25 m/s

f time = 2000 m / 6.25 m/s = 320 s

g distance = 6 m/s × 500 s = 3000 m

5 10 km = 10 000 m, $\frac{1}{2}$ hour = 30 minutes = 30 × 60 = 1800 seconds

speed = 10 000 m / 1800 s = 5.56 m/s

or 10 km / 1800 s = 0.00556 km/s = 55.6 m/s

6 20 km = 20 000 m

time = 20 000 m / 4 m/s = 5000 s

7 **a** A speed = 2000 m / 400 s = 5 m/s

B speed = (2400 m – 2000 m) / (600 s – 400 s) = 400 m / 200 s = 2 m/s

C speed = 0 m / 50 s = 0 m/s (or accept 0 m/s because line is horizontal)

D speed = (2700 m – 2400 m) / (800 s – 650 s) = 300 m / 150 s = 2 m/s

E speed = (3000 m – 2700 m) / (850 s – 800 s) = 300 m / 50 s = 6 m/s

b average speed = 3000 m / 850 s = 3.53 m/s

8 12 km = 12 000 m, 4 hours = 4 × 60 × 60 = 14 400 s

speed = 12 000 m / 14 400 s = 0.83 m/s

SP1c Acceleration

Student Book

1 Acceleration is the change in velocity per second. It is calculated from the formula: acceleration = change in velocity / time taken.

2 acceleration = 80 m/s / 2 s = 40 m/s^2

3 acceleration = (10 m/s – 25 m/s) / 5 s = −15 m/s / 5 s = −3 m/s^2

4 distance = (8 m/s × 8 m/s – 2 m/s × 2 m/s) / (2 × 1.5 m/s^2) = 60 / 3 = 20 m

5 **a** acceleration = 12*g* = 12 × 9.8 m/s^2 = 117.6 m/s^2 (or 12 × 10 m/s^2 = 120 m/s^2)

b it is much higher/it is approximately 10 times higher than the acceleration of a sports car

S1 A very good answer will include the following points:

Negative acceleration means the acceleration is acting in the opposite direction to the object's velocity (provided the initial velocity is taken to be positive) so the object's velocity in the original direction will decrease − it will slow down.

If a negative acceleration continues to act, then eventually the object will stop and then start to get faster in the opposite direction.

Positive acceleration acts in the same direction as the object's velocity so the object's velocity will increase (it will get faster).

An acceleration of zero will not change the object's velocity so it will continue at a constant speed.

S2 acceleration = (0 m/s – 40 m/s) / 8 s = −5 m/s^2

distance = (0 × 0 – 40 m/s × 40 m/s) / (2 × −5 m/s^2) = 160 m (for students working at this level, accept the answer if *v* and *u* are substituted the wrong way round and acceleration is given as a positive number).

E1 time = (0 m/s – 35 m/s) / −0.5 m/s^2 = 70 s

distance = (0 × 0 – 35 m/s × 35 m/s) / (2 × −0.5 m/s^2) = 1225 m

Exam-style question

substitution (1)

30 m/s / 3 s

evaluation (1)

= 10 m/s^2

Activity and Assessment Pack

SP1c.1 Acceleration due to gravity

3 **a, b** The accelerations are expected to be similar (approximately 10 m/s^2) – any variation occurs, it is likely to be a smaller acceleration when the card is dropped from a greater height if air resistance slows it down enough to be detected.

SP1c.2 Acceleration – Strengthen

1 scalar, vector, vector, direction

speed, velocities, minus

velocity, vector

speed up, slow down, decelerate (last two in either order), zero

2 **a**

Symbol	represents…	value in question	unit
a	acceleration	??	m/s^2
v	final velocity	0	m/s
u	initial velocity	40	m/s
t	time	8	s

b −40 m/s

c −40 m/s / 8 s = −5 m/s^2

3 40, 40, −5

distance = 160 m

SP1c.3 Acceleration – Extend

1 a $t = (v – u) / a$
  b 35 m/s
  c 0 m/s
  d −35 m/s
  e The change in velocity is in the opposite direction to the velocity itself, which means the train has slowed down.
  f t = −35 m/s / −0.5 m/s^2 = 70 s

2 a $v^2 = 0$, $u^2 = 1225$
  b x = (1225 – 0) / (2 × −0.5) = 1225 m

3 a a = (28 m/s – 0 m/s) / 5 s = 5.6 m/s^2
  b t = (0 m/s – 28 m/s) / −5 m/s^2 = 5.6 s

4 a Acceleration due to gravity is downwards, which is in the opposite direction to the movement of the ball.
  b change in velocity = $a \times t$ = −9.8 m/s^2 × 2 s = −19.6 m/s
   final velocity after 2 s = 20 m/s – 19.6 m/s = 0.4 m/s
  c change in velocity after 4 s = −9.8 m/s^2 × 4 s = −39.2 m/s
   final velocity after 4 s = 20 m/s – 39.2 m/s = −19.2 m/s
  d The ball is moving in the opposite direction to its original motion (i.e. it is moving downwards).

5 a change in velocity = $a \times t$ = 200 000 m/s × 0.001 s = 200 m/s
   This is also the muzzle velocity, as initial velocity was zero.
  b time = change in velocity / acceleration = −200 m/s / −9.8 m/s^2 = 20.4 s
  c change in velocity = -200 m/s – (–200 m/s) = –400 m/s
   time = −400 m/s / −9.8 m/s^2 = 40.8 s
  d distance = (200 m/s × 200 m/s – 0 m/s × 0 m/s) / (2 × 200 000 m/s^2) = 0.1 m or 10 cm

SP1c.4 Acceleration – Homework 1

1 a a = (12 m/s – 8 m/s) / 4 s = 1 m/s^2, arrow to the right
  b a = (5 m/s – 11 m/s) / 3 s = -2 m/s^2, arrow to the left

2 a a = (10 m/s – 0 m/s) / 2 s = 5 m/s^2
  b a = (0 m/s – 30 m/s) / 20 s = −1.5 m/s^2

3 9.8 m/s^2 (or 10 m/s^2)

4 a $x = (v^2 – u^2) / (2 \times a)$
  b time
  c x = (50 m/s × 50 m/s – 0 m/s × 0 m/s) / (2 × 10 m/s^2) = 2500 / 20 = 125 m

SP1c.5 Acceleration – Homework 2

1 a a = (15 m/s – 10 m/s) / 5 s = 1 m/s^2, the bicycle is accelerating to the right/in the direction of travel/speeding up
  b t = (6 m/s – 12 m/s) / –3 m/s^2 = 2 s, the bicycle is accelerating to the left/in the opposite direction to its velocity/slowing down
  c $(v – u)$ = −2.5 m/s^2 × 3 s = −7.5 m/s, v = −7.5 m/s + 12.5 m/s = 5 m/s, the bicycle is accelerating in the opposite direction to its velocity/it is slowing down
  d $(v – u)$ = −2 m/s^2 × 4.5 s = −9 m/s, u = 11 m/s – (−9 m/s) = 20 m/s, the bicycle is accelerating in the opposite direction to its velocity/it is slowing down

2 a t = 10 m/s / 2 m/s^2 = 5 s
  b change in velocity = 1.5 m/s^2 × 3 s = 4.5 m/s, v = 5 m/s + 4.5 m/s = 9.5 m/s

3 a g
  b change in velocity = 10 m/s^2 × 2 s = 20 m/s
  c a velocity of 15 m/s in the opposite direction to the original – in this case, it means the velocity is upwards
  d a velocity of 15 m/s upwards – in the opposite direction to the original velocity
   −15 m/s – 20 m/s = −35 m/s
  e a = −35 m/s / 0.2 s = −175 m/s^2

4 Dog: u = 0 m/s, v = 10 m/s^2, a = 2 m/s^2 (from question)
 x = (10 m/s × 10 m/s – 0 m/s × 0 m/s) / (2 × 2 m/s^2) = 100 / 4 = 25 m
 Cat: u = 5 m/s, a = 1.5 m/s^2 (from question), v = 9.5 m/s (answer to question 2b)
 x = (9.5 m/s × 9.5 m/s – 5 m/s × 5 m/s) / (2 × 1.5 m/s^2) = (90.25 – 25) / 3 = 21.75 m

5 a change in velocity = −15 m/s, as the ball comes to a stop at its highest point
   t = −15 m/s / 10 m/s^2 = 1.5 s
  b change in velocity = 20 m/s
   height = 20 m/s × 2 s / 2 = 20 m
  c change in velocity = 15 m/s
   height = 15 m/s × 1.5 s / 2 = 11.25 m

SP1c.7 Equation practice 1

1 a acceleration = 15 m/s / 7.5 s = 2 m/s^2
  b acceleration = (20 m/s – 10 m/s) / 5 s = 2 m/s^2
  c acceleration = (30 m/s – 5 m/s) / 25 s = 1 m/s^2
  d acceleration = (10 m/s – 25 m/s) / 3 s = –5 m/s^2

2 time = (2 m/s – 12 m/s) / –2.5 m/s^2 = 4 s

3 time = 10 m/s / 0.5 m/s^2 = 20 s

4 time = –15 m/s / –3 m/s^2 = 5 s

5 change in velocity = 1.25 m/s^2 × 20 s = 25 m/s

6 a change in velocity = 10 m/s^2 × 3 s = 30 m/s. u = 0, so final velocity = 30 m/s downwards

b change in velocity = 1.6 m/s^2 × 3 s = 4.8 m/s. u = 0, so final velocity = 4.8 m/s downwards

7 acceleration = 4 × 10 m/s^2 = 40 m/s^2

change in velocity = 40 m/s^2 × 10 s = 400 m/s, u = 0, so final velocity = 400 m/s

8 change in velocity = 2.5 m/s^2 × 10 s = 25 m/s, v = 10 m/s + 25 m/s = 35 m/s

9 change in velocity = –0.5 m/s^2 × 8 s = –4 m/s, v = 6 m/s + (–4 m/s) = 2 m/s

10 change in velocity = –4 m/s^2 × 1 s = –4 m/s, v = 5 + (-4 m/s) = 1 m/s

11 change in velocity = –10 m/s^2 × 1.5 s = –15 m/s, v = 10 m/s + (–15 m/s) = –5 m/s

12 3 minutes = 3 × 60 = 180 seconds

change in velocity = 0.2 m/s^2 × 180 s = 36 m/s, u = v – 36 m/s = 200 m/s

13 change in velocity = 364 m/s – 400 m/s, 1 hour = 3600 seconds, –36/3600 = –0.01 m/s^2

14 change in velocity = 120 m/s^2 × 2 s = 240 m/s, v = –30 m/s + 240 m/s = 210 m/s upwards

15 time = 1500 m/s / 5 × 10^5 m/s^2 = 0.003 s (or 3 × 10^{-3} s)

16 change in velocity = 2 × 10^5 m/s^2 × 5 × 10^{-3} s = 1000 m/s (or 1 × 10^3 m/s), u = 0 so this is the final velocity

SP1c.8 Equation practice 2

1 acceleration = (25 m/s × 25 m/s) / (2 × 100 m) = 3.125 m/s^2

2 acceleration = (20 m/s × 20 m/s – 10 m/s × 10 m/s) / (2 (80 m) = 1.875 m/s^2

3 distance = (0 – 15 m/s × 15 m/s) / (2 × –3 m/s^2) = 37.5 m.

When going through this question with students ensure they have used minus signs correctly, as treating v as 15 m/s rather than 0 m/s and using a positive value for acceleration will also result in the correct answer, even though two mistakes have been made.

4 distance = (700 m/s × 700 m/s) / (2 × 35 m/s^2) = 7000 m

5 acceleration = (35 m/s × 35 m/s – 10 m/s × 10 m/s) / (2 × 225 m) = 2.5 m/s^2

6 a deceleration = (0 – 10 m/s × 10 m/s) / (2 × 10 m) = –5 m/s^2

b distance = (0 – 20 m/s × 20 m/s) / (2 × –5 m/s^2) = 40 m

7 deceleration = (0 – 8 m/s × 8 m/s) / (2 × 3000 m) = –0.01067 m/s^2

8 acceleration = (150 m/s × 150 m/s) / (2 × 1.15 m) = 9783 m/s^2

9 acceleration = (800 m/s × 800 m/s) / (2 × 0.8 m) = 400 000 m/s^2

10 a v^2 = (2 × 3 m/s^2 × 100 m) + 0 = 600, v = 24.5 m/s

b v^2 = (2 × 2 m/s^2 × 150 m) + (10 m/s × 10 m/s) = 700, v = 26.5 m/s

c v^2 = (2 × –4 m/s^2 × 20 m) + (15 m/s × 15 m/s) = 65, v = 8.1 m/s

11 v^2 = (2 × 0.003 (15 000 000 m) + (15 000 m/s × 15 000 m/s = 225 090 000, v = 15 003 m/s

12 a u^2 = (20 m/s × 20 m/s) – (2 × 2 m/s^2 × 50 m) = 200, u = 14.1 m/s

b u^2 = 0 – (2 × –3 m/s^2 × 40 m) = 240, u = 15.5 m/s

c u^2 = (8 m/s × 8 m/s) – (2 × 0.5 m/s^2 × 10 m/s) = 54, u = 7.3 m/s

13 u^2 = 0 – (2 × –2 m/s^2 × 6 m) = 24, u = 4.9 m/s

14 u^2 = 0 – (2 × –1.4 m/s^2 (2000 m) = 5600, u = 74.8 m/s

15 v^2 = (30 m/s × 30 m/s) – (2 (–6 m/s^2 × 60 m) = 180, v = 13.4 m/s. She will still be travelling at over 13 m/s when the car has moved 60 m, so she will hit the wall.

SP1d Velocity/time graphs

Student Book

1 constant velocity

2 a B

b E

c C, F

3 acceleration = (0 m/s – 140 m/s) / (30 s – 24 s) = −140 m/s / 6 s = −23.3 m/s^2

4 a distance = area under parts A, B and C on the graph.

= (0.5 × 1 s × 5 m/s) + (10 s × 5 m/s) + (0.5 × 1 s × 5 m/s)

= 2.5 m + 50 m + 2.5 m

= 55 m

b distance = area under parts E and F
= (0.5 × 4 s × 140 m/s) + (0.5 × 6 s × 140 m/s)
= 280 m + 420 m
= 700 m

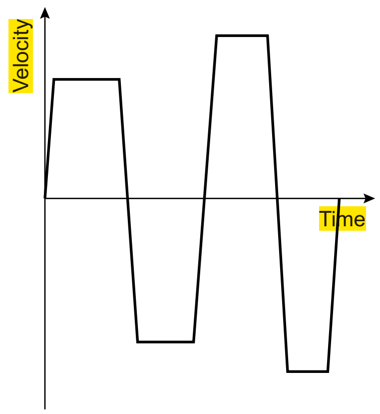
5 A bus journey is very unlikely to be straight, so as the direction of the bus changes during the journey the graph is showing its speed, not its velocity.

S1 Graph correctly drawn from points with correct labels for accelerating, constant velocity, decelerating.

Students could also calculate the following accelerations for the different sections of the journey: 0.5 m/s², 2 m/s², 0 m/s², −0.5 m/s².

And the following distances travelled: 100 m, 200 m, 900 m, 900 m, total distance = 2100 m.

E1 Sketch graph like this:



Key points are each successive horizontal section is further from the axis (greater speed) and shorter (shorter time).

Exam-style question

Explanation that makes reference to the following points:

distance = velocity (speed) × time (1)

at a constant speed, the area under the graph is a rectangle, area = base × height (1)

which is a time multiplied by velocity (speed) (1)

Activity and Assessment Pack

SP1d.1 Ticker tape graphs

10 The lines should be straight, indicating uniform acceleration.

11 The line on the chart for Slope 2 should be steeper than that for Slope 1.

SP1d.2 Shooting script

1 suitable graph

2 15–17 s; steepest slope

3 **a** 5–15 s and 17–20 s
b horizontal lines on graph

4 **a** 15–17 s and 22–25 s
b the line slopes downwards with time

5 accelerations: 6 m/s², 0 m/s², −7.5 m/s², 0 m/s², 2.5 m/s², −6.7 m/s²

6 75 m, 300 m, 45 m, 45 m, 35 m, 30 m

SP1d.3 Velocity/time graphs Strengthen

1 completed graph

2 **a** accelerating at 0–20 s and at 20–30 s
b decelerating at 60–120 s
c constant speed between 30 and 60 s

3 between 20 and 30 seconds (line is steepest)

4 10, 0
20, 0
a = 0.5 m/s²

5 **a** 2 m/s²
b 0
c −0.5 m/s²

6 **a** 10 s, 10 m/s, 100 m
b 10 s, 20 m/s, 100 m
c 200 m

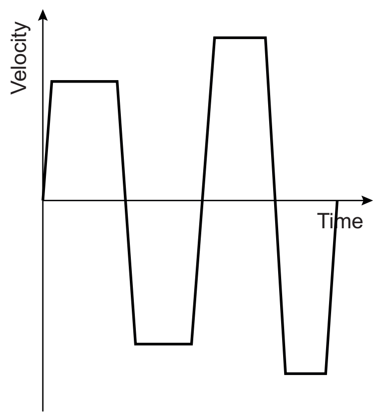
7 **a** 100 m
b 900 m
c 900 m

8 2100 m

SP1d.4 Velocity/time graphs Extend

1 **b** **i** faster
ii shorter time, as they are covering the same distance at a greater speed
iii negative

c Final sketch graph like this:



Key points are each successive horizontal section is further from the axis (greater speed) and shorter (shorter time).

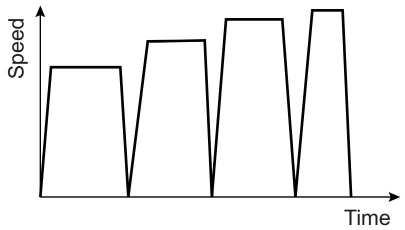
2 **a** suitable graph

b 100 m, 200 m, 900 m, 900 m

c suitable graph

3 both show time on the horizontal axis; d–t graph shows distance on the vertical axis, v–t graph shows velocity; d–t graph is plotting two scalar quantities, v–t graph is plotting a vector against a scalar; sloping line on d–t graph shows constant speed, sloping line on v–t graph shows acceleration; horizontal line on d–t graph shows stationary object, on v–t graph shows constant velocity

4 New graph of speed against time should resemble that below:



Speed and distance are scalars, and do not have directions.

Velocity and displacement are vectors, with a direction as well as a magnitude.

For the fitness test, the displacement after four lengths of the hall is zero, as students are back at their starting point, but they have run a distance of four times the length of the hall.

The area under the speed/time graph will give this distance.

The area under a velocity/time graph will not give this distance, because the areas below the axis will have negative values and will cancel out the areas above the axis. The areas between the line and the time axis on a velocity/time graph will give zero in this example, and this is the displacement. (Note that if you ignore the signs and add all the areas, this will give the distance.)

SP1d.5 Velocity/time graphs Homework 1

1 **a** Correct lines drawn (from left to right on graph): walking at a steady velocity, speeding up into a trot, trotting at a steady velocity; speeding up into a gallop; galloping at a steady velocity; slowing down to a stop.

b speeding up into a gallop; steeper slope

2 **a** acceleration = (15 m/s – 12 m/s) / (8 s – 5 s) = 3 m/s / 3 s = 1 m/s^2

b acceleration = (5 m/s – 15 m/s) / (10 s – 8 s) = −10 m/s / 2 s = −5 m/s^2

c distance = 0.5 × 3 s × 12 m/s + 2 s × 12 m/s = 18 m + 24 m = 42 m

SP1d.6 Velocity/time graphs Homework 2

1 A, 4 m/s^2; B, 0 m/s^2; C, 1 m/s^2; D, −5 m/s^2

2 distance = 0.5 × 3 s × 12 m/s + 2 s × 12 m/s = 18 m + 24 m = 42 m

3 velocities for each section: A = 200 m / 50 s = 4 m/s; B = 150 m / 30 s = 5 m/s; C = 0 m/s; D = 80 m / 40 s = 2 m/s

Velocity–time graph for the following:

Time (s)	Velocity (m/s)
0–50	4
50–80	5
80–90	0
90–130	2

4 **a** velocity/time graph (straight line sloping down from maximum velocity 30 m/s)

b at 3 seconds

c −10 m/s^2

d This is the distance travelled from 0 to 3 s: distance = 0.5 × 3 s × 30 m/s = 45 m

e distance = 90 m

f Zero, as returned to its starting point.

SP1d.7 Equation practice 1

1 **a** between 10 and 20 seconds, between 30 and 50 seconds, and between 70 and 80 seconds

b between 0 and 10 seconds, between 20 and 30 seconds, and between 80 and 100 seconds

c between 50 and 70 seconds (some students may give this as two sections, as the deceleration changes)

2 **a** gradient = (5 m/s – 0 m/s) / (10 s – 0 s) = 0.5 m/s^2

b gradient = (15 m/s – 5 m/s) / (30 s – 20 s) = 10 m/s / 10 s = 1 m/s^2

c gradient = (10 m/s – 15 m/s) / (65 s – 50 s) = –5 m/s / 15 s = –0.33 m/s^2

d gradient = (0 m/s – 10 m/s) / (70 s – 65 s) = –10 m/s / 5 s = –2 m/s^2

e gradient = (20 m/s – 0 m/s) / (100 s – 80 s) = 20 m/s / 20 s = 1 m/s^2

3 **a** area of rectangle = 5 m/s × 10 s = 50 m

b area of rectangle = 15 m/s × 20 s = 300 m c area of triangle = 0.5 × 10 s × 5 m/s = 25 m

d area of triangle = 0.5 × 20 s × 20 m/s = 200 m

e total distance = area of rectangle + area of triangle = (10 s × 5 m/s) + (0.5 × 10 s × 10 m/s) = 50 m + 50 m = 100 m

f total distance = area of rectangle + area of triangle + area of triangle = (15 s × 10 m/s) + (0.5 × 15 s × 5 m/s) + (0.5 × 5 s × 10 m/s) = 150 m + 37.5 m + 25 m = 212.5 m

4 Those sections of the graph are horizontal, which means that the acceleration is zero.

5 **a** gradient = (2 m/s – 10 m/s) / (10 s – 0 s) = –8 m/s / 10 s = –0.8 m/s^2

b gradient = (0 m/s – 2 m/s) / (20 s – 15 s) = –2 m/s / 5 s = –0.4 m/s^2

c gradient = (5 m/s – 0 m/s) / (30 s – 25 s) = 5 m/s / 5 s = 1 m/s^2

d gradient = (6 m/s – 5 m/s) / (35 s – 30 s) = 1 m/s / 5 s = 0.2 m/s^2

e gradient = (10 m/s – 6 m/s) / (50 s – 40 s) = 4 m/s / 10 s = 0.4 m/s^2

6 **a** distance = area of rectangle = 5 s × 2 m/s = 10 m

b distance = area of rectangle = 5 s × 6 m/s = 30 m

c distance = area of triangle = 0.5 × 5 s × 2 m/s = 5 m

d distance = area of triangle = 0.5 × 5 s × 5 m/s = 12.5 m

e distance = area of rectangle + area of triangle = (15 s × 6 m/s) + (0.5 × 10 s × 4 m/s) = 90 m + 20 m = 110 m

SP1d.8 Equation practice 2

1 **a** distance = (75 m/s × 75 m/s) / (2 × 35 m/s^2) = 80.4 m

b t = 75 m/s / 35 m/s^2 = 2.14 s

c t = 80.4 m / 1.5 m/s = 53.6 s

2 **a** a = (0 – 70 m/s) / 2 s = –35 m/s^2

b distance = (0 – 70 m/s × 70 m/s) / (2 × –35 m/s^2) = 70 m

3 **a** a = (0 – 1.5 m/s × 1.5 m/s) / (2 × 3 m) = –0.375 m/s^2

b t = (0 – 1.5 m/s) / –0.375 m/s^2 = 4 s

4 **a** v^2 = 2 (10 m/s^2 (2 m = 40, v = 6.32 m/s

b a = (–40 m/s) / (2 (3 m) = –6.6 m/s^2

SP2a Resultant forces

Student Book

1 a Speed is 20 km/h, so it is not changing.

b The direction is changing all the time so the velocity is changing.

2 a Both forces are in the same direction so they are added. Resultant = 15 N, acting backwards (i.e. against the direction of motion).

b 25 N – 15 N = 10 N forwards (or 25 N – 10 N – 5 N = 10 N)

3 a resultant = 10 000 N – 10 000 N = 0 N

b resultant = 3000 N – 2500 N = 500 N in the forwards direction

4 a balanced

b unbalanced

S1 students' own concept maps

E1 vertical resultant = 900 N – 850 N = 50 N acting downwards

horizontal resultant = 30 N + 100 N – 50 N = 80 N acting forwards

E2 Sketch of diver with downwards arrow and forwards arrow – the forwards arrow should be larger than the downwards one.

Exam-style question

the resultant force is zero (1)

because if there are balanced forces it means that the forces in each direction cancel each other out (or similar wording) (1).

Activity and Assessment Pack

SP2a.1 Forces in action

2 **a** Weight acting downwards, force from table acting upwards.

b As **2 a** but also force from force meter, friction acting in opposite direction.

3 Rougher surfaces have more friction, so a greater force will be needed to balance the friction.

4 Weight of the object pulling down, which stretches the spring. As the spring stretches it pulls back, and it only stops stretching when the upwards force from the spring balances the weight. There is also an upwards force from the hand holding the force meter.

5 **a** Weight acting downwards and upthrust acting upwards – when the object is floating the two forces balance each other/are the same size but in opposite directions.

b All the weight is being balanced by the upthrust.

6 **a** Weight acting downwards and upthrust acting upwards – the weight is greater than the upthrust, which is why the object sinks.

b The upthrust is balancing/cancelling part of the weight.

SP2a.2 Resultant forces Strengthen

1 Students' own concept maps

SP2a.3 Resultant forces – Extend

1 **a** 30 N + 100 N = 130 N

b 130 N – 50 N = 80 N acting forwards

2 Vertical resultant = 900 N – 85 N = 815 N acting downwards

3 Sketch of diver with downwards arrow and forwards arrow – the forwards arrow should be larger than the downwards one.

4 **a** Its direction is continuously changing, and velocity depends on both speed and direction.

b Sketch of diagram from worksheet with arrow pointing from satellite towards centre of Earth.

5 Total forwards force = 3 × 200 N = 600 N, resultant = 600 N – 50 N = 550 N

6 **a** Total thrust = 960 kN + (2 × 7080 kN) = 15 120 kN, resultant = 15 120 kN – 7700 kN = 7420 kN

b Some of the fuel will have been used up, so the weight will be smaller.

SP2a.4 Different forces Homework 1

1 A force has both a size and a direction.

2 Longer arrow drawn in the opposite direction.

3 Arrow drawn pointing to the right and approximately half the length of the forwards force arrow.

4 **a** Equal sized up and down arrows labelled ‘upthrust’ and ‘weight’.

b Arrow drawn pointing in the direction the boat is sailing labelled ‘force from sails’.

c Arrow pointing backwards and smaller than the forwards arrow, labelled ‘drag’.

5 Balanced, zero resultant.

6 Unbalanced, non-zero resultant, resultant acts forwards.

SP2a.5 Different forces
Homework 2

1 Speed only has a magnitude, velocity has a magnitude and direction (or speed is a scalar quantity, velocity is a vector).

2 a Forces in the opposite directions to those shown, from friction and air resistance. The total of these rearward forces is about half the magnitude of the force from the engine.

b There must be rearwards force(s) because the resultant force is smaller than the forwards force from the engine.

c Unbalanced, because the resultant force is not zero.

3 a Sketch of boat showing up arrow labelled 'upthrust' and a slightly longer down arrow labelled 'weight'. Resultant is 50 N downwards, forces are unbalanced.

b Sketch of ball in hand, with up arrow labelled 'force from hand' and down arrow labelled 'weight' and approximately 0.2 times the length of the upwards arrow. Resultant force = 3 N upwards, forces are unbalanced.

c Sketch of ball with only 'weight' arrow. Resultant force = 2 N downwards, forces are unbalanced.

d Sketch of person with arrow pointing towards them labelled 'force from wind' and same sized arrow pointing from them labelled 'force from person leaning into the wind'. Resultant force = 0 (as forces are balanced).

e Sketch of boat with up arrow labelled 'upthrust', down arrow of same size labelled 'weight', resultant force in vertical direction = 0, vertical forces are balanced. Forwards arrow labelled 'force from sails', rearwards arrow labelled 'drag' and approximately 0.75 times the length of the forwards arrow. Resultant force = 50 N forwards, forces are unbalanced.

f Sketch of ball with downwards arrow labelled 'weight' and horizontal arrow approximately 4 times the length labelled 'air resistance'. Resultant force in the vertical direction = 40 N, vertical forces are unbalanced. Resultant force in the horizontal direction = 200 N, horizontal forces are unbalanced.

4 Note that this question relies on students recalling work on the effects of unbalanced forces from Key Stage 3.

Sketch of object going around Earth, arrow labelled weight (or gravity) pointing towards centre of Earth. Forces are not balanced.

Sketch of same object with downwards weight arrow and larger upwards air resistance arrow. Forces are not balanced.

Sketch of object under parachute, with equal sized weight and air resistance arrows. Forces are balanced.

Sketch of object in water, with equal sized weight and upthrust arrows. Forces are balanced.

SP2b Newton's First Law

Student Book

7th 1 a her weight, acting downwards

7th b it will reduce her upwards speed (or change her vertical speed)

7th 2 a it will not change, because the forces are balanced/there is no resultant force

7th b its velocity will increase because the forces are unbalanced and the resultant is acting in the forwards direction

7th 3 a The drag force must be 300 N divided by the same size as the force from the sails because it is travelling at a constant speed so the horizontal forces on it must be balanced.

8th b There is not much friction when something is moving across ice. If the friction on the ice yacht is less than the water resistance on the sailing dingy, then there will be a resultant forwards force on the ice yacht so its velocity will increase.

9th 4 H There is a force of gravity on it acting towards the centre of the Earth. This is changing the direction in which the satellite is moving/making it move in a circle, and as its direction is changing its velocity must be changing.

S1 Horizontal: resultant force in the forwards direction, which is why the speed is increasing.

Vertical: no resultant force/resultant = zero, as the motion in the vertical direction is not changing.

E1 Waiting to be fired: weight of human cannonball, upwards force from the platform they are standing on. The resultant force is zero as their motion is not changing.

Being fired: weight acting downwards and upwards force from the platform which is greater than their weight, so there is a resultant force acting upwards. Their velocity increases in an upwards direction.

Flying through the air: weight acting downwards, air resistance acting downwards while they are still moving upwards, then acting upwards once they are moving downwards again. The resultant is always downwards and it causes their upwards speed to get less until they come to a stop at the top of their flight, and then they accelerate downwards again.

Landing in net: weight acting downwards, force from net acting upwards. Resultant is upwards/against the direction of motion and it slows them down until they stop.

A very good answer might also describe the net stretching and the force from the net increasing as it stretches.

E2 H A centripetal force is a force on a body that is moving in a circle and acts towards the centre of the circle. This force continuously changes the direction of motion and so continuously changes the velocity of the object.

Examples are tension in strings or wires (such as fairground rides, hammer-throwing, stones on string), friction (road vehicles cornering) and gravity (keeping planets and satellites in orbit).

Exam-style question

the push chair is slowing down so friction is greater (1)

than the force provided by the man (1)

Activity and Assessment Pack

SP2b.1 Tug of war

2 Calculate the overall resultant force on the block. If the resultant is zero the block will not move. If the resultant is not zero, the block will move in the direction of the resultant force.

SP2b.2 Why do things move?

- **a** True (Hint card 8 applies)
- **b** False (card 7)
- **c** False (card 6)
- **d** True (card 3)
- **e** False (card 1)
- **f** False (card 2)
- **g** True (card 4)
- **h** True (card 5)
- **i** False
- **j** False

SP2b.3 Newton's First Law Strengthen

1
- **a** Neither/no
- **b** Weight/gravity
- **c** Upwards
- **d** Balanced
- **e** Zero

2
- **a** Force from pedals, air resistance, friction.
- **b** No
- **c** Forwards, non-zero

3
- **a** Balanced, zero
- **b** Do not, direction
- **c** Unbalanced, non-zero
- **d** Stationary, can

4
- **a** Arrows chosen so that resultant is zero.
- **b** Arrows chosen to give a forwards resultant.
- **c** Arrows chosen to give a backwards resultant.
- **d** Arrows chosen to give a force acting to one side.

SP2b.4 Newton's First Law – Extend

1 Waiting to be fired: weight of human cannonball, upwards force from the platform they are standing on. The resultant force is zero, as their motion is not changing.

Being fired: weight of human cannonball, upwards force from the platform which is greater than their weight, so there is a resultant force acting upwards. Their velocity increases in an upwards direction.

Flying through the air: weight acting downwards, air resistance acting downwards while they are still moving upwards, then acting upwards once they are moving downwards again. The resultant is always downwards, and it causes their upwards speed to get less until they come to a stop at the top of their flight, and then they accelerate downwards again.

Landing in net: weight acting downwards, force from net acting upwards. Resultant is upwards/against the direction of motion, and it slows them down until they stop.

A very good answer might also describe the net stretching and the force from the net increasing as it stretches.

2 H **a** A centripetal force is a force on a body that is moving in a circle and acts towards the centre of the circle. This force continuously changes the direction of motion, and so also continuously changes the velocity of the object.

b Examples are tension in strings or wires (such as fairground rides, hammer-throwing, stones on string), friction (road vehicles cornering) and gravity (keeping planets and satellites in orbit).

3 'Forwards' and 'rearwards' here refer to the original direction in which the trawler was travelling.

a Forwards force from engine/propeller, rearwards forces from air and water resistance. Zero resultant force, as the trawler was travelling at a constant speed.

b Rearwards force from submarine (and from air and water resistance, as the trawler was still moving in the original direction), forwards force from trawler engines. Resultant force rearwards, which would make the trawler slow down and then move backwards/increase its velocity in the rearwards direction.

c Rearwards force from the submarine, 'forwards' drag force and force from trawler's engines. No resultant force, so submarine is towing trawler at a constant speed.

d (Assuming the trawler's engines still running) forwards force from trawler's engines and from drag (as the trawler would still be moving backwards immediately after the nets were released). Resultant force forwards which would slow down the backwards movement. A detailed answer might go on to explain that the force would then make the trawler start to move in its original direction, at which point the drag force would begin to act backwards.

4 When the trawler is moving at its maximum speed, the force from its engines is enough to balance the drag forces. When the submarine was pulling it backwards, the force from the submarine's engines was large enough to balance the drag forces from the trawler and the submarine, and probably also the force in the opposite direction from the trawler's engines.

SP2b.5 Resultant forces and motion Homework 1

1 **b** Accelerates forward.

c Slows down (accelerates backwards).

d Changes direction.

2 **a** Right

b 4 N

3 **a** 0

b It will stay the same.

c 3000 N upwards

d It will accelerate upwards.

4 **a** 500 N to the left (accept backwards)

b 3000 N downwards

c It will slow down and start to gain speed downwards.

SP2b.6 Resultant forces and motion Homework 2

1 **a** Resultant upwards, bag will gain speed upwards.

b Resultant forwards, ball will gain speed forwards.

c Resultant backwards, skateboarder will slow down.

d Zero resultant, speed will not change.

e Resultant forwards, the ball will gain speed forwards.

f Resultant forwards, the car will gain speed.

2 **a** 200 N forwards (zero resultant force in the vertical direction)

b Its forward speed will increase, which will increase the lift from the wings so then there will also be a resultant force in the upwards direction. The aeroplane will start to move upwards as well.

3 To turn/follow a curved path there needs to be a resultant centripetal force/force acting towards the centre of the turn. With the aeroplane banked, part of the lift force is acting towards the centre of the turn.

4 On a flat track, if there is not enough friction between tyres and the surface, the car or bicycle might skid sideways. If the track is banked, what is normally an upwards force from the track will be tilted and so partly pointing towards the centre of the turn. This will form part of the centripetal force and reduce the amount of friction force needed to keep the car/bicycle following the curve of the track.

SP2c Mass and weight

Student Book

5th **1** any of: go to the toilet, cut hair, remove clothing

5th **2 a** 300 kg – the mass of an object does not change unless the object itself is changed

6th **b** weight = 300 kg × 1.4 N/kg = 420 N

7th **3** *g* = *W* / *m* = 685 N / 185 kg = 3.7 N/kg

5th **4** Her mass does not change (and g does not change) so her weight does not change.

8th **5** When she was falling at a constant speed the resultant force was zero. When the air resistance suddenly increases there is a resultant force acting upwards. As her motion is downwards, this reduces her velocity.

S1 Mass is the amount of matter in an object. It is measured in kilograms.

Weight is the force of gravity pulling on an object. It is measured in newtons.

S2 weight = 2 kg × 10 N/kg = 20 N

E1 Mass is the amount of matter in an object, measured in kilograms. Weight is the pull of gravity on an object, measured in newtons. The weight of an object depends on its mass but also on the gravitational field strength. The gravitational field strength on Earth is 10 N/kg.

The mass of an object can only be changed by adding matter to it or taking some away. The weight of an object can be changed by changing its mass, or taking it to a place with a different gravitational field strength, such as a different planet.

E2 mass = weight / gravitational field strength = 280 N / 1.4 N/kg = 200 kg

weight on Earth = mass × g = 200 kg × 10 N/kg = 2000 N

Exam-style question

mass of spanner on the Moon = 0.2 kg (1)

as the mass is the quantity of matter and does not change unless the spanner itself is changed (1).

the weight will be less on the Moon (1)

because the gravitational field strength on the Moon is less (1).

Activity and Assessment Pack

SP2c.1 Investigating mass and weight

2 Graphs should show a straight line of best fit through the origin.

3 Weight is directly proportional to mass.

4 Gradient should be approximately 9.8 (or 10) N/kg.

5 b Suggestions could include errors in determining masses or weights, not drawing the best line through the points, etc.

SP2c.2 Forces on a skydiver

1–3 Just after leaving aeroplane: H, E, L, A, resultant = 690 N downwards.

3 seconds after leaving aeroplane: J, F, L, A, resultant = 555 N downwards.

15 seconds after leaving aeroplane: I, D, L, B, resultant = 0.

30 seconds after leaving aeroplane: I, D, L, B, resultant = 0.

Just after opening parachute: K, G, L, C, resultant = 70 N upwards.

5 seconds after opening parachute: H, D, L, B, resultant = 0.

30 seconds after opening parachute: H, D, L, B, resultant = 0.

4 The skydiver's mass does not change during the jump, so the weight stays the same.

5 a Just after leaving the aeroplane, 3 seconds after leaving it: at these stages the weight is greater than the air resistance and the speed is increasing.

b Just after opening parachute: the air resistance force is greater than the weight, and the speed is decreasing.

c 15 and 30 seconds after leaving aeroplane, 5 and 30 seconds after opening parachute: at these stages the air resistance and weight forces are the same and the skydiver is falling at a constant speed.

SP2c.3 Mass and weight – Strengthen

1 a Mass is the amount of matter in an object.

b kilograms

2 a Weight is the force of gravity pulling on an object.

b newtons

3 a Mass, field strength

b 2, 10

c 20

4 2 × 3.7 = 7.4

5 Mass = 40 N / 3.7 N/kg = 10.8 kg

SP2c.4 Mass and weight – Extend

1 Mass is the amount of matter in an object, measured in kilograms. Weight is the pull of gravity on an object, measured in newtons. The weight of an object depends on its mass but also on the gravitational field strength. The gravitational field strength on Earth is 10 N/kg.

The mass of an object can only be changed by adding matter to it or taking some away. The weight of an object can be changed by changing its mass, or taking it to a place with a different gravitational field strength, such as a different planet.

2 **a** Mass = weight / gravitational field strength = 280 N / 1.4 N/kg = 200 kg

b Weight on Earth = mass × g = 200 kg × 10 N/kg = 2000 N

3 Weight on Titan = 319 kg × 1.4 N/kg = 447 N

Weight on Earth = 319 kg × 10 N/kg = 3190 N

4 **a** A falling object increases speed until its weight is balanced by its air resistance. The weight of the probe on Titan is less than on Earth because the gravitational field strength on Titan is less than on Earth, so the speed at which the air resistance balances the weight will be less. The probe will fall more slowly on Titan than it would on Earth.

b If the atmosphere is denser, the air resistance will be greater for a given speed. This means that the air resistance needed to balance the weight on Titan will be reached at an even lower speed. So the answer that the probe will fall more slowly on Titan is still valid.

5 A smaller parachute would be needed on Titan than on Earth because the gravity is weaker and the atmosphere is denser.

A smaller parachute would be needed on Mars than on Earth if the weaker gravity were the only difference. However the thinner atmosphere would mean a large parachute would be needed. We cannot compare the size of parachute needed on Mars and Earth without knowing which of these effects is the greatest.

SP2c.5 Gravity and weight 1

1 Force, gravity, newtons; mass, strength, gravitational, N/kg; matter, kilograms

2 **a** Weight

b Mass

c Gravitational field strength

d Mass, gravitational field strength

3 **a** Weight = 3000 kg × 10 N/kg = 30 000 N

b Downwards arrow on balloon a little shorter than the upthrust arrow shown.

c 34 000 N – 30 000 N = 4000 N upwards

d It will increase in an upwards direction.

4 Mass = weight / *g* = 28 000 N / 10 N/kg = 2800 kg

SP2c.6 Gravity and weight 2

1 **a** Weight using 10 N/kg = 500 kg × 10 N/kg = 5000 N

Weight using 9.81 N/kg = 500 kg × 9.81 N/kg = 4905 N

Difference = 95 kg

b Any sensible suggestion, such as working out how much lift an aeroplane/balloon needs, how much force a crane needs to be able to lift, working out a satellite's orbit, etc.

2 **a** g at equator = 48.90 N / 5 kg = 9.780 N/kg

g at the poles = 49.46 N / 5 kg = 9.832 N/kg

g in Mexico City = 48.88 N / 5 kg = 9.776 N/kg

b It is the mean of the values for the equator and poles (in fact, it is the value worked out for a latitude of 45º but the answer given here is an acceptable simplification).

3 Suggestions should be approximately 9.83 N, obtained by finding the difference between the sea level value for the equator and the value for Mexico City, and subtracting this from the sea level value at the poles.

4 Weight change = mass × gravitational field strength change = 200 kg × 0.005 N/kg = 1 N

5 95 kg / 4905 kg × 100% = 1.9%

6 0.005 / 1.622 × 100.% = 0.3%

SP2c.7 Equation practice

1 **a** weight = 5 kg (10 N/kg = 50 N

b 1200 kg × 10 N/kg = 12 000 N

c 15 kg × 10 N/kg = 150 N

d 200 g = 0.2 kg, weight = 0.2 kg × 10 N/kg = 2 N

e 100 g = 0.1 kg, weight = 0.1 kg × 10 N/kg = 1 N

f 50 mg = 0.05 g = 0.00005 kg, weight = 0.00005 kg × 10 N/kg = 0.0005 N

2 **a** mass = 400 N / 10 N/kg = 40 kg

b 850 N / 10 N/kg = 85 kg

c 0.2 N / 10 N/kg = 0.02 kg

d 125 000 N / 10 N/kg = 12 500 kg

e 8 000 000 N / 10 N/kg = 800 000 kg

f 1.5×10^4 N / 10 N/kg = 1.5×10^3 kg

3 a mass = 2 N / 1.6 N/kg = 1.25 kg

b weight = 1.25 kg × 9.8 N/kg = 12.25 N

c weight = 1.25 kg × 3.7 N/kg = 4.625 N

d 3 g = 0.003 kg, weight = 0.003 kg × 1.6 N/kg = 0.0048 N

4 a mass of tool = 8 N / 3.7 N/kg = 2.16 kg, weight on Earth = 2.16 kg × 9.8 N/kg = 21.17 N

b weight on Mercury = 2.16 kg × 3.7 N/kg = 7.99 N (or 8 N). Accept answer of 8 N because the gravitational field strength on Mercury is the same as that on Mars.

c weight on Moon = 2.16 kg × 1.6 N/kg = 3.46 N

5 weight of 5 kg mass in London = 5 kg × 9.816 N/kg = 49.08 N

weight in Mexico City = 5 kg × 9.766 N/kg = 48.83 N

difference = 0.25 N

SP2d Newton's Second Law

Student Book

1 It will start to move, change speed or direction.

2 a The car will accelerate faster/at a greater rate than the lorry because it has a smaller mass.

b There would need to be a bigger force on the lorry, to make up for its greater mass.

3 force = 1500 kg × 4 m/s^2 = 6000 N

4 acceleration = 800 N / 1500 kg = 0.53 m/s^2

5 160 N / 2 m/s^2 = 80 kg

S1 The limit on force that the engines can produce is an upper limit on acceleration. The lower limit on mass means that the mass cannot be reduced further, so the acceleration cannot be increased. Both rules set an upper limit on acceleration.

S2 250 kg × 5 m/s^2 = 1250 N

E1 Acceleration depends on resultant force and mass, so you would need to know the mass of each vehicle, the maximum engine force and also the size of the resistive forces (air resistance and friction) to work out the resultant.

E2 Objects with larger masses have larger forces from gravity on them, but the larger mass also needs a larger force to give it a certain acceleration. This is not usually seen on Earth because air resistance affects the rate of fall.

Students studying the Higher Tier could be expected to mention inertial mass in their answer:

The inertial mass is the same value as the mass that is pulled on by gravity. The increased force on an object of larger mass is exactly balanced by the greater force needed to give the same acceleration as experienced by the smaller mass.

Exam-style question

equation (1)

force = mass × acceleration

substitution (1)

3000 N = mass × 2 m/s^2

evaluation (1)

= 1500 N

SP2d Core practical – Investigating acceleration

1 Acceleration is a change in speed over time (1), so find the difference in the two speeds and divide by the time taken to move between the two light gates. (1)

2 Weight is the force of gravity acting on a mass. (1)

3 The most likely suggestion is to prevent the masses or trolley falling on feet (1) by putting a box or other object beneath the masses. (1)

4 Ramp, supports for ramp, trolley, pulley, string, mass hanger, stacking masses, 2 light gates, data logger (1) plus whatever apparatus is involved in the safety suggestion they made in answer to question 3. (1)

5 To measure the time the trolley takes to move between the two light gates (1) as acceleration is calculated from a change in velocity divided by time (or equivalent explanation). (1) Do not accept 'to measure the speed/velocity at the beginning'.

6 The masses on the end of the string are accelerating as well as the trolley and any masses on it. (1) If the masses were just added to the end of the string, the accelerating mass would change each time as well as the force (1) so it would not be a fair test/the effect of the change in force could not be investigated. (1)

7 The acceleration is proportional to the force. (1)

8 a The acceleration gets less as the mass increases. (1) Do not accept 'the acceleration is inversely proportional to the mass' at this point as this cannot be determined for certain from the shape of the graph.

b Plot acceleration against 1/mass (or mass against 1/acceleration), (1) if this is a straight line it will show that the acceleration is inversely proportional to the accelerating mass. (1)

Activity and Assessment Pack

SP2d.1 Investigating force, mass and acceleration

6 a Acceleration decreases as mass increases. (Acceleration is inversely proportional to mass, although students cannot determine that the relationship *is* one of inverse proportion without plotting a graph of acceleration against 1/mass and obtaining a straight line.)

SP2d.2 Accelerating vehicles

1 Caterham (500 kg), 5.5 m/s^2, 2750 N

a Clio (1000 kg), 2.5 m/s^2, 2500 N

b Focus (1500 kg), 3.0 m/s^2, 4500 N

c Volvo (2000 kg), 3.5 m/s^2, 7000 N

d Range Rover (2500 kg), 2 m/s^2, 5000 N

2 Unused cards are 4 m/s^2 and 2200 N, giving a mass of 550 kg.

SP2d.3 Newton's Second Law – Strengthen

1 a increases

b decreases

c maximum, maximum, above

d above

e upper

2 a mass × acceleration

b 250 kg × 5 m/s^2

c 1250 N

3 a force / mass

b 1000 N / 300 kg

c 3.33 m/s^2

4 mass = force / acceleration = 1000 N / 2.5 m/s^2 = 400 kg

SP2d.4: Newton's Second Law – Extend

1 a resultant force, mass

b The greater the resultant force, the greater the acceleration. The greater the mass the less the acceleration.

2 It is the resultant force on the vehicles that matters so you also need to take into account air resistance and friction.

3 a mass and gravitational field strength

b mass and resultant force

c Objects with larger masses have larger forces from gravity on them, but the larger mass also needs a larger force to give it a certain acceleration.

Students studying the Higher Tier could be expected to mention inertial mass in their answer:

The inertial mass is the same value as the mass that is pulled on by gravity, so the increased force on an object of larger mass is exactly balanced by the greater force needed to give a certain acceleration.

4 Answers will depend on the masses chosen as examples.

10 kg mass: weight = 10 kg × 1.6 N/kg = 16 N; acceleration = 16 N / 10 kg = 1.6 m/s^2

20 kg mass: weight = 20 kg × 1.6 N/kg = 32 N; acceleration = 32 N / 20 kg = 1.6 m/s^2

5 a 0.5 mg = 0.0000005 kg; force = 0.0000005 kg × 2000 m/s^2 = 0.001 m/s^2

b mass = 1200 N / 15 m/s^2 = 80 kg

c acceleration = 6000 N / 500 kg = 12 m/s^2

6 a acceleration = (20 m/s – 10 m/s) / 5 s = 2 m/s^2

force = 2000 kg × 2 m/s^2 = 4000 N

b The force from the engine will need to be bigger, as it has to counter friction and air resistance to produce a resultant force of 4000 N.

c The acceleration will be less. As the car is going faster, the air resistance will be greater; with the same force from the engine, the resultant force will be less than before.

7 a Use the masses to accelerate the trolley along the ramp. (A very good answer will include a description of setting up the ramp with a slight slope to compensate for friction). Use information from the light gates to find the acceleration, and the divide the force provided by the masses by the acceleration to find the mass.

b 1.5 kg. The value found using the ramp and light gates is the inertial mass of the trolley, and is always the same value as that obtained by weighing an object and dividing by the gravitational field strength.

SP2d.5 Acceleration calculations Homework 1

1 a 50 N
b 75 N
c 160 N
d 160 N

2 a greater
b smaller

3 a resultant force 8 N, to the left, 4 m/s^2
b resultant force 2 N, to the right, 10 m/s^2
c resultant force 3 N, upwards, 0.75 m/s^2
d resultant force 5 N, upwards, 0.5 m/s^2
e resultant force 100 N, to the right, 40 m/s^2
f resultant force 6 N, upwards, 0.6 m/s^2

SP2d.6 Acceleration calculations Homework 2

1 a resultant force 26 N, downwards, 0.5 m/s^2
b resultant force 2 N, downwards, 0.002 m/s^2

2 sprinter – 160 N
charging elephant – 1 m/s^2
racing car – 4500 N
cyclist – 100 kg
bullet – 40 000 m/s^2
hockey ball – 0.13 kg

3 a 180 000 m/s^2
b 8100 N

4 a –0.0072 m/s^2 (accept the number without the minus sign, as sign conventions for directions have not been discussed)
b 2 160 000 N

5 a The mass of an object found by dividing the resultant force acting on it by the acceleration produced by the force.
b Both values will be the same.

6 A car is accelerating as it corners. The acceleration is towards the centre of the circle and experiences a centripetal force directed towards the centre of the circle. This is provided by friction between the tyres and the road. For a lower mass car, the force needed to achieve this acceleration is less, so the car is less likely to skid.

7 a acceleration = 140 000 N / 28 000 kg = 5 m/s^2
b change in speed = acceleration × time = 5 m/s^2 × 10 s = 50 m/s
c the force given in the question remains the same/there are no other forces acting on the fighter
d The actual speed will be less, because as the fighter gains speed the drag forces will increase so the resultant force will decrease.

SP2d.7 Equation practice

1 a force = 1500 kg × 2 m/s^2 = 3000 N
b 1500 kg × 1.5 m/s^2 = 2250 N
c 1500 kg × 3 m/s^2 = 4500 N
d 1500 kg × 4 m/s^2 = 6000 N

2 a force = 1000 kg × 3.0 m/s^2 = 3000 N
b mass = 3750 N / 2.5 m/s^2 = 1500 kg
c acceleration = 1500 N / 1000 kg = 1.5 m/s^2
d mass = 2400 N / 1.2 m/s^2 = 2000 kg
e acceleration = 1500 N / 3000 kg = 0.5 m/s^2

3 total mass = 45 kg + 80 kg = 125 kg
force = 125 kg × 120 m/s^2 = 15 000 N

4 50 g = 0.05 kg, acceleration = 30 N / 0.05 kg = 600 m/s^2

5 1 mg = 0.001 g = 0.000001 kg, force = 0.000001 kg × 1200 m/s^2 = 0.0012 N

6 a force = 1200 kg × 5 m/s^2 = 6000 N
b total mass = 1200 kg + 500 kg = 1700 kg, force = 1700 kg × 5 m/s^2 = 8500 N

7 15 tonnes = 15 000 kg
a total mass = 3000 N / 0.1 m/s^2 = 30 000 kg, mass of load = 30 000 kg – 15 000 kg = 15 000 kg
b total mass = 1750 N / 0.05 m/s^2 = 35 000 kg, load = 35 000 kg – 15 000 kg = 20 000 kg
c total mass = 4000 N / 0.2 m/s^2 = 20 000 kg, load = 20 000 kg – 15 000 kg = 5000 kg

8 a 4 g = 0.004 kg, force 0.004 kg × 2.5 × 10^5 m/s^2 = 1000 N
b 1.6 g = 0.0016 kg, acceleration = 1000 N / 0.0016 kg = 625 000 m/s^2

9 total thrust (force) = 1015 kN + 13 300 kN = 14 315 kN = 14 315 000 N
780 tonnes = 780 000 kg
acceleration = 14 315 000 N / 780 000 kg = 18.4 m/s^2

SP2e Newton's Third Law

Student Book

8th 1 the ground pushing up on the dog

9th 2 a arrows showing weight pushing on ground and ground pushing on person

9th b arrows showing person pushing on wall and wall pushing on person (or feet pushing sideways on ground and ground pushing sideways on feet)

7th 3 weight downwards and force from the ground upwards

8th 4 H force from the ball on the ground and an equal and opposite force from the ground on the ball

8th 5 H The force from the head on the ball causes the ball's velocity to change/ball to bounce off the head. The force of the ball on the head causes the head's velocity to change/pushes the head backwards. The head has a greater mass than the ball (and also the neck muscles provide an opposing force) so the change in motion of the ball is more obvious.

S1 your weight pushing down on the chair and the chair pushing up on you

Balanced forces both act on the same object (the person), whereas action-reaction forces act on different objects.

E1 Various answers are possible.

Action-reaction pairs: pull of one team on the rope, pull of the rope on the team; pull of the Earth's gravity on one team, pull of the team's gravity on the Earth; feet of one team pushing horizontally against the ground, ground pushing horizontally against the feet.

Balanced forces: pull of one team on the rope, pull of the other team on the rope; pull of the Earth's gravity on one team, upwards force from the Earth on the team; feet of one team pushing horizontally against the ground, pull of the rope on the team.

E2 The Earth and the ball attract each other with the same size force but in opposite directions. The pull of the Earth on the ball is a resultant (or the only) force on the ball so it makes the ball accelerate downwards. The pull of the ball on the Earth makes the Earth accelerate upwards. There is the same force on the ball and on the Earth but the Earth's mass is so much greater that the acceleration of the Earth is too small to be noticed.

Exam-style question

force (weight) of apple pulling on spring and force of spring pulling on the apple

OR

weight of apple (force of gravity pulling on the apple) and force of the apple pulling on the Earth (1)

Activity and Assessment Pack

SP2e.1 Weakest link

1 **a** 10 N

b 10 N

c any sensible prediction involving action–reaction pairs (if students have studied the Student Book for this topic)

5 **a** balanced forces – both forces are acting on the masses (and are also different types of force)

b action–reaction pair – forces are on different objects

c action–reaction pair – forces are on different objects

6 If a chain is under tension/being pulled, the forces on each link are the same, so the weakest link in the chain will determine the maximum force the chain can withstand.

SP2e.2 Forces at play

The two arrows in each force pair must be the same length and in opposite directions. Labels placed according to the locations in the text on the labels and in the appropriate directions. E.g. 'force of ground on the clown' must be next to an upwards pointing arrow, and be paired with 'force of clown on the ground' an equally-sized, downwards pointing arrow.

SP2e.3 Newton's Third Law Strengthen

1 **a** the force of gravity from you pulling up on the Earth

b the chair pushing up on you

2 **a** the chair pushing up on you

b the Earth pushing up on the chair

3 **a** action–reaction

b both

c both

d balanced

e action–reaction

f action–reaction

SP2e.4 Newton's Third Law – Extend

1 **a** the pull of the rope on the team
b the pull of the team's gravity on the Earth
c the ground pushing horizontally against the feet

2 **a** the pull of the other team on the rope
b the upwards force from the Earth on the team
c the pull of the rope on the team

3 **a** the same size as the pull of the Earth on the ball, and in the opposite direction
b The pull of the Earth on the ball is a resultant (or the only) force on the ball, so it makes the ball accelerate downwards.
c The pull of the ball on the Earth makes the Earth accelerate upwards. There is the same force on the ball and on the Earth, but the Earth's mass is so much greater that the acceleration of the Earth is too small to be noticed.

4 **a** The ground exerts a force on the ball.
b The ball stops/changes velocity/bounces upwards.
c The force makes the Earth change velocity/move away.
d The acceleration caused by the force of the ball on the Earth is too small to notice because the mass of the Earth is so large.

5 The weight of the aeroplane will stay the same.

When the chickens take off, their weight is no longer (directly) providing a downwards force on the floor of the plane.

When the chickens are flying, the action of their wings produces an upwards force from the air on the chickens, and a downwards force from the chickens on the air (action–reaction pair). The upwards force on the chickens must be equal to their weight to keep them airborne (balanced forces), so the downwards force on the air (the action–reaction force) must also be equal in magnitude to the total weight of the chickens.

This force makes the air move downwards. When the moving air hits the floor of the aeroplane it exerts a force on the floor of the plane, and the floor exerts a force on the air (action–reaction pair). This force makes the air stop moving. The force needed to stop it must be equal to the force needed to start it moving downwards, which was in turn equal to the weight of the chickens.

So although the chickens are no longer standing on the floor, they are still exerting the same downwards force on the floor of the plane. The overall weight of the plane does not change.

SP2e.5 Action–reaction forces Homework 1

1 **a** pull of string on the brick/pull of brick on the string; pull of string on the balloon/pull of balloon on the string
b weight of the balloon, pull of string on the balloon
c upthrust from the air

2 upthrust, weight, balanced, the same object

3 **a** arrows drawn similar to those at Ben's foot
b 40 N
c friction
d W and Z

SP2e.6 Action–reaction forces Homework 2

1 **a** **i** the force of the ground on your foot
ii it stops your foot slipping backwards
iii There is less friction between ice and a shoe than between rough ground and a shoe, so you can only put a small backwards force on the ground before there is not enough friction to provide the forwards force that stops your foot slipping.
b **i** it pushes the Earth down
ii The force is so small compared to the mass of the Earth that the acceleration it produces is too tiny to detect.

2 **a** both involve forces that are the same size (or at least, for balanced forces the sum of all the forces in one direction is the same as the sum of all the forces in the opposite direction); the forces are in opposite directions
b Balanced forces act on the same body, action–reaction pairs act on different bodies; action–reaction pairs are always the same type of force, balanced forces are not always the same type.
c they have no effect (or the object stays still or continues to move at the same velocity as before)
d they can change the velocity of an object

3 **a** upthrust and weight – these are balanced forces because they are both acting on the same object
b equal and opposite labelled arrows for force of astronaut pulling on rope and force of rope pulling on astronaut
c the astronaut will start to move (to the left)

4 **a** 40 N to the left

b Ben is pushing backwards on the ground with his feet, the ground is pushing in the opposite direction with the same size force.

c The force of Al pushing on Ben, and the force of the ground pushing on Ben's feet. These two forces are in opposite directions and both acting on the same object, so they are balanced forces.

5 Ben exerts a 30 N force on Al, because the forces are an action-reaction pair.

6 a The reaction force pushes on the astronaut and pushes her in the opposite direction – away from the space station.

b Sensible suggestions such as using ropes or clips.

SP2f Momentum H

Student Book

8th **1** Momentum depends on mass as well as velocity, and motorcycles usually have smaller masses than cars.

9th **2** momentum = 500 kg × 10 m/s = 5000 kg m/s

10th **3** velocity = momentum / mass = 1500 kg m/s / 500 kg = 3 m/s

10th **4** force = ($mv - mu$) / t = (1000 kg × 15 m/s – 1000 kg × 0 m/s) / 15 s = 15 000 / 15 = 1000 N

9th **5 a** moving penguin: 20 kg × 6 m/s = 120 kg m/s; stationary penguin: zero

9th **b** 120 kg m/s

8th **c** to the right

9th **d** 20 kg × 3 m/s + 20 kg × 3 m/s = 120 kg m/s to the right

9th **e** Momentum has been conserved because the momentum after they collide is the same as the momentum before the collision.

S1 momentum of one truck = 5000 kg × 5 m/s = 25 000 kg m/s

momentum of other truck = –25 000 kg m/s (it has the same mass and speed but is travelling in the opposite direction)

total momentum before collision = –25 000 kg m/s + 25 000 kg m/s = 0

After the collision the momentum is zero as the trucks are not moving. Momentum is the same before and after the collision, so momentum has been conserved.

E1 momentum of bullet = 0.001 kg × 300 m/s = 0.3 kg m/s

total mass of bullet and wood = 1.001 kg

Momentum is conserved and the momentum of the block of wood was zero as it was stationary, so the final momentum must be the same as the initial momentum of the bullet.

velocity of bullet + wood = 0.3 kg m/s / 1.001 kg = 0.2997 m/s = 0.3 m/s to 2 s.f.

Exam-style question

equation (1)

momentum = mass × velocity

substitution (1)

= 1800 kg × 35 m/s

evaluation (1)

= 63 000 kg m/s

Activity and Assessment Pack

SP2f.1 Investigating momentum

3 The total momentum before and after the collision should be the same each time.

SP2f.2 Snooker balls

1 Momentum is conserved in a collision. As the white ball stops after the collision, then mass × velocity of the grey ball after the collision must be the same value as mass × velocity for the white ball before the collision. As both balls have the same mass, the velocities must also be the same.

2 a The total momentum of both balls in the y direction after the collision must be the same as the momentum of the white ball before the collision. As there are two balls, they both must have a smaller velocity to make the total momentum the same.

b It could be 0.5 m/s if the velocities of both balls in the y direction are equal.

3 If both balls go off at the same angle to the line of the original movement, then they will both have the same velocity in the y direction.

4 a zero

b zero/There is no momentum in the x direction, because there is no movement in that direction.

5 a Zero – momentum is conserved because one ball has a velocity in the positive direction and one in the negative direction.

b They are moving in opposite directions, so the velocity of one in the x direction has a positive value and the other has a negative value. The two values add up to zero.

SP2f.3 Momentum – Strengthen

1 momentum = mass × velocity = 5000 kg × 5 m/s = 25 000 kg m/s

2 **a** The minus sign shows that it is travelling in the opposite direction to truck A.

b momentum = 5000 kg × –5 m/s = –25 000 kg m/s

3 25 000 kg m/s + (–25 000 kg m/s) = 0

4 **a** They are stationary, so velocity and momentum are both zero.

b The total momentum is the same before and after the collision.

5 **a** 56 kg m/s

b –36 kg m/s

c they are opposite

d 56 kg m/s + (–36 kg m/s) = 20 kg m/s (to the right, i.e. in the positive direction)

e –28 kg m/s

f The total momentum after the collision must be the same. 48 kg m/s + (–28 kg m/s) = 20 kg m/s

g 48 kg m/s = 6 kg × ? m/s, velocity = 48 kg m/s / 6 kg = 8 m/s

6 change in momentum = ($mv - mu$) = (4 × 3) – (4 × 0) = 12

F = 12 / 2 = 6 N

7 change in momentum = ($mv - mu$) = (5 × 5) – (5 × 2) = 25 – 10 = 15

time = change in momentum / force = 15 / 20 = 0.75 s

SP2f.4 Momentum – Extend

1 **a** momentum = 0.001 kg × 300 m/s = 0.3 kg m/s

b mass = 1.001 kg

c 0.3 kg m/s – momentum is conserved: the momentum of the block of wood was zero as it was stationary, so the final momentum must be the same as the initial momentum of the bullet.

d velocity of bullet + wood = 0.3 kg m/s / 1.001 kg = 0.2997 m/s

2 momentum of first ball = 0.1 kg × 12 m/s = 1.2 kg m/s

momentum of larger ball after collision = 1.2 kg m/s (as first ball stops)

velocity of larger ball = 1.2 kg m/s / 0.2 kg = 6 m/s

(Accept answers that explain that the second ball must have half the velocity of the first ball as it has twice the mass.)

3 initial momentum = 80 kg × 4 m/s = 320 kg m/s

momentum of man and trolley after collision = 320 kg m/s

total mass after collision = 80 kg + 40 kg = 120 kg

velocity after collision = 120 kg / 320 kg m/s = 0.375 m/s

4 momentum of first car = 200 kg × +3 m/s = +600 kg m/s

momentum of second car = 130 kg × –2 m/s = –260 kg m/s

total momentum is 600 kg m/s + (–260 kg m/s) = +340 kg m/s

The momentum after the collision is the same as this, so the cars must end up moving in the positive direction.

5 momentum of cyclist and bike before picking up package = 100 kg × 10 m/s = 1000 kg m/s.

momentum of package = 0, so total momentum before = 1000 kg m/s

momentum after picking up package = 1000 kg m/s.

velocity after picking up package = 1000 kg m/s / 125 kg = 8 m/s

6 If the gun is not moving, the momentum before it is fired is zero, so the momentum after firing is also zero. The bullet and the gun move in opposite directions such that their momentums are equal in magnitude but in opposite directions and they cancel out. As the gun has a much larger mass than the bullet, it must have a much smaller velocity to give the same magnitude of momentum.

7 **a** force = ($mv - mu$) / t = (1000 × 3 – 1000 × 0) / 5 = 3000 / 5 = 600 N

b that the force from the two people is the same as the resultant force on the car (or that there is no friction to overcome)

c it will be larger, as the force calculated in part **a** is the resultant force and there are frictional forces to overcome

8 **a** force = ($mv - mu$) / t = (150 × 15 – 150 × 5) / 2 = (2250 – 750) / 2 = 1500 / 2 = 750 N

b 750 N as this is the same acceleration as in part **a**

c The engine force needed to accelerate from 5 m/s will be greater than that calculated in part **a**, as that number was the resultant force and there are frictional and drag forces to overcome. For the acceleration from 15 m/s the engine force will need to be even greater, as the drag forces increase with speed.

SP2f.5 Momentum – Homework 1

1 **a** False: momentum is the product of mass and velocity, so if velocity is zero the momentum is also zero.

b False: the *m* stands for mass.

c False: the momentum increases as the object accelerates (or decreases as it decelerates).

d False: momentum depends on both velocity and mass, so if the effect of the mass decreasing is greater than the effect of the velocity increasing, the momentum will decrease.

e true

f False: if mass and velocity do not change, the momentum will not change.

g True: an elephant standing still has zero momentum.

h False: the lorry has a greater mass, so it will have a greater momentum.

i True: the total momentum before the collision was zero (as both had the same magnitude/size of momentum but in opposite directions) so the momentum after the collision must be zero. If they stick together, the only way this can be true is if their combined velocity is zero.

2 **a** The total momentum before the collision is 25 kg m/s + 10 kg m/s = 35 kg m/s. The total momentum after the collision must be the same, so ball B must have 35 – 5 = 30 kg m/s of momentum.

b It had greater momentum, and as they have equal masses, ball A must have been moving faster.

c It has greater momentum and their masses are the same.

3 **a** momentum of C = 10 kg × +5 m/s = +50 kg m/s

momentum of D = 15 kg × –10 m/s = –150 kg m/s

b total momentum = +50 kg m/s + (–150 kg m/s) = –100 kg m/s

c east

d East, as the initial total momentum is towards the east/in the negative direction. As there is only one object (the two trolleys stuck together) after the collision, the velocity must be in this direction.

e 25 kg

f –100 kg m/s = 25 kg × ? m/s
velocity = −100 / 25 = −4 m/s

4 *F* = (*mv* – *mu*) / *t* = (10 kg × 8 m/s −10 kg × 5 m/s) / 2 s = (80 − 50) / 2 = 30 / 2 = 15 N

5 **a** change in momentum = force × time = 5 N × 3 s = 15 kg m/s

b 15 kg m/s / 30 kg = 0.5 m/s

change in velocity = 0.5 m/s

SP2f.6 Momentum – Homework 2

1 The momentum of the ball after it is hit is the same as the momentum of the golf club before the ball is hit. Momentum is the product of mass and velocity, so as the mass of the ball is less than the mass of the golf club, its velocity must be greater to give the same momentum.

2 **a** momentum = 0.5 kg × 3 m/s = 1.5 kg m/s

b 1.5 kg m/s

c total mass after impact = 0.6 kg

velocity = 1.5 kg m/s / 0.6 kg = 2.5 m/s

3 momentum before collision = 75 kg × 5 m/s = 375 kg m/s

mass after collision = 75 kg + 55 kg = 130 kg

velocity after collision = 375 kg m/s / 130 kg = 2.88 m/s in the same direction as the original motion

4 momentum before collision = 0.01 kg × 1 m/s = 0.01 kg m/s

momentum of 10 g marble after collision = 0.01 kg × 0.4 m/s = 0.004 kg m/s

total momentum after collision = 0.01 kg m/s, so momentum of 5 g marble = 0.01 kg m/s – 0.004 kg m/s = 0.006 kg m/s

velocity of 5 g marble = 0.006 kg m/s / 0.005 kg = 1.2 m/s

5 momentum before collision = 10 kg × 5 m/s + 15 kg × –10 m/s = 50 kg m/s – 150 kg m/s = –100 kg m/s

combined mass = 25 kg

final velocity = –100 kg m/s / 25 kg = –4 m/s

6 momentum of golf ball = 0.045 kg × 54 m/s = 2.43 kg m/s

velocity of club = 2.43 kg m/s / 0.75 kg = 3.24 m/s

7 force = change in momentum / time = (0.005 kg × 400 m/s) / 0.002 s = 2 / 0.002 = 1000 N

8 If the axe always comes to a stop in the same time, then the force that decelerates the axe depends on the change in momentum. If the speed is also the same, the change in momentum depends on the mass of the axe head. So the greater the mass of the axe head, the greater the force needed to bring it to a stop. The force of the wood on the axe and the force of the axe on the wood are an action–

reaction pair of forces, so this also means that there is a greater force from the axe on the wood with a more massive axe head.

9 The clay and the Earth stick together, and both move together in the direction of the original motion. However the mass of the Earth is so large compared to the mass of the clay, that the change in its momentum results in a velocity far too small to be detected.

A very good answer may point out that as the clay was falling the action–reaction forces of gravity would have accelerated the Earth upwards at the same time as the clay was accelerated downwards, but again the mass of the Earth would have made the former so small as to be undetectable. So the two effects balance each other out.

