3 a) The activation energy is the minimum amount of energy that is needed to start a reaction ***[1 mark]***.

b) Reaction A is the most suitable reaction ***[1 mark]***.
Reaction C is endothermic / does not give out heat ***[1 mark]***.
Reaction A has a lower activation energy than Reaction B / gives out more energy than Reaction B ***[1 mark]***.

Page 150 — Measuring Temperature Changes

1 a) Any three from: e.g. thermometer / polystyrene cup (and lid) / mass balance / measuring cylinder / beaker filled with cotton wool ***[1 mark for each]***.

b) How to grade your answer:

Level 0: There is no relevant information. ***[No marks]***

Level 1: The method is vague, and misses out important details about how the investigation could be carried out. The points made are basic and not linked together. ***[1 to 2 marks]***

Level 2: The method is clear, but misses out a few key details about how the investigation would be carried out or how the variables could be controlled. Some of the points made are linked together. ***[3 to 4 marks]***

Level 3: A detailed method is given that includes ways to reduce energy transfer to the surroundings, and specifies variables that should be controlled throughout the investigation. The points made are well-linked and the answer has a clear and logical structure. ***[5 to 6 marks]***

Here are some points your answer may include:
Place a polystyrene cup into a large beaker of cotton wool.
Add a measured volume of water to the polystyrene cup.
Record the initial temperature of the water.
Add a measured number of moles of salt A.
Stir the mixture.
Place a lid on the polystyrene cup to reduce the amount of energy transferred to the surroundings.
Record the maximum or minimum temperature reached by the mixture.
Repeat the experiment for salt B.
Use the same volume of water when repeating the experiment.
Use the same equipment/container/amount of insulation/ thermometer when repeating the experiment.

c)

Salt	Initial temperature / °C	End temperature / °C	Temperature change / °C
A	21.0	16.0	**–5.0**
B	21.0	26.5	**5.5**

[1 mark for each row correctly completed]

d) C ***[1 mark]***

Pages 151-152 — Bond Energies

Warm-up
C

1 a) E.g. energy change = energy required to break bonds – energy released by forming bonds
bonds broken: (1 × C=C) + (1 × H—O)
= 614 + 463 = 1077 kJ mol^{-1}
bonds made: (1 × C—C) + (1 × C—H) + (1 × C—O)
= 347 + 413 + 358 = 1118 kJ mol^{-1}
energy change = 1077 – 1118 = **–41 kJ mol^{-1}**
[3 marks for correct answer, otherwise 1 mark for calculating the energy of bonds broken and 1 mark for calculating the energy of bonds made.]

If there are any bonds that appear on both sides of the equation, you can ignore them (that's what we've done here). But if you find it easier to work out the total energy of all the bonds in the products and the total energy of all the bonds in the reactants, that's fine. You'll get the same answer.

b) The reaction is exothermic ***[1 mark]*** as the energy change of reaction is negative / energy is given out during the reaction / it takes less energy to break the bonds in the reactants than the energy given out when the bonds in the products are made ***[1 mark]***.

2 a) The energy released by forming bonds in the products is greater than the energy used to break the bonds in the reactants ***[1 mark]***.

b) E.g. bonds broken: (1 × C—H) + (1 × Cl—Cl)
= 413 + 239 = 652 kJ mol^{-1}
bonds made: (1 × C—Cl) + (1 × H—Cl) = 339 + H—Cl
energy change = energy required to break bonds – energy released by forming bonds
–119 = 652 – (339 + H—Cl)
–119 = 313 – H—Cl
H—Cl = 313 + 119 = **432 kJ mol^{-1}**
[3 marks for the correct answer, otherwise 1 mark for correctly calculating energies of bonds made and broken and 1 mark for a correct expression for energy change of reaction including the H—Cl bond .]

c) Cl—Cl, C—Cl, C—C, C—H, H—Cl
[1 mark for correct order.]

Stronger bonds take more energy to break, so stronger bonds will have higher bond energies.

Section 16 — Fuels and Earth Science

Pages 153–155 — Fractional Distillation and Hydrocarbons

Warm-up
Bitumen — Surfacing roads and roofs.
Diesel — Fuel for cars, lorries and trains.
Kerosene — Fuel for aircraft.

1 a) A compound formed from hydrogen and carbon ***[1 mark]*** only ***[1 mark]***.

b) B ***[1 mark]***

c) One day it will run out / it is being used at a much faster rate than the rate at which it is being reformed ***[1 mark]***.

2 They have molecular formulas that differ by CH_2 from neighbouring compounds ***[1 mark]***. They share similar chemical properties ***[1 mark]***. They show a gradual variation in physical properties ***[1 mark]***.

3 a) i) When they are burned, they give out lots of energy ***[1 mark]***.

ii) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
[1 mark for formulas of all reactants and products correct, 1 mark for correct balancing.]

b) C ***[1 mark]***

4 a) Fuel oil has the highest boiling point ***[1 mark]***. Fuel oil has the longest / largest molecules of the three fractions, and the longer / larger the hydrocarbon, the higher its boiling point ***[1 mark]***.

b) Fuel oil is more viscous than kerosene ***[1 mark]***. Fuel oil has longer / larger molecules than kerosene, and the longer / larger the hydrocarbon, the higher the viscosity ***[1 mark]***.

It's perfectly fine if you phrased your answer the other way round here (i.e. "Kerosene will be less viscous than fuel oil, because...").

c) Kerosene is easier to ignite than diesel oil ***[1 mark]***. Kerosene has shorter / smaller molecules than diesel oil, and the shorter / smaller the hydrocarbon, the easier it is to ignite ***[1 mark]***.

Same here — it's fine if you phrased your answer the other way round (i.e. "Diesel oil will be harder to ignite than kerosene, because...").

5 a) E.g. fuel for large ships ***[1 mark]*** and in power stations ***[1 mark]***.

b) i) triacontane ***[1 mark]***

ii) E.g. the further down the column a hydrocarbon is collected, the higher its boiling point ***[1 mark]***. Long hydrocarbons, like triacontane, have higher boiling points than shorter hydrocarbons like heptane ***[1 mark]***. This is because their chains are much longer, so the intermolecular forces between the chains are stronger ***[1 mark]***. More energy is needed to overcome these forces and turn the hydrocarbon into a gas ***[1 mark]***, so triacontane will have a higher boiling point than heptane and will be collected further down the column ***[1 mark]***.

c) Bitumen / fuel oil ***[1 mark]***.

Since alkane X is more viscous than triacontane, it must be a longer molecule. So it must either be a longer hydrocarbon from the fuel oil fraction, or be in the only fraction with longer molecules (bitumen).

Page 156 — Pollutants

1 a) C ***[1 mark]***

b) Any two from: e.g. lakes could become acidic causing plants and animals to die / trees could be killed / damage to limestone buildings and stone statues / corrosion of metals *[1 mark for each correct answer]*.

2 a) Nitrogen and oxygen from the air *[1 mark]* react together at the high temperatures produced by combustion in the engine *[1 mark]*.

b) Soot can cause respiratory problems *[1 mark]*.

c) Carbon monoxide *[1 mark]*. It binds to red blood cells, reducing the amount of oxygen they can transport *[1 mark]*. This can lead to fainting, coma or even death *[1 mark]*.

d) Any two from: e.g. burning hydrogen only produces water/does not produce pollutants/carbon dioxide/carbon monoxide/soot like burning fossil fuels does. / Hydrogen is obtained from water which is a renewable source (so it won't run out, unlike fossil fuels). / More hydrogen can be made from the water produced by the fuel cell as a waste product *[1 mark for each correct answer]*.

Page 157 — Cracking

1 a) B *[1 mark]*

b) The amount of some fractions produced does not always meet the demand for those products *[1 mark]*. More of the product can be produced by cracking longer molecules into smaller, more useful ones *[1 mark]*.

c) E.g. $C_{10}H_{22} \rightarrow C_7H_{16} + C_3H_6$ *[1 mark]*

Cracking equations must always be balanced and have a shorter alkane and an alkene on the right-hand side.

2 a) Gases *[1 mark]* and petrol *[1 mark]*.

b) Molecules from the fuel oil and bitumen fractions could be cracked to produce extra diesel *[1 mark]*.

Page 158 — The Atmosphere

1 A *[1 mark]*

2 a) i) carbon dioxide *[1 mark]*

ii) Any two from, e.g: plants evolved which removed carbon dioxide through photosynthesis / carbon dioxide was locked in fossil fuels/sedimentary rocks / carbon dioxide dissolved in the oceans *[1 mark for each correct answer]*.

b) i) As green plants photosynthesised, they produced oxygen *[1 mark]*. Hardly any oxygen is present in Mars' atmosphere as there are no plants / no discovered life on Mars *[1 mark]*.

ii) Oxygen gas will relight a glowing splint *[1 mark]*.