SP2f.7 Equation practice 1

1 a momentum = 1800 kg × 30 m/s = 54 000 kg m/s
  b momentum = 75 kg × 10 m/s = 750 kg m/s
  c velocity = 300 kg m/s / 60 kg = 5 m/s
  d mass = 1.8 kg m/s / 40 m/s = 0.045 kg
  e mass = 6.4 kg m/s / 40 m/s = 0.16 kg
  f 10 cm/s = 0.1 m/s, momentum = 7 kg × 0.1 m/s = 0.7 kg m/s
  g 58 g = 0.058 kg, velocity = 3.19 kg m/s / 0.058 kg = 55 m/s
  h 160 g = 0.16 kg, momentum = 0.16 kg × 10 m/s = 1.6 kg m/s
  i velocity = 0.1 kg m/s / 0.16 g = 0.625 m/s

2 mass = 40 000 kg, velocity = 800 000 kg m/s / 40 000 kg = 20 m/s

3 mass = 0.000001 kg, momentum = 0.000001 kg × 1 m/s = 0.000001 kg m/s

4 initial momentum = 2000 kg × 5 m/s = 10 000 kg m/s, final momentum = 2000 kg × 20 m/s = 40 000 kg m/s, difference = 30 000 kg m/s (or change in momentum = mass × change in velocity = 2000 kg × 15 m/s = 30 000 kg m/s)

5 20 cm/s = 0.2 m/s, momentum = 30 × 10^{-15} kg × 0.2 m/s = 6 × 10^{-15} kg m/s

6 a momentum = 2 kg × 2 m/s = 4 kg m/s
  b 4 kg
  c 4 kg m/s
  d velocity = 4 kg m/s / 4 kg = 1 m/s

7 momentum before crash = 30 000 kg × 25 m/s = 750 000 kg m/s

mass after crash = 32 000 kg, velocity = 750 000 kg m/s / 32 000 kg = 23 m/s

8 momentum before crash = 2 kg × 1.5 m/s = 3 kg m/s

total mass after crash = 3 kg m/s / 1 m/s = 3 kg

trolley D has a mass of 1 kg

9 initial momentum = 0 kg m/s.

momentum of trolley E after separation = 5 kg × 2 m/s = 10 kg m/s.

momentum of trolley F must be –10 kg m/s, so velocity = –10 kg m/s / 4 kg = –2.5 m/s

10 momentum of trolley G = 2 kg × 3 m/s = 6 kg m/s

momentum of trolley H = 1.5 kg (–5 m/s = –7.5 kg m/s

total momentum before collision = –1.5 kg m/s

mass after collision = 3.5 kg

velocity after collision = –1.5 kg m/s / 3.5 kg = −0.43 m/s

SP2f.8 Equation practice 2

1 a *F* = 2000 kg × 15 m/s / 7.5 s = 4000 N
  b *F* = (2000 kg × 20 m/s – 2000 kg × 10 m/s) / 5 s = 4000 N
  c *F* = (2000 kg × 30 m/s – 2000 kg × 5 m/s) / 25 s = 2000 N
  d F = (2000 kg × 10 m/s – 2000 kg × 25 m/s) / 3 s = −10 000 N

2 *F* = (70 kg × 2 m/s – 70 kg × 12 m/s) / 4 s = –175 N

3 *F* = 4000 kg m/s / 5 s = 800 N

4 *t* = 1500 kg × 30 m/s / 2500 N = 18 s

5 a *F* = (30 000 kg × 15 m/s – 30 000 kg × 5 m/s) / 30 s = 10 000 N
  b *t* = (35 000 kg × 15 m/s – 35 000 kg × 5 m/s) / 10 000 N = 35 s
  c *F* = (35 000 kg × 20 m/s) / 10 s = 70 000 N

6 a *t* = (90 kg × 5 m/s – 90 kg × 15 m/s) / –225 N = 4 s
  b $v - u = F \times t / m$

  $v = F \times t / m + u$

  $v = (-150 \times 2) / 90 + 5$

  $v = -3.33 + 5$

  $v = 1.67$ m/s

7 *m* = 1875 N × 8 s / (10 m/s – 0 m/s) = 1500 kg

8 3 minutes = 180 s

(*mv* – *mu*) = 250 N × 180 s = 45 000 kg m/s

v – *u* = 45 000 kg m/s / 20 000 kg = 2.25 m/s

u = 236 m/s – 2.25 m/s = 233.75 m/s

9 *m* = 5000 N × 30 s / (400 m/s – 250 m/s) = 1000 kg

10 $v - u = 1200\text{ N} \times 0.005\text{ s} / 0.004\text{ kg} = 1500\text{ m/s}$

11 **a** $v - u = -2500\text{ N} \times 6\text{ s} / 1000\text{ kg} = -15\text{ m/s}$
$v = -15\text{ m/s} + 30\text{ m/s} = 15\text{ m/s}$

b $v - u = 3600\text{ N} \times 5\text{ s} / 1200\text{ kg} = 15\text{ m/s}$
$u = 20\text{ m/s} - 15\text{ m/s} = 5\text{ m/s}$

c $v - u = 3000\text{ N} \times 10\text{ s} / 1500\text{ kg} = 20\text{ m/s}$
$v = 20\text{ m/s} + 10\text{ m/s} = 30\text{ m/s}$

d $v - u = -5600\text{ N} \times 5\text{ s} / 1400\text{ kg} = -20\text{ m/s}$
$u = 5\text{ m/s} - (-20\text{ m/s}) = 25\text{ m/s}$

SP2g Stopping distances

Student Book

5th **1** in order to leave a safe distance so they do not crash when a hazard appears

6th **2** 17 m

6th **3** **a** The car is moving during the driver's reaction time, so the longer the driver takes to respond to a stimulus, the further the car will have moved.

6th **b** The faster the car is moving, the further it will go during the driver's reaction time.

6th **4** In a computer test there is just a light/colour change (or a sound); in the simulator there are lots of things to look at/the driver might not be looking in the correct direction when the hazard appears/the driver has to decide if something they can see *is* a hazard.

6th **5** Drinking alcohol increases reaction time, therefore increasing thinking distance. This increases stopping distance, leading to more crashes.

6th **6** The thinking distance is the same but cars have much smaller masses than lorries, so the braking distance (and so the overall stopping distance) will be less.

6th **7** The lower speed limit is for wet weather, when the reduced friction between tyres and the road will make braking distances longer.

S1 A good answer will contain the following points.

Thinking distance is increased by: alcohol; drugs; tiredness; faster speed.

Braking distance is increased by: faster speed; higher mass; worn brakes; worn tyres; lower friction road surface, e.g. mud, gravel, wet, ice.

E1 The paragraph should be coherent and concise, and should contain most of the following points:

- fog does not affect the thinking or braking distances
- fog reduces the distance at which a hazard can be identified
- if the distance at which the hazard is identified is less than the stopping distance, the car will hit the object
- drivers need to reduce their speed in foggy conditions until the stopping distance is less than the maximum distance they can see ahead.

Exam-style question

Description that makes reference to the following points:

- the thinking distance is how far the vehicle travels while the driver is reacting to a hazard (1).
- the faster the vehicle is travelling the greater the distance travelled whilst the driver is thinking (1).
- braking distance is how far the vehicle travels while it is slowing down (1).
- the faster the vehicle is travelling the longer it takes to stop (1)

Activity and Assessment Pack

SP2g.1 Investigating reaction times

4 the person being tested

6 Answers should refer to whichever method produced the smallest range of results.

7 **a** The reaction times are likely to be longer.

b Alcohol is a depressant/increases reaction times.

SP2g.2 Stopping distances Strengthen

1 **a** thinking, braking (either order)

b longer, braking

c thinking, braking (either order)

d shorter, thinking

e braking, longer

f braking, longer

g braking, shorter

2 **a** time, stimulus, stimulus, road

b 0.25 seconds

c thinking, brake

d fast, thinking, longer

e increased, alcohol

SP2g.3 Stopping distances – Extend

1 **a** It does not affect the driver's reaction time.
b No, it doesn't affect how long it takes the vehicle to stop.
c a kilometre
d accept a few metres or 100 metres
e The car will not be able to stop before it reaches the hazard.
f about 35 mph (the stopping distance at 30 mph is 23 m, at 40 mph it is 36 m)

2 The paragraph should be coherent and concise, and should contain most of the following points:
- fog does not affect the thinking or braking distances
- fog reduces the distance at which a hazard can be identified
- if the distance at which the hazard is identified is less than the stopping distance, the car will hit the object
- drivers need to reduce their speed in foggy conditions until the stopping distance is less than the maximum distance they can see ahead.

3 Charts should include tiredness, alcohol, illness and drugs feeding into the thinking distance box, and tyres, road conditions, mass of vehicle and vehicle speed feeding into braking distance box.

4 If based on the chart of the worksheet, further 'branches' leading from 'what is the standard stopping distance' box to 'slow down' could be 'is the road ahead straight enough for me to see the full stopping distance (no)', 'are my brakes and tyres in good condition (no)', 'is my vehicle more heavily loaded than normal (yes)', 'is the road surface in good condition and dry (no)', 'am I tired/ill (yes)', 'have I been drinking/ taking drugs (yes)'.

SP2g.4 Road safety – Homework 1

1 **a** True: it travels further while the driver is thinking/the braking distance is longer.
b False: the thinking distance will be greater.
c True: many drugs increase reaction time.
d False: the braking distance will be longer as friction will be less.
e False: the braking distance will be longer because the car has more mass.
f True: there will be less friction between the tyres and the road.

2 reacting, thinking, braking, stopping, closer to shorter, better
decrease, increase

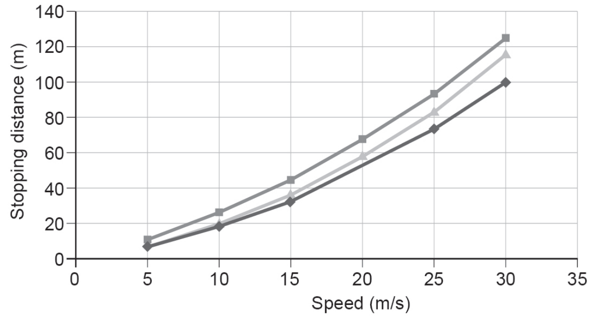
3 A faster car will travel further during the thinking time. A faster car also travels further during the braking time/it is harder to stop a faster car so it travels further.

SP2g.5 Stopping distance graphs Homework 2

1 10, 15, 20, 25, 30

2 18, 32, ?, 73, 100

3 **a** graph as shown, with the lowest line plotted



b The actual values are 51 m stopping distance, 31 m thinking distance.

4 thinking times are all 1.8 m, thinking distances are 9, 18, 27, 36, 45, 54, stopping distances are 11, 26, 44, 67, 93, 124

5 the upper line plotted in the graph for question **3a**

6 braking distances: 2.4, 9.6, 20.4, 37.2, 57.6, 84
stopping distances: 7.4, 19.6, 35.4, 57.2, 82.6, 114.0

7 the middle line plotted in the graph for question **3a**

8 The worn brakes cause a greater increase to the overall stopping distance than the drunk driver in this example.

9 It is an easy method for making sure drivers have sufficient space to stop safely if the car in front stops suddenly.

10 These make the stopping distance longer.

11 If the car in front is moving faster, it will take longer to stop as well.

12 students' own suggestions

SP2h Braking distance and energy

Student book

1 work = 5 N × 5 m = 25 J

2 25 J, as the final kinetic energy is the same as the work done to accelerate it (assuming no energy is wasted).

3 kinetic energy = 0.5 × 0.5 kg × (20 m/s)^2
= 100 J

4 a kinetic energy
= 0.5 × 1500 kg × (20 m/s)^2
= 300 000 J

distance = 300 000 J / 10 000 N
= 30 m

b kinetic energy
= 0.5 × 1500 kg × (40 m/s)^2
= 1 200 000 J

distance = 1 200 000 J / 10 000 N
= 120 m

5 the braking distance increases by a factor of four/is multiplied by four

S1 The braking distance depends on kinetic energy, which depends on speed squared. So if the speed doubles the braking distance goes up by a factor of four/is multiplied by four.

E1 The braking distance depends on the force used for braking and on the amount of stored kinetic energy that has to be transferred. The kinetic energy depends on the mass of the vehicle and on its speed squared. Lorries have a much higher mass than cars, so their kinetic energy at a given speed is much higher. This means that the lorry needs more powerful brakes. The lower speed limit helps to reduce the braking distance by reducing the amount of kinetic energy that has to be transferred during braking.

Any suitable calculation to compare the stopping distances for different mass vehicles or with different braking forces.

e.g. A 15 000 kg lorry compared to a 1500 kg car, both travelling at 30 m/s with a braking force of 10 000 N (braking force and car mass chosen because these are given in Worked Example 3 in the Student Book *SP2h*).

kinetic energy of lorry
= 0.5 × 15 000 kg × (30 m/s)^2 = 6 750 000 J

kinetic energy of car =
0.5 × 1500 kg × (30 m/s)^2 = 675 000 J

braking distances
= 6 750 000 J/10 000 N
= 675 m for the lorry, 67.5 m for the car.

without more powerful brakes than the car, the stopping distance for the lorry would be over half a kilometre.

Exam-style question

Any four points from the following:

The braking distance depends on the kinetic energy that has to be transferred during stopping, and the force used to stop the car. (1) Kinetic energy depends on mass and velocity squared, (1) so if the speed doubles the kinetic energy goes up by a factor of 4. (1) The braking distance is the work done to stop the car, which is the same as the kinetic energy stored in the moving car. (1) So if the braking force stays the same (1) if the speed doubles the braking distance will be 40 metres. (1)

Activity and Assessment Pack

SP2h.1 Accelerating trolleys

5 Students should get a scatter graph with points along a line through the origin at 45° (assuming the scale on both axes is the same).

6 work done = kinetic energy

7 b The closer the points are to the line of best fit, the better quality the data are likely to be.

8 b Suggestions could include measurement, recording or calculation errors.

SP2h.2 Factors affecting braking distance

1 Graph with labelled axes and a smooth curve drawn through the points. This should show the line curving gradually upwards with increasing speed.

2 a The line is curved upwards.

b Braking distance increases with velocity, but the relationship is not linear/directly proportional.

3 a

Speed (m/s)	Kinetic energy (J)
5	18 750
10	75 000
15	168 750
20	300 000
25	468 750
30	675 000
35	918 750

b Graph with labelled axes and a line of best fit drawn through the points. This should be a straight line through the origin.

c The braking distance is directly proportional to the kinetic energy.

4 H A graph of braking distance against momentum should curve upwards with increasing momentum (similar shape to the graph drawn for question 1).

Braking distance increases with momentum, but the relationship is not linear/directly proportional.

5 Students should produce a set of graphs that show that the only directly proportional relationship between braking distance and speed/kinetic energy/momentum is the one with momentum.

SP2h.3 Braking distance and energy Strengthen

1 a makes it decelerate
b thermal energy in the brakes and surroundings
c KE = $\frac{1}{2}$ × mass × speed^2
d it is multiplied by 4
e four times as much energy
f four times as long

S1 The brakes apply a force that … makes the car decelerate.
The brakes transfer energy stored in the moving car (kinetic energy) to … thermal energy in the brakes and the surroundings.
The kinetic energy is calculated using the formula … KE = $\frac{1}{2}$ × mass × speed^2.
If the speed of the car doubles, the kinetic energy … is multiplied by four.
This means that the brakes must transfer … four times as much energy.
So the braking distance at 30 m/s is …. four times as long as it is at 15 m/s.

2 correct words are: increases, doubles, increases, is multiplied by 4

3 1200 kg, 30 m/s
540 000 J
540 000 J
work / force = 540 000 J / 9000 N
60 m

SP2h.4 Braking distance and energy Homework 1

1 energy, distance, joule
force, distance
moving, mass, speed
mass, speed
brakes, equal to, braking, force

2 a 30 000 kg, 20 m/s
6 000 000 J
b distance = work / force
c stopping distance
= 6 000 000 J / 90 000 N = 67 m

3 kinetic energy = $\frac{1}{2}$ × 40 000 kg × (20 m/s)^2
= 8 000 000 J
distance = 8 000 000 J/90 000 N = 89 m

SP2h.5 Braking distance and energy Homework 2

1 275 km/h = 76.38 m/s
kinetic energy of train
= $\frac{1}{2}$ × 715 000 kg × (76.38 m/s)^2
= 2 085 620 823 J
force = work/distance
= 2 085 620 823 J / 4000 m = 521 405 N

2 350 km/h = 97.2 m/s
kinetic energy = 3 377 602 800 J
distance = work / force
= 3 377 602 800 J / 521 405 N
= 6478 m (or approx. 6.5 km)

3 kinetic energy = $\frac{1}{2}$ × 250 000 kg × (75 m/s)^2
= 703 125 000 J
braking distance = 703 125 000 J / 4 × 10^5 N
= 1758 m

4 Lorry A: kinetic energy = $\frac{1}{2}$ × 40 000 kg × (25 m/s)^2
= 12 500 000 J
braking distance = work / force
= 12 500 000 J / 90 000 N
= 139 m
Lorry B: kinetic energy = $\frac{1}{2}$ × 20 000 kg × (25 m/s)^2
= 6 250 000 J
braking distance = work / force
= 6 250 000 J / 90 000 N
= 69 m
Lorry C: kinetic energy = $\frac{1}{2}$ × 30 000 kg × (15 m/s)^2
= 3 375 000 J
braking distance = work / force
= 3 375 000 J / 90 000 N
= 37.5 m
Lorry D: kinetic energy = $\frac{1}{2}$ × 30 000 kg × (15 m/s)^2
= 3 375 000 J
braking distance = work / force
= 3 375 000 J / 45 000 N
= 75 m

5 a Students may suggest that braking distance is directly proportional to mass.
b Students may suggest that braking distance is inversely proportional to force from the brakes.
c Students should suggest carrying out further calculations for the same speed and braking force but different lorry masses, to get at least five different results. Plotting these on a graph should show a straight line.
d Carry out further calculations for the same speed and mass but different braking forces, to obtain at least five results. Plotting these on a graph should show a

curve. However, if the inverse of either the distance or the braking force is plotted, the graph should show a straight line if the relationship is directly proportional.

6 energy in moving car = force × distance
= 9500 N × 25 m
= 237 500 J

This is the KE of the car.
237 500 J = $\frac{1}{2}$ × 1200 kg × speed^2

speed^2 = 237 500 J / ($\frac{1}{2}$ × 1200 kg) = 395.8

speed = 19.9 m/s

7 Lorry mass:

distance = work/force

work = kinetic energy = $\frac{1}{2}$ × mass × speed^2

so distance = ($\frac{1}{2}$ × mass × speed^2)/force

If speed and force are the same, then distance = mass × a fixed quantity, so distance is directly proportional to mass.

Braking force:

as above, distance = ($\frac{1}{2}$ × mass × speed^2) / force

If mass and speed are the same, then distance = a fixed quantity / force, so distance is inversely proportional to force.

SP2i Crash hazards

Student Book

8th **1 a** The deceleration when it comes to a stop is greater if it was travelling faster to start with, so there is a greater force on the vehicle.

8th **b** The lorry has a greater mass than the car, so the force needed to stop it is greater.

7th **2** If a back seat passenger is not wearing a seatbelt they will continue to move forwards until they hit the seats or people in front.

A good answer may include mention of action–reaction pairs – when the flying back seat passenger hits the person in front, there will be equal and opposite forces on both of them, so they will both be injured.

8th **3** On impact, the bubbles squash slowly, reducing the acceleration and so reducing the force on the object being protected.

10th **4 H a** force = (1800 kg × 0 m/s − 1800 kg × 20 m/s) / 0.03 s = −1 200 000 N

9th **H b** The force is greater because the car has a greater mass and it was moving faster before it crashed, so its starting momentum was greater. It also came to a stop in a shorter time, so the rate of change of momentum was greater.

S1 Any two from: crumple zones, air bags, wearing seat belts, driving more slowly.

Crumple zones increase the time taken for the car to stop; air bags increase the time it takes for a person's head to stop (compared to hitting the dashboard or steering wheel); seat belts ensure the people stop at the same rate as the car (rather than carrying on at their original velocity and then stopping suddenly when in contact with the dashboard/wheel/windscreen). All four methods reduce the deceleration and so reduce the force on the vehicle.

E1 H Any suitable set of calculations using the formula relating force to the rate of change of momentum to demonstrate that decreasing the speed or mass of a vehicle, or increasing the time taken to stop (i.e. if the car has a crumple zone), decreases the force.

One possible set of calculations is:

force on a 1000 kg car stopping in 0.05 s from different speeds:

15 m/s: force = (1000 kg × 0 m/s − 1000 kg × 15 m/s) / 0.05 s = −15 000 / 0.05 = −300 000 N

30 m/s: force = (1000 kg × 0 m/s − 1000 kg × 30 m/s) / 0.05 s = −30 000 / 0.05 = −600 000 N

conclusion for speed: When the speed doubles the force doubles (if all other factors stay the same). A good answer may also point out that the force will be proportional to the speed if the mass and time stay the same.

force on two cars of different masses stopping in 0.05 s from 15 m/s:

1000 kg car: as above, force = −300 000 N

2000 kg car:
force
= (2000 kg × 0 m/s − 2000 kg × 15 m/s) / 0.05 s
= −30 000 / 0.05
= −600 000 N

When the mass doubles the force doubles (if all other factors stay the same). A good answer may also point out that the force will be proportional to the mass if the speed and time stay the same.

A crumple zone increases the time for the car to stop:

1000 kg car at 15 m/s stopping in 0.05 s: as above, force = −300 000 N

same car stopping in 0.1 s:
force = (1000 kg × 0 m/s – 1000 kg × 15 m/s) / 0.1 s
= –15 000 / 0.1 = –150 000 N

The time has doubled and the force has halved. The force is inversely proportional to the time it takes the car to come to a stop.

Exam-style question

Explanation that makes reference to the following points:

- the crumple zone reduces the deceleration when the car hits an obstacle (1)
- and this reduces the force on the car and any passengers strapped into the car (1)
- if the passengers are not strapped in they carry on moving forwards when the car stops (1)
- and the effect of the crumple zones is negligible because the deceleration when the passenger hits the dashboard is so large. (1)

Activity and Assessment Pack

SP2i.2 Safer roads

Escape lanes are typically filled with deep sand or gravel that provides a large resistance to movement. This slows the vehicle down rather than stopping it abruptly as would be the case with a rigid barrier.

Roadside barriers A car running into the back of another car travelling in the same direction may not come to a complete stop, meaning less deceleration/change in momentum and so smaller forces. A car crossing into the opposite carriageway is more likely to be stopped by a collision, and so likely to encounter larger forces in a collision.

The new concrete barriers are more effective than the steel ones as they do not bend/deform, do not usually need to be replaced after an accident and need less maintenance.

Note that barriers of this type are not designed to absorb head-on collisions from vehicles, but to deflect a vehicle *along* the barrier.

Crash cushions are placed around obstructions such as bridge supports on motorways because a car hitting the support would come to a complete stop. If they run into the main part of the barrier they will be deflected along it instead, and will therefore encounter much smaller forces. If they hit the *end* of the barrier, however, they will come to a complete stop. Crash barriers work in a similar way to crumple zones and reduce the deceleration of the colliding vehicle. Some work by deforming when they are hit, others consist of barrels or other containers with water – these move when they are hit but bring the vehicle to a much more gradual stop than hitting the end of a solid barrier.

SP2i.3 Crash hazards – Strengthen

1 **a** increases forces
b increases forces
c reduces forces
d reduces forces
e reduces forces
f reduces forces

2 Explanations should include a reference to increasing the time it takes for the car/occupant to come to a stop, hence reducing the deceleration and reducing the force on the person.

explanation cards: 1a and 1b are not safety features (1a – J, 1b – I, C)

seat belt – K; air bags – (E), B, D, F; driving slowly – A, D, F; crumple zone – H, D, F

SP2i.4 Crash hazards – Extend H

1 **a** force
= (1000 kg × 0 m/s − 1000 kg × 15 m/s) / 0.05 s
= −15 000 / 0.05
= −300 000 N

b force
= (1000 kg × 0 m/s − 1000 kg × 30 m/s) / 0.05 s
= −30 000 / 0.05
= −600 000 N

2 When the speed doubles the force doubles (if all other factors stay the same). A good answer may also point out that the force will be proportional to the speed if the mass and time stay the same.

3 For the 1000 kg car the answer is the same as question **1a**.

For the 2000 kg car: force
= (2000 kg × 0 m/s − 2000 kg × 15 m/s) / 0.05 s
= −30 000 / 0.05 = −600 000 N.

When the mass doubles the force doubles (if all other factors stay the same). A good answer may also point out that the force will be proportional to the mass if the speed and time stay the same.

4 force
= (1000 kg × 0 m/s − 1000 kg × 15 m/s) / 0.1 s
= −15 000 / 0.1 = −150 000 N

The time has doubled and the force has halved. The force is inversely proportional to the time it takes the car to come to a stop.

5 **a** Car B, because it has a longer bonnet and so is likely to have a longer crumple zone.

b Car B is also much bigger, and so will have a greater mass. The force depends on both mass and time to stop, so unless we have more details of mass/time to stop we cannot say which factor will make the most difference.

6 Car B has a greater mass, so if the cars are initially travelling at the same speed, a greater force from the brakes will be needed to provide the same deceleration.

SP2i.5 Car designs 1

1 increase, decrease, decrease
increase
decrease
longer, longer, smaller, smaller, smaller

2 forces, decelerate
crumple zone, seat belts, decelerate, velocity
force, greater, greater

SP2i.6 Car designs 2

1 a The acceleration will increase, because acceleration is inversely proportional to mass (or similar explanation).

b The stopping distance will be shorter, as the momentum at a particular speed will be less so the same braking force will stop the car more quickly.

c The force will be less, because the momentum will be less (or the deceleration to bring it to a stop will be less).

2 a The increased engine force will increase the acceleration, and once the car is moving the more streamlined shape will reduce air resistance so the resultant force accelerating the car will be greater.

b The increased braking force will reduce the stopping distance – if a greater force can be produced the change in momentum to stop the car can be produced in a shorter time/the greater braking force will produce a greater deceleration.

3 Assuming that the greater bonnet length is used to create a longer crumple zone, it will increase the time it takes for a car to come to a stop in a collision, so the deceleration will be less and so will the force on the car. Students may also mention that a greater bonnet length is likely to give the car increased mass, which will counteract the above effect as a greater mass gives greater momentum and so greater force for the same deceleration. If students mention both, it is acceptable for them to conclude that they cannot say whether or not the longer bonnet will improve the safety of the car as they don't know the relative sizes of the two effects.

4 a collisions when another car runs into the side of the car we are discussing

b A crumple zone requires part of the car to get shorter during the collision – unless cars are made a lot wider there isn't enough to the side of a car to act as a crumple zone.

c Both cases involve an acceleration (which is negative in the case of the car coming to a stop)/a change in momentum, and a force on the car is needed in both cases. In both cases the rate of change of velocity/momentum is reduced by the airbag.

5 force
= (final momentum − initial momentum) / time
= (26 000 kg m/s − 12 000 kg m/s) / 10 s
= 1400 N

6 change in momentum = 14 300 kg m/s, as the car comes to a stop

time = change in momentum / force
= 14 300 kg m/s / 1500 N = 9.53 s

7 change in momentum = force × time
= 250 000 N × 0.05 s
= 12 500 kg m/s

change in velocity
= change in momentum / mass
= 12 500 kg m/s / 1250 kg
= 10 m/s

8 new force
= change in momentum (from Q9) / time
= 12 500 kg m/s / 0.15 s
= 83 333 N

difference = 166 667 N

percentage change
= 166 667 N / 250 000 N × 100%
= 67% of original

9 a reduce mass

b A car with a smaller mass would need a smaller force to give it a certain acceleration. So less fuel would be burnt and less carbon dioxide emitted.

c It would reduce it. A car with less mass has a smaller weight, so there would be less force pressing the tyres against the road and so less friction.

d The expected answer is that it would improve safety, because a smaller mass means a smaller momentum for a given speed and hence smaller forces in a crash, and/or a given force from the brakes reducing speed more quickly when the brakes are applied. Against this is the reduced friction between tyres and road, but the former two arguments probably outweigh the reduced friction.

SP3a Energy stores and transfers

Student Book

1 Energy originally stored in chemicals in the fuel is transferred by forces to a store of kinetic energy in a moving car. If students have worked through the whole page before answering the questions, they should also add that energy is also transferred by heating and by sound and that these are transfers of wasted energy.

2 The original store of kinetic energy is transferred by forces to gravitational potential energy as the ball rises, until all the stored energy is gravitational potential energy. Then as the ball falls, the gravitational potential energy is transferred back to kinetic energy. A very good answer might also point out that some energy is transferred to the surroundings by heating due to air resistance/friction.

3 by forces, by electricity, by heating, by light, by sound

4 The total amount of energy remains the same, so the energy transferred to the kettle and surroundings is 1000 J − 850 J = 150 J.

5 thermal energy stored in the surroundings

6 **a** The diagram should show kinetic energy in the bullet being transferred (by forces) to kinetic energy in the egg fragments, the remaining kinetic energy stored in the bullet, and thermal energy stored in the egg, bullet and surroundings. Students may include energy transferred by sound when the bullet hits the egg, but this will also end up being stored in the surroundings as thermal energy.

b There would be no kinetic energy remaining in the car itself, unlike the bullet which is not stopped by the egg.

7 The question requires a sketch, not an accurately drawn Sankey diagram. The output arrow for the kettle should be around 85% of the width of the input, and the output arrow for the surroundings around 15%. Diagrams should be correctly labelled with the transfer methods and the correct amounts of energy.

S1 A store of chemical energy in your muscles is transferred by forces to a store of gravitational potential energy when you are at the top of the diving board. When you jump off, this store is gradually transferred by forces to kinetic energy stored in your moving body. When you hit the water, some of this energy is transferred to kinetic energy in the moving drops of water but all of it ends up transferred to the water by heating, so the final store is thermal energy in the swimming pool (and possibly a little in the air above it).

E1 The energy transferred by heating is 25 J − 10 J because energy is conserved/the total amount of energy remains the same.

Sankey diagram should be drawn correctly to scale.

Exam-style question

a A flow diagram or a Sankey diagram showing energy transferred to the television by electricity, (1) and transferred from it by light, sound (1) and heating. (1)

b The transfers by sound and light are the useful energy transfers. (1) No mark if electricity and/or heating are also mentioned.

Activity and Assessment Pack

SP3a.1 Energy fair

1 **a** Possible stores:

- kinetic: the moving roller coaster and chair ride, dodgem cars, bullets in rifle range, etc.
- gravitational potential: roller coaster cars, chair ride (especially the chairs at the top), hammer above girl's head
- chemical: candy floss, fish and chips
- thermal: human bodies, cookers in fish and chip stall

Possible transfers:

- by light and sound: any lights in the fairground, any music from rides, screams from roller coaster riders etc.
- by heating: from bodies, from the cooker in the fish and chip stall
- by forces: moving the chair ride around, starting the roller coaster off, dodgem cars hitting each other
- by electricity: supply to motors in the rides, to lights

b Possible useful energy transfers: kinetic to gravitational potential and back as the roller coaster moves along the ride, by heating from cooker in fish and chip stall to food, by electricity to motors in dodgem cars

Possible wasted energies: energy released by heating from motors etc., by sound from noise of roller coaster moving, by heating from cooker in fish and chip stall to the surroundings

SP3a.2 Energy diagrams

1 From left to right: chemical, strain/elastic potential/kinetic

2 by forces

3 **a** by electricity to the kettle, energy transferred by heating for all three arrows leading from the kettle, energy stored as thermal energy in the hot water, in the kettle, in the surroundings

b We use a kettle to heat water, so only the thermal energy stored in the hot water is useful.

4 **a** 17 squares = 17 × 5 J = 85 J

b 2 squares = 10 J

c square = 5 J

5 **a** by electricity

b 60 J − 33 J = 27 J

c Sankey diagram drawn correctly to scale and labelled

SP3a.3 Energy stores and transfers Strengthen

1 Energy is stored in our bodies. Energy stored in this way is sometimes called *chemical* energy. As you climb the ladder some of the energy stored in your body is transferred to *gravitational* potential energy. When you jump, the gravitational *potential* energy is transferred to *kinetic* energy as you accelerate downwards.

Not all the energy is transferred as useful energy – your body gets warmer as you climb, and this *thermal* energy is transferred to your surroundings *by heating*.

2 **a** any example such as fire, light bulb, etc.

b any example such as fire, light bulb, TV, Sun, etc.

c any example such as radio, TV, human voice, MP3 player

d any example such as motor, car, etc.

3 **a** any example such as a moving car, moving ball etc.

b any example such as fuel, food, batteries

c any example such as box on shelf, ball in air, etc.

d any example such as stretched elastic band, bent bow etc.

4 flow diagram continues with energy stored in squashed ball as it hits floor (elastic potential energy); energy stored in moving ball (kinetic energy); energy stored in ball as it rises (gravitational potential energy) B or D, B or D, C, A, E

5 **a** 15 J

b total energy adds up to 100 J/energy cannot be created or destroyed

6 by heating

SP3a.4 Energy stores and transfers Homework 1

1 **a** chemical energy

b kinetic energy

c thermal/energy transferred by heating, energy transferred by sound

d Friction in the brakes transfers kinetic energy to thermal energy by forces. Friction causes the temperature of the brakes to increase, so energy is transferred to the surroundings by heating.

2 **a** gravitational potential energy

b kinetic energy

3 **a** gravitational potential, kinetic, strain/elastic potential

b The store of strain/elastic potential energy is transferred to a store of kinetic energy by forces.

4 **a** total energy transferred is 100 J, so 100 J − 85 J − 5 J = 10 J

b 15 J

SP3a.5 Energy stores and transfers Homework 2

1 cuckoo clock: gravitational potential becomes kinetic, transfer is by forces

spring clock: elastic potential becomes kinetic, transfer is by forces

2 **a** It heats the kettle itself and most is then transferred to the surroundings.

b Flow diagram shows energy being transferred to the kettle by electricity, and energy being transferred from the kettle by heating to three stores of thermal energy – hot water, the kettle, the surroundings. The arrow and energy store for the surroundings may lead from the thermal store for the kettle.

3 **a** energy transferred to the surroundings by heating

b Correctly drawn and labelled Sankey diagram representing 100 J input energy, 95 J transferred by heating and 5 J transferred by light.

4 **a** by heating

b The total energy transferred by the TV is equal to the total energy supplied, as energy cannot be created or destroyed. So wasted energy = 300 J − 5 J − 5 J = 290 J

c Correctly drawn and labelled Sankey diagram showing 300 J in, 5 J transferred by light, 5 J by sound and 290 J by heating.

d Wasted energy is energy that is not able to be used usefully.

5 **a** gravitational potential

b kinetic

c strain/elastic potential

6 Flow diagram should show a store of gravitational potential energy transferring to kinetic energy, to strain energy, to kinetic energy and then to gravitational potential energy again. All transfers are by forces.

7 **a** Half as much, as it only reached half the original height.

b It is stored as thermal energy in the ball as a result of it being squashed and rebounding, and in the ball and surrounding air as a result of friction with the air.

8 If the ball is thrown downwards, it is a store of both kinetic and gravitational potential energy at the start. Ignoring any transfers by heating, all this energy is converted to kinetic energy just before it hits the ground, so this store of kinetic energy is greater than if the ball had been dropped without being given an initial downwards velocity. This energy is all transferred to gravitational potential energy at the top of the first bounce, with no kinetic energy as the ball is stationary at the top of the bounce. So the height must be greater than that of the initial drop.

If transfers by heating are taken into account, this is still possible as long as the extra kinetic energy originally given to the ball is greater than all the energy transfers by heating during the first fall and bounce.

SP3b Energy efficiency

Student Book

6th **1** **a** There will be more friction in the chain.

7th **b** by heating

6th **2** The low-energy bulb transfers more useful energy/less wasted energy (for the same amount of energy input).

8th **3** efficiency = 45 J ÷ 100 J = 0.45

8th **4** efficiency = 5 J ÷ 12 J = 0.42

8th **5** H Suggestions such as keeping all moving parts, such as the chain and the axles, clean and oiled will remove friction

S1 The oil reduces friction in the hinge/between the moving parts in the hinge, so less wasted energy is transferred to the surroundings by heating and by sound.

S2 The rest of the energy is transferred to the radio and the surroundings by heating.

efficiency = 5 J ÷ 50 J = 0.1

E1 useful energy = efficiency × total energy supplied = 0.4 × 1000 J = 400 J

If the efficiency is doubled by using the hot water, then total useful energy transferred = 0.8 × 1000 J = 800 J. As 400 J of this is transferred by electricity, then 400 J must be usefully transferred by heating.

As energy cannot be created or destroyed, the wasted energy is = 1000 J − 800 J = 200 J. This is also transferred by heating, but to the power station itself and to the surroundings. This wasted energy is likely to be caused by friction in the machinery and by energy being transferred from hot water in pipes before it reaches its destination. Some energy will also be wasted due to electrical heating in the wires (this is not covered until the next topic but some students may mention it if they recall the heating effect of current from KS3 work).

Exam-style question

Efficiency is the useful energy transferred divided by the total energy transferred. (1)

Both kettles transfer the same amount of useful energy, but kettle A transfers less total energy to achieve this (1) so A is the most efficient. (1)

Activity and Assessment Pack

SP3b.1 Efficiency of a kettle

1 Students' plans should include apparatus, details of measuring volume of water and the time to boiling, and how they know when the water is boiling.

5 **a** Depends on student's results, but the measured amount is likely to be higher than the theoretical value.

b The kettle is not 100% efficient/some of the energy is transferred to/stored in the kettle and the surroundings, so more must be supplied than is needed just to heat the water.

8 measure mass, time to boil kettle more accurately; repeat procedure or take a mean of class results; measure or control start temperature so that it matches the value in the theoretical calculation.

9 Whenever a measurement is made, there will always be some uncertainty or doubt about the result obtained, including the random effects of 'unseen' influences on the measurement. Repeating measurements using the same equipment under same conditions should produce consistent results (low variability). If the variation is low we can take a mean and this will reduce the uncertainty for the mean.

SP3b.2 Efficiency card sort

Card groups:

10, 7, 13 (or 14), 11 (or 1)

2, 19, 17, 1 (or 11)

15, 12, 5, 6

9, 8, 14 (or 13), 3

18, 16, 4, 20

SP3b.3 Energy efficiency – equation practice

1 a 80 J / 100 J = 0.8
  b 6.25 J / 25 J = 0.25
  c 12 J / 30 J = 0.4
  d 68 J / 80 J = 0.85
  e 0.9 × 1200 J = 1080 J
  f 0.95 × 5000 J = 4750 J
  g 0.3 × 750 J = 225 J
  h 350 J / 0.7 = 500 J
  i 260 J / 0.65 = 400 J
  j 10 J / 0.2 = 50 J

2 5 J / 100 J = 0.05

3 10 J / 300 J = 0.033

4 0.05 × 400 J = 20 J

5 a 9 J / 20 J = 0.45
  b 9 J / 0.05 = 180 J

6 a 300 000 J / 0.95
  = 315 790 J (or 300 kJ / 0.95 = 315.8 kJ)
  b 300 000 kJ / 0.9
  = 333 333 J (or 300 kJ / 0.9 = 333.3 kJ)

7 90 000 J / 0.8 = 112 500 J

8 useful energy transferred = 0.24 × 50 J = 12 J
  energy transferred by sound = 12 J – 8 J = 4 J

9 energy transferred to light bulb = 1 J / 0.05
  = 20 J
  energy transferred to transmission lines
  = 20 J / 0.9 = 22.22 J
  energy transferred to power station
  = 22.2 J / 0.5 = 44.4 J

SP3b.4 Energy efficiency Strengthen

1 friction, heat up, noise, lubricant, reduces, friction, less, forces, sound, less

2 a by heating
  b by sound
  c useful, total

4 5 J / 50 J = 0.1

5 *When you pedal a bike, the links in the chain move as the chain moves around. When two objects move past each other,* friction causes some of the energy to be transferred to the objects and to the surroundings by heating. This means that some of the energy transferred to the pedals by forces is wasted so you have to push harder on the pedals to make the bike move.

  Oil is a lubricant and reduces the friction between moving parts. If there is less friction there will be less wasted energy so not as much force on the pedals will be needed to make the bike move.

  (Oiling increases the efficiency of the bike, but this is not expected as this is part of a Higher Tier statement.)

SP3b.5 Energy efficiency Homework 1

1 efficiency = useful energy transferred / total energy transferred (last box)

2 a False
  b True
  c True
  d False
  e False
  f True

3 Statement a is wrong because energy transferred by heating is not the useful output, or because the 6 J is likely to be the energy transferred by light

  Statement d is wrong because the total energy input should be used in the calculation, not the wasted energy

  Statement e is wrong because an inefficient appliance wastes more energy than an efficient one.

4 by heating

5 friction, temperature, by heating, wasted, thermal, friction, lubricating

SP3b.6 Energy efficiency Homework 2

1 a 0.73 × 5.5 kWh × 3 600 000 J = 14 454 000 J (accept 5.5 kWh × 0.73 = 4 kWh as it is scientifically correct)

b to the surroundings, by heating

c Increase the thickness of the insulation/lagging jacket to reduce the amount of energy transferred to the surroundings by heating.

2 a energy transferred by heating and by sound from the motor

b 1.2 kWh = 1.2 × 3 600 000 J = 4 320 000 J
efficiency = 14 454 000 J / 4 320 000 J = 3.3 (this looks incorrect because the number is greater than 1)
(accept 4 kWh / 1.2 kWh = 3.3 as it is scientifically correct)

3 a there is also energy in the warm air going into the heat pump

b smaller, because the energy in the air is part of the input energy

c the one calculated in question 2, because it reflects the amount of energy they have to pay for

d how much each item costs and how much they would cost to install

4 a go up

b Either: energy is being supplied to the room in the form of the electricity being used by the fridge, so the total energy in the room is increasing and this will be in the form of energy transferred from the fridge by heating. Or: all the energy extracted from the air inside the fridge will be given out at the back of the fridge, so this will not affect the temperature. However, the fridge has a motor which will be less than totally efficient, so the wasted energy from the motor will be transferred into the room by heating.

SP3c Keeping warm

Student Book

1 a By conduction through the metal pan: a very good answer will refer to energy from the cooker making the particles in the pan vibrate and these vibrations being passed on through the metal and into the water.

b By convection in the water: a very good answer will talk about the water in contact with the pan warming up and becoming less dense and rising, and setting up a convection current.

2 It contains lots of trapped air: a very good answer will state that air is a good insulator because it has a very low thermal conductivity and the bubbles trap the air so it cannot transfer energy by convection.

3 a lower, because a straw bale as thin as the aerogel would not prevent the hand from burning

b Because the heat from the flame is not being conducted by the aerogel, it must have a lower thermal conductivity than straw bales.

4 The walls are thicker and they have a lower thermal conductivity.

5 a The wall is thicker and it contains an air gap (and air is a better insulator than brick).

b The foam/filling stops convection currents forming in the gap and transferring energy between the walls.

6 It reduces the rate at which energy is transferred between the inside and outside. To keep hot drinks hot, it reduces the flow of energy from the liquid to the surroundings. To keep cold drinks cold, it reduces the flow of energy from the surroundings to the liquid.

S1 Any two from:

- Walls can be built with a cavity because air is a poor conductor/has poor thermal conductivity.
- Cavity walls can be filled with foam because this stops energy being transferred across the gap by conduction.
- Walls can be built of a material with a low thermal conductivity, such as straw bales.
- Walls can be made thicker, as the thickness of a material reduces the rate of energy transfer by heating.

S2 Any two from the following, or similar examples:

- duvets/blankets on bed contain trapped air and keep us warm at night: the air is a poor conductor and it cannot transfer energy by convection because it cannot move
- carpets are made from insulating materials and reduce energy transferred through the

floor, and curtains help to reduce energy transfer through windows

- windows can be double glazed: the air gap between them reduces the energy that can be transferred by conduction
- warm clothing contains trapped air: the air is a poor conductor and it cannot transfer energy by convection because it cannot move
- fridges/freezers have walls and doors made from insulating materials to stop energy being transferred into the machine from the surroundings

E1 Energy transfer by radiation is reduced by the silvered surfaces because silver is a poor emitter and absorber of infrared radiation.

Energy transfer by conduction is reduced because glass is a poor conductor/an insulating material and energy cannot be conducted across the vacuum between the two walls.

Energy transfer by convection is not possible because there is no fluid (solid glass and a vacuum).

Exam-style question

Walls with a low thermal conductivity will reduce the rate at which energy is transferred through the walls of the building. (1) Less energy is needed to keep the house warm than would be needed for a house with walls of a higher thermal conductivity. (1)

Activity and Assessment Pack

SP3c.1 Testing insulation

1 same thickness of insulation, same type of beaker, same volume of hot water, same starting temperature of hot water

4 Temperature changes for the three beakers should be across the same time interval.

5 & 6 This should be the material that kept the water warm longer.

8 To see if the insulation made any difference at all.

10 a to identify any readings (or sets of readings) that are wrong (such as incorrect temperature readings or recordings)

b as the temperature is plotted against time, any outliers/incorrect measurements can be identified as they do not fall on a smooth curve drawn through the points

SP3c.2 Insulating homes

A 1 Thermal conductivities in W/(m K): snow 0.05–0.25 , nylon 0.25, soil 0.6–1.1, brick 1.3–1.6, wood 0.17 (in comparison, iron as used in corrugated iron roofing has a thermal conductivity of 80). Units are not important, as long as students have used the same units for all values.

2 The insulating properties of a material depend on its thickness as well as its thermal conductivity so the thickness of the walls/roof would also need to be known.

3 The walls of an igloo are much thicker than the walls of a tent so even if the snow has the higher thermal conductivity given (it depends on the degree of compaction, amongst other things), which is similar to that of nylon, the walls of the igloo will provide better insulation.

4 Thermal conductivity of ice is 2.2, so it is a better conductor/worse insulator than snow. Ice typically does not contain air pockets which snow does, even compacted snow, and the air pockets improve its insulating properties.

B 1 Celtic roundhouse – stone or wooden pillars, with the gaps between filled in with wattle and daub (woven wooden panels covered in a mixture of soil/sand/animal dung/straw); conical thatched roof

Scottish blackhouse – low, thick double walls of stone filled with earth, thatched roof usually secured by passing ropes across it with heavy stones fastened to the ends

alpine chalet – often stone first floor with timber construction above, roof with large overhang covered in wood, slates or stone tiles

Spanish/Greek villas – usually stone, with enclosed courtyards, small windows and often painted white

2 Celtic roundhouses – western Europe – cold in the winter and warm in the summer, often damp

Scottish blackhouses – northern Scotland – colder than most of Europe, wetter and much windier

alpine chalets – very cold winters with lots of snow, warmer summers

Spanish/Greek villas/houses – very hot summers with very mild winters; much drier than for the other houses here

3 Celtic roundhouses – made from available materials, heated with open fire inside, thin walls do not provide much insulation but the wattle and daub made them draught-proof

Scottish blackhouse – made from available materials, thick walls and roof help insulation, ropes across roof help to stop it blowing away alpine chalet – overhanging eaves help to protect walls against rain and snow and also shade the house in the summer

Spanish/Greek villas – stone takes a long time to heat up so helps to keep the house cool inside, courtyard provides shaded area to keep cool, small windows reduce amount of sunlight that can enter and heat the house

SP3c.3 Keeping warm – Strengthen

1 Walls can be built of materials with better insulating properties.

The thermal conductivity of a material is a measure of how well it transfers energy by heating.

A material with a low thermal conductivity is a good thermal insulator.

Using thicker materials reduces the rate at which energy is transferred.

2 blankets, warm, reduce

trapped air, poor, low, convection

cold, insulating, reduces, warmer, cold

SP3c.4 Keeping warm Homework 1

1 Less energy is transferred through the walls by heating, less energy is needed to heat it if both houses are kept at the same temperature.

2 **a** silver foil behind radiators

b one from: loft insulation, carpets on floors, double glazing

c one from: cavity wall insulation, draught proofing

3 **a** false

b true

c false

d true

4 A material with a high thermal conductivity is a good conductor or A material with a low thermal conductivity is a good insulator.

Materials that contain trapped air are good thermal insulators.

5 Air is a good insulator/poor conductor but it transfers energy by convection. If the air is trapped convection cannot happen, so the trapped air is a good insulator.

6 Insulation reduces the transfer of energy from a warm place to a cooler place. When insulation keeps something cold, it is reducing the energy transferred to the object from the surroundings.

SP3c.5 Keeping warm Homework 2

1 Fluffing up the feathers traps more air so fluffed up feathers act as a better insulator.

2 Air is a poor thermal conductor so the air trapped between the two sheets of glass improves the insulating properties of the window.

3 The foil is a thermal conductor whereas a blanket is a good insulator; however the foil will reflect (infrared) radiation. It can also be folded up into a small packet and so it is easier to carry around than a blanket. (Students may also mention convection if they recall this from Key Stage 3 work but both the foil and a normal blanket would reduce energy transfers by convection.) A potential disadvantage is that if the person is already colder than the surroundings the blanket could insulate them so they cannot absorb energy from the warm surroundings.

4 Not too much of the energy transferred to the house by the heating system is transferred to the surroundings.

5 Loft insulation has a low thermal conductivity and so reduces the conduction of energy from the air in the house to the loft space (where heating is not needed).

Double glazing reduces the energy transferred through windows by conduction as the air gap is a poor conductor.

Silver foil reflects radiated heat from the radiators so that this is less likely to be transferred through the outer walls.

Carpets have a low thermal conductivity and so reduce the amount of energy conducted from the air in the house to the floor so reduces the amount transferred to the ground.

Draught proofing reduces the flow of air out of the house and reduces energy losses by convection.

The cavity wall is filled with foam which has a low thermal conductivity. This reduces energy transfer through the cavity by conduction and also stops any convection taking place.

6 The insulating properties of a material depend on its thickness as well as its thermal conductivity.

7 **a** If the snow has melted, then energy has probably been transferred through the roof of that house. As insulation is usually applied to the loft floor, not to the underside of the roof tiles, it is likely that the air in the loft of the houses with melted snow is warmer than the air in the lofts of other houses.

b The houses with melted snow could be kept warmer overall or they could have less loft insulation.

8 Wide overhang helps to stop sun shining on the walls and heating the house.

Small windows reduce the amount of sunshine that can shine through to heat the rooms. Shutters can stop the sun shining in at all.

White walls will reflect sunlight and reduce the amount absorbed by the building.

SP3d Stored energies

Student Book

1 GPE depends on the strength of the gravitational field as well as on the mass moved and the change in height. If the field is weaker, there will be less GPE stored for a given mass and height gain.

2 a ΔGPE = 100 kg × 10 N/kg × 5 m = 5000 J

b height = 3000 J / (100 kg × 10 N/kg) = 3 m

3 a KE = 0.5 × 2 kg × $(2\ \text{m/s})^2$ = 4 J

b KE = 0.5 × 70 kg × $(8\ \text{m/s})^2$ = 2240 J

4 mass = KE / (0.5 × v^2)
= 98 000 J / (0.5 × $(7\ \text{m/s})^2$)
= 4000 kg

S1 a GPE = 1000 kg × 10 N/kg × 100 m = 1 000 000 J

b KE = 0.5 × 1000 kg × $(220\ \text{m/s})^2$ = 24 200 000 J

E1 GPE = 0.015 kg × 10 N/kg × 5 m = 0.75 J

E2 v^2 = KE / (0.5 × m) = 0.75 J / (0.5 × 0.015) = 100 m/s

v = 10 m/s

Exam-style question

Kinetic energy depends on the mass of the object and on the speed squared. (1) The car is both moving faster and has a greater mass than the cyclist. (1)

Activity and Assessment Pack

SP3d.1 The car catapult

4 Graphs should show that the greater the initial kinetic energy, the greater the change in GPE.

5 a elastic potential energy → kinetic energy

b kinetic energy → gravitational potential energy

6 Some energy is wasted/transferred to the surroundings.

SP3d.2 Bouncing balls

7 The GPE before the bounce should be used as the total energy supplied, and the GPE after the bounce is the useful energy transferred.

9 Students should predict that the ball with the highest calculated efficiency will bounce for longer.

10 It is difficult to accurately measure the height of the ball, so obtaining 10 measurements and ignoring outliers/anomalous results is likely to produce a more accurate result.

11 Suggestions could include using a video camera or marking the position against a wall.

SP3d.3 Stored energies – Equations

1 a ΔGPE = 4 kg × 10 N/kg × 2 m = 80 J

b ΔGPE = 2.5 kg × 10 N/kg × 3 m = 75 J

c ΔGPE = 0.5 kg × 10 N/kg × 2.5 m = 12.5 J

d mass = 800 J / (10 N/kg × 2 m) = 40 kg

e Δh = 1125 J / (75 kg × 10 N/kg) = 1.5 m

f Δh = 1500 J / (50 kg × 10 N/kg) = 3 m

g mass = 50 J / (10 N/kg × 0.5 m) = 10 kg

2 a ΔGPE = 2 kg × 1.6 N/kg × 1.5 m = 4.8 J

b g = 11.1 J/(2 kg × 1.5 m) = 3.7 N/kg

c g = 280 000 J / (400 kg × 500 m) = 1.4 N/kg

3 a KE = 0.5 × 0.16 kg × $(44\ \text{m/s})^2$ = 154.9 J

b KE = 0.5 × 0.4 kg × $(30\ \text{m/s})^2$ = 180 J

c KE = 0.5 × 0.15 kg × $(30\ \text{m/s})^2$ = 67.5 J

d mass = 185 J / (0.5 × $(48\ \text{m/s})^2$) = 0.16 kg

e mass = 142 J / (0.5 × $(70\ \text{m/s})^2$) = 0.058 kg

f KE = 0.5 × 0.0027 kg × $(40\ \text{m/s})^2$ = 2.16 J

g mass = 186.3 J / (0.5 × $(90\ \text{m/s})^2$) = 0.046 kg

4 a KE = 0.5 × 1500 kg × $(10\ \text{m/s})^2$ = 75 000 J

b KE = 0.5 × 1500 kg × $(20\ \text{m/s})^2$ = 300 000 J

c KE = 0.5 × 1500 kg × $(30\ \text{m/s})^2$ = 675 000 J

5 bounce 1, GPE = 0.02 kg × 10 N/kg × 1.4 m = 0.28 J

bounce 2, GPE = 0.02 kg × 10 N/kg × 1.0 m = 0.20 J

bounce 3, height = 0.14 J / (0.02 kg × 10 N/kg) = 0.7 m

bounce 4, height = 0.10 J / (0.02 kg × 10 N/kg) = 0.5 m

bounce 5, height = 0.07 J / (0.02 kg × 10 N/kg) = 0.35 m

6 bounce 3: v^2 = 0.14 J / (0.5 × 0.02 kg) = 14 $(\text{m/s})^2$, v = 3.74 m/s

bounce 4: v^2 = 0.10 J / (0.5 × 0.02 kg) = 10 $(\text{m/s})^2$, v = 3.16 m/s

bounce 5: v^2 = 0.07 J / (0.5 × 0.02 kg)
= 7 $(m/s)^2$, v = 2.65 m/s

7 **a** Δ*GPE* = 30 kg × 10 N/kg × 0.5 m = 150 J

b v^2 = 150 J/(0.5 × 30 kg) = 10 $(m/s)^2$, v = 3.16 m/s

8 **a** Δ*GPE* = 5000 kg × 10 N/kg × 6 m
= 300 000 J

v^2 = 300 000 J / (0.5 × 5000 kg) = 120 $(m/s)^2$, v = 10.95 m/s

b Δ*GPE* = 5000 kg × 10 N/kg × 3 m = 150 000 J

v^2 = 150 000 J/(0.5 × 5000 kg) = 60 $(m/s)^2$, v = 7.75 m/s

SP3d.4 Stored energies – Strengthen

1 **a** mass, gravitational field strength (or *g*), change in height (or height, m)

b 900 kg × 10 N/kg × 500 m

c 4 500 000 J

d $\frac{1}{2}$ (or 0.5), mass, speed (or velocity)

e $\frac{1}{2}$ × 900 kg × $(50\ m/s)^2$

f 1 125 000 J

2 20 000 J / (4 kg × 10 N/kg)
height = 20 000/40 = 500 m

3 240 J / (0.5 × $(20\ m/s)^2$)
mass = 240 / 200 = 1.2 kg

SP3d.5 Stored energies – Homework 1

1 0.5 m

Δ*GPE* = 10 kg × 10 N/kg × 0.5 m

Δ*GPE* = 50 J

2 70 cm = 0.7 m

Δ*GPE* = 15 kg × 10 N/kg × 0.7 m

Δ*GPE* = 105 J

3 **a** *KE* = 0.5 × 10 kg × $(2\ m/s)^2$

KE = 20 J

b 20 J, all the GPE would be converted to KE as it fell (or similar explanation)

c height = 20 J/(10 kg × 10 N/kg) height
= 20 / 100 = 0.2 m

4 mass = 22.5 J/(0.5 × $(3\ m/s)^2$)

mass = 22.5/4.5 = 5 kg

SP3d.6 Stored energies – Homework 2

1 **a** total mass = 11.5 kg, GPE
= 11.5 kg × 10 N/kg × 0.7 m
= 80.5 J

b *h* = 45 J / (10 N/kg × 4.5 kg) = 1 m

2 **a** total height of tank above ground level = 6 m

GPE = 200 kg × 10 N/kg × 6 m = 12 000 J

Assumption is that all the water is 6 m above the floor, or that the 6 m height is to the middle of the tank. Accept GPE of 10 000 J if it is stated that the reference point is the level of the kitchen taps (so the height difference is 5 m).

b bathroom: height difference = 2 m, so change in GPE per kg of water = 1 kg × 10 N/kg × 2 m = 20 J

v^2 = 20 J / (0.5 × 1 kg) = 40 $(m/s)^2$, v = 6.3 m/s

kitchen: height difference
= 5 m, so change in GPE per kg of water
= 1 kg × 10 N/kg × 5 m = 50 J

v^2 = 50 J / (0.5 × 1 kg) = 100 $(m/s)^2$, v = 10 m/s

3 **a** mass = 1000 m^3 × 1000 kg/m^3 = 1 × 10^6 kg

b *GPE* = 1 kg × 10 N/kg × 100 m = 1000 J

c v^2 = 1000 J / (0.5 × 1 kg) = 2000 $(m/s)^2$, v = 44.7 m/s

d Some energy will be transferred to the surrounding air due to air resistance (or similar explanation).

e total energy = 1000 J/kg × 1 × 10^6 kg
= 1 × 10^9 J

f Some energy will be transferred to the surroundings by sound, some by friction etc., and all will end up stored as thermal energy in (very slightly) warmer surroundings.

4 **a** *GPE* = 10 kg × 10 N/kg × 0.5 m = 50 J

b v^2 = 50 J / (0.5 × 10 kg) = 10 $(m/s)^2$, v = 3.2 m/s

c 50 J extra – explanation in terms of doubling the height gain so doubling the energy stored

d v^2 = 100 J / (0.5 × 10 kg) = 20 $(m/s)^2$, v = 4.5 m/s

e Advantage: it will be better at knocking in the post because it will be falling faster when it hits it (for the same starting height). Disadvantage: it will be more difficult for the person to lift.

5 **a** force
= (10 kg × 0 m/s − 10 kg × 3.2 m/s) / 0.5 s
= −64 N

b the resistance of the ground to the post being pushed into it (accept just ‘the post’)

c If the ground were softer there would be less resistance to the post being pushed in, so the force slowing down the post driver would be less and it would take longer to come to a stop (and the post would be pushed in further in the process).

SP3e Non-renewable resources

Student Book

1 They store a lot of energy and they are easy to store/use in engines.

2 It produces less pollution and produces less carbon dioxide per unit of electricity generated.

3 **a** There is no production of carbon dioxide during operation.

b It may produce radioactive waste pollution. It is very expensive to decommission/accidents can have serious consequences.

4 **a** It has to be built very carefully so that no radioactive materials escape.

b You have to make sure any radioactive material from the power station is stored safely for a very long time to come.

5 Radioactive material from the blast can be blown to other countries by winds, or spread through the oceans

6 Answers may vary, but should include some of the following points:

The electricity generated using coal and oil have both decreased.

Natural gas started to be used in about 1985 and its use increased after 1992.

Other fuels have been used throughout this period but their use has increased steadily from about 1990.

At the beginning of the period, most electricity was generated using coal, followed by oil, nuclear energy and other.

In 2010, the amount of coal and natural gas used was roughly equal, followed by nuclear and other.

S1 Coal: used in power stations (and also in homes for open fires).

Oil: used to make petrol/diesel for use in vehicles, some used in power stations.

Natural gas: used for home heating/cooking, used in power stations.

Nuclear: used in power stations.

S2 Students may include some of these points.

Burning fossil fuels causes pollution, including the release of carbon dioxide, which is contributing to climate change.

Fossil fuels and nuclear fuel are non-renewable resources, which means that they will run out one day. Using less means supplies will last longer.

Obtaining and transporting oil can cause pollution if there are accidents.

Nuclear power stations can spread radioactive materials a long way if there is an accident. Nuclear power stations are expensive to build and decommission.

E1 In power stations: Advantages – the fuel stores a lot of energy in a relatively small volume and for nuclear fuels, no carbon dioxide is emitted. (Also, electricity generated using fossil fuels is available at any time, although students need to recall KS3 work to give this answer at this stage in the unit). Disadvantages – carbon dioxide emitted when fossil fuels are burnt, plus other pollution; nuclear power stations cost a lot to build and decommission; accidents in nuclear power stations can contaminate wide areas; accidents in drilling for or transporting oil can pollute the sea/kill wildlife.

In vehicles/aeroplanes/ships: Advantages – petrol/diesel stores a lot of energy in a relatively small volume; both are easy to store in vehicles and to feed to the engine. Disadvantages – release of carbon dioxide and other pollutants; accidents in drilling for or transporting oil can pollute the sea/kill wildlife.

In heating homes/cooking: Advantages – natural gas stores plenty of energy; natural gas is piped to homes/easy to transport to where it is needed. Disadvantages – release of carbon dioxide.

Exam-style question

To make supplies of fossil fuels last longer, (1) to reduce the pollution caused by burning fossil fuels (1)

Activity and Assessment Pack

SP3e.2 Changing use of fuels

1 **a** Coal provided approximately a quarter of the energy in 1970 but provided only a very small proportion in 2010.

b Natural gas was only a small proportion of total energy used in 1970 but provided about one third of the energy in 2010.

c The proportion of oil used has remained fairly constant, at just below half.

2 bar chart correctly plotted using data on worksheet

3 The table and bar chart both indicate how the actual amounts of energy used have changed since 1970, not just the how the proportions of different resources used have changed.

4 Some coal, oil and natural gas is used to generate electricity, so if we are considering only the original sources of energy, the 'electricity' segments/quantities should be divided up between these three (and also nuclear fuel).

5 a Coal was used for heating rooms before central heating became popular. Almost all homes have central heating now and much of this uses natural gas. (A very good answer might also refer to chart D in the student book, and point out that the change is probably greater than that shown, as the chart in the book shows that more natural gas and less coal is being used to generate electricity, but these changes would be hidden in the 'electricity' amounts shown on the worksheet.)

b In addition, natural gas can generate more electricity for a certain amount of carbon emission, so as concern about climate change has developed, more electricity generation has been switched to natural gas.

We have a lot more electrical gadgets/machines than in 1970 so more electricity is used (even though appliances have become more efficient, the increased numbers of them outweighs the efficiency savings).

c There are a lot more vehicles on the road now, using more oil. However oil is now a very much smaller proportion of the energy used to generate electricity so the two effects are cancelling each other out.

d Concern over climate change has been increasing since the 1970s and switching to biofuels is thought to help to reduce carbon dioxide emissions.

SP3e.3 Non-renewable resources Strengthen

1 coal – used in power stations

oil – used in power stations, used to make petrol and diesel for use in vehicles

natural gas – used in power stations, used in many homes for central heating and hot water

nuclear fuel – used in nuclear power stations

2 coal – advantages: stores a lot of energy; disadvantages - releases carbon dioxide when it burns, carbon dioxide contributes to climate change, releases polluting gases when it is burned, will run out one day

oil – advantages: stores a lot of energy, easy to store in vehicles and to feed to engines; disadvantages - releases carbon dioxide when it burns, carbon dioxide contributes to climate change, releases polluting gases when it is burned, will run out one day, spills can pollute the seas and kill wildlife

natural gas - advantages: stores a lot of energy, causes less pollution than other fossil fuels for the same amount of electricity generated; disadvantages - releases carbon dioxide when it burns, carbon dioxide contributes to climate change, releases polluting gases when it is burned, will run out one day

nuclear fuel – advantages: does not release carbon dioxide when it is used, stores a lot of energy; disadvantages - expensive to build power stations, accidents can spread radioactive materials over a wide area, produces dangerous waste that is difficult to store

3 non-renewable, reducing, fuels, carbon dioxide, climate, less, tankers, wildlife, nuclear, expensive, decommission, radioactive

SP3e.4 Electric cars 1 – Homework 1

1 a No, because it has to be generated using other energy stores/resources.

b petrol/diesel

c It is easy to store/it stores a lot of energy/it is easy to transfer to the engine.

d It emits carbon dioxide, which contributes to climate change/it emits polluting gases.

2 a coal, natural gas (oil is also correct, although as shown in chart D in the Student Book, oil is not currently a major energy resource for electricity generation)

b Natural gas is also used to heat homes.

c carbon dioxide

d climate change (global warming and/or greenhouse effect are also acceptable answers)

e nuclear

3 The expected answer is no, because electricity generated from fossil fuels will have resulted in the emission of polluting gases into the atmosphere.

4 It transfers 75 J of useful energy for every 100 J stored in the battery.

5 a less than 0.375

b Yes – although the efficiency is a lot less than the 0.75 given in the advert, the efficiency of a petrol car is only 0.15, so unless a great deal of energy is transferred in the power lines (which is why the efficiency of the electric car is 'less than 0.375' rather than 0.375), then the electric car is still more efficient.

SP3e.5 Electric cars 2

1 **a** Electricity has to be generated using other energy resources.

b Electricity is needed to charge the car and most electricity in the UK is generated in fossil-fuelled power stations. These power stations emit polluting gases, so even though the car itself emits no pollution, the use of the car has caused pollution elsewhere.

2 **a** It stores a lot of energy in a fairly small volume; the fuel is easy to store in the car and transfer to the engine.

b Burning petrol or diesel adds carbon dioxide and other polluting gases to the atmosphere.

3 Ensure that the electricity used to charge the batteries is generated in a way that does not result in the emission of waste gases – for example by a nuclear power station or by renewable resources.

4 For every 100 J of energy stored in the battery, 75 J is transferred to useful energy (or similar explanation).

5 If the electric car uses electricity generated in a power station with scrubbers that remove carbon dioxide, then charging its batteries does not result in the addition of carbon dioxide to the atmosphere. It is not practical to fit scrubbers to car exhausts so using a petrol driven car will always end up adding carbon dioxide to the atmosphere.

6 **a** $0.5 \times 0.75 = 0.375$

Accept any working that gives the above answer, such as taking 100 J of stored energy in the fossil fuel, 50 J of this is transferred to the car by electricity, then 0.75×50 J = 37.5 J is transferred to useful energies by the car, giving an overall efficiency of 0.375.

b Yes – although the efficiency is a lot less than the 0.75 given in the advert, the efficiency of a petrol car is only 0.15, so the electric car is more efficient. Even if losses in transmission lines are included, unless a great deal of energy is transferred in the power lines then the electric car is still more efficient.

SP3f Renewable resources

Student Book

1 They do not produce carbon dioxide (a greenhouse gas)/pollution/They will not run out.

2 solar cells to convert solar energy directly into electricity; using heat from the Sun to turn turbines, either by using the energy to heat water to make steam or to heat air that moves up a chimney

3 build a barrage across an estuary with turbines in it which turn when water is let in and out; put turbines underwater in places where tidal currents flow

4 **a** hydroelectricity; biomass (geothermal energy is also available at any time, but this is not covered in the book)

b tidal power

c hydroelectricity; tidal (and wind but this is less limited by location than the other resources mentioned here). (Geothermal energy can also only be used in certain places but this resource is not discussed in the book.)

d solar, wind, waves

5 **a** The use of all renewables has increased, with the increases in biofuels and wind being the greatest.

b To use energy resources that do not add carbon dioxide to the atmosphere (or do not add as much); to make fossil fuel supplies last longer/to switch to resources that will not run out

S1 Solar energy comes from the Sun. It can be used to produce electricity directly in solar cells. It can also be used to generate electricity in solar power stations by heating water or air. Solar energy can also be used to heat water for use in homes.

Hydroelectricity and tidal power use energy stored in moving water to generate electricity. Hydroelectric power stations use water in rivers or flowing down from reservoirs in high places. Tidal power can be generated by underwater turbines. These can be placed in underwater currents or in barrages that trap water at high tide and let it flow out later.

Wind turbines use energy stored in moving air to generate electricity.

Biofuels are made from plants or from animal wastes. They can be burnt in the same way as fossil fuels.

S2 Two from: no pollutant gases; no carbon dioxide; can be switched on and off quickly; readily available fuel; cheaper fuel; fuel supply will not run out.

E1 A possible answer could be: The only renewable resources that can be used to generate electricity all the time are biofuels and hydroelectricity (also geothermal energy but this is not discussed in the book). We do not have enough suitable sites in the UK to produce enough electricity using these resources. Other renewable resources such as tides can generate electricity only at certain predictable times, while others, such as solar and wind, depend on the weather. If we had efficient ways of storing electricity, we could store energy when more was being generated than was needed for times when the weather or tides were not suitable. However, we would still need to build a lot more renewable power stations/wind turbines etc to be able to generate this amount of electricity.

Exam-style question

Advantage – one from: do not cause pollution; supply will not run out; no fuel costs. (1)

Disadvantage – one from: most renewable resources are not available all the time; not all places/countries can use all types of renewables. (1)

Activity and Assessment Pack

SP3f.1 Solar cells

1 The voltage will get less. As light spreads out from the lamp, the further away the lamp, the less energy from it will fall on a certain area/the solar cell, and so the lower the voltage will be.

4 The expected conclusion is that the voltage decreases as the distance increases.

5 The voltage with the lamp off is the voltage provided by the light in the room. If we want to investigate the effect of the lamp only, we need to subtract this from the voltage with the lamp on.

SP3f.2 Fair Isle

1 October – the hours from wind more than doubled in this month

2 **a** 16 hours, or 17 hours (500 ÷ 30 = 16.67) – accept answers near this if students have estimated from the graph

b There are fewer days in February.

3 **a** Most wind energy is available in the winter months.

b The number of hours of wind-generated electricity each day is also greatest in the winter months (fewer hours of electricity were generated using diesel).

4 **a** Information for a whole year with both turbines operating (or for more than one year) because data for just one year might not be representative.

b No – most onshore sites would be sheltered from the wind from some directions.

5 about 70% over a whole year

Approximate figures from graph A are (hours diesel/wind):

Jun – 420/80; Jul – 410/120; Aug – 410/100; Sept – 360/200; Oct – 70/650; Nov – 120/570; Dec – 380/350; Jan – 100/620; Feb – 120/510; Mar – 230/420; Apr – 220/400; May – 190/480

totals: diesel – 3030, wind – 4500 so approx 67% was supplied by wind

6 any two from: We would need a lot of wind turbines to provide a significant proportion of our electricity. Most of the windy sites for these will be in scenic locations where there are likely to be objections to building them. These are also places where we would need new connections to send the electricity to users. Putting wind turbines out at sea costs more in building and maintenance.

SP3f.3 Renewable resources Strengthen

1 Sun, solar cells, electricity, water, homes

moving water, hydroelectric, moving water/water, turbines, barrages

moving air

plants, burnt

2 **a** ✓ H, S, T, W

b ✓ H, B

c ✗ S

d ✗ S, W

e ✗ H

f ✗ T

g ✗ W

h ✓ B

i ✓ T

SP3f.4 Electricity from renewable resources – Homework 1

1 A – Solar energy: t is available only during the day and is highest when the weather was sunniest.

B – Wind: the graph is highest in the afternoon and evening when it was windiest.

C – Tidal: two periods of high energy correspond to the two high tides (note that students have not been told there are only two high tides per day, but they should be able to work out that C is tidal by a process of elimination).

D – Hydroelectric: not affected by the weather.

2 **a** hydroelectricity
b tidal
c solar
d wind

3 Supplies of non-renewable fuels will run out, and most forms of renewable energy do not contribute to climate change/do not put carbon dioxide into the atmosphere.

SP3f.5 Tidal lagoons – Homework 2

1 sluice gates are shut at high tide when the lagoon is full of water; they stay shut while the tide falls outside; when there is enough difference in the water levels the water is allowed to run out through turbines; the gates are shut near low tide and the water rises outside the lagoon; near high tide, water is allowed to run into the lagoon through the turbines.; the turbines will be used to drive generators

2 **a** Lagoons are likely to have less effect on wildlife because they will not block off the whole river – they will not prevent fish migration, will not have much impact on mud flats (which are habitats and feeding grounds for birds).
b Lagoons will create less disruption to shipping, which can sail round them rather than having to go through locks specially built in the barrage.
c Lagoons need a lot more aggregate than the barrage.
d The visual impact of the lagoons is likely to be less – they will be almost invisible at high tide; the visual impact of the barrage could be said to extend up the river as far as it affects the tidal flow in the river.

3 The barrage needs to have locks incorporated to allow ships to sail up the Severn – these will have to be very big to take full-sized ships.

4 **a** The lagoons will generate more electricity than the barrage (about one-third more).
b Electricity from the lagoons will be cheaper than electricity from the barrage because the barrage is much more expensive to build.

5 The electricity from the tidal lagoons is not available all the time, but it is available at predictable times and the amount that can be generated each time is also predictable. The electricity from wind farms may be available all the time when the weather is right but the times and amounts available are not predictable.

6 The tides are at different times in the Severn Estuary and in the Irish Sea (around 5 hours later), so electricity from tidal power will be available more of the time.

SP4a Describing waves

Student Book

6th **1** all the water would move to the other end

6th **2** The particles move backwards and forwards about a fixed position as a wave passes. The wave does not transfer matter.

4th **3 a** any two from: waves on the surface of water, electromagnetic waves, some seismic waves

4th **b** sound waves, some seismic waves

6th **4** the brightness varies

6th **5 a** 2 Hz

6th **b** 0.5 s

5th **6** energy – e.g. earthquakes, waves on the sea, energy from the Sun, any other sensible example

information – e.g. reading a book, listening to music, talking/hearing, any other sensible example

S1 Drawing of wave with amplitude and wavelength marked correctly. Ensure the amplitude label indicates the distance from the undisturbed position to a crest or trough.

S2 similarities – both transfer energy and/or information, neither transfer matter, both can be described using terms such as amplitude, frequency, period and wavelength

differences – in transverse waves the particles move in a direction at right angles to the direction of travel, in longitudinal waves the particles move back and forth in the same direction as the wave travels

E1 Suitable definitions of amplitude, frequency, period, wavelength, longitudinal and transverse, with examples of longitudinal and transverse waves.

E2 Sound waves are often used to transfer information, waves on the surface of water are not usually used for this purpose. Sound waves are longitudinal, waves on the surface of water are transverse.

Exam-style question

A sound wave is a longitudinal wave and so the particles move backwards and forwards in the same direction as the wave is moving.

A wave on the surface of water is a transverse wave, and so the particles move at right angles to the direction in which the wave is moving.

Marks: stating sound waves are longitudinal (1); stating direction of particle movement (1); stating waves on the surface of water are transverse (1); stating direction of particle movement (1).

Activity and Assessment Pack

SP4a.1 Transferring information with waves

1 a sound waves

b light waves/electromagnetic waves

2 Similarity: both are transferring information using sound waves

Difference: a radio programme sends a lot more information quickly (in the form of speech or music)

3 Morse code is a series of on–off pulses, so the frequency does not matter, and the amplitude only needs to be enough for the sound to be heard.

Student's descriptions of their own codes will depend on the code used, but should describe varying sounds in terms of their frequency/wavelength changing or their amplitude changing.

4 Students' own answers. As students' models are only required to send a few different messages, they might find their own model simpler and therefore easier to use. However, answers could also consider the ease of telling different frequencies or amplitudes apart, as opposed to the simplicity of a light or sound that is either off or on.

SP4a.2 Wave tanks

1 a tank A, as wind turbines are often located far out to sea where the water is deeper

b tank B, as the water will be relatively shallow next to the coast

c tank A, as oil rigs are often located far out to sea where the water is deeper

d tank B, as the water will be relatively shallow next to the coast

2 a the amplitude is reduced

b the frequency is increased

3 2 m

4 In the pipe the paddle will make sound waves, which are longitudinal. The waves made on the surface of the water in tank B are transverse.

5 a Increase the amplitude by increasing the distance moved by the paddle/piston for each wave. Decrease the amplitude by decreasing the distance moved.

b Increase the frequency by moving the paddle/piston back and forwards faster/more times each second.

c Increase the period by moving the paddle/piston back and forwards fewer times each second.

SP4a.3 Describing waves
Strengthen

1 amplitude and wavelength labelled correctly

2 **a** both
b neither
c both
d longitudinal
e transverse
f both
g longitudinal
h transverse

3 **a** period
b amplitude
c frequency
d frequency

SP4a.4 Describing waves
Homework 1

1 **a** longitudinal, wavelength, energy
b transverse, wavelength, amplitude, energy

2 **a** sound, some seismic waves
b any two from: electromagnetic waves, waves on the surface of water (do not accept ‘water waves’ or ‘waves in water’), some seismic waves

3 **b** …energy and information.
c …is half the distance from the top to the bottom (or a correction in terms of maximum displacement from rest position)
d The period of a wave…
e The frequency of a wave…

SP4a.5 Describing waves
Homework 2

1 **a** 25 cm/5 = 5 cm (or 0.05 m)
b 5 Hz
c 1/5 s (or 0.2 s)

2 **a** amplitude and wavelength correctly marked on diagram
b wavelength correctly marked on diagram
c mark one of the coils and see how far it moves from its original position as a wave passes
d Find frequency by counting how many waves pass in 1 s.

Find the period from 1/f (students may give this answer if they have looked up period and frequency), or by timing how long it takes for one wave to pass.

For both measurements, students may suggest timing for a longer period/finding the time for more waves to pass to improve the accuracy of the measurement.

3 **a** Model A is a good model for waves on the surface of water as both are transverse waves, and both are movements in matter. However, model A does not show what happens to water beneath the surface as the wave passes.
b Model A and electromagnetic waves are both transverse waves. However, model A is a wave in matter, whereas electromagnetic waves do not involve movements in matter, so the model is not as good as a representation of electromagnetic waves.

4 Sound waves produced by the explosion travel out from the explosion; the particles in the air are set in motion in longitudinal waves; the waves transfer energy from the explosion to the windows.

5 Waves on the surface of water are transverse waves, but sound waves can travel in water and they are longitudinal waves.

6 Sound waves are longitudinal waves passed on by particles moving backwards and forwards along the same line as the wave is travelling. This also describes longitudinal seismic waves.

7 model C: The first waves will make the building move up and down, and the next waves to arrive will make the building move from side to side.

model D: The first waves will make the building move from side to side, and the next waves will make it move up and down.

SP4b Wave speeds

Student Book

1 v = 900 000 000 m/3 s = 300 000 000 m/s

2 **a** x = 330 m/s × 5 s = 1650 m
b that the light does not take time to travel

3 v = 170 Hz × 2 m = 340 m/s

4 λ = 5000 m/s / 100 Hz = 50 m

5 Light slows down as it goes from air to water. As speed is frequency × wavelength, if the frequency does not change the wavelength must have decreased to make the speed decrease.

6 x = 10 m, so v = 10 m / 7 s = 1.4 m/s

S1 v = 2000 m / 1.3 s = 1538 m/s

S2 λ = 1538 m/s / 3000 Hz = 0.51 m

E1 To calculate velocity you need to know the frequency and wavelength. Frequency can be obtained by counting the number of ripples that pass a point each second. Wavelength can be measured using a ruler. Wave velocity is then calculated by multiplying the frequency and the wavelength.

Very good answers will explain that more accurate values for frequency would be obtained by counting the number of ripples passing in 10 seconds and dividing by 10, and that wavelength measurements would be more accurate if taken from a photo rather than trying to measure the wavelength of moving waves.

Exam-style question

$f = v / \lambda$ = 330 m/s / 16 m = 20.6 Hz

Marks: 1 for transposition of formula; 1 for correct substitution (substitution and transposition in any order); 1 for evaluation.

SP4b Core practical Investigating waves

1 speed = 660m / 2s = 330 m/s (1 for substitution, 1 for evaluation)

2 wavelength = 1482 m/s / 100 Hz = 148.2 m (1 for substitution, 1 for evaluation)

3 Divide the number of waves counted in 10 seconds by 10 (1) to find the number of waves per second. (1)

4 Emily's method is likely to be more accurate, (1) (but only with an explanation), because it is easier to take accurate measurements from a photo/something that is not moving. (1)

5 Use a stopwatch to find how long it takes one wave to go from one buoy to the other, (1) and calculate the speed by dividing 20 m by the measured time. (1)

6 0.4 m/s is likely to be more accurate. It is easier to measure the frequency and wavelength than the speed, as the waves are moving quite fast (1), so the speed worked out from these measurements is more likely to be accurate. (1) (Note: the marks are only for the explanation, not for choosing 0.4 m/s.)

7 The speed of sound in a metal is much higher than in air, (1) and the time between a sound being made and its echo reaching the end of a rod is too short to be measured using a stopwatch. (1)

8 wavelength = 1.6 m (1) speed = 1.6 m × 4000 Hz = 6400 m/s (1 for substitution, 1 for evaluation)

Activity and Assessment Pack

SP4b.1 Measuring wave velocities in solids and liquids – Core practical

1 Students' own results.

2 Students' own results.

3 Results may vary because of different water depths (and different frequencies/wavelengths for the measurement of the series of waves).

4 There may be less than one wave in a second/ any errors in counting the waves are spread out over 10 s, so this will give a more accurate value.

5 Comments are likely to mention the difficulty of measuring the wavelength while the waves were moving. The digital camera 'freezes' the motion of the waves so it is easier to take a precise and accurate measurement.

6 Comments are likely to relate to the speed of the wave; difficult to measure an accurate time when something is moving fast. Suggestions could include using a video camera with a timer also displayed.

7 Students' own results.

8 Students' own results.

9 Students could justify either answer: the wavelength, as this is obtained from a static measurement of the rod; the frequency, as this is measured electronically.

10 Students' own table.

11 The sound travels too fast to use a stopwatch/ human reaction time would introduce errors greater than the time being measured.

SP4b.2 Equation practice

1 a v = 2000 m/6 s = 333.3 m/s
b v = 50 m/0.5 s = 100 m/s
c x = 5000 m/s × 4 s = 20 000 m
d t = 600 000 m/3000 m/s = 200 s
e x = 200 m/s × 25 s = 5000 m
f t = 3000 m/1500 m/s = 2 s

2 a t = 100 000 m/1500 m/s = 66.7 s
b x = 1500 m/s × 600 s = 900 000 m (or 900 km)

3 v = 100 m/0.3 s = 333 m/s

4 a v = 12 200 Hz × 0.5 m = 6100 m/s
b v = 50 Hz × 80 m = 4000 m/s
c f = 330 m/s/1.65 m = 200 Hz
d λ = 1500 m/s/15 000 Hz = 0.1 m
e λ = 3500 m/s/500 Hz = 7 m
f f = 150 m/s/0.015 m = 10 000 Hz

5 λ = 4 m/s/8 Hz = 0.5 m

6 f = 0.021 m/s/0.015 m = 1.4 Hz

7 a t = (2 × 322 000 m) / (3 × 10^8 m/s) = 0.002 s
b t = (2 × 2.25 × 10^{11} m) / (3 × 10^8 m/s) = 1500 s (or 25 minutes)
c t = (2 × 4.9 × 10^{12} m) / (3 × 10^8 m/s) = 32 667 s (or 544 minutes or 9.1 hours)

8 x = 3 × 10^8 m/s × (4 × 60 × 60) = 4.32 × 10^{12} m
This is the total distance travelled by the signal, so the distance of the probe from Earth = 4.32 × 10^{12} m/2 = 2.16 × 10^{12} m.

9 a x = 1533 m/s × 2 s = 3066 m, depth = 3066 m/2 = 1533 m
b x = 1493 m/s × 2 s = 2986 m, depth = 2986 m/2 = 1493 m
c x = 1533 m/s × 0.05 s = 76.65 m, distance to fish = 38.3 m
x = 1533 m/s × 0.7 s = 1073.1 m, distance to fish = 536.6 m

10 a 120 kHz = 120 000 Hz, λ = 1533 m/s/120 000 Hz = 0.0128 m
200 kHz = 200 000 Hz, λ = 1533 m/s/200 000 Hz = 0.0077 m
b 120 kHz = 120 000 Hz, λ = 1493 m/s/120 000 Hz = 0.0124 m
200 kHz = 200 000 Hz, λ = 1493 m/s/200 000 Hz = 0.0075 m
c t = 2 × 3000 m/1533 m/s = 3.91 s

11 v = 300 m/0.2 s = 1500 m/s
λ = 1500 m/s/50 000 Hz = 0.03 m

SP4b.3 Wave velocity – Strengthen

1 a wave speed = distance/time (or x/t)
b = 10 m/16 s
c = 0.625 m/s

2 a wave speed = frequency × wavelength (or $f \times \lambda$)
b wavelength = speed/frequency (or v/f)
c = 0.625 m/s/0.2 Hz
d = 3.125 m

3 a the distance the sound travels/the distance to the wall and back
b wave speed = distance/time

4 a the wavelength
b wave speed = frequency × wavelength

SP4b.4 Wave velocity – Homework 1

1 x – distance, m; v – wave speed, m/s; t – time, s; f – frequency, Hz; λ – wavelength, m

2 a 2000 m
b v = 2000 m/2.5 s = 800 m/s

3 t = 10 000 m/3000 m/s = 3.33 s

4 a λ = 1500 m/s/30 Hz = 50 m
b x = 1500 m/s × 300 s = 450 000 m (or 450 km)

5 total distance = 1700 m, v = 1700 m/5 s = 340 m/s

6 v = 8 600 000 m/61 200 s = 140.5 m/s

SP4b.5 Wave velocity – Homework 2

1 v = 2000 m/2.5 s = 800 m/s

2 t = 10 000 m/3000 m/s = 3.33 s

3 a λ = 1500 m/s / 30 Hz = 50 m
b x = 1500 m/s × 300 s = 450 000 m (or 450 km)

4 total distance = 1700 m, v = 1700 m/5 s = 340 m/s

5 a 17 hours = 17 × 60 × 60 = 61 200 s
v = 8 600 000 m/61 200 s = 140.5 m/s
b x = 1 500 000 m/140.5 m/s = 10 676 s (or 177.9 minutes or 3 hours)

6 a Arrival time for seismic wave = 8 600 000 m/800 m/s = 10 750 s
So this will be 61 200 s – 10 750 s = 50 450 s ahead of the tsunami (or 840 minutes or 14 hours)
b Arrival time for seismic wave = 1 500 000 m/800 m/s = 1875 s
So this will be 10 676 s – 1875 s = 8801 s ahead of the tsunami (or 147 minutes or 2.4 hours)

7 a f = 3 × 10^8 m/s / 100 m = 3 × 10^6 Hz
b λ = 3 × 10^8 m/s / 3 × 10^{10} Hz = 0.01 m
c f = 3 × 10^8 m/s / 1 × 10^{-6} m = 3 × 10^{14} Hz
d λ = 3 × 10^8 m/s / 3 × 10^{12} Hz = 1 × 10^{-4} m
e f = 3 × 10^8 m/s / 1 × 10^{-7} m = 3 × 10^{15} Hz
f λ = 3 × 10^8 m/s / 3 × 10^{19} Hz = 1 × 10^{-11} m

8 a = 385 000 000 m/3 × 10^8 m/s = 1.28 s

b Assuming that the laser beam travels the shortest possible distance, the distance travelled

= 2 × (distance between centres – radius of Earth – radius of Moon)

= 2 × (385 000 km – 6371 km – 1740 km) = 753 778 km

time = 753 778 000 m/3 × 10^8 m/s = 2.5 s

SP4c Refraction

Student Book

1 **a** it bends away from the normal

b it bends towards the normal

2 **a** Light will not travel in a straight line from the insect to the fish's eyes, so it needs to aim in a different direction to the direction in which it is seeing the insect. Accept light bends/changes direction when it enters the water.

b diagram showing a light ray from the insect bending towards the normal as it enters the water

3 In shallower water the waves move more slowly and they get closer together.
As the waves meet the interface at an angle, one part of the wave starts to slow down before the rest of the wave does. This has the effect of changing the direction in which the waves travel. The direction gets closer to the normal.

4 The waves still slow down, but all of a wave will change direction at the same time, so there is no change in direction.

5 When the waves move into deeper water they speed up. If the waves arrive at the interface at an angle, one part of a wave will speed up before the rest of it and so the direction of travel will change away from the normal.

6 Light bends towards the normal as it goes into glass or water, bending towards the normal happens when light slows down.

S1 Light going from air into water bends towards the normal. Light going from water into air bends away from the normal.

E1 Light entering the glass bends towards the normal,but it bends away from the normal again when it leaves the glass, so the two effects cancel out. However it has travelled through the glass in a different direction, so when it emerges is it not in line with the original light ray.

Exam style question

Light waves bend/refract when they go from one medium/material into another (1), and if the surface of the water is not flat, the ripples will cause the light to bend by different amounts at different times (1). Accept similar answers.

Activity and Assessment Pack

SP4c.1 Models for refraction

1 the direction the waves are travelling

2 The arrow, as it shows the way in which the waves are moving, and a ray on a ray diagram shows the direction the light is moving.

3 **a** it slows down

b it does not change

4 **a** it will change direction to the right of its current path

b The right-hand wheel hits the sand first, and slows down before the left-hand wheel does, which makes the car turn to the right.

5 **a** the new medium in which the wave travels more slowly

b a section of a wave

c One of the wheels slows down before the other, making the car turn – this is equivalent to part of a wave slowing down before the rest of the wave.

6 **a** wavelength

b frequency

7 **a** they slow down

b a wave may slow down when it crosses an interface between two materials

8 **a** Some of the students reach the line on the floor before others, so they slow down first. This makes one end of the line of students slow down when the other is still moving at the same speed, so the line bends as it crosses the line on the floor. Once all the students have crossed the line on the floor the whole line of students is now moving in a different direction.

b The line of students represents one wave, and the line on the floor represents the boundary between deep and shallow water (as waves travel more slowly in shallow water).

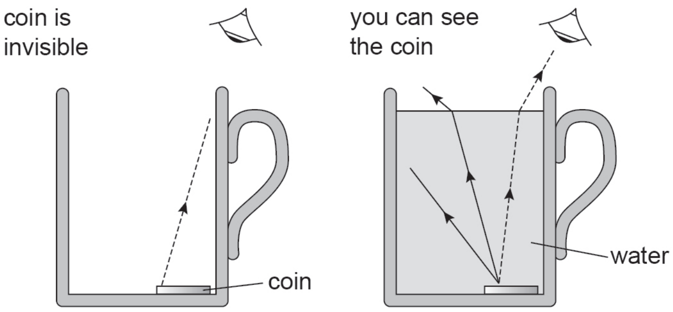
c Light slows down as it enters glass, and its direction changes, so the model helps us to understand why this happens in terms of waves.

9 Light speeds up as it leaves glass, so the line of students would have to approach the line on the floor at an angle, and start to take longer steps as they cross the line on the floor.

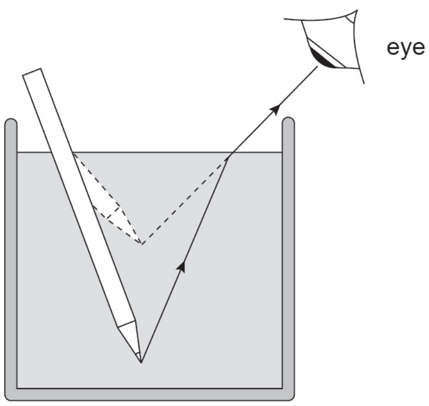
10 Students' own responses.

SP4c.2 Refraction effects

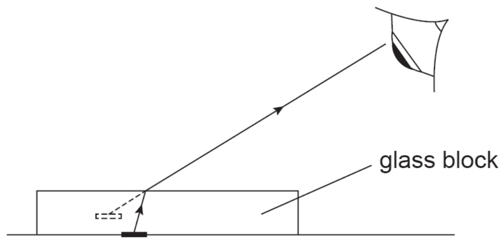
1 The rays in dashed lines here should be highlighted.



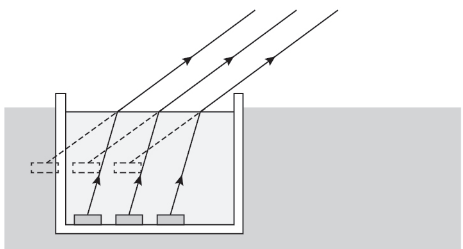
2



3



4



SP4c.3 Refraction – Strengthen

1 **a** a line at right angles to the interface between two materials

2 **b** line continues straight through

c and d Line inside the glass is at a smaller angle to the normal than the incident ray and joins up with the normal provided at the bottom. Emerging ray is parallel to the original incident ray.

3 **a** towards

b away from

4 refracted, medium, interface

refracted, water, refraction

SP4c.4 Refraction – Homework 1

1 **a** Refraction can happen when a wave… crosses an interface between two different materials.

b The normal is a line…drawn at right angles to an interface.

c When light travels from air into water…it bends towards the normal.

d When light travels from water into air…it bends away from the normal.

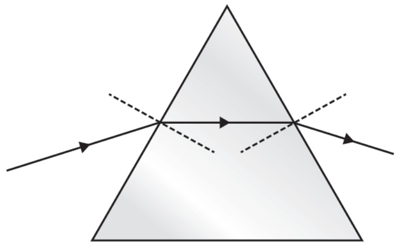
e Refraction when light goes from air into water…is similar to refraction when light goes from air into glass.

f If a ray of light crosses an interface at right angles…its direction does not change.

2 **a** normal

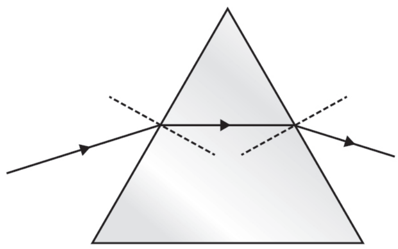
b Ray inside block is at a smaller angle to the normal than the incident ray; the emerging ray is parallel to the original incident ray.

3



SP4c.5 Refraction – Homework 2

1



2 **a** Towards the normal when it slows down. Light bends towards the normal when it goes from air into glass or water, and the table shows that the speed of light in glass and water is slower than it is in air.

b The amount of refraction depends on the difference of the speed in the two materials. So the order is: glass → water (speed difference of 0.25×10^8 m/s), glass → diamond (speed difference of 0.76×10^8 m/s), air → glass (speed difference of 1×10^8 m/s), air → diamond (speed difference of 1.76×10^8 m/s)

3 frequency = wave speed/wavelength
$= 3 \times 10^8$ m/s/700×10^{-9} m $= 4.29 \times 10^{14}$ Hz

a in glass,
wavelength = wave speed/frequency
$= 2 \times 10^8$ m/s/4.29×10^{14} Hz $= 4.67 \times 10^{-7}$ m

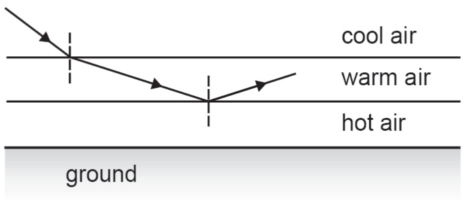
b in water,
wavelength = wave speed/frequency
$= 2.25 \times 10^8$ m/s/4.29×10^{14} Hz
$= 5.24 \times 10^{-7}$ m

c in diamond,
wavelength = wave speed/frequency
$= 1.24 \times 10^8$ m/s/4.29×10^{14} Hz
$= 2.89 \times 10^{-7}$ m

4 a The amount of refraction depends on the speed of light in the two materials, so the light will bend by a different amount when going from water into the materials in the eye than when it is going from air into the eye.

b Goggles or face masks have flat glass, which may change the direction of light slightly (unlike windows, as the light is going from water to glass to air), but they trap air next to the eye so when light enters the eye it is going from air to eye, as normal.

5 a As the light enters a layer of warmer air it bends away from the normal, which has the effect of making the angle shallower. Eventually the light has bent so far that it appears to be coming from the ground. Diagram showing this.



b Similar sketch to that on the worksheet, but inverted – showing, for example, a curved Earth with a ship just over the horizon and light from it bent to curve downwards.

SP4d Waves crossing boundaries

Student Book

6th **1** The table is absorbing more light because it looks darker than the white vase.

7th **2** Transmission and reflection. Light is transmitted through the glass in the mirror before reflecting from the aluminium and then being transmitted back through the glass.

5th **3 a** We can see that light has gone through the prism, so it is transmitting light. It is refracting light because it has changed the direction of the light entering it/it has split up white light into different colours.

7th **b** Some of the white light going into the prism has been split up to form a spectrum/set of different colours.

5th **4** the material reflects sound poorly and absorbs sound very well, to help stop echoes

8th **5 a** wavelength = velocity ÷ frequency = 330 m/s / 10 000 Hz = 0.033 m

8th **b** wavelength = 1500 m/s / 10 000 Hz = 0.15 m

S1 Both glasses transmit light, although the prescription glasses transmit more of the light compared to the sunglasses. Prescription glasses are designed to refract light to help you to see more clearly. Sunglasses are designed not to refract light so they do not affect your vision. Sunglasses reflect and/or absorb light to lessen how much light gets through them.

E1 When the sound reaches the brick wall some of it will be reflected and travel back into the air – this is the echo. Some of the sound will be transmitted through the brick. Because sound travels faster in brick than in air, if it hits the wall at an angle it will be refracted. Its wavelength is longer in the brick. Some of the sound wave may be absorbed by the brick, which means some of the energy transferred by the wave may be transferred to the material.

A very good answer may point out that the sound wave will be refracted away from the normal as it enters the brick.

Exam-style question

Reflection and refraction both involve waves changing direction. (1)

When reflection occurs at a boundary the wave stays in the original material. Refraction occurs when the wave passes from one material to another. (1)

Activity and Assessment Pack

SP4d.1 Sound absorption and transmission

2 Either answer is acceptable, as long as a sensible reason is given.

3 Apparatus is likely to include a source of sound (e.g. buzzer or bell, or even a mobile phone that can be used with a tone generator or can be rung from another phone), a microphone connected to a data logger or a sound sensor for detecting the sound, and a list of suitable materials to be tested.

4 Instructions should include a description of how to make the test fair, such as using the same volume of sound each time, measuring the sound from the same position outside the box, and using the same thickness of material each time.

6 The plan should include an equipment list (source of sound, sound detector, materials to be tested) and how to make the test fair (same thickness of material each time, same volume and frequency of sound used each time, detecting the sound in the same way and in the same place outside the box). Safety involves not playing loud noises close to ears.

8 Students' own conclusions, which will depend on the materials being tested.

9 No, only two materials have been tested so there is not enough evidence to state that (say) all soft materials absorb more sound than stiff materials.

10 As for question 6, but students should also include a way of changing the frequency (e.g. using a signal generator and loudspeaker, or using a mobile phone app).

11 Student's own responses – they should find some effect of changing frequency, although the effect will depend on the materials tested.

12 Students' own responses.

SP4d.2 What are the waves doing?

All cards can involve the transmission of the wave through air, all cards involving light can describe light reflecting from surfaces, and all can describe the absorption of some light/sound by surfaces. The main points for each card are:

A reflection (of IR) by the wall, absorption of the wave by the TV

B transmission of light through the window, reflection of light by the mirror, absorption of light in Beth's eyes (some students could add refraction of light by the lenses in Beth's eyes)

C reflection of light by the base of the pool, refraction of light by the water in the pool, transmission of light by the water in the pool

D absorption of light by the sunglasses and the cap

E absorption of sound by the pillow

F refraction of light by the magnifying glass, reflection of light from the beetle

G reflection of sound by the hard surfaces in the bathroom, absorption of sound by Jenna's ears

H absorption of sound by the garage walls, some transmission of sound by the garage walls, absorption of sound by Mr Kellington's ears

I reflection of light by the coin, refraction of light by the water in the pool, transmission of light by the water in the pool

J reflection of light by the surface the contact lens is on, transmission of light by the contact lens, refraction of light by the contact lens

SP4d.3 Waves crossing boundaries Strengthen

1
- **a** sunglasses
- **b** neither
- **c** both
- **d** prescription
- **e** prescription
- **f** sunglasses
- **g** neither

2
- **a** transmit light
- **b** absorb some light
- **c** refract light

3
- **a** stays the same, increases
- **b** stays the same, decreases

SP4d.4 Waves crossing boundaries Homework 1

1 absorb – when the energy carried by a wave is transferred to the material it hits or is passing through

reflect – when a wave bounces off something

refract – when a wave changes direction as it passes from one medium to another

transmit – when a wave passes through a material and is not absorbed or reflected

2
- **a** It is reflected.
- **b** It is refracted.
- **c** It is absorbed.
- **d** It is transmitted.

3 transmitted, reflected, transmitted
transmit/reflect (either order), absorb

4 transmitted
slows down, frequency, wavelength
refraction
speeds up, frequency, wavelength

SP4d.5 Waves crossing boundaries Homework 2

1 As light from the Sun reaches the beach umbrella, the umbrella reflects some of it and absorbs some of it, so not all the light from the Sun is transmitted through it. Beyond the umbrella, almost all the light from the Sun is transmitted through the air.

The umbrella does transmit some light, and some light is reflected from the sand around the umbrella – both these sources provide enough light to be reflected from Jenny's book into her eyes to allow her to read.

2 a It is designed to transmit light so that drivers can see what is happening on the road ahead.

It is designed not to reflect or absorb light, because both of these would reduce the amount of light reaching the driver and so make the view dimmer or impossible to see at night.

It is designed to keep the distortion by refraction to a minimum.

b Light is refracted as it enters and leaves the windscreen, but this is made of smooth glass so that the view is not distorted. Drops of rain on the windscreen also refract light, but the surface of the drops is curved (students may also refer to rain running down the windscreen, etc.), and so this refraction distorts the view and prevents the driver seeing clearly.

3 In the bathroom, sound is transmitted through the air. Then some is transmitted through the walls and a lot is reflected by the walls, bath and floor, most of which will be made of hard materials. In the bedroom, soft furnishings (carpet, curtains, bedding) absorb a lot of the sound, so less is reflected from the walls back to Danny's ears.

4 a Light from the bulb is transmitted through air, refracted as it enters glass, transmitted through water, refracted by the water, reflected from the fish, transmitted through water, refracted as it enters the glass, transmitted through the glass, refracted as it leaves the glass, and transmitted through air.

b Light is refracted as it enters and leaves the glass tank, but the tank has smooth, even sides, so the refraction does not affect the overall direction of the light. Light is refracted as it leaves the surface of the water, but the surface is often not smooth, and so some of the light goes off in different directions.

5 a speed and wavelength decrease but frequency stays the same

b speed and wavelength increase and frequency stays the same

6 a f = 343 m/s / 0.06 m = 5717 Hz

b λ = 4180 m/s / 5717 Hz = 0.73 m

7 a λ = 343 m/s / 15 000 Hz = 0.023 m

b λ = 6100 m/s / 15 000 Hz = 0.41 m

c λ = 1433 m/s / 15 000 Hz = 0.10 m

8 a The light slows down and its wavelength decreases but its frequency stays the same.

b The red light appears red inside the prism and when it leaves the prism. The wavelength of the light increases as it leaves the prism, and the light speeds up. As the colour does not appear to change, it must be the frequency and not the wavelength that our eyes detect as red.

c The different frequencies are slowed by different amounts. The amount of refraction that occurs when a wave passes from one medium into another depends on the difference in the speed of the wave within the two media. Red light is refracted by the smallest amount, and so must be slowed down by the smallest amount. Violet is refracted the most, and so must be slowed down more. So in glass, red light travels faster than violet light.

SP4e Ears and hearing

Student Book

4th 1 (ear canal), ear drum, ear bones, liquid in cochlea

4th 2 cochlea

5th 3 a ear drum, ear bones

5th b liquid in cochlea

5th c ear canal

5th 4 a transmits the vibrations from the bones to the membrane

5th b parts vibrate when waves in the fluid reach it

6th c detect the vibrations of the membrane

5th **5** **a** thick

6th **b** so different frequencies can be detected

S1 A flow chart outlining the following processes in this order: vibrations in the air in the ear canal make the ear drum vibrate; this makes the ear bones vibrate, and they also amplify the vibrations and transmit them to the cochlea; the vibrations travel through liquid in the cochlea and make a membrane vibrate; hair cells in the cochlea detect the vibrations of the membrane and send nerve impulses to the brain.

E1 Birds have much smaller heads than humans, so there is less space for a cochlea. Also, as it is straight and not coiled up, the length of the membrane inside the cochlea will be shorter than in a human. This may mean it cannot distinguish as many different frequencies within its hearing range. The maximum thickness is less than that in the human cochlea, because the lowest frequency that the pigeon can hear is higher than the lowest frequency humans can hear.

Exam-style question

The movement of air particles in a sound wave causes pressure changes on a solid (1) which make particles in the solid vibrate (1).

Activity and Assessment Pack

SP4e.1 Parts of the ear

2, 3

1: outer ear – helps to channel sound waves into our heads

2: ear canal – tube down which sound waves can pass

3: eardrum – thin membrane, sound waves in the air make this vibrate, its vibrations are passed on to the ear bones

4: bones – three tiny bones, amplify the vibrations, pass vibrations on to the cochlea

5: cochlea – filled with liquid, contains a membrane that is thicker at one end than the other, membrane has hair cells that detect its vibration, vibrations are turned into nerve impulses

6: auditory nerve – made up of neurones, passes impulses to the brain

SP4e.2 Hearing problems

Types of conductive hearing loss:

Glue ear – a childhood condition where the middle ear (beyond the eardrum) fills with fluid. This prevents the ear bones from moving freely, causing hearing loss (it reduces the transmission and amplification of the vibrations). The condition will clear up on its own, but if hearing loss is severe, a grommet (small tube) can be put into the eardrum to allow the fluid to drain.

Ear wax – this can build up in the ear canal. The wax can completely block the canal and absorbs sound waves. This reduces the transmission of vibrations to the eardrum. Wax can be removed using ear drops or can be washed out by a nurse.

Fused bones (fused ossicles), also called otosclerosis – abnormal bone growth fuses one of the tiny ear bones to the surrounding bones. This prevents it from vibrating properly, so vibrations cannot be passed on from the eardrum to the cochlea very well. Hearing aids can help, or surgery may be possible to help improve hearing.

Perforated eardrum – a hole in the eardrum, which can be caused by infection causing pus to put pressure on the eardrum, by injury such as a blow to the head or poking things in the ear, or by sudden loud noises. Once the hole heals, hearing usually goes back to normal. A perforated eardrum reduces the transmission of sound from the air to the ear bones.

Types of sensorineural hearing loss

Damage to hair cells in cochlea – this affects the hair cells' ability to detect vibrations and convert them to nerve impulses. Damage can be caused by regular exposure to loud noises, such as when a person is working in a noisy environment (including one with loud music, such as a nightclub), or listening to loud music using earphones. A sudden loud noise can also cause this. Most people gradually develop this kind of hearing loss as they get older. It generally affects high frequencies first. Noise-induced hearing loss from this cause can be prevented by wearing ear protection/ear plugs in noisy environments, and not listening to loud music through headphones.

Damage to the auditory nerve – prevents nerve impulses being sent from the ear to the brain.

Both types of damage above are permanent and can only be helped with hearing aids. Causes in addition to those above include some treatments such as radiotherapy, chemotherapy or certain antibiotics, and some diseases such as diabetes, multiple sclerosis and stroke.

SP4e.3 Ears and hearing Strengthen

1 a ear canal and reach the eardrum
  b eardrum
  c ear bones causing them to vibrate
  d the vibrations … cochlea
  e membrane
  f the membrane vibrate
  g by tiny hair cells, which convert them to nerve impulses
  h the brain along the auditory nerve

2 → ear bones vibrate and amplify vibrations → liquid in cochlea vibrates → membrane vibrates → hair cells detect vibrations → hair cells produce nerve impulses → auditory nerve transmits impulses to brain

3 The correct order is:
  d A sound wave causes the particles in air to <u>vibrate</u>.
  c The air <u>pressure</u> changes as the sound wave travels.
  b The changes in pressure at the surface of a solid cause <u>particles in the solid to vibrate</u>.
  e The vibrations in the particles in the solid are <u>transmitted through the solid</u>.
  a Some of the energy transferred through the air is <u>reflected or absorbed</u>.

4 density of the solid, frequency of the sound wave, stiffness of the solid

5 frequencies, membrane
  thicker/stiffer (either order), highest
  thinner/less stiff (either order), lowest

SP4e.4 Ears and hearing Homework 1

1 a eardrum
  b cochlea
  c ear canal
  d bones
  e auditory nerve
  f bones

2 ear canal, eardrum, bones, cochlea, auditory nerve

3 a 20 000 Hz
  b 20 Hz

4 higher

5 a Wax absorbs vibrations/energy and transmits less of it to the eardrum.
  b The hair cells cannot convert the vibrations into nerve impulses.
  c The bones cannot vibrate, so they cannot amplify the vibrations or transmit them to the cochlea.

SP4e.5 Ears and hearing Homework 2

1 a Wax absorbs vibrations/energy and transmits less of it to the eardrum.
  b The hair cells cannot convert the vibrations into nerve impulses.
  c The bones cannot vibrate, so they cannot amplify the vibrations or transmit them to the cochlea.
  d Air can pass through the eardrum, so it will not vibrate as much as it would have done, and so the vibrations passed to the ear bones are weaker/have a lower amplitude.

2 It needs to increase the amplitude, as loudness depends on amplitude.

3 The area of the end of the ear trumpet is greater than the area of the end of the ear canal, so sound waves become concentrated as they go down it, and the amplitude of the vibrations/loudness of the sound is increased at the eardrum.

4 The hearing aid makes the sound louder, so the person with hearing loss can hear the sound.

5 If the person can hear low frequencies normally, a hearing aid that amplified sound at all frequencies would make the lower frequencies sound too loud (or similar explanations).

6 The eardrum vibrates when sound waves reach it and passes the vibrations on to the ear bones. These amplify the vibrations and pass them on to the cochlea. The cochlea is filled with a fluid that makes a membrane vibrate. Hairs on the membrane convert vibrations into nerve impulses.

7 The microphone (instead of the eardrum) detects vibrations. The electronics (instead of the ear bones) amplify the sound and turns it into signals to be sent to the brain (instead of the cochlea).

8 The Eustachian tubes link the back of the mouth to the spaces behind the eardrums (one tube for each ear). Air can pass through the tube to equalise the air pressure on each side of the eardrum. The Eustachian tubes also allow any mucus caused by infections to drain out of this part of the ear. If they get blocked,

mucus can build up behind the eardrum and cause earache or temporary hearing loss.

SP4f Ultrasound

Student Book

4th **1** sounds with frequencies higher than 20 kHz

5th **2** Bats make ultrasounds/sounds above 20 kHz, and humans cannot hear ultrasounds/frequencies above 20 kHz.

5th **3** Light does not travel very far through water.

7th **4** **a** distance = 1500 m/s × 3 s = 4500 m

7th **b** depth = 4500 m/2 = 2250 m

6th **5** Visible light is reflected by the skin/ doesn't go inside the body.

S1 Labels to include the following information: a ship sends out a pulse of ultrasound and listens for the echo from the sea bed; the machine uses the speed of sound to calculate how far the sound has travelled so it can work out the depth of the water; the ultrasound will also be reflected by fish so if there are two echoes, the one that arrives first has probably echoed from a shoal of fish; a sample calculation to be included, similar to the Worked example in the Student Book (the distance travelled or time taken must be halved).

E1 Ultrasound waves are sent into the body from a scanner. A gel is used to help stop the ultrasound being reflected by the skin. Inside the body, some of the ultrasound is reflected each time it meets a different material such as fat or bone. The machine detects the echoes and displays information about echo time on a screen, which forms an image of the inside of the body.

Exam-style question

Dolphins use sonar/ultrasound to detect the mines (1). This may allow them to detect mines that are further away OR this may allow them to detect mines hidden in sand/mud (1).

Activity and Assessment Pack

SP4f.1 Ultrasound scans

1 F – jelly, G – woman's body

2 **a** 99%

b 1%

c 0.1%

d 99.9%

e The jelly stops most of the ultrasound energy from being reflected before it enters the woman's body. This leaves plenty of energy to be reflected by various parts of the foetus. If the scanner is not touching the jelly, most of the ultrasound energy is reflected when the ultrasound reaches the jelly, because the energy passes into the jelly from the air.

3 **a** time = distance/wave speed = 0.30 m/1580 m/s = 0.00019 s

b It assumes that the ultrasound is only passing through muscle, whereas it is likely to pass through many different tissues, all with slightly different properties that affect the speed of sound.

SP4f.2 Ultrasound – Strengthen

1 **a** The sonar equipment sends a pulse of ultrasound into the water.

Some of the ultrasound is reflected by the sea bed.

Some of the reflected sound is detected by the sonar equipment.

The equipment measures the time between the pulse being sent out … and the echo being detected.

b If there are fish under the boat … some of the ultrasound will be reflected by the fish.

The echo from the fish will be detected … before the echo from the sea bed.

The depth of the sea or the fish is worked out … using the echo time and the speed of sound in water.

The echo time is 3 seconds … and the speed of sound in sea water is 1500 m/s.

The ultrasound has travelled for 1500 m/s × 3 s = 4500 m

c The sound has gone down and back up again… so the depth is half of this value (2250 m).

2 Ultrasound pulses are sent into the woman's body.

Jelly is used to make sure the ultrasound … is not reflected by her skin.

Some of the ultrasound is reflected each time … it meets a different material such as bone, muscle or fluid.

The scanner detects the echoes … and measures the time the sound has taken.

It uses the times to calculate the distance … to the different parts of the foetus … and builds up an image.

SP4f.3 Ultrasound – Homework 1

1 **a** Travel across the ocean sending sonar pulses down, to make a map of how deep the water is.

b Look for echoes from above the sea bed, which might come from fish.

c Make an ultrasound scan of a foetus to check it is healthy.

2 The equipment sends a pulse of ultrasound into the water and records how long the echo takes to return. It uses the speed of sound in the type of water it is in to calculate the distance the sound has travelled. Half of this distance is the depth of the water or the depth below the surface of fish/submarines/whatever it has been reflected by.

3 **a** total distance = 2 × 2000 m = 4000 m

b time = 4000 m/1533 m/s = 2.61 s

4 **a** distance travelled = 1533 m/s × 6.52 s = 9995 m

b depth = 9995 m/2 = 4997 m = 5000 m to 2 s.f.

5 **a** 106 ms = 0.106 s

b distance travelled = 2 × 79 m = 158 m

c speed = 158 m/0.106 s = 1491 m/s

6 **a** 50 ms = 0.05 s

distance travelled = 1491 m/s × 0.05 s = 74.55 m

b depth = 74.55 m/2 = 37.3 m

7 **a** 20 cm = 0.2 m, distance travelled = 0.4 m

b time = 0.4 m/343 m/s = 0.001166 s = 0.0012 s, to 2 s.f.

SP4f.4 Ultrasound – Homework 2

1 **a** A machine sends ultrasound waves into the body. Some of the ultrasound energy (or wave) is reflected each time it passes into a different material. The machine detects the echoes, and a computer processes into an image all the times between sending the signal and receiving the echo.

b The speed of sound in the jelly is similar to the speed of sound in skin/water, so not much ultrasound energy is reflected as it passes through the jelly into the body. The speed of sound in air is different to that in the body, so if the jelly were not used most of the ultrasound energy would be reflected before it entered the body.

c Ultrasound waves would be reflected by the air in the bubbles and would appear on the screen (or would mean not much energy was going into the body to be reflected).

d The speed of sound in metal is different from the speed of sound in body tissues, so an ultrasound wave is reflected when it reaches the metal object.

2 The equipment sends a pulse of ultrasound into the water and records how long the echo takes to return. It uses the speed of sound in the type of water it is in to calculate the distance the sound has travelled. Half of this distance is the depth of the water or the depth below the surface of fish/submarines/whatever it has been reflected by.

3 **a** time = 2 × 2000 m/1533 m/s = 2.61 s

b The boat is directly above the ridge, because if it was off to one side the distance to the top of the ridge would be greater than the depth of the water (or similar explanation).

4 **a** distance travelled = 1533 m/s × 6.52 s = 9995 m, depth = 9995 m/2 = 4998 m

depth = 5000 m to 2 s.f.

b distance travelled = 1533 m/s × 14.35 s = 21 999 m, depth = 21 999 m/2 = 10 999 m

depth = 11 000 m to 2 s.f.

5 **a** distance travelled = 2 × 79 m = 158 m, 106 ms = 0.106 s

speed = 158 m/0.106 s = 1491 m/s

b 50 ms = 0.05 s

distance travelled = 1491 m/s × 0.05 s = 74.55 m

depth = 74.55 m/2 = 37.3 m

6 Lake Baikal: distance travelled = 2 × 1637 m = 3274 m, time = 3274 m/1491 m/s = 2.2 s

Loch Morar: distance travelled = 2 × 310 m = 620 m, time = 620 m/1491 m/s = 0.42 s

7 20 cm = 0.2 m, distance travelled = 0.4 m, time = 0.4 m/343 m/s = 0.0012 s

= 1.2 ms, to 2 s.f.

8 If the speed of sound is 1533 m/s, the time for the signal to travel to the sea bed and return is 8000 m/1533 m/s = 5.22 seconds. A 1 per cent error in the speed of sound is 15.33 m/s. If the speed of sound is actually 1548 m/s (1533 m/s ± 15 m/s), then a 5.22-second time implies a depth of 1548 m/s × 5.22 s = 8080 m. The error in depth would therefore be 80 m (overestimate). (The error in depth would be 78 m, an underestimate, if the speed of sound is 1 per cent lower than that assumed.)

SP4g Infrasound

Student Book

1 No, infrasounds have frequencies below 20 Hz.

2 **a** a wave that travels through the Earth

b an instrument that detects seismic waves

3 P waves are infrasound waves because they are longitudinal waves. S waves are not, because they are transverse waves.

4 S waves cannot travel through liquids, so the shadow zone suggests that there is a liquid section inside the Earth that stops the S waves being transmitted/ absorbs the waves.

5 **a** The speed must change as refraction is occurring. A more detailed (level 7) answer will say that the speed changes gradually with depth, which causes the curved lines, but must change suddenly between the mantle and the core/ outer core as the P waves change direction sharply here.

b The properties must change, as this is what causes the speed of the seismic waves to change.

6 P waves follow curved paths through the mantle. Waves that go deeper into the Earth meet the outer core, and are refracted even more as they enter it and again when they leave it. So there is a big change of direction between a wave that just skims the outer core and one that enters it, leaving a large zone where P waves do not arrive.

S1 Infrasound waves can travel long distances, so waves produced by earthquakes can be detected around the world and provide information about what they have passed through.

E1 The S wave shadow zone shows there must be something within the Earth that stops S waves being transmitted, and this is a liquid core. The P wave shadow zone confirms this, as it is caused by the refraction of P waves as they pass into and out of the core. The few P waves that do arrive in the P wave shadow zone indicates that there is a solid inner core.

Exam-style question

a Infrasound describes sound waves with frequencies less than 20 Hz (1).

b Infrasound waves can be used to explore the Earth's core (or similar statement) (1).

Activity and Assessment Pack

SP4g.1 Finding the focus

1 **a, b**

A: 86 s – 52 s = 34 s, distance = 294.1 km

B: 160 s – 98 s = 62 s, distance = 536.3 km

C: 150 s – 116 s = 34 s, 294.1 km

4 The focus should be approximately 300 km north of A and 65 km east. (Allow for some variation in the times read from the graphs.)

5 **a** There are likely to be differences from slight differences in reading the S wave arrival times from the graph, and errors in drawing the arcs.

b The person may have used a larger scale. If the same scale was used, the person may have got some measurements wrong or recorded less accurate results for the position of the earthquake.

SP4g.2 Build a seismometer

1 The seismometer works if the pen stays in one position when the ground moves. The more mass there is in the cup, the less it will move when the table moves.

2 **a** P waves are longitudinal waves, so the pen will move backwards and forwards in the same direction as X.

b S waves are transverse waves, so the pen will move at right angles to direction X.

3 P waves. The P waves will be moving the Earth up and down.

SP4g.3 Infrasound – Strengthen

1 **a** all ticked except for 'too high for humans to hear'

b the following circled: can travel further than sound waves that we can hear, can be reflected at boundaries between different materials, can be refracted by changes in the properties of materials

c Infrasound waves can travel a long way, so waves from earthquakes can be detected all around the world. The way the waves have been reflected or refracted can tell scientists about the inside of the Earth.

2 Infrasound – Sound waves with a frequency below 20 Hz … which is too low for the human ear to detect.

P waves – Longitudinal seismic waves … that travel through the Earth faster than… transverse seismic waves.

S waves – Transverse seismic waves … that travel through the Earth slower than… longitudinal seismic waves.

Seismic waves – Waves produced by an explosion or earthquake… and which travel through the Earth…(they include P waves and S waves).

Seismometer – An instrument that detects… seismic waves.

Shadow zone – A part of the surface of the Earth …that P waves or S waves from an earthquake do not reach … because of the way they have been reflected or refracted within the Earth.

SP4g.4 Infrasound – Homework 1

1 **a** ultrasound, infrasound
b ultrasound
c infrasound
d infrasound
e all three ticked

2 **a** both
b both
c P waves
d both

3 Part of the Earth that seismic waves passing through the Earth from an earthquake do not reach.

4 S waves cannot pass through liquid, so waves that reach the outer core are stopped/absorbed, and this makes the shadow zone.

5 It makes a sharp change in direction as it enters the core and again as it leaves the core. Its path through each part of the Earth is curved.

6 Waves bend towards the normal when they enter a medium where they travel more slowly, and this is what happens to P waves entering the outer core.

SP4g.5 Infrasound – Homework 2

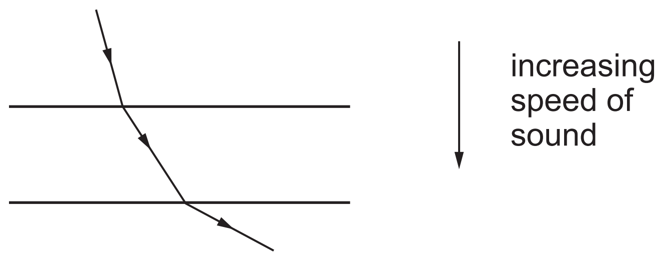
1 Similarities: all longitudinal waves that need a medium, so all involve the vibration of particles in the same direction as the direction of travel.

Differences: sound waves can be detected by human ears, ultrasound and infrasound cannot; ultrasound has frequencies greater then 20 000 Hz, infrasound has frequencies below 20 Hz. Infrasound can be detected at greater distances than the others.

2 **a** P waves are longitudinal waves, so the particles in the Earth vibrate along the same direction as the wave is travelling. S waves are transverse waves, so the particles vibrate at right angles to the direction the wave is travelling.
b P waves can travel through solids, liquids and gases. S waves can only travel through solids.

3 **a** an area of the Earth where seismic waves are not detected after an earthquake
b The S wave shadow zone covers almost the whole hemisphere opposite the earthquake (or similar description). The P wave shadow zone is a band around the Earth that starts in a similar place to the S wave shadow zone but does not extend right down to the opposite side.

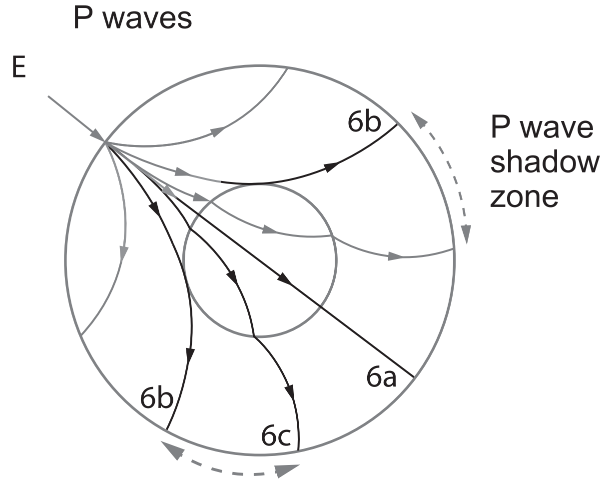
4 **a** refraction
b The speed of sound increases with depth, because the waves effectively bend away from the normal.



5 **a** The inner circle on the diagram represents the edge of the Earth's outer core, which is liquid. S waves are transverse waves and cannot pass through liquids, so the wave stops.
b wave drawn with a curve that just grazes the edge of the core and meets the surface again at the start of the S wave shadow zone

6 **a** This will pass through the Earth in a straight line, because it is a longitudinal wave that can pass through a liquid, and it meets the boundaries between different materials at right angles, so refraction does not change its direction. Students show this wave continuing straight through the Earth.
b wave drawn with a curve that just grazes the edge of the core and meets the surface again at the start of the P wave shadow zone

c waves drawn in as shown



7 Treaties agree that tests should only be done underground. A nuclear explosion produces seismic waves similar to those of an earthquake, and seismometers can detect these waves. The timings of waves arriving at different seismometers allow scientists to work out where the explosion happened.

SP5a Ray diagrams

Student Book

1 30°

2 it bends away from the normal

3 There is always some light reflected when light hits glass. It is easier to notice this when it is dark outside because in daylight the light coming from outside is much brighter than the reflection.

4 Light travels slower in glass than air, and total internal reflection only happens when light goes into a material in which it travels faster. Alternatively, light bends towards the normal when it goes from air into glass, so it will never bend towards the boundary.

5 A ray diagram showing light from manatee reflecting from underside of water surface and going towards a camera, with the angles of incidence and reflection equal.

6 **a** A ray diagram showing light passing from a glass block into air with an angle of incidence of 35° and an angle of refraction greater than this (the angle of refraction would be approximately 60° but students are not expected to be able to work this out).

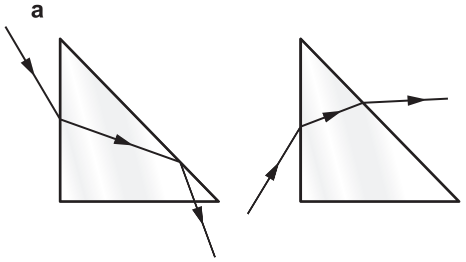
b A ray diagram showing light being totally internally reflected inside a glass block, with angles of incidence and reflection equal.

S1 A ray diagram showing light being reflected by a mirror with equal angles of incidence and reflection.

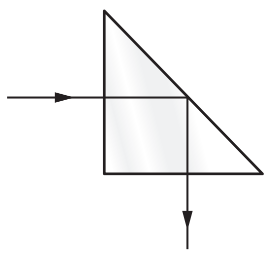
S2 If light in glass meets a boundary with air at an angle of 42°, the light will be refracted to pass along the boundary. If light meets the boundary at angles greater than this, it will be totally internally reflected.

E1 Various answers are possible for part a, depending on where the incident ray is drawn. See diagram below.

a



b



Exam-style question

In both, the angles of incidence and reflection are equal (1) and both occur at a surface/boundary/interface (1).

Reflection can occur at any surface, whereas total internal reflection only happens inside a transparent medium (1).

SP5a Core practical Investigating refraction

1 light travels more slowly/at a different speed in glass (1)

2 **a** A line at right angles to the interface between two materials. (1)

b The angle between the normal and a ray of light travelling towards an interface between two materials. (1)

c The angle between the normal and a ray of light leaving the interface between two materials. (1)

3 **a** Rectangular block drawn with a normal line perpendicular to part of one surface, (1) incident ray drawn at an angle of incidence of 30° (accept ± 1°). (1)

b Refracted ray drawn at an angle of refraction of 20° (accept ± 1°). (1)

4 **a** Graph with sensible scales on axes (1) and axes labelled. (1) All points correctly plotted to ± half a square. (2) Only 1 mark if one point plotted in error, 0 marks if more than one error. Smooth curve passing through all the points. (1)

b The angle of refraction increases as the angle of incidence increases, (1) but the angle of refraction is always less than the angle of incidence. (1) The relationship between the angles of incidence and refraction is not a linear/proportional relationship. (1)

c The answer should be 9.5° (from the values supplied for plotting the graph), accept ± 1°. (1)

5 **a** Graph with sensible scales on axes (1) and axes labelled. (1) All points correctly plotted to ± half a square. (2) *Only 1 mark if one point plotted in error, 0 marks if more than one error*. Smooth curve passing through all the points. (1)

b The angle of refraction increases as the angle of incidence increases (1), but the angle of refraction is always greater than the angle of incidence. (1) The relationship between the angles of incidence and refraction is not a linear/proportional relationship. (1)

c The answer should be about 27.5°, accept ± 1°. (1)

6 The student may not have measured the angles accurately/may not have drawn the normal correctly. (1)

Activity and Assessment Pack

SP5a.1 Investigating refraction

3 There is a correlation between the angles of incidence and refraction. For air to glass, the angle of refraction increases as the angle of incidence increases, but the angle of refraction is always less than the angle of incidence. For glass to air, the angle of refraction is always greater than the angle of incidence. The angle of refraction is not directly proportional to the angle of incidence.

4 It is parallel, but not along the same line.

5 Light bends towards the normal when it enters the glass block and bends away again when it leaves. The angle of refraction increases as the angle of incidence increases, but there is not a linear relationship between them.

6 Students' own answers. Suggestions for improvements may include making the light ray thinner, drawing crosses more accurately, etc.

SP5a.2 Investigating total internal reflection

2 Students' own answers. Explanations may refer to the difficulty of marking rays accurately, not always having the ray of light pointing at the correct place on the straight edge of the block, etc.

3 Light going into the semi-circular block does not change direction, because it enters at right angles to the surface of the block.

SP5a.3 Ray diagrams – Strengthen

1 **a** normal line continued

b existing line continued to meet the mirror, with an arrow drawn on it

c 45°

d reflected ray drawn with an angle of reflection of 45°

e angles of incidence and reflection labelled correctly

2 **a** angles of incidence and refraction labelled correctly

b C

c B

d 42° (accept a couple of degrees' error either way)

3 away from, larger, refraction, interface, critical, reflected, internal

SP5a.4 Ray diagrams – Homework 1

1 ray diagram completed correctly, with angles of incidence and reflection equal, and arrows on the rays

2 normal, angle of incidence and angle of reflection labelled correctly

3 The angle of reflection is equal to the angle of incidence.

4 **a** ray drawn with an angle of refraction less than the angle of incidence (the correct angle of refraction is 28°, although students are not expected to be this accurate)

b ray drawn with angle of refraction greater than the angle of incidence (the angle of refraction should be 49°)

c ray shown reflecting inside the glass, with angle of reflection equal to angle of incidence

5 angles of incidence and refraction labelled correctly

6 diagram c

7 **a** ray drawn along surface of glass

b The angle of incidence for light going from glass to air at which the refracted ray travels along the edge of the glass. At angles of incidence greater than the critical angle, the light is reflected inside the glass.

SP5a.5 Ray diagrams – Homework 2

1 The angle of incidence is equal to the angle of reflection.

2 **a** The light is bent towards the normal.

b The light is bent away from the normal.

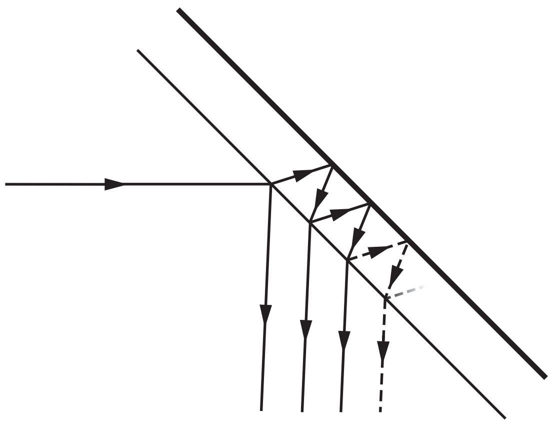
3 It is the angle of incidence for light going from glass to air at which the refracted ray travels along the edge of the glass. At angles of incidence greater than the critical angle, the light is reflected inside the glass.

4 **a** single ray drawn through the periscope, showing light being reflected correctly at the internal diagonal face of each prism

b 45°

c If the critical angle was greater than 45°, the light would not be reflected inside the prisms.

5 **a** Diagram should show refraction as the light enters the glass, reflection at the back surface and refraction as the light leaves the glass. It should also show partial reflection each time the light reaches the surface of the glass, whether from inside or outside.



b Glass mirrors give multiple reflections, which would make the image less clear. Prisms also reflect more of the light hitting them than mirrors do.

6 **a** to allow bicycles to be seen more easily at night by reflecting car headlights back towards the driver

b The light is reflected back in the direction it came from. With a mirror, unless the car was directly behind the bicycle, the angle of reflection would equal the angle of incidence and the light would be reflected to one side and not back at the driver.

c When the light hits the back of the reflector, it is totally internally reflected/it hits the inside of the back of the reflector at an angle greater than the critical angle.

d The reflector only works over a restricted range of angles. At greater angles, the back of the reflector does not internally reflect the light, because the light hits it at an angle less than the critical angle. So having sections at different angles allows the reflector as a whole to reflect light back at a greater range of angles.

SP5b Colour

Student Book

6th **1** Each ray of light shown has the angle of reflection equal to the angle of incidence, the light only appears to be scattered because the surface is at lots of different angles.

6th **2** **a** They are reflecting only yellow light and absorbing all the other colours.

6th **b** They are reflecting only blue light and absorbing all the other colours.

6th **3** **a** It reflects all the colours in white light.

6th **b** They absorb all the light hitting them.

7th **4** **a** Window glass transmits all colours and does not absorb any. (In practice a little will be absorbed, usually evenly across the colours, but this level of answer is not expected.) We know this because the colour of objects/light does not appear to change when viewed through glass.

7th **b** transmits red light and absorbs all the other colours

8th **5** **a** The white parts will reflect all colours, but if only blue light is hitting them they can only reflect blue light.

8th **b** The blue parts reflect only blue light and absorb the other colours, so if red light falls on them they absorb it and do not reflect any light.

8th **c** The red and blue parts both absorb green light, so no light is reflected.

S1 The red flower reflects the red wavelengths in the light from the Sun and absorbs all the other colours.

S2 A filter is a piece of transparent material that transmits one colour of light and absorbs the other colours.

E1 We see objects when light is reflected from them and enters our eyes. We see a post box because it reflects some light from the Sun. It appears red because it reflects red light and absorbs all the other colours.

E2 A blue spotlight emits only blue light. As the red post box absorbs all colours except red, it will absorb the blue light and so will appear black.

Exam-style question

Both reflect light so that the angles of reflection are equal to the angles of incidence (1).

However the surface of the mirror is very smooth so that all the reflected rays go in the same direction, whereas the rough surface of the paper results in the rays being scattered in different directions (1).

Activity and Assessment Pack

SP5b.1 Investigating filters and coloured light

1 The filter makes white light into coloured light. A red filter transmits red light and absorbs all the other colours in white light.

2 No light gets through. The first filter only transmits one colour from white light. If the second filter is a different colour, it will only transmit this other colour and absorb the colour of light transmitted by the first filter.

3 **a** The light is spread out to show the colours of the visible spectrum.

b The light is refracted by the prism but the colour does not change.

c The filter will only transmit one colour in the spectrum of light from the prism.

4 **a** The different colours in white light are refracted by different amounts.

b There is only one colour going into the prism, so only one colour can come out.

c The filter absorbs all but one of the colours in the visible spectrum.

5 The mixture of the two lights appears a different (third) colour. The actual colours reported by students will depend on the filters they have available and which combinations they choose.

6 Each filter absorbs some of the light, so between the two filters they absorb all of the light coming from the ray box. With two different coloured lights, all the light from both is hitting the same place.

SP5b.2 Colours and coloured light

The completed and matched up cards (if used) will give the following sentences.

The [named colour] filter absorbs all the colours in white light … except for [named colour] light.

The [named colour] filter transmits [named colour] light.

The first, [named colour] colour filter only transmits [named colour] colour light … and the second [second named colour] colour filter absorbs this light, so no light gets through the [second named colour] colour filter.

The [named colour] surface absorbs all the colours in white light … except for [named colour] light.

The [named colour] surface reflects [named colour] light.

There is only [named colour] light reaching the surface … but the surface absorbs [named colour] light, so no light is reflected and it looks [black].

SP5b.3 Colour – Strengthen

1 red, orange, yellow, green, blue, indigo, violet

2 white, visible, white

reflect, all, some, absorb

red, absorbs, red

3 **a** true

b false

c false

d false

4 **b** White light contains all the colours of the spectrum (or list of the colours).

c A blue filter transmits blue light.

d A blue filter absorbs red light.

5 In specular reflection, light is reflected evenly.

In diffuse reflection, light is scattered by a surface in lots of different directions.

SP5b.4 Colour – Homework 1

1 We see things when light ~~refracted~~ [reflected] from them goes into our eyes. Things with smooth surfaces, like mirrors, have ~~spectacle~~ [specular] reflection, where the light is reflected evenly. Rough surfaces have diffuse reflection where light is ~~absorbed~~ [scattered].

White light has all the colours of the visible ~~specular~~ [spectrum]. When light hits a red object like a post box, the red light is reflected and the other colours are ~~transmitted~~ [absorbed]. This is why the post box looks red.

2 **a** all circled
b B
c all *except* B circled
d all *except* B circled
e B

3 white, reflected, white
filter, transmits, absorbs
no, transmits, absorbs
green, absorbed, green, green, black, red, green

SP5b.5 Colour – Homework 2

1 **a** In diffuse reflection, the reflected light is scattered in all directions. In specular reflection, the reflected rays all go in the same direction/are reflected evenly.
b mirrors/very smooth, shiny surfaces

2 **a** White light is a mixture of all the colours in the visible spectrum. The post box reflects the red part of white light and absorbs the other colours.
b The post box only reflects red light. As there is no red light reaching it, it cannot reflect any light and so it looks black.

3 A coloured filter transmits one of the colours in white light and absorbs all the other colours.

4 Yes, it must reflect some light or you would not be able to see it.

5 **a** Only green light reaches the plant. White surfaces reflect all colours, so the white parts look green. Green surfaces reflect green light, so the green parts also look green and the stripes may not be visible.
b The white parts reflect the red light and look red. The green parts absorb red light, so they look black. The plant appears to be black with red stripes.

6 As only the red light gets through the filter, the red light in the room is dimmer/less intense than the white light would have been. (The other reason is that the rods in our retinas do not detect red light, and so the red light does not cause the pupil to contract – but students are not expected to know this.)

7 If light only comes from one direction, objects with only specular reflection will only be visible from one angle, depending on the angle between the surface and the light. With diffuse reflection, light hitting an object is scattered in all directions, even if it only comes from a single source, so the object will be visible from many directions.

8 The retina has rods and cones. There are three types of cone, which detect the three primary colours of light (red, green, blue). The cones work in lower light levels but only detect light and dark, not colours. At night/in low light conditions, there is not enough light for the cones to work, so we effectively see in black and white.

SP5c Lenses

Student Book

5th 1 how much it bends light passing through it

5th 2 the ×20 is more powerful

6th 3 **a** it would be thinner/less curved

6th **b** the focal length would be shorter

6th 4 They both bend light/change the direction of light that passes through them. The converging lens makes parallel rays of light come together, the diverging lens makes parallel rays spread out.

6th 5 converging lens, as the lens needs to bring rays together

7th 6 They must use converging lenses, because an image on a screen is a real image and only converging lenses can produce real images. Diverging lenses only produce virtual images.

S1 The more curved the lens the more it bends the light and so the greater its power.

S2 The camera must form an image on the screen/film that records the image. This is a real image, so the camera must have a converging lens.

E1 A real image is formed when rays of light are brought together and can be projected onto a screen. A virtual image is one where the rays of light only appear to come from the image. The statement is not true, as a converging lens can produce both real and virtual images, depending on where the object is relative to the lens/the focal point of the lens.

Exam-style question

The object must be placed close to the lens (within the focal length of the lens) (1).

This can be used to make objects look bigger/as a magnifying glass (1).

Activity and Assessment Pack

SP5c.1 Different lenses

1 Thicker lenses have shorter focal lengths.

2 Thicker lenses are more powerful.

3 Thicker lenses have more curved surfaces, so the greater the curvature on a lens, the greater the power.

5 **a** Parallel rays of light are bent inwards, so they pass through a single point on the far side of the lens.

b The rays are bent, so they emerge as parallel rays.

6 Parallel rays of light are bent outwards, so they appear to come from a point on the same side of the lens as the light source.

7 The greater the curvature of a lens, the shorter its focal length.

SP5c.2 Lenses

1 The view through the telescope will be magnified, inverted and (with a simple telescope) probably not as sharp as the real-world view.

2 The image should be larger and inverted, but may not be very sharp.

SP5c.3 Lenses – Strengthen

1 how much the lens bends light

2 **a** Y

b Y

c Y

3 Y, bend, power

4 **a** diverging, converging

b Rays diverge beyond the first one, and converge beyond the second one.

Rays should have arrows on them.

5 **a** real

b virtual

c virtual

d real

e virtual

f real, virtual

6 The camera must form an image on the screen/film that records the image. This is a real image, so the camera must have a converging lens.

SP5c.4 Lenses – Homework 1

1 **A** a second ray straight through the lens, and a third ray mirror image of top one, crossing the axis at the same point

B completed as for A, but with the rays crossing much further from the lens

C a second ray straight through the lens, and a third ray mirror image of top one, with the virtual extension of the ray meeting the axis in the same place

D completed as for C, but with the rays diverging more/the virtual extension of the rays crossing closer to the lens

2 C and D

3 focal point and focal length labelled correctly on B

4 focal point labelled correctly on C

5 **a** A

b B

6 The most powerful lens is the one with the most curved surface.

7 **a** virtual

b The rays appear to come from the same point; they do not actually cross.