Pages 159–160 — The Greenhouse Effect and Climate Change

Warm-up

Walking to school

Turning central heating down

1 a) Any two from: e.g. carbon dioxide / methane / water vapour *[1 mark for each correct answer]*

b) E.g. burning fossil fuels / deforestation *[1 mark for each correct answer]*

2 a) B *[1 mark]*

b) Elvis is incorrect, e.g. because greenhouse gases are responsible for the greenhouse effect, which is important as it keeps the Earth warm enough to support life *[1 mark]*.

3 a) How to grade your answer:

Level 0: There is no relevant information. *[No marks]*

Level 1: There is a brief explanation of what the data in the graph shows, but uncertainty is not discussed. The points made are basic and not linked together. *[1 to 2 marks]*

Level 2: There is an explanation of what the data in the graph shows. There is some mention of the uncertainty associated with any conclusions drawn from this data. Some of the points made are linked together. *[3 to 4 marks]*

Level 3: There is a clear and detailed conclusion of what the data in the graph shows, and the uncertainty associated with conclusions drawn from this data is thoroughly discussed. The points made are well-linked and the answer has a clear and logical structure. *[5 to 6 marks]*

Here are some points your answer may include:

The data in the graph shows that CO_2 emissions in the UK have decreased from the 1993 through to 2013.

The data shows that global sea levels have risen from the 1993 through to 2013.

The data suggests that CO_2 emissions are not the cause of rising sea levels as the CO_2 emissions in the UK decreased as the sea level rose.

The data in this graph does not support a link between human activity and climate change.

The CO_2 emissions from burning fossil fuels are only from one country and are not a global figure.

The global CO_2 emissions from burning fossil fuels may be increasing so there could be a link between CO_2 emissions and a rise in sea levels.

CO_2 emissions from other sources, not just burning fossil fuels, should be considered.

b) Any two from: e.g. encouraging energy efficiency / creating financial incentives to reduce CO_2 emissions / using more renewable energy / increasing research into new energy sources *[1 mark for each correct answer]*.

Section 17 — Motion, Forces and Conservation of Energy

Pages 161-162 — Distance, Displacement, Speed and Velocity

Warm-up

Scalar — mass, time, temperature

Vector — acceleration, weight, force

1 C *[1 mark]*

2 340 m/s *[1 mark]*

3 a) 7 m *[1 mark]*

b) 12 m *[1 mark]*

c) 

[1 mark for arrow of correct length in the correct direction]

d) 2 m *[1 mark]*

4 a) distance travelled = average speed × time *[1 mark]*

b) 22 minutes = 22 × 60 = 1320 s

distance travelled = average speed × time

= 4.0 × 1320 = 5280 m

5280 m = 5280 ÷ 1000 = 5.28 km = **5.3 km (to 2 s.f.)**

[4 marks for correct answer to two significant figures, otherwise 1 mark for correctly converting the time into seconds, 1 mark for correctly substituting the numbers into the equation, 1 mark for correct numerical answer for distance travelled]

5 a) distance travelled = average speed × time

Typical walking speed = 1.4 m/s (accept 1-2 m/s)

time = distance travelled ÷ average speed

= 3500 ÷ 1.4

= **2500 s** (accept 1750-3500 s)

[4 marks for correct answer, otherwise 1 mark for stating the correct equation, 1 mark for using a suitable estimate for walking speed, 1 mark for correctly substituting the numbers into the equation]

b) Typical cycling speed = 5.5 m/s (accept 4.5-6.5 m/s)

distance travelled = average speed × time, so:

time = distance travelled ÷ average speed

= 3500 ÷ 5.5 = 636.363... s

2500 – 636.363... = 1863.636... s

= **2000 s (to 1 s.f.)** (accept 1000-3000 s)

[4 marks for correct answer, otherwise 1 mark for using a suitable estimate for cycling speed, 1 mark for correctly substituting the numbers into the equation, 1 mark for subtracting from the answer to part a)]

c) time = 15 × 60 = 900 s, 7.2 km = 7200 m

distance travelled = average speed × time, so:

average speed = distance travelled ÷ time

= 7200 ÷ 900 = **8 m/s**

[3 marks for correct answer, otherwise 1 mark for correctly converting the time into seconds and km into m, 1 mark for correctly substituting the numbers into the equation]

Pages 163-164 — Acceleration

Warm-up

A sprinter starting a race — 1.5 m/s^2

A falling object — 10 m/s^2

A bullet shot from a gun — 2×10^5 m/s^2

1 It will be slowing down/decelerating ***[1 mark]***

2 a) $a = (v - u) \div t$

$= (3.2 - 0) \div 8.0 =$ **0.4 m/s^2**

[3 marks for correct answer, otherwise 1 mark for using correct acceleration equation, 1 mark for correctly substituting the numbers into the equation]

b) $a = (v - u) \div t$, so:

$v = (a \times t) + u$

$= (0.4 \times 6.0) + 3.2 =$ **5.6 m/s**

[3 marks for correct answer, otherwise 1 mark for rearranging acceleration equation for final velocity, 1 mark for substituting the correct numbers into the equation]

3 $v^2 - u^2 = 2 \times a \times x$ so as x = height, and $g = 10$ m/s^2

height $= (v^2 - u^2) \div (2 \times a)$

$= (12^2 - 0^2) \div (2 \times 10) =$ **7.2 m**

[3 marks for correct answer, otherwise 1 mark for rearranging the equation for distance (height), 1 mark for substituting the correct numbers into the equation]

4 a) 1.2 km = 1200 m

$v = \sqrt{(2 \times a \times x) + u^2} = \sqrt{(2 \times 0.25 \times 1200) + (5.0)^2} =$ **25 m/s**

[3 marks for correct answer, otherwise 1 mark for rearranging the equation for final velocity, 1 mark for substituting the correct numbers into the equation]

b) $a = (v - u) \div t$, so:

$t = (v - u) \div a = (25 - 5.0) \div 0.25 =$ **80 s**

[3 marks for correct answer, otherwise 1 mark for rearranging the equation correctly, 1 mark for correctly substituting the numbers into the equation]

5 $v^2 - u^2 = 2 \times a \times x$ so

$a = (v^2 - u^2) \div (2 \times x) = (18^2 - 30^2) \div (2 \times 360) = -0.8$ m/s^2

So deceleration = **0.8 m/s^2**

[3 marks for correct answer, otherwise 1 mark for rearranging the equation for acceleration, 1 mark for substituting the correct numbers into the equation]

6 $21 \times 1000 \div 60 \div 60 = 5.83...$ m/s

Say it takes the cyclist 7 s to accelerate.

acceleration = change in velocity ÷ time $= 5.83... \div 7$

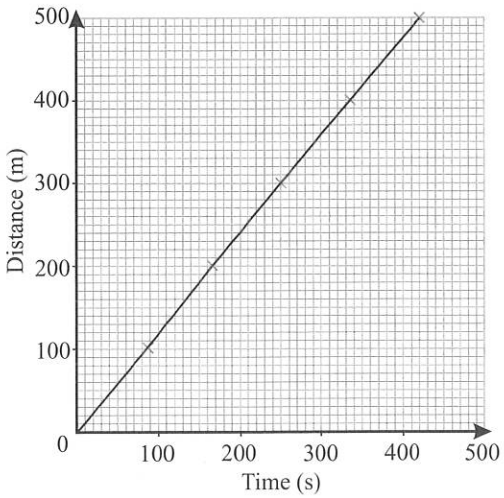
$= 0.832...$ = **0.8 m/s^2 (to 1 s.f.)**

[3 marks for a correct answer using a time between 5 and 15 seconds, otherwise 1 mark for correctly converting the speed into m/s, 1 mark for an estimated time taken of 5-15 seconds]

You might have estimated the distance it took for the cyclist to get up to speed, then used $v^2 - u^2 = 2 \times a \times x$. As long as you used a sensible distance and correctly substituted your numbers into the equation, you'd still receive full marks.