8 C and D

9 A and B

SP5c.5 Lenses – Homework 2

1 cornea, lens

2 real – the light rays come together at the retina/the retina acts like a screen

3 **a** more powerful

b It must become fatter/more curved, as a more curved lens is more powerful.

4 Light is being bent too much by the lens, so if the light rays are made to diverge a little before they enter the eye, then the point where they eventually come together will be further from the lens (or any similar explanation).

5 **a** Their eyeballs are too short, or the lenses in their eyes are not powerful enough.

b The light rays need to converge more, so they need to use converging lenses.

c diagram showing light rays converging beyond retina, and with a converging lens allowing light rays to meet at the retina

6 **a** converging

b ray diagram showing light rays being brought to a point by a converging lens

c long-sighted, as they have converging lenses in their spectacles

7 **a** The glasses are acting like magnifying glasses, so they must be converging lenses and the person must be long-sighted.

b diagram similar to diagram D in the student book

SP5d Electromagnetic waves

Student Book

6th **1** Violet light has the highest frequency. Ultraviolet light has a higher frequency than visible light, and infrared has a lower frequency, so violet light will be at the high frequency end of the visible spectrum and red light at the low frequency end.

6th **2** like the one on the right, as birds can detect ultraviolet light

6th **3** **a** transverse

6th **b** different frequencies and wavelengths

6th **4** Any two similarities from: they are both electromagnetic waves; both transverse waves; both travel at the same speed in a vacuum; both transfer energy from source to observer.

Any two differences from: ultraviolet has a higher frequency; ultraviolet has a shorter wavelength; we can detect infrared as warmth on our skin but we cannot detect ultraviolet.

6th **5** their heads

6th **6** **a** red (accept orange or yellow)

6th **b** Infrared transferred more energy than any of the colours in visible light.

S1 Energy is transferred from the Sun to the Earth. The flower reflects some of this energy and our eyes detect it.

S2 Our eyes detect the parts of the electromagnetic spectrum we call visible light. Birds can also detect ultraviolet light, so anything that reflects ultraviolet light as well as visible light will appear different to them.

E1 Similarities: they are all electromagnetic waves, so they are all transverse, can all travel in a vacuum, all travel at the same speed in a vacuum and all transfer energy from a source to an observer.

Differences: the three types of wave have different wavelengths and frequencies. They can be detected in different ways and may have different effects on the objects they transfer energy to (for example, infrared will cause things to heat up, ultraviolet will not). Students may also mention different uses for the three types of wave – uses will be covered in more detail later in the unit.

E2 No. It shows that thermometers absorb more energy from red light than from violet light, not necessarily that red light is transferring more energy. (In fact violet light transfers more energy as it has a higher frequency – covered in SP5e. However this energy does not cause as much of a temperature rise in the thermometers as the smaller amount of energy transferred by red light does.)

Exam-style question

Any two of the following points:

- they are all transverse waves (1)
- they all transfer energy (1)
- they can all travel in a vacuum (1)
- they all travel at the same speed in a vacuum (1)

Activity and Assessment Pack

SP5d.1 Repeating Herschel's experiment

1 If students have used the Student Book pages, they should predict that red will give the greatest temperature rise of the visible colours. If not, any sensible prediction with an explanation is acceptable.

2 Student's own table.

3 Student's own graph.

4 Students should conclude that the temperature rise is greater for red light than blue light, and greater still when the thermometer is placed just beyond the red end of the spectrum.

SP5d.2 Electromagnetic waves Strengthen

1 sources, Sun, energy, eyes, reflect, transferred, reflected

2 electromagnetic waves

3 **a** visible light

b ultraviolet

c infrared

4 Our eyes detect the parts of the electromagnetic spectrum we call visible light. Birds can also detect ultraviolet light, so anything that reflects ultraviolet light as well as visible light will appear different to them.

5 c, d, e ticked

SP5d.3 Electromagnetic waves Homework 1

1 blue, 6 °C; yellow, 9 °C; beyond red, 11 °C

2 Correctly plotted line graph showing three smooth curves. Line for blue light at the bottom and beyond red at the top. Lines should all start from the same place and rise at different rates. The line for yellow light should be in the middle of the other two (ideally students should have ignored the anomalous result at 4 minutes when drawing this curve). Lines should be labelled.

3 All get hotter over time; beyond red it gets the hottest, then yellow, with blue having the lowest temperature rise.

4 a Reading at 4 minutes for yellow should be ringed either on the table or on the graph.
b The student may have misread the thermometer, or any other sensible suggestion.

5 The thermometers had the same starting temperature.

6 Use three thermometers and take all the readings at the same time.

7 a infrared
b ultraviolet

8 They are all transverse waves, and they all travel at the same speed in a vacuum.

SP5d.4 Electromagnetic waves Homework 2

1 blue, 6 °C; yellow, 9 °C; beyond red, 11 °C

2 Correctly plotted line graph showing three smooth curves. Line for blue light at the bottom and beyond red at the top. Lines should all start from the same place and rise at different rates. The line for yellow light should be in the middle of the other two and students should have ignored the anomalous result at 4 minutes. Lines should be labelled.

3 All get hotter over time; beyond red it gets the hottest, then yellow, with blue having the lowest temperature rise.

4 After a time, the maximum possible temperature for that colour is reached.

5 a The four-minute reading on the yellow curve doesn't fit the pattern, so it is anomalous.
b The student may have misread the thermometer, or any other sensible suggestion.

6 Start temperature was always 19 °C.

7 There should have been three thermometers recording the temperature at the same time in case of, for example, warm draughts.

8 a infrared
b ultraviolet

9 They are all transverse waves, and they all travel at the same speed in a vacuum.

10 H The different frequencies/colours change speed by different amounts when they enter and leave the prism.

Extra challenge

11 Two more similar curves, in the gaps between the three already drawn (green between blue and yellow, and red between yellow and 'beyond red'). Students should justify this by suggesting that the temperature rise increases from the violet to the red end of the spectrum, so you would expect green to produce a greater temperature rise than blue, but not quite as much as yellow.

SP5e The electromagnetic spectrum

Student Book

5th 1 any three from: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays

5th 2 gamma rays

5th 3 ultraviolet

6th 4 energy emitted by the Sun/stars/other objects in space as electromagnetic waves reach us on Earth

7th 5 The atmosphere absorbs infrared radiation, so a telescope on the ground would not detect much infrared radiation from objects in space. A very good answer will also point out that the atmosphere is warm (compared with temperatures in space) and so will be emitting its own infrared radiation, so the small amount of infrared from the stars that might be detected on the ground would probably be masked by radiation from the atmosphere itself.

S1 List in this or reverse order: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays.

Radio waves have the lowest frequencies and longest wavelengths; gamma rays have the highest frequencies and shortest wavelengths.

E1 H All electromagnetic waves can travel in a vacuum, but some of them are absorbed by the atmosphere. Astronomers can study the frequencies that do pass through the atmosphere using telescopes on the ground, but any frequencies that get absorbed by the atmosphere can only be studied using telescopes in space. Larger telescopes are needed to study waves with longer wavelengths, and the materials used to focus the waves also depend on the wavelength, as different wavelengths are absorbed or transmitted differently by different materials.

Exam-style question

Similarities – any one of the following points: they are electromagnetic waves, are transverse waves, transfer energy, travel in vacuum, travel at same speed in vacuum. (1)

Differences – any one of the following points: X-rays have higher frequency, X-rays have shorter wavelength, we can detect visible light but not X-rays with our eyes, H X-rays are absorbed by the atmosphere but visible light is not (1).

Other answers are possible, such as different uses of light and X-rays from student's existing knowledge.

Activity and Assessment Pack

SP5e.1 Make a spectrometer

1 Predictions can be for the hypothesis to be true or not true, but should be backed up with a plausible reason.

2 student's own answers

3 student's answers based on what they can see

4 Students should see that there are more lines near dawn/sunset than during the middle of the day.

5 student's own evaluation

6 Students are likely to have gathered only a few observations, which would not be enough to rule out weather or other effects not dependent on the time of day. The quality is also likely to be poor, particularly if observations are only recorded manually.

SP5e.2 Ordering the EM spectrum

1, 2 The order is the same in both grids.

In order of wavelength:

gamma rays: 1×10^{-10} m to 1×10^{-12} m

X-rays: 1×10^{-8} m to 1×10^{-11} m

ultraviolet: 4×10^{-7} m to 1×10^{-8} m

visible: 7×10^{-7} m to 4×10^{-7} m

infrared: 1×10^{-3} m to 7×10^{-7} m

microwaves: 1 m to 1×10^{-3} m

radio waves: 1×10^{3} m to 1 m

In order of frequency:

gamma rays: 3×10^{18} Hz to 3×10^{20} Hz

X-rays: 3×10^{16} Hz to 3×10^{19} Hz

ultraviolet: 7.5×10^{14} Hz to 3×10^{16} Hz

visible: 4.3×10^{14} Hz to 7.5×10^{14} Hz

infrared: 3×10^{11} Hz to 4.3×10^{14} Hz

microwaves: 3×10^{8} Hz to 3×10^{11} Hz

radio waves: 3×10^{5} Hz to 3×10^{8} Hz

SP5e.3 The electromagnetic spectrum – Strengthen

1 gamma rays, infrared, microwaves, radio waves, ultraviolet, visible light, X-rays

2 frequencies

short, low, wavelengths

lowest, wavelengths

frequencies, shortest

spectrum

seven, spectrum, orange, green, violet

wavelength, highest, shortest

3 list in either order: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays

4 if the list started with radio waves:

a lowest frequency

b longest wavelength

if the list started with gamma rays:

a highest frequency

b shortest wavelength

5 If the list started with radio waves: the frequency increases and the wavelength decreases along the list.

If the list started with gamma rays: the frequency decreases and the wavelength increases along the list.

SP5e.4 The electromagnetic spectrum – Homework 1

1 a microwaves
  b gamma rays
  c radio waves
  d ultraviolet
  e visible light
  f infrared

2 Correct words are:
  a frequency
  b wavelengths
  c radio
  d highest
  e the same

3 red, orange, yellow, green, blue, indigo, violet

4 a radio
  b microwaves
  c infrared
  d visible
  e ultraviolet
  f X-rays
  g gamma

5 student's own answer

SP5e.5 The electromagnetic spectrum – Homework 2

1 a The atmosphere absorbs almost all of the gamma rays passing through it. On a mountain there is less atmosphere above the telescope to absorb the gamma rays, so some of them will get through.
  b Advantage: gamma rays can be detected without any atmospheric absorption.
  Disadvantage: any from – it costs more, cannot be easily repaired, has to be smaller/lighter, or any other sensible disadvantage.
  c telescopes to detect ultraviolet or infrared radiation

2 nanometres, micrometres, millimetres, centimetres, metres, kilometres

3 a 100 nm = 1×10^{-7} m
  b 1 μm = 1×10^{-6} m
  c 10 μm = 1×10^{-5} m
  d 1 km = 1×10^{3} m

4 (Answers may vary if students choose different typical wavelengths.)
  gamma and X-rays: $f = 3 \times 10^8$ m/1×10^{-9} m
  $= 3 \times 10^{17}$ Hz
  ultraviolet: $f = 3 \times 10^8$ m/1×10^{-7} m
  $= 3 \times 10^{15}$ Hz
  infrared: $f = 3 \times 10^8$ m/1×10^{-4} m $= 3 \times 10^{12}$ Hz
  microwaves: $f = 3 \times 10^8$ m/1×10^{-2} m
  $= 3 \times 10^{10}$ Hz
  radio waves: $f = 3 \times 10^8$ m/10 m $= 3 \times 10^{7}$ Hz

5 a A typical wavelength of ultraviolet rays is 100 nm, and a typical wavelength of gamma rays is 1 nm, so for these values ultraviolet waves have a wavelength 100 times longer. However this is not always correct, it depends on where within the range of wavelengths for ultraviolet waves and for gamma rays you take your examples.
  b Taking a typical radio wave wavelength as 100 m and a typical microwave wavelength as 1 cm (0.01 m), then radio waves have wavelengths 10 000 times longer than those of microwaves.

6 wavelength $= 2 \times 10^8$ m/s / 3×10^{14} Hz
  $= 6.7 \times 10^{-7}$ m

7 speed $= 2.4 \times 10^{16}$ Hz $\times 5 \times 10^{-9}$ m
  $= 1.2 \times 10^{8}$ m/s.

SP5f Using the long wavelengths

Student Book

5th 1 a eyes
5th b skin
6th 2 radio waves, microwaves, infrared (visible light could also be an acceptable answer, although this is not mentioned in the Student Book)
6th 3 infrared is used in grills and toasters (and some hobs); microwaves are used in microwave ovens
8th 4 Our bodies give off infrared but do not emit other wavelengths. If the security systems detected other wavelengths, such as visible light reflected from intruders, they would have to light the area as well (or similar explanations).
8th 5 H The Earth is curved, so waves that travel in a straight line can only go a certain distance before the Earth gets in the way (and absorbs them). Radio waves are refracted by part of the atmosphere so their path can be bent, which allows them to reach places further away. Microwaves are not affected by this layer, so they can only reach places out of line of sight by being sent to a satellite and then back down to the ground again.

S1 Tables or lists should include most or all of the following uses.

- visible light: vision, photography, illumination
- infrared: cooking, thermal imaging, short-range communications, optical fibres, TV remote controls, security systems
- microwaves: cooking, communications (including satellite transmissions)
- radio waves: broadcasting, communications (including satellite transmissions)

E1 Infrared, microwaves and radio waves are all used for communications of different types, although infrared is only used at short range (including in optical fibres and for remote control devices). Microwaves and radio waves can be sent via satellite. **H** Radio waves are better for longer range communications as they can be used over greater distances without the need for satellites.

Infrared is used in burglar alarms and other security devices – some students may add that visible light is used for security too, in terms of illuminating places at night.

Microwaves and infrared are both used for cooking, although in different ways. Accept other comparisons of uses for the different frequencies.

Exam-style question

Microwaves are used in microwave ovens which heat water inside the food (1), whereas infrared is used in grills/toasters which heat food from the outside (1).

Activity and Assessment Pack

SP5f.1 Long wavelengths in the electromagnetic spectrum

1 **a** Adjusting the frequency will affect which station you can hear and/or whether/how clearly you can hear clear speech/music or if you just hear noise.

b Moving the aerial will affect the quality of the reception.

c no

d display on the radio

e No, there are usually frequency gaps, so a radio only picks up the station the user wants to listen to. (For short ranges, the frequencies of the gaps may be used in different areas, but in each area there will be gaps in the frequencies used.)

f FM is usually both speech and music, but students will probably find more music than speech.

3 **a–e** as for question 1

f AM is usually used for speech (e.g. sports channels).

4 **a** no

b It should be warmer.

c The metal and glass should still feel cool.

d any of the following points: the energy is absorbed by water and the water heats up; glass and metal do not appear to absorb microwaves, as they are still cool; metal must reflect microwaves, otherwise they would escape from the oven (students may also suggest that the glass in the door reflects microwaves; this is not the case – it is the metal mesh in the door that does this – but students are not expected to know this)

5 **H** Radio waves have a different frequency to microwaves, and so may be absorbed/reflected differently by water. Microwaves have a higher amplitude/are more powerful, because they are produced right next to the water, whereas radio waves have spread out from the transmitter, which may be many kilometres away.

6 **a** The detector/camera should detect a light/flickering light. The different signals produced by pressing different buttons are unlikely to be noticeable to students.

b not normally, unless the remote control unit is moved a long way away, because the infrared beam is fairly well focused

c no

d The controller emits enough energy to be detected by the camera, but not enough to be detected by our skin.

SP5f.2 Masts and aerials

1 Mobile phones use microwaves, which travel in straight lines, as light waves do.

2 The building allows the transmitter to be in a high position, to get a long range, without a similarly high tower having to be built.

3 **a** distance = $3570 \times \sqrt{15}$ m = 13 827 m

b distance = $3570 \times \sqrt{25}$ m = 17 850 m

c Advantage: fewer masts are needed, because each one covers a bigger area.

Disadvantage: one from – taller towers are more expensive to build/more likely to spoil the view.

d The power of the transmitter may not be sufficient, and the signal may be reflected or absorbed by buildings/trees etc.

e There are likely to be a lot more calls made in a city because there are a lot more people, so more masts are needed to handle the number of calls.

4 Height above sea level of top of mast = 456 m + 309 m = 765 m

Distance from top of mast = 3570 × √765 m = 98 741 m

5 H The radio waves may be refracted/undergo refraction in the ionosphere.

6 mobile phones: wavelength = 3 × 10^8 m/s / 800 000 000 Hz = 0.375 m

FM radio: wavelength = 3 × 10^8 m/s / 100 000 000 Hz = 3 m

longwave: wavelength = 3 × 10^8 m/s / 270 000 Hz = 1111 m

7 mobile phones 0.1875 m, FM radio 1.5 m, longwave radio 555 m

SP5f.3 Using the long wavelengths Strengthen

1 Radio waves: satellite transmissions, radio and TV broadcasts, police radio

Microwaves: cooking, satellite transmissions, mobile phones

Infrared: cooking, thermal imaging, optical fibres, remote controls, security systems

Visible light: seeing things/vision, photography, light bulbs and spotlights/illumination

SP5f.4 Using the long wavelengths Homework 1

1 Cyril's magazine had an interesting story about a radio telescope looking for possible signals from aliens. He put the magazine down to get his porridge out of the microwave. At the same time the toaster popped up. His toast was burnt again. He switched off the radio and took his breakfast into the living room to watch TV.

He pressed the remote to switch on. There was a news report from the USA, live by satellite. Cyril shivered with the cold and switched the electric fire on. He could feel the warmth as soon as he pressed the switch.

He was soon bored with the news and changed channel to watch *Amazing Police Chases*. There was a view from a police helicopter at night. The suspects showed up as light coloured blobs in the thermal image. When the suspects moved onto open ground the pilot switched on a searchlight so that the officers on the ground could see more easily. The chase was just getting really exciting when Cyril's phone vibrated; it was Anya saying Cyril had to leave now to meet her on the way to school.

2 a microwaves
b radio waves
c infrared
d visible light
e infrared

3 a with our eyes
b with our skin/feel it
c using electronics/mobile phones/TVs etc.

SP5f.5 Using the long wavelengths Homework 2

1 In the order they appear in the story:

radio waves – being detected by radio telescopes to see if there are any signals from aliens

microwaves – cooking food

infrared – cooking toast

radio waves – radio broadcasts

visible light – watching TV

infrared – remote control

microwaves – broadcast via satellite

infrared – electric fire

2 a cameras detect and record visible light in photography

b infrared detectors are used to detect intruders in security systems, or infrared beams are used in security systems

c microwaves are used for mobile phone transmissions

3 time = 50 000 m / 3 × 10^8 m/s = 1.7 x 10^{-4} s

4 time for light to travel in an optical fibre = 50 000 m / 2 × 10^8 m/s = 2.5 × 10^{-4} s

difference in time = 2.5 × 10^{-4} s – 1.7 × 10^{-4} s = 8 × 10^{-5} s

5 H a by oscillations/variations in current and voltage in electric circuits

b The waves induce oscillations/variations in current and voltage in an aerial, which can be detected by electronic circuits.

6 H Radio waves reaching the ionosphere can be refracted back towards the Earth, and this gives them a greater range than microwaves. Microwaves are not refracted by the ionosphere. This means that radio waves must change velocity in the ionosphere, and microwaves do not (or they do not change velocity enough for refraction to reflect them back towards the Earth).

7 H a All of these waves can pass through glass (we can receive radio broadcasts indoors, and we can feel the warmth from the Sun through glass), so there is no effect that depends on wavelength.

b Radio waves and microwaves can pass through brick (we can receive radio broadcasts and mobile phone calls indoors), while light and infrared are absorbed (we cannot see through brick or detect the Sun's warmth through a wall), so the longer wavelengths are transmitted and the shorter ones are absorbed.

8 H Mirrors can be made from polished metal, so visible light is reflected by metals.

Metal mirrors can also be used to focus infrared radiation, as in the curved, shiny material behind the elements in many electric fires.

Microwave ovens have metal grids in their doors to reflect microwaves back into the oven, or satellite TV receivers have metal dishes that reflect and focus microwaves towards a receiver.

Radio telescopes have metal dishes to reflect and focus radio waves towards a receiver.

SP5g Radiation and temperature

Student Book

6th **1** the tea at 75 °C, as hotter objects emit more radiation

7th **2** The hotter the object, the shorter the wavelength at which it emits most radiation. Blue light has a shorter wavelength than yellow light.

6th **3** it must receive 30 kW of energy by heating

7th **4 a** power absorbed = 51% × 343 W = 175 W

7th **b** 6% × 343 W = 20.6 W (it is 6% of the total incoming power)

6th **c** the Earth/atmosphere would get warmer

7th **5** power absorbed and radiated must be equal, as temperature is constant

S1 As the iron gets hotter it will start to glow red, then orange, then yellow, because the wavelength at which most radiation is emitted decreases as the temperature increases.

E1 Some of the radiation from the Sun would not reach the Earth, so the Earth would absorb less power from the Sun. The Earth would cool down a little and would therefore emit less radiation. When the amount of radiation emitted became equal to the new amount being absorbed, the temperature would stop falling and would stabilise at a new level.

Exam-style question

The stove at 150 °C will emit more radiation than the cooler one (1) and the radiation will be at shorter wavelengths (1).

SP5g Core practical Investigating radiation

1 infrared (1)

2 The wavelength of the radiation emitted by a body depends on its temperature (1) and the water is not hot enough to emit radiation at visible wavelengths (1).

3 any sensible safety precaution, such as taking care when pouring hot water so as not to burn yourself, or mopping up any spilled water to avoid slip hazards (2 marks – 1 for saying what the precaution is, and 1 for explaining how it improves safety)

4 a line graph with sensible scales on axes and axes labelled (1)

all points correctly plotted to +/- half a square (2 marks – only 1 mark if more than two points plotted in error, 0 marks if more than four errors)

smooth curve passing through all the points for each set of results (1)

b The final point for the grey tube does not follow the trend of the other points (1).

c The temperature decreases with time for all tubes (1), with the rate of decrease getting less as the temperature of the water gets cooler (1). Some tubes cool down faster than others (1), with dull black cooling the fastest, then shiny black, grey, silver (1).

5 Black or dark coloured surfaces emit more radiation than lighter coloured surfaces (1). A dull surface emits more radiation than a shiny surface of the same colour (1).

6 Black (1), because black surfaces emit more radiation than lighter coloured ones (1).

7 a silver −27 °C (1), dull black −33 °C (1), shiny black −31 °C (1), grey −34 °C (1)

b It makes it easier to see the pattern of the temperature decrease and easier to see any results which were not collected correctly (1). In this case using the graph would give a different/more accurate order for the rate of cooling because of the error in the final reading for the grey coloured tube (1).

8 The test was not fair (1) as the black and grey colours were achieved using paper/paint and the one for silver was done using metal foil (as shown in Figure B) (1), and metal foil conducts energy better than paper (1). Accept similar explanations.

9 apparatus should include test tubes or beakers of water covered in different coloured materials, thermometers and a stop clock (1) and a source of infrared radiation such as a heat lamp (1) (accept a statement that the beakers will be put on a sunny windowsill or similar)

method should describe measuring the temperature of the water in each tube at regular intervals (1)

any two fair test points, for 1 mark each, e.g. put the same volume of water in each tube, ensure the starting temperature of the water is the same in each tube, stand all the tubes the same distance from the lamp, ensure the paint/paper/coloured materials are the same thickness for each and/or made of the same material

10 a It suggests that dark surfaces absorb more radiation than lighter ones (1) as soot is darker than ice and sooty ice must be absorbing more energy if it is melting faster (1).

b Light coloured surfaces appear lighter because they reflect more of the visible light that falls on them (1). This means they may also reflect more infrared wavelengths (1). If they reflect more they must absorb less (1).

Activity and Assessment Pack

SP5g.1 Investigating radiation

2 Graphs should show curved lines with the gradient reducing as the temperature drops.

3 The rate of cooling gets less as the temperature drops.

4 Students should conclude that tubes covered with dark, dull materials are better at emitting radiation than those covered in light or shiny materials. Students' answers should relate the emission of radiation to the cooling rates shown on their graph.

5 Students' answers should discuss any anomalous readings and how much difference in cooling rate there is between the different tubes.

6 No, only four different materials have been tested.

SP5g.2 A model swimming pool

1 Students should predict that the temperature will stay roughly constant, as that is what the water bath is designed to do. Some students might suggest that the temperature will vary a little around the set temperature.

3 The shape of the graph will depend on how and when the temperature setting was changed.

4 Students' own answers, but explanations should include temperature rising if the energy supplied by the heating element was greater then the energy being transferred to the surroundings, and cooling if the energy transferred to the surroundings was greater than the energy supplied by the heater.

5 a The rate of energy transferred to the water is the same as the energy being transferred away from the water.

b More energy is being transferred to the water than from it.

c More energy is being transferred from the water than to it.

SP5g.3 Radiation and temperature Strengthen

All objects *emit* some radiation. Hotter objects emit *more* radiation … than *cooler* objects. We say that the intensity of radiation … *increases* with increasing temperature.

The wavelengths of the radiation … also change with *temperature*. Most objects around us are not very hot … and emit *infrared* radiation that we cannot see. This has a *longer* wavelength … than visible light.

As an object gets hotter, it emits radiation … at *shorter* wavelengths. If an object gets hot enough we can … see the radiation as *red* light. If it gets even hotter, the main wavelengths get *shorter* … and so the colour changes to *orange* and then *yellow*.

A blacksmith can estimate how *hot* iron is … by looking at the *colour*. It is hot enough to work with when … it is emitting yellow light.

SP5g.4 Radiation and temperature Homework 1

1 a false
  b true
  c false
  d false
  e true

2 a *All objects* emit radiation.
  c An object at 150 °C emits *less* intense radiation than one at 200 °C, or an object at 200 °C emits *more* intense radiation than one at 150 °C.
  d A hot object (or *all objects*) emit radiation at *a mixture of* wavelengths.

3 The lower the temperature, the less intense the radiation and also the longer the wavelengths (so more energy is being emitted at the red end of the visible spectrum).

4 red, orange, yellow, green, blue, indigo, violet

5 a infrared
  b ultraviolet
  c infrared
  d gamma rays
  e radio waves

6 a X-rays
  b infrared
  c microwaves
  d ultraviolet

SP5g.5 Radiation and temperature Homework 2

1 The water-heating system must supply exactly the same power as is radiated.

2 The Earth is constantly radiating the same power as it receives, so its temperature remains constant.

3 a The atmosphere absorbs radiation emitted from the ground. This warms the atmosphere. Then the atmosphere starts radiating. This means that the temperature is higher as heat is trapped on Earth, but the temperature will be constant when the emitted power equals the power absorbed.
  b More heat would be trapped, so the temperature would be higher. Again, the temperature will be constant (but at a higher level) when the emitted power equals the power absorbed.

4 When the Sun is not shining on one side of the Earth, that side radiates more power than it absorbs, so its temperature falls.

5 a

Planet	Distance from Sun (AU)	Proportion of Sun's radiation received (compared to Mercury)	Atmospheric carbon dioxide	Average temperature (°C)
Mercury	0.35	100%	None	420
Venus	0.7	25%	96%	460
Earth	1	16%	<1%	14

  b From the distances and hence amounts of sunlight received, we would expect the temperatures to be in the order of Mercury hottest, then Venus, then Earth. Mercury has no atmosphere to trap heat. Earth has a small amount of carbon dioxide so is a bit warmer then expected. However, Venus has a large amount of carbon dioxide so is much hotter than it would be without it.

6 The temperature does not vary, even though the nights are so long. This is likely to be because the dense carbon dioxide atmosphere traps heat and effectively insulates the planet.

SP5h Using the short wavelengths

Student Book

7th 1 to kill bacteria/microorganisms in the sewage

7th 2 So that if it is stolen and then recovered, the police can trace the owner. If the ink is not visible in normal light the thieves may not try to remove the markings, and/or it won't spoil the appearance of the item.

7th **3** It is quicker to use a scanner and a hand search may not find objects concealed inside other objects, whereas the X-ray machine can 'see' inside most things. Students may also say that it avoids having to disrupt people's packed belongings.

6th **4** any two from: sterilising medical instruments, detecting cancer, treating cancer

7th **5** H Bone absorbs X-rays but the other tissues transmit them. All three substances transmit gamma rays.

S1 a any three from: security marking, fluorescent lamps, detecting forged bank notes, disinfecting water

b observing the internal structure of objects, airport security scanners, medical X-rays

c any three from: sterilising food, sterilising medical equipment, detecting cancer, treating cancer

E1 a Similarities: both can be used to kill microorganisms; both have higher frequencies/shorter wavelengths than visible light. Students may also include knowledge from earlier topics, such as both being transverse waves travelling at the same speed in a vacuum, etc.

Differences: gamma rays are transmitted by all body tissues/most substances but ultraviolet is absorbed; gamma rays have higher frequencies/shorter wavelengths than ultraviolet; gamma rays are used in medicine (or any other differences related to their uses).

b Similarities: both are used to diagnose medical problems; both can pass through substances such as metal etc.; both have higher frequencies/shorter wavelengths than visible light. Students may also include knowledge from earlier topics, such as both being transverse waves travelling at the same speed in a vacuum, etc.

Differences: gamma rays pass through bone but X-rays are absorbed; gamma rays have higher frequencies/shorter wavelengths than X-rays; gamma rays are used to sterilise food/medical instruments (or any other differences related to their uses).

Exam-style question

a description which makes reference to any three of the following points: X-rays can be used to make images of the inside of the body; gamma rays can be used to sterilise medical equipment, to detect cancer, to treat cancer (1 mark each point)

Activity and Assessment Pack

SP5h.1 Short wavelengths in the EM spectrum

1 a This depends on what visible light the lamp emits in addition to ultraviolet radiation. Students are likely to report that the paper looks purple.

b No – the paper looks purple because it is reflecting purple light. If the paper is also reflecting ultraviolet radiation, we cannot see it, because our eyes do not detect ultraviolet.

c The ink from the security pen absorbs ultraviolet light and re-emits the energy as visible light, which is detected by our eyes.

d Ultraviolet radiation passes through air, but it can be absorbed by some substances such as the ink in security marker pens.

2 a depends on the X-ray photo(s) used

b no

c X-rays transfer energy, and this energy is absorbed or reflected by substances such as bone, and is transmitted by soft tissues/muscles.

3 a Yes, the counter counts up.

b no

c Yes, it is background radiation (and possibly still some radiation from the gas mantle).

d They are not readily absorbed by air, because they can be detected by the GM tube.

SP5h.2 Investigating ultraviolet

2 student's plan

5 possible suggestions could be to photograph the beads to record the colours, to compare two materials/lamps side by side to put them in a ranking order, to make a numbered colour chart to record the depth of colour.

SP5h.3 Using the short wavelengths Strengthen

1 a gamma rays

b X-rays

c gamma rays

d X-rays

e ultraviolet

f ultraviolet, ultraviolet, ultraviolet

g gamma rays

h ultraviolet

i X-rays

2 a Paragraph written in complete sentences mentioning any three from: security marking, fluorescent lamps, detecting forged bank notes, disinfecting water.
b Paragraph written in complete sentences mentioning observing the internal structure of objects, airport security scanners, medical X-rays.
c Paragraph written in complete sentences mentioning any three from: sterilising food, sterilising medical equipment, detecting cancer, treating cancer.

3 a ultraviolet, gamma rays
b X-rays, gamma rays

SP5h.4 Using the short wavelengths Homework 1

1 a visible light
b infrared, microwaves
c X-rays
d gamma rays
e infrared
f X-rays
g ultraviolet
h microwaves
i gamma rays
j infrared
k gamma rays
l gamma rays

2 ultraviolet, radiation, visible
fluorescent, ultraviolet
security, ultraviolet, stolen, police
X-rays, visible, X-rays, guns

SP5h.5 Using the short wavelengths Homework 2

1 X-rays can pass through most of the materials in the body, whereas ultraviolet and visible light cannot.

2 a Muscle and other soft tissues transmit most X-rays, because they hardly show up at all on X-ray images.
b Bone absorbs most of the X-rays reaching it, so it shows up as almost white on X-ray images.
c Metal absorbs (or reflects) all the X-rays hitting it, and so shows up as white.
d Plastic absorbs/reflects less than metal, because it shows up as fainter than metal objects.

3 a A patient is given a substance that emits gamma rays and that will collect in cancer cells. A scanner is used to identify places where the gamma ray emitter is collecting cancer cells.
b The gamma rays originate inside the body. With an X-ray, the radiation is passed through the body, and the detector measures how much is transmitted through different parts of the body.
c They can both pass through the body.
d H Gamma rays can pass through all materials in the body. X-rays are mostly absorbed by bone.

4 They can be used to kill cancer cells, and they can be used to sterilise surgical instruments.

5 It is used to sterilise water.

6 a Infrared sensors can be used to detect radiation emitted by intruders, and can also be used to make beams inside entrances/buildings that intruders break, thus setting off an alarm.
b Special inks are used on bank notes that only show up in ultraviolet light. Ultraviolet light can be used to check bank notes (and identify forgeries). Similar ink can also be used to mark items such as TVs, so that if they are stolen and then recovered they can be returned to their owners.
c X-rays can be used to inspect baggage before it is taken on aeroplanes, to look for guns/explosives.

Extra challenge

7 The barium meal involves the patient swallowing a compound containing barium. This coats the inside of the digestive tract. It absorbs X-rays, whereas the tissues of the digestive system transmit most of the X-rays that reach them. The coated parts of the digestive tract show up much more clearly on X-ray images.

SP5i EM radiation dangers

Student Book

6th 1 Infrared radiation from the fire can cause burns.

7th 2 Microwaves escaping from the oven could heat water in our bodies and damage them.

7th 3 wear sun cream, wear clothing and/or hats, wear sunglasses

7th **4** The benefit from diagnosing the problem is greater than the possible harm from a limited exposure to X-rays.

8th **5** The 100 000 Hz wave will cause the most harm. It has a higher frequency and so will transfer more energy.

8th **6** It causes electrons to be lost from the atom, leading to a net positive charge.

S1

a internal heating of body

b skin burns

c one from: sunburn, skin cancer, snow blindness

d mutation to DNA/cell damage, which can lead to cancer

E1

Part of spectrum	Hazards
microwaves	internal heating of cells
infrared	skin burns
ultraviolet	damage to skin cells and eyes, skin cancer, eye conditions
X-rays	mutation or damage to cells, cancer
gamma rays	mutation or damage to cells, cancer

The higher the frequency, the greater the potential danger.

Exam-style question

The atmosphere absorbs a lot of ultraviolet radiation (1). If its composition changes it may not absorb as much, and the increased UV could cause more skin cancers (1).

Activity and Assessment Pack

SP5i.1 Investigating sun creams

1 Further instructions could include:

mounting the plastic using a bulldog clip held onto the clamp stand, so the plastic is always the same distance from the lamp

using a new piece of plastic each time, of the same type and thickness, so that only one type of cream is tested each time

adding the same amount of sun cream to each card (using a balance or syringe to get the same amount each time) and spreading it evenly over the same area, so there is the same thickness of cream each time

ensuring the plastic is large enough so that all the ultraviolet from the lamp goes through it/so the sensor does not detect any ultraviolet that has passed around the edge of the card

shielding the apparatus from sunlight/other light sources, so that only light from the lamp that has passed through the treated plastic is detected

doing one test with no sun cream, to check how much ultraviolet is absorbed by the plastic

2 student's table

3 student's bar chart

4–6 student's own answers, depending on the results from the investigation

SP5i.2 EM radiation dangers Strengthen

1 **b** spectrum named in order, with gamma rays on the left

c highest frequency and greatest potential danger on left, and longest wavelength on right

d DNA damage with gamma rays and with X-rays, sunburn and damage to eyes with ultraviolet, skin burns with infrared, internal heating with microwaves

2 atoms, spectrum, ions

nuclei, visible, infrared

SP5i.3 EM radiation dangers Homework 1

1, 2 Points to be circled are shown here in italics.

The shoe-fitting fluoroscope was used in shoe shops about 80 years ago. They had a wooden box with a hole at the bottom where you put your feet. When you looked through a hole on the top, you could *see* an image of the bones of the feet and the outline of the shoes. This picture was made by an X-ray scanner.

The fluoroscope was an X-ray tube. *X-rays have very high frequency, so are very high energy and we now know they can cause cancer after long-term exposure.* The only protection between your feet and the tube was a 1 mm thick sheet of aluminium.

Despite high exposures, there were no reported health problems for shoe shop customers. Unfortunately many shoe salespeople put their hands into the X-ray beam to feel the shoe during the fitting. One salesperson who had operated a fluoroscope 10 to 20 times each day over a 10-year period *developed a skin disorder*. *A shoe model received such a serious radiation burn* that her leg had to be removed. These machines were used in Britain until around 1970.

3 From about 80 years ago, until around 1970

4 because of the health hazards

5 They used them all the time, so had increased exposure.

6 If they could not, then the X-rays would not be able to form an image of the foot (or similar explanation).

7 **a** gamma rays
b more – the higher the frequency, the greater the potential danger

8 damage cells in the body/cause mutations/ cause cancer

9 **a** heat cells inside the body
b burn the skin
c damage the skin/damage the eyes/cause skin cancer

SP5i.4 EM radiation dangers Homework 2

1 If they could not, then the X-rays would not be able to form an image of the foot (or similar explanation).

2 X-rays hit a substance that fluoresces.

3 **a** helps to get shoes that fit properly
b X-rays can cause health problems to the customers and workers.

4 They used them all the time, so had increased exposure.

5 **a** gamma rays
b more – the higher the frequency, the greater the potential danger

6 damage cells in the body/cause mutations/ cause cancer

7 **a** cause heating to body cells inside the body
b skin burns
c damage skin, possibly leading to skin cancer, and can also damage eyes

8 **a** mutations caused by X-rays or gamma rays
b fluorescence, when changes in atoms caused by radiation (X-rays, in the example here) cause them to emit radiation

9 In medical use, the benefits of the fluoroscopy outweigh the possible harm. This is not the case when X-rays are used to fit shoes.

SP6a Atomic models

Student Book

1 the particles are held together in fixed arrangements

2 the negative charges on the electrons balance/cancel out the positive charge in the pudding part of the atom

3 0.36 millionths of a millimetre or 3.6×10^{-10} m

4 the nucleus

5 100 000 mm (or 100 m)

S1 Answers should include most of the following points.

- the atom has a central nucleus with a positive charge which contains almost all the mass of the atom
- electrons have negative charges and almost no mass and move around the nucleus
- most of the atom is empty space.

E1 Diagram of atom with nucleus and electrons labelled. An explanation for not drawing it to scale is that the outer diameter of the atom would have to be 100 m if the nucleus was 1 mm across (or similar).

E2 A few alpha particles bounced back in Rutherford's experiment, so they must have bounced off a small, dense part of the atom which has a positive charge that repelled the positive alpha particles.

Most alpha particles went straight through, so the atoms must consist mostly of empty space.

Exam-style question

Similarities – two from: both contain positive and negative charges, both have the electrons as individual particles within the atom, both imagine atoms as spheres. (1 mark for each)

Differences – two from: in the plum pudding model there is no empty space whereas Rutherford's model is mostly empty space; in the plum pudding model the positive charge is spread out through the whole atom whereas in Rutherford's model the positive charge is concentrated in the nucleus; in the plum pudding model only the electrons are modelled as spheres rather than both the electrons and the nucleus. (1 mark for each)

Activity and Assessment Pack

SP6a.1 Building a model of the atom

1 The statement is not correct as it stands, as an atom is so much smaller than the Solar System. However, proportionally to their sizes, the atom has more empty space. You can see this from the size of the models. If you made two models, one of an atom and one of the Solar System, and represented the nucleus of an atom as the same size as the Sun, then the atom model would have the electrons orbiting 5 metres away, as compared with the outermost planet Neptune, orbiting only 30 cm away. By this comparison, there is over 3000 times more space in an atom than in the Solar System.

2 If an electron was 1 mm across in a model, the proton would be about 1 m across. This would make the atom about 100 km across, so the electron would be 50 km away from the nucleus.

3 **a** If the pinprick was 0.1 mm across, then the electron would be 0.0001 mm across.

b bacteria or other microorganisms

4 about 1 : 10^{-11}

5 **a** An atom is 5 orders of magnitude bigger than a proton (10^{-10} m compared with 10^{-15} m).

b A proton is 3 orders of magnitude bigger than an electron.

c An atom is 8 orders of magnitude bigger than an electron.

SP6a.2 Atomic models – Strengthen

1 **b** nucleus and electrons correctly labelled

c nucleus labelled as containing most of the mass of the atom

d nucleus labelled as containing positive charge, and electron(s) labelled as containing negative charge

2 1.2×10^{-10} m

SP6a.3 Atomic models – Homework 1

1 2, 3, 1

2 **a** plum pudding model and atoms as spheres

b plum pudding model and Rutherford's model

c plum pudding model and Rutherford's model

d plum pudding model

e Rutherford's model

f Rutherford's model

g Rutherford's model

3 All the alpha particles would go through the foil, because there would not be enough mass concentrated in one place to deflect them.

4 Some alpha particles passed straight through the foil.

Some alpha particles were scattered, some of them by large angles.

5 The particles that went straight through … passed through the empty space between the nucleus and the electrons in the atoms.

The particles that were deflected by small angles … passed close to the positively charged nucleus.

The particles that were deflected by large angles … hit the dense, positively charged nucleus.

SP6a.4 Atomic models – Homework 2

1 The atom is filled with a positively charged material, with electrons scattered through it.

2 **a** Most of the alpha particles went straight through the foil, but some were deflected. Some of these were deflected by large angles.

b All the alpha particles would pass straight through because there would be no concentrations of mass/charge large enough to deflect them.

c a central, very small nucleus containing all the positive charge and almost all the mass of the atom; negatively charged electrons at a distance from the nucleus

d The alpha particles that were deflected came very close to or hit one of the dense, positively charged nuclei.

3 a paragraph or two of text, in a sensible order (covering the Dalton ‘spherical atom’, the plum pudding model and the Rutherford model), describing each model and the evidence for it (or what it explains)

4 The Dalton model, as used in the kinetic theory or particle theory, is sufficient to explain phenomena such as expansion on heating. Nothing would be gained by using a more complex model.

SP6b Inside atoms

Student Book

1 **a** protons, neutrons

b protons, electrons

c protons, neutrons

2 **a** number of protons and number of electrons

b total number of protons and neutrons

3 $^{4}_{2}$He

4 **a** 4

b 9 – 4 = 5

5 **a** 18 – 8 = 10

b 13 – 6 = 7

S1 atomic number – number of protons in the nucleus of an atom

- electron – tiny particle with a negative charge that orbits around the nucleus of an atom
- isotope – atoms of the same element with different numbers of neutrons
- mass number – total number of protons and neutrons in the nucleus of an atom
- neutron – particle found in the nucleus of an atom with no charge and a relative atomic mass of 1
- proton – particle found in the nucleus of an atom with a positive charge and relative atomic mass of 1

E1 Isotopes are atoms of the same element with different numbers of neutrons in their atoms.

All three isotopes have the same number of protons/one proton in their nuclei and the same number of electrons/one electron orbiting the nucleus. Hydrogen-1 has no neutrons, hydrogen-2 has one neutron and hydrogen-3 has two neutrons – so the three isotopes have different mass numbers.

Exam-style question

No. Isotopes have the same number of protons but different numbers of neutrons, (1) so isotopes would have different mass numbers. (1)

Activity and Assessment Pack

SP6b.1 Find the isotopes

1 card 1 – $^{7}_{4}$X, card 2 – $^{9}_{4}$X, card 3 – $^{10}_{4}$X, card 4 – $^{10}_{5}$X, card 5 – $^{11}_{5}$X, card 6 – $^{12}_{6}$X, card 7 – $^{13}_{6}$X, card 8 – $^{14}_{6}$X, card 9 – $^{13}_{7}$X, card 10 – $^{14}_{7}$X, card 11 – $^{15}_{7}$X

2 cards 1, 2, 3; cards 4, 5; cards 6, 7, 8; cards 9, 10, 11

3 beryllium (proton number 4), boron (proton number 5), carbon (proton number 6) and nitrogen (proton number 7)

SP6b.2 Atomic notation practice

1 a mass number 11, atomic number 5
b mass number 14, atomic number 7
c mass number 4, atomic number 2
d mass number 59, atomic number 28
e mass number 55, atomic number 25
f mass number 48, atomic number 22
g mass number 108, atomic number 47
h mass number 195, atomic number 78

2 a 5 protons, 6 neutrons
b 7 protons, 7 neutrons
c 2 protons, 2 neutrons
d 27 protons, 32 neutrons
e 25 protons, 30 neutrons
f 22 protons, 26 neutrons
g 47 protons, 61 neutrons
h 78 protons, 117 neutrons

3 a $^{7}_{3}Li$
b $^{19}_{9}F$
c $^{32}_{16}S$
d $^{84}_{36}Kr$
e $^{40}_{20}Ca$
f $^{59}_{27}Fe$
g $^{23}_{11}Na$
h $^{127}_{53}I$

4 $^{16}_{8}O$, $^{17}_{8}O$, $^{18}_{8}O$

5 $^{238}_{92}U$, $^{235}_{92}U$

6 a $^{54}_{26}Fe$, 26 protons, 28 neutrons
b $^{56}_{26}Fe$, 26 protons, 30 neutrons
c $^{57}_{26}Fe$, 26 protons, 31 neutrons
d $^{58}_{26}Fe$, 26 protons, 32 neutrons

7 a 63
b 120
c 136, 54
d 226, 88
e 37
f 65

SP6b.3 Inside atoms – Strengthen

1 a false – change atomic number to mass number, or change neutrons to protons
b true
c false – change electrons to neutrons, or change ‘the same mass’ to ‘different masses’
d false – change electrons to neutrons
e true
f false – change ‘the same number’ to ‘different numbers’
g true
h true
i true

2 a protons
b negative, mass
c neutrons
d protons, neutrons (either order)
e no/zero, 1
f positive, 1

3 a 7
b 13
c $^{13}_{7}N$

SP6b.4 Inside atoms – Homework 1

1

Atom	Atomic number	Mass number	Number of protons	Number of neutrons	Number of electrons
$^{1}_{1}H$	1	1	1	0	1
$^{2}_{1}H$	1	2	1	1	1
$^{3}_{1}H$	1	3	1	2	1
$^{6}_{3}Li$	3	6	3	3	3
$^{7}_{3}L$	3	7	3	4	3
$^{12}_{6}C$	6	12	6	6	6
$^{14}_{6}C$	6	14	6	8	6
$^{24}_{12}Mg$	12	24	12	12	12
$^{25}_{12}Mg$	12	25	12	13	12
$^{26}_{12}Mg$	12	26	12	14	12

2 **a** atoms with the same number of protons but different numbers of neutrons

b three

c atomic number, number of protons and number of electrons

d mass number and number of neutrons

3

Particle	Location	Relative charge	Relative mass
proton	in nucleus	+1	1
electron	around nucleus	–1	1/1835
neutron	in nucleus	0	1

4 **a** number of protons/atomic number, number of electrons

b number of neutrons

c $^{10}_{5}B$, $^{11}_{5}B$

SP6b.5 Inside atoms – Homework 2

1 **a**

Atom	No. of protons	No. of neutrons	No. of electrons
A	6	7	6
B	7	6	7

b The mass number is the same.

c They have different numbers of protons, neutrons and electrons.

d no, because the proton numbers are different

2 **a**

Atom	No. of protons	No. of neutrons	No. of electrons
C	5	5	5
D	5	6	5

b same proton number and same number of electrons

c They have different numbers of neutrons, and the mass numbers are different.

d Yes, they have the same number of protons but different numbers of neutrons, so they are isotopes of the same element.

3 **a** $^{9}_{4}Be$

b $^{31}_{15}P$

c $^{40}_{18}Ar$

d $^{27}_{13}Al$

e $^{39}_{19}K$

f $^{24}_{12}Mg$

4 **a** You cannot have half a proton or neutron.

b 75% Cl-35, 25% Cl-37

c The mass number must be the average/mean mass of chlorine atoms. The mean is closer to 35 than to 37, so there must be a higher proportion of chlorine-35 than chlorine-37.

SP6c Electrons and orbits

Student Book

1 There are three different colours; neon produces orange light so the other colours must be caused by different gases.

2 There are a lot of different jumps between orbits that the electrons can make. Each jump is a different amount of energy/emits light at a different wavelength.

3 most of the emission lines for neon are red/orange/yellow

4 **a** almost all the mass and all the positive charge in a tiny nucleus in the centre of the atom; negatively charged electrons moving around the nucleus; most of the atom is empty space

b electrons can move only in specific orbits around the nucleus

5 electrons move into higher orbits, but do not leave the atom

6 **a** 11 protons, 11 electrons

b 11 protons, 10 electrons

S1 Diagram with labels showing all the positive charge (protons) and most of the mass in a central nucleus. Electrons (with very small mass and negative charge) shown moving in specific orbits around the nucleus.

S2 It absorbs enough energy for one of the electrons to leave the atom completely (leaving behind an ion with more positive charges than negative ones, so a positive overall charge). Students may also point out (from learning in chemistry topics) that atoms can lose more than one electron.

E1 Electrons occupy particular orbits in an atom. If an atom absorbs energy, electrons can move to higher orbits. If an electron moves to a lower orbit the atom emits energy. This is often as light, and the colour of the light depends on the amount of energy emitted, which in turn depends on the gap between orbits that the electron moves across.

Exam-style question

Atoms emit energy when they are heated but only specific frequencies (shown as lines on a spectrum). (1)

Each spectral line corresponds to a particular energy change when electrons move from one orbit to another. (1)

Activity and Assessment Pack

SP6c.1 Flame tests

3 Answers should consider any colours that are similar, the fact that students have tested only a few metals, and that even if every metal on the periodic table had its own colour, some colours would be very close to each other and hard to distinguish.

SP6c.2 Sorting out ideas

2 (J, 8) The first models of atoms represented them … as spheres.

(C, 2) J.J. Thompson carried out some experiments that showed … that atoms also contained tiny particles with negative charges.

(A, 15) He developed the plum pudding model, which … said the atom was a positively charged pudding containing negatively charged electrons.

(D, 9) Ernest Rutherford carried out some experiments … by firing alpha particles at gold foil.

(I, 20) These experiments showed that … there must be a tiny nucleus inside the atom containing almost all the mass.

(Q, 1) Rutherford's model is of an atom with all the mass and all the positive charge … in the nucleus, with electrons orbiting around it.

(M, 7) The nucleus of an atom is made up of … protons and neutrons.

(H, 14) Protons have a relative mass of 1 and … a relative charge of +1 (positive).

(B, 18) Neutrons have a relative mass of 1 and … do not have a charge.

(L, 3) Electrons have a negligible mass … and a relative charge of –1 (negative).

(P, 13) All atoms of a particular element have … the same number of protons.

(K, 4) Atoms of the same element may have … different numbers of neutrons.

(E, 17) Atoms of the same element with different mass numbers… are called isotopes.

(O, 10) Bohr developed a model of the atom in which … electrons exist only in certain orbits, called electron shells.

(G, 6) If an atom absorbs energy, one or more electrons … may jump to higher orbits.

(R, 19) An atom emits energy when electrons … fall to lower orbits.

(F, 12) Each element has a characteristic pattern of … wavelengths at which it emits energy.

(N, 16) If an atom absorbs enough energy… one or more electrons may leave the atom completely.

(T, 5) An atom that has lost one or more electrons … is an ion with a positive charge.

(S, 11) Radiation that causes electrons to escape … is called ionising radiation.

SP6c.3 Electrons and orbits Strengthen

1 left-hand side: nucleus, electron shells, electrons

right hand side: neutron, proton, Bohr, protons, nucleus

2 absorbs, electron, orbit

energy, electron

escape

ion

protons, electrons (either order)

electrons, positive, charge, positive

SP6c.4 Electrons and orbits Homework 1

1 **a** A, D

b B

c B

d A, C, D

e C

2 **a** 10

b 0

c 10

d An atom has the same number of protons as electrons, because the charges balance/cancel out.

e +1

f It has one fewer electron than it has protons, and the charge on a proton is +1 (or similar explanation).

3 **a** D

b A

c Atoms can only absorb/emit electromagnetic radiation/energy of specific wavelengths.

SP6c.5 Electrons and orbits Homework 2

1 Chemiluminescence is the odd one out, as the energy that makes it work comes from chemical reactions not from the atom absorbing energy from electromagnetic radiation.

2 a a small nucleus containing protons and neutrons, surrounded by electrons in a number of set orbits

b In the Rutherford model, the electrons are orbiting the nucleus, but the model does not say that there are only a limited number of orbits that the electrons can occupy. (In addition, Rutherford did not know about neutrons, but the key idea here is the nature of the orbits.)

c the fact that different elements absorb and emit light of only a few specific wavelengths

3 a Electrons absorb energy and move to a higher orbit.

b Electrons move to a lower orbit and emit energy as electromagnetic radiation.

4 Electrons can only exist in fixed orbits, and can only move from one orbit to another. An atom can only absorb electromagnetic radiation that provides just the right amount of energy for electrons to move between these fixed orbits. Because energy is linked to wavelength, atoms can only absorb certain wavelengths. When electrons move to lower orbits, they can only make a certain number of fixed 'jumps', and each of these corresponds to a certain wavelength of light.

5 by electricity (e.g. in neon tubes) or by heating (e.g. in flame tests)

6 One or more electrons gains enough energy to leave the atom completely. The atom then has fewer electrons than protons, so it has an overall positive charge.

7 a If there is no light, then atoms cannot absorb the electromagnetic radiation needed to cause fluorescence.

b The animals also exhibit bioluminescence, and light from this causes fluorescence.

SP6d Background radiation

Student Book

1 The largest part of the background radiation comes from radon, which is produced by certain kinds of rock. The types of rock are different in different parts of the country.

2 84% (all sources except for medical and nuclear power)

3 radioactive substances from the soil are taken up by plants, and animals eat plants

4 People in aeroplanes receive more cosmic rays than people on the ground because the atmosphere has absorbed fewer cosmic rays at that height. As there are more high-energy particles during a solar storm, there are more cosmic rays reaching the Earth, so aeroplanes should fly lower to reduce the amount of cosmic rays received by people in them.

5 mean value for background count
= 18 counts per minute

corrected count
= 186 – 18
= 168 counts per minute

S1 Any three from: radon gas, ground and buildings, medical, nuclear power, cosmic rays, food and drink.

S2 using photographic film, which goes dark when radiation reaches it; using a Geiger-Müller tube and counter, which clicks/counts each time radiation passes through it

E1 Any instrument measuring the radioactivity of a source will also detect background radiation, so the values obtained will be too high unless the readings are corrected for the background radiation.

Exam-style question

Answers should include the following points:

- any statement that indicates naturally occurring sources of radiation (e.g. radon gas, food, etc.) (1)
- any statement that indicates human-made sources of radiation (e.g. nuclear power stations, nuclear waste, medical sources) (1)
- most background radiation comes from natural sources (1)
- …so it is more likely that natural radiation will hurt you but human-made radiation won't. (1)

Activity and Assessment Pack

SP6d.1 Measuring radiation

4 The GM tube will detect background radiation/radiation from the surroundings as well as radiation from the sources being measured. To obtain measurements of radiation only from the source, the background radiation must be subtracted, and so must be measured.

5 There should be some variation in background counts and in the counts obtained from the samples. However, as long as there is sufficient difference in the activity of the different samples, students should all get the same rank order for the samples tested.

6 The background radiation is not constant. By taking the mean of the readings at the beginning and end of the investigation, Saira is probably obtaining a more accurate correction for her other readings.

SP6d.2 How a GM tube works

1 correctly labelled diagram

2 The central wire is connected to … a positive voltage from the counter.

The outer casing is connected to … a negative voltage from the counter.

No current can flow because … the GM tube is full of a non-conducting gas.

Radiation can enter the GM tube … through the thin window at one end.

If the radiation hits one of the gas molecules … the molecule will absorb energy.

An electron in the molecule may escape … leaving a positive ion.

The positive ion is attracted to … the negative outer casing.

The electron is attracted to … the positive central wire.

This movement of charged particles … allows a short pulse of current to flow.

Each pulse of current … increases the reading on the counter by 1.

SP6d.3 Background radiation Strengthen

1 ticks against: bananas, some rocks, radiation from space

2 **a** false

b true

c true

d false

3 **a** Radiation cannot be detected using a mobile phone camera/Radiation can be detected using a GM tube or photographic film.

d GM tubes are connected to counters so we can see how much radiation has been detected.

4 radiation, background

largest, radon, uranium, radon

radioactive, building, background

space, rays, stars

food, medical

SP6d.4 Background radiation Homework 1

1 **a** 10%

b One person might have a job that involves more exposure (e.g. pilot, medical technician) or they may have had more medical treatments, such as X-rays or radiotherapy, or they might eat different foods.

2 cosmic ray – the Sun and other stars

radon gas – uranium in rocks in the ground

medical – radiotherapy treatment and X-rays

food – radioactive isotopes in the environment

3 all except cosmic rays

4 Levels of radon gas from rocks in the ground vary due to the different rock types in different places.

5 **a** cosmic rays and food and drink, because all of the others come from the Earth or from things like medical sources that are not present on the space station

b The proportion of background radiation from cosmic rays is higher in space (no shielding by atmosphere); the proportion from ground and buildings, radon gas and medical is lower; but the proportion from food and drink is likely to be similar.

6 Using a film badge or a Geiger-Müller tube and counter.

SP6d.5 Background radiation Homework 2

1 Nothing is completely safe. Even low activities/amounts can be potentially harmful to cells.

2 They compare the activity with the background radiation activity. If they are similar, the source is safe.

3 The average amount is what people in the UK are exposed to. Since no harm comes to most people from this level of radiation, it would be deemed safe.

4 any three from: rocks, buildings, food, medical techniques like X-rays, cosmic rays from outer space

5 a ionising radiation from outer space

b No, the value depends on altitude. For example, people travelling on a plane are exposed to more cosmic rays than people at ground level (due to less protection from the atmosphere).

6 Yorkshire, Aberdeen, Devon and Cornwall.

7 rocks, which contain small amounts of uranium-238 and thorium-232, for example

8 Some food is radioactive, and if this becomes part of our bodies then we will become radioactive too.

9 Houses were much more draughty 100 years ago (as most were heated by open fires with chimneys), so the air in the room changed more often and levels of radon gas did not build up as much.

SP6e Types of radiation

Student Book

8th 1

Radiation	Charge	Relative mass
alpha	+2	4
beta	−1	$\frac{1}{1835}$
positron	+1	$\frac{1}{1835}$
gamma	not a particle, no charge	not a particle, no mass
neutron	0	1

9th 2 Carbon-14 will decay, because only unstable isotopes decay.

8th 3 Beta particles will be absorbed and stopped by a few millimetres of aluminium or a few metres of air.

10th 4 it absorbs all three types of radiation (it has to be so thick to absorb all the gamma radiation)

10th 5 Alpha radiation would be absorbed by the air before it reached the lorry and beta radiation would probably be absorbed by the material used to make the sides of the lorry. Only gamma radiation can pass through the materials used for the lorry.

10th 6 Radioactive sources emit ionising radiation. When an oxygen molecule is hit by ionising radiation, the radiation transfers enough energy to the molecule to allow one (or more) electrons to leave it.

S1 Alpha particles are a helium nucleus/two protons and two neutrons. They have a charge of +2 and a relative mass of 4.

Beta particles are electrons emitted from the nucleus. They have a charge of −1 and a relative mass of $\frac{1}{1835}$.

Gamma radiation is electromagnetic radiation and so has no charge or mass.

S2

Radiation	Penetration	Ionisation
alpha	poor – stopped by a few cm of air	highly ionising
beta	medium – stopped by a few mm of aluminium	medium
gamma	good – only stopped by thick lead or very thick concrete	poor

E1 Alpha particles have a very much greater mass than beta particles. Moving alpha particles therefore store a lot of (kinetic) energy, and can transfer a lot of energy to particles that they hit. This ionises them easily. However, because they can easily transfer energy to other particles, they lose their own energy very quickly and so do not travel very far through any material.

Beta particles have a much smaller mass and so a moving beta particle stores much less (kinetic) energy than an alpha particle, and so transfers less energy when it hits something. It is therefore less ionising, but can travel further through materials.

Exam-style question

An atom can become ionised when it absorbs energy (1) and when an electron from one of the orbits around the nucleus leaves the atom. (1)

In β^- decay an electron is emitted from an unstable nucleus (1) in a random process. (1)

Activity and Assessment Pack

SP6e.1 Radiation badges

1 The cloth of the pocket could absorb some of the radiation.

2 There may be an unexpected source of radiation, or other workers may not all be following safe practice. Allow any sensible suggestions.

3 Alpha radiation will only darken the part of the film that has no covering. Beta radiation will darken that and the part that is covered in thin plastic.

4 Any radiation reaching this part must be gamma rays with a lot of energy.

5 A: most beta and all gamma
B: some beta and all gamma
C: alpha, beta and gamma
D: some gamma

6 The other types are also dangerous – although they are less penetrating, they are more ionising.

7 The badge is intended to record the radiation dose received by each individual to see if it is within safe limits. It cannot do this if badges are swapped.

8 They could use weaker sources, use better shielding, stay further from the sources, use the sources less often/limit the time they are exposed.

9 Natural radiation levels are less than the levels that people might be exposed to as part of their job.

SP6e.2 Investigating other planets

The description should include the following.

The different screens are lowered in turn to go between the sample and the detection tube. The different screens will stop different types of particle. Alpha particles will be stopped by the paper, as they are not very penetrating. Most beta particles will be stopped by the aluminium, as they are quite penetrating. The lead screen will reduce the amount of gamma radiation but not stop it. The background radiation can be counted when the sample is lowered out of the way. The computer can work out which types of radiation are being emitted by the sample by the drop in the count rate with the different screens in place. The water will wash any rock sample off the platform so that there will be no contamination for the next sample. The sample platform has to be quite close to the detector, because alpha particles have a limited range in air (gas).

SP6e.3 Types of radiation Strengthen

1 alpha particle: two protons and two neutrons, charge of +2, relative mass of 4
beta particle: electron from the nucleus, charge of –1, relative mass negligible
gamma ray: electromagnetic radiation, high frequency, no mass or charge

2

Radiation	Penetration	Stopped by	Ionisation
alpha	poor	a few centimetres of air	highly ionising
beta	medium	a few millimetres of aluminium	medium
gamma	good	thick lead or very thick concrete	only slightly ionising

3 alpha particles: α, ${}^{4}_{2}\mathrm{He}$
beta particles: β^-, ${}^{0}_{-1}\mathrm{e}$
positrons: β^+, ${}^{0}_{+1}\mathrm{e}$
gamma rays: γ

4 neutron

SP6e.4 Types of radiation Homework 1

1

Radiation	Blocked by	Penetrating	Ionising
alpha	skin, paper, few cm air	slightly	highly
beta	few mm aluminium	partly	partly
gamma	thick lead	highly	slightly

2

alpha particle	beta particle	positron	neutron	gamma ray
P, +, 1	P, –	P, +	P, 1	(none)

3 unstable, random, decay, ions, loses, gains (last two in either order)

4 Alpha particles can be stopped by a few centimetres of air, so they will not reach the people in the house.

SP6e.5 Types of radiation Homework 2

1 a alpha
b alpha
c gamma
d beta
e gamma
f beta
g alpha
h gamma

2 If alpha particles cannot reach you then they cannot cause damage to the cells in your body: they will be absorbed by skin cells on the skin's surface (or by the air before they reach your skin).

3 a A, C and D

b B and E

c Beta particles are less ionising and so travel further than alpha particles.

d no, because they are emitted in a random process

e alpha particles, because they are more ionising so as they travel they will form more ions that vapour can condense around

4 Radioactive sources may emit alpha, beta and gamma radiation. Lead is used because it stops all three types of radiation. (Using aluminium would not be any good, because gamma rays can pass through aluminium and damage the body.)

5 Peter would still be irradiated and contaminated by the air that he breathed in and the food and drink that he ate. It is not possible to be completely protected from radiation, as it is present in your body. Also, you can never be sure that all gamma radiation from a source has been stopped by the lead.

SP6f Radioactive decay

Student Book

1 a neutron in the nucleus changes into a proton and an electron, which is ejected from the nucleus

2 Gamma radiation is a way of transferring energy by electromagnetic radiation – it is not a particle and so does not have mass or carry a charge. Emitting gamma radiation therefore does not change the number of nucleons in the atom.

3 a a neutron has a relative mass of 1 so when it is ejected, there is less mass left in the nucleus

b the atomic number is the number of protons and this has not changed

4 a mass number of product = 208 – 4 = 204

atomic number of product = 84 – 2 = 82

This is lead (Pb).

${}^{208}_{84}Po \rightarrow {}^{4}_{2}He + {}^{204}_{82}Pb$

b mass number of product = 99 – 0 = 99

atomic number of product = 43 – –1 = 44

This is ruthenium (Ru).

${}^{99}_{43}Tc \rightarrow {}^{0}_{-1}e + {}^{99}_{44}Ru$

c mass number of product = 37 – 0 = 37

atomic number of product = 19 – 1 = 18

This is argon (Ar).

${}^{37}_{19}K \rightarrow {}^{0}_{+1}e + {}^{37}_{18}Ar$

5 In radioactive decay the number of protons in the nucleus changes so the atom becomes another element. In a chemical reaction the atoms themselves do not change, they just combine in different ways.

S1

Type of decay	Particle emitted	Effect on atomic number	Effect on mass number
α	helium nucleus (${}^{4}_{2}He$)	decreases by 2	decreases by 4
β^-	electron (${}^{0}_{-1}e$)	increases by 1	no change
β^+	positron (${}^{0}_{+1}e$)	decreases by 1	no change
neutron	neutron (n)	no change	decreases by 1

S2 mass number does not change, atomic number increases by 1

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

E1 ${}^{216}_{84}Po \rightarrow {}^{4}_{2}He + {}^{212}_{82}Pb$

${}^{212}_{82}Pb \rightarrow {}^{0}_{-1}e + {}^{212}_{83}Bi$

Exam-style question

In β^+ decay, a proton becomes a neutron and a positron. (1)

The mass number does not change but the atomic number goes down by 1. (1)

Activity and Assessment Pack

SP6f.1 Sorting out nuclear equations

${}^{120}_{56}Aa \rightarrow {}^{4}_{2}He + {}^{116}_{54}Qq$

${}^{120}_{56}Aa \rightarrow {}^{0}_{-1}e + {}^{120}_{57}Ss$

${}^{132}_{61}Bb \rightarrow {}^{4}_{2}He + {}^{128}_{59}Rr$

${}^{132}_{61}Bb \rightarrow {}^{0}_{-1}e + {}^{132}_{62}Uu$

${}^{48}_{23}\text{Cc} \rightarrow {}^{4}_{2}\text{He} + {}^{44}_{21}\text{Tt}$

${}^{48}_{23}\text{Cc} \rightarrow {}^{0}_{-1}\text{e} + {}^{48}_{24}\text{Pp}$

${}^{215}_{85}\text{Dd} \rightarrow {}^{4}_{2}\text{He} + {}^{211}_{83}\text{Ww}$

${}^{215}_{85}\text{Dd} \rightarrow {}^{0}_{-1}\text{e} + {}^{215}_{86}\text{Vv}$

SP6f.2 Nuclear equation practice

1 a ${}^{251}_{87}\text{Fr}$
 b ${}^{20}_{10}\text{Ne}$
 c ${}^{4}_{2}\text{He}$
 d ${}^{53}_{25}\text{Mn}$
 e ${}^{4}_{2}\text{He} + {}^{148}_{62}\text{Sm}$

2 a ${}^{240}_{92}\text{U}$
 b ${}^{233}_{91}\text{Pa}$
 c ${}^{8}_{4}\text{Be}$
 d ${}^{187}_{77}\text{Ir}$
 e ${}^{222}_{86}\text{Rn}$
 f ${}^{16}_{7}\text{N}$
 g ${}^{200}_{83}\text{Bi}$

3 a ${}^{0}_{-1}\text{e}$
 b ${}^{0}_{+1}\text{e}$
 c ${}^{4}_{2}\text{He}$
 d ${}^{4}_{2}\text{He} + {}^{142}_{60}\text{Nd}$
 e ${}^{0}_{-1}\text{e} + {}^{247}_{96}\text{Cm}$

4 a ${}^{223}_{87}\text{Fr}$
 b ${}^{38}_{19}\text{K}$
 c ${}^{144}_{60}\text{Nd}$
 d ${}^{24}_{11}\text{Na}$
 e ${}^{20}_{11}\text{Na}$

SP6f.3 Radioactive decay – Strengthen

1

Type of decay	Alpha (α)	Beta (β⁻)	Positron (β⁺)	Neutron
particle emitted	helium nucleus	electron from nucleus	positron from nucleus	neutron
symbol of particle	${}^{4}_{2}\text{He}$	${}^{0}_{-1}\text{e}$	${}^{0}_{+1}\text{e}$	n
mass of particle	4	0	0	0
effect on mass number	decreases by 4	no change	no change	no change
charge on particle	+2	–1	+1	0
effect on atomic number	decreases by 2	increases by 1	decreases by 1	no change

2 ${}^{0}_{-1}\text{e} + {}^{42}_{20}\text{Ca}$

3 ${}^{0}_{+1}\text{e} + {}^{17}_{8}\text{O}$

4 ${}^{4}_{2}\text{He} + {}^{227}_{89}\text{Ac}$

SP6f.4 Radioactive decay Homework 1

1 nucleus, proton, electron (last two in either order), electron, atomic, more
nucleus, neutron, positron (last two in either order), positron, number, decreases, proton

2 a 4, +2
 b 0, –1
 c 0, +1
 d 1, 0

3 alpha – mass number decreases by 4, atomic number decreases by 2

beta (electron) – mass number does not change, atomic number increases by 1

positron – mass number does not change, atomic number decreases by 1

neutron – mass number decreases by 1, atomic number does not change

4 a ${}^{211}_{87}\text{Fr} \rightarrow {}^{4}_{2}\text{He} + {}^{207}_{85}\text{At}$
 b ${}^{13}_{9}\text{Be} \rightarrow {}^{1}_{0}\text{n} + {}^{12}_{9}\text{Be}$
 c ${}^{59}_{26}\text{Fe} \rightarrow {}^{0}_{-1}\text{e} + {}^{59}_{27}\text{Co}$
 d ${}^{258}_{100}\text{Fm} \rightarrow {}^{4}_{2}\text{He} + {}^{254}_{98}\text{Cf}$
 e ${}^{234}_{90}\text{Th} \rightarrow {}^{0}_{-1}\text{e} + {}^{234}_{91}\text{Pa}$

SP6f.5 Radioactive decay Homework 2

1 a Both consist of charged particles.
 b Alpha radiation consists of helium nuclei with a 2+ charge and relative mass of 4. Beta radiation consists of particles with negligible mass and a 1– charge.

2 Gamma radiation is electromagnetic radiation and does not consist of particles.

3 a less ionising
 b more penetrating
 c no mass
 d no charge

4 a decreases by 2
b decreases by 4

5 a no effect
b no effect

6 a no effect
b decreases by 1

7 a increases by 1
b no effect

8 thorium-234

9 neptunium-244

10 a alpha decay
b beta decay

11 a ${}^{211}_{87}\text{Fr} \rightarrow {}^{4}_{2}\text{He} + {}^{207}_{85}\text{At}$
b ${}^{13}_{9}\text{Be} \rightarrow {}^{1}_{0}\text{n} + {}^{27}_{13}\text{Al}$
c ${}^{59}_{26}\text{Fe} \rightarrow {}^{0}_{-1}\text{e} + {}^{59}_{27}\text{Co}$

12 neptunium-244

13 phosphorus-31

14 a ${}^{14}_{7}\text{N} + {}^{4}_{2}\text{He} \rightarrow {}^{17}_{8}\text{O} + {}^{1}_{1}\text{H}$
b ${}^{14}_{7}\text{N} + {}^{1}_{0}\text{n} \rightarrow {}^{14}_{6}\text{C} + {}^{1}_{1}\text{H}$

SP6g Half-life

Student Book

1 2

2 the time it takes for half of the unstable nuclei in a sample to decay, or the time it takes for the activity of a sample to halve

3 30 years

4 a 1
b 2
c 4
d 0.5

5 half-life is 3.8 days

a 1 half-life;
10 million / 2 = 5 million

b 2 half-lives;
10 million / 2 = 5 million
5 million / 2 = 2.5 million

c 3 half-lives;
10 million / 2 = 5 million
5 million / 2 = 2.5 million
2.5 million / 2 = 1.25 million

d 0.5 half-lives so half the amount that would decay in 1 half-life, or 2.5 million decay; 10 – 2.5 = 7.5 million undecayed nuclei left

6 source A: about 5 seconds; source B: about 20 seconds

S1 half-life of caesium-137 = 30 years

90 years is 3 half-lives

activity = 100 / 2 = 50, 50 / 2 = 25,
25 / 2 = 12.5 Bq

E1 The half-life tells you the time it will take for half of the unstable nuclei in a sample to decay. After one half-life there are only half of the original number of unstable nuclei present.

Decay is a random process, but the more unstable nuclei there are present, the more likely it is that there will be some of them decaying. Therefore, the activity depends on the number of unstable nuclei present. When half of the nuclei have decayed, there are only half as many left that *can* decay, so after one half-life the activity is also half the original amount.

E2 1.5 × 2 = 3 (double the activity lost in one half-life), 3 × 2 = 6, 6 × 2 = 12, 12 × 2 = 24

so the change in activity from 24 Bq to 1.5 Bq takes 4 half-lives

the half-life of carbon-14 is 5730 years, so the decrease would take 4 × 5730 years = 22 920 years

Exam-style question

Measure the activity of the source at (regular) intervals over a period of time. (1)

Work out how long it takes for the activity to halve. (1)

Activity and Assessment Pack

SP6g.1 Modelling radioactive decay

2 a, b graphs should show a smooth curve similar in shape to those in *CP6g Half-life* in the Student Book
c The answer should be approximately the same each time.

3 a It should take three or four rolls.
b It should be roughly constant.
c the face of the cube that shows is a random process

4 The numbers of cubes remaining after each roll is greater, but the number of rolls for the number to halve remains the same.

5 The cubes represent undecayed nuclei. Each roll of all the cubes represents a time interval in which some nuclei may decay. The cubes that come to rest with the marked face up (and are then removed) represent nuclei that have decayed in that time interval. The number of cubes removed after each roll represents the activity of the material during a time interval.

6 The model represents radioactive decay quite well, including the way the cubes/nuclei remaining reduce with the number of rolls/time, and that this pattern is produced by a random process.

SP6g.2 Radiocarbon dating

1 **a** One nuclear decay per second.
b It decreases by half.
c about 5700 years

2 **a** They have decayed.
b a quarter, or 25%
c a quarter, or 25%
d 2
e 11 400 years

3 **a** one-eighth, or 12.5%
b one-eighth, or 12.5%
c about 17 000 years (17 100 years)

SP6g.3 Half-life – Strengthen

1 the number of radioactive decays per second

2
- the time it takes for the activity of a sample to fall to half its value
- the time it takes for half the number of unstable nuclei in a sample to decay

3 **a** 40
b 20
c 10
d 5

4 **a** 250
b 125

5 random, predict, decay
large, approximately, activity, becquerel, fewer, decreases
half, decreased, unstable

SP6g.4 Half-life – Homework 1

1 **a** 70 seconds
b 110 s – 40 s = 70 seconds
c 160 s – 90 s = 70 seconds

2 The values are the same – in each case, it is the time taken for the radioactivity to halve. It is the half-life of the source.

3 **a** time taken for activity to drop from 100 Bq to 50 Bq = six hours (accept any other valid working)
b time taken for activity to drop from 100 Bq to 50 Bq = 30 years (accept any other valid working)

4 **a** three days = one half-life, 200 000 undecayed nuclei left
b six days = two half-lives, so 100 000 left
c 12 days = four half-lives, so 25 000 left

5 **a** this is half, so one half-life = three days
b this is a quarter, so two half-lives = six days

SP6g.5 Half-life – Homework 2

1 **a** 4000 → 2000 → 1000 → 500 → 250 = four half-lives
b 4 × 5700 years = 22 800 years ago

2 **a** After 1 half-life, the activity would have been 4 Bq. If the change over time was linear, then an activity of 6 Bq represents a time interval of 2850 years.
b The answer assumes that the change of activity over time is linear, but it is not: the activity would have dropped faster at the start, so the time needed for the activity to fall from 8 Bq to 6 Bq is less than 2850 years.

3 A drop in activity of 1 Bq represents approximately one-eighth of a half-life, and so represents a time interval of approximately 710 years. The age claimed is not accurate.

4 A 20 g sample would have a count rate of 16 g when living. So two half-lives must have passed for the activity to have fallen to 4 Bq. Age = 2 × 5700 years = 11 400 years.

5 75 000 years is 13.15 half-lives. Take this as 13. Divide 40 000 by 2 13 times (divide by 2^{13}) to give the answer of 4.9 Bq, so a suitable range would be 0–10 Bq or similar (i.e. sensitive enough to distinguish between readings of 100, 10 and 1).

6 The change in activity over five years would be very small, and probably not noticeable in the variation in activity due to the random nature of radioactive decay.

7 Radon is produced by the decay of uranium. The half-life of uranium is 700 million years, so over the few years (or decades) in which humans might monitor the production of radon, the activity of uranium will be almost constant and so the production of radon gas will be almost constant.

8 Working depends on the points on the tangents at which students read values. Allow some variation in the answers below due to the small size of the graph on the worksheet and the likely variability in the tangents drawn.

- **a** –0.83 Bq/s
- **b** –0.72 Bq/s
- **c** –0.61 Bq/s

SP6h Using radioactivity

Student Book

7th **1** The food is exposed to gamma rays, which kill bacteria living on the food, which in turn increases the time before the food begins to rot.

7th **2** The bag will stop the sterilised items becoming contaminated/microorganisms getting on the sterilised items before they are used.

8th **3** radiation from beta sources would be absorbed by parts of the body/the ground

8th **4** the count detected by monitor decreases, so the computer increases pressure applied to the rollers

7th **5** alpha particles would be stopped by the paper

6th **6** alpha particles

9th **7** The half-life is much greater than the life of the product, so the radioactivity of the americium will remain approximately the same while the smoke alarm is in use.

S1 smoke alarms – where the radiation produces ions which maintain a current in the alarm unless smoke absorbs them; irradiating food – kills bacteria on it and makes the food last longer; irradiating surgical instruments – sterilises them by killing microorganisms; tracers – radioactive substances can be used for finding leaks (and in cancer detection); beta particles can be used to help to control the thickness of manufactured materials such as paper.

E1 Sterilising surgical equipment requires radiation that will pass through the bag the equipment is sealed in, so beta or gamma sources are needed. The radiation also needs to pass through parts of the equipment so the insides are sterilised, therefore gamma rays are best.

Sources used as tracers need to produce radiation that will penetrate ground (or other substance in which it is being used), so gamma rays are needed.

For controlling paper thickness, the radiation needs to be partly absorbed by the paper but not completely. Alpha particles would be stopped completely and not enough gamma rays would be absorbed to show up small differences in paper thickness, so beta radiation is needed.

Smoke alarms are used in homes, so the radiation must not travel very far from the smoke alarm. Alpha sources are used, which will be absorbed by the air in the alarm and the plastic casing. Also, the alarm works by ionising air and alpha particles are the most ionising form of radiation.

Exam-style question

Any four points from the following: send beta-particles through the foil to a detector (1); measure the count with the correct thickness of material (1); if the count increases above this the foil is too thin (1) so decrease pressure on rollers (1); if the count is lower the material is too thick (1) so increase pressure on rollers (1).

Activity and Assessment Pack

SP6h.1 Smoke detectors and paper thickness

Smoke detector, order of labels on diagram clockwise from left:

Alpha particles ionise the air, and these charged particles move across the gap, producing a current.

Smoke in the machine will slow down the ions and so the detector current falls.

An americium-241 source gives off a constant stream of alpha particles.

The siren will sound when the detector current falls below a certain level.

A detector senses the amount of ionised air particles as a current.

Paper making machine, order of labels on diagram clockwise from top left:

The detector counts the number of beta particles that get through the paper.

When the paper is too thick, the computer senses that the number of beta particles getting through the paper has fallen.

The computer increases the pressure applied to the rollers to make the paper thinner.

Some of the beta particles are absorbed by the paper.

Beta particles are emitted by the source.

SP6h.2 Food irradiation: opinion and facts

A opinion

B fact (The irradiation damages the DNA in microbes, which is what kills them. It is likely to also damage the DNA in food, but then so does most forms of cooking.)

C fact, correct

D opinion (see B)

E fact, but a false one

F opinion

G fact, correct

H fact, correct (Although this would not necessarily make the food safe to eat, as harm can be caused by substances released by bacteria while they were growing on the food.)

I fact, correct

J fact, correct

SP6h.3 Using radioactivity Strengthen

irradiating food, gamma rays, they kill bacteria

sterilising surgical instruments, gamma rays, they kill bacteria, they can pass through the bags holding the instruments

tracers to detect water leaks, gamma rays, they can pass through the ground above the pipes so they can be detected

treating cancer, gamma rays, they can kill cells in the body

tracers to detect cancer, gamma rays, they can pass through the body so they can reach a detector

checking the thickness of materials such as paper, beta particles, they are penetrating enough for some to pass through the paper, they are not so penetrating that they all pass through the material

smoke alarms, alpha particles, they easily ionise air particles so a current can flow, they are safe to use because they are not penetrating enough to escape from the smoke detector

SP6h.4 Using radioactivity Homework 1

1 **a** gamma
- **b** beta
- **c** gamma
- **d** beta
- **e** alpha
- **f** alpha

2 **a** to help them to find leaks in pipes
- **b** The gamma rays can penetrate the ground above the pipes.

3 They would be absorbed by the packaging.

4 **a** alpha
- **b** It is very ionising/most ionising (accept an alternative response that its lack of penetration means that no radiation will escape from the smoke detector).
- **c** The smoke absorbs the ions, which reduces the current. The drop in current sets off the alarm/siren.

5 **a** beta
- **b** Beta particles need to be able to penetrate the material, and they go through paper more easily than through metal.
- **c** More beta particles get through, and the computer/controller reduces the pressure on the rollers.

SP6h.5 Using radioactivity Homework 2

1 Because the gamma rays can penetrate up to 15 cm of solid steel.

2 The camera shows the shapes of things in the truck and they do not take up all the space.

3 They are absorbing some of the gamma rays.

4 Black, because lead is good at absorbing gamma rays.

5 No, because the gamma rays from the cobalt-60 source will penetrate solid steel up to 15 cm thick.

6 Metals will absorb some gamma rays so the guns would make a darker image than things made of wood or other non-metals. The image would show the shape of the weapons.

7 GM tube or other sensible suggestions

8 Any two descriptions and reasons from the following:
- irradiating food to preserve it, gamma rays are used because they can kill bacteria
- sterilising surgical instruments, gamma rays are used because they can kill bacteria
- tracers to detect leaks in water pipes, gamma rays are used because they can pass through the ground
- treating cancer, as gamma rays can kill cells.

9 **a** hidden rooms or passageways where items may be found

b Need to be able to get to both sides of the structure as the source has to be on the opposite side to the camera; object cannot be too big otherwise gamma rays will not get through at all.

SP6i Dangers of radioactivity

Student Book

1 radiation burns and DNA damage/mutations, leading to cancer

2 The source is kept further from the hands and intensity decreases with distance so less radiation can reach the hands. Lead will stop all three types of radiation.

3 so they do not breathe in radioactive particles/get radioactive particles in their lungs

4 **a** beta is more harmful outside the body, because skin can stop alpha particles but will not stop beta particles

b apha is more harmful inside the body because it is more ionising

5 A substance with a longer half-life will be radioactive for much longer, and so will affect anyone permanently contaminated with it for longer. However a substance with a short half-life will have a higher activity, and so might cause more harm immediately.

S1 **a** Radiation can harm the body, and the more radiation the body gets (the higher the dose) the more likely it is to cause harm.

b any three from: limiting dose to patients to the minimum possible; using sources with short half-lives; workers staying a long way from sources; using shielded sources; not spending much time near sources; using badges to monitor how much radiation they have received

E1 **a** any two from:

- handing sources with tongs – to keep the source further from the body so the intensity of the radiation is less
- pointing sources away from the body – less radiation goes towards the body
- storing sources in lead-lined boxes – to absorb all radiation before it can leave the box
- using badges to monitor the amount of radiation received – so that if they have received the maximum acceptable dose they can be moved to another job where they will not be exposed to radiation

b any two from:

- limiting doses to patients – so they get no more radiation than is necessary for the diagnosis/treatment. This can be done by limiting the amount of radioactive material used, and by choosing sources with short half-lives so the activity does not go on for very long
- workers staying a long way from sources – the intensity decreases with increasing distance
- using shielded sources – so radiation cannot spread out from them
- not spending much time near sources – the less time spent near sources, the less radiation can be absorbed
- using badges to monitor the amount of radiation received – if they have received the maximum acceptable dose they can be moved to another job where they will not be exposed to radiation

c any two from:

- not spending much time near sources – the less time spent near sources, the less radiation can be absorbed
- using badges to monitor the amount of radiation received – so that if they have received the maximum acceptable dose they can be moved to another job where they will not be exposed to radiation
- wearing overalls and breathing masks – to stop their bodies/clothes becoming contaminated.

Exam-style question

Contamination is when radioactive substances get onto or into the body or clothing (1 mark).

Irradiation is when a person is exposed to radiation from a source that is not on their body or clothing (1 mark).

Activity and Assessment Pack

SP6i.1 Safe handling?

cards A, F, J

cards B, E, L

cards C, H, K

cards D, G, I

SP6i.2 Researching radiation dangers

A

- Chernobyl is in Ukraine (then a part of the USSR), with nearly 50 000 people living in Pripyat at the time of the disaster.
- Workers at the power station were carrying out an experiment, which caused the reactor to overheat and this caused a couple of steam explosions and then a fire.
- Radioactive particles rose into the air in the smoke from the fire, and winds spread them as far as Norway and the UK.
- The most harmful isotopes were iodine-131 (half-life 8 days), caesium-134 (2 years), caesium-137 (30 years) and strontium-90 (29 years).
- In the first three months 31 people died.
- Estimates of the total number of deaths resulting from irradiation and contamination vary widely, but figures up to 33 000 have been quoted. There were some deaths from acute radiation poisoning and thyroid cancer known to be related to the accident, plus some related to the physical trauma rather than radiation (e.g. a helicopter crash). Later deaths attributed to radiation or contamination from the accident are due to cancer.

B

- A tsunami flooded the power station and the reactors automatically shut down, but generators used for cooling the reactors were destroyed and the reactors overheated.
- Isotopes detected worldwide include iodine-131, caesium-134 and caesium-137. These were spread both in the atmosphere and in the ocean, as the power plant is on the coast.
- The iodine-131 posed the least danger after a month, as its half-life of 8 days meant that after a month the radiation from it was less than $\frac{1}{8}$ of the original amount.
- There were no deaths attributed directly to the accident, but there is a higher risk of various cancers for people in the area at the time (particularly children).

C

- Litvinenko was poisoned by polonium-210, which is an alphaemitter and dangerous because, although it cannot get through skin, it is highly ionising and causes a lot of damage if it is taken into the body.
- It was thought to have been put into tea that he drank in a restaurant. Its half-life is 138 days, so the radiation he was exposed to from the poisoning would have decreased a little during the time he was ill, but not by a large amount.
- His first symptoms were diarrhoea and vomiting, with weakness and severe pain.
- It was thought to have been administered by someone acting on behalf of Russia, as Litvinenko had been a security officer and was living in political asylum in the UK.
- This was an example of contamination, as the radioactive isotope was inside his body.

SP6i.3 Dangers of radioactivity Strengthen

1 skin burns, mutations to DNA, cancer

2 background, radioactive
risks, small
lead, radiation
tongs
pointing
limit, far away from, shielded, time
patients, benefits, lowest, short, short

3
- **a** contamination
- **b** irradiation
- **c** contamination
- **d** irradiation
- **e** contamination

SP6i.4 Dangers of radioactivity Homework 1

1
- **a** Hold with tongs.
- **b** Store in lead-lined box.

2
- **a** cancer
- **b** The treatment is only given if the benefits outweigh the risks. The lowest possible dose is used. Use isotopes with short half-lives, so that the exposure is kept short.

3 They spend as little time as possible near sources. They stay as far as possible from the source.

4 They wear a dosimeter badge. (Accept radiation badge or similar description.)

5
- **a** Chen
- **b** Sally
- **c** Sally, as Chen only has to move away from the radioactive source but Sally will be exposed as long as the radioactive particles are inside her body.

SP6i.5 Dangers of radioactivity Homework 2

1 **a** Irradiation is being exposed to radiation from outside the body. Contamination is when a source of radiation is directly on the body or inside it.

b Only people who were near the radioactive materials in the nuclear pile could have been exposed to radiation from it, so only the workers may have been affected by irradiation.

2 **a** Cows breathed in radioactive isotopes or ate grass contaminated with radioactive isotopes. The radioactive isotopes were absorbed/incorporated into milk.

b Contamination, because it resulted from radioactive isotopes getting inside the cows' bodies.

3 **a** Rain washed radioactive particles from the air onto the ground, and sheep ate contaminated grass. Very good answers may also refer to the contamination getting into the soil and hence appearing in the grass growing there for many years.

b After Chernobyl the contamination was mainly due to caesium-137, which has a much longer half-life than the iodine-131 that was the main problem after the Windscale fire.

c Eating the sheep would have taken beta emitters into the body, where they could ionise cells and cause harm. In the case of beta emission happening inside sheep, the sheep have layers of tissue, skin and wool for the beta emission to get through before reaching a farmer handling the sheep. Most of the beta particles would be absorbed before a person could be irradiated.

4 Any answer from a few days to a few weeks is acceptable, as long as it is accompanied by a reference to the eight-day half-life of iodine-131.

5 The iodine-131 emits beta particles that can ionise atoms in cells. This may cause mutations to the DNA in cells and cause cancer.

6 Plutonium does not occur in nature. Answers should refer to the fact that plutonium has a higher mass number and atomic number than uranium, so the plutonium must absorb neutrons to increase the mass number. Some of these extra neutrons decay by beta emission to increase the atomic number. No more detail than this is required.

SP6j Radioactivity in medicine

Student Book

1 internal bleeding, cancer

2 top of femur

3 they would be absorbed by body tissues instead of passing through the body to be detected by the camera

4 The radioactive isotopes have very short half-lives, so if they had to be transported any distance the activity would have become too low by the time they reached the patient.

5 some beta particles may pass through the body, so the patients may be radioactive

6 In internal radiotherapy the source is placed very close to the tumour so most of the beta particles will be absorbed by the tumour, not the surrounding tissue, and beta particles are more ionising than gamma rays. If external radiotherapy used beta emitters, more damage would be caused to healthy tissue that the radiation passed through on the way to the tumour.

S1 A gamma source can be used as a tracer and detected by a gamma camera, or a source of positrons can be used with a PET scanner.

S2 Similarity: both use radioactive sources to kill cancer cells. Difference: one from – internal uses beta emitters, external uses gamma emitters; internal may involve surgery/involves placing a course inside a patient, external involves directing radiation at the tumour from outside the patient.

E1 A radioactive substance is chosen that will collect in the organ being examined and injected or otherwise put into the patient. If this is a gamma emitter, a gamma camera is used to find where the most emissions are coming from. If this is a positron emitter, a PET scanner detects two gamma rays produced when the positron interacts with electrons and builds up a detailed image of the inside of the body.

E2 Both treatments involve killing cancer cells in tumours using radiation. For internal radiotherapy, the source is put inside the patient and is usually a beta emitter. For external radiotherapy gamma rays are used and directed at the tumour from outside the patient.

Exam-style question

Substances with short half-lives are needed (1) so that the activity only continues long enough to make the diagnosis and does not continue to irradiate the patient's body longer than needed (1). The tracer needs to produce gamma radiation (1) because this is the only type that will pass through all body tissues and be detected by a camera (1).

Activity and Assessment Pack

SP6j.1 Gamma ray therapy

1 a lung
  b ovaries
  c breast

2 a WI; CR; SD; VG (other answers possible)
  b QF; SH; DO; NC (other answers possible)
  c DN; SK; RJ; PH (other answers possible)

3 Large amounts of ionising radiation can damage the skin by burning it.

SP6j.2 Radiation in medicine Strengthen

1 a both
  b tracers
  c PET scanners
  d PET scanners
  e PET scanners
  f tracers
  g both

2 cancer, external, gamma, internal, radioactive, beta

3 They have very short half-lives, so their activity would get too low if they had to be transported for long distances.

SP6j.3 Radiation in medicine Homework 1

1 a gamma
  b It can penetrate through body tissues to leave the body/reach the camera.

2 2, 5, 1, 7, 4, 3, 6

3 a internal
  b internal
  c external
  d internal

4 Correct words are: short, least, technetium-99m gamma rays, short, long, cobalt-60.

SP6j.4 Radiation in medicine Homework 2

1 It works by detecting two gamma rays that are emitted in opposite directions. The directions are random, so the sensors need to surround the patient to make sure any gamma rays emitted can be detected.

2 The isotope is injected into the patient's body. It is only needed for the short time that the PET scan takes, and the radiation it emits could harm the patient if it goes on longer than needed, so an isotope with a short half-life is used.

3 Alpha particles would not penetrate the body to be detected outside the body. Alpha particles are also highly ionising and so would be much more likely to harm the patient than gamma rays. Beta particles are more penetrating than alpha particles, but many would not get through the muscles/organs/skin, but would ionise parts of the body and cause harm. Gamma rays are the least likely to ionise body molecules and are penetrating enough to pass right through all body tissues.

4 In external radiotherapy, radiation is sent into the patient from outside. For internal radiotherapy, a radioactive source is put inside the patient.

5 In external radiotherapy a machine beams gamma rays into the body from outside. Cobalt-60 will continue to emit radiation for a few years before the isotopes would need replacing, whereas with technetium-99m the machine would need to be recharged almost hourly. Beta particles are not needed, but can be prevented from reaching the patient with some shielding.

  For a tracer, the isotope only needs to be active for a short time, while the imaging is being done. The activity of technetium-99m will reduce rapidly and so is suited for this purpose. It also does not emit beta rays, which are more likely to cause ionisation inside the patient and harm them.

6 Alpha particles can be stopped by skin, and so may only affect the outsides of tumours. Gamma rays are not very ionising, and so might not kill the cancerous cells.

7 Cancer cells divide more rapidly than other cells, and so would need more glucose, so the scan would show areas of higher radiation coming from the tumours. For a patient with Alzheimer's disease, the brighter areas on the scan would show normal brain tissue, and areas producing less radiation would be the diseased areas, as they are not taking up glucose.

SP6k Nuclear energy

Student Book

6th **1** uranium-235

7th **2** they last a long time/don't need refuelling, and the air in the submarine is not used up in combustion as would be the case for oil

8th **3** Advantage: nuclear power stations do not produce carbon dioxide/polluting gases or nuclear fuel will last a long time. Disadvantage: nuclear power stations produce radioactive waste that is expensive to treat/expensive to decommission.

7th **4** radiation can harm or kill people

7th **5** any sensible suggestions, such as we are used to air pollution and don't notice it, nuclear accidents get a lot more publicity than accidents or illnesses due to burning natural gas, etc.

S1 radioactive decay, where a nucleus emits alpha, beta or gamma radiation; nuclear fission, where a large nucleus splits up to form smaller ones; nuclear fusion, where small nuclei join up to produce larger ones

S2 A table showing – advantages: no carbon dioxide/greenhouse gas emissions, nuclear fuel will last a long time; disadvantages: risk of accidents contaminating the environment over a large area, high cost of treating waste/decommissioning, many people think it is dangerous.

E1 Nuclear power stations do not emit carbon dioxide or other polluting gases in normal operation and so are better for the environment than fossil fuel power stations. However if there is an accident large areas can be affected, and it is also expensive and difficult to dispose of nuclear waste safely.

Overall nuclear power is safer than using fossil fuels, if all aspects including pollution are taken into account.

However most of the public do not realise this and there are often objections to nuclear power plants.

Exam-style question

Nuclear power stations do not produce pollution in normal operation (1), unlike fossil-fuelled power stations which emit carbon dioxide (1) and other polluting gases (1).

Activity and Assessment Pack

SP6k.1 Nuclear energy: advantages and disadvantages

1 Advantages: B, E, H, J
Disadvantages: A, C, D, F, I, K, L, M, O, P
Neutral: G, N

2 Students' paragraphs should summarise all the points made on the cards.

3 Either answer is acceptable, as long as it is backed up by sensible reasons.

SPk.2 Nuclear energy Strengthen

1 **a** fusion
b decay
c fission
d fusion
e fission

2 energy

3 **a** disadvantage
b advantage
c disadvantage
d disadvantage
e advantage
f advantage
g disadvantage

SP6k.3 Nuclear energy Homework 1

1 **a** true
b false
c true
d false
e false
f true

2 **b** In *fission* reactions…. OR In *fusion* reactions *small* nuclei *join* up to form *bigger* ones.
d In fission reactions large *nuclei* break up to form smaller ones.
e Fusion makes large *nuclei* out of smaller ones.

3 fission, non-renewable, fossil fuels burnt, dioxide, climate change, carbon

4 Nuclear power stations produce radioactive waste which…is expensive to dispose of safely.

An accident in a nuclear power station could… contaminate a large area.

Many people do not trust nuclear power because…they think it is dangerous.

Parts of nuclear power stations become radioactive as they are used and so… it costs a lot of money to decommission a nuclear power station safely.

SP6k.4 Nuclear energy Homework 2

1 **a** In nuclear fission, large uranium-235 nuclei absorb a neutron and then split up to form two smaller, daughter nuclei and release two or three neutrons. Energy is also released.

b In fusion, two small nuclei fuse together to form a larger nucleus. Energy is released.

In nuclear decay, unstable nuclei emit alpha or beta particles or gamma rays to become more stable.

2 Nuclear power stations do not emit carbon dioxide or other polluting gases that are emitted by fossil fuel power stations, and so their emissions do not contribute to climate change.

3 **a** Uranium is a non-renewable fuel, but supplies will last much longer than supplies of fossil fuels.

b Wind and solar power are only available when the weather conditions are suitable. Nuclear energy is available at any time.

4 **a** coal (Accept 'fossil fuels'.)

b Fossil fuels, as we get more electricity from fossil fuels than from nuclear, and fossil fuels cause more deaths overall.

5 The level of answer expected here will depend on whether students have done Explaining 2. If this was not done, the answer should state that the waste is sealed into glass or concrete and buried safely. If they have done Explaining 2, there may also be reference to storing the waste until it is not releasing energy as heat/ until the radioactivity is less, in addition to the above answer.

6 Any sensible answer, such as they are more familiar with fossil fuel power stations, a fire or explosion in a fossil fuel power station would not spread pollution over a very large area, etc.

7 Articles should mention all the advantages (no carbon dioxide emissions, supplies of fuel will last longer than fossil fuels, may also compare availability with renewables) and disadvantages (risks, public perception, waste treatment and storage), and include a conclusion.

8 UK – approx. 21%, France – 75%, Japan – 30% (although at the time of writing, many of the country's reactors are shut down after the Fukushima accident).

SP6l Nuclear fission

Student Book

7th **1** a neutron

8th **2** barium-141, krypton-92 and 3 neutrons

8th **3** **a** The total mass before the fission is 236 (U-235 + 1 neutron). The total mass of the xenon and strontium nuclei is 234, so 2 neutrons must be produced.

9th **b** if there are more neutrons produced, there are more chances for a new fission reaction, so more neutrons are likely to lead to a faster chain reaction

8th **4** if it is not controlled, the number of fission reactions will continue to increase and the reactor will get too hot/start burning/explode

8th **5** **a** to absorb neutrons, to control the number of fission reactions taking place in the reactor

b to slow down neutrons so they are more likely to be absorbed by the fuel and start a fission reaction

8th **6** control rods are withdrawn from the core so that fewer neutrons are absorbed and more are available to start fission reactions

S1 sensible definitions for the following: daughter nuclei, chain reaction, fuel rod, moderator, control rod

S2 flow diagram should include the following stages: fission reactions release energy → energy transferred to water via coolant → water heated to steam → steam drives turbine → turbine drives generator

E1 The amount of energy released depends on the number of fission reactions taking place in the core. This is controlled using the control rods. When these are fully inserted into the core they absorb the neutrons produced by fission reactions and so no new reactions start. As the control rods are withdrawn, fewer neutrons are absorbed by them and so more neutrons are available to start fission reactions and the energy released increases.

The energy released heats a coolant, which transfers the energy to water to make steam. The steam turns a turbine which turns a generator.

Exam-style question

The control rods absorb neutrons (1). The moderator lets neutrons pass through but it slows them down (1). The control rods can be adjusted to control how many fission reactions occur (1). The moderator is there to allow the neutrons produced by fission reactions to start other fission reactions (1).

Activity and Assessment Pack

SP6l.1 Chain reaction models

1 Accept any sensible predictions. The correct predictions are that:

W is a controlled chain reaction; the others are uncontrolled chain reactions.

2 W – the dominoes fall over in sequence.

X – all the dominoes fall over.

Y – only the dominoes at the top of the pattern fall over.

Z – dominoes fall over in a triangular pattern, with the apex at the pushed domino.

3 W is a controlled chain reaction; the others are uncontrolled chain reactions.

4 One suggestion could be to have the first domino knock over three more, but only one of these has other dominoes close enough to be knocked over by it when it falls.

5 A change in one domino (falling over) sets off a similar change in other dominoes.

6 a neutron being ejected by a nuclear reaction

7 a neutron causing a fission reaction

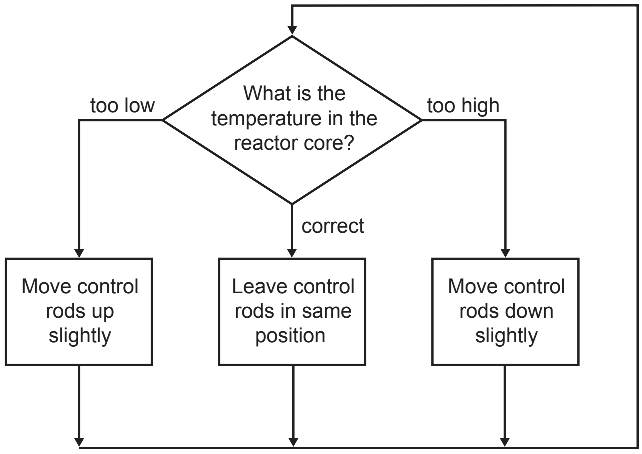
8 **a** Strengths – one of: it shows how a change in one thing can cause another change, it shows the difference between a controlled and an uncontrolled chain reaction.

b Weakness – it does not model neutrons.

9 Each domino should be able to knock over three more dominoes.

SP6l.2 Control rod feedback loop

1



2 The answer obtained by rearranging the sentences on the sheet is given below. Students who write their own answers should include similar points.

a Engineers must pull the control rods further out of the core.

b When a uranium nucleus splits up, it produces neutrons as well as daughter nuclei.

These neutrons can cause more uranium nuclei to split up.

The control rods absorb some of these neutrons to prevent them causing the fission of other nuclei.

Pulling the control rods out allows more neutrons to hit other uranium nuclei.

The chain reaction speeds up, and more energy is released.

The extra energy is transferred in the heat exchanger, and makes more steam.

The turbine spins faster, and drives the generator faster to make more electricity.

SP6l.3 Nuclear fission Strengthen

1 Chain reaction: The sequence of reactions produced…when a nuclear fission reaction triggers…one or more further fissions.

Control rod: A rod that can be lowered into the core of a nuclear reactor…to absorb neutrons…and slow down the nuclear chain reaction.

Core: The main part of a nuclear reactor…made of the moderator and…containing fuel rods and control rods.

Daughter nuclei: the nuclei produced…when the nucleus of an unstable atom… splits into two during fission.

fuel rod: A rod containing…the nuclear fuel for a nuclear reactor.

moderator: A substance in a nuclear reactor… that slows down neutrons…so that they can be absorbed by the nuclear fuel more easily.

2 D → B → A → E → C

SP6l.4 Nuclear fission – Homework 1

1 **a** neutron
b It becomes unstable.
c nuclear fission

2 **a** daughter nuclei
b neutrons
c energy

3 **a** Only one of the three neutrons released goes on to cause the fission of another uranium-235 nucleus.
b The other neutrons are absorbed by another material/by the control rods.

4 reaction, core, coolant, heats up, exchanger, heat, water, steam, turbine, generator, electricity

SP6l.5 Nuclear fission – Homework 2

1 **a** There will be a controlled chain reaction. A good answer will comment on the reaction proceeding at the same rate/ similar number of fission reactions per second.
b There will be an uncontrolled chain reaction, as the number of fission reactions increases after each set of reactions.
c The chain reaction will slow down, and might stop altogether.

2 one of the nuclei produced when the uranium-235 nucleus splits up

3 Accept any sensible suggestions. The proton numbers of the two nuclei should add up to 92. The mass numbers of the products (including two or three neutrons) should add up to 236.

4 A: control rod, B: moderator, C: turbine, D: generator, E: nuclear reactor or reactor core, F: heat exchanger

5 The control rods absorb neutrons and slow down the chain reaction. Without them, all of the neutrons could go on to cause more nuclear fissions – the reaction would then be uncontrolled and the reactor could explode.

The moderator slows down the neutrons so they can be absorbed more easily. The neutrons are travelling very fast when emitted and are not absorbed by the uranium-235 nuclei, so without the moderator there would not be a chain reaction.

6 The control rods should be raised slightly to increase the rate of the chain reaction. This will produce more energy to keep the temperature of the superheated water at the correct level.

7 The energy is used to convert water into steam. The steam is used to drive a turbine, which drives a generator to produce electricity.

8 No, the pump should be left switched on. It will take a little while for the chain reaction to stop, so fission is still happening and producing energy. The fission products are also producing energy. If the pump is switched off at the same time, the reactor could overheat and catch fire.

SP6m Nuclear fusion

Student Book

7th **1** fusion of hydrogen nuclei

7th **2** helium

8th **3** hydrogen nuclei do not have enough energy to overcome the electrostatic force of repulsion

9th **4** the pressure is much greater in the Sun (so nuclei are closer together)

8th **5** Very high temperatures and pressures are needed to overcome electrostatic forces of repulsion, and it is incredibly difficult to sustain these conditions.

S1 nuclei split up in fission but join together in fusion; fission can take place at normal temperatures and pressures but fusion needs high temperatures and pressures; fission creates radioactive waste from fuel while fusion does not (but in both processes containment vessels become radioactive)

E1 large nuclei split up in fission, initiated by a nucleus absorbing a neutron, whereas in fission two small nuclei join up to make a larger one; fission can take place at normal temperatures and pressures, and nuclear power stations and power plants for ships/ submarines have been working for some time; very high temperatures and pressures are needed to make hydrogen nuclei come together against the force of electrostatic repulsion, and so far experimental reactors have needed more energy to make the fusion reaction happen than is released by the reaction, so commercial generation of electricity is not yet possible

Exam-style question

The hydrogen is heated to very high temperatures (1) so the particles are moving very fast (1). High pressures are also used (1) which makes the nuclei more likely to collide (1).

Activity and Assessment Pack

SP6m.2 Nuclear jigsaw

Jigsaws are assembled correctly with sensible labels. Cards are listed across the top row then across the bottom row.

Decay – cards G, A, V, C, M, Q

Fission – cards N, S, U, K, D, E, F, H

Fusion – cards T, R, L, O, B, I, J, P

SP6m.3 Nuclear fusion – Strengthen

1 **a** both
b fusion
c both
d fission
e fusion
f fission
g fission
h fission
i fission
j both
k fusion

2 fusion, small, larger, close, positive, repel, electrostatic, pressures, high, fast, more

SP6m.4 Nuclear fusion Homework 1

1 **a** false
b true
c false
d false
e false
f false
g true

2 **a** A uranium-235 nucleus splitting into two daughter nuclei is an example of *nuclear fission*.
c *Both nuclear fission* and nuclear fusion make the reactor radioactive.
d Nuclear *fusion* is the reaction that is the source of energy in stars.
e Uranium-235 splits up to form two daughter nuclei and two or three *neutrons are released*.
f In nuclear fusion, *smaller* nuclei are joined together to form *larger* ones.

3 Fusion involves the joining of two small nuclei to make a larger one

whereas fission involves one large nucleus splitting up to make two smaller ones and some neutrons.

The conditions needed for fission can be produced fairly easily

whereas the conditions needed for fusion are difficult to produce.

We use nuclear fission reactors to generate a lot of electricity

but we only have experimental reactors for nuclear fusion.

SP6m.5 Nuclear fusion Homework 2

1 Fusion involves joining two nuclei, whereas fission involves splitting one nucleus. Fusion requires conditions that are currently difficult to achieve, whereas fission conditions can be achieved relatively easily. Fusion to generate energy is still experimental, whereas fission is a major source of the generation of electricity.

2 The nuclei cannot overcome the electrostatic force of repulsion in these conditions.

3 A fusion reactor has one reaction that starts with deuterium and tritium and ends up with helium and a neutron. The Sun has several reactions that start with hydrogen nuclei and finish with helium nuclei and neutrons. The temperature in a fusion reactor is about 10 times higher than that of the Sun, but the pressure in a fusion reactor is lower than in the Sun.

4 to overcome the electrostatic force of repulsion

5 **a** Stage 2
b $^{3}_{2}He$

6 It is very difficult to reproduce the high pressure conditions inside the Sun. (Also, the rate of the reaction in the Sun is 1000 times lower than that needed in a fusion reactor, so a successful fusion reaction would have to be able to create even higher temperatures and/or pressures.)

7 **a** $2^{2}_{1}H + 2^{1}_{1}H \rightarrow 2^{3}_{2}He$
b $2^{3}_{2}He \rightarrow 2^{1}_{1}H + ^{4}_{2}He$

SP7a The Solar System

Student Book

1 a model with the Earth at the centre

2 a The Earth is in the centre of the Ptolemy's model, the Sun is in the centre of Copernicus's model; in Ptolemy's model the planets follow small circles in their orbits.

b Two of: the number of planets; fixed stars; circular orbits.

3 Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune

4 One of: more planets; dwarf planets; the stars are not fixed; orbits are not circular.

5 They show that not everything orbits the Earth, as Ptolemy thought.

6 light waves, radio waves, infrared (other radiations are also acceptable, e.g. microwave, gamma rays)

7 To get away from pollution/clouds, to detect waves that are absorbed by the atmosphere.

S1 The Sun is a star and is in the centre of the Solar System. Planets are large bodies that orbit the Sun. Dwarf planets are smaller than planets, asteroids are small lumps of rock and comets are made of ice – all these orbit the Sun. Moons orbit planets.

S2 Any two from: astronomers today use telescopes; they can record their observations using cameras and computers; they can investigate waves other than light waves; they can use telescopes in space; probes can be sent to other planets.

E1 Students should describe the following points in their answers: development of telescope allowed greater detail to be seen, and smaller and fainter objects to be discovered; invention of the telescope showed that not everything orbits the Earth; photography allows better data recording; computers help with data analysis; some telescopes can detect radio waves/infrared/other parts of the EM spectrum; detecting waves other than visible light allows objects that are not visible to be investigated.

Exam-style question

The two models are similar as in both cases (any two): they have the same number of planets (1), the orbits are based on circles (1), the model is surrounded by fixed stars (1). However, Ptolemy's model has the Earth in the centre but Copernicus's has the Sun in the centre (1). Ptolemy's model has the planets moving in circles around points on their orbits and Copernicus's model has the planets moving in simple circles around the Sun (1).

Activity and Assessment Pack

SP7a.1 Changing ideas

1 Order is H, C, A, F, and then the order of D, B, E, G is debatable, but these all follow on from the invention of the telescope.

2 A – 7 & 9, B – 8, C – 6, D – 3, E – 4, F – 5, G – 2, H – 1

3 Student's own answers

SP7a.2 Ways of observing

1 & 2

Telescope A

Advantages: F, G, I

Disadvantages: L

Telescope B

Advantages: C, E, J

Disadvantages: D, H, K

3 Students' answers should summarise, in their own words, the advantages and disadvantages given on the cards.

SP7a.3 The Solar System Strengthen

1 a comet
b asteroid
c star
d planet
e natural satellite/moon
f dwarf planet

2 a both ticked
b today
c both ticked
d today
e today

3 Mercury, Venus, [Earth], Mars, Jupiter, Saturn, Uranus, Neptune

4 3, 1, 2, 4

SP7a.4 The Solar System Homework 1

1 Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune

2 **a** A star makes its own light and a planet does not./A planet orbits a star, a star does not orbit a planet. (Accept that a star is larger than a planet at this point in the unit, as students have not yet learnt about white dwarves and neutron stars.)

b A planet is bigger than a dwarf planet.

c A planet orbits the Sun, a natural satellite orbits a planet.

d Comets are made mostly of ice, asteroids are mostly rocky. (Accept that a comet has a much more elliptical orbit than an asteroid, although this has not been mentioned in this topic.)

3 **a** Copernicus and current models

b Ptolemy and Copernicus models

c Ptolemy model

d Current model

e Copernicus and current models

4 **a** C

b A, B

c B

d A, C

e B

SP7a.5 The Solar System Homework 2

1 **a** Bell had to look at paper printouts. Today the signals would be recorded in a computer, and probably be analysed by the computer as well.

b Computers can analyse a lot more data than humans can.

2 This could be anything that sends out radio signals, such as radio transmitters, etc. Many electrical devices also cause some sort of interference.

3 They did not know of any stars that could produce signals that pulsed so fast.

4 It would be very unlikely that four alien civilisations living in completely different parts of the Universe would choose to communicate in exactly the same way.

5 **a** Bell and Hewish checking for interference from Earth-based sources, and checking the rest of the sky for similar signals

b the article in *Nature*

c other scientists examining their findings and making their own observations

6 **a** Ground – radio waves pass through the atmosphere, and so do not need to be in orbit.

b To detect EM wavelengths that are absorbed by the atmosphere and, for wavelengths that can pass through the atmosphere, to avoid interference from clouds, dust, etc. in the atmosphere.

7 This should be a diagram showing a star emitting light in two narrow beams (accept one beam, unless students have specifically been asked to research their answer), and an indication of rotation. The explanation is that radio waves from the star are only detected when the part of the star emitting them is facing the receiver, so observers on the Earth only see a pulse as the beam sweeps past.

SP7b Gravity and orbits

Student Book

4th **1** the mass of the object and the gravitational field strength of the planet

5th **2** Mars has a greater mass than the Moon.

8th **3** Three from: geostationary orbits – where the satellite stays over one place on the Earth; polar orbits – where the satellite goes over the poles; highly elliptical orbits – used for communications for areas near the poles; low earth orbits – which are close to the Earth.

8th **4** The satellite is moving in a circle or ellipse so its direction is constantly changing. As velocity is a vector quantity, this means that its velocity is always changing, even if its speed remains the same.

9th **5** As it speeds up, the force of gravity on it will not be large enough to hold it in its current orbit, so it will move further away from the Earth. However, as it moves away from the Earth gravity will start to slow it down, and when the effects of its speed and the gravity force on it are once again balanced it will settle into a new, higher orbit.

S1 Different planets have different gravitational field strengths because they have different masses and radii.

S2 A planet's orbit is almost circular. The orbit of a comet is very elliptical.

E1 Surface gravity depends on the mass of a planet – the higher the mass, the stronger the gravitational field strength. It also depends on the radius of a planet. For two planets with the same mass, if one is larger than the other the gravity at its surface will be weaker than that of the other.

E2 If a satellite speeds up it will move into a higher orbit. If it slows down it will move into a lower orbit.

Exam-style question

The weight of an object depends on its mass (1) and on the gravitational field strength (1). The gravitational field strength is less on the Moon than on the Earth so the weight of an object is less on the Moon (1).

Activity and Assessment Pack

SP7b.1 Investigating orbits

2 The force needed increases when the mass increases.

3 The force needed increases when the speed increases.

4 The force needed decreases when the radius increases.

5 The radius of the circle is bigger, so if each circle was completed in the same time, the mass would actually be moving faster.

6 Take repeated measurements and work out means.

7 **a** satellite

b the force of gravity between the satellite and the planet

8 **a** twice as much (Accept 'a greater force'.)

b double

c The model shows that twice the force is needed for a 'satellite' with twice the mass, and in the real situation the force would be doubled, so the model is a good one for this purpose.

9 **a** increased

b no

c If its speed increases it needs a greater force to keep it in its orbit, but the force does not change so it will fly off/leave its orbit/move to a higher orbit.

d The model shows that a greater force is needed to keep a faster moving object in orbit, but as gravitational force does not change in the real situation being modelled, this is not a very good model for this purpose.

10 **a** decreased

b The gravitational force on F will be less.

c The model shows that the force is less for a higher orbit, and this is the case in real life, so the model is a good one. (Note that this answer is based on the qualitative information that the students have at this point; if all factors are taken into account the model is not quite as good.)

11 **a** The force halves.

b The force is a quarter of its original value.

c In the model, the force on the string halved when the radius doubled, but in real life the force on a satellite would decrease by a factor of 4, so the model is good qualitatively but not quantitatively.

SP7b.2 Orbital speeds

1 Answers (shown as additional columns in the table) may vary slightly depending on factors such as the value for π and rounding.

Planet	Orbital radius (m)	Orbital period (Earth years)	(a) Distance for one orbit (m)	(b) Orbital period (s)	(c) Speed (m/s)
Mercury	5.83×10^{10}	0.24	3.66×10^{11}	7.57×10^{6}	48 374 (4.84×10^{4})
Venus	1.08×10^{11}	0.62	6.76×10^{11}	1.96×10^{7}	34 568 (3.46×10^{4})
Earth	1.50×10^{11}	1	9.39×10^{11}	3.16×10^{7}	29 771 (2.98×10^{4})
Mars	2.27×10^{11}	1.88	1.42×10^{12}	5.93×10^{7}	24 071 (2.41×10^{4})
Jupiter	7.78×10^{11}	11.86	4.88×10^{12}	3.74×10^{8}	13 053 (1.31×10^{4})
Saturn	1.43×10^{12}	29.46	8.96×10^{12}	9.30×10^{8}	9639 (9.64×10^{3})
Uranus	2.87×10^{12}	84.01	1.80×10^{13}	2.65×10^{9}	6796 (6.80×10^{3})
Neptune	4.50×10^{12}	164.8	2.82×10^{13}	5.20×10^{9}	5430 (5.43×10^{3})

2 **a** Correctly plotted graph with smooth curve joining the points: this should show the speed decreasing as the orbital radius increases, the decrease being very steep at first and then the gradient becoming more shallow.

b The further a planet is from the Sun, the slower its speed. Stretch students may have also plotted 1/speed against orbital radius to investigate whether the two factors are inversely proportional (they are not).

3

Satellite	Height (km)	Orbital period (s)	(a) Orbital radius (m)	(b) Distance (m)	(c) Speed (m/s)
A	500	5668	6.87×10^6	4.31×10^7	7613
B	10 000	20 846	1.64×10^7	1.03×10^8	4932
C	20 000	42 619	2.64×10^7	1.66×10^8	3886
D	30 000	69 031	3.64×10^7	2.28×10^8	3309
E	40 000	99 376	4.64×10^7	2.91×10^8	2930

4 **a** Correctly plotted graph with smooth curve joining the points. The shape should be similar to the graph in question **2a**.

b Both graphs show that the speed decreases with increasing orbital radius, but we cannot tell from the graph whether the relationship is exactly the same, as this plots height above the surface whereas the first graph plotted orbital radius. The scales on the axes are also different.

5 **a** Correctly plotted graph with smooth line joining the points: this shows the period increasing with height above surface, with the line gently curving upwards with increasing height.

b The time given is 24 hours, and the orbital height for this period is approximately 35 786 km. The accuracy of students' responses will depend on the size of their graph and how precisely they have read from it.

c It orbits the Earth once in the same time as the Earth spins on its axis once, so it stays above the same point on the Earth.

6 **a** Slower, as it takes longer to move the same distance.

b If the mass is smaller, the speed is lower for an orbit of the same radius.

SP7b.3 Gravity and orbits Strengthen

1 **a** B

b A

2 **a** gravitational field strength

b 1.62 N/kg

3 **a** Y

b Z

c X

4 **a** almost circular

b highly elliptical

5 **a** … is constant.

b … is continually changing.

c … will move to a higher orbit.

d … faster than the speed of a satellite in a high orbit.

SP7b.4 Gravity and orbits Homework 1

1 gravitational field strength

2 **a** Io

b Gravitational field strength/g is greater on Io.

3 field, mass, radius (last two in either order)

greater, surface

stronger

stronger, greater, greater, larger

smallest, strongest, smallest, smaller

4 **a** The orbit of a planet is almost circular, a comet has an elliptical orbit.

b A planet orbits the Sun, a moon orbits a planet.

5 **a** Y

b arrow drawn in the direction of motion, tangential to the orbit

c move to higher orbit

6 Their direction is changing as they go around, and velocity is a vector/velocity has a magnitude and direction.

SP7b.5 Gravity and orbits Homework 2

1 **a** the mass of the body and its radius

b It has a higher mass, and although it also has a greater radius, the difference in mass more than makes up for the difference in radius.

c It has the smallest radius. Although it also has the smallest mass, its smaller radius has a greater effect on its surface gravity.

2 The Earth has more mass, and it is closer to the Sun.

3 Planets and moons have almost circular orbits, but planets orbit the Sun and moons orbit planets. Comets and planets all orbit the Sun, but planets have almost circular orbits and comets have highly elliptical orbits.

4 Velocity is a vector quantity, so it has direction as well as magnitude. As the satellites are in circular orbits, their direction is continually changing, and so their velocity is changing.

5 Y is moving faster. It is in a lower orbit, and the force of gravity between it and the Earth is stronger so it has to be moving faster to stay in its orbit.

6 It will move away from the Earth/into a higher orbit. A very good answer will say that unless the rockets keep firing, as it moves further away from the Earth the force of gravity will slow it down until it stops moving away from the Earth and continues to orbit.

7 X needs to be slowed down. This will make it fall towards the Earth. It will accelerate as it does so. When it is at the correct height the rockets must be fired again to give it the correct speed for the new orbit, which will be higher than its original speed.

Students may also discuss the fact that X may need to catch up with Y, or allow Y to catch up with X. To ‘catch up’, X needs to be slowed down so it falls into a lower orbit. It will catch up with Y because in a lower orbit it does not have as far to travel, and also because it will speed up as it falls. When it is in the correct position it needs to be speeded up enough to move to an orbit at the same height as Y, and its speed adjusted again so that it maintains this orbit. Attempting to catch up by increasing speed will result in the satellite moving to a higher orbit, slowing down as it goes, and it will fall further behind.

8 Io’s mass is $\frac{8.9}{14.8}$ = 0.6 of the mass of Ganymede, so if the surface gravity depended only on mass, Io’s gravity would be 0.6 times the gravity of Ganymede, as *g* is proportional to the mass of the body.

Io’s radius is $\frac{1820}{2631}$ = 0.69 of the radius of Ganymede. As *g* is proportional to $1/r^2$, then if *g* depended only on radius it would be approximately twice as large on Io as on Ganymede.

The smaller radius increases the gravity more than the smaller mass reduces it, so Io has a greater value of surface gravity than Ganymede. The gravity of Io is approximately 0.6 × 2 = 1.2 times the gravity of Ganymede.

SP7c Life cycles of stars

Student Book

1 hydrogen

2 A cloud of dust and gases is pulled together by the force of gravity, becoming denser and denser until it gets hot enough for fusion reactions to start.

3 **a** A normal star that has used up most of its hydrogen – its core has collapsed but its outer layers have expanded.

b A collapsed star in which no fusion reactions happen, so it is cooling down.

4 red giant

5 An explosion that happens at the end of the life of a red supergiant.

6 Because it does not have enough mass to go through the part of the life cycle that ends in a black hole.

S1 **a** cloud of gas → protostar → main sequence star → red giant → white dwarf

b cloud of gas → protostar → massive main sequence star → red super giant → supernova → neutron star or black hole

E1 Every star forms from a cloud of gas pulled together by gravity, and all burn hydrogen fuel during the main sequence part of their life cycle. At the end of its life cycle a smaller mass star, like the Sun, expands to form a red giant, then throw off a shell of gas and become a white dwarf. Larger mass stars form red supergiants, which then explode in supernovas. If the remaining mass is high enough it forms a black hole, otherwise it forms a neutron star.

Exam-style question

Any two from: gravity pulls a cloud of gas together and compresses it until fusion starts (1); gravity collapses the core of a star when a red giant forms (1); gravity will compress the remains of a red giant into a white dwarf (1); gravity collapses a star at the end of its red supergiant period to cause a supernovas explosion (1); gravity pulls the remains of a supernova explosion together to form a neutron star/black hole (1).

Activity and Assessment Pack

SP7c.1 Sorting out stars

1 Stars like the Sun: nebula, protostar, main sequence star, red giant, shell of gas, white dwarf.

Stars with greater masses: nebula, protostar, massive main sequence star, red supergiant, supernova, neutron star/black hole (last two shown as alternatives).

2 If the sentences provided are used:

Stars like the Sun:

A cloud of dust and gas… is pulled together by gravity.

As the cloud gets smaller… it begins to heat up.

Nuclear reactions heat the star… and the outward pressure balances the compression due to gravity.

Most of the hydrogen is used up and the core collapses… but the outer layers expand.

The outer layers of the star are thrown off… and the rest is pulled together by gravity to form a white dwarf.

No fusion reactions are happening in the star… and it will gradually cool to become a black dwarf.

Stars with greater masses:

A cloud of dust and gas… is pulled together by gravity.

As the cloud gets smaller… it begins to heat up.

Nuclear reactions heat the star… and the outward pressure balances the compression due to gravity.

Most of the hydrogen is used up and the core collapses… but the outer layers expand.

The whole star collapses… and then explodes.

If what is left is more than four times the mass of the Sun… the material is pulled together by gravity to form a black hole.

If what is left is less than four times the mass of the Sun…the material is pulled together by gravity to form a neutron star.

SP7c.2 Life cycles of stars Strengthen

1 left-hand chart: protostar, main sequence star, red giant, white dwarf

right-hand chart: protostar, massive main sequence star, supernova, neutron star, black hole (last two in either order)

2 nebula, gravity, protostar, pressure, fusion, pressure, sequence

SP7c.3 Life cycles of stars Homework 1

1 **a** protostar – a hot cloud of gas, not quite hot enough for nuclear reactions

shell of gas – gas thrown off by a star when it finishes its red giant stage

nebula – cloud of dust

main sequence star – a stable star using hydrogen in fusion reactions

white dwarf – a small, cooling star, in which fusion reactions have finished.

red giant – a star that has used up most of its hydrogen and expanded greatly

b C, A, D, F, B, E

2 gravity

3 fusion reactions

4 **a** red supergiant

b supernova

5 **a** gravity

b pressure from hot gases

6 **a** X is larger than Y

b X and Y are the same

c X and Y are the same

SP7c.4 Life cycles of stars
Homework 2

1 B – because the Sun is expected to end its life as a white dwarf.

2 **a** A **b** It would be more massive.

3 **a** main sequence star in A and B (Red giant and red supergiant are also correct answers, but students are not expected to know this.)

b red giant and red supergiant in A and B

c neutron star in A

d nebula and protostar stages in A and B

e protostar in A and B

f main sequence star and red supergiant in A, main sequence star and red giant in B

4 **a** Gravity pulls the material of the star inwards, the pressures push it outwards.

b In the nebula and in the protostar gravity is stronger, because the material is contracting in these phases.

In what is left after the star throws off the shell of dust and gas, gravity is stronger as the material collapses to form a white dwarf.

c Outward pressure increases between the protostar and main sequence stages, because as gravity pulls the material together it gets hotter and so the outward pressure increases.

d main sequence and red giant stages

5 In biology, 'life cycle' refers to a continuous cycle of birth to death and includes reproduction. For stars, there is no reproduction involved.

SP7d Red-shift

Student Book

5th **1** **a** The frequency is higher as the ambulance approaches, and lower as it heads away.

6th **b** The wavelength is shorter as the ambulance approaches, and longer as it heads away.

6th **2** The shifting of lines in the spectra of stars towards the red end of the spectrum.

7th **3** Diagram should show that the distance between two stars changes with time, so that light emitted from a star appears (to an observer elsewhere) to have a longer wavelength.

7th **4** Galaxy A – the further away a galaxy is, the faster it is moving away.

8th **5** If the lines are blue-shifted that means the wavelengths are shorter and so the Andromeda galaxy is moving towards us.

S1 That the galaxy is moving away from us.

S2 The more distant a galaxy is from us the faster it is moving away.

E1 Measure the red-shift of the new galaxy and compare it to the red-shift of galaxies at known distances: the new galaxy is at the same distance as known galaxies with the same red-shift because the red-shift increases with increasing distance.

Exam-style question

The pattern of dark lines in the galaxy's spectrum is compared to the lines in light from the Sun (which is not moving towards or away from us) (1). The change in wavelength of the lines/how far they have moved towards the red end of the spectrum is measured (1).

Activity and Assessment Pack

SP7d.1 Binary stars

1 Light is shifted towards the blue end of the spectrum – i.e. the frequency gets higher and the wavelength shorter – because the object emitting the light is moving towards us.

2 If the stars are orbiting each other, one must be going away from us as the other is coming towards us. The light from the one coming towards us would be blue-shifted, so the other would be red-shifted.

3 **a** A and D – although they show red-shift and blue-shift, these vary about the zero axis.

b D – the frequency of the changes is higher/period is shorter.

c B and C – the average shift is red.

d B – the red-shift is greater.

4 If it was just one star, the red-shift would be constant. When one of the stars is moving away from us (as part of the rotation of the binary pair) its red-shift increases above the average value. When it is moving towards us, its red-shift is less than the average value.

5 In E there would be no red-shift or blue-shift at all, because the stars are not moving towards or away from the Earth.

In F there would be some red-shift and blue-shift from each star, but less than in G, because part of the movement is not towards or away from the Earth.

In G there would be the full range of red-shift and blue-shift.

SP7d.2 Red-shift – Strengthen

1 Red-shift is when light from a galaxy… is shifted towards the red end of the spectrum.

Red-shift shows that the galaxy… is moving away from us.

The greater the red-shift… the faster the galaxy is moving away.

Galaxies are at different distances… from the Earth.

More distant galaxies have… greater red-shifts.

The relationship between distance and red-shift… shows that the Universe is expanding.

2 the same

closer together, higher, behind, longer

longer, red-shifted

SP7d.3 Red-shift – Homework 1

1 pitch – how high or low a sound is

frequency – the number of waves per second

wavelength – the distance between one wave and the next

2 It sounds higher pitched as it comes towards you.

It sounds lower pitched as it moves away from you.

3 Doppler effect

4 **a** X

b arrow pointing to the left

c ‘low’ written to the right of the object in X

5 **a** When light from the galaxy is shifted towards the red end of the spectrum.

b away from

c More distant galaxies have greater red-shifts.

d It is expanding.

SP7d.4 Red-shift – Homework 2

1 The movement of an object makes the waves it emits have a shorter wavelength in front of it and a longer wavelength behind. Diagrams could be similar to diagram A in the Student Book.

2 The speed at which a galaxy (or other object) is moving away from us.

3 **a** Albefoil **b** AR348

4 **a** AR348, NM86B, Albefoil

b The closer a galaxy is to us, the more slowly it is moving away, and so the smaller its red-shift.

5 The lines have been moved away from the red end of the spectrum (or moved towards the blue end). It is moving towards us, rather than away from us.

6 One far away – the further away a galaxy is, the faster it is moving away, and so the bigger its red-shift.

7 The galaxy is rotating. This means that on the side of the galaxy rotating away from us, the stars are moving away from us faster than the galaxy as a whole, so the red-shift will be increased slightly. On the other side, the stars are moving towards us as the galaxy rotates, so this means their speed away from us is a bit less, and the red-shift is reduced slightly.

SP7e Origin of the Universe

Student Book

(6th) **1** The galaxies are moving away from us.

(5th) **2** **a** Steady State

(5th) **b** Big Bang

(6th) **3** Both theories say that the Universe is expanding.

(6th) **4** **a** cosmic microwave background (radiation)

(6th) **b** CMB is radiation emitted by the Big Bang, which now has a much longer wavelength because of the expansion of the Universe.

(7th) **5** **a** Big Bang and Steady State

(7th) **b** Big Bang

S1 The Big Bang theory says that the Universe started from a point 13.5 billion years ago and has been expanding ever since. It is supported by the data showing that space is expanding, and the CMB radiation.

The Steady State theory says that the Universe has always existed and is expanding. New matter is created as the Universe expands. This theory is supported by the data showing that space is expanding.

S2 The Big Bang theory is supported by most scientists because it has more data supporting it.

E1 A possible answer: In 1900 astronomers did not know the distances to any other galaxies or that they were moving relative to us. Now they know that most other galaxies are moving away from us, and they explain this using a model that says the Universe has expanded from a starting point called the Big Bang. There is other evidence, such as CMB, that supports this theory.

Exam-style question

Both theories include an expanding Universe (1). The Big Bang theory says that the Universe started at a single point 13.5 billion years ago (1), whereas the Steady State theory says it has always existed (1).

Activity and Assessment Pack

SP7e.1 Timeline for the Universe

In order, from the bottom up:

Universe forms in the Big Bang.

Galaxies form.

The Solar System starts to form.

The Sun becomes a main sequence star, and produces light and heat from hydrogen fusion.

The Earth forms.

The first life appears.

Humans observe the sky with the naked eye.

Galileo uses a telescope to observe the stars.

Astronomers use other parts of the EM spectrum to make observations.

The Sun turns into a red giant.

The Sun becomes a white dwarf.

The white dwarf cools.

SP7e.3 Origin of the Universe Strengthen

1 (evidence) E The red-shift of distant galaxies… B is greater than the red-shift of closer ones.

(interpretation) D The Universe… A is expanding.

(evidence) H Microwave radiation can be detected… F from the whole of the sky.

(interpretation) G This is energy released at the beginning… C of the Universe, with its wavelength increased.

2 b/d, g: The Universe is expanding. BB, SS

a, j: Matter is continually… being created. SS

f, c: All matter was created… at the beginning of the Universe. BB

b/d, i: The Universe… has always existed. SS

e, h: The Universe started… about 13.5 billion years ago. BB

3 **a** Big Bang
b It has the most evidence for it.

4 cosmic microwave background radiation (Accept CMB radiation.)

SP7e.4 Origin of the Universe Homework 1

1 **a** both ticked
b Big Bang
c Steady State
d Big Bang
e Big Bang

2 when light from distant galaxies is shifted towards the red end of the spectrum

3 **a** away from us
b It is expanding.

4 **a** red-shift
b both Steady State and Big Bang
c radiation coming from all over the sky
d Big Bang
e Big Bang

SP7e.5 Origin of the Universe Homework 2

1 It was coming from all over the sky.

2 The findings were published in a scientific journal. Before publication, the article would have been sent out to other scientists to check (peer review). When it was published, anyone else who had the right equipment would have looked for the background radiation.

3 Observation by Hubble – Most galaxies are moving away from us.

Question – Why is this happening?

Theory – Big Bang or Steady State theory

Predict – There should be some radiation left over from the Big Bang.

Observations – CMB discovered (but not by the same people who made the predictions!). This is evidence for the Big Bang.

Conclude – Big Bang is the better model (do not accept 'the truth' or similar).

4 **a** The higher the temperature the shorter the wavelength (or the lower the temperature the longer the wavelength).

b Infrared radiation has a shorter wavelength than microwave radiation.

c Space has expanded, so the wavelength of the radiation has got longer/been stretched.

5 It often takes some years for it to become clear how important a particular discovery is. Sometimes a discovery appears to be important, but later work shows it to be incorrect. The time delay prevents the prize being awarded for this kind of discovery.

SP8a Work and power

Student Book

1 the energy transferred when a force moves something

2 work = 1800 N × 1.5 m = 2700 J

3 a work = 280 N × 1.5 m = 420 J

b work = 140 N × 760 m = 106 400 J

4 distance = $\frac{\text{work}}{\text{force}}$

$= \frac{2200\text{ J}}{550\text{ N}} = 4\text{ m}$

5 a work = 500 N × 3 m = 1500 J

b Iesha's power = $\frac{1500\text{ J}}{10\text{ s}}$

= 150 W

Fran's power = $\frac{1500\text{ J}}{12\text{ s}}$

= 125 W

6 The motor will transfer energy when it makes something move. Friction between a moving object and its surroundings will cause heating. A good answer may also mention that energy wasted in the motor will also transfer energy to its surroundings by heating.

S1 Work is calculated from a force multiplied by the distance moved by the force, so you would need to measure the distance the horses pulled the plough and the force they used to pull it.

S2 a work = 1000 N × 5 m = 5000 J

b power = $\frac{5000\text{ J}}{10\text{ s}}$ = 500 W

E1 work done = power × time = 7800 W × 10 s
= 78 000 J

distance = $\frac{\text{work}}{\text{force}} = \frac{78\,000\text{ J}}{5000\text{ N}} = 15.6\text{ m}$

Exam-style question

Work done depends on force and distance moved in the direction of the force (1), so if they have the same mass and move the same distance, they will both have done the same work (1).

Power is the rate of doing work (or similar explanation) (1). The child that takes twice as long is therefore exerting half the power of the other child (1).

Activity and Assessment Pack

SP8a.2 Work done and power

1 (Rows can be in any order – here they are in the order the quantity symbol appears in the word box.)

Symbol	Description	Unit symbol	Work done or power equation?
d	distance moved in direction of force	m	work done
E	work done	J	work done
E	work done	J	power
F	force	N	work done
P	power	W	power
t	time taken	s	power

2 a work done = 30 N × 3 m = 90 J

b power = $\frac{90\text{ J}}{10\text{ s}}$ = 9 W

3 a Δ*GPE*

b mass × gravitational field strength

c change in vertical height

4 a work done = 50 N × 1 m = 50 J

b Δ*GPE* = 5 kg × 10 N/kg × 1 m = 50 J

5 a Δ*GPE* = 500 kg × 10 N/kg × 20 m
= 100 000 J

b 10 000 J is wasted energy. Energy cannot be created or destroyed, so the difference between the 100 000 J stored in the raised mass and the total energy transferred by the crane is the wasted energy.

c It is stored as heat in the crane or its surroundings. It is not useful, because it is dissipated/spread out.

d efficiency = $\frac{100\,000\text{ J}}{110\,000\text{ J}} = 0.91$

SP8a.3 Equation practice

1 a work done = 50 N × 4.8 m = 240 J

b work done = 80 N × 4.0 m = 320 J

c work done = 180 N × 4.5 m = 810 J

d work done = 250 N × 4.5 m = 1125 J

e work done = 55 N × 2.0 m = 110 J

f work done = 100 N × 2.0 m = 200 J

g work done = 140 N × 2.5 m = 350 J

h work done = 153 N × 2.5 m = 382.5 J

i work done = 40 N × 1.5 m = 60 J

2 a force = $\frac{10\ 000\ J}{20\ m}$ = 500 N

b force = $\frac{10\ J}{0.5\ m}$ = 20 N

c distance = $\frac{80\ J}{40\ N}$ = 2 m

d distance = $\frac{350\ J}{70\ N}$ = 5 m

e force = $\frac{5\ 000\ 000\ J}{500\ m}$ = 10 000 N

f distance = $\frac{0.16\ J}{0.2\ N}$ = 0.8 m

3 work done = 100 N × 7 m = 700 J

4 a power = $\frac{90\ 000\ J}{30\ s}$ = 3000 W

b work done = 20 W × 5 s = 100 J

c power = $\frac{100\ J}{2\ s}$ = 50 W

d time taken = $\frac{245\ J}{700\ W}$ = 0.35 s

e work done = 25 W × 75 s = 1875 J

f time taken = $\frac{500\ 000\ J}{50\ 000\ W}$ = 10 s

g power = $\frac{450\ J}{3\ s}$ = 150 W

h time taken = $\frac{5\ J}{0.5\ W}$ = 10 s

5 a work done = 500 N × 0.8 m = 400 J

b power = $\frac{400\ J}{5\ s}$ = 80 W

c work done = 160 N × 2.5 m = 400 N

d power = $\frac{400\ N}{8\ s}$ = 50 W

6 a work done = 750 N × 200 m = 150 000 J

b 20 min = 1200 s

power = $\frac{150\ 000\ J}{1200\ s}$ = 125 W

c time = $\frac{150\ 000\ J}{5000\ W}$ = 30 s

SP8a.4 Work and power – Strengthen

1 energy, force, joules, force, distance, direction

force, newtons, distance, metres

2 a 1000 N

b This is the force in the direction the car will move.

3 Work done is the energy transferred.

4 work done = 1200 N × 4 m = 4800 J

5 $\frac{4800\ J}{10\ s}$ = 480 W

6 electricity, heating (any order)

SP8a.5 Work and power Homework 1

1 a joule or J

b watt or W

c 1 watt = 1 joule per second

2 by heating or by electricity (either order)

3 a 550 N × 6 m = 3300 J

b 20 N × 6 m = 120 J

c Jill. They are the same weight/have used the same force and moved the same distance so the work is the same. Jill has transferred the same energy in a shorter time.

d power = $\frac{120\ J}{5\ s}$ = 24 W

4 a distance = $\frac{\text{work done}}{\text{force}} = \frac{450\ N}{50\ N}$ = 9 m

b time = $\frac{\text{work done}}{\text{power}} = \frac{450\ N}{25\ W}$ = 18 s

SP8a.6 Work and power Homework 2

1 a 550 N × 6 m = 3300 J

b 20 N × 6 m = 120 J

c Joe. They are the same weight/have used the same force and moved the same distance so the work is the same. Joe has transferred the same energy in a shorter time.

d power = $\frac{120\ J}{5\ s}$ = 24 W

2 a distance = $\frac{\text{work done}}{\text{force}} = \frac{450\ N}{50\ N}$ = 9 m

b time = $\frac{\text{work done}}{\text{power}} = \frac{450\ N}{25\ W}$ = 18 s

3 Bill: work done = 650 N × 5 m = 3250 J

power = $\frac{3250\ J}{6.5\ s}$ = 500 W

Ben: work done = 700 N × 5 m = 3500 J

power = $\frac{3500\ J}{7\ s}$ = 500 W

4 a The force needed to move the suitcase upwards is the same magnitude as the weight of the suitcase. This is multiplied by the distance moved, which is the height of the platform.

b The force is less but the distance the suitcase has to move is greater.

c There may be some friction in the wheels of the suitcase that will increase the force needed to push it.