Pages 165-166 — Distance/Time Graphs

1 a)



[3 marks for graph plotted correctly, otherwise 1 mark for three points correct, 1 mark for a straight line going through all plotted points]

b) 360 m (accept between 355 m and 365 m) ***[1 mark]***

c) 210 s (accept between 205 s and 215 s) ***[1 mark]***

d) E.g. referring to the same point on the boat / making sure that the timings are measured from exactly level with the posts / making sure timings are made close to the posts to avoid parallax ***[1 mark for any correct answer]***

2 a) 12 minutes ***[1 mark]***

b) Accelerating ***[1 mark]***

3 a) Speed = gradient $= (92 - 20) \div (6 - 3) = 72 \div 3 =$ **24 m/s** (accept between 23 m/s and 25 m/s)

[3 marks for correct answer, otherwise 1 mark for stating that speed = gradient, 1 mark for a correct calculation attempting to find the gradient of the straight part of the d/t graph between 3 and 6 seconds]

b) Speed = gradient of a tangent to the line

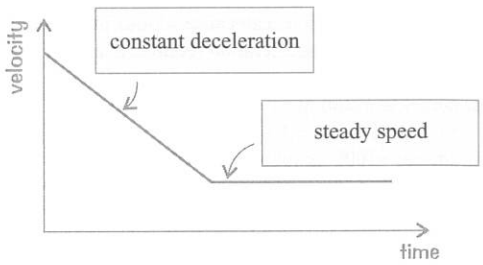
$= (16 - 0) \div (3 - 1) = 16 \div 2 =$ **8 m/s**

(accept between 6 m/s and 10 m/s)

[3 marks for correct answer, otherwise 1 mark for a correct tangent to the line at 2 s, 1 mark for a correct calculation of the gradient of the tangent drawn]

Pages 167-168 — Velocity/Time Graphs

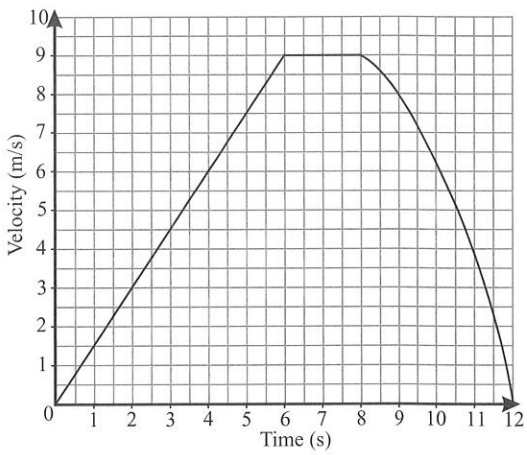
Warm-up



1 C ***[1 mark]***

2 A ***[1 mark]***

3 a)



[1 mark for correct shape of graph, 1 mark for graph ending at 0 m/s and 12 s]

b) $a = (v - u) \div t$ = gradient of the line

$a = (9 - 0) \div (6 - 0) =$ **1.5 m/s^2**

[2 marks for correct answer, otherwise 1 mark for a correct method to calculate the gradient of the graph between 0 and 6 seconds]

c) distance = speed × time = area under the line

0-6 s: area = ½ × base × height = ½ × 6 × 9 = 27 m

6-8 s: area = base × height = 2 × 9 = 18 m

Total distance in 8 s = 27 + 18 = **45 m**

[3 marks for correct answer, otherwise 1 mark for finding the area for 0-6 s, 1 mark for finding the area for 6-8 s]

d) 1 square is worth 0.5 s on the x-axis (time)

1 square is worth 0.5 m/s on the y-axis (velocity)

distance = speed × time = 0.5 × 0.5 = 0.25 m ***[1 mark]***

Squares under the line between 8 s and 12 s = 91

[1 mark for a number that matches your graph ±5 squares]

91 × 0.25 = **22.75 m** ***[1 mark for correctly multiplying your number of squares by your value of s]***

Pages 169-170 — Newton's First and Second Laws

Warm-up

Newton's First Law of motion says that an object will remain stationary or moving at a constant velocity if there is a zero resultant force acting on it. If there is a non-zero resultant force acting on the object, it will accelerate.

1 a) A *[1 mark]*

$F = m \times a = 110\ 000 \times 5.0$
$= 550\ 000$ N

b) There is no resultant force acting on the rocket (as there is no force from the thrusters or from friction) *[1 mark]*.

2 $F = m \times a$, so
$m = F \div a = 38 \div 10$
$= \mathbf{3.8\ kg}$
[3 marks for correct answer, otherwise 1 mark for giving the correct equation, 1 mark for substituting in the correct numbers]

3 $F = m \times a = 60 \times 0.4 = 24$ N
F = force from wind – drag force
So drag force = force from wind – F
$= 44 - 24 = \mathbf{20\ N}$
[4 marks for the correct answer, otherwise 1 mark for the correct equation, 1 mark for substituting the correct numbers into the equation, 1 mark for the correct resultant force]

4 a) E.g. very large decelerations can cause serious injuries *[1 mark]*. This is because a larger acceleration requires a larger force (since $F = m \times a$) *[1 mark]*.

b) The car comes to a stop in ~1 s (accept 0.5-2 s).
$a = (v - u) \div t = (0 - 14) \div 1 = -14$ m/s^2
Mass of the car ~1000 kg (accept 600-2000 kg)
$F = m \times a = 1000 \times -14 = -14\ 000$ N
So the resultant force is about **14 000 N**
(accept 8000-28 000 N).
[5 marks for correct answer, otherwise 1 mark for correctly estimating the time taken to stop, 1 mark for using the correct acceleration equation and estimating the acceleration, 1 mark for correctly estimating the mass of the car, 1 mark for stating $F = m \times a$]

5 Typical speed of a lorry is 25 m/s
(accept 20-30 m/s)
$v^2 - u^2 = 2 \times a \times x$
$a = (v^2 - u^2) \div (2 \times x) = (0^2 - 25^2) \div (2 \times 50)$
$= -625 \div 100 = -6.25$ m/s^2 (accept 4-9 m/s^2)
$F = m \times a = 7520 \times -6.25$
$= \mathbf{(-)\ 47\ 000\ N}$ (accept 30 100-67 700 N)
[5 marks for correct answer, otherwise 1 mark for correctly estimating the speed of the lorry, 1 mark for correctly substituting in the numbers into the acceleration equation, 1 mark for stating $F = m \times a$, 1 mark for correctly substituting in the numbers to calculate the force]

Page 171 — Weight and Circular Motion

Warm-up

1) True
2) False
3) True
4) True

1 a) Weight is the force acting on an object due to gravity/ a gravitational field *[1 mark]*.

b) weight = mass of object × gravitational field strength
$= 65 \times 10 = \mathbf{650\ N}$
[2 marks for correct answer, otherwise 1 mark for substituting in the correct numbers]

c) $W = m \times g$ for g:
$g = W \div m = 232 \div (65 + 80) = \mathbf{1.6\ N/kg}$
[3 marks for correct answer, otherwise 1 mark for rearranging weight equation for g, 1 mark for the correct numerical value, 1 mark for the correct unit]

2 No — velocity is speed in a given direction *[1 mark]*. The satellite travels at a constant speed, but is always changing direction so its velocity is always changing *[1 mark]*.

Page 172 — Investigating Motion

1 a) Any one from: e.g. using a light gate gets rid of the human error caused by reaction times when using a stopwatch / using a light gate is more accurate than a human using a stopwatch / a light gate can be directly linked to a data logger *[1 mark]*.

b) E.g. she calculates the difference in the speed of the trolley between the two light gates and divides this by the time it took the trolley to travel between the light gates *[1 mark]*.

c) i) $F = m \times a$, so
$a = F \div m$
$= 1.5 \div 3 = \mathbf{0.5\ m/s^2}$
[3 marks for correct answer, otherwise 1 mark for rearranging the equation correctly, 1 mark for substituting in the correct numbers]

ii) As the mass of the trolley is increased, the acceleration decreases *[1 mark]*.

d) By finding the range of the results used to calculate that mean *[1 mark]* and then using uncertainty = range ÷ 2 *[1 mark]*.

Page 173 — Inertia and Newton's Third Law

Warm-up

When two objects interact, they exert equal and opposite forces on each other.

1 a) E.g. how difficult it is to change the velocity of an object / ratio of force over acceleration / $m = F \div a$
[1 mark for any correct definition]

b) Trolley B has the highest inertial mass *[1 mark]*, because it has the lowest velocity after the force has been applied, so its velocity is more difficult to change (than the velocities of the other trolleys) *[1 mark]*.

2 a) As the students push the wall, the wall will exert an equal and opposite force on each student *[1 mark]*. As there is no friction, each student will have a resultant force pushing them away from the wall which causes them to move *[1 mark]*.

b) A *[1 mark]*

The acceleration of each can be found from acceleration = force ÷ mass. The acceleration of student A = 24 ÷ 80 = 0.3 m/s^2. The acceleration of student B = 24 ÷ 40 = 0.6 m/s^2, so the difference between the two = 0.6 − 0.3 = 0.3 m/s^2.