5 a Power is the rate of doing work, so if something is moving faster it is doing work in less time.

b The force needed to move the lift. If the force needed is greater for a given distance, then more work is done in a certain time and so more power is needed.

c A slower lift moves a shorter distance in each time interval. However, if it is lifting a greater load it could be much more powerful than a fast lift moving only a small load.

SP9a Objects affecting each other

Student Book

1 a Upthrust from the water is making the narrowboat float. Water resistance is slowing down its movement.

b The weight of the boat is pushing down on the water and has pushed some of the water out of the way. Some students might also add that the boat moving through the water also pushes water out of the way/ makes ripples or waves.

2 The weight of the aqueduct pushes down on the ground. There is an upwards normal contact from the ground that balances this weight.

3 It keeps the Earth in orbit around the Sun.

4 3.5×10^{22} N. A good answer may add that the two forces act in opposite directions.

5 Diagram can consist of two circles (or other shapes) with an arrow from each circle of equal size, with:

a the two arrows pointing towards each other

b the two arrows pointing away from each other.

S1 contact forces – three from: friction, upthrust, normal contact force, water resistance, air resistance, drag, etc.

non-contact forces: gravity, magnetism, static electricity

E1 The weight of the box pushes down on the table. There is a normal contact force from the table pushing up on the box. The two forces are equal in size and opposite in direction.

The box and the Earth attract each other as the box is within the Earth's gravitational field. The forces are the same size but in opposite directions.

E2 Similarity: both can affect things without touching them.

Differences: a gravitational field acts on all objects with mass but a magnetic field only acts on certain materials; a gravitational field only produces attractive forces, a magnetic field can attract or repel.

Exam-style question

There is a force due to the electric fields/static electricity between the two rods (1). These two forces are equal in size but opposite in direction (1). The rods and the Earth attract each other because the rods are within the Earth's gravitational field (1). The gravitational forces are equal in size and opposite in direction (1).

A statement that the force between the rods is repelling them is not expected at this stage in the course.

Activity and Assessment Pack

SP9a.1 Force field effects

1 Answers could just be that the weight is proportional to the mass, but better answers will recall earlier work and state that weight = mass × gravitational field strength or weight = mass × 10 N/kg.

2 the gravitational field of the Earth/the force of gravity between the mass and the Earth

3 Diagrams should have force arrows of equal sizes and in opposite directions between the mass and the Earth, in a direction that will pull them together.

4 Diagrams should have force arrows of equal sizes and in opposite directions between the bar magnets, in a direction that will push them apart.

5 The direction a magnetic north pole would move/the direction the needle of a plotting compass would point.

6 a Diagram should have force arrows of equal sizes and in opposite directions between the two rods, in a direction that will push them apart.

b As for part **a**, but with the arrows in a direction that will pull the rods together.

SP9a.2 Models of fields and forces

1 a C

b the direction of the force and its magnitude/size/strength

2 a A

b The lines are closer together.

c The direction a magnetic north pole would move/the direction the needle of a plotting compass would point.

3 a B, D, F. They all show something that acts symmetrically around the Earth.

b In B, the shading is darker closer to the Earth. In D, the lines could be like contours, and they are thicker and blacker closer to the Earth. In F, the lines are closer together close to the Earth.

c F shows the direction of the force field as well as how strong it is.

4 a B, D, E, F – they all show something that is stronger close to the central (charged) object.

b E could not be a gravitational field, as gravity does not repel, only attracts, and E shows a field that would repel an object.

SP9a.3 Objects affecting each other – Strengthen

1 forces between objects that are not touching each other

2 a contact
b contact
c non-contact
d contact
e non-contact
f non-contact

3 a vector
b vector
c scalar
d scalar
e scalar
f vector

4 a A
b two bar magnets drawn with similar ends together, and equal sized arrows showing attraction between them

SP9a.4 Objects affecting each other – Homework 1

1 a Any two from magnetism, gravity, static electricity.
b Any two from upthrust, friction, air resistance, water resistance, normal contact force (or any other sensible description of a contact force).

2 the magnitude/size of the force and its direction

3 the direction in which the car is moving

4 a gravity
b two arrows of equal size and opposite direction indicating attraction between the Sun and the Earth

5 a two arrows of equal size and opposite direction indicating repulsion between the two magnets
b as for **a**, but with arrows in opposite directions

6 magnetic field

7 around objects that have mass

SP9a.5 Objects affecting each other – Homework 2

1 contact: upthrust, friction, air resistance, water resistance, normal contact force (or any other sensible description of a contact force)

non-contact: magnetism, gravity, static electricity

2 the space around an object (mass/magnet/charge) where it can affect other objects

3 a The mark scheme could include:

Similarities:

- Both fields can affect objects without touching them.
- The shapes of the fields are similar shapes.
- Both fields are strongest near the object causing the field.

Differences:

- A gravitational field acts on things with mass and an electric field acts on objects with a charge.
- A gravitational field can only attract whereas an electric field can attract or repel, depending on the charges.

b 1 mark, as only one difference has been given.

4 a A vector quantity has both magnitude and direction. Any other example such as velocity, displacement, acceleration, momentum.
b scalar
c any two examples of scalar quantities, such as energy, mass, speed, distance

5 Arrows should be of equal length and in opposite directions, showing the two bodies attracting each other.

6 a Arrows should be of equal length and in opposite directions, showing the two bodies attracting each other.
b The arrows would be longer, showing that the forces are greater.

7 a The arrows would point in the opposite directions.
b Gravitational fields can only attract other objects with mass, whereas this diagram shows that it is repelling.

8 a Zero – the force from the Earth is cancelled out by the force from the Moon.

b The gravitational field strength of the Earth is greater than that of the Moon, so you need to be further from the Earth to get part of its field to cancel out the field of the Moon exactly.

c diagram similar to the one with question **7** on the worksheet, but with all the arrows pointing inwards

d Explanations should refer to the gravitational field of the Earth making the lines point towards the Earth, and being bent because at this point an object with mass would also be attracted towards the Moon, resulting in the kind of curved path shown.

SP9b Vector diagrams H

Student Book

7th **1** The resultant force must be pointing backwards/in the opposite direction to the car's movement.

8th **2 a** Diagram should show equal sized up and down arrows, labelled weight and normal contact force.

8th **b** Diagram should have equal sized forward and backward arrows, labelled force from engine and drag (or friction). Also equal-sized up and down arrows labelled weight and normal contact force.

8th **3** Diagram similar to diagram B in the Student Book, with the long force vector scaled to represent 50 kN and the shorter one 15 kN and an angle of 145° between them. Parallelogram completed to give a resultant of approximately 37 kN. (A triangle is also an acceptable method of answering this type of question.)

7th **4 a** drag/air resistance

8th **b** If the aeroplane is moving at a constant speed, there must be zero resultant force. The total drag must therefore be of the same magnitude as the resultant from question **3**, but acting in the opposite direction.

9th **5** Diagram similar to diagram D in the Student Book, with a thrust vector drawn to represent 200 kN at 50° to the horizontal, rectangle completed to give a vertical component of 153 kN and a horizontal component of 129 kN.

S1 a resultant force = 20 N – 5 N = 15 N

b The force will make the car accelerate.

c Diagram should have forward arrow three times as long as the backward arrow. It should also have upwards and downwards forces of the same size as each other.

E1 Diagram similar to diagram D in the Student Book, with a thrust vector drawn to represent 50 N at 20° to the vertical, rectangle completed to give a vertical component of 47 N and a horizontal component of 17 N.

Exam-style question

If the angle of the force to the horizontal is smaller, the horizontal component will be larger than 173 kN and the vertical component will be smaller than 100 kN.

Activity and Assessment Pack

SP9b.1 Balancing three forces

1–6 Depend on students' results.

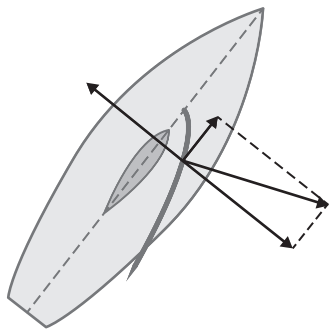
7 The resultant of the two smallest forces is equal in size but in the opposite direction to the largest force.

SP9b.2 Sailing and forces

1 If students have copied the lines accurately (with the 1000 N force shown at 65° to the centreline of the boat), the force along the centreline will be 423 N and at right angles to it will be 906 N. (See answer to question **3.**)

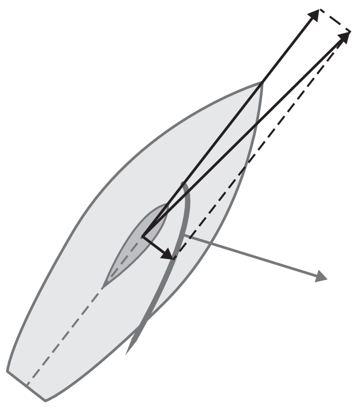
2 If there is only one force on the boat, the boat will move in the direction of that force – i.e. the 1000 N force shown.

3 a The extra force should be along the same line as the resolved 906 N force but in the opposite direction. The arrow should be scaled correctly (i.e slightly shorter than the 906 N force drawn in question **1**). The diagram below shows the resolved forces from question **1**.



b 906 N – 850 N = 56 N on the downwind side of the boat (the right hand side, in these diagrams).

4 **a** If drawn accurately, the resultant will be 427 N at an angle of 7.5° clockwise to the centreline of the boat.



b The water resistance must be the same size, but in the opposite direction, as the forces on the boat must be balanced if the boat is moving at a constant speed.

5 The direction of the force from the sails is at a smaller angle to the centreline of the boat, so the component of the force in the forward direction is greater in the diagram on the right than in the diagram above.

SP9b.3 Vector diagram practice

1 Answers will depend on the accuracy of students' drawings, but should be close to the following values.

a 56 N at an angle of 27° to A

b 126 N at an angle of 16° to A

c 68 N at an angle of 29° to A

2 **a** The resultant will act between the two forces shown, closer to the direction of the 20 kN force than the 5 kN force.

The resultant is 21 kN at an angle of 14° from the direction the aeroplane is pointing.

b The resultant will act between the two forces shown, closer to the 40 kN force than the 10 kN force.

The resultant is 48 kN at an angle of 6° from the direction the aeroplane is pointing.

3 **a** Along the direction the sled is moving – if it is the only force on the sled, the force and the direction of movement must be the same (or the forces are symmetrical about the line of movement, so the resultant must be along that line).

b If the two forces were in line, the resultant would be 100 N; as they are at an angle it must be a bit less than this. Accept answers between 80 N and 95 N.

c resultant = 90 N

4 **a** The resultant will be at an angle to the right of vertical on the diagram. Its size will be less than the sum of the two forces – accept estimates between 2000 N and 2400 N.

b resultant = 2317 N at an angle of 18° to the right of the line of the 1000 N force

5 **a** normal component = 1182 N, component along slope = 208 N

b normal component = 1992 N, component along slope = 104 N

c normal component = 1409 N, component along slope = 513 N

6 **a** sketch showing slope at 60° to the horizontal, and a skier with a vertical weight marked

b 693 N

c 400 N

7 **a** 259 N

b 287 N

SP9b.4 Vector diagrams Strengthen

1 100 N – 80 N = 20 N, and the 100 N force is in the forwards direction (or any other sensible explanation).

2 Speed will increase/boat will accelerate.

3 Vertical arrow drawn going upwards, same size as down arrow. Arrows labelled 'upthrust' and 'weight'. Horizontal arrow to the right, 0.8 times as long as the one shown. Arrows labelled 'force from engines' and 'water resistance'.

4 **a, b** parallelogram correctly drawn and resultant drawn along the diagonal

5 correct construction of rectangle with the weight arrow as the diagonal

SP9b.5 Vector diagrams Homework 1

1 **a** Free body diagram with equal sized horizontal arrows labelled 'force from engines' and 'water resistance' (or 'drag'). Equal sized vertical arrows, larger than the horizontal ones, labelled 'upthrust' and 'weight'.

b The arrow representing force from the engines would be longer than that for the water resistance, as a resultant force in the forwards direction would be needed to make the submarine accelerate.

2 **a–c** correctly drawn scale diagram

d 58 N

e 31°

3 **a** work done = 800 N × 1.5 m = 1200 J

b correctly drawn scale diagram (Size of component down the ramp should be 274 N.)

c work done = 274 N × 4.4 m = 1206 N

d The values are approximately the same. They should be exactly the same, but there may be small errors in working out the size of the force acting down the ramp.

SP9b.6 Vector diagrams Homework 2

1 **a** Free body diagram with equal sized horizontal arrows labelled force from engines and water resistance (or drag). Equal sized vertical arrows, larger than the horizontal ones, labelled 'upthrust' and 'weight'.

b The arrow representing force from the engines would be longer than the water resistance, as a resultant force in the forwards direction would be needed to make the submarine accelerate.

2 correctly drawn scale diagram, with the resultant as 58 N

3 **a** The force along the rope can be divided into a component pulling the boat along the canal and a component pulling it towards the bank. The boat needs to be steered to avoid this component making the boat hit the bank.

b sketch diagram showing the force along the rope and components along the canal and at right angles to the bank

c If the rope is longer, the angle of the rope from the direction of the canal will be smaller. For the same pulling force from the horse, the component of the force along the canal will be greater. (A good answer will also point out that less energy will be wasted steering the boat away from the bank.) Sketch showing this.

4 **a** work done = 800 N × 1.5 m = 1200 J

b correctly drawn scale diagram (Size of component down the ramp should be 274 N.)

c work done = 274 N × 4.4 m = 1206 N

d The values are approximately the same. They should be exactly the same, but there may be small errors in working out the size of the force acting down the ramp.

5 Students need to use a scale diagram to find the resultant of the two forces, and measure the angle between the 40 kN force and the resultant. This should be 14°.

SP9c Rotational forces

Student Book

1 Any two situations with a force producing a turning moment. Examples could include pushing on bicycle pedals, steering a bicycle, turning a door handle, bending arms/legs.

2 moment = 100 N × 0.5 m
= 50 N m

3 **a** clockwise moment
= 5000 N × 0.5 m
= 2500 N m
= anticlockwise moment
= effort force × 2 m

$$\text{effort force} = \frac{2500 \text{ N m}}{2 \text{ m}}$$
$$= 1250 \text{ N}$$

b The system would no longer be balanced. There would be a greater force on the load and the load would move up.

4 $\text{force} = \frac{2500 \text{ N m}}{3 \text{ m}}$

= 833 N

5 **a** $\frac{1}{4}$ turn

b 4 turns

S1 The turning force/moment increases if the distance of the force from the pivot increases. So with a longer spanner you can get the same turning force with a smaller effort.

S2 **a** moment = 600 N × 1.5 m
= 900 N m

b Sally's moment must be 900 N m in the opposite direction.
900 = 400 N × distance,

$$\text{so distance} = \frac{900 \text{ N m}}{400 \text{ N}}$$
$$= 2.25 \text{ m}$$

E1 Answers may vary in detail, but should include the following points.

A lever can be used to increase the size of a force. If the force applied to one side of the lever is further from the pivot than the load is, the force on the load will be greater than the force applied.

For example, if a load with a weight of 1000 N is to be lifted, and it is 1 m from the pivot, a moment of 1000 N m will be needed to lift it.

If the effort force is applied 4 m from the pivot, the force needed is only $\frac{1000 \text{ N m}}{40 \text{ m}}$ – 250 N.

Exam-style question

Correct conversion of units used in substitution: 15 cm = 0.15 m, 0.5 cm = 0.005 m (1).

Rearrangement: force = force applied × distance from pivot/distance of lid from pivot (1).

Substitution: force = $\frac{10 \text{ N} \times 0.15 \text{ m}}{0.005 \text{ m}}$ (1).

answer: force = 300 N (1).

3 marks for correct answer even if no working shown. Substitution and rearrangement can be done in either order.

Activity and Assessment Pack

SP9c.1 Equilibrium forces

5 suggestions could include errors in positioning the masses or in reading the force meter

SP9c.2 Gears

1 a C : D = 15 : 60 = 1 : 4

b D : C = 4 : 1, so D will complete ¼ turn for every complete turn of C

2 a moment = 20 N × 0.2 m = 4 N m

b moment = 20 N × 0.1 m = 2 N m

c ratio of diameters (and so teeth) E : F = 0.2 m : 0.1 m = 2 : 1

ratio of speeds = 1 : 2, F rotates twice as fast as E

d Gear F has half the diameter and rotates twice as fast, but provides only half the moment/turning force of gear E.

3 moment for B = 50 N × radius, radius of A is 3 × the radius of B, so the moment will be 3 times the size

4 If a gear has a diameter X times that of another, it will have X times the moment about its centre but will rotate at only 1/X times the speed.

5 a If I was next to G, it would turn in the opposite direction. Gear H turns in the opposite direction to G, which means that I must turn in the same direction as G. This is needed so that the second hand and the minute hand both turn in the same direction.

b The ratio of the diameters must be 1 : 60, as the minute hand moves at 1/60th of the speed as the second hand. H can be any diameter (X). If the diameter of G is 1, then the speed of H is X : 1. The speed of I is then 60 : X, and the X cancels out. *OR* The diameter of H does not matter as for every tooth of H driven around by G, a tooth on the opposite side of it drives I round by the same amount.

c Another small gear must be added, similar to H, and then a gear that has 60 times as many teeth as I. The new small gear is to make sure the new large gear turns in the same direction as G and I. The new large gear will be connected to the hour hand, and will move at 1/60th the speed of the minute hand.

SP9c.3 Moments equation practice

1 a moment = 5 N × 2 m = 10 N m

b moment = 20 N × 1.5 m = 30 N m

c distance = $\frac{0.6 \text{ N m}}{0.4 \text{ N}}$ = 1.5 m

d force = $\frac{90 \text{ N m}}{3 \text{ m}}$ = 30 N

e distance = $\frac{20 \text{ N m}}{100 \text{ N}}$ = 0.2 m

f moment = 80 N × 0.1 m = 8 N m

g force = $\frac{12 \text{ N m}}{1.2 \text{ m}}$ = 10 N

h distance = $\frac{4 \text{ N m}}{8 \text{ N}}$ = 0.5 m

2 a force = $\frac{200 \text{ N m}}{1.6 \text{ m}}$ = 125 N

b distance = $\frac{200 \text{ N m}}{50 \text{ N}}$ = 4 m

3 a moment = 50 N × 0.1 m = 5 N m

b moment = 50 N × 0.8 m = 40 N m

4 moment = 0.02 N × 0.005 m = 0.0001 N m = 1×10^{-4} N m

5 a moment = 400 N × 2 m = 800 N m

b It must be 800 N m in the opposite direction.

c distance = $\frac{800 \text{ N m}}{500 \text{ N}}$ = 1.6 m

6 a total moment = 300 N × 1.5 m + 400 N × 1 m = 450 N m + 400 N m = 850 N m

b force = $\frac{850 \text{ N m}}{2 \text{ m}}$ = 425 N

7 a 5

b 6

8 $\frac{300}{60}$ = 5, so the second gear must have 5 times as many teeth = 100 teeth

SP9c.4 Rotational forces Strengthen

1 pivot

moment, greater, force, longer/greater, 90°

moment, large, small

2 a force, distance, force

500 N, 1.2 m

600 N m

b 600 N m

moment/force

600 N m/400 N

1.5 m

3 a A

b 12

SP9c.5 Rotational forces Homework 1

1 a 0.86 m, this distance is normal/perpendicular to the force

b 150 N × 0.86 m = 129 N m

2 a moment = 400 N × 2 m = 800 N m

b distance = $\frac{800 \text{ N m}}{300 \text{ N}}$ = 2.67 m

3 a the teeth on the wheels interlock/make them move

b anti-clockwise arrow drawn near B

c 1

d 8

SP9c.6 Rotational forces Homework 2

1 a It will take more force to cut through a branch than a twig. The loppers have much longer handles, so they will magnify the force more.

b moment exerted by gardener = 40 N × 0.12 m = 4.8 N m

force on stems = $\frac{4.8 \text{ N m}}{0.03 \text{ m}}$ = 160 N

c moment on blades = 1000 N × 0.05 m = 50 N m

force on handles = $\frac{50 \text{ N m}}{0.52 \text{ m}}$ = 96 N

2 a 0.86 m, as this is the distance perpendicular to the force.

b moment = 150 N × 0.86 m = 129 N m

c they must be the same

d weight = $\frac{\text{moment}}{\text{distance}} = \frac{129 \text{ N m}}{0.43 \text{ m}}$ = 300 N

e No, it will be the same. The horizontal distance between the rope and the hinge will get less, so the moment produced by the force on the rope will get less. However the horizontal distance between the point of action of the weight of the trapdoor and the hinge will also get less. The two changes will balance each other out.

f If the rope is at right angles to the trapdoor, the distance used to calculate the moment remains at 1 m for all trapdoor angles. However, the weight continues to act vertically, and as the trapdoor rises the distance between the line of action of the weight and the hinge gets less, so a smaller moment is needed to overcome the moment of the trapdoor. Thus the force needed to lift the trapdoor will get less as the trapdoor rises, as long as the line of action of the force remains perpendicular to the trapdoor.

3 moment from weight = 200 N × 1.5 m = 300 N m

As she is not moving, the moment provided by her father must be the same as this.

force = $\frac{300 \text{ N m}}{2.5 \text{ m}}$ = 120 N

4 moment of 400 N boy = 400 N × 2 m = 800 N m

distance of 300 N boy = $\frac{800 \text{ N m}}{300 \text{ N}}$ = 2.67 m

5 The answer should discuss the gear ratio needed, and also mention the fact that the hands all need to turn in the same direction. A possible answer is given below.

Assuming the motor drives the minute hand, there must be a system of gears to make the hour hand move at 1/60th the speed of the minute hand, so the ratios of gear teeth must be 1 : 60. If there were only these gears, then the hour hand would move in the opposite direction to the minute hand, so there must be another gear between them.

6 The combined moments of the two smaller boys must add up to 800 N m. So 800 N m = (200 N × X m) + (300 N × Y m). Answers may vary, but one possible set of solutions is:
X = 1 m, Y = 2 m; X = 1.5 m, Y = 1.67 m;
X = 2 m, Y = 1.33 m.

7 Ratio of teeth on gears A : B = 40 : 200 = 1 : 5, so B turns 1/5 of the speed of A, and makes 2 turns for every 10 turns of A. It turns anti-clockwise. Ratio of teeth on gears B : C = 200 : 50 = 4 : 1, so C turns 4 times for every turn of B. For every 10 turns of A, B makes 2 turns so C must make 8 turns. C turns clockwise because B turns anti-clockwise.

SP10a Electric circuits

Student Book

7th **1**

Name of particle	Charge	Mass (relative to the proton)	Location
electron	−1	$\frac{1}{1835}$ (negligible)	shells around nucleus
proton	+1	1	nucleus
neutron	0	1	nucleus

8th **2** diagram of carbon 14 atom with 6 protons and 8 neutrons in the nucleus and 6 orbiting electrons, 2 in inner shell, 4 in outer shell

4th **3 a** circuit diagram of a series circuit with 2 lamps; cell or battery, may have a switch open or closed, any order of components

4th **b** circuit diagram of a series circuit with 4 lamps; cell or battery, may have a switch open or closed, any order of components

5th **4** circuit diagram of a parallel circuit with 2 lamps; cell or battery, may have a switch open or closed, any order of components

6th **5** circuit diagram of any circuit with 2 lamps and 3 switches (open or closed); cell or battery, any order of components

S1 circuit diagram with a cell, two lamps in parallel and two switches one in each branch so that each lamp can be turned off separately

S2 Arrow showing current from + terminal to − terminal of cell, labelled ‘current’. Arrow showing current from − terminal to + terminal of cell, labelled ‘electron flow’.

E1 Protons and neutrons are close together in the centre/nucleus. Electrons are in orbits called shells. They are widely spaced, 2 in first shell, then 8 in the second. In metal atoms the electrons in the outer shells are not tightly held. They can become separated/delocalised and carry a current.

E2 Series circuits have one route for current, parallel circuits have more than one route. Current is the same everywhere in a series circuit but can be different in different branches of parallel circuits, though the total current is the same. Potential difference adds up across components in series to give the same potential difference as the cell or battery. Potential difference is the same across components in parallel. This means lamps in series will all go out if one blows but others will stay lit in parallel. In parallel, components can be switched independently.

Exam-style question

In the LH circuit the lamps will all go out (1) because the circuit is broken and no current can flow (1). In the RH circuit the other 2 lamps will stay on (1) because the current can flow in the other two branches of the circuit (1).

Activity and Assessment Pack

SP10a.1 Series and parallel circuits

1 Table showing series circuits have dimmer lamps but those with parallel lamps are unchanged.

2 a series with three lamps
b three

3 a one
b It is the same.

4 In a series circuit, the electric current has to pass through more lamps than in a parallel circuit.

5 Use ammeters to measure the current, and compare.

SP10a.2 Circuit symbols

From top to bottom, left to right:

1 – lamp
2 – battery
3 – cell
4 – switch
5 – voltmeter
6 – ammeter
7 – resistor
8 – motor
9 – diode
10 – thermistor
11 – variable resistor
12 – light-dependent resistor (LDR)
13 – light-emitting diode (LED)

SP10a.3 Electric circuits – Strengthen

1 a lamp
b switch
c cell

2 circuit diagram with a cell switch and lamp

3 missing words filled in the following order: current, electron, negative, conventional

4

Particle	Relative charge	Relative mass	Location in atom
proton	+1	1	nucleus
neutron	0	1	nucleus
electron	–1	$\frac{1}{1835}$ (negligible)	around nucleus

SP10a.4 Atoms and circuits Homework 1

1 pairs: 1c, 2d, 3e, 4b, 5f, 6a

2 **a** f

b d

3 circuit diagram of series circuit with two cells; positive terminal connected to lamp then switch, lamp, switch

4 nucleus, proton, neutron and electron labelled in correct positions

SP10a.5 Series circuits, parallel circuits and atoms – Homework 2

1 **a** protons

b neutrons

c Neutrons have no charge.

2 diagram labelled ‘nitrogen-14 atom’; seven protons and seven neutrons labelled in nucleus; seven electrons labelled around nucleus

3 circuit diagrams:

a series circuit; two cells, positive terminal to lamp then switch, lamp, switch, lamp

b parallel circuit; two cells, positive terminal to switch branch to two lamps in parallel, then rejoin to one lamp in series and back to negative terminal

4

Series circuits
If one lamp breaks, they all go out.
Lamps cannot be switched on and off independently.
As more lamps are added, the brightness of each one is dimmer.
Parallel circuits
If one lamp breaks, the others stay on.
A lamp in a branch of the circuit can be switched on and off independently from the other branches.
As more lamps are added, the brightness of each one stays the same.

5 The third and fourth will have the same brightness.

6 **a** a flow of charge

b Conventional current goes from the positive terminal of the cell around the circuit to the negative terminal; the flow of electrons is in the opposite direction, from negative to positive.

7 A metal has free electrons that can move through the metal and carry a charge. Wood does not.

SP10b Current and potential difference

Student Book

1 **a** X = 0.2 A

b Y = 0.4 A

c Z = 0.6 A

2 0.4 A

3 The marbles will roll down the ramp and reach a higher speed at the bottom, because they have more gravitational potential energy at the top, which is transferred to kinetic energy.

4 **a** To transfer energy to the electrons or so that there is a force on the electrons to make them move.

b So that there is a complete path for the electrons.

5 A = 3 V, B = 1.5 V, C = 4.5 V

S1 voltmeter, ammeter, lamp, switch and cell

S2 A = 20 mA, B = 0.75 V

E1 A = 20 mA because that is the current in the circuit; B = 0.75 V because there are two lamps in series so the voltage is halved across both of them; C = 20 mA because the current is 40 mA in the whole circuit but halved in one of the branches; D = 40 mA because the current is 40 mA in the whole circuit; E = 3 V because there is a voltage of 3 V in the circuit as a whole; F = 0 V because that part of the circuit is not closed so no current will flow.

Exam-style question

Connect an ammeter in series with the lamp to measure current (1) and a voltmeter in parallel with the lamp to measure potential difference (1).
(Can be shown on a circuit diagram.)

Activity and Assessment Pack

SP10b.1 Measuring current and potential difference in circuits

2 The current decreased.

3 The potential difference across each lamp decreased.

4 Current for two lamps = half current for one lamp. Current for three lamps = one third current for one lamp.

5 (If lamps are identical) potential difference for two lamps = half potential difference for one lamp. Potential difference for three lamps = one-third potential difference for one lamp.

6 Total current increased.

7 The potential difference stayed the same across each lamp.

8 Current for two lamps = twice current for one lamp. Current for three lamps = three times current for one lamp.

9 Potential difference stays the same.

10 **a** student's own answer

b If yes, then we can assume that lamps were the same; if no, this could be because the lamps were different (although it could also be due to differences in the batteries or poor connections).

SP10b.2 Using models

1 **a** electrons

b conductors

c cell

d lamp

2 They will continue to roll down the slope.

3 The current stops everywhere when the cell is disconnected.

4 Make the lift higher. The marbles would roll faster.

5 **b** The cell pushes the electrons around the wires in the circuit.

c The electrons do not get used up, they just go around and around the circuit.

d The lamp transfers energy by heating and radiating.

e This increases the thermal store of energy in the room.

6 B

7 C

SP10b.3 Current and potential difference – Strengthen

1 correct match of symbol and label

2 **a** ammeter

b voltmeter

c series

d series

e potential difference

3 3 V

4 **a** decrease

b decrease

c decrease

SP10b.4 Circuits – Homework 1

1 **a** current

b potential difference (voltage)

c ammeter in series, voltmeter in parallel

2 A = 1 A, B = 4.0 A

3 A = 2 V, B = 4.5 V

4 the same as, half, half, half

SP10b.5 More about circuits Homework 2

1 **a** circuit with battery, lamp and switch; ammeter in series and voltmeter in parallel

b ammeter

c voltmeter

2 a potential difference (provided by a cell/battery) across the circuit and a complete unbroken circuit

3 The potential difference between two points is the difference in potential energy that a charge would have after moving from one point to the other. (The potential difference between two points is 1 V if 1 J of energy is transferred to or from a charge of 1 C when it moves from one point to the other.)

4 **a** single lamp (F) = 4.8 A, two lamps in parallel = 2.4 A (i.e. half through each), three lamps in parallel = 1.6 A (i.e. one-third through each)

b potential difference = sum of series potential differences = (6.6 + 3.3 + 2.2) V
= 12.1 V

5 Cells in series have a higher total potential difference than one cell, but will last for the same time as one cell. Cells in parallel will have the same potential difference as one cell but will last for a longer time than one cell.

6 **a** a = b = c = 0.1 A, d = 3 × a (or b or c) = 0.3 A, e = d + a (or b or c) = 0.4 A

b V across a = V across b = V across c = 0.6 V

c V across d = V across a + V across b + V across c = 1.8 V

V across E = 2.4 V

Battery potential difference = 1.8 V + 2.4 V = 4.2 V

SP10c Current, charge and energy

Student Book

4th **1** A current is the rate of flow of charge. In metals the current is caused by electrons moving.

6th **2** 2 A × 8 s = 16 C

7th **3** $\frac{10\text{ C}}{0.5\text{ A}}$ = 20 s

7th **4** 8 C × 3 V = 24 J

8th **5** $\frac{150\text{ J}}{50\text{ C}}$ = 3 V

S1 Doubling the current doubles the rate at which charge flows, so there is twice as much in the same time. Switching on for 3 times as long means 3 times as much charge will flow. So 2 × 3 = 6 times as much charge flows in the circuit.

S2 A cell with double the potential difference will transfer double the energy to each coulomb of charge passing through it.

E1 charge = 44 × 60 × 60 = 158 400 C

potential energy = 158 400 × 12 = 1 900 800 J or 1.9 × 10^6 J (2 significant figures)

Exam-style question

A potential difference of 4 V means that 4 J of potential energy (1) is transferred to (or from) each coulomb of charge (1).

Activity and Assessment Pack

SP10c.1 Measuring energy transferred in a circuit

(page 1)

3 The values calculated and measured should be similar but, owing to the small size of the unit, there is likely to be quite a large difference in the actual numbers.

4 Doubling the time should double the energy transfer.

(page 2)

4 Doubling the time will double the energy transferred.

5 Energy will be transferred by heating to the wires in the circuit and to the meters.

6 No, because the joulemeter is measuring the energy transferred in more connecting wires and in the ammeter and voltmeter.

7 The meters will probably give slightly different values depending on exactly where they are placed in the circuit. This is because they are not connected across exactly the same circuit.

SP10c.2 Rope model of an electric circuit

1 boxes on diagram, clockwise from top left:

a cell; a current; a component, e.g. lamp; a component, e.g. lamp; a transfer of energy by heating; the electrons in the wire; a switch

2 added to table:

good – Current is the same everywhere in a circuit.

poor – A complete circuit is needed for current to flow.

good – Current stops everywhere when there is a break in the circuit.

SP10c.3 Current, charge and energy Strengthen

1 coulomb, C

2 $t = \frac{Q}{I}$

3 **a** doubled

b halved

c doubled

4 $V = \frac{E}{Q}$

5 It will double.

6 **a** 60 C

b 0.5 C

7 18 J

8 **a** 1 J

b joule, coulomb

SP10c.4 Calculating charge and energy 1 – Homework 1

1 **a** charge

b electrons, charge, potential difference, current

- **c** potential difference
- **d** energy, coulomb, volt

2
- **a** charge = current × time
- **b** The total amount of charge doubles.
- **c** 72 C
- **d** 900 C
- **e** 40 s

3
- **a** The energy transferred doubled.
- **b** 7200 J
- **c** 270 J
- **d** 400 C

4
- **a** 360 C
- **b** 1620 J

SP10c.5 Calculating charge and energy 2 – Homework 2

1 rate of flow of charge

2 A metal contains electrons that are free to move. When there is a potential difference across the metal the electrons all move in the same direction. They have a negative charge. This flow of charge forms a current.

3 540 C

4 900 C

5 7 A

6 600 s = 10 minutes

7 the energy transferred to a unit charge which passes through the cell

8 1 volt = 1 joule ÷ 1 coulomb

9 8100 J

10 5200 C

11
- **a** 2970 C
- **b** 59 400 J
- **c** Some energy transferred by heating, dissipated, increasing the thermal energy store of the surroundings.

12
- **a** $t = 6 \times 60 \times 60 = 21\ 600$

  $Q = 0.9 \times 21\ 600 = 19\ 440$

  $E = 19\ 440 \times 5 = 97\ 200$ J
- **b** The electric current transfers energy to the battery, where it increases the chemical store of energy in the battery. Some energy is transferred by heating the charger, the wires, the battery and the surroundings, or some energy is transferred by heating and dissipated in the surroundings.

SP10c.6 Equation practice

1
- **a** 180 C
- **b** 12.5 A
- **c** 720 s
- **d** 0.5 A
- **e** 3600 s (or 1 hour)

2
- **a** 180 C
- **b** 3000 s or 50 minutes

3
- **a** 220 C
- **b** 15 840 C

4
- **a** 11 400
- **b** 3
- **c** 300
- **d** 2000
- **e** 12

5
- **a**
  - **i** $Q = I \times t = 0.001 \times 1 \times 60 \times 60 = 3.6$ C
  - **ii** 6000 mA = 6A

    $Q = I \times t = 6 \times 1 \times 60 \times 60 = 21\ 600$ C
  - **iii** $t = Q \div I = 21\ 600 \div 2 = 10\ 800$ s or 3 hours
- **b**
  - **i** $E = Q \times V = 21\ 600 \times 5 = 108\ 000$ J
  - **ii** $E = Q \times V = 1000 \times 5 = 5000$ J

SP10d Resistance

Student Book

1 $\frac{9\text{ V}}{600\ \Omega} = 0.015$ A or 15 mA

2 Current increases because resistance has decreased and more current can flow.

3
- **a** $\frac{6\text{ V}}{30\ \Omega} = 0.2$ A
- **b** $\frac{12\text{ V}}{0.2\text{ A}} = 60\ \Omega$ (or 30 + 30 = 60)

4 Total R is 120 Ω so $I = \frac{12}{120} = 0.1$ A, i.e. half of previous current.

Potential difference across X is 0.1 A × 20 Ω = 2 V and across Y is 0.1 A × 100 Ω = 10 V (or 12 – 2 = 10 V) so V across X is less than it was but it has increased across Y.

5 It is smaller because there are two pathways for the current to pass through.

S1 Voltage = current × resistance. If you increase the resistance but not the voltage then the current will drop. To get the same current at a higher resistance, you need to increase the voltage.

S2 Diagram of three 100 Ω in series which gives maximum resistance. This is because the current has to pass through all three (or because the total of the potential differences across each resistor gives the total potential difference so there is less p.d. across each resistor, so current will be less). Three resistors in parallel give minimum resistance because there are three routes for current to pass.

E1 Potential difference across each resistor is equally shared, i.e. 6 V.

current = $\frac{6\text{ V}}{200\ \Omega}$ = 0.03 A so total resistance is

$\frac{12\text{ V}}{0.03\text{ A}}$ = 400 Ω

E2 total $I = \frac{12\text{ V}}{200\ \Omega} + \frac{12\text{ V}}{200\ \Omega}$

= 0.06 A + 0.06 A = 0.12 A

total $R = \frac{12\text{ V}}{0.12\text{ A}}$ = 100 Ω

Exam-style question

V across resistor Z = 9 V – 3 V = 6 V (1)

For Z $R = \frac{6\text{ V}}{0.05\text{ A}}$ (1) = 120 Ω (1) ecf value of 6 V

Activity and Assessment Pack

SP10d.1 Investigating resistors

(page 2)

2 **c** larger
d the current doubled
e doubles

3 **b** should be a straight line through the origin
d should be a straight line through the origin but steeper

SP10d.2 Resistors in series

(page 2)

2 **b** They are the same.
c The calculated value is the sum of the two resistances.

3 total resistance in series = sum of all the resistances

4 1 kΩ + 1 kΩ = 2 kΩ

SP10d.3 Resistance – Strengthen

1 ohm Ω

2 difficulty, current

3 **a** $I = \frac{V}{R}$
b $I = \frac{12}{3}$ = 4 A
c $I = \frac{12}{6}$ = 2 A
d When the resistance increased the current decreased.

4 **a** smaller, larger
b larger, smaller

SP10d.4 Resistors and resistance Homework 1

1 A = cell, B = resistor, C = variable resistor

2 **a** increases, easier
b ohm, Ω

3 $V = I \times R$

4 9 × 3 = 27 V

5 100 ÷ 4 = 25 Ω

6 **a** 200 + 180 = 380 Ω
b (1.5 × 1000) + 500 = 2000 Ω (or 2 kΩ)

7 **a** increases
b decreases

8 **a** current and potential difference
b ammeter added in series – anywhere in the circuit
voltmeter added in parallel with the resistor – not with the variable resistor or the cell
c by decreasing the resistance of the variable resistor (Changing is worth some credit – but decreasing is correct.)
d Decreasing the resistance makes it easier for the current to pass around the circuit. (‘Increases the potential difference across the resistor’ is also an acceptable answer.)

SP10d.5 Resistance and resistors Homework 2

1 **a** ohm Ω
b $V = I \times R$

2 **a** Current decreases.
b Increased resistance means it is more difficult for current to flow, so for the same potential difference current is less.

3 $\frac{9}{36}$ = 0.25 A

4 $\frac{230}{12}$ = 19 Ω (or 19.2 Ω to 3 sf)

5 **a** The total resistance is increased because the current has to pass through both resistors so it is more difficult. (or Because the potential difference is shared between the resistors.)

b The total resistance is less because there are two paths for current to pass so it is easier.

6 **a** $\frac{24}{3 \times 1000}$ = 0.008 A (or 8 mA)

b 3 kΩ + 5 kΩ = 8 kΩ

c $I = \frac{V}{R} = \frac{24}{8}$ kΩ = 0.003 A or 3 mA

d **i** 3 kΩ × 3 mA = 9 V

ii 5 kΩ × 3 mA = 15 V

7 **a** Series circuit: cell or battery, variable resistor, fixed resistor, ammeter (switch optional). A voltmeter connected in parallel with the resistor – not with the variable resistor or the cell.

b **i** Measure current and potential difference.

ii Use $V = I \times R$ to calculate resistance.

iii Adjust the variable resistor so that the resistance is lower to give a higher current.

8 **a** Connect each wire in turn in series with a battery and an ammeter. There will be no current through the broken wire.

b Series circuit: battery, ammeter, yellow wire, 47 Ω resistor, blue wire, 10 Ω resistor, red wire, 3 Ω resistor, green wire, battery.

c resistors in series:
total resistance = 47 Ω + 3 Ω + 10 Ω
= 60 Ω

d $\frac{12\ \text{V}}{60\ \Omega}$ = 0.2 A (or 200 mA)

e $\frac{12\ \text{V}}{0.16\ \text{A}}$ = 75 Ω

f all 4 wires: 75 Ω − 60 Ω = 15 Ω
1 wire = 15 ÷ 4 = 3.75 Ω (3.8 Ω to 2 sf)

SP10d.6 Equation practice

1 230, 4, 1800, 12, 0.1, 18 (17.7 to 3 sf)

2 $\frac{5}{1000} \times (1 \times 1000) = 5$ V

3 **a** $\frac{9}{3} = 3\ \Omega$

b $\frac{3}{12} = 4$ A

4 **a** $A = \frac{12}{0.030} = 400\ \Omega$

$B = \frac{6}{0.012} = 500\ \Omega$

$C = \frac{12}{0.015} = 800\ \Omega$

b C

SP10e More about resistance

Student Book

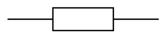
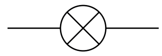
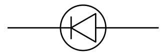
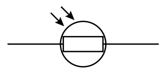
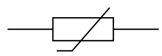
1 **a** A fixed resistor is an electrical component which has the same resistance for all values of the potential difference across it.

b The current is doubled.

2 Because it is not a straight line.

3 As the light intensity increases, the resistance of the LDR decreases.

4

Component	Symbol
Fixed resistor	
Filament lamp	
Diode	
Light-dependent resistor	
Thermistor	

5 As the temperature increases, resistance in a thermistor decreases, so more current flows.

6 **a** Measure the current and potential difference in the circuit at the lowest possible resistance. Then increase the resistance and measure potential difference and current for each resistance increase.

b As the potential difference increases the current will increase, but they will not be in direct proportion because the resistance increases.

7 **a** thermistor, beaker, ice, kettle, thermometer

b circuit diagram which is similar to figure D in the Student Book, but with a thermistor in place of the lamp

7th

c Measurements of current and potential difference should be taken at a variety of temperatures, i.e. close to freezing and then in roughly five-degree intervals to about 40 degrees (the equipment will be damaged above this temperature).

S1 **a** Fixed resistor is a straight line, lamp is an S shape/curved/non-linear.

or

For the fixed resistor resistance does not change as potential difference is changed. This means that the current is in direct proportion to the potential difference and there is a straight line on the graph. For the filament lamp the current also increases as the potential difference increases but the resistance is not constant. The resistance increases as the potential difference increases.

b The resistance does not change in the fixed resistor and there is a straight line on the graph, which means that current is in direct proportion to potential difference. The resistance in the diode is very high when the potential difference is in one direction, in fact no current flows at all. When the direction of the potential difference swaps direction the current does flow and the diode behaves more like a fixed resistor.

S2 Heater – use a thermistor: when the temperature falls the resistance will rise and this can be used to turn on a heater.

Light – light dependent resistor: when it gets dark the resistance in the LDR will rise and this can be used to turn on a light.

E1 between 0 °C and 1 °C (i.e. low temperature)

Exam-style question

As light intensity increases, the current increases (1) because the resistance of the LDR decreases (1).

SP10e Core practical – Investigating resistance

Student Book

1 ohms (or Ω) (1)

2 **a** An ammeter has to measure the current through a component (1), so the same current must flow through the ammeter (1).

b It has to measure the potential difference across the component (1), and not transfer energy itself, so it has to be connected in parallel (1).

3 Graph with sensible scales on axes (1) and axes labelled (1).

All points correctly plotted to ± half a square (2). Only one mark if 1 point plotted in error, 0 marks if more than one error.

Smooth curve passing through all the points for each line (1), suitable key (1).

4 **a** R (at 1 V) = $\frac{1\text{ V}}{0.2\text{ A}}$ (1) = 5 Ω (1)

R (at 6 V) = $\frac{6\text{ V}}{1.2\text{ A}}$ = 5 Ω (1)

b R (at 1 V) = $\frac{1\text{ V}}{0.12\text{ A}}$ = 8.3 Ω (1),

R (at 6 V) = $\frac{6\text{ V}}{0.53\text{ A}}$ = 11.3 Ω (1)

5 **a** The graph for the resistor shows that the current is directly proportional to the potential difference (1), which means that the resistance is constant even when the voltage changes (1). This is supported by the calculations, which show the same resistance at 1 V and 6 V (1).

b Any three points from: the graph for the filament lamp shows that there is no linear/proportional relationship between potential difference and current (1). The line shows that for each 1 V increase in potential difference, the increase in current gets less and less (1). This means that the resistance increases with increasing potential difference (1). This conclusion is supported by the calculations which show that the resistance is higher at 6 V than at 1 V (1).

c Repeat the investigation with other resistors and filament lamps (1). If the same results were obtained it would support the conclusion (1) but would not prove that the conclusion held for *all* resistors/lamps (1).

6 **a** Both should be 0.23 A (1) because the current is the same everywhere in a series circuit (1).

b 0.82 A (1) because the current through the power pack/cell is the sum of the currents in the branches of the circuit (1).

7 **a** **i** $R = \frac{4\text{ V}}{0.23\text{ A}}$ (1) = 17.4 Ω (1)

ii $R = \frac{4\text{ V}}{0.82\text{ A}}$ (1) = 4.9 Ω (1)

b Connect them in parallel. (1)

Activity and Assessment Pack

SP10e.1 Investigating resistance

3 **a** Students' graphs should show a straight line through the origin for the resistor, although a curve will result if wires get hot. There should be a curve (the slope of the line becoming shallower at higher potential difference values) for the filament lamp.

b As the potential difference increases, the resistance of the resistor stays the same – but the resistance of the filament lamp increases with increasing potential difference.

c The graph for the resistor is a straight line through the origin, which means that current is proportional to potential difference and so the resistance is the same for all values of potential difference. Students may also refer to the resistance calculations they carried out for 1 V and 6 V power pack settings.

The graph for the filament lamp shows that the current is not proportional to the potential difference. As the potential difference increases, the current does increase but the change in current gets less and less for each increase in potential difference. This shows that the resistance increases as the potential difference increases.

4 **a** students' own answers

b Answers should refer to better-quality data producing points that lie close to the line of best fit.

5 student's own answers

6 **a** In circuit C, the reading on A2 should be the sum of the readings on A3 and A4, because current is conserved and the current through A2 splits to go through A3 and A4.

A good answer might also point out that if all the lamps are identical, the current in A1 will be half that in A3 and A4, because the potential difference across each lamp in circuit B is half that across each lamp in circuit C.

b If the lamps are identical, V2 and V3 will be the same. V1 = V2 + V3, because the potential difference in a series circuit is divided between the components.

In circuit C, the readings on all the voltmeters should be the same, because the voltage is the same across each branch of a parallel circuit.

8 **a** The current through each filament lamp in parallel should be twice the current measured in circuit B.

b The potential difference across each filament lamp in parallel should be twice the potential difference across each lamp when they are in series.

9 Increasing the potential difference across the supply changes the resistance of the filament lamps. This should not affect how the potential differences across the circuits compare, but may mean that the current through A3 and A4 is twice that of A1 only for lower potential difference settings, and is less than twice A1 at higher potential difference settings.

10 If fixed resistors are used, changing the potential difference across each circuit should not affect the comparisons, because the resistance does not change with potential difference.

SP10e.2 Resistance in fixed resistors, filament lamps and diodes

1 **a** line graph of current (vertical-axis) versus potential difference (horizontal-axis)

b a straight line through the origin

c two values of 25 Ω

d Current is directly proportional to potential difference.

2 **a** line graph of current (vertical-axis) versus potential difference (horizontal-axis)

b A curve starting at the origin; the slope decreases as potential difference increases.

c As the slope decreases the resistance increases.

3 **a** milliamp/milliampere

b line graph of current (vertical-axis) versus potential difference (horizontal-axis)

c The graph is flat/horizontal for negative and low values of potential difference. The graph then curves upwards and the gradient increases until it is very steep.

d For negative potential differences the current is zero.

SP10e.3 More about resistance Strengthen

1 **a** diode, light-emitting diode (LED)

b light-dependent resistor (LDR)

c thermistor

2 **a** Z

b potential, resistance, curves and becomes less steep

3 **a** heater or a fan (or air conditioning)
b light

4 series circuit with battery ammeter and LDR, voltmeter in parallel with LDR

SP10e.4 Components and resistances Homework 1

1 **a** variable resistor
b filament lamp
c thermistor
d diode and light-emitting diode
e light-dependent resistor
f LDR
g thermistor
h LED
i diode

2 The current will decrease.

3 **a** $\frac{10\ \text{V}}{2\ \text{A}} = 5\ \Omega$ (correct answer not crossed out)
b it doubles
c doubles, stays the same

4 **a** increases, increases
b decreases
c increases

5 **a** e.g. stopping a current flowing the wrong way in an appliance and causing damage
b e.g. switching a light on when it gets dark
c e.g. switching on a heater, switching on a cooling fan

6 **a** decreases
b decreases

SP10e.5 Components with changing resistance – Homework 2

1 It increases.

2 It doubles because the resistance is constant and $V = I \times R$.

3 **a** A graph of I against V showing I is zero for negative values of V and for very small positive values. It then increases with very steep gradient (see graph A in *CP9e More about resistance* in the Student Book).
b The current is zero because the diode can only conduct in one direction.
c At a small value of positive potential difference the resistance of the diode falls so the diode starts to conduct and the current increases. It now has a very small resistance so a small increase in potential difference causes the current to rise by a large amount.
d To stop current passing in the wrong direction in a circuit and causing damage, for example.
e A light-emitting diode.

4 **a** $\frac{5\ \text{V}}{100\ \Omega} = 0.05\ \text{A}$
b It will decrease.
c It will increase.
d e.g. to switch on a light when it gets dark

5 **a** $\frac{12\ \text{V}}{3\ \text{A}} = 4\ \Omega$
b It will increase.
c It will decrease.
d e.g. switching on a heater, switching on a cooling fan

Extra challenge

6 **a** **i** It will be very large.
ii It may damage the LED.
b to keep the potential difference across the LED to 2 V or less (Accept ‘to keep the current low’, but do not accept ‘so it doesn’t damage the LED’.)
c If p.d. across LED is 2 V then p.d. across resistor is 5 − 2 = 3 V.
The current in the circuit is 10 mA = 0.01 A or 1×10^{-2} A.
The resistance of the resistor is
$\frac{3\ \text{V}}{0.01\ \text{A}} = 300\ \Omega$
d Higher, so that the potential difference across the resistor is higher and the current through it is lower. This will mean the potential difference across the LED is lower than 2 V.

SP10f Transferring energy

Student Book

5th **1** Any four from: kettle, oven, grill, hotplate, toaster, sandwich maker, tumble dryer, washing machine, dishwasher, electric heater, immersion (water) heater, de-mister on car windows, etc. (but not a microwave oven).

5th **2** Example such as computer/TV/fridge/electric motors/electric cables where the energy is transferred by heat and dissipates.

7th **3** A larger current means that there are more electrons colliding with the ions in the lattice every second. More collisions means more energy is transferred. This means that more heat is dissipated so the resistor gets hotter.

8th **4** The wires are thick because thicker wires have lower resistance. They are made of copper because this is a metal with low resistance. The lower the overall resistance, the less work has to be done against resistance and so the less energy is transferred from the wires to the surroundings (be heating).

8th **5** $E = 0.9\text{ A} \times 230\text{ V} \times 60\text{ s} = 12\,420\text{ J}$

8th **6** $E = 0.22\text{ A} \times 4.5\text{ V} \times (30 \times 60\text{ s}) = 1782\text{ J}$

8th **7** $V = 900\text{ J}/0.5\text{ A} \times (20 \times 60\text{ s}) = 1.5\text{ V}$

S1 When the current flows, energy will be transferred as heat from the cable. If the cable is wound up, all the heat will be transferred in a small space. This will cause a large temperature change, which may melt the insulation and/or cause a fire.

E1 There will be more collisions with the electrons and so the resistance will increase.

E2 1 mA = 0.001 A; in 1 second, the LED transfers 3 V × 0.02 A = 0.06 J while the filament lamp transfers 2.5 V × 0.32 A = 0.8 J, i.e. the filament lamp transfers more than 13 times more energy.

Exam-style question

Some of the energy transferred by the kettle will be used to raise the temperature of the heating element (1) and some will be dissipated to the surroundings (1) and not used to boil the water.

Activity and Assessment Pack

SP10f.1 Heating water

2 change in water temperature = about 10 °C (12 V) and 5 °C (6 V)

3 $E = 12\text{ V} \times 2.08\text{ A} \times 14 \times 60\text{ s}$

$= 20\,966\text{ J}$

$= 210\,000\text{ J}$ (3 sf)

4 Less, as some energy transferred to the surroundings, e.g. wires, heater, beaker.

5 **a** Less (5 °C)

SP10f.2 Advantages and disadvantages of electrical heating

2

Electrical appliance	Useful heating effect	Example of alternative without electricity
electric fire	[heating a room]	[gas fire]
electric blanket	heating a bed	water bottle or warming pan or hot brick
toaster	toasting bread	gas grill or toasting fork over coals
kettle	boiling water	pan on gas/wood/coal fire
iron	getting creases out of clothes	metal iron heated in gas/wood/coal fire
immersion heater	heating water	gas/oil/coal boiler
hair dryer	drying hair	towel
glue-gun	melting glue to stick things	other types of glue

3

e.g. electric oven	cooking food	gas/coal/oil/wood oven
e.g. deep fat fryer	frying food	pan of oil on gas/coal/oil/wood stove

4 This will depend on the appliances chosen, but could be cleaner (e.g. than coal/wood fire), quicker (e.g. than wood/coal), more controllable (e.g. iron/toaster/kettle), easier to use (e.g. iron/deep fat fryer), safer (e.g. deep fat fryer/iron).

5 The problems are:

- Overheating may cause damage (especially TV).
- Overheating may cause fires (especially cables in house walls).
- Overheating is unwanted transfer to thermal energy and this electrical energy is charged for by the electricity company. All losses, including overhead cable losses, have to be paid for by the electricity companies and they will pass on the costs to consumers.

P9f.3 Equation practice

1 a 496 800 J
  b 86 400 J
  c 4 A
  d 6 V
  e 900 s
  f 3000 s

2 230 V × 2 A × 1 × 60 s = 27 600 J

3 2880 J ÷ (12 V × 0.5 A) = 480 s = 8 minutes

4 230 V × 13 A × 1 × 60 × 60 s
= 10 764 000 J
= 11 MJ to the nearest MJ

5 82 800 J ÷ (230 V × 0.3 A)
= 1200 s
= 20 minutes

6 energy used by kettle A
= 230 V × 13 A × 5 × 60 s
= 897 000 J

time taken by kettle B
= 897 000 J ÷ (230 V × 10 A)
= 390 s = 6.5 minutes

or Allow directly from $E = I \times V \times t$
say $I \times t$ is the same in both cases
(because E and V are the same)
so:

time = (13 A ÷ 10 A) × 5 minutes = 6.5 minutes.

SP10f.4 Transferring energy Strengthen

1 a kettle, toaster, iron, electric blanket, glue-gun, hair-dryer, coffee machine
  b damage: any
  fire: any except overhead cables
  waste of energy: TV, laptop, phone charger, overhead cables, table lamp

2 a C
  b B

3 The surface area of the cakes exposed to the air is higher.

4 Correct order is essential:

positive ions, free electrons, free electrons, positive ions, hotter, positive ions, free electrons, positive ions, energy, positive ions, hotter.

5 E = 230 V × 13 A × 50 s = 149 500 J

SP10f.5 Electrical heating Homework 1

1 e.g. kettle, toaster

2 a e.g. an appliance such as TV, connecting wires/cables, overhead cables, chargers/transformers
  b One of: will cost more to run because of wasted energy, could damage it, could cause a fire.

3 To stop them overheating.

4 a left-hand label = positive ions
  right-hand label = free electrons
  b arrows on free electrons pointing to the left
  c They vibrate more.
  d They make more collisions with the positive ions.
  e It increases because it is more difficult for them to pass through and they transfer energy to the ions.

5 a energy transfer, heats
  b work, resistance, dissipated, thermal energy

6 a E = 230 V × 13 A × 5 × 60 s = 897 000 J
  b t = 1 200 000 J ÷ (1000 V × 4 A)
  = 300 s = 5 minutes

SP10f.6 Resistance and thermal energy – Homework 2

1 e.g. kettle. Electric current passes through the element which heats up and then heats the water.

2 e.g. a cable carries a high current, it gets very hot and sets fire to something in the surroundings, e.g. walls of a house.

3 There are a lot of currents close together and the chip gets very hot. If it did not have a fan the chip would overheat, which damages it – or even causes it to catch fire.

4 a current = 0.16 + 0.3 + 0.4 = 0.86 A
  b These items all carry a much higher current – when these are added the total current in the cable may make the cable too hot and start a fire.

5 a Diagram similar to Figure b, page 392 Student Book
  b When free electrons pass through the material they collide with the positive ions. Energy is transferred to the ions so these collisions cause resistance.
  c more ions closer together

d Increasing temperature causes ions to vibrate more so that it is more difficult for the electrons to pass through without colliding. More collisions cause more resistance.

e More electrons passing through leads to more collisions, and more collisions leads to more energy transfer to the ions.

6

1 Choose a material with a lower resistance, e.g. copper rather than iron.

2 Use thicker wires.

3 Cool the wires.

7 E = 13 A × 230 V × 3 × 60 × 60 s

= 32 292 000 J = 32 MJ (to nearest MJ)

8 t = 2 400 000 J ÷ (0.4 A × 230 V)

= 26 086.9 s = 7 hours 15 minutes (to nearest minute)

Extra challenge

9 a Energy required
= 5.1 × 10^5 J × (49 − 15) °C
= 1.734 × 10^7 J

Time required
= 1.734 × 10^7 J ÷ (13 A × 230 V)
= 5799 s
= 1 hour 37 min (to nearest minute)

b Some of the energy is needed to heat the tank, the wires and the heater, and some thermal energy will be transferred to the surroundings, so the current will need to pass for a little longer for this additional energy to be transferred.

c If there is no water the thermal energy will not be conducted and convected away from the heating element of the immersion heater as efficiently. The heating element will overheat and will be damaged.

SP10g Power

Student Book

7th **1 a** $E = P \times t$

E = 3000 W × (60 × 60) s
= 3000 × 3600
= 10 800 000 J (or 10 800 kJ or 10.8 MJ)

8th **b** 28 halogen lights running for two hours = 10 800 000 J (second sentence in the Student Book).

For 1 halogen light = $\frac{10\ 800\ 000}{28}$
= 386 000 (to 3 sf).

8th **c** $P = \frac{E}{t}$

$= \frac{386\ 000}{3600}$

= 107 W

8th **2** $\frac{540\ 000}{3 \times 60}$ = 3000 W

7th **3** 20 × 12 = 240 W

8th **4** 1 kW = 1000 W

$\frac{3000}{230}$ = 13.0 A

8th **5** $\frac{46}{1150}$ = 0.04

So, current (I) = $\sqrt{0.04}$ = 0.2 A

S1 It transfers 650 joules of electrical energy every second.

S2 power (W) = $\frac{\text{energy transferred (J)}}{\text{time (s)}}$

or power = current (A) × potential difference (V)
or power = current (I)^2 × resistance (Ω)

E1 use power (W) = current (A) × potential difference (V); re-arrange to give

current (A) = $\frac{\text{power (W)}}{\text{potential difference (V)}}$

at 250 V, current = $\frac{500}{250}$ = 2 A

at 1000 V, current = $\frac{500}{1000}$ = 0.5 A

E2 use power (W) = current (A)^2 × resistance (Ω)

at 250 V power = 2^2 × 100 = 400 W

at 1000 V, power = 0.5^2 × 100 = 25 W

Much less energy is transferred to the surroundings every second at the higher potential difference so it is more efficient.

Exam-style question

For each spotlight, energy transferred (J) = power (W) × time (s) (1 mark for substitution and 1 mark for correct answer).

5 × (2 × (60 × 60)) = 18 000 J (or 18 kJ)

Activity and Assessment Pack

SP10g.1 Power ratings

6 Heating appliances generally have higher power ratings.

7 Appliances that are on for longer use more energy, so a low-power light on for many hours can use more than a high-power kettle that is only on for a few minutes.

SP10g.2 Energy and power

1 Predictions: (Students are not required to give their reasoning, but you might wish to discuss this with them so it is included here.)

Students should choose a heating device for the highest power rating, but not the iron (energy transferred less than three times that for the hair dryer, although on for three times as long), the hair dryer (less than twice the kettle, though on for twice as long), or the toaster (much less than the kettle although time not much less) – so fan heater or kettle. The kettle has the highest power; as they all have the same voltage this means it has the highest current and lowest resistance.

For lowest, LED light is sensible choice – on for longest yet only two appliances use less energy, both of which are only on for very short time. The LED lamp has the lowest power, as they all have the same voltage this means it has the lowest current and highest resistance.

Answers to **2a, 4a** and **7a** are in the table.

Appliance	Power (W)	Current (A)	Resistance (Ω)
Fan heater	2000	8.70	26
Filament bulb	100	0.43	529
iron	1000	4.35	53
Hair dryer	2200	9.57	24
television	150	0.65	353
kettle	2800	12.17	19
toaster	1200	5.22	44
LED light	3	0.01	17 633
Electric drill	600	2.61	88
Blender	300	1.30	176

2 **b** highest kettle, lowest LED light

3 highest kettle, lowest LED light (because voltage is the same, $P = I \times V$, and these have the highest and lowest power)

4 **b** highest kettle, lowest LED light

5 The appliance with the highest current will be the one with the highest power rating.

6 highest LED light, lowest kettle (because voltage is the same, $V = I \times R$ and current is lowest for LED light and highest for kettle)

7 **b** highest LED light, lowest kettle

8 The appliance with the highest resistance will be the one with the lowest power rating.

SP10g.3 Power – Strengthen

1 energy, energy, second

energy, time

watt, W

multiplied by OR times OR ×

2 **a** 1000 W
b 20 W
c 30 W
d 100 W
e 150 W

3 **a** 3000
b 7

4 $P = I \times V$

5 $P = I^2 \times R$

6 $\frac{4500\text{ J}}{3\text{ s}} = 1500\text{ W}$

7 30 A × 230 V = 6900 W

8 $(2\text{ A})^2 \times 6\ \Omega = 24\text{ W}$

SP10g.4 Electric power – Homework 1

1 **a** energy, second
b watts
c energy, time taken
d potential difference, current

2 **a** $\frac{18\,000\text{ J}}{60\text{ s}} = 300\text{ W}$

b $\frac{300\,000\text{ J}}{1000\text{ W}} = 300\text{ s} = 5\text{ minutes}$

3 $P = I \times V$

4 **a** 2 A × 12 V = 24 W

b $\frac{2000\text{ W}}{230\text{ V}} = 8.7\text{ A}$

5 $P = I^2 \times R$

6 **a** $(5\text{ A})^2 \times 100\ \Omega = 2500\text{ W}$

b $\frac{6400\text{ W}}{(8\text{ A})^2} = 100\ \Omega$

7 **a** 18 W × 10 s = 180 J

b $\frac{18\text{ W}}{9\text{ V}} = 2\text{ A}$

c $\frac{18\text{ W}}{(2\text{ A})^2} = 4.5\ \Omega$

(or $\frac{9\text{ V}}{2\text{ A}} = 4.5\ \Omega$)

8 Power transferred is equal to the potential difference multiplied by the current.

SP10g.5 Electric power and energy transfer – Homework 2

1 **a** watts, W

b Power is the rate of transfer of energy OR power is the energy transferred per second.

2 $P = \frac{E}{t}$

3 $P = I \times V \quad P = I^2 \times R$

4 **a** 400 W × 2 × 60 s = 48 kW

b 230 V × 2.2 A = 506 W

c $\frac{1400 \text{ W}}{230 \text{ V}} = 6.1 \text{ A}$

5 energy transfer in 3 kW kettle = 3000 × 5 × 60 s = 900 000 J

1.8 kW kettle: $\frac{900\,000 \text{ J}}{1800 \text{ W}} = 500 \text{ s}$ = 8 minutes 20 seconds

6 **a** $\frac{78\,000 \text{ J}}{5 \times 60 \text{ s}} = 260 \text{ W}$

b $\frac{260 \text{ W}}{36 \text{ V}} = 7.2 \text{ A}$

c $\frac{260}{(7.2)^2} = 5.0\ \Omega$ (or $\frac{36 \text{ V}}{7.2\text{A}} = 5.0$ A)

7 $\frac{200 \text{ W}}{(0.87 \text{ A})^2} = 264\ \Omega$ (260 Ω, to 2sf)

8 **a** $\frac{3 \times 10^3}{400 \times 10^3} = 7.5$ mA OR 7.5×10^{-3} A

$\frac{3 \times 10^3}{230 \text{ V}} = 13 \text{ A}$

b $(7.5 \times 10^{-3})^2 \times 10 = 5.6 \times 10^{-5}$ W OR 0.056 mW which is very small but $(13)^2 \times 240 = 1690$ W which is much larger.

c At 230 V over half of the 3 kW transmitted was transferred in heating the cable, because of its resistance, whereas at 400 kV only a very small amount was transferred in heating the cable. As the overhead cables are long they will have some resistance and the power wasted is much less at the higher voltage.

SP10g.6 equation practice

1 **a** 2700 W

b 780 J

c 1800 s

2 **a** 14 000 W

b 0.43 A

c 18 V (Accept answers with extra figures which round to these values.)

3 **a** 100 W

b 8 A

c 115 Ω

4 (Allow use of $P = \frac{V^2}{R}$ where appropriate.)

a **i** $P = I \times V = 2300$ W

ii $P = \frac{E}{t}$ (or $E = P \times t$) = 69 000 J

iii $P = I^2 \times R$ or $R = \frac{P}{I^2} = 23\ \Omega$

b **i** $P = I \times V$ or $I = \frac{P}{V} = 0.039$ A or 39 mA

ii $P = I^2 \times R$ or $R = \frac{P}{I^2} = 5900\ \Omega$

iii $E = P \times t = 5400$ J

c $P = I \times V$ or $I = \frac{P}{V} = 4.17$ A

$P = I^2 \times R$ or $R = \frac{P}{I^2} = 2.9\ \Omega$

SP10h Transferring energy by electricity

Student Book

1 **a** Energy stored in the battery is transferred by electricity to the motor in the toothbrush, where it is transferred to a store of kinetic energy in the vibrating brush.

b Energy stored in the battery is transferred by electricity to the high resistance wire in the cup, where it is transferred to a store of thermal energy in the hot wire.

2 **a** Electrical energy provided by the mains is transferred to the high resistance wires in the straighteners, where it is transferred to a store of thermal energy in the hot wires.

b Electrical energy provided by the mains is transferred to the motor in the drill, where it is transferred to a store of kinetic energy.

3 The charger reduces/changes the mains voltage from 230 V to 5 V in the phone and converts the alternating current/AC of the mains to direct current/DC in the phone.

4 **a** In direct current the charges move in one direction but in alternative current the charges move back and forth.

b In direct current, the voltage remains constant but in alternating current the voltage is continually changing.

5 The higher the power rating, the more energy is transferred.

6 1200 × 1 × 60 × 60 = 4 320 000 J

S1 Energy stored in the battery is transferred by electricity to the motor and the high resistance wire in the hair dryer. In the motor, electrical energy is transferred into stored kinetic energy in the fan that blows air. In the high resistance wire, electrical energy is transferred into stored thermal energy in the hot wire. All the energy is eventually transferred into thermal energy in the surroundings.

S2

	Mains electricity	12 V car battery
Voltage	large, 230 V, alternating/changes direction, 50 Hz	small, 12 V direct/one direction
Movement of charge	changes direction (100 times/second)	moves constantly in one direction

E1 A kettle has a high power rating. Using mains electricity means that the current is fairly low and safe. If a battery was used the current would be very large and the wires would heat up and be dangerous. Also the battery's store of energy would be used up very quickly.

Exam-style question

Electrical energy supplied by the mains is transferred into thermal energy in the high resistance wires in the fryer (1). The thermal energy is transferred from the hot wires to the oil so the oil becomes hot (1). Some thermal energy is also used to increase the temperature of the container and the surroundings. Eventually all the thermal energy is transferred to the surroundings (1).

Activity and Assessment Pack

SP10h.1 Energy stores and transfers

2 **a** The thermal store of the appliance and surroundings is increased.
b The mains appliances and items have the largest energy transfers.
c These are larger because there is a larger (kinetic) store of energy; batteries have only a small (chemical) store by comparison.

SP10h.2 Comparing a.c. and d.c.

1 = d.c.; 2 = d.c.; 3 = a.c.; 4 = d.c. in opposite direction; 5 = d.c. varying but always positive; 6 = a.c.; 7 = a.c. although most of time it is in positive direction

8A = 50 Hz (1 period = 0.02 s); 8B = 25 Hz (1 period = 0.04 s); 8C = 0.02 Hz (1 period = 50 s); so 8A is mains a.c.

SP10h.3 Transferring energy by electricity – Strengthen

1 **a** chemical
b kinetic
c thermal

2 **a** electricity, heating, dissipated
b electricity, light

3 230 V

4 **a** current, same
b same
c negative, positive
d current
e reversing
f peak
g 50

5 twice as much

SP10h.4 Transferring energy by electricity – Homework 1

1 **a** B
b A

2 **b** Energy is transferred by electricity from the chemical store of the battery to the heating wires in the hand warmer, and then by heating to the jacket and then the body, and then is dissipated in the surroundings.
c Energy is transferred by electricity from the kinetic store of the spinning turbine/generator at the power station to the heating element in the kettle, and then by heating from the element to the water, and then is dissipated in the surroundings.

3 alternating current and direct current

4 **a** all four boxes are in the same direction as first two
b repeat box 2, box 3 and box 4

5 230 V

6 50 Hz

7 9 W × 30 s = 270 J

8 3000 W × 60 s = 180 000 J

SP10h.5 Electricity and energy transfer – Homework 2

1 a chemical
  b kinetic
  c kinetic

2 heating devices: **a**, **d**, **e**; motors: **b**, **c**; both: **f**

3 a kinetic
  b thermal

4 a Energy is transferred by electricity from the chemical store of the battery to the thermal store of the blanket.
  b Energy is transferred by electricity from the kinetic store of the spinning turbine/ generator at the power station to the sewing machine motor. It increases the kinetic store of the motor.
  c Energy is transferred by electricity from the chemical store of the battery to the motor of the screwdriver. It increases the kinetic store of the motor.
  d Energy is transferred by electricity from the kinetic store of the spinning turbine/ generator at the power station to the thermal store of the heating elements in the curling tongs.

5 a Current is always in the same direction. Graph should show a current that is always positive.
  b Current that continually changes direction. Graph should show current that changes periodically from positive to negative.
  c Direct voltage is always in the same direction, whereas alternating voltage changes direction.
  d constant current and direction
  e a.c. voltage 230 V, frequency 50 Hz

6 portable (accept: already d.c., already low voltage)

7 high voltage (so higher power)

8 energy transferred is power rating × time

9 Appliance A transfers double the energy.

10 a 3000 × 15 × 60 s = 2700 kJ
   b 2500 × 60 × 60 s = 9×10^6 J or 9 MJ

11 a Energy in nuclear store of the Sun (not atomic – no atoms in the Sun) is transferred by light to the potential energy store of the electron. It is then transferred by electricity to the battery where it increases the chemical store of the battery.
   b 400×10^6 W × 2 × 60 × 60 s = 2.88×10^{12} J

SP10i Electrical safety

Student Book

1 live – red, neutral – blue, earth – yellow and green stripes

2 a 230 V
  b 0 V (no connection in normal use)
  c 0 V

3 5 A because the 3 A fuse would blow when the iron is carrying its normal current of 4 A

4 There is a large potential difference between the metal of the faulty appliance (up to 230 V) and the ground you are standing on (0 V).

5 It is the live wire that has the voltage of 230 V and carries the current from the power station to the appliance.

6 An ordinary wire would not melt if the current increased and would not break the circuit. The large current would continue to flow and would pass through you if you touched the metal part of the appliance. This current could kill you.

7 Similarities – both are safety devices that cut off the current if there is a problem.

Differences – circuit breakers are faster than fuses and so can stop you getting a shock, circuit breakers be do not need to be replaced so circuits can be set up safely again quickly.

S1

Wire	Voltage	Function
Live	230 V	Carries current from the power station to the appliance
Neutral	0 V	Returns current from the appliance to the power station
Earth	0 V	Provides a low resistance route for current from the appliance to the ground should a fault occur in the appliance

S2 A fuse contains a wire that melts and breaks the circuit if the current gets dangerously large.

The earth wire connects the metal parts of the appliance to the ground to carry the current safely away if a fault occurs in the appliance instead of allowing the current to pass through a person touching the appliance.

A circuit breaker is an automatic switch that cuts the circuit if too much current flows or it flows through the wrong wires.

E1 If the normal current through an appliance is quite low (less than 3 A) then a current of 10 A or more may damage the appliance but a 13 A fuse would not blow. It is safer to use a fuse with a lower current rating. The fuse chosen for a particular appliance should have a current rating a little larger than the normal current in the appliance.

Exam-style question

The earth wire connects the metal parts of the appliance to the ground (1) to carry the current safely away if a fault occurs in the appliance (1).

Activity and Assessment Pack

SP10i.1 Blowing a fuse

3 The maximum current increased as the thickness of the wire increased.

SP10i.2 Earth protection

Example boxes for flowchart, faulty toaster that is earthed:

Live wire touches casing.

Casing becomes live.

Current flows from live wire through fuse and metal casing to earth connection.

Current flows from earth connection through earth wire to plug (and then to metal spike in the ground).

Current blows fuse, breaking circuit.

Person touches metal case.

Nothing happens (toaster does not work and person does not get a shock).

Example boxes for flowchart, faulty toaster that is not earthed:

Live wire touches casing.

Casing becomes live.

Person touches metal case.

Current flows from live wire through metal casing to person.

Current flows from person to earth giving them an electric shock.

(The boxes may vary – as long as main steps are present. They may add 'person dies' to the second one which would not be unreasonable. Statements in brackets may be omitted.)

SP10i.3 Electrical safety – Strengthen

1 live – connects the appliance to the generators at the power station – 240 V

neutral – the return path to the power station – 0 V

earth – connects the metal parts to ground for safety – 0 V

2 live – brown, neutral – blue, earth – green and yellow

3 **a** clockwise from pin at top: earth wire to earth pin, live wire to live pin, neutral wire to neutral pin

b labelled clockwise from pin at top: earth pin/wire, fuse, live pin/wire, neutral pin/wire

4 It melts/breaks.

5 It increases.

6 switch, current, breaker, off

SP10i.4 Electricity at home Homework 1

1 **a** fuse: melts to cut off the circuit if the current is too high

b

Pin	Name of wire	Colour of wire	Voltage (V)
A	earth	green/yellow	0
B	live	brown	230
C	neutral	blue	0

2 **a** melts/blows, high/large, breaks

b earth, current, fuse, shock, appliance/case/metal

c switch, off, large/high

d blow/melt as soon as the appliance is switched on. (wording may vary)

e not melt until a large current flows which may damage the appliance or cause a fire. (wording may vary)

SP10i.5 Safety features – Homework 2

1 C = fuse

Key			
Pin	**Wire**	**Colour**	**Voltage (V)**
A	earth	green/yellow	0
B	live	brown	230
D	neutral	blue	0

2 Divide the power rating in watts by the mains voltage 230 V to get the normal current. The fuse should be slightly higher so it does not keep blowing.

3 **a** 3 A (current = 2.2 A)
b 13 A (current = 8.7 A)
c 13 A (current = 12.6 A)

4 **a** Damage/fire could occur before fuse blows.
b It will blow when the appliance is switched on and has the normal current.

5 A (earth) = to a metal spike in the ground

B (live) = to the generators at the power station

D (neutral) = return path to the power station

6 The current from live to earth blows the fuse safely, breaking the circuit.

7 **a** changes in current
b Current makes it get hot, and too high a current melts it and so breaks the circuit.
c Two of:
- Circuit breakers can be switched back on after fault is fixed; fuses must be replaced.
- Circuit breakers switch off much more quickly; fuses take time to melt.
- (Residual current) circuit breakers switch off when there is a difference in the live and neutral current, not just when the current is too high.

8 **a** The live wire could touch the metal case.
b The current flows from the live wire through the metal case to the earth wire. It then flows through the earth wire to the metal spike in the ground. This is a low resistance path so the current is very large. The large current melts the fuse. The circuit is broken so there is no current flow and the case is no longer live.
c **i** If the earth wire is not connected in the plug, there will not be a large current from live to earth, so the fuse will not blow.
ii If the fuse is replaced with a metal wire then it will not melt if there is a high current, and the case will still be live.
iii If the live and the neutral wires are connected the wrong way round, and the live wire touches the case, the fuse will blow, cutting off the neutral wire, so the case could still be live.

SP11a Charges and static electricity

Student Book

1 **a** negative
b positive

2 **a** They repel because both acetate rods have positive/the same type of charge.
b They repel because both polythene rods have negative/the same type of charge.
c They attract because they have different sign charges or one (polythene) is negative and the other (acetate) is positive.

3 The rulers will have the same type of charge so will repel each other.

4 All the strands of hair have the same type of charge so they will all repel each other and each strand of hair will move far away from the others.

5 **a** The balloon has a negative charge. This repels negative electrons in the wall. The surface of the wall becomes positively charged.
b The balloon is charged because when it is rubbed with the duster electrons are transferred to or from the balloon. The wall is charged because electrons are repelled away from the surface – but there is no actual transfer of electrons to or from the wall.

6 The rubbing charges the ruler. The charged ruler affects the distribution of charge in the paper so that the part of the paper nearest the ruler has the opposite charge to the ruler. The paper is then attracted to the ruler and jumps up towards it.

7 The bits of polystyrene are easily charged and they then affect the distribution of charge on the skin. The skin becomes oppositely charged and the pieces of polystyrene are attracted to the person's arms.

S1 Taking off the jumper causes friction between the jumper and your hair. This rubs off electrons from either the hair or the jumper. This makes the hair strands repel other hair strands and similarly charged clothing.

S2 The balloon is attracted to a positively charged rod so it must have a negative charge. If the balloon is brought close to a negatively charged rod the two will repel because like charges repel.

E1 The distribution of charge in the uncharged rod will be affected by the charged rod so there will be attraction between the hanging rod and the charged rod.

E2 The mirror becomes charged when it is rubbed by the duster because electrons are transferred to or from the duster. The distribution of charge in the dust is affected by the charged mirror, so that the part of the dust nearest the mirror has the opposite charge to the mirror. The dust is attracted and sticks to the mirror.

Exam-style question

a The balloons will move apart (1) because they both have the same charge and like charges repel (1).
b The balloons will move towards each other (1) because the distribution of charge on the uncharged balloon is affected by the charge on the charged balloon (1) so that the part of the balloon nearest the charged balloon has the opposite charge and the two balloons will be attracted (1).

Activity and Assessment Pack

SP11a.1 Attracting and repelling

3 **a** repel
b attract

SP11a.2 Static effects

4 **a** The paint droplets have lost electrons (to the needle).
b The paint droplets all have the same charge, and so repel one another.

SP11a.3 Charges and static electricity – Strengthen

1 Correctly labelled diagram. Refer to diagram A (and table B) on *SP6b Inside atoms* in the Student Book.

2 electricity, friction, negatively, negatively, positively, positively, repel

3 **a** positively charged
b repulsion

4 negative, repels, negative, positive, induced, attracts

SP11a.4 Static electricity Homework 1

1 positive, neutrons, electrons, mass, negative

2 a electrons
b protons
c friction
d attraction

3 a repel
b attract
c repel

4 a It loses electrons and so ends up with more positively charged protons than negatively charged electrons.
b It gains a negative charge because it receives negatively charged electrons.

5 a They are attracted to the plastic.
b negative
c induced (charge)
d The tissue paper and the plastic have opposite charges and opposite charges attract.

SP11a.5 Charges – Homework 2

1 a Electrons have been removed from it, leaving it with more protons than electrons.
b attract
c The two materials always interact in the same way, with one giving electrons to the other.
d The distance increases (increased electrostatic force of repulsion).

2 a the type of material
b the number of times/length of time the balloon is rubbed for (Accept other answers on their merits, such as doing all the experiments at the same time to avoid problems caused by changes in humidity.)
c This material (hair) was better at transferring electrons/gave electrons away most easily.
d The negative charges on the balloon repel the negative charges on the tissue paper. These charges move away from the surface of the tissue paper, leaving it with an induced positive charge. The negatively charged balloon and positively charged paper surface attract. Diagram similar to Figure C on page 161 of the student book, with pieces of tissue paper in place of the wall.

3 a Furniture polish is usually applied by rubbing (or a spray-on polish is then rubbed off with a duster). The rubbing action will transfer electrons between the cloth and the surface being rubbed, leaving the surface with a static charge that will attract dust.
b The polish contains a conducting material (such as a special polymer) that is left behind as a very thin layer when the solvent in the polish evaporates. This forms a thin conducting layer that prevents a static charge building up.

SP11b Dangers and uses of static electricity

Student Book

1 When you slide off the car seat, friction rubs electrons off or onto your clothes. This means that you are charged. When you touch the metal car, electrons flow through the car body so that the charges are balanced.

2 a from the metal to the boy
b Plastic is an insulator so charges cannot move through the insulator.

3 When lightning from the cloud strikes, electrons flow from earth up the lightning conductor to the cloud so that the cloud no longer has an unbalanced positive charge.

4 The plane might be charged, or become charged, and there might be a spark as it discharges. The spark might ignite the fuel vapour.

5 Because a spark could cause petrol or petrol fumes to ignite.

6 a The charge on the droplets causes the droplets to repel each other and spread out in a fine mist. The droplets change the charge distribution on the plant so that there is attraction between the plant and the spray and the spray sticks to the plant.
b Less insecticide is needed, which means it is better for the environment/money is saved by the farmer; the whole plant is covered so this spraying is more efficient.

S1 removing excess charge by allowing electrons to flow through a conducting path to or from the ground

S2 Disadvantages include sparks, which are dangerous when refuelling or uncomfortable when you get out of a car; advantages include that they can be used for efficient spraying (e.g. paint or insecticide).

E1 The tanks and pipes are earthed (for planes a bonding line is connected) so that there is no build-up of unbalanced charge. This avoids the risk of a spark, which could ignite the fuel vapour.

E2 Because the paint droplets are all charged (with the same charge) they spread out and are attracted to the object, so will coat it evenly all over.

Exam-style question

When the charged paint droplets land on the surface, they charge the surface, so eventually it would repel any more paint droplets (1). By earthing the object, the paint droplets continue to be attracted to the surface as the painting continues (1).

Activity and Assessment Pack

SP11b.1 Helicopters and static

A–3 d When the helicopter lands its static charge is earthed through the tyres, so it is safe to touch.

B–8 c The helicopter will have a large static charge. If a person standing on the ground touches it, that charge will run to earth through them and give them a severe electric shock.

C–2 f The helicopter will have a large static charge. If a person standing on the ground touches it, or uses an object to touch it, that charge will run to earth through them and give them a severe electric shock.

D–7 h The discharge wand allows the charge to run through the wand and the wire to earth, without passing through the person.

E–6 a The helicopter will have a large static charge. If a person standing on the ground touches the cable, that charge will run to earth through the cable and through them and give them a severe electric shock.

F–4 e The discharge wand allows the charge to run through the wand and the wire to earth, without passing through the person. However, as the helicopter is still hovering, it will quickly build up another charge unless the wand is kept in contact.

G–1 b This is unsafe because the person will be the first thing to touch the ground, so the static charge on the helicopter will be discharged through them.

H–5 g The cable will touch the ground first, so the static charge will run through the cable, not the person.

SP11b.2 Dangers and uses

Shocks from static electricity

B, G, K, E, P

Refuelling an aircraft

A, C, D, J, N, O

Spraying using static electricity

H, I, L, Q, F, M

SP11b.3 Dangers and uses of static electricity – Strengthen

1 friction, electrons, negative, insulating, electrons, conducting, person, earth, earthing, shock, discharged

2 **a** The charged drops spread out and so cover more crops.

b It earths the aeroplane and the tanker so there are no sparks.

c A cord of conducting material that allows electrons to flow through it.

3 **a** Ice and water droplets rub against each other, friction causes electrons to be transferred between them.

b from the ground into the cloud

SP11b.4 Static electricity, its dangers and uses – Homework 1

1 Your shoes rub on the carpet as you walk.

Some electrons are transferred from the carpet to your body.

You now have a negative charge.

When you touch a door handle, the charge can flow into the door and to earth.

You feel a shock when the charge jumps from you to the handle.

You are now discharged.

(Down the table: 1, 6, 3, 4, 2, 5)

2 friction, charges, positive, electrons, lightning, discharged, electrons, earthing

3 **a** The plane's static electricity would discharge (to the ground).

This could cause a spark

which could ignite the fuel.

b The bonding line allows an easy route for electrons to flow and to balance the charges on the aeroplane with the earth.

4 a They all have the same charge.
b To attract the oppositely charged paint droplets better.
c One of: ensures a more even coverage, less paint is wasted.

SP11b.5 Static problems Homework 2

1 The answer should include how charge can build up on a person, and what happens when a metal object is touched. Advice could include changing shoes for ones made of a different material that might not build up such a high charge, or holding a metal object towards the door so the spark jumps from the metal and not from the person's hand.

2 a They all have the same charge.
b The positively charged paint particles attract the electrons on the surface parts of the plants and induce a negative charge. The positive droplets are attracted to this induced negative charge.

3 a They rub together and the friction between them transfers electrons.
b The diagram should show the ground, and a cloud with the top being positively charged and the bottom being negatively charged.
c An arrow inside the cloud from negative to positive (from bottom to top if the previous question was answered correctly).
d The negatively charged bottom of the cloud will repel the electrons in the ground, leaving its surface with an induced positive charge.
e When the difference between the charge on the bottom of the cloud and the charge on the ground is great enough, lightning will be triggered.

4 a If one of the straps is broken it will not conduct electricity/electrons between the person and the casing of the board being worked on. So any static built up on the person could suddenly discharge into one of the components when it is touched.
b If the strap is working properly the lamp will light as there will be a complete circuit. If one is broken (i.e. not conducting between the wrist strap itself and the clip that is fastened to the equipment being worked on) then it will not conduct electricity and so will not discharge the person using it.

5 Sparks arising from static electricity could damage the circuitry in such items. If the prongs on a chip are all stuck into carbon-filled foam the conducting nature of the foam prevents a build-up of static charge that could harm the component. (Hard drives and new circuit boards are also delivered in anti-static bags.)

SP11c Electric fields

Student Book

5th 1 z

6th 2 Two diagrams, each showing a point charge with radial, evenly spaced field lines from the point charge. The field lines should have arrow heads pointing away from the charge and the charge with a stronger field should have more lines, closer together.

6th 3 a to the left, away from the point charge, in the direction of the field line
6th b to the right, towards the point charge, in the direction shown by the field line

6th 4 It would be attracted towards the electrode.

6th 5 It would move directly towards the negative charged plate/directly away from the positive charged plate.

7th 6 It is the same (because the field lines are evenly spaced everywhere).

S1 Diagrams showing two parallel plates with the second diagram having twice as many, evenly spaced, parallel field lines (so that the spacing is halved).

S2 Diagram from S1 with a small rectangle added and labelled, showing a positive charge induced in the side of the rectangle closest to the negative plate and a negative charge in the side closest to the positive plate.

E1 The electric field shows the direction a positive charge will move – it can't move in two directions at once, or the field line shows the direction of the field and it can only have one direction at any point.

E2 Two magnets attracting produce a field pattern in which the field lines go directly from the north pole to the south pole. This suggests that the field between a positive point charge and a negative point charge would form the same type of pattern.

Exam-style question

The paper is in the electric field of the charged balloon and the charges in the paper experience a force that changes their charge distribution (1). The charges closest to the balloon have the opposite charge to the balloon. They are in the strongest part of the field from the balloon and experience a force that attracts them to the balloon (1). The paper moves towards the balloon and sticks to it (1).

Activity and Assessment Pack

SP11c.2 Representing electric fields

A three lines drawn below the midline, to match those above it

arrows added on those lines, pointing away from the central positive charge

B two lines drawn (vertical above the central negative charge, horizontal to the right of the central negative charge)

arrows drawn on all lines, pointing towards the central negative charge

C line drawn (vertical below the central charge)

arrows added to all lines, pointing away from the central charge

positive charge (+) symbol added to central charge

D lines drawn on the right-hand side of the charge to match those on the left

arrows added to all lines, pointing towards the central charge

negative charge (−) symbol added to central charge

E curved line added below the midline, to reflect the one above it

arrow added to that line, pointing from left to right (+ to −)

F two vertical lines drawn to the right of the existing lines

new lines are equally spaced compared with the existing ones

downward pointing arrows added to the new lines

G negative (–) charge symbols added to the rectangle at the top

positive (+) charge symbols added to the rectangle at the bottom

up to 10 vertical lines drawn

new lines are both to the left and to the right of the existing vertical lines

new lines are equally spaced compared with the existing ones

upwards pointing arrows added to the new lines

SP11c.3 Electric fields – Strengthen

1 **a** positive charge

b (electric) field lines

c two vertical lines drawn to the right of the existing lines

new lines are equally spaced compared with the existing ones

downward pointing arrows added to the new lines

d up to 10 vertical lines drawn

new lines are both to the left and to the right of the existing vertical lines

new lines are equally spaced compared with the existing ones

downwards pointing arrows added to the new lines

e B

f The lines are closer together in B.

2 electrons, negatively, induced, repel, positively, positive, negative, field

SP11c.4 Thinking about electric fields – Homework 1

1 field, force, magnetic, gravitational, electric/electrostatic, electric/electrostatic

2 **a** Label on diagram A indicating that the electric field is strongest closest to the point charge.

b The field lines are closest together here.

c C

d Its field lines are closer together than the other two point charges.

e Arrows added to each of the lines in diagram C, pointing towards the central negative charge.

3 **a** Diagram to show two rectangles, with uniformly distributed field lines stretching from one to the other, the rectangle that represents the hand should have an indication that it is negative, the rectangle that represents the plate should have an indication that it is positive; arrowheads on the field lines pointing from positive to negative.

b Electrons flow from you to the metal plate, removing the excess negative charge from you.

SP11c.5 More electric fields Homework 2

1 **a** electrostatic field

b a force

c X is negative, Y is negative.

d The field line arrows are pointing towards the charges, these arrows always point towards negative charge (away from positive charge).

e nearest the charge

f This is where the field lines are closest together.

2 **a** The negative charge of the cloud repels electrons in the ground, leaving the surface of the ground with an induced positive charge.

b Diagram to show two rectangles, with uniformly distributed field lines stretching from one to the other, the top rectangle represents the cloud and should have an indication that it is negative, the bottom rectangle represents the ground and should have an indication that it is positive; arrowheads on the field lines pointing from positive to negative.

c The diagram drawn is uniform (the fields around point charges are not uniform).

d The speck would move upwards, attracted by the negatively charged cloud.

3 As you walk along the carpet you become negatively charged (because electrons have a negative charge). The charge cannot leave you because the carpet is an insulator. Just before your hand touches the handle, the door handle develops an induced positive charge. An electric field forms between your negative hand and the positive door handle. And molecules can become ionised, and allow electrons to flow from your hand to the door handle, giving you a shock.

4 Drawing similar to the drawing on the sheet, but X now has twice as many field lines emanating from it, and the diamond pattern in the centre between the two charges is no longer centred equidistant between the two charges, but is shifted closer to Y.

SP12a Magnets and magnetic fields

Student Book

1 Iron/steel (or cobalt or nickel) – they must be made of a magnetic material to become induced magnets.

2 The paperclips would have their south poles at the top and north poles at the bottom.

3 Magnets will attract steel food cans but not aluminium drinks cans because aluminium is not a magnetic material.

4
- Place the plotting compass near the magnet and mark the position of the end of the needle.
- Move the compass so the tail of the needle is on the previous dot and mark the point of the needle again.
- Repeat to produce a line, then start again near the magnet.
- Keep repeating until the direction of the field all around the magnet has been plotted.

5 A uniform field has the same strength and direction throughout. The field around a bar magnet has different strengths and different directions in different places around the bar magnet.

6 **a** Near the poles, as the lines are closest together here.

b Above the equator and above the Earth, as the lines are furthest apart here.

S1 The Earth has a magnetic field with a similar shape to a bar magnet. Compass needles are small magnets that can move around. The Earth’s magnetic field attracts and repels the two ends of the compass so that the needle points towards the Earth's north pole.

E1 If a magnet is suspended on a thread it can move around if there is a force on it from other magnets. The Earth has a magnetic field, and will attract the north end of the magnet so it points along the magnetic field lines towards the north magnetic pole. In some parts of the world this will make the magnet tilt at an angle to the horizontal as well as pointing north. To find the shape of the whole field, the magnet would have to be used in many places on and above the Earth.

Exam-style question

A permanent magnet is always magnetic (1). An induced magnet only acts as a magnet when it is in the magnetic field of another magnet (1).

Activity and Assessment Pack

SP12a.2 Using magnets

Magnets in the home:

- Simple uses are door latches (including fridge doors), fridge magnets, knife holders.

Soft iron:

- Electromagnets in car junk yards need to be able to put the cars down once they have been moved, which would not be possible if the iron in the electromagnet retained its magnetism.
- A solenoid is a coil of wire with an iron core that makes it a stronger electromagnet when a current is flowing. Electric bells and relays both involve switches that are turned on and off by electricity. If the core was made of magnetically hard iron, the switch would not turn off when the current stops.

Magnetic sound:

- A loudspeaker has a permanent magnet and an electromagnet. The magnetism of the electromagnet changes as the current to the loudspeaker changes, and the combination of the two magnetic fields makes the coil move relative to the permanent magnet. The electromagnet or the permanent magnet is attached to a cone, which vibrates as the current varies.

Magnadur magnets:

- Magnadur is a ceramic material made from iron oxide and barium oxide.
- A flat magnet has its north and south poles on the large, flat faces, a bar magnet has its poles at the ends.
- Two flat magnets facing each other have a uniform magnetic field between them. Two bar magnets arranged with opposite poles close to each other have a similar field but it is not quite as uniform due to the smaller sizes of the two poles.
- Flat magnets can be used to produce a uniform magnetic field for model motors or generators.

SP12a.3 Magnets and magnetic fields – Strengthen

1 magnet, attracted, repelled

core, magnetic, South, north

2 **a** repel

b attract

3 Any three uses such as door latches, fridge magnets, knife holders, electric motors, generators, loudspeakers.

4 a lines that show the direction and strength… of the magnetic field around a magnet
b the space around a magnet… where it affects magnetic materials
c a magnet that is always magnetic
d something that becomes a magnet… when it is in the magnetic field of another magnet
e a small compass that is used… to find the shape of a magnetic field

SP12a.4 Magnets and magnetic fields – Homework 1

1 cobalt, iron, nickel, steel (circled)

2 a S–N
b N–S

3 a The arrows in the compasses all point along the field lines from N to S.
b X drawn close to one end of the magnet
c The field is strongest where the lines are closest together.

4 straight lines drawn between the magnets, with arrows pointing from N to S (similar to Figure D on *SP12a Magnets and magnetic fields*)

5 a permanent magnet
b induced magnet
c permanent magnet

SP12a.5 Magnets and magnetic fields – Homework 2

1 north poles together or south poles together

2 The bar magnet is a permanent magnet, as it is always magnetic. When the paperclips are close to the bar magnet they become induced magnets, which makes them attracted to the bar magnet and to each other. If the paperclips are taken out of the magnetic field of the bar magnet they will stop being induced magnets.

3 a Three from: knife holder, door latch, fridge magnet, or any other sensible suggestion.
b Three from: loudspeakers, motors, generators, or any other sensible suggestion.

4 Place a plotting compass near the magnet and mark the two ends of the needle. Move the compass so that the tail of the needle is on the place where the point was, and mark the new position of the point. Do this several times, then start again at a different position near the magnet. (Accept any similar description.)

5 a diagram similar to diagram C on page 403 of the Student Book
b The field is strongest where the lines are closest together (i.e. near the magnet).

6 a a field where all the lines are in the same direction/parallel to each other
b The magnets should be arranged with opposite/unlike poles facing each other. This works best with flat/Magnadur magnets.

7 a True north is the direction towards the Earth's North Pole (geographic pole – the axis of rotation).
Magnetic north is the direction towards the Earth's north magnetic pole.
Grid north is the line of the north–south grid lines on the map, and in many places is not exactly the same direction as true north because of the distortions resulting from representing a curved surface on a flat piece of paper (or computer/phone screen).
b The difference between true north and grid north is a function of the map sheet and, unless the map is redrawn using a different projection, this will not change. The position of the Earth's magnetic poles changes slowly with time, and so the angle between magnetic north and true north will change with time.

SP12b Electromagnetism

Student Book

7th 1 Sketch of a wire with an arrow pointing down to indicate current flow. Field lines/circles go around the wire with arrows pointing clockwise on the field lines.

7th 2 The lines are closer together near the wire.

7th 3 Inside the coil of wire, as the lines are closer together there (or, the inside of the coil is the place that is closest to all parts of the coil, so the field would be stronger there).

7th 4 a Iron is a magnetic material, copper is not.

7th b Increase the current or increase the number of turns of wire (strictly, the field strength depends on the number of turns of wire per unit length, not the total number of turns, but this is beyond the requirements of the specification).

7th **c** Reverse the direction of the current (accept coil the wire the other way).

S1 The magnetic field around a straight wire is a series of circles/cylinders around the wire.

The magnetic field of a coil of wire has a similar shape to the magnetic field of a bar magnet.

E1 The strength of the magnetic field around a coil of wire depends on the size of the current – a larger current will produce a stronger magnetic field. The larger magnetic field can be detected by seeing how much it deflects a compass needle or by how far away it will affect a compass needle.

Exam-style question

The strength of the field can increased by increasing the current (or decreased by decreasing the current) (1) and the direction can be changed by changing the direction of the current (1).

Activity and Assessment Pack

SP12b.1 Magnetic fields and wires

2 Point your thumb along the direction of the current (from + to −) and your fingers will point in the direction of the magnetic field.

3 Curl the fingers of your right hand so they show the direction in which the current is flowing around the coil/solenoid, and your thumb will point in the direction of the magnetic field in the centre of the coil.

SP12b.2 Strength of electromagnets

5 Students should conclude that increasing the current increases the strength of the electromagnet, and increasing the number of coils increases the strength.

8 Answers may vary – one possible suggestion is: The electromagnet could be used to attract one end of a pivoted pointer. The greater the current, the stronger the magnetic field of the electromagnet and the more the pointer will move.

SP12b.3 Electromagnets Strengthen

1 Diagram B should be as the completed diagram A but with the arrows pointing in the opposite direction.

2 Diagram should be completed to resemble part b of diagram D on page 405 of the Student Book.

3 **a** circles around the wire

b This is similar to the shape of the magnetic field of a bar magnet/field lines come out of one end of the solenoid and curve round to enter at the other end, with a uniform field inside it.

4 changing the direction of the current

5 increasing the current

6 in the middle of the coil

7 outside the coil

SP12b.4 Electromagnets Homework 1

1 close to the wire

2 two more circles added, with increasing spacing, arrows added in an anti-clockwise direction

3 Put a plotting compass near the wire; the needle will show the direction of the field.

4 **a** The field would go the other way/the arrows would point in the opposite direction.

b The field would be weaker so the lines would be further apart.

5 **a** bar magnet

b increase the current/add more turns of wire

c inside the coil

d N drawn at right-hand end. Field lines point away from the north pole of a magnet.

6 It is only magnetic while current is flowing in the electromagnet.

SP12b.5 Electromagnets Homework 2

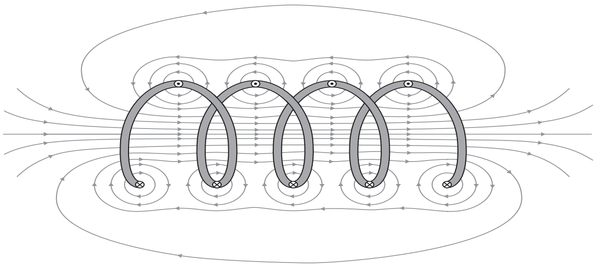
1 Diagram should show concentric circles drawn around wire symbol, with increasing spacing as the circles get further from the wire, and arrows showing the field direction anti-clockwise.

2 **a** Change the direction of the current.

b Increase the current.

3 **a** Diagram should show: field lines drawn around both wires, concentrating between the wires; arrows showing field anti-clockwise around the top wire and clockwise around the bottom wire (i.e. going left to right in the space between the two wires).

b Diagram should be as shown here.



4 The current is flowing in opposite directions compared to the plane of the paper in each half of the coil, so the circular fields around the coil go in opposite directions. All the field lines are in the same direction between the two sections of wire, so the field is reinforced/stronger here.

5 **a** The field lines are closer together where the field is stronger.

b The fields from each half of the coil add up/reinforce each other in the centre of the coil, and partially cancel each other out outside the coil.

6 Make a solenoid by coiling up insulated wire and connecting it to the d.c. terminals of a power pack. Hold a plotting compass at various points around the solenoid while the current is flowing, and check whether the direction of the needle corresponds to the diagram.

7 A bar magnet and an electromagnet have similar shaped magnetic fields, but the electromagnet is only magnetic while the current is flowing. An induced magnet is only magnetic while it is in the magnetic field of another magnet.

8 When the bell is switched on a current flows in the electromagnet and it attracts the armature, making the clapper hit the bell (X). At the same time the movement of the armature breaks the circuit at the contacts so the electromagnet stops being magnetic and the armature springs back again (Y), then the whole cycle repeats.

SP12c Magnetic forces H

Student Book

1 a force experienced by a wire carrying a current in a magnetic field

2 The force will be in the opposite direction/downwards.

3 **a** The size of the force will double.

b The size of the force will decrease.

4 The motor effect produces a force on the wire but it produces an equal and opposite effect on the magnets. So there will be a downwards force on the magnets and the reading on the balance will increase.

5 **a** force = 0.5 N/A m × 0.3 A × 0.1 m
= 0.015 N

b current = 0.02 N/(0.5 N/A m × 0.1 m)
= 0.4 A

S1 **a** force = 0.2 N/A m × 0.5 A × 2 m = 0.2 N

b Reverse the direction of the current or reverse the direction of the magnetic field.

E1 Each wire has a magnetic field around it when the current flows. So each wire is in the magnetic field of the other wire and experiences a force due to the motor effect.

A very good answer will involve using the right-hand rule given and Fleming's left-hand rule to work out that if the forces on the wires are repelling each other, the two wires must have currents flowing in the same direction.

Exam-style question

If the current increases, the size of the force increases. (1)

If the magnetic field is stronger, the force increases. (1)

If there is a greater length of wire within the magnetic field, the force increases. (1)

Activity and Assessment Pack

SP12c.2 Making a current balance

1 Answers may vary, but could include that the commercially built ammeter is easier to use and likely to be more accurate. A possible advantage of the current balance is that it helps to reinforce understanding about electricity and magnetism.

2 Suggestions could include: using a smaller movable weight to make the balance more sensitive; using a flat sheet of stiff material in place of the straw to make it easier to mark the scale on it.

SP12c.3 Magnetic forces – equation practice

1 F represents force, measured in newtons (N), B represents magnetic flux density, measured in tesla (T) or N/A m, I represents current, measured in amps/amperes (A), and l represents length, measured in metres.

2 $B = \frac{F}{I \times l}$

3 a F = 0.2 N/A m × 1.2 A × 0.5 m = 0.12 N

b $B = \frac{0.06\ \text{N}}{0.01\ \text{A} \times 1.2\ \text{m}} = 5\ \text{N/A m}$

c $B = \frac{0.02\ \text{N}}{10\ \text{A} \times 20\ \text{m}} = 0.0001\ \text{N/A m}$

d $I = \frac{0.1\ \text{N}}{0.01\ \text{N/A m} \times 2\ \text{m}} = 5\ \text{A}$

e $l = \frac{0.016\ \text{N}}{0.02\ \text{N/A m} \times 2\ \text{A}} = 0.4\ \text{m}$

f F = 4 N/A m × 0.001 A × 0.2 m = 0.0008 N

g $I = \frac{0.6\ \text{N}}{2\ \text{N/A m} \times 0.1\ \text{m}} = 3\ \text{A}$

h $l = \frac{0.003\ \text{N}}{0.005\ \text{N/A m} \times 2\ \text{A}} = 0.3\ \text{m}$

4 50 cm = 0.5 m

$B = \frac{0.02\ \text{N}}{5\ \text{A} \times 0.5\ \text{m}} = 0.008\ \text{N/A m}$

5 4 mA = 0.004 A, 10 cm = 0.1 m, 2 mT = 0.002 T

F = 0.002 T × 0.004 A × 0.1 m = 0.000 000 8 N (8×10^{-7} N)

6 $I = \frac{3 \times 10^{-4}\ \text{N}}{0.002\ \text{T} \times 0.1\ \text{m}} = 1.5\ \text{A}$

7 $F = 2 \times 10^{-3}$ T × 0.5 A × 0.05 m = 5×10^{-5} N

SP12c.4 Magnetic forces Strengthen

1 a force, newtons

b magnetic flux density, tesla or N/A m

c current, amps

d length, metres

2 F = 0.5 N/A m × 0.8 A × 1.5 m = 0.6 N

3 a Coil of wire – experiences a force in a magnetic field when a current is flowing.

Magnets – provide a magnetic field.

Carbon brushes – make electrical contact between a moving coil and the external circuit.

Split-ring commutator – swaps over the connections every half turn of the coil.

b To swap over the connections so that the coil always experiences forces making it rotate in the same direction.

4 reversing the current, reversing the direction of the magnetic field

5 a arrows drawn on circuit from + to − terminal; arrows drawn on field from N to S

b downwards arrow drawn on wire

SP12c.5 Magnetic forces Homework 1

1 a current arrow drawn showing direction from positive to negative, magnetic field arrows drawn from N to S

b ‘force on wire’ arrow shown pointing upwards

c ‘force on magnet’ arrow shown pointing downwards

d same size

2 There will be no force, because the wire is along the same direction as the field lines, not across them (or similar explanation).

3 F = 0.05 N/A m × 0.02 A × 2 m = 0.002 N

4 a greater force, as there is a greater length of wire in the magnetic field

b smaller force, as the magnetic flux density is less

c greater force, as force depends on current

d Motor will spin the other way, because reversing the direction of the field reverses the direction of the force.

SP12c.6 Magnetic forces Homework 2

1 The rule is used to work out the direction of the force on a wire when it carries a current at right angles to a magnetic field. Hold thumb and first two fingers all at right angles to each other: thumb points in the direction of the force, first finger in the direction of the field (N to S) and second finger in the direction of the current (+ to −).

2 The force on the wire is upwards, and so there is an equal and opposite force acting downwards on the magnet.

3 There will be no force, because the wire is along the same direction as the field lines, not across them (or similar explanation).

4 **a** greater force, as there is a greater length of wire in the magnetic field

b smaller force, as the magnetic flux density is less

c greater force, as force depends on current

d Motor will spin the other way, because reversing the direction of the field reverses the direction of the force.

5 It connects the rotating coil to the external circuit. A split metal ring is attached to the coil, and carbon brushes press against this to connect the external circuit. The split in the ring is to allow the connections to be swapped over every half turn, so the motor always spins in the same direction.

6 F = 0.05 N/A m × 0.02 A × 2 m = 0.002 N

7 force/flux density = 2 N/0.5 N/A m = 4

any two combinations of current and length that multiply to give 4, such as 2 A and 2 m, 1 A and 4 m, etc.

8 **a** 1

b When the wire is at right angles, $\sin\theta = 1$, and so the value calculated from the other variables is not changed (or any similar explanation).

9 F = 0.05 N/A m × 0.02 A × 2 m × sin 45°
= 0.0014 N

SP13a Electromagnetic induction H

Student Book

1 a to the right in the middle of the loop of wire

b The magnetic field inside the loop opposes the direction of movement of the magnetic field of the bar magnet.

2 Any two from: move the magnet faster, use a stronger magnet, use a coil of wire instead of a single loop.

3 Turn the coil faster, use stronger magnets, put more turns of wire on the coil.

4 Similarities: both provide connections between a moving coil and an external circuit, both use carbon brushes to do this.

Differences: slip rings always connect one part of the circuit to the same part of the coil whereas a commutator switches the connections over each half-turn.

5 Variations in air pressure make a diaphragm move and this makes a coil move. The coil is wrapped around a magnet so as it moves the magnetic field changes relative to the coil. This movement induces a current in the wire that varies as the movement of the coil varies.

6 Similarities: both have a diaphragm, both have a coil that can move, both include a magnet.

Differences: the microphone converts variations in air pressure into variations in current and the loudspeaker converts variations in current into variations in air pressure, the microphone uses movement to induce a current, the loudspeaker uses current variations to produce movement.

S1 In a microphone, pressure variations make a diaphragm move and this makes a coil move backwards and forwards near a permanent magnet. This induces a changing current in the coil of wire, which can be recorded or sent to loudspeakers.

In loudspeakers a varying current flows through a coil in a magnetic field. This causes the coil to move, which moves a diaphragm and produces sound waves.

E1 If the coil spins faster the size of the induced current is greater. However, a larger induced current will induce a stronger magnetic field around the coil. As this magnetic field opposes the original motion, the stronger field will make it harder to turn the coil.

Exam-style question

Both use a moving coil in a magnetic field (or moving a magnet inside coils of wire) (1) to generate a current (1). The alternator produces alternating current and the dynamo produces direct current (1) because in a dynamo the connections to the coil are swapped over every half-turn (1).

Activity and Assessment Pack

SP13a.1 Investigating induction

3 Students should conclude that the current increases with a stronger magnetic field, increasing speed of movement and number of turns in the coil, and that the direction of movement of the magnet affects the current direction but not its strength.

4 Mainly qualitative, as it is difficult to measure the strength of the magnetic field and the speed of movement of the magnet.

5 a Suggestions could include comparing results with other groups, repeating the tests, or repeating investigations with different magnets and coils.

b Suggestions could include finding a way to measure the speed of movement of the magnet or coil.

SP13a.2 Make a loudspeaker

1 The coil is in a magnetic field, so when a current flows through the coil it experiences a force. The varying current from the power pack or signal generator produces a varying force. This force makes the cone move/vibrate and produce sound waves.

2 a Sound waves reaching the cone would make it move/vibrate, and so the coil would also move. As the coil is in a magnetic field this would induce a varying current in the coil.

b Suggestions could include a thinner diaphragm to pick up quieter sounds, or practical suggestions such as making it smaller/portable.

SP13a.3 Electromagnetic induction Strengthen

1 Possible endings are:

Microphones convert pressure variations in sound waves … into a varying electric current.

The pressure variations make … a diaphragm vibrate.

The diaphragm is connected to a … coil of wire.

The coil of wire is wrapped around a … permanent magnet.

The movement of the coil produces … a current in the coil by electromagnetic induction.

A loudspeaker converts variations in … an electric current into sound waves.

A coil of wire inside the loudspeaker is wrapped around a … permanent magnet.

When a current flows through the coil there is a force that … makes the diaphragm move.

Changes in the current cause changes in the … movement of the diaphragm, and this produces sound waves.

2 **a** both

b both

c alternator

d dynamo

e both

f dynamo

g alternator

3 Yes. It does not matter if it is the magnet or the coil that moves, as long as one is moving relative to the other.

SP13a.4 Electromagnetic induction Homework 1

1 **a** Move the magnet faster, have more turns of wire in the coil.

b Reverse the direction of movement of the magnet with respect to the coil.

c current, magnetic, magnetic, magnet, repels

2 **a** electricity

b sound, electricity

c electricity, sound

3 (any order) coil of wire, permanent magnet

4 An alternator uses slip rings and carbon brushes to connect the coil to a circuit, and produces alternating current. A dynamo uses a commutator, which swaps the connections over every half-turn, and so produces direct current.

5 **a** Both contain a coil and permanent magnet; both produce an electric current.

b Any two from:

The generator is turned, using forces to move the coil; the microphone uses movements caused by sound waves.

The coil in the generator spins; the coil in the microphone moves backwards and forwards.

The generator produces a regular pattern of current; the current produced by the microphone does not necessarily follow a regular pattern.

6 Students' answers should include the similarities and two of the differences given above, written in complete sentences and in a sensible order.

SP13a.5 Electromagnetic induction Homework 2

1 **a** Move the magnet faster, have more turns of wire in the coil.

b Reverse the direction of movement of the magnet with respect to the coil.

c The current in the coil induces a magnetic field around the coil. The direction of this magnetic field is opposite to the field of the magnet, so there is a force that repels the magnet.

2 **a** forces → electricity

b sound → electricity

c electricity → sound

3 **a** An alternator uses slip rings and carbon brushes to connect the coil to a circuit, and produces alternating current. A dynamo uses a commutator, which swaps the connections over every half-turn, and so produces direct current.

b Sketch graph similar to that in diagram C on *SP13a Electromagnetic induction* in the Student Book, labelled dynamo. The graph should also have a horizontal line above the Time axis, labelled battery.

4 1 or 2 marks. The student has given one similarity, and a partial difference.

5 The answer should mention that both items include a coil and permanent magnet, and that both produce electricity by electromagnetic induction. It should also give two differences, from:

- The generator is turned, using forces to move the coil; the microphone uses movements caused by sound waves.

- The coil in the generator spins; the coil in the microphone moves backwards and forwards.
- The generator produces a regular pattern of current; the current produced by the microphone does not necessarily follow a regular pattern.

The answer should be written in complete sentences and in a sensible order.

6 A diode lets current flow in only one direction, so putting a diode in the circuit would produce a current that flowed in only one direction (direct current). However, the current would still be changing, and would be zero for half the time. The current from a dynamo is continually changing but there is a current for almost all of the time.

Sketch graph similar to that in diagram C on *SP13a Electromagnetic induction* in the Student Book, but showing only every other peak with the current at zero between them.

SP13b The national grid

Student Book

1 25 000 V, 400 kV, 33 kV, 11 kV, 0.23 kV

2 A is a step-up transformer. It is used to increase the voltage of the electricity coming out of the power station before it is sent through the transmission lines, because less energy is wasted through heating when the voltage is higher.

B and C are step-down transformers. They are used to reduce the voltage of the electricity from the transmission lines, because factories/buildings do not use such high voltages (or because higher voltages are more dangerous).

3 Iron is a magnetic material, so it concentrates the magnetic field produced by the primary coil and ensures the field reaches the secondary coil.

4 It will increase the strength of the magnetic field, because the size of the current in the primary coil will be changing faster.

5 $V_S = \dfrac{V_P \times N_S}{N_P}$

$= \dfrac{20\,000\text{ V} \times 30\,000}{1500}$

= 400 000 V (or 400 kV)

S1 Electricity goes from a power station to a step-up transformer, which increases the voltage from 25 000 V to about 400 000 kV. The energy is then sent around the country in wires called transmission lines. The electricity is sent through these at a high voltage because less energy is wasted through heating. Near where the electricity is to be used it goes to a step-down transformer which reduces the voltage to 33 000 V, which is the right voltage for large factories to use. Some electricity goes to another step-down transformer to reduce it to 11 000 V for smaller factories, or to 230 V for homes.

E1 A step-down transformer reduces the voltage, so 11 kV is the primary voltage and 500 V is the secondary voltage.

$N_S = \dfrac{N_P \times V_S}{V_P}$

$= \dfrac{10\,000 \times 500\text{ V}}{11\,000\text{ V}}$

= 455 turns

Exam-style question

They increase the voltage/potential difference of the electricity from power stations before it is sent across the country (1) and they reduce the voltage/potential difference again before the electricity goes to consumers (1).

Activity and Assessment Pack

SP13b.3 Transformer turns ratio – Equation practice

1 **a** $V_p = \dfrac{10 \times 0.2\text{ V}}{0.4} = 5\text{ V}$

b $V_p = \dfrac{10 \times 11\text{ V}}{0.5} = 220\text{ V}$

c $V_p = \dfrac{1000 \times 400\,000\text{ V}}{16\,000} = 25\,000\text{ V}$

d $N_p = \dfrac{10\text{ V} \times 2000}{200\text{ V}} = 100$

e $N_p = \dfrac{2\text{ V} \times 5}{0.4\text{ V}} = 25$

f $N_p = \dfrac{2\text{ V} \times 400}{10\text{ V}} = 80$

g $V_s = \dfrac{50\text{ V} \times 25}{500} = 2.5\text{ V}$

h $N_s = \dfrac{20 \times 250\text{ V}}{25\text{ V}} = 200$

i $V_s = \dfrac{20\text{ V} \times 20}{500} = 0.8\text{ V}$

j $N_s = \dfrac{80 \times 0.25\text{ V}}{5\text{ V}} = 4\text{ V}$

2 a $N_s = \frac{10\,000 \times 400\,000\text{ V}}{25\,000\text{ V}} = 160\,000$

b $N_s = \frac{10\,000 \times 33\,000\text{ V}}{400\,000\text{ V}} = 825$

c $N_s = \frac{10\,000 \times 230\text{ V}}{33\,000\text{ V}} = 70$

3 $N_p = \frac{230\text{ V} \times 20}{5\text{ V}} = 920$

SP13b.4 The national grid Strengthen

1 Cards assembled in the order indicated by diagram A on *SP13b The national grid* in the Student Book.

2 it increases the efficiency, less energy is wasted by heating in the wires.

3 Correct words are: increases, decreases, decreases, increases.

4 Electricity goes from a power station to a step-up transformer, which increases the voltage from 25 000 V to about 400 000 V. The energy is then sent around the country in wires called high voltage transmission lines. The electricity is sent through these at a high voltage because less energy is wasted by heating. Near where the electricity is to be used it goes to a step-down transformer, which reduces the voltage to 33 000 V to make it the right voltage for large factories to use. Some electricity goes to another step-down transformer to reduce it to 11 000 V for smaller factories, or to 230 V for homes, offices and shops.

SP13b.5 The national grid Homework 1

1 It wastes less energy.

2 heating

3 step-up, step-down, step-down

4 230 V – voltage used in homes, shops and schools

11 kV – voltage used by small factories

25 kV – voltage generated in power stations

33 kV – voltage used by large factories

400 kV – voltage in transmission lines

5 a step-up (SU) on left hand transformer, step-down (SD) on all the others

b voltages from left to right: 25 kV, 400 kV, 33 kV, 11 kV, 230 V

SP13b.6 The national grid Homework 2

1 a Transmitting electricity at high voltages wastes less energy by heating

b step-up transformer

c Domestic equipment only needs low voltages; higher voltages would be dangerous in situations where there are people.

2 Transformers: step-up on left hand transformer, step-down on all the others.
Voltages from left to right: 25 kV, 400 kV, 33 kV, 11 kV, 230 V

3 a by heating

b No. In some devices such as electric fires/cookers/showers the energy transferred by heating is a useful energy transfer.

4 An alternating current in the primary coil induces a continuously changing magnetic field in the iron core. The core ensures this changing magnetic field reaches the secondary coil, where it induces a current.

5 Both use electromagnetic induction to produce a current; both involve a coil in a changing magnetic field. In the generator the changing field is produced by moving magnets relative to the coil. In the transformer the changing field is due to the alternating current that produces the magnetic field.

6 $N_s = \frac{5000 \times 11\,000\text{ V}}{400\,000\text{ V}} = 137.5$ (or 138)

7 Low voltages are needed for end users for safety reasons. The voltage of a direct current cannot be changed using a transformer, so the transmission from power station to the end user must all happen at a low voltage, such as the 230 V used in homes. At low voltages the currents need to be larger and so more energy is wasted by heating in the wires. If the electricity has to be sent long distances from a few large power stations the losses will be very high, so it is more efficient (from the transmission point of view) to generate electricity in lots of small power stations so the transmission distances are smaller.

SP13c Transformers and energy

Student Book

6th 1 current $= \frac{20\text{ W}}{230\text{ V}}$

$= 0.09\text{ A}$

7th **2 a** 5000 W

7th **b** The power transferred by electricity will be less, as some of the energy transferred to the transformer by electricity will be lost through heating.

9th **3 a** $V_p = \frac{200 \text{ V} \times 0.1 \text{ A}}{2 \text{ A}}$

$= 10 \text{ V}$

9th **b** $I_s = \frac{33\,000 \text{ V} \times 2 \text{ A}}{230 \text{ V}}$

$= 287.0 \text{ A}$

9th **4 H** current required

$= \frac{2 \times 10^6 \text{ W}}{3.3 \times 10^4 \text{ V}}$

$= 60.6 \text{ A}$

power transferred by heating
$= (60.6 \text{ A})^2 \times 0.08\ \Omega$
$= 294 \text{ W}$

energy transferred per hour
$= 294 \text{ W} \times 3600 \text{ s}$
$= 1.06 \times 10^6 \text{ J}$

9th **5 H a** $V_P = \frac{V_S \times N_P}{N_S}$

$= \frac{230 \text{ V} \times 10\,050}{70}$

$= 33\,021 \text{ V}$ (or 33 kV)

8th **H b** Less energy is wasted when it is transmitted at high voltages.

S1 $I_p = \frac{5 \text{ V} \times 2 \text{ A}}{500 \text{ V}}$
$= 0.02 \text{ A}$

E1 total power of bulbs = 6 × 50 W
= 300 W

current supplied by transformer

$= \frac{300 \text{ W}}{12 \text{ V}}$
$= 25 \text{ A}$

$I_P = \frac{I_S \times V_S}{V_P}$

$= \frac{25 \text{ A} \times 12 \text{ V}}{230 \text{ V}}$
$= 1.3 \text{ A}$

E2 H current required
$= \frac{1.2 \times 10^9 \text{ W}}{400 \times 10^3 \text{ V}}$
$= 3000 \text{ A}$

Power transferred by heating
$= (3000 \text{ A})^2 \times 2\ \Omega$
$= 1.8 \times 10^7 \text{ W}$

energy wasted per year
$= 1.8 \times 10^7 \text{ W} \times (365 \times 24 \times 3600) \text{ s}$
$= 5.7 \times 10^{14} \text{ J}$

Exam-style question

The power of an electric current is worked out from the current and the voltage (1). Energy is conserved (1) so the current must be reduced if the voltage is increased (or vice versa), otherwise energy would not be conserved (1).

Activity and Assessment Pack

SP13c.1 Modelling power lines

3 There is more power transferred by the bulb closest to the power pack. This is because some of the energy transferred to the other bulb is wasted/transferred to the surroundings by heating in the wires. Students may also refer to the current in the more distant lamp being lower because the resistance of that part of the circuit is higher.

4 a the power pack
b the bulb furthest from the power pack
c the nichrome wires

5 Nichrome is not representative as a model of the power lines used in the national grid, as they would have a lower resistance. However, it is useful in the model, because with a lower resistance wire the wires would have to be much longer to show the effect being demonstrated.

SP13c.2 Transformers card sort

2 and 3 (V_s, I_s pairs in either order for each row)

Transformer	Power supplied (W)	V_s (V)	I_s (A)	V_s (V)	I_s (A)
A	20	20	1	2	10
B	1	40	0.025	5	0.2
C	1150	2300	0.5	23	50
D	3000	2000	1.5	20	150
E	2.4	6	0.4	48	0.05

4 The transformer is 100% efficient.

5 and 6

Transformer	Power supplied (W)	V_s (V)	I_s (A)	V_s (V)	I_s (A)
A	16	20	0.8	2	8
B	0.8	40	0.02	5	0.16
C	920	2300	0.4	23	40
D	2400	2000	1.2	20	120
E	1.92	6	0.32	48	0.04

SP13c.3 Transformer power Equation practice

1 **a** $\frac{12\text{ V} \times 3\text{ A}}{0.75\text{ A}} = 48\text{ V}$

b $\frac{12\text{ V} \times 4\text{ A}}{6\text{ V}} = 8\text{ A}$

c $\frac{60\text{ V} \times 4\text{ A}}{120\text{ V}} = 2\text{ A}$

d $\frac{20\text{ V} \times 30\text{ A}}{5\text{ A}} = 120\text{ V}$

e $\frac{200\text{ V} \times 0.75\text{ A}}{50\text{ V}} = 3\text{ A}$

f $\frac{60\text{ V} \times 8\text{ A}}{32\text{ A}} = 15\text{ V}$

g $\frac{80\text{ V} \times 20\text{ A}}{5\text{ A}} = 320\text{ V}$

h $\frac{4000\text{ V} \times 5\text{ A}}{200\text{ V}} = 100\text{ A}$

2 Students can calculate from either the primary values or the secondary values.

a 12 V × 3 A = 36 W

b 12 V × 4 A = 48 W

c 120 V × 2 A = 240 W

d 120 V × 5 A = 600 W

e 50 V × 3 A = 150 W

f 60 V × 8 A = 480 W

g 80 V × 20 A = 1600 W

h 4000 V × 5 A = 20 000 W

3 $\frac{230\text{ V} \times 20\text{ A}}{33\,000\text{ V}} = 0.139\text{ A}$

4 For 33 kV:

current = $\frac{40\,000\,000\text{ W}}{33\,000\text{ V}} = 1212\text{ A}$

power transferred by heating = $(1212\text{ A})^2 \times 2\ \Omega$
= 2 937 888 W

energy transferred per day
= 2 937 888 W × 24 × 60 × 60
= 2.54×10^{11} J

For 11 kV:

current = $\frac{40\,000\,000\text{ W}}{11\,000\text{ V}} = 3636\text{ A}$

power transferred by heating = $(3636\text{ A})^2 \times 2\ \Omega$
= 26 440 992 W

energy transferred per day
= 26 440 992 W × 24 × 60 × 60
= 2.28×10^{12} J

The energy wasted if the electricity is supplied at 11 kV is approximately 10 times as much as if it is supplied at 33 kV.

SP13c.4 Transformers and energy Strengthen

1 **a** 300 V, I_p, 900 V, 1.5 A

b 300 V × I_p = 900 V × 1.5 A, 300 V × I_p = 1350,

$I_p = \frac{1350}{300} = 4.5\text{ A}$

2 **a** power

b watts (W)

3 The transformer is 100% efficient. The transformer does not transfer any energy to its surroundings by heating.

4 200 V × 2 A = V_s × 0.04 A, 400 = V_s × 0.04 A,

$V_s = \frac{400}{0.04} = 10\,000\text{ V}$

SP13c.5 Transformers and energy Homework 1

1 potential, coils, electrically, iron, primary, secondary

difference, current, waste, secondary

watt, volt, amp

2 **a** 200 V × I_p = 10 V × 80 A, 200 V × I_p = 800,

$I_p = \frac{800}{200} = 4\text{ A}$

b 100 V × 2 A = V_s × 20 A, 200 = V_s × 20 A,

$V_s = \frac{200}{20} = 10\text{ V}$

c 10 V × 3 A = 200 V × I_s, 30 = 200 V × I_s,

$I_s = \frac{30}{200} = 0.15\text{ A}$

SP13c.6 Transformers and energy Homework 2

1 **a** Change the voltage/potential difference of an electricity supply.

b A transformer consists of an iron core with two coils of wire wrapped around it, not electrically connected to each other. The primary coil is connected to the electricity supply, the secondary coil produces the output voltage/potential difference.

c electromagnetic induction

2 **a** Power is the rate at which energy is transferred/is the energy transferred per second.

b current through the appliance and potential difference/voltage across it

c power (W) = current (A) × potential difference (V)

3 **a** power = 0.04 A × 230 V = 9.2 W

b current = $\frac{9.2\text{ W}}{100\text{ V}}$ = 0.092 A

4 **a** V_p is the potential difference across the primary coil, I_p is the current in the primary coil.

V_s is the potential difference across the secondary coil, I_p is the current in the secondary coil.

b 100% efficiency

5 **a** 200 V × I_p = 10 V × 80 A, 200 V × I_p = 800,

$I_p = \frac{800}{200}$ = 4 A

b 100 V × 2 A = V_s × 20 A, 200 = V_s × 20 A,

$V_s = \frac{200}{20}$ = 10 V

c 10 V × 3 A = 200 V × I_s, 30 = 200 V × I_s,

$I_s = \frac{30}{200}$ = 0.15 A

6 Energy wasted at 230 V:

current = $\frac{40\ 000\text{ W}}{230\text{ V}}$ = 174 A

power transferred by heating = (174 A)^2 × 0.3 Ω
= 9083 W

energy transferred per year
= 9083 W × 365 × 24 × 60 × 60
= 2.86 × 10^{11} J

For 1 kV:

current = $\frac{40\ 000\text{ W}}{1000\text{ V}}$ = 40 A

power transferred by heating = (40 A)^2 × 0.3 Ω
= 480 W

energy transferred per day
= 480 W × 365 × 24 × 60 × 60
= 1. 5 × 10^{10} J

Energy saved per year
= 2.86 × 10^{11} J – 1.5 × 10^{10} J
= 2.7 × 10^{11} J.

7 **a** current = $\frac{9.2\text{ W}}{4\text{ V}}$ = 2.3 A

b It is not 100% efficient, as some energy is being transferred to the surroundings by heating.

c Less. Not all the energy/power transferred to the transformer is being output as electricity.

SP14a Particles and density

Student Book

1 **a** Keep their shape, incompressible/keep their volume.

b Can flow/take the shape of container, incompressible/keep their volume.

c Compressible, expand to fill/take shape of container.

2 **a** The particles in solids are held in a fixed arrangement by strong forces between the particles. The forces between the particles in liquids and gases are not strong enough to keep them fixed together.

b In gases there is a lot of space between the particles so they can be pushed closer together. In solids and liquids the particles are already close together so they cannot be pushed any closer.

3 The right-hand beaker, because most substances become denser when they freeze and the solid will sink in the liquid.

4 The particles in a gas are more spread out, so the same number of particles/mass of substance takes up a larger volume. The same mass in a larger volume has a lower density.

5 $\text{density} = \dfrac{500\text{ kg}}{0.185\text{ m}^3}$
$= 2702.7\text{ kg/m}^3$

6 $\text{volume} = \dfrac{5000\text{ kg}}{8960\text{ kg/m}^3}$
$= 0.558\text{ m}^3$

S1 The particles are close together, so it is incompressible. The particles are held by fairly strong forces of attraction, so it does not expand to fill its container like a gas does but the forces are not strong enough to keep it in a fixed shape like a solid.

S2 mass = density × volume
$= 1000\text{ kg/m}^3 \times 2500\text{ m}^3$
$= 2\,500\,000\text{ kg}$

E1 The particles in a solid are slightly closer together than they are in a liquid, so the same mass of substance takes up less space and the solid has a higher density than the liquid.

E2 $\text{volume of solid} = \dfrac{2000\text{ kg}}{8960\text{ kg/m}^3}$
$= 0.223\text{ m}^3$

$\text{volume of liquid} = \dfrac{2000\text{ kg}}{8020\text{ kg/m}^3}$
$= 0.249\text{ m}^3$

$\text{difference} = 0.249\text{ m}^3 - 0.223\text{ m}^3$
$= 0.026\text{ m}^3$

Exam-style question

Solids keep their shape; gases take the shape of their container/do not have a fixed shape (1).

Solids are incompressible; gases are compressible (1).

Solids keep their shape because there are very strong forces of attraction holding the particles in fixed positions, whereas the forces between particles in a gas are very weak (1).

Solids cannot be compressed because the particles are all very close together. Gases can be compressed because the particles are far apart and can be pushed closer (1).

SP14a Core practical Investigating densities

1 **a** In solids the particles can only vibrate about fixed positions (1), in liquids particles can move around within the liquid (1).

b The particles in liquids are usually a little further apart than in solids (1).

2 **a** $\text{density} = \dfrac{\text{mass}}{\text{volume}}$ (or $\rho = \dfrac{m}{V}$) (1)

b mass in kg, volume in m^3, density in kg/m^3 (accept g/cm^3) (all three correct for 1 mark)

3 **a** balance (1), measuring cylinder (1), beaker, salt, water, spatula (1 for remaining items)

b Weigh 1 g of salt (or other specified mass) and put it in a measuring cylinder. Add pure water until it makes a volume of 50 cm^3 (or other stated volume) (1). Find the mass of the solution by placing a beaker on a balance and zeroing it, then reading the mass when the solution is put into the beaker (1). Repeat the first two steps, using an extra 1 g of salt each time (1).

c Any one from: ensure the temperature remains constant, as changes in temperature affect volume/can make substances expand or contract; use the same type of salt each time; any other sensible and relevant suggestion (1).

4 46 g = 0.046 kg (1)

$\text{density} = \dfrac{0.046\text{ kg}}{0.000\,05\text{ m}^3}$ (1) $= 920\text{ kg/m}^3$ (1)

5 volume = 2 m × 0.5 m × 0.02 m = 0.02 m^3 (1)

density = $\frac{12\text{ kg}}{0.02\text{ m}^3}$ (1) = 600 kg/m^3 (1)

6 a The measured mass was too low **or** the measured volume was too high (1). (Do not accept 'a measurement error'.)

b Any sensible suggestion, such as: use a measuring cylinder with more accurate markings; zero the balance with the measuring cylinder on it and pour the liquid into that, so no liquid is left behind in the measuring cylinder (1).

7 Changes in temperature can make a solid change volume (or increases/decreases in temperature make substances expand/contract) (1), and so the density must also change with temperature (1).

Activity and Assessment Pack

SP14a.1 Investigating densities

5a, b The range of densities for the solids tested is likely to have been greater than the range of densities for the liquids.

6 The answer depends on the materials tested. Answers could point out that, in general, solids are more dense than liquids, although some solids are less dense. Very good answers may also suggest whether each solid will float or sink in the different liquids tested.

SP14a.2 Changing density

Thermometers

2 The volume increased, because the length of the liquid visible inside the thermometer increased (or similar answer).

3 It stayed the same, because no liquid was added to the thermometer or taken out of it.

4 a The spacing of the particles must have increased, because the liquid took up more space/increased in volume.

b Because the mass stayed the same and the volume increased, the density must have gone down.

Bimetallic strip

1 straight

2 It bent.

3 The one on the outside of the curve expanded more.

4 a Yes, the density changes. If the metals have expanded, their volumes have increased. Their masses have stayed the same, so the densities have decreased.

b The metal that expanded the most had the greatest change in volume and so the greatest decrease in density.

SP14a.3 Density – Equation practice

1 a density = $\frac{50\text{ kg}}{5\text{ m}^3}$ = 10 kg/m^3

b density = $\frac{125\text{ kg}}{2.5\text{ m}^3}$ = 50 kg/m^3

c density = $\frac{0.8\text{ kg}}{4\text{ m}^3}$ = 0.2 kg/m^3

d mass = 0.8 kg/m^3 × 3 m^3 = 2.4 kg

e mass = 70 kg/m^3 × 1.5 m^3 = 105 kg

f volume = $\frac{20\text{ kg}}{25\text{ kg/m}^3}$ = 0.8 m^3

g volume = $\frac{0.6\text{ kg}}{0.02\text{ kg/m}^3}$ = 30 m^3

h mass = 15 kg/m^3 × 0.4 m^3 = 6 kg

i mass = 6 kg/m^3 × 7.5 m^3 = 45 kg

j volume = $\frac{0.8\text{ kg}}{0.04\text{ kg/m}^3}$ = 20 m^3

2 density = $\frac{200}{0.074}$ kg/m^3 = 2703 kg/m^3

(Reference value is 2712 kg/m^3; this answer is a result of giving the volume to only 2 s.f.)

3 density = $\frac{50}{0.0044}$ kg/m^3 = 11 364 kg/m^3

(Reference value is 11 340 kg/m^3, this answer is a result of giving the volume to only 2 s.f.)

4 volume = $\frac{12.4\text{ kg}}{19\,320\text{ kg/m}^3}$ = 0.000 62 m^3

5 density = $\frac{1030\text{ g}}{1000\text{ cm}^3}$ = 1.03 g/cm^3

6 a 30 g = 0.03 kg

density = $\frac{0.03\text{ kg}}{0.05\text{ m}^3}$ = 0.6 kg/m^3

b 60 g = 0.06 kg

volume = $\frac{0.06\text{ kg}}{0.8\text{ kg/m}^3}$ = 0.075 m^3

7 mass of oil = 0.85 g/cm^3 × 30 cm^3 = 25.5 g

mass of vinegar = 1.05 g/cm^3 × 10 cm^3 = 10.5 g

total mass = 25.5 g + 10.5 g = 36 g

8 volume of hydrogen = $\frac{0.2\text{ kg}}{0.08\text{ kg/m}^3}$ = 2.5 m^3

volume of air = $\frac{0.2\text{ kg}}{1.205\text{ kg/m}^3}$ = 0.166 m^3

difference = 2.5 m^3 – 0.166 m^3 = 2.334 m^3

SP14a.4 Particles and density Strengthen

1 forces, do not expand

particles, fixed, can move around, flow, shape

close together, difficult

2 mass: *m*, kg

volume: *V*, m^3

density: ρ, kg/m^3

3 b density = $\frac{\text{mass}}{\text{volume}}$

c mass = density × volume

4 mass = density × volume
= 1000 kg/m^3 × 0.8 m^3
= 800 kg

5 The particles get much further apart.

The particles spread out to fill their container.

The particles move faster.

SP14a.5 Particles and density Homework 1

1 A, E, C, D, B

2 a The particles are already very close together, so they cannot get any closer.

b They do not have a fixed shape.

3 Correct words are: more, further apart, increases, decreases.

4 density, kg/m^3

volume, m^3

mass, kg

5 density = $\frac{800\text{ kg}}{0.6\text{ m}^3}$ = 1333.3 kg/m^3

6 mass = 2200 kg/m^3 × 2 m^3 = 4400 kg

SP14a.6 Particles and density Homework 2

1 A, E, C, D, B

2 a The particles are already very close together, so they cannot get any closer.

b They do not have a fixed shape.

3 Ice is less dense than water, because it increases in volume when it freezes. For most substances the particles get closer together when the substance changes from a liquid to a solid, and so the substance becomes more dense.

4 a No new substance is formed, and the change can be reversed.

b Mass is conserved.

5 density = $\frac{800\text{ kg}}{0.6\text{ m}^3}$ = 1333.3 kg/m^3

6 mass = 2200 kg/m^3 × 2 m^3 = 4400 kg

7 mass of 2.5 m^3 of bricks = 2000 kg/m^3 × 2.5 m^3 = 5000 kg, so the van can only carry 600 kg of bricks

volume of 600 kg of bricks = $\frac{600\text{ kg}}{2000\text{ kg/m}^3}$
= 0.3 m^3

mass of 2.5 m^3 of pine wood
= 420 kg/m^3 × 2.5 m^3 = 1050 kg,
so the van can only carry 600 kg of pine wood

volume of 600 kg of pine wood = $\frac{600\text{ kg}}{420\text{ kg/m}^3}$
= 1.43 m^3

mass of 2.5 m^3 of balsa wood
= 160 kg/m^3 × 2.5 m^3 = 400 kg

8 a Gold is denser than silver, so if some of the gold is replaced by silver the volume of the crown would be greater if it had the same mass.

b volume of a pure gold crown
= $\frac{800\text{ g}}{19.320\text{ g/cm}^3}$ = 41.4 cm^3

volume of 400 g of gold = $\frac{41.4}{2}$ cm^3
= 20.7 cm^3

volume of 400 g of silver = $\frac{400\text{ g}}{10.49\text{ g/cm}^3}$
= 38.1 cm^3

total volume = 58.8 cm^3

difference in volume = 17.4 cm^3

SP14b Energy and changes of state

Student Book

2nd 1 a degrees Celsius or °C

4th b joules or J

7th 2 There is a greater mass of liquid in the pan.

8th 3 a The water, because it took longer to reach 50 °C so it must have needed more energy for the same temperature rise.

8th b Both were heated at the same rate.

4 The energy being transferred to the liquid is overcoming the forces of attraction between the particles rather than making the substance hotter/increasing the temperature of the substance.

5 Sketch of a graph which should descend, flatten out (labelled as condensing), descend then flatten out again (labelled as freezing) and then descend a little further; axes should be correctly labelled (temperature against time).

6 It takes more energy to evaporate a certain mass of a substance than it does to melt it, so the latent heat of melting is less than the latent heat of evaporation.

S1 Specific heat capacity of the food – a higher heat capacity means it stores more energy; mass of the food – the greater the mass, the more energy it transfers; change in temperature – more energy is transferred when the temperature change is greater.

S2 Latent heat is released (a better explanation will state that latent heat is a measure of the energy needed to overcome the forces of attraction holding the particles together in a solid and that this is released when the liquid turns back into a solid).

E1 Energy is needed to raise the temperature of water to boiling point but any further energy transferred to the water after this point will be used to make some of the water evaporate. The extra energy is used to overcome the forces of attraction holding the particles in the water close to each other and the temperature will not rise further than the boiling point. (A very good answer may also explain that some heating is still necessary to balance energy transferred from the boiling water to the potatoes and/or the surroundings.)

Exam-style question

a Sketch of a graph which should ascend, flatten out then continue ascending (1 mark for labelled axes: temperature/time, 1 for the line becoming horizontal for a time at 0 °C).

b Any three from the following (1 mark each):

- as the ice is heated, the energy increases the movement of the particles
- …and so the temperature rises
- when the ice reaches melting point/0 °C the energy transferred to it overcomes the forces of attraction between the particles
- …and the ice starts to melt instead of the temperature rising
- the energy needed to melt the ice is called the latent heat (of melting).