Pages 174-175 — Momentum

1 a) momentum = mass × velocity *[1 mark]*

b) $p = m \times v$
$= 220 \times 25$
$= \mathbf{5500\ kg\ m/s}$
[2 marks for correct answer, otherwise 1 mark for correctly substituting in the numbers]

2 Rearrange equation:
$m = p \div v = 46\ 000 \div 15 = 3066.6... = \mathbf{3070\ kg\ (to\ 3\ s.f.)}$
[3 marks for correct answer, otherwise 1 mark for rearranging the equation, 1 mark for rounding to an appropriate degree of accuracy]

3 In Figure 1, the total momentum of the system is equal to the mass of the moving ball multiplied by its velocity *[1 mark]*. As it hits the line of balls, it transfers this momentum to them and comes to a stop. All of this momentum is transferred along the line of balls to the ball at the end of the line, which is why the middle balls don't move *[1 mark]*. This final ball has the momentum of the first ball, causing it to move with the same velocity (because all of the balls have the same mass) that the moving ball in Figure 1 had *[1 mark]*. In Figure 2, the total momentum of the system is equal to the total momentum in Figure 1 *[1 mark]*.

4 $F = (mv - mu) \div t$, so:
$mv - mu = Ft$
$m = Ft \div (v - u)$
$= -0.15 \times 4 \div (0 - 3)$
$= \mathbf{0.2\ kg}$
[3 marks for correct answer, otherwise 1 mark for correctly rearranging the equation, 1 mark for substituting in the correct numbers]

5 $p = mv$
Before collision:
Momentum of first player = 80 × 8.0 = 640 kg m/s
Momentum of second player = 100 × –5.5 = –550 kg m/s
Total momentum = 640 – 550 = 90 kg m/s
After collision:
Mass = 80 + 100 = 180 kg
Momentum = 180 × v
Momentum before = momentum after, so
90 = 180 × v
v = 90 ÷ 180 = **0.5 m/s**
[4 marks for correct answer, otherwise 1 mark for stating the equation for momentum, 1 mark for correctly calculating the total momentum before the tackle, 1 mark for correctly calculating the combined mass and substituting this into the equation]

6 Newton's third law says that when ball 1 collides with ball 2, an equal but opposite force is exerted on each object. So the force exerted on ball 2 during the collision is 6 N.
$F = (mv - mu) \div t$
$(mv - mu) = F \times t$
$v = (F \times t + mu) \div m = (6 \times 0.1 + 0.2 \times 0) \div 0.2 =$ **3 m/s**
[5 marks for correct answer, otherwise 1 mark for correct equation for force, 1 mark for correctly stating the force on ball 2, 1 mark for rearranging the equation for v, 1 mark for correctly substituting the numbers into the equation]

Pages 176-177 — Stopping Distances and Reaction Times

1 a) The distance travelled during the driver's reaction time ***[1 mark]***.
b) Stopping distance = thinking distance + braking distance
12 + 24 = **36 m** ***[1 mark]***

2 a) B ***[1 mark]***
b) Any three from: tiredness / alcohol / drugs / distractions
[3 marks — 1 mark for each correct answer]

3 a) The distance travelled under the braking force of the vehicle ***[1 mark]***.
b) There will be less friction between the tyres and the road (than there would be if the road was dry and clear of leaves) ***[1 mark]***, and so the braking distance will increase ***[1 mark]***.

4 a) E.g. clicking a mouse when a computer screen changes colour ***[1 mark]***.
b) Hold a ruler between the open forefinger and thumb of the person being tested ***[1 mark]***. Align their finger to the zero line of the ruler ***[1 mark]***. Drop the ruler without warning ***[1 mark]*** and have the test subject close their thumb and finger to catch the ruler ***[1 mark]***. The distance the ruler falls can be read from the ruler ***[1 mark]***. The time taken for it to fall can be calculated, as the acceleration (due to gravity) is constant. This is the reaction time of the test subject ***[1 mark]***.

5 How to grade your answer:
Level 0: There is no relevant information. ***[0 marks]***
Level 1: There is a brief description of at least one factor that would affect the car's stopping distance, and the effect that it would have. The points made are basic and not linked together. ***[1-2 marks]***
Level 2: There is a more detailed description of some of the factors that would affect the car's stopping distance, and the effect that each factor would have. Some of the points made are linked together. ***[3-4 marks]***
Level 3: There is a clear detailed description of the factors that would affect the car's stopping distance, and an explanation of the effect that each factor would have. The points made are well-linked and the answer has a clear and logical structure. ***[5-6 marks]***
Here are some points your answer may include:
The driver's reaction time may be increased by being tired.
Increasing the driver's reaction time will increase their thinking distance, which will increase the stopping distance.
The stopping distance may also be increased by the distractions of their friends talking / the music on the radio.
The car's stopping distance may be increased by the wet weather. This is because the wet weather may increase the car's braking distance.
The car has a group of people in it, which means its mass is higher than if there was only the driver in the car, and it will take longer to stop.
The condition of the brakes could affect the stopping distance, as brakes that are worn or faulty are likely to increase the braking distance.
The speed at which the car is travelling will affect its braking distance.
A car that's travelling faster will take longer to stop.
The dark and wet conditions also make the situation less safe as they may mean the driver is less likely to notice a hazard in time to stop.

Page 178 — Energy Stores

Warm-up
Kinetic energy store — A toy car rolling along the ground
Magnetic energy store — Two magnets attracted to each other
Electrostatic energy store — Two electric charges repelling each other
Chemical energy store — Petrol in a car
Elastic potential energy store — A stretched rubber band
Nuclear energy store — A nucleus about to undergo a nuclear reaction
Thermal energy store — A hot potato
Gravitational potential energy store — A person on top of a mountain

1 change in gravitational potential energy
= mass × gravitational field strength × change in vertical height
= 0.1 × 10 × 0.5 = **0.5 J**
[2 marks for the correct answer, otherwise 1 mark for correctly substituting in the numbers]

2 a) kinetic energy = ½ × mass × (speed)^2 ***[1 mark]***
b) ΔGPE = 0.50 × 10 × 42 = 210 J
$\frac{1}{2}mv^2 = 210$
$v^2 = (2 \times 210) \div 0.5 = 840$
$v = \sqrt{840} = 28.98... =$ **29 m/s (to 2 s.f.)**
[5 marks for the correct answer, otherwise 1 mark for correctly substituting the values into the equation for change in gravitational potential energy, 1 mark for correct value for energy transferred to the kinetic energy store of the rock, 1 mark for correctly rearranging the equation for v or v^2, 1 mark for correctly substituting the numbers into this equation]

Page 179 — Transferring Energy

Warm-up
From left to right: mechanically, by heating

1 a) Energy can be stored, transferred between stores or dissipated — but it can never be created or destroyed ***[1 mark]***.
b) By heating ***[1 mark]***.
c) Energy is transferred mechanically ***[1 mark]*** from the gravitational potential energy store of the bike ***[1 mark]*** to the kinetic energy store of the bike ***[1 mark]***.
d) The golf club has energy in its kinetic energy store ***[1 mark]***. Some of this energy is transferred mechanically to the kinetic energy store of the ball ***[1 mark]***. Some is transferred mechanically to the thermal energy stores of the golf club and the ball (and to the surroundings by heating) ***[1 mark]***. The rest is carried away by sound ***[1 mark]***.

Page 180 — Efficiency

1 a) E.g. by heating the fan / by heating the surroundings / transferred away by sound waves
[1 mark for one correct answer]
b) Find the energy that is transferred usefully:
useful energy transferred = total energy input – wasted energy
= 7250 – 2030 = 5220 J

$$\text{efficiency} = \frac{\text{useful energy transferred}}{\text{total energy supplied}}$$

$$= \frac{5220}{7250} = \mathbf{0.72}\ (\text{or } \mathbf{72\%})$$

[3 marks for correct answer, otherwise 1 mark for calculating the useful energy transferred, 1 mark for correctly stating the efficiency equation]

2 a) Useful energy transferred by air blower:
efficiency = useful energy transferred ÷ total energy supplied
useful energy transferred
= efficiency × total energy supplied by air blower
= 0.6 × 30 000
= 18 000 J
Useful energy transferred by the turbine:
Efficiency = 12% = 0.12
total energy supplied = useful energy transferred by air blower
useful energy transferred
= efficiency × total energy supplied by turbine
= 0.12 × 18 000
= **2160 W**
[4 marks for correct answer, otherwise 1 mark for stating the efficiency equation, 1 mark for finding the amount of energy usefully transferred by the air blower, 1 mark for substituting the correct numbers into the efficiency equation to find the useful energy transferred by the turbine]

b) Any two from: e.g. adding more sails so there is a larger surface area for the air to hit / increasing the size of the sails so there is a larger surface area for the air to hit / adding a lubricant to the moving parts of the turbine to reduce friction / changing the angle of the sails so they get hit by more wind / using wires with a lower resistance
[2 marks — 1 mark for each sensible suggestion]

Page 181 — Reducing Unwanted Energy Transfers

1 The oil acts as a lubricant ***[1 mark]***, which reduces the energy lost due to friction ***[1 mark]***.

Instead of saying that the oil acts as a lubricant, you could have said that the oil reduces the amount of friction to gain the first mark here.

2 a) D ***[1 mark]***

A low thermal conductivity means the rate of energy transfer through the bricks is lower. A thicker wall will reduce the rate of energy transfer.

b) E.g. the builder could use cavity walls ***[1 mark]***.

c) Wasted energy = total energy input – useful energy output
= 22.5 – 13.5
= **9 kJ** ***[1 mark]***

Pages 182-183 — Energy Resources

Warm-up
Renewable — bio-fuel, solar, tidal, hydro-electricity, wind
Non-renewable — oil, coal, gas, nuclear fuel

1 E.g. a non-renewable energy resource will one day run out ***[1 mark]*** but a renewable energy resource is renewed as it is used ***[1 mark]***.

2 a) coal, oil, (natural) gas ***[1 mark]***

b) E.g. burning coal on fires / using gas central heating / generating electricity / using a gas fire
[1 mark for any correct answer]

c) Bio-fuels are solids, liquids or gases that are produced from plants or from animal waste ***[1 mark]***.

d) E.g. because fossil fuels will eventually run out / because fossil fuels harm the environment
[1 mark for any correct answer]

3 a) E.g. wind turbines can be noisy / they spoil the view ***[2 marks — 1 mark for each correct answer]***

b) E.g. solar panels only produce electricity in the daytime / wind turbines can produce electricity through the night ***[1 mark for any correct answer]***

4 a) E.g. Both energy resources are reliable ***[1 mark]***. Both methods of producing electricity have minimal running costs ***[1 mark]*** and no fuel costs ***[1 mark]***. Hydro-electric power plants require the flooding of valleys, which causes a loss of habitat for animals/plants ***[1 mark]***. Tidal barrages create no pollution, but they do alter the habitat of nearby animals ***[1 mark]***.

b) How to grade your answer:
Level 0: There is no relevant information. ***[0 marks]***
Level 1: There is a brief explanation of an advantage or a disadvantage of fossil fuels. The points made are basic and not linked together. ***[1-2 marks]***
Level 2: There is some explanation of both advantages and disadvantages of fossil fuels. Some of the points made are linked together. ***[3-4 marks]***
Level 3: There is a clear and detailed explanation of the advantages and disadvantages of using fossil fuels. The points made are well-linked and the answer has a clear and logical structure. ***[5-6 marks]***

Here are some points your answer may include:
Advantages:
Fossil fuels are reliable.
They are extracted at a fast enough rate that there is always some in stock.
Power plants can respond quickly to peaks in demand.
Running costs of fossil fuel power plants aren't that expensive compared to other energy resources.
Fuel extraction costs are also low.
Disadvantages:
Fossil fuels are slowly running out / they are a non-renewable energy resource.
Burning fossil fuels releases carbon dioxide into the atmosphere.
Carbon dioxide in the atmosphere contributes to global warming.
Burning coal and oil also releases sulfur dioxide, which causes acid rain.
Oil spillages kill sea life and birds and mammals that live near to the sea.

Page 184 — Trends in Energy Resource Use

1 a) 1.2 TWh ***[1 mark]***

b) i) 2015: 3.0 + 1.6 = 4.6 TWh
1995: 3.8 + 0.2 = 4.0 TWh
4.6 – 4.0 = **0.6 TWh**
[2 marks for a correct answer, otherwise 1 mark for correctly calculating the electricity produced each year.]

ii) E.g. the population may have increased / people may have started using electricity for more things ***[1 mark]***.

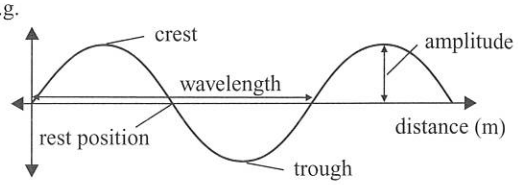
c) E.g. from 1995 to 2015, the production of electricity from non-renewable sources has decreased from 3.8 to 3 TWh ***[1 mark]*** and the production of electricity from renewable resources has increased, from 0.2 to 1.2 TWh ***[1 mark]***. This may be because the country wants to decrease their use of non-renewable energy sources because they will run out one day/ because non-renewables cause a lot of environmental damage ***[1 mark]***. The country may want to increase their use of renewable sources because they won't run out /they don't cause as much environmental damage as non-renewable sources ***[1 mark]***.

You could have used any data from the graph, as long as it supported the trend you were describing. You could also have given other reasons for the trend, such as becoming increasingly worried about nuclear accidents and nuclear waste, or renewable energy sources having improved in efficiency between 1995 and 2015.

Section 18 — Waves and the Electromagnetic Spectrum

Pages 185-186 — Wave Basics

Warm-up
E.g.



1 C ***[1 mark]***

2 B ***[1 mark]***

3 a) E.g. they both transfer energy (or information) but not particles / they both have a wavelength/period/frequency/speed ***[1 mark]***.

b) In longitudinal waves, the vibrations are parallel to the wave's direction of travel ***[1 mark]***, but in transverse waves, the vibrations are at right angles to the wave's direction of travel ***[1 mark]***.

4 a) Because although the ripples travel across the pond, the water just travels up and down, so the ripples cannot move the leaf across the pond ***[1 mark]***.

b) $1.4 \div 100 = 0.014$ m
wave speed = frequency × wavelength = $15 \times 0.014 =$ **0.21 m/s**
[2 marks for correct answer, otherwise 1 mark for correct substitution.]

c) The time taken for a full cycle of a wave to pass a point ***[1 mark]***.

5 a) i) wave speed = distance ÷ time, or $v = x \div t$ ***[1 mark]***

ii) time = distance ÷ wave speed = $17 \div 340 =$ **0.05 s**
[2 marks for correct answer, otherwise 1 mark for correct substitution.]

b) Frequency is the number of waves passing a point per second, so $220 \times 5 =$ **1100 waves**
[2 marks for a correct answer, otherwise 1 mark for multiplying the frequency by the number of seconds.]

Here, you assume that the frequency of the sound waves the violin produces is the same as the frequency of the waves on the violin's strings.

Pages 187-188 — Measuring Waves

1 Rod length = $\lambda \div 2$, so $\lambda = 2 \times 0.2 = 0.4$ m
$v = f\lambda = 8500 \times 0.4 =$ **3400 m/s**
[4 marks for correct answer, otherwise 1 mark for correct calculation of wavelength, 1 mark for correct equation, 1 mark for correct substitution]

2 a) Any two from: e.g. the position of the dipper / the position of the cork when she starts timing / the depth of water in the tank / the equipment used.
[2 marks — 1 mark for each correct answer]

b) i) The result of the third trial is anomalous.
$(12 + 11 + 11 + 14) \div 4 =$ **12**
[3 marks for correct answer, otherwise 1 mark for identifying the anomalous result, 1 mark for correct method for calculating the average number of bobs]

ii) Frequency = number of bobs per second
$12 \div 30 =$ **0.4 Hz**
[2 marks for a correct answer, otherwise 1 mark for correct calculation.]

c) i) wave speed = frequency × wavelength ***[1 mark]***

ii) 10 waves cover 0.18 m
So 1 wavelength = $0.18 \div 10 = 0.018$ m
$v = 12 \times 0.018 = 0.216 =$ **0.22 m/s (to 2 s.f.)**
[3 marks for correct answer to correct number of significant figures, otherwise 1 mark for correct substitution, 1 mark for correct numerical value for wave speed.]

3 How to grade your answer:
Level 0: There is no relevant information. ***[0 marks]***
Level 1: A simple method to find the speed of sound waves in air is partly outlined. The points made are basic and not linked together. ***[1-2 marks]***
Level 2: A method to find the speed of sound in air is outlined in some detail. Some of the points made are linked together. ***[3-4 marks]***
Level 3: A method to find the speed of sound waves in air is fully explained in detail. The points made are well-linked and the answer has a clear and logical structure. ***[5-6 marks]***

Here are some points your answer may include:
Connect a signal generator to a speaker and set it to generate a sound of a specific frequency.
Connect two microphones to an oscilloscope so that the waves detected at each microphone will be displayed as separate waveforms on the oscilloscope.
Place the microphones next to each other in front of the speaker. At this point, the waveforms will be aligned with each other on the oscilloscope (i.e. peaks and troughs appear at the same point).
Keeping both microphones directly in front of the speaker, slowly move one microphone away from the speaker, until the two wave-forms on the oscilloscope next become aligned.
The microphones should now be located one wavelength of the sound apart.
Measure this distance, λ, and note down the frequency of the sound generated, f.
Use the formula $v = f\lambda$ to calculate the speed of sound, v.
To get more accurate results the experiment can be repeated for different frequencies and a mean value calculated.

Page 189 — Wave Behaviour at Boundaries

Warm-up
wave is reflected — it bounces back off the material
wave is absorbed — it transfers all its energy to the material
wave is transmitted — it passes through the material

1 a) E.g. an echo would be created ***[1 mark]***

b) E.g. the black object would heat up ***[1 mark]***

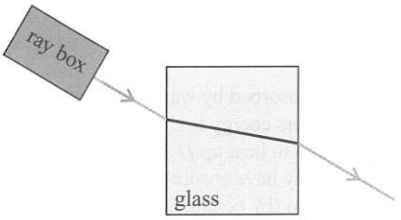
2 a) 40° ***[1 mark]***

b) The material is (optically) denser than air ***[1 mark]*** because the refracted ray bends towards the normal ***[1 mark]***.

Page 190 — Investigating Refraction

1 a) E.g. A ray box creates a thin ray of light which is easy to trace ***[1 mark]***

b)



[1 mark for a correctly completed diagram]

c) 10° ***[1 mark]*** (Allow between 9° and 11°)

d) Water ***[1 mark]*** as it has the largest angle of refraction ***[1 mark]*** which means it has bent the ray the least and so the change of speed of the ray is the smallest ***[1 mark]***.

Pages 191-192 — Electromagnetic Waves

Warm-up
True, True, False

1 a) From left to right: Infrared ***[1 mark]***, X-rays. ***[1 mark]***

b) Arrow must point to the left (i.e. from gamma rays to radio waves / from high energy to low energy) ***[1 mark]***.

c) From left to right: yellow, green, blue, indigo
[2 marks for all correct, 1 mark for 3 correct]

d) The nucleus ***[1 mark]***

2 a) As the frequency increases, so does the potential danger ***[1 mark]***.

b) Infrared — skin burns
Microwaves — internal heating of cells
X-rays — cell mutation and cancer
[1 mark for all 3 correct]

c) Any two from: e.g. damage to surface cells of skin/skin cancer ***[1 mark]*** / damage to surface cells of eyes/eye conditions ***[1 mark]***

3 a) i) Source: X-ray machine
Observer: Photographic film/Radiation badge
[1 mark for two sensible answers]

ii) Energy is transferred from the kinetic energy store of the electrons ***[1 mark]*** by radiation (the X-rays) to the chemical energy store of the photographic film ***[1 mark]***.

b) E.g. infrared waves transferring energy from a heater's thermal energy store to the thermal energy store of a person ***[1 mark]***.

Pages 193-196 — Uses of EM Waves

Warm-up
True, True, False, True.

1 a) Ultraviolet — fluorescent lights
Visible light — photography
Infrared — security lights
Radio waves — satellite communications
[2 marks for all four correct, 1 mark for 3 correct]

b) Any two from: e.g. TV remotes / optical fibres / sending files between phones and laptops
[2 marks — 1 mark for each correct answer]

c) B ***[1 mark]***

2 a) C ***[1 mark]***

b) A UV light can be shone onto the stolen object which will cause the ink to glow/become visible ***[1 mark]*** and can be used to prove the object belongs to him ***[1 mark]***.

c) E.g. marking bank notes ***[1 mark]***

3 a) X-rays are directed at the body part being imaged. A detector is placed behind the body. The X-rays are absorbed by bones ***[1 mark]***, but transmitted by the rest of the body tissue/muscles ***[1 mark]***. A negative image is formed with brighter areas where fewer X-rays get through, indicating the bones ***[1 mark]***.

b) E.g. security scans at airports ***[1 mark]***

4 a) It detects infrared radiation emitted by an object and converts this into an electrical signal which is displayed on a screen as an image ***[1 mark]***. Different temperatures appear brighter/as different colours, so you can build a thermal image of the surroundings ***[1 mark]***.

b) When it is dark there is very little visible light for a normal camera to pick up so a hiding criminal could be hard to see ***[1 mark]***. The criminal will be warmer than the surroundings and so will emit more infrared radiation ***[1 mark]***. This will make them stand out from the surroundings if using an infrared camera ***[1 mark]***.

5 a) The microwaves are absorbed by water molecules in the potato ***[1 mark]***. This transfers energy to the water molecules, causing the water in the potato to heat up ***[1 mark]***. The water molecules transfer the energy they have absorbed to the rest of the molecules in the potato (by conduction), cooking it ***[1 mark]***.

b) The glass plate does not absorb any microwaves ***[1 mark]*** as it does not contain any water molecules, and so it is only heated by (conduction from) the potato ***[1 mark]***.

c) Satellites are located above the atmosphere ***[1 mark]***. The atmosphere contains water molecules ***[1 mark]***. The microwaves used in microwave ovens could not reach satellites as they would be absorbed by water molecules in the atmosphere ***[1 mark]***. Different wavelengths which are not absorbed by the atmosphere must be used to communicate with satellites ***[1 mark]***.

6 a) An alternating current (a current made of oscillating charges) flows through walkie-talkie ***[1 mark]***. Electrons in the walkie-talkie's aerial oscillate, producing radio waves ***[1 mark]***. These radio waves travel through the air to the aerial of the second walkie-talkie, where they are absorbed ***[1 mark]***. The energy carried by the radio waves is transferred to the electrons in the receiver aerial ***[1 mark]***. This causes electrons in the aerial to oscillate ***[1 mark]*** which produces an alternating current in the second walkie-talkie ***[1 mark]***.

b) How to grade your answer:

Level 0: There is no relevant information. ***[0 marks]***

Level 1: There is a brief explanation of the differences between radio wave types used for broadcasting. The points made are basic and not linked together. ***[1-2 marks]***

Level 2: There is some explanation of the differences between radio wave types used for broadcasting, including their different ranges and how this affects which broadcast can be heard. Some of the points made are linked together. ***[3-4 marks]***

Level 3: There is a clear and detailed explanation of the differences between radio wave types used for broadcasting, including their different ranges and how this affects which broadcast can be heard. The points made are well-linked and the answer has a clear and logical structure. ***[5-6 marks]***

Here are some points your answer may include:
FM radio is transmitted using very short wavelength radio waves. These radio waves can only be received while the receiver is in direct sight of the transmitter.
This is because these wavelengths are easily absorbed by obstacles, e.g. buildings, and cannot bend much around obstacles.
France is far away, so the signal cannot be received in France.
Long-wave radio waves can be transmitted over long distances. This is because long-wave radio waves bend around the curved surface of the Earth.
Long-wave radio waves can also bend around obstacles such as mountains.
Hence the signal can travel a long distance and be received in France.

Section 19 — Radioactivity

Page 197 — The Model of the Atom

Warm-up
1×10^{-10} m

1 a) The plum pudding model ***[1 mark]***. This model describes an atom as a sphere of positive charge, with electrons spread throughout it ***[1 mark]***.

b) E.g.:
Property: The atom is mostly made up of empty space / most of the atom's mass is concentrated at the centre in a tiny nucleus ***[1 mark]***.
Observation: Most of the alpha particles they fired at the thin gold foil passed straight through ***[1 mark]***.

2 a) Proton: (+)1 ***[1 mark]***
Neutron: 0 ***[1 mark]***

b) The protons and neutrons make up a central nucleus ***[1 mark]*** and the electrons orbit the nucleus ***[1 mark]***.

c) 26 electrons ***[1 mark]***. Protons and electrons have equal but opposite charges (and neutrons are neutral). As there are the same number of protons and neutrons in an atom, atoms are neutral ***[1 mark]***.

Page 198 — Electron Energy Levels

Warm-up
In Bohr's atomic model, electrons orbit the nucleus at fixed distances called energy levels or shells.

1 a) An electron can move into a higher energy level / further from the nucleus, by absorbing electromagnetic radiation ***[1 mark]***, and move into a lower energy level / closer to the nucleus, by emitting electromagnetic radiation ***[1 mark]***.

b) Ion ***[1 mark]***

c) +1 ***[1 mark]***

2 As you get further away from a nucleus, the energy levels get closer together ***[1 mark]***. So electrons falling to the first energy level have a greater change in energy than those falling to the second energy level ***[1 mark]***. This means they release electromagnetic radiation with a higher energy ***[1 mark]*** and so a higher frequency is released when an electron falls to the first energy level ***[1 mark]***.

Pages 199-200 — Isotopes and Nuclear Radiation

Warm-up
A — mass number, Z — atomic number, X — element symbol

1 a) Atoms with the same number of protons ***[1 mark]*** but different numbers of neutrons (in their nucleus) ***[1 mark]***.

b) alpha, beta, gamma
[3 marks in total — 1 mark for each correct answer]

c) i) alpha ***[1 mark]***

ii) E.g. a few centimetres ***[1 mark]*** because alpha particles are strongly ionising ***[1 mark]***.

2 a) beta ***[1 mark]***

b) Gamma ***[1 mark]*** because it is highly penetrating so it can travel through paper and aluminium ***[1 mark]***. It can be absorbed by sheets of lead ***[1 mark]***.

3 a) 23 ***[1 mark]***

Remember that the nucleon number is another name for the mass number.

b) 23 – 11 = 12 neutrons ***[1 mark]***

The number of neutrons is the difference between the mass number and the atomic number.

c) D ***[1 mark]***

An isotope has the same number of protons (so the same atomic number), but a different number of neutrons (so a different mass number).

d) The atomic number of the neon isotope is lower, so there are fewer protons in the neon isotope's nucleus ***[1 mark]***. So the charge on the neon isotope's nucleus is lower than the charge on the sodium isotope's nucleus ***[1 mark]***.

Page 201 — Nuclear Equations

Warm-up

The atomic number decreases by two.

The mass number decreases by four.

1 a) It increases the positive charge on the nucleus / makes the nucleus 'more positive' ***[1 mark]***.

b) No effect ***[1 mark]***

2 a) The atomic numbers on each side are not equal ***[1 mark]***.

b) ${}^{0}_{-1}e$ or ${}^{0}_{-1}\beta$ ***[1 mark]***

The other particle must be a beta-minus particle, as this will balance the equation.

c) ${}^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$

[3 marks in total — 1 mark for each correct nucleus or particle in standard notation]

You know that the mass number of the radium is 226 (that's what 'radium-226' means). You also know that an alpha particle is ${}^{4}_{2}He$, so you can find the mass and atomic numbers of radon by balancing the equation.

d) Rn-222 has 222 – 86 = 136 neutrons ***[1 mark]***

2 alpha decays = 2 × 2 = 4 neutrons released ***[1 mark]***

136 – 4 = **132** ***[1 mark]***

Pages 202-203 — Half-life

1 a) E.g. the average time taken for the number of radioactive nuclei in an isotope to halve ***[1 mark]***.

b) 75 s ***[1 mark]***

You need to find the time it takes for the count rate to halve. For example, the initial count-rate is 60 cps. Half of this is 30 cps, which corresponds to 75 seconds on the time axis.

c) After 1 half-life, there will be 800 ÷ 2 = 400 undecayed nuclei remaining. After 2 half-lives, there will be 400 ÷ 2 = 200 undecayed nuclei remaining.
So 800 – 200 = **600** nuclei will have decayed.
[2 marks for correct answer, otherwise 1 mark for correctly calculating the number of decayed/undecayed nuclei after one half-life]

d) C ***[1 mark]***

After 2 half-lives, there are 200 undecayed nuclei. The ratio is 200:800, which simplifies to 1:4. You don't even need the numbers to work out this ratio. For any radioactive isotope, after two half lives, the initial number of undecayed nuclei will have halved and then halved again. It will be one quarter of the original number, so the ratio is always 1:4.

2 a) Isotope 1 (it has the shortest half-life) ***[1 mark]***.

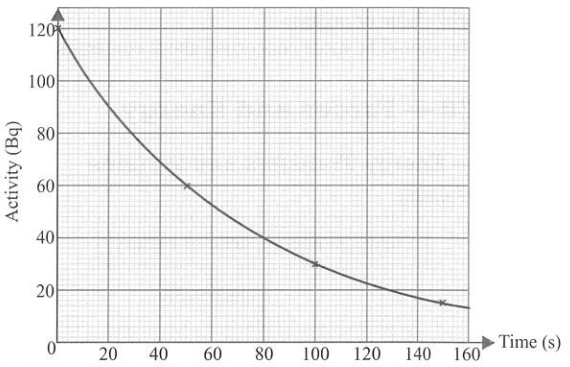
b) Isotope 1 ***[1 mark]***, because each isotope starts with the same number of nuclei, but isotope 1 has the shortest half-life, so more nuclei will decay per second ***[1 mark]***.

For isotope 1, it takes 4 minutes for 10 000 nuclei to decay, but it takes 72 years for 10 000 nuclei of isotope 2 to decay and 5 years for 10 000 nuclei of isotope 3 to decay. The activity of isotope 1 quickly decreases, but it takes longer for isotope 2 and isotope 3's activity to decrease.

3 a) E.g.
After 1 half-life, the activity will be 8800 ÷ 2 = 4400 Bq.
After 2 half-lives, the activity will be 4400 ÷ 2 = 2200 Bq.
After 3 half-lives, the activity will be 2200 ÷ 2 = 1100 Bq.
So it will take **3 half-lives**.
[3 marks for correct answer, otherwise 1 mark for correct method, 1 mark for correct calculations]

b) 6 hours is the same as 3 half-lives
which means that 1 half-life is
6 hours ÷ 3 = **2 hours** ***[1 mark]***.

4 a)



[1 mark for all points plotted correctly, 1 mark for smooth curve joining the points]

Start the graph at 120 Bq. After 50 s, this will have halved to 60 Bq. After another 50 s (i.e. 100 s altogether), it will have halved again, to 30 Bq. Plot these points, then join them up with a nice smooth curve.

b) 70 Bq (accept between 68 Bq and 72 Bq)
[1 mark for correct value from your graph]

c) From a), you know that the activity has dropped to 15 Bq in the first 150 s. 200 s is one more half-life after this.
After 200 s, 15 ÷ 2 = 7.5 = **8 Bq**
[2 marks — 1 mark for correct calculation of activity, 1 mark for correct activity to one significant figure]
E.g. radioactive decay is random ***[1 mark]*** and the effect of randomness on the results will be greater for lower activities ***[1 mark]***.

Page 204 — Background Radiation and Contamination

1 Any two from: e.g. rocks / space/cosmic rays / fallout from nuclear weapons
[2 marks — 1 mark for each correct answer]

2 a) Contamination is when unwanted radioactive particles get onto an object ***[1 mark]***. Irradiation is when an object is exposed to radiation ***[1 mark]***.

b) For irradiation: e.g. use shielding/stand behind barriers / work in a different room to the source / store the sample in a lead-lined box.
For contamination: e.g. wear gloves / handle the source with tongs / wear a protective suit or mask.
[2 marks in total — 1 mark for a correct measure for irradiation, 1 mark for a correct measure for contamination]

3 How to grade your answer:

Level 0: There is no relevant information. ***[0 marks]***

Level 1: There is a brief explanation of the dangers of contamination or radiation. The points made are basic and not linked together. ***[1-2 marks]***

Level 2: There is some explanation of the dangers and risks of contamination and radiation and a conclusion is given with some logical justification. Some of the points made are linked together. ***[3-4 marks]***

Level 3: There is a clear and detailed explanation of the dangers and risks of contamination and radiation, used to justify the conclusion that the clockmaker should either be more concerned about contamination or irradiation. The points made are well-linked and the answer has a clear and logical structure. ***[5-6 marks]***

Here are some points your answer may include:
Alpha particles are stopped by skin or thin paper.
Being irradiated won't make the clockmaker radioactive.
But irradiation may do some damage to his skin.
However, the radiation cannot penetrate his body and cause damage to his tissue or organs.
If the clockmaker's hands get contaminated with radium-226, he will be exposed to more alpha particles. Or he may accidentally ingest (eat) some.
Or if particles of the radium get into the air, he could breathe them in.
The radium will then decay whilst inside his body.
Alpha particles are strongly ionising.

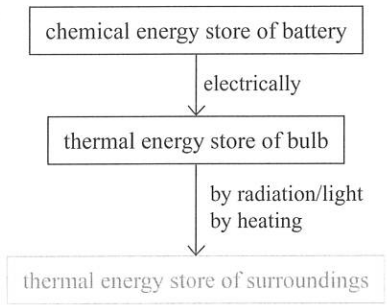
This means that the alpha particles can do lots of damage to nearby tissue or organs.
So he should be more concerned about contamination.

Section 20 — Forces and Energy

Page 205 — Energy Transfers and Systems

1 C *[1 mark]*

2 E.g.



[1 mark for energy transferred electrically from battery, 1 mark for thermal energy store of bulb, 1 mark for energy transfer by radiation or heating from bulb]

3 a) i) KE = $\frac{1}{2}mv^2 = 0.5 \times 0.08 \times 7.00^2 =$ **1.96 J**
[3 marks for correct answer, otherwise 1 mark for correct equation, 1 mark for correct substitution]

ii) Work done by gravitational force *[1 mark]*

b) $\Delta GPE = mg\Delta h = 1.96$
$\Delta h = 1.96 \div mg = 1.96 \div (0.08 \times 10) =$ **2.45 m**
[4 marks for correct answer, otherwise 1 mark for using correct equation, 1 mark for correct rearrangement, 1 mark for correctly substituting in all of the values]

Pages 206-207 — Work Done and Power

Warm-up
As a rubber ball falls, it experiences a force due to gravity. Work is done on the ball and energy is transferred from the ball's gravitational potential energy store to its kinetic energy store.

1 B *[1 mark]*

2 a) $t = 125 \times 60 = 7500$ seconds
$P = E \div t$ so $E = Pt = 600 \times 7500 = 4\,500\,000 =$ **4500 kJ**
[4 marks for the correct answer, otherwise 1 mark for correct equation, 1 mark for the correct substitution, 1 mark for correct conversion to kJ]

b) Time taken = $125 \times 60 = 7500$ seconds
$P = E \div t = 3\,930\,000 \div 7500 =$ **524 W**
[2 marks for correct answer, otherwise 1 mark for correct substitution]

3 a) i) Work done = force applied × distance moved in the direction of the force *[1 mark]*

ii) $50 \times 15 =$ **750**
[2 marks for correct answer, otherwise 1 mark for correct substitution]

b) The temperature of the wheel increases *[1 mark]* because doing work causes some energy to be transferred to the thermal energy store of the wheel *[1 mark]*.

4 a) Efficiency = useful energy transferred by the device ÷ total energy supplied to the device
Power is the energy transferred per second,
so in 1 s the old engine transfers 52 000 J usefully.
Total energy supplied to the engine (in 1 second)
= useful energy transferred by the engine ÷ efficiency
= 52 000 ÷ 0.25 = 208 000 J
For the new engine:
Useful energy transferred by the engine (in 1 second)
= efficiency × total energy supplied to the engine
= 0.30 × 208 000 = 62 400 J
So every second, the new engine outputs 62 400 J of energy.
Power is energy per second, so the output power of the new engine is **62 400 W**.
[5 marks for correct answer, otherwise 1 mark for correct efficiency equation, 1 mark for finding total energy supplied to the engine, 1 mark for converting efficiency to a decimal, 1 mark for correctly substituting into the efficiency equation at any point]

You could also have put power = energy ÷ time straight into the efficiency equation to get efficiency = power output ÷ power input and then used this for your calculations.

b) It will decrease the time *[1 mark]* because more energy is being transferred to the kinetic energy store of the car per second *[1 mark]*. This decreases the time needed for enough energy to be in the car's kinetic energy store to cause it to travel at 20 m/s *[1 mark]*.

Pages 208-209 — Forces

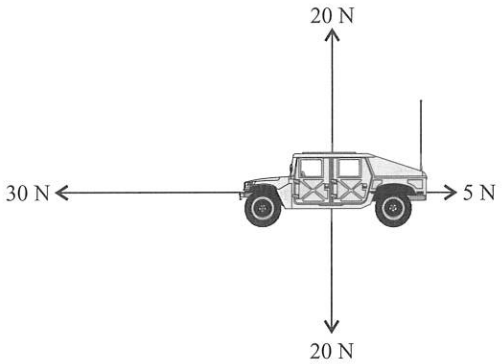
1 a) i) E.g. a force that acts between objects that are touching *[1 mark]*.

ii) Any two from: e.g. friction / normal contact force / air resistance
[2 marks — 1 mark for each correct answer]

b) E.g. gravitational force / magnetic force / electrostatic force
[1 mark]

2 C *[1 mark]*

3



[1 mark for correct directions of forces, 1 mark for arrows drawn to scale]

4 a)

[1 mark for correct arrow length (same as 30 N arrow length), 1 mark for correct direction]

b) 100 N *[1 mark]*

As the ladder isn't moving, there must be a resultant force of zero acting on it. This means that the weight of the ladder must equal the vertical force between the ladder and the ground.

5 a)

[1 mark for correct arrow length (same as the arrow on magnet B), 1 mark for correct direction]

b) E.g. the magnetic fields of the two magnets interacting *[1 mark]*.

c) Both arrows need to be longer
(to indicate the stronger interaction) *[1 mark]*.
The arrows need to be the same size as each other *[1 mark]*.

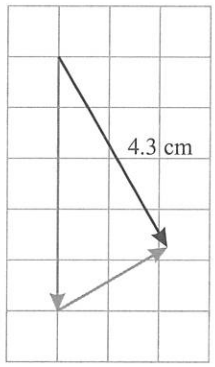
The repulsion forces between the magnets are an interaction pair — so they are always equal in size but act in the opposite direction to each other.

Pages 210-211 — Forces and Vector Diagrams

Warm-up
Horizontal component = 4 N
Vertical component = 3 N

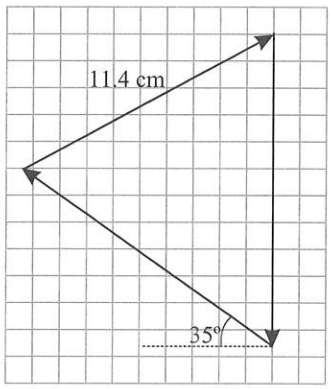
1 a) 1 cm = 100 N *[1 mark]*

b)



1 cm = 100 N, so 4.3 cm = 4.3 × 100 = 430 N
Magnitude = **430 N (accept between 420 N and 440 N)**
[1 mark for correct construction of resultant force, 1 mark for correct magnitude]

2 E.g.



Scale for drawing above: 1 cm = 50 N
Length of 620 N force: 620 ÷ 50 = 12.4 cm
Length of 610 force: 610 ÷ 50 = 12.2 cm
Length of force X = 11.4 cm
11.4 × 50 = 570 N
Magnitude of force X = **570 N** (accept between 565 and 575)
Direction = **062 °** (accept between 61 and 63 °)
[1 mark for using a sensible scale, 1 mark for correctly drawing a closed shape, 1 mark for vector arrows the correct length and in the correct direction, 1 mark for correct magnitude of force X, 1 mark for direction of force as a bearing]

Section 21 — Electricity and Circuits

Page 212 — Current and Circuits

Warm-up
Current is the rate of flow of electric charge (electrons) around a circuit. The driving force that pushes current around a circuit is called the potential difference. A current will flow around a circuit if the circuit is closed and there is a source of potential difference.
The current flowing through a component increases when the potential difference across it increases or when the resistance of the component decreases.

1 B ***[1 mark]***

2 a) charge = current × time = 3.5 × 120 = **420 C**
[3 marks for correct answer, otherwise 1 mark for using the correct equation, 1 mark for substituting in correct values]

b) Rearrange charge = current × time for time:
time = charge ÷ current = 770 ÷ 3.5 = **220 s**
[3 marks for correct answer, otherwise 1 mark for rearranging charge equation for time, 1 mark for substituting in the correct values]

Page 213 — Potential Difference and Resistance

Warm-up
True, False, True

1 a) $E = Q \times V$, so
$Q = E \div V = 276\,000 \div 230 =$ **1200 C**
[3 marks for correct answer, otherwise 1 mark for rearranging energy transferred equation for charge, 1 mark for correctly substituting in the values]

b) $E = Q \times V = 1000 \times 230 = 230\,000 =$ **230 kJ**
[2 marks for correct answer, otherwise 1 mark for correctly substituting in the values]

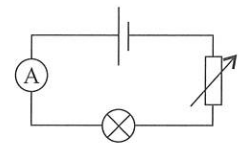
2 a) $V = IR$ so $R = V \div I$
$R = 18 \div 3 =$ **6 Ω**
[4 marks for correct answer, otherwise 1 mark for correctly rearranging the equation for resistance, 1 mark for substituting in the correct values, 1 mark for correct value, or 1 mark for correct unit]

b) When current flows through the resistor, electrons collide with the ions in the lattice of the resistor ***[1 mark]***. This transfers energy to the ions ***[1 mark]*** causing them to vibrate more and causing the resistor to heat up ***[1 mark]***. The more the ions vibrate, the harder it is for the electrons to pass through the lattice, so the current decreases ***[1 mark]***.

Page 214 — Investigating Components

1 a) D ***[1 mark]***

b)



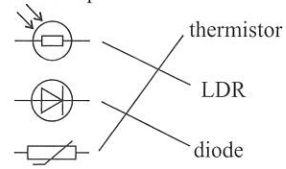
[1 mark for an ammeter anywhere in series on the circuit]

2 How to grade your answer:
Level 0: There is no relevant information. ***[0 marks]***
Level 1: There is a brief description of a method to investigate the resistance of the diode. The points made are basic and not linked together. ***[1-2 marks]***
Level 2: There is a description of a method to investigate the resistance