Activity and Assessment Pack

SP14b.1 Melting ice

4 Graphs should show an increase in temperature, a horizontal section while the ice is melting, and then a further rise in temperature as the water begins to warm up.

5 As the ice is heated, the particles move faster and the temperature rises. Eventually the temperature reaches the melting point of the substance, and the energy from the water bath is being used to break the bonds holding the particles together in the solid. The temperature remains constant while this is happening. When all the ice has melted, the particles in the liquid move around faster as they get more energy, so the temperature rises again.

6 **a** Sources of systematic errors could be a faulty thermometer or the thermometer not immersed fully in the substance being tested.

b Check the thermometer against a known pair of temperatures (e.g. in ice and in boiling water) or compare it with another thermometer.

7 **a** Suggestions could include not reading the thermometer at the correct time, not recording the reading correctly, using the thermometer incorrectly (e.g. by taking it out of the substance to read the temperature).

b Answers depend on the errors suggested in part **a**. Accept any sensible methods of reducing errors.

SP14b.2 Storing energy

1 Any two examples, such as the Sun only shining during the day/in good weather, the wind not always being fast enough to turn turbines, there only being two tides a day.

2 **a** The location needs a reservoir above the power station, so it needs to be in a hilly area. Students may also mention that not all places will have sufficient water/rainfall.

b Suggestions could include: gravel storage tanks can be put anywhere; small units can be located near to small wind farms (for example), whereas pumped storage power stations are likely to be bigger (if you include the two reservoirs); it is more difficult/expensive to build hydroelectric power stations than gravel storage.

3 The water stores the most energy, because it takes more energy to increase the temperature of each kg by 1 °C.

4 The energy being transferred to it while it is changing state is being used to overcome the forces between the particles.

5 Sodium nitrate will store the most energy, because it needs more energy to melt each kilogram.

6 Graph should show temperature rising, levelling off and then rising again. The temperature at which the horizontal section of the graph occurs should be marked as the melting point.

7 Answers should include some of these points: Water is only liquid over a range of 100 °C. To attain the same temperature difference as achieved with the gravel, the water would be changing from solid to liquid to gas. Transfer of energy to and from ice could be difficult, or ice could damage any heat transfer pipes in the tank as it expands when it freezes. If the water boils, the gas produced will cause high pressures inside the container.

SP14b.3 Energy and changes of state – Strengthen

1 its temperature, the material it is made from, its mass

2 the energy needed to raise the temperature of 1 kg of a material by 1 °C

3 C, D on the first sloping section; B, E, F on the horizontal section; A, G on the final sloping section

4 foam, bubble wrap (in either order), reduce, by heating

reducing, object, surroundings

reducing, surroundings, object

SP14b.4 Energy and changes of state – Homework 1

1 a specific latent heat
b temperature
c specific heat capacity

2 a It reduces the rate at which energy is transferred from the hot contents of the mug to the surroundings (or equivalent answer).
b It reduces the rate at which energy is transferred from the warmer surroundings to the cold contents of the mug (or equivalent answer).

3 a M written next to the horizontal portion of the graph
b L next to the right hand sloping portion of the graph

4 a more slowly
b A higher specific heat capacity means it takes more energy to increase the temperature of each kilogram (by 1 °C). (If they are being heated at the same rate) it will take longer for this amount of energy to be transferred.
c Dashed line continued, horizontal section drawn at a lower temperature than the solid line, then the line rises again at the same angle as the first part of the curve.

5 It levels off while the solid is melting, because the energy is being used to overcome the forces between the particles (instead of making it hotter).

SP14b.5 Energy and changes of state – Homework 2

1 a a measure of the movement of the particles in a substance
b the amount of energy needed to increase the temperature of 1 kg of a substance by 1 °C
c the amount of energy needed for 1 kg of a substance to change state

2 The insulation reduces the rate at which energy is transferred through it by heating. When there is a hot drink in the mug, insulation reduces the rate at which energy is transferred from the mug to the surroundings. When the mug contains a cold drink, insulation reduces the rate at which energy is transferred from the surroundings to the drink.

3 The graph should slope downwards, with two horizontal sections (representing condensation and freezing). Labels should be (from top left): gas, condensing, liquid, freezing, solid

4 a graph similar to diagram C in the Student Book, with the melting point labelled as −97 °C and the boiling point labelled as 65 °C
b The line goes upwards with time as the methanol is being heated. When the methanol reaches its melting point, the energy being transferred to it overcomes the bonds between the particles instead of increasing the temperature. Once all the solid has melted, the energy increases the temperature again until the boiling point is reached. At this point, the energy is again used to overcome the forces between the particles in the liquid to turn it into a gas.

The temperature of the gas increases once all the liquid has evaporated.

5 The slope of the line on the graph shows the increase in temperature. If the two substances have different heat capacities, then for the same amount of energy their temperature increases will be different. Each substance has a different specific latent heat, which means the substances need different amounts of energy to make them melt and boil. If energy is being supplied at the same rate, the one with the higher specific latent heat will have a longer horizontal line, because more energy must be transferred to it before all of it changes state.

6 When the steam condenses, it releases the extra energy that the particles had when they were a gas.

7 A heat sink is a component attached to electronic devices to keep them cool. It absorbs energy and transfers it to the surroundings (it often has fins to increase the surface area or is cooled using a fan). The material usually has a high specific heat capacity, so it can absorb a lot of energy without getting too hot.

SP14c Energy calculations

Student Book

1 **a** So it can store more energy, as the amount of energy stored depends on the mass.

b energy = 800 kg × 840 J/kg °C × 40 °C
= 26 880 000 J

2 temperature change

$$= \frac{25\,000 \text{ J}}{1 \text{ kg} \times 840 \text{ J/kg °C}}$$

= 29.8 °C

3 if the water was below boiling point, some of the energy transferred would make the water hotter instead of evaporating some of the water

4 energy = 10 kg × 334 000 J/kg
= 3 340 000 J

5 $$\text{mass} = \frac{100\,000 \text{ J}}{2\,257\,000 \text{ J/kg}}$$

= 0.044 kg

S1 temperature change

$$= \frac{8000 \text{ J}}{0.2 \text{ kg} \times 4182 \text{ J/kg °C}}$$

= 9.6 °C

S2 $$\text{mass} = \frac{10\,000 \text{ J}}{2\,257\,000 \text{ J/kg}}$$

= 0.0044 kg

E1 energy released by condensing steam
= 0.001 kg × 2 257 000 J/kg
= 2257 J

energy released as 1 g of water cools from 100 °C to 30 °C = 0.001 kg × 4182 J/kg °C × 70 °C
= 292.7 J

total energy released by steam condensing and water cooling = 2257 J + 292.7 J
= 2550 J

(Note that all these answers assume that all the energy stored in the hot water/steam is transferred to the skin.)

Exam-style question

energy needed to boil water
= 0.5 kg × 4182 J/kg °C × 90 °C
= 188 190 J (2 marks)

energy needed to evaporate water
= 0.5 kg × 2 257 000 J/kg
= 1 128 500 J (2 marks)

(Note that this answer assumes that no evaporation takes place while the water is being brought to boiling point, although this amount is likely to be negligible.)

SP14c Core practical Investigating water

1 **a** Ice is a solid, so the particles are held in a fixed arrangement (1) by strong forces (1).

b Any two from: the forces between particles are not as strong as in ice/a solid (1) so the particles can move around (1) within the liquid (1).

2 Graph with sensible scales on axes (1) and axes labelled (1).

All points correctly plotted to ± half a square (2). Only 1 mark if one point plotted in error, 0 marks if more than one error.

Smooth curve passing through all the points (1).

3 **a** This is where the ice is melting (1) so the energy being transferred to it (from the hot water) is being used to overcome the forces between the particles (1).

b Ice and water must have different specific heat capacities (1).

4 The amount of energy that must be transferred to it to increase the temperature of 1 kg by 1 Celsius degree (1).

5 **a** They stop the thermometer falling over and breaking/stop the thermometer tipping the cup over and spilling the water (1).

b Polystyrene is a better insulating material than glass (1), so less of the energy transferred to the water will be transferred to the surroundings (1), so the results are more accurate (1).

6 **a** correct change of 11 kJ to 11 000 J and 250 g to 0.25 kg (1)

substitution: $\text{SHC} = \dfrac{11\,000}{0.25 \text{ kg} \times 10\ °\text{C}}$ (1)

evaluation: SHC = 4400 J/kg °C (1 – units not required)

Allow all three marks for correct answer without working.

b The textbook result will have been obtained using very accurate and precise measurements/apparatus (or similar comment) (1)...

whereas in this case some of the energy transferred to the water will be transferred to the surroundings (1)...

so it will appear that it takes more energy to raise the temperature of the water by 1 Celsius degree (1).

c Any comment suggesting how insulation around the cup could be improved, such as adding a lid, using a thicker cup/two cups (1).

Activity and Assessment Pack

SP14c.1 Specific heat capacity

5 to stop the beaker falling over

6 Polystyrene is a better insulating material than glass, so less energy from the warm water will be transferred to the surroundings.

7 The beaker would have allowed more energy from the water to be transferred to the surroundings, so it would look as if more energy was needed to raise the temperature of the water, and the value of specific heat capacity calculated would be too high.

8 Suggestions for systematic errors could include a faulty thermometer, balance or joulemeter. Suggestions for random errors include not reading the instruments correctly.

SP14c.2 Latent heat investigations

1 mass = 85.7 g – 80 g = 5.7 g = 0.0057 kg

2 $\text{energy/kg} = \dfrac{15\,265 \text{ J}}{0.0057 \text{ kg}} = 2\,678\,070 \text{ J/kg}$

3 **a** Higher. Not all the energy transferred to the water will have been used to evaporate the water; some will have been transferred by heating to the flask and to the surroundings.

b It makes sure all steam is condensed before it reaches the end of the tube. Without this, some of the evaporated water might escape and would not be measured when the students find the mass of water in the beaker.

c Insulate the flask in which the water is heated, so that less energy is transferred to the surroundings.

4 **a** energy = 0.2 kg × 4182 J/kg °C × 30 °C
= 25 092 J

b energy = 0.216 kg × 4182 J/kg °C × 22 °C
= 19 873 J

c energy transferred to ice
= 25 092 J – 19 873 J = 5219 J

d $\text{specific latent heat} = \dfrac{5219 \text{ J}}{0.016 \text{ kg}}$
= 326 188 K/kg

e At the beginning of the experiment described, when the water is warmer than the surrounding air, some energy will be transferred from the water to the surroundings as well as some being transferred to the ice. At the end of the experiment, when the water is colder than the surroundings, some energy will be transferred from the surroundings to the water. Because energy is transferred in both directions during the experiment, the effects of this on the accuracy should cancel each other out (or partially cancel out).

If the water is hotter than the surroundings throughout the experiment, the only energy transfer between the water and surroundings will be to the surroundings, so the error in the amount of energy that has not gone into the ice will be greater, and this group will get less accurate results.

SP14c.3 Energy – Equation practice

1 **a** energy = 2 kg × 1005 J/kg °C × 10 °C
= 20 100 J

b energy = 5 kg × 840 J/kg °C × 20 °C
= 84 000 J

c temperature change
$= \dfrac{5000 \text{ J}}{3 \text{ kg} \times 880 \text{ J/kg °C}} = 1.9\ °\text{C}$

d $\text{specific heat capacity} = \dfrac{62\,790 \text{ J}}{20 \text{ kg} \times 15\ °\text{C}}$
= 209.3 J/kg °C

e mass = $\frac{10\ 000\ J}{800\ J/kg\ °C \times 5\ °C}$ = 2.5 kg

f temperature change
= $\frac{3000\ J}{10\ kg \times 1480\ J/kg\ °C}$ = 0.2 °C

g mass = $\frac{2500\ J}{4182\ J/kg\ °C \times 20\ °C}$ = 0.03 kg

h specific heat capacity = $\frac{673\ 500\ J}{50\ kg \times 30\ °C}$
= 449 J/kg °C

2 **a** energy = 10 kg × 1480 J/kg °C × 80 °C
= 1 184 000 J

b energy = 10 kg × 800 J/kg °C × 80 °C
= 640 000 J

c mass = $\frac{20\ 000\ J}{800\ J/kg\ °C \times 80\ °C}$ = 0.3125 kg

3 **a** energy = 0.5 kg × 846 000 J/kg
= 423 000 J

b mass = $\frac{5\ 000\ J}{846\ 000\ J/kg}$ = 0.006 kg

c latent heat = $\frac{5960\ J}{0.02\ kg}$ = 298 000 J/kg

d latent heat = $\frac{20\ 860\ 000\ J}{70\ kg}$ = 298 000 J/kg

e energy = 25 kg × 2 257 000 J/kg
= 56 425 000 J

f mass = $\frac{950\ 000\ J}{2\ 257\ 000\ J/kg}$ = 0.42 kg

g mass = $\frac{321\ 600\ J}{402\ 000\ J/kg}$ = 0.8 kg

h energy = 0.2 kg × 402 000 J/kg = 80 400 J

4 **a** energy = 3 kg × 298 000 J/kg = 894 000 J

b energy = 0.5 kg × 846 000 J/kg
= 423 000 J

c energy = 0.02 kg × 402 000 J/kg = 8040 J

5 mass = $\frac{80\ 000\ J}{846\ 000\ J/kg}$ = 0.095 kg

6 latent heat = $\frac{6\ 420\ 000\ J}{20\ kg}$ = 321 000 J/kg

7 **a** copper: $\Delta\theta$ = 1495 °C – 20 °C = 1475 °C
energy = 0.5 kg × 390 J/kg °C × 1475 °C
= 287 625 J

silver: $\Delta\theta$ = 961 °C – 20 °C = 941 °C
energy = 0.5 kg × 230 J/kg °C × 941 °C
= 108 215 J

gold: $\Delta\theta$ = 1063 °C – 20 °C = 1043 °C
energy = 0.5 kg × 130 J/kg °C × 1043 °C
= 67 795 J

b energy needed to reach melting point
= 287 625 J

energy available to melt copper
= 300 000 J – 287 625 J = 12 375 J

mass of copper melted = $\frac{12\ 375\ J}{207\ 000\ J/kg}$
= 0.06 kg

8 **a** energy needed to reach melting point
= 108 215 J

energy available to melt silver
= 200 000 J – 108 215 J = 91 785 J

energy needed to melt all the silver
= 0.5 kg × 88 000 J/kg = 44 000 J

energy to heat liquid silver
= 91 785 J – 44 000 J = 47 785 J

temperature rise in liquid silver
= $\frac{47\ 785\ J}{0.5\ kg \times 280\ J/kg\ °C}$ = 341.3 °C

final temperature = 961 °C + 341.3 °C
= 1302.3 °C = 1300 °C (3 s.f.)

b energy needed to reach melting point
= 0.05 kg × 130 J/kg °C × (1063 °C – 20 °C) = 6779.5 J

energy needed to melt gold
= 0.05 kg × 67 000 J/kg = 3350 J

energy needed to heat liquid gold to 1200 °C
= 0.05 kg × 150 J/kg °C × (1200 °C – 1063 °C)
= 1027.5 J

total energy = 6779.5 J + 3350 J + 1027.5 J
= 11 157 J = 1.12×10^4 J

SP14c.4 Energy calculations Strengthen

1 mass: *m*, kg

specific heat capacity: *c*

change in temperature: °C

change in thermal energy: *Q, J*

mass: *m*, kg

2 $\Delta\theta = \frac{\Delta Q}{m \times c}$

$= \frac{5000\ J}{0.1\ kg \times 4182\ J/kg\ °C}$

= 11.96 °C
(or 12 °C if students round the answer)

3 $m = \frac{Q}{L}$

$= \frac{5000\ J}{2\ 257\ 000\ J/kg}$

= 0.0022 kg

SP14c.5 Energy calculations Homework 1

1 a change in thermal energy = mass × specific heat capacity × change in temperature

b thermal energy needed for a change of state = mass × specific latent heat

2 a 100 °C – 10 °C = 90 °C

b energy = 1.5 kg × 4182 J/kg °C × 90 °C = 564 570 J

c $\text{mass} = \frac{\text{energy}}{\text{specific latent heat}} = \frac{50\,000\ \text{J}}{2\,257\,000\ \text{J/kg}} = 0.022\ \text{kg}$

3 $L = \frac{3340\ \text{J}}{0.01\ \text{kg}} = 334\,000\ \text{J/kg}$

SP14c.6 Energy calculations Homework 2

1 a energy = 0.5 kg × 10 N/kg × 1.2 m = 6 J

b 6 J × 20 = 120 J

c $c = \frac{120\ \text{J}}{(0.5\ \text{kg} \times 1.5\ °\text{C})} = 160\ \text{J/kg °C}$

d Some of the thermal energy transferred to the lead would then have been transferred to the surroundings and the bung and tube. If all the energy had stayed in the lead, the temperature rise would have been greater and the calculated value of specific heat capacity would have been lower.

2 a energy transferred = 1400 W/m^2 × 3600 s = 5 040 000 J

sand: temperature change $= \frac{5\,040\,000\ \text{J}}{(100\ \text{kg} \times 835\ \text{J/kg °C})} = 60.4\ °\text{C}$

water: temperature change $= \frac{5\,040\,000\ \text{J}}{(100\ \text{kg} \times 4200\ \text{J/kg °C})} = 12\ °\text{C}$

b No energy is transferred from the material being heated to its surroundings.

3 a energy = 1.5 kg × 4182 J/kg °C × 90 °C = 564 570 J

b $\text{mass} = \frac{564\,570\ \text{J}}{2\,257\,000\ \text{J/kg}} = 0.25\ \text{kg}$

4 a energy = 0.150 kg × 4182 J/kg °C × 20 °C = 12 546 J

b energy = 0.015 kg × 334 000 J/kg = 5010 J

c energy stored = 12 546 J – 5010 J = 7536 J

$\text{temperature} = \frac{7536\ \text{J}}{0.165\ \text{kg} \times 4182\ \text{J/kg °C}} = 10.9\ °\text{C}$

5 The energy transferred to the lead shot as it falls is calculated from the gravitational potential energy and is proportional to the mass of lead shot. The specific heat capacity is calculated by dividing the energy transferred by the change in temperature and the mass. The mass cancels out.

SP14d Gas temperature and pressure

Student Book

1 forces due to moving particles

2 The speed of the particles increases, causing more collisions with a greater force.

3 a 227 °C

b −173 °C

4 a 773 K

b 173 K

5 The temperature in kelvin is doubled so the average kinetic energy of the particles is doubled.

S1 Absolute zero is the temperature at which particles have no kinetic energy. It is 0 K or −273 °C.

E1 a The pressure of a gas increases with increasing temperature.

b The pressure of a gas increases with increasing average kinetic energy of its particles.

Exam-style question

The point where the line crosses the horizontal axis is the temperature at which there is zero pressure/particle movement stops (1), this is known as absolute zero/is at a temperature of –273 °C (1).

Activity and Assessment Pack

SP14d.1 Investigating gas pressure and temperature

2 The graph should be a straight line with a positive gradient that does not pass through the origin.

3 Pressure increases linearly with temperature, or there is a linear relationship between pressure and temperature.

4 As the temperature increases the particles move around faster so they hit the walls of the container/pressure sensor harder and more often, which increases the pressure.

5 Students' own answers, but should be somewhere near –273 °C.

7 Suggestions could include errors in measuring temperatures or pressures, or the difficulties of accurately extrapolating such a long way on a graph.

SP14d.2 Gas temperature and pressure – Strengthen

1 **a, b** The temperature of a gas … is a measure of the average kinetic energy of the particles.

When a gas is cooled down the average speed of the particles … decreases

Particles moving slowly have … less kinetic energy than faster-moving particles

If you make a gas cold enough all the particles … stop moving and have zero kinetic energy.

Absolute zero is the temperature … at which particles stop moving and have no kinetic energy.

The temperature of absolute zero is … –273 °C and 0 K

2 moving, force, particles, pressure

faster, more, increases

3 Correct words are: Celsius, kelvin

4 **a** 273, 300 K
b 273, 80 °C

SP14d.3 Gas temperature and pressure – Homework 1

1 **a** B
b The particles are moving more quickly (and are further apart).

2 the temperature at which all particles stop moving

3 **a** 273 K
b 100 °C
c 293 K
d 268 K
e –100 °C

4 **a** Pressure increases.
b The particles move faster, so they hit the walls harder and more often.
c The increased pressure may make the can explode.

SP14d.4 Gas temperature and pressure – Homework 2

1 **a** The warm one will be harder to squeeze than the cooler one.
b In the warm bottle the particles have more kinetic energy and are moving faster, so they hit the walls of the bottle harder and more often. This increases the pressure and makes the bottle harder to squeeze.

2 If the can is heated the particles will move faster, hit the walls of the can harder and more often, and so the pressure will increase. At temperatures above 50 °C, there is a risk that the increased pressure may make the can explode.

3 **a** the temperature at which particles have no kinetic energy/stop moving
b Measure the pressure of a fixed volume of gas at different temperatures. Plot a graph of pressure against temperature, and extrapolate the line to zero pressure. The temperature corresponding to zero pressure is absolute zero.

4 **a** 273 K
b 100 °C
c 293 K
d 268 K
e –100 °C

5 **a** Student B is incorrect. Kinetic energy is directly proportional to temperature, but only when the temperature is plotted in kelvin.
b Change the temperatures to the kelvin scale and make sure the second temperature is double the first one when both are in kelvin.

6 When she puts the cap on, the can is filled with steam and hot air. As the can cools down the steam may condense, so there is less gas in the container. This means the pressure will be less because there are fewer particles to hit the walls of the container. The air trapped in the can will also cool down, so the particles will hit the walls with less force, and there will be fewer collisions with the walls. This will also contribute to lower pressure inside the can. The can crumples when the difference between atmospheric pressure outside the can and the pressure from the air inside the can provides enough force over the area of the can.

SP14e Gas pressure and volume

Student Book

1 **a** increase

b If there are more particles there will be more collisions with the wall and so a greater force on the wall. We measure this as the pressure.

2 If there is a smaller space for the particles to move around in, they will hit the walls more often and so there will be a greater force on the walls.

3 If the temperature changes, the average speed of the particles will change, and so the force with which they hit the walls will also change. The temperature must be kept the same if only the effects of volume are being measured.

4 $V_1 = \dfrac{230\,000\,000 \text{ Pa} \times 0.15 \text{ m}^3}{100\,000 \text{ Pa}}$
$= 345 \text{ m}^3$

5 **H** Work is done on the gas to compress it. This increases the average speed of the particles and so the temperature is higher.

S1 Drawing of a balloon with force arrows at right angles to the surface.

S2 $P_2 = \dfrac{100\,000 \text{ Pa} \times 0.000\,025 \text{ m}^3}{0.000\,010 \text{ m}^3}$
$= 250\,000 \text{ Pa}$

E1 The volume would be too great if they were stored at atmospheric pressure. The amount of gas that can be stored in the cylinder depends on the pressure the cylinder can withstand (P_2) and the volume of the cylinder (V_2). The volume of air at atmospheric pressure (100 000 Pa, P_1) can be calculated using $V_1 = \dfrac{P_2 \times V_2}{P_1}$.

E2 **H** The air in the gun transfers energy to/does work on the ball/pellet. The particles that bounce off the moving ball as it leaves the gun will have a lower speed, so the average speed of the particles in the gas left behind will be lower, and we see this as a drop in temperature.

Exam-style question

The volume increases (1).

Activity and Assessment Pack

SP14e.1 Pressure and volume for a gas

6 Volume decreases as pressure increases.

7 **b** The comment should link points being close to the line to good quality data (or vice versa).

9 The answer should refer to having only a limited set of results to base the conclusion on.

10 Suggestions could include more careful measurements of things such as the internal diameter of the syringe, or refer to any difficulties in reading an accurate volume from the syringe.

SP14e.2 Gas pressure and volume – Equation practice

1 **a** $P_1 \times 3 \text{ m}^3 = 150 \text{ kPa} \times 2 \text{ m}^3$,
$P_1 = \dfrac{300}{3} = 100 \text{ kPa}$

b $50 \text{ N/cm}^2 \times 5 \text{ cm}^3 = P_2 \times 12.5 \text{ cm}^3$,
$P_2 = \dfrac{250}{12.5} = 20 \text{ N/cm}^2$

c $P_1 \times 25 \text{ cm}^3 = 10 \text{ N/cm}^2 \times 37.5 \text{ cm}^3$,
$P_1 = \dfrac{375}{25} = 15 \text{ N/cm}^2$

d $75 \text{ N/cm}^3 \times V_1 = 25 \text{ N/cm}^3 \times 180 \text{ cm}^3$,
$V_1 = \dfrac{4500}{75} = 60 \text{ cm}^3$

e $800 \text{ Pa} \times V_2 = 1000 \text{ Pa} \times 60 \text{ m}^3$,
$V_2 = \dfrac{60\,000}{800} = 75 \text{ m}^3$

f $30 \text{ N/cm}^2 \times V_1 = 900 \text{ N/cm}^2 \times 0.2 \text{ cm}^3$,
$V_1 = \dfrac{180}{30} = 6 \text{ cm}^3$

g $80 \text{ N/cm}^2 \times V_2 = 200 \text{ N/cm}^2 \times 400 \text{ cm}^3$/,
$V_2 = \dfrac{80\,000}{80} = 1000 \text{ cm}^3$

h $P_2 \times 16 \text{ m}^3 = 1000 \text{ kPa} \times 80 \text{ m}^3$,
$P_2 = \dfrac{80\,000}{16} = 5000 \text{ kPa}$

i $P_1 \times 30 \text{ cm}^3 = 10 \text{ N/cm}^2 \times 75 \text{ cm}^3$,
$P_1 = \dfrac{750}{30} = 25 \text{ N/cm}^2$

j $40 \text{ N/cm}^2 \times V_1 = 8 \text{ N/cm}^2 \times 100 \text{ cm}^3$,
$V_1 = \dfrac{800}{40} = 20 \text{ cm}^3$

2 $P_2 \times 8 \text{ cm}^3 = 10 \text{ N/cm}^3 \times 10 \text{ cm}^3$,
$P_2 = \dfrac{100}{8} = 12.5 \text{ N/cm}^3$

3 100 kN/m³ × V_2 = 15 000 kN/m² × 0.5 m³,
$V_2 = \frac{7500}{100} = 75\ m^3$

4 500 Pa × V_2 = 100 000 Pa × 0.2 m³,
$V_2 = \frac{20\,000}{500} = 40\ m^3$

5 100 000 Pa × V_2 = 2.5 × 10⁷ Pa × 3 m³,
$V_2 = \frac{7.5 \times 10^7}{100\,000} = 750\ m^3$

6 1 000 000 Pa × V_2 = 100 000 Pa × 30 cm³,
$V_2 = \frac{3\,000\,000}{1\,000\,000} = 3\ cm^3$

7 P_2 × 50 cm³ = 100 000 Pa × 200 cm³,
$P_2 = \frac{20\,000\,000}{50} = 400\,000$ Pa

8 Total volume of air in ball if it is at atmospheric pressure (V_1) = 6000 cm³ + (50 × 35 cm³)
= 7750 cm³

P_2 × 6000 cm³ = 10 N/cm² × 7750 cm³,
$P_2 = \frac{77\,500}{6000} = 12.9\ N/cm^2$

SP14e.3 Gas pressure and volume – Strengthen

1 arrows drawn at right angles to the surface of the balloon

2 a P_1 = 100 000 Pa, V_1 = 0.000 030 m³,
V_2 = 0.000 015 m³

b $P_2 = 100\,000\ Pa \times \frac{0.000\,030\ m^3}{0.000\,015\ m^3}$
= 200 000 Pa

3 moving, particles, force, particles, pressure
more, increase
less, decrease
pressure, volume, pressure, volume, temperature

SP14e.4 Gas pressure and volume – Homework 1

1 The gas can be stored in a much smaller volume.

2 a Pressure decreases.

b Particles hit the walls of the container less often (or similar explanation).

c If the temperature increases, the particles move faster, and so hit the walls harder and more often, so the pressure increases.

3 a bigger

b V_1 = 0.2 m³, P_1 = 15 000 000 Pa,
P_2 = 100 000 Pa.

c 15 000 000 Pa × 0.2 m³ = 100 000 Pa × V_2

d 3 000 000 = 100 000 × V_2,
$V_2 = \frac{3\,000\,000}{100\,000} = 30\ m^3$

e yes (assuming parts **a** and **d** are correct)

4 a higher

b 100 000 Pa × 200 cm³ = P_2 × 80 cm³,
20 000 000 = P_2 × 80 cm³,
$P_2 = \frac{20\,000\,000}{80}$
= 250 000 Pa

SP14e.5 Gas pressure and volume Homework 2

1 The gas can be stored in a much smaller volume.

2 a The pressure decreases, because the particles hit the walls less often, so the overall force exerted on the walls by the particles is less. A very good answer will point out that the particles hit the walls less often because they have further to go between collisions.

b If the temperature increases, the particles move faster and so hit the walls harder and more often, so the pressure increases. If the temperature decreases, the particles move more slowly and so do not hit the walls as hard or as often, and the pressure decreases.

3 $V_2 = 15\,000\,000\ Pa \times \frac{0.2\ m^3}{100\,000\ Pa} = 30\ m^3$

4 $V_2 = 150\,000\ Pa \times \frac{1.25\ m^3}{20\,000\,000\ Pa} = 0.0094\ m^3$

5 $P_2 = 100\,000\ Pa \times \frac{15\ m^3}{5\ m^3} = 300\,000$ Pa

6 $V_2 = 100\,000\ Pa \times \frac{30\ cm^3}{400\,000\ Pa} = 7.5\ cm^3$

7 $P_2 = 100\,000\ Pa \times \frac{200\ cm^3}{80\ cm^3} = 250\,000$ Pa

8 Each time the pump handle is pushed in, work is being done on the gas. The energy transferred to the gas in the pump raises its temperature, and some of this energy is transferred to the body of the pump.

9 If the volume of the container is doubled to 2V, the pressure will be halved to $\frac{P}{2}$ if the

temperature does not change. If the pressure doubles compared with the starting pressure (to $2P$), it must have increased by a factor of 4 from the reduced pressure in the larger container (increase is from $\frac{P}{2}$ to $2P$, $\frac{P}{2} \times 4 = 2P$). As pressure is proportional to temperature, the temperature (as measured on the Kelvin scale) must also increase by a factor of 4.

10 Gauge pressure is the difference in pressure between the gas being measured and the surrounding pressure (usually atmospheric pressure). Absolute pressure is the pressure compared with a vacuum. If a tyre pressure gauge is reading zero with air in the tyre, it means the air in the tyre is at atmospheric pressure.

SP15a Bending and stretching

Student Book

1 Any two materials, such as clay, sticky-tack, dough.

2 a Elastic, the diving board resumes its original shape when the diver has left it.

b the weight of the diver and the normal contact force from the place where the diving board is mounted

3 a 12 cm

b There is a directly proportional relationship between force and extension, so as the force has increased by a factor of 3, the extension will also increase by a factor of 3.

4 a As the force increases the extension increases in direct proportion, until a certain point is reached when each extra amount of force produces a much greater increase in extension than before.

b The extension increases as the force increases, but after a certain force you get a greater increase in extension. As the force increases further, the amount of extra extension for extra force reduces again.

S1
- Elastic – something that goes back to the original shape when forces deforming it are removed.
- Inelastic – something that does not regain its original shape when deforming forces are removed.
- Extension – the extra length of a spring when it is being stretched, or the stretched length of a spring minus its original length.
- Linear relationship – a relationship between two variables that gives a straight line on a scatter graph, or a relationship where the change in one variable is proportional to the change in the other.
- Directly proportional – a relationship between two variables where one doubles when the other doubles. A directly proportional relationship gives a straight line through (0,0) on a scatter graph.
- Non-linear – a relationship between two variables that does not produce a straight line on a graph/is not proportional.

E1 Students may plot a graph to show the data points, but this is not essential to answer the question. It is not a spring, because the changes in length are not proportional to the changes in force (or similar explanation). There are small changes in length at first for each newton added, then larger ones, then the extra length for each extra newton decreases again. This is a similar pattern to that shown in the graph for a rubber band.

Exam-style question

For a spring the increase in extension is proportional to the increase in length (or there is a linear relationship between force and extension) (1), up to a certain force where the relationship becomes non-linear (1).

For a rubber band the relationship is non-linear throughout (1).

Activity and Assessment Pack

SP15a.1 Springs and rubber bands

3 Both graphs show the extension increasing as the force increases. The graph for the spring should be a straight line, the line for the rubber band is not straight.

4 The graph for the spring should show a directly proportional relationship between force and extension (until the point at which the spring exceeds its limit of proportionality, if students have tested it this far), the graph for the rubber band does not show a linear relationship/is a non-linear relationship.

SP15a.2 Squashing a ball

7 The exact results will depend on the quality, age and state of the tennis ball. However, the deformation is unlikely to be proportional. Trials show a deformation of around 1 mm for 1 kg.

SP15a.3 Bending and stretching Strengthen

1 An elastic material is one that will … return to its original shape when forces on it are removed.

An inelastic material is one that will … keep its new shape when forces on it are removed.

The extension of a spring is … its stretched length minus its original length.

A graph showing a directly proportional relationship … is a straight line through the origin.

A graph showing a linear relationship … is a straight line.

A graph showing a non-linear relationship … is not a straight line.

2 **a** E
b E
c I
d I
e E
f E

3 **a** B
b A
c C

4 **a** A
b C

SP15a.4 Bending and stretching Homework 1

1 **a** 2, 4, 6, 7, 7.5
b, c points correctly plotted and joined with a smooth curve

2 Rubber band, because the line is not straight/ because the line for a spring would be a straight line.

3 **a** non-linear
b straight line on graph starting at the origin

4 **a** Elastic, because the ruler will go back to its original shape when the student lets go of one end.
b **i** Any sensible example of something behaving elastically (e.g. tennis ball, spring).
ii Any sensible example of something behaving inelastically (e.g. modelling clay).

SP15a.5 Bending and stretching Homework 2

1 Simple diagram of a rubber band fastened to a table edge with masses suspended from it, with an upwards arrow at the top of the spring labelled ‘upwards force from table‘, and downwards arrow at the bottom labelled ‘force from masses‘ or ‘weight of masses‘. Accept equivalent wording for labels.

2 **a** 0, 0.5, 2, 4, 6, 7, 7.5
b, c points correctly plotted and joined with a smooth curve, axes with sensible scales and labelled correctly

3 A spring would show a linear/directly proportional relationship, and this graph shows a non-linear relationship.

4 **a** straight line drawn through the origin, labelled as ‘spring behaving elastically‘ or similar
b straight line through the origin that starts to curve at 25 N force (similar to the red line on the right-hand side of diagram D in *SP15a Bending and stretching* in the Student book), curved section labelled as ‘non-linear’

5 Elastic materials change shape when forces are applied to them but regain their original shape when the forces are removed.

Inelastic materials change shape when forces are applied to them but do not regain their original shape when the forces are removed.

6 **a** Rubber bands are used to hold things together. They are intended to behave elastically. Forces need to be applied to a rubber band to stretch it around whatever it is holding, and when these forces are removed the force from the rubber band that is trying to return it to its original shape/length means it grips and holds the things it is surrounding.
b Clay is used to make pottery, because it can be shaped with quite small forces. It is used because it behaves inelastically with quite small forces.

7 B will extend half as much as A, because there is only half the weight being supported by each spring and extension is directly proportional to force.

C will extend twice as much as the same force is being applied to both springs, and each one will stretch by the same amount as A.

In D, the extension will be 1.5 times that in A, because the top part will stretch only half as far and the bottom spring will stretch by the same amount.

In E, an acceptable answer is that the extension will be one-third that of A. However, the force is not symmetrical, so the right-hand spring might stretch a little more than this, and the left-hand spring a little less.

In F, the extension will be three times that in A, as each spring will stretch by the same amount as the spring in A.

SP15b Extension and energy transfers

Student Book

1 a force = 400 N/m × 0.8 m
= 320 N

b force = 400 N/m × 0.1 m
= 40 N

2 k = 20 N/0.5 m
= 40 N/m (or any other two values taken from the graph)

3 The energy transferred depends on the spring constant as well as the extension. Spring X has a larger spring constant so will need the most energy to be stretched by a given amount.

4 energy = 0.5 × 200 N/m × $(0.5\text{ m})^2$
= 25 J

5 $k = \dfrac{5\text{ J}}{0.5 \times (0.1\text{ m})^2}$
= 1000 N/m

S1 $x = \dfrac{80\text{ N}}{400\text{ N/m}}$
= 0.2 m

S2 energy = 0.5 × 400 N/m × $(0.05\text{ m})^2$
= 0.5 J

E1 a $k = \dfrac{50\text{ N}}{0.1\text{ m}}$
= 500 N/m

b $x^2 = \dfrac{10\text{ J}}{0.5 \times 500\text{ N/m}}$
= 0.04 m^2
$x = \sqrt{0.04} = 0.2$ m

Exam-style question

They would need to know the maximum force to be measured and the maximum length the spring could be to fit in the force meter (1). The required spring constant can be found by dividing the force by the maximum extension (or similar answer) (1).

SP15b Core practical Investigating springs

1 a a measure of the force needed to stretch/extend the spring by 1 metre (1)

b $F = k \times x$ or $k = \dfrac{F}{x}$ (1)

c force in newtons or N, extension in metres or m, spring constant in newtons per metre or N/m (1 mark for all three correct)

2 a The force needed to stretch a spring increases as the spring is extended (1), so there is not just one value of force that can be used (or similar explanation) (1).

b spring constant = $\dfrac{20\text{ N}}{0.5\text{ m}}$ = 40 N/m
(1 for substitution, 1 for evaluation)

energy transferred = 0.5 × 40 N/m × $(0.5\text{ m})^2$ = 5 J (1 for substitution, 1 for evaluation)

3 a The spring will stretch (1) until the force with which the spring pulls back/reaction force from the spring balances the weight of the baby (1).

b While the spring is still stretched, the energy is stored in the spring (1). When he releases the baby, the stored energy is transferred to energy in the moving bouncer and baby (kinetic energy) as the force from the spring pulls the baby upwards (1).

4 stand with two clamps (accept 'clamp stand'), metre rule, spring, masses/weights and hanger (1)

5 a

Weight (N)	Extension (m)	
	X	Y
0	0.000	0.000
1	0.034	0.048
2	0.070	0.102
3	0.102	0.152
4	0.131	0.191
5	0.169	0.248
6	0.205	0.303
7	0.235	0.355
8	0.270	0.415
9	0.300	0.448
10	0.335	0.510

(1 for correct conversion of centimetres to metres, 1 for correct values)

b Graph with sensible scales on axes (1) and axes labelled (1).

All points correctly plotted to ± half a square (2). Only 1 mark if one point plotted in error, 0 marks if more than one error.

Line of best fit drawn through the points (1).

c The results for X are probably more accurate, because they lie closer to a straight line (1).

d Values for force and extension read from line of best fit (1).

1 mark for substitution into $k = \frac{F}{x}$

1 mark for evaluation

The value obtained should be approximately 30 N/m.

e Drawing a line of best fit helps to compensate for any random errors (1), so points taken from the line are more likely to be accurate/give an accurate value for the spring constant (1).

6 **a** The unstretched length of X is longer than Y (1) but Y extends more for any given force (or Y has a lower spring constant than X) (1).

b X stores the greatest energy for any given extension (1) because it needs a greater force to give it this extension/has a higher spring constant, so more energy is transferred as the spring is stretched by a given amount (or similar explanation) (1).

7 **a** If the total extension is 1 cm, the change with each weight added will be very small, (1) and it will be difficult to get an accurate measurement of the extension for each weight (1). (Accept similar explanations.)

b Use heavier weights (1), so the total extension is greater (1).

Activity and Assessment Pack

SP15b.1 Investigating springs

5 The springs with the largest spring constants should feel the stiffest.

SP15b.2 Calculating work done

1 **a** students' own answers

b Answers may be yes or no, depending on how well students managed to maintain a constant force. If the answer was yes, the explanation should mention the difficulty of applying a constant force to a moving object.

2 **a** students' own answers

b Students should comment that the force increased as the spring stretched.

3 The force needed to stretch a spring increases because the extension increases/ is proportional to extension. Accept answers along the lines of the more you stretch a spring the harder it pulls back.

4 The force is constant (or is meant to be constant) when pulling the block along the table. The force while the spring is being extended is not constant, so there is no one value that can be used for the force in the equation when considering the spring.

7 **a** Work done is force × distance, and the area under the graph is also a force × a distance.

b Extension is a distance, and work done is the amount of energy transferred, so the area under the graph is the equivalent of force × distance for the changing force.

c The area under graph B is given by $\frac{1}{2}$ × force × extension (the area of a triangle). The equation involving the spring constant shows that force = spring constant × extension, so energy = $\frac{1}{2}$ × spring constant × extension × extension.

SP15b.3 Extension and energy transfers – Equation practice

1 **a** $f = 2\text{ N/m} \times 0.2\text{ m} = 0.4\text{ N}$

b $f = 15\text{ N/m} \times 0.6\text{ m} = 9\text{ N}$

c $k = \frac{6\text{ N}}{2\text{ m}} = 3\text{ N/m}$

d $x = \frac{5\text{ N}}{50\text{ N/m}} = 0.1\text{ m}$

e $x = \frac{16\text{ N}}{800\text{ N/m}} = 0.02\text{ m}$

f $k = \frac{37.5\text{ N}}{0.5\text{ m}} = 75\text{ N/m}$

g $f = 28\text{ N/m} \times 0.03\text{ m} = 0.84\text{ N}$

h $x = \frac{0.005\text{ N}}{0.01\text{ N/m}} = 0.5\text{ m}$

2 $k = \frac{20\text{ N}}{0.02\text{ m}} = 1000\text{ N/m}$

3 $k = \frac{30\text{ N}}{0.13\text{ m} - 0.1\text{ m}} = 1000\text{ N/m}$

4 $k = \frac{10\,000\text{ N}}{0.05\text{ m}} = 200\,000\text{ N/m}$

5 $k = \frac{1000\text{ N}}{0.05\text{ m}} = 20\,000\text{ N/m}$

6 $k = \frac{120\text{ N}}{0.003\text{ m}} = 40\,000\text{ N/m}$

7 **a** $E = 0.5 \times 4\text{ N/m} \times (0.3\text{ m})^2 = 0.18\text{ J}$

b $E = 0.5 \times 16\text{ N/m} \times (0.5\text{ m})^2 = 2.0\text{ J}$

c $E = 0.5 \times 6\text{ N/m} \times (3\text{ m})^2 = 27\text{ J}$

d $k = \frac{0.8\text{ J}}{(0.5 \times (0.2\text{ m})^2)} = 40\text{ N/m}$

e $k = \frac{0.48\text{ J}}{(0.5 \times (0.04\text{ m})^2)} = 600\text{ N/m}$

f $k = \frac{9\text{ J}}{(0.5 \times (0.6\text{ m})^2)} = 50\text{ N/m}$

g $E = 0.5 \times 14\ \text{N/m} \times (0.04\ \text{m})^2 = 0.0112\ \text{J}$

h $k = \dfrac{0.0064\ \text{J}}{(0.5 \times (0.8\ \text{m})^2)} = 0.02\ \text{N/m}$

8 $E = 0.5 \times 50\ \text{N/m} \times (0.2\ \text{m})^2) = 1\ \text{J}$

9 a $x^2 = \dfrac{200\ \text{J}}{(0.5 \times 20\ \text{N/m})} = 20$,
$x = 4.47$ m (or 4.5 m)

b $x^2 = \dfrac{15\ \text{J}}{(0.5 \times 20\ \text{N/m})} = 1.5$,
$x = 1.22$ m (or 1.2 m)

c $x^2 = \dfrac{50\ \text{J}}{(0.5 \times 20\ \text{N/m})} = 5$,
$x = 2.24$ m (or 2.2 m)

10 $E = 0.5 \times 30\,000\ \text{N/m} \times (0.1\ \text{m})^2 = 150\ \text{J}$

11 $k = \dfrac{20\ \text{N}}{0.5\ \text{m}} = 40\ \text{N/m}$

$E = 0.5 \times 40\ \text{N/m} \times (0.5\ \text{m})^2 = 5\ \text{J}$

12 $k = \dfrac{50\ \text{J}}{0.5 \times (0.01\ \text{m})^2} = 1\,000\,000\ \text{N/m}$

$F = 1\,000\,000\ \text{N/m} \times 0.01\ \text{m} = 10\,000\ \text{N}$

SP15b.4 Extension and energy transfers – Strengthen

1 force = spring constant × extension

extension = $\dfrac{\text{force}}{\text{spring constant}} = \dfrac{30\ \text{N}}{200\ \text{N/m}}$
= 0.15 m

2 extension = 0.08 m

energy = $0.5 \times 200\ \text{N/m} \times (0.08\ \text{m})^2 = 0.64\ \text{J}$

3 extension = 0.3 m – 0.2 m = 0.1 m

force = 50 N/m × 0.1 m = 5 N

SP15b.5 Extension and energy transfers – Homework 1

1 the force needed to stretch it by a metre

2 force = spring constant × extension

3 a force = 80 N/m × 0.1 m = 8 N

b extension = $\dfrac{2\ \text{N}}{80\ \text{N/m}} = 0.025\ \text{m}$

4 energy = $0.5 \times 80\ \text{N/m} \times (0.4\ \text{m})^2 = 6.4\ \text{J}$

5 spring constant = $\dfrac{300\ \text{J}}{(0.5 \times (0.2\ \text{m})^2)}$
= 15 000 N/m

SP15b.6 Extension and energy transfers – Homework 2

1 the force needed to give it an extension of one metre

2 spring constant = $\dfrac{\text{force}}{\text{extension}}$
(accept force = spring constant × extension)

3 a force = 35 N/m × 0.2 m = 7.0 N

b extension = $\dfrac{2\ \text{N}}{35\ \text{N/m}} = 0.057\ \text{m} = 5.7\ \text{cm}$

length of spring = 10 cm + 5.7 cm = 15.7 cm (or equivalent working in metres)

4 energy = $0.5 \times 35\ \text{N/m} \times (0.8\ \text{m})^2 = 11.2\ \text{J}$

5 $k = \dfrac{300\ \text{J}}{(0.5 \times (0.3\ \text{m})^2)} = 6666.7\ \text{N/m}$

6 a $k = 20$ N/m (any two points from the graph used for working)

b $x^2 = \dfrac{40\ \text{J}}{(0.5 \times 20\ \text{N/m})} = 4$, $x = 2$ m

7 work done = 20 N × 0.5 m = 10 J

8 energy = $0.5 \times 40\ \text{N/m} \times (0.5\ \text{m})^2 = 5\ \text{J}$

9 The work done is bigger than the energy transferred when stretching the spring. This is because the force on the spring increases with extension, and 20 N is only the maximum force needed.

A very good answer will point out that the energy transferred stretching the spring is half as much as the work done by a force moving through a distance, and relate this to the direct proportionality between force and extension, so the mean force during the stretching is 10 N.

10 a $k = \dfrac{400\ \text{N}}{0.001\ \text{m}} = 400\,000\ \text{N/m} = 4 \times 10^5\ \text{N/m}$

b Each metre of the wire would stretch by 1 mm, so the total extension would be 2 mm.

SP15c Pressure in fluids

1 pressure = $\dfrac{900\ \text{N}}{0.16\ \text{m}^2}$
= 5625 N/m^2

2 It increases, because as you descend there is more atmosphere above you.

3 a force = pressure × area
= 100 000 Pa× 0.01 m^2
= 1000 N

b There is the same pressure acting upwards on the other side of your hand.

4 At sea level the air pressure outside and inside the bag would balance each other. When the bag is taken to a higher altitude the pressure outside the bag decreases, so the pressure inside pushes the bag outwards.

5 a Pressure acts on the ball in all directions. (A very good answer will also say that the pressure acting upwards on the bottom of the ball is slightly greater than the pressure acting downwards on the top.)

b the weight of water above it and the weight of the atmosphere above the water

6 Total pressure = 10 000 Pa + 100 000 Pa = 110 000 Pa, as the pressure under water is due to the pressure of the water itself and the pressure of the atmosphere on the top of the water.

7 The pressure will be greater in salt water, as the greater density of sea water means there will be a greater weight of water above the whale.

S1 The area of the points is much smaller than the area of the boots, so the pressure under the points is greater and they will sink into the ice and provide a grip.

S2 The air pressure will reduce the higher they go, as there is less air above them.

E1 Pressure is caused by the weight of water and air above her. If she was diving in the sea the pressure would be greater because the part of it that is due to air pressure will be greater at a lower altitude. Students may also know that sea water is denser than salt water and that this will also contribute to the increased pressure on her.

Exam-style question

In both cases the pressure is caused by the weight of fluid above (1). Water is much denser than air, so the increase in pressure as you go down in the sea is greater than as you go down in the atmosphere (1). Also, the pressure in water is due to the weight of the water and air above (1).

Activity and Assessment Pack

SP15c.1 Hydraulics

1 a The other plunger moved out.

b the one with the smaller diameter.

2 Students should feel the greatest force on the plunger with the greater diameter.

3 Students should report that the plunger did not move as far, or that it felt ‘squashy’.

4 When one syringe is pushed in, it pushes a certain volume of water through the tube. The other syringe has a different diameter, so moves a different distance when this same volume of water is pushed into it.

5 Energy is conserved, so the work done by each syringe must be the same. As work done = force × distance moved, if the force is greater the distance moved must be smaller (and vice versa).

6 Gases are compressible, so some of the force put into the plunger is being used to compress the gas, not to move the other piston. Liquids are not compressible (or are very difficult to compress).

8 The ratio of the distances moved should be the same each time.

9 The ratio of the distances moved should be the opposite of the ratio of the cross-sectional areas.

SP15c.2 High and low pressures

These answers are more detailed than would be expected of most students.

A The highest town in the world is in Peru, at an altitude of just over 5000 metres. Other countries with high-altitude towns or villages include China, India, Nepal, Chile, Argentina.

The higher you go, the less oxygen there is for each lungful of air. People can go to higher altitudes, but may become ill especially if they stay there for some time.

High-altitude adaptations in humans occur in some populations in Tibet, the Andes and Ethiopia. Different populations have different adaptations, so accept any one of the following. Tibetans tend to have larger lung capacities and more rapid breathing rates than lowlanders. In the Andes, people may have a higher haemoglobin concentration, and can also carry more oxygen in each red blood cell. People in Ethiopia also have higher haemoglobin concentrations.

Lowlanders going to high altitude may become ill due to not getting enough oxygen. Temporary adaptations take place over days or weeks and include an increase in the number of red blood cells. There are also adaptations to prevent the blood becoming too alkaline due to the higher breathing rate (respiratory alkalosis), but for students working at this level mentioning the increase in red blood cells is sufficient.

Extra challenge

Altitude sickness (also known as acute mountain sickness) is caused by lack of oxygen and can include (in increasing order of severity) breathlessness, headache, upset stomach, dizziness, sleep disturbance, swelling of hands, feet and face, pulmonary oedema (fluid in the lungs) or cerebral oedema (swelling of the brain) – these last two can be fatal. The quickest and only reliable treatment is to descend (or to put the patient into a pressurised bag that simulates living at a lower altitude).

B The cabin of passenger aircraft is pressurised. The pressure inside the cabin is usually not the same as at sea level, but may be the equivalent of an altitude of 2400 m – this is the 'cabin altitude'.

The rules for the use of oxygen in small aircraft vary between countries, but typically are for the pilot to use oxygen for flights above 10 000 ft or 12 500 ft (altitudes in aviation are still given in feet), sometimes with a waiver that this is only necessary if they are above that altitude for more than 30 minutes. There is a higher altitude (14 000 ft) at which the 30 minute waiver does not apply and oxygen must be used at all times. Passengers should have oxygen available but are not required to use it. The difference in the rules for pilot and passengers is so that the pilot remains mentally and physically competent to control the aircraft safely.

Extra challenge

Humans can survive short periods (up to 90 seconds) of exposure to very low pressures if they are re-pressurised promptly, as evidenced from a handful of accidents. Most of the symptoms have been discovered by experiments on animals and are assumed to apply to humans. These include the formation of gas bubbles in the blood or other fluids (ebullism), lack of oxygen, rupture of the lungs if the mouth is closed (so open your mouth!). If this happens in space, the person may also be exposed to extreme temperature variations, including evaporative cooling as water evaporates from the lungs, eyes and mouth.

C The maximum depth for scuba diving is around 40 metres. To dive to much greater depths an atmospheric diving suit is required. This is a rigid suit with moveable joints that maintains roughly atmospheric pressure inside it.

'The bends', or decompression sickness, refers to symptoms that occur when a person has been in conditions of increased pressure and quickly returns to normal pressures. At high surrounding pressure, more gases than usual can dissolve in the blood, and if the person decompresses too rapidly these gases come out of solution and form bubbles in the blood. The bubbles cause anything from joint pain to mental confusion, seizures, unconsciousness and death.

Divers avoid the bends by decompressing slowly. In recreational diving this involves hanging around (literally, quite often, by holding onto a line anchored to the sea floor) for some time at gradually reducing depths. Commercial divers may use a decompression chamber in which they can sleep, read, etc, while the pressure is gradually reduced.

Extra challenge

One adaptation is that the animals' lungs can collapse during deep dives, which reduces the amount of nitrogen from the air in them that can dissolve in the blood. This, in turn, greatly reduces the possibility of bubbles forming in the blood when the animal ascends again. The animals can also store a lot of oxygen in blood and muscles.

D Modern military submarines can descend to around 500 m. Some submersibles have descended to the deepest part of the oceans, over 10 000 m deep.

Submersibles are much smaller than submarines, typically with a crew of 1–3 people, and are only occupied for limited periods (in the order of hours). Some military submarines can stay at sea and submerged for months at a time.

Some submersibles can operate alone, but some are tethered to a surface ship that supplies power and air. Manned submersibles usually have windows and external arms that can be operated by the crew to gather samples etc. Submarines do not normally have either of these.

Extra challenge

A diving bell is a bell-shaped device that is lowered into the sea. There is a seat or other means for people to sit inside it. Air trapped as it is lowered allows the crew to breathe. However, as it is lowered, pressure from the water compresses the air inside it, so the crew would suffer the same effects of pressure as a scuba diver would (e.g. bends if they ascend too quickly).

SP15c.3 Pressure in fluids equation practice

1 **a** pressure = $\frac{4\text{ N}}{0.02\text{ m}^2}$ = 200 Pa

b pressure = $\frac{200\text{ N}}{0.5\text{ m}^2}$ = 400 Pa

c force = 20 000 Pa × 2.5 m^2 = 50 000 N

d force = 200 Pa × 3 m^2 = 600 N

e area = $\frac{750\text{ N}}{15\text{ Pa}}$ = 50 m^2

f area = $\frac{600\text{ N}}{12\text{ Pa}}$ = 50 m^2

g force = 330 Pa × 0.3 m^2 = 99 N

h area = $\frac{0.5\text{ N}}{50\text{ Pa}}$ = 0.01 m^2

i area = $\frac{60\text{ N}}{30\,000\text{ Pa}}$ = 0.002 m^2

j force = 250 Pa × 0.12 m^2 = 30 N

2 force = 50 000 Pa × 0.2 m^2 = 10 000 N

3 pressure = $\frac{20\,000\text{ N}}{3\text{ m}^2}$ = 6666.67 Pa

4 **a** force = 3750 Pa × 0.16 m^2 = 600 N

b pressure = $\frac{600\text{ N}}{0.03\text{ m}^2}$ = 20 000 Pa

5 pressure under one foot of elephant

= $\frac{40\,000\text{ N}}{0.15\text{ m}^2}$ = 266 667 Pa

pressure under one foot of man = $\frac{850\text{ N}}{0.03\text{ m}^2}$

= 28 333 Pa

There is greater pressure under the elephant.

6 area of wood = 0.5 m × 0.5 m = 0.25 m^2

force = 100 000 Pa × 0.25 m^2 = 25 000 N

7 **a** total pressure = 3000 Pa + 100 000 Pa
= 103 000 Pa

b force = 103 000 Pa × 1.5 m^2 = 154 500 N

8 pressure under original fence post = $\frac{100\text{ N}}{0.01\text{ m}^2}$

= 10 000 Pa

pressure under sharpened post = $\frac{100\text{ N}}{0.004\text{ m}^2}$

= 25 000 Pa

change in pressure = 15 000 Pa

SP15c.4 Pressure in fluids Strengthen

1 weight, area, pressure

area, smaller, area, smaller, higher, high

2 the depth of the fluid, the density of the fluid

3 correct words are: density, more, bottom, above, less, less, less

4 pressure = $\frac{\text{force}}{\text{area}} = \frac{900\text{ N}}{0.03\text{ m}^3}$ = 30 000 Pa

5 force = pressure × area = 80 000 Pa × 0.6 m^2
= 48 000 N

SP15c.5 Pressure in fluids Homework 1

1 a liquid or a gas

2 density, depth/height

3 **a** There is more weight of water above the diver.

b Arrows above and below the diver at right angles to his body.

c air, water

4 The density of sea water is greater than that of fresh water, so for a certain depth there is a greater weight of water above.

5 pressure = $\frac{\text{force}}{\text{area}} = \frac{150\text{ N}}{0.12\text{ m}^2}$ = 1250 Pa

6 weight (or force) = pressure × area
= 150 Pa × 0.6 m^2 = 90 N

SP15c.6 Pressure in fluids Homework 2

1 When the bag was sealed the pressure was the same inside and outside. When it is taken to 1000 m the air pressure outside it is less. The higher pressure inside the bag makes it expand.

2 **a** There is a greater depth of water above the diver.

b at right angles to the surface of their body, on all parts of their body

c air, water

3 The density of sea water is greater than that of fresh water, so for a certain depth there is a greater weight of water above.

4 **a** pressure = $\frac{60\text{ N}}{0.03\text{ m}^2}$ = 2000 Pa

b 2000 N, the pressure is the same throughout the fluid.

c force = 2000 N × 0.12 m^2 = 240 N

d work done = 60 N × 0.6 m = 36 J

e 36 J – energy is conserved.

f distance = $\frac{\text{work done}}{\text{force}} = \frac{36\text{ J}}{240\text{ N}}$ = 0.15 m

5 pressure caused by B = $\frac{20\text{ N}}{0.12\text{ m}^2}$ = 166.67 Pa

force on A = 166.67 Pa × 0.03 m^2 = 5 N

work done on B = 20 N × 0.2 m = 4 J

distance moved by A = $\frac{4\text{ J}}{5\text{ N}}$ = 0.8 m

6 **a** The cylinders at the wheels will have the largest diameter, this will give them a larger area, which means they can magnify the force applied by the brake pedal.

b It doesn’t affect the force, as the pressure in the liquid is the same throughout the system. (The only way that different forces will be applied at the brakes is if the cylinders have different diameters.)

7 When piston A is moved, the volume of liquid it pushes through the system = 0.03 m^2 × 0.6 m = 0.018 m^3.

This volume of liquid is pushed through the system and pushes piston B upwards.

The distance it moves = $\frac{\text{volume of liquid}}{\text{area of B}}$

$= \frac{0.018\text{ m}^3}{0.12\text{ m}^2}$

= 0.15 m

SP15d Pressure and upthrust H

7th **1** pressure
= 2992 m × 1030 kg/m^3 × 10 N/kg
= 30 817 600 Pa

8th **2** depth = $\frac{\text{pressure}}{\text{density} \times g}$

$= \frac{500\,000\text{ Pa}}{1030\text{ kg/m}^3 \times 10\text{ N/kg}}$

= 48.5 m

7th **3** 7.5 N, as the block is floating there are balanced forces on it so the upthrust must have the same magnitude as the weight but in the opposite direction.

8th **4** **a** pressure difference
= 0.1 m × 1000 kg/m^3 × 10 N/kg
= 1000 N/m^2
force = pressure difference × area
= 1000 N/m^2 × 0.1 m × 0.1 m
= 10 N

7th **b** The upthrust is 10 N and the weight of the block is 12 N, so the upthrust is not enough to balance the weight.

8th **5** The upthrust is equal to the weight of fluid displaced. If the object is denser than water, the volume of water it displaces will have a smaller weight than the weight of the object and so the upthrust is less than the weight and it will sink.

S1 The pressure in a fluid depends on the depth of the object in the fluid and the density of the fluid. The pressure on the fish in the sea is greater both because sea water is more dense than fresh water, and because the fish in the sea is also deeper in water than the fish in the fresh-water lake.

S2 The pressure on the top of the hot air balloon is less than the pressure underneath it. There is therefore a pressure difference that causes upthrust. Because the heated gas within the balloon is less dense than the cold gas in the surrounding atmosphere, the weight of the atmosphere displaced by the balloon is equal to the total weight of the balloon and so the upthrust balances the weight of the balloon.

E1 The fluid is denser than water, so each block will need to displace less fluid to float. The three blocks that are floating in water will float higher in the dry cleaning fluid.

The density of the dry cleaning fluid is greater than the density of the ebony block, so that will also float.

pressure difference for submerged wooden block = 0.1 m × 1622 kg/m^3 × 10 N/kg
= 1622 N/m^2

upthrust = force
= pressure difference × area
= 1622 N/m^2 × 0.1 m × 0.1 m
= 16.22 N

Exam-style question

The pressure in a fluid increases with depth (1). The submersible has to go to 10 times the depth of the submarine so it will need to withstand pressures 10 times as great (1).

Activity and Assessment Pack

SP15d.1 Floating and sinking

5 The upthrust should be equal to the weight of water displaced.

6 If students have carried out their measurements accurately, the points should fall on a line through the origin with a gradient of 1. (This will be an angle of 45° if students have used the same scale on both axes.)

7 The upthrust is equal to the weight of water displaced.

8 Either answer is acceptable, but the more likely answer is that the relationship is easier to see on a graph.

9 The greater the scatter of points away from the line, the less precise the results.

12 a The depth in the water should be less for the salty water.

b Salty water is more dense then tap water, so for the same weight of water to be displaced the volume is smaller.

13 The same as the weight of the block.

15 Suggestions are likely to include errors in finding the weight of the blocks, difficulties in making accurate measurements of the depth of the block in the water.

16 If the block is on end the pressure at the bottom of the block is greater. However, the area on which the water pressure is acting is smaller, and the two factors cancel out.

SP15d.2 Manometers

4 The graph should be a straight line through the origin, showing that density and height difference are in direct proportion.

5 The liquid with the lowest density should have given the largest height difference. The pressure of the gas is found from density × height difference, so if the density decreases the height difference should increase (assuming the gas pressure is the same each time).

6 Height difference is directly proportional to liquid density. If students have not started their axes at zero they may say that the relationship is linear.

7 Answers should refer to any outliers in the table, or how closely the points on the graph lie to the line of best fit.

8 Reasons could include variations in the gas pressure as well as measurement inaccuracies or errors.

SP15d.3 Pressure and upthrust Equation practice

1 a pressure = 1 m × 1000 kg/m^3 × 10 N/kg = 10 000 Pa

b pressure = 5 m × 1022 kg/m^3 × 10 N/kg = 51 100 Pa

c height = $\frac{67\ 950 \text{ Pa}}{(13\ 950 \text{ kg/m}^3 \times 10 \text{ N/kg})}$ = 0.5 m

d height = $\frac{70\ 000 \text{ Pa}}{(700 \text{ kg/m}^3 \times 10 \text{ N/kg})}$ = 10 m

e density = $\frac{8000 \text{ Pa}}{(0.8 \text{ m} \times 10 \text{ N/kg})}$

= 1000 kg/m^3

f density = $\frac{2400 \text{ Pa}}{(0.2 \text{ m} \times 10 \text{ N/kg})}$

= 1200 kg/m^3

g height = $\frac{1200 \text{ Pa}}{(400 \text{ kg/m}^3 \times 10 \text{ N/kg})}$ = 0.3 m

h pressure = 1.2 m × 850 kg/m^3 × 10 N/kg = 10 200 Pa

i height = $\frac{19\ 250 \text{ Pa}}{(550 \text{ kg/m}^3 \times 10 \text{ N/kg})}$ = 3.5 m

j density = $\frac{10\ 800 \text{ Pa}}{(1.2 \text{ m} \times 10 \text{ N/kg})}$

= 900 kg/m^3

2 a pressure = 2 m × 920 kg/m^3 × 10 N/kg = 18 400 Pa

b height = $\frac{18\ 400 \text{ Pa}}{(711 \text{ kg/m}^3 \times 10 \text{ N/kg})}$ = 2.59 m

3 a density = $\frac{23\ 550 \text{ Pa}}{(3 \text{ m} \times 10 \text{ N/kg})}$ = 785 kg/m^3

b height = $\frac{23\ 550 \text{ Pa}}{(13\ 590 \text{ kg/m}^3 \times 10 \text{ N/kg})}$

= 0.17 m

4 a pressure = 10 m × 1000 kg/m^3 × 10 N/kg = 100 000 Pa

b pressure = 10 m × 1022 kg/m^3 × 10 N/kg = 102 200 Pa

difference = 102 200 Pa – 100 000 Pa = 2200 Pa

5 pressure at the bottom of tube of mercury = 0.2 m × 13 590 kg/m^3 × 10 N/kg = 27 180 Pa

height of water column

= $\frac{27\ 180 \text{ Pa}}{(1000 \text{ kg/m}^3 \times 10 \text{ N/kg})}$ = 2.72 m

6 **a** pressure on Earth
$= 2\text{ m} \times 1000\text{ kg/m}^3 \times 10\text{ N/kg}$
$= 20\,000\text{ Pa}$

b Moon: $g = \frac{3200\text{ Pa}}{(2\text{ m} \times 1000\text{ kg/m}^3)}$
$= 1.6\text{ N/kg}$

Mars: $g = \frac{7400\text{ Pa}}{(2\text{ m} \times 1000\text{ kg/m}^3)}$
$= 3.7\text{ N/kg}$

SP15d.4 Pressure and upthrust Strengthen

1 Sentence endings may vary if students have not used the help section on the sheet.

The pressure on an object beneath the surface of a fluid depends on…its density and the depth of fluid above.

The fish in the sea is in water with a greater… density than fresh water.

So even if it were only 5 m below the surface, the pressure … on it would be greater.

The fish in the sea also has … a higher column of water above it.

So there is a greater … weight of fluid above it.

2 **a** true
b false – decreases with height
c true
d false – greater on the bottom
e true

3 A suitable order is b, e, d, c, a

4 **a** pressure $= 5\text{ m} \times 1000\text{ kg/m}^3 \times 10\text{ N/kg}$
$= 50\,000\text{ Pa}$

b pressure $= 30\text{ m} \times 1030\text{ kg/m}^3 \times 10\text{ N/kg}$
$= 309\,000\text{ Pa}$

SP15d.5 Pressure and upthrust Homework 1

1 Upthrust is an upwards force on an object in any fluid. It is caused by the pressure difference between the top and bottom of the object. The upthrust is equal to the weight of water displaced. Something floats if the upthrust is equal to its weight.

2 **a** Z, X, Y

b Z is the heaviest because it sinks (‘heaviest’ is valid here as all the blocks are the same size and shape). X is heavier than Y as it is displacing more water, and so the upthrust is greater. When an object floats the upthrust is equal to the weight of the object.

c Z has the greatest upthrust on it, as upthrust is equal to the weight of water displaced. Z is completely submerged and is displacing the greatest volume and so also displacing the greatest weight of water.

d The upthrust will increase, as the bottom of the block is deeper in the water there will be more pressure under it so the force on the bottom of the block caused by the pressure will increase.

3 **a** pressure $= 0.1\text{ m} \times 1000\text{ kg/m}^3 \times 10\text{ N/kg}$
$= 1000\text{ Pa}$

b force $= 1000\text{ Pa} \times 0.04\text{ m}^2 = 40\text{ N}$

4 **a** upthrust = weight = 64 N, as the block is floating

b pressure $= \frac{64\text{ N}}{0.04\text{ m}^2} = 1600\text{ Pa}$

c The pressure is greater. This is expected, as the bottom of X is lower in the water than the bottom of block Y, and pressure increases with depth.

d depth $= \frac{1600\text{ Pa}}{(1000\text{ kg/m}^3 \times 10\text{ N/kg})} = 0.16\text{ m}$

5 **a** pressure difference
$= 0.2\text{ m} \times 1000\text{ kg/m}^3 \times 10\text{ N/kg} = 2000\text{ Pa}$
force $= 2000\text{ Pa} \times 0.04\text{ m}^2 = 80\text{ N}$

b The block is resting on the bottom of the container, so we only know that its weight is greater than the upthrust.

SP15d.6 Pressure and upthrust Homework 2

1 **a** pressure $= 0.05\text{ m} \times 1000\text{ kg/m}^3 \times 10\text{ N/kg}$
$= 500\text{ Pa}$

b pressure $= 0.18\text{ m} \times 1000\text{ kg/m}^3 \times 10\text{ N/kg}$
$= 1800\text{ Pa}$

2 **a** height difference $= \frac{800\text{ Pa}}{(789\text{ kg/m}^3 \times 10\text{ N/kg})}$
$= 0.101\text{ m} = 10.1\text{ cm}$

b height difference
$= \frac{800\text{ Pa}}{(13\,590\text{ kg/m}^3 \times 10\text{ N/kg})}$
$= 0.0059\text{ m} = 0.59\text{ cm}$

c height difference $= \frac{800\text{ Pa}}{(1000\text{ kg/m}^3 \times 10\text{ N/kg})}$
$= 0.08\text{ m} = 8\text{ cm}$

3 **a** weight = 40 000 kg × 10 N/kg = 400 000 N

b 400 000 N. If the submersible is floating at a constant depth, the upthrust on it must balance its weight.

c pressure difference = $\frac{\text{force}}{\text{area}}$

$$= \frac{400\,000 \text{ N}}{20 \text{ m}^2}$$

$$= 20\,000 \text{ N/m}^2$$

d The pressure difference is due to the difference of depth between the top and bottom of the submersible.

$$\text{height} = \frac{20\,000 \text{ N/m}^2}{(1030 \text{ kg/m}^3 \times 10 \text{ N/kg})} = 1.94 \text{ m}$$

4 Upthrust on a block
= weight of water displaced
= mass of water displaced × 10 N/kg

mass of water displaced = density × volume
= 1000 kg/m^3 × 0.04 m^3
= 40 kg

so upthrust = weight of water
= 40 kg × 10 N/kg = 400 N

apparent weight = 960 N – 400 N = 560 N

5 **a** weight of block
= weight of water displaced, so
mass of block = mass of water displaced

mass of water displaced
= density × volume
= 1000 kg/m^3 × 1.1 × 10^{-5} m^3
= 1.1 × 10^{-2} kg

$$\text{density of block} = \frac{1.1 \times 10^{-2} \text{ kg}}{1.5 \times 10^{-5} \text{ m}^3}$$

$$= 733 \text{ kg/m}^3$$

b You cannot work out the weight (and hence mass) if it does not float, as you only know that the weight of the object is greater than the weight of water displaced.

6 Simple diagram of a sealed tube full of liquid inverted in an open dish of the liquid. There should be a gap at the top of the tube. Explanation that the height of the column of liquid in the tube is equal to the air pressure on the liquid in the dish. Mercury is suitable as atmospheric pressure produces a column of mercury approximately 0.76 m high. If water were used, the column of liquid would be approximately 10 m high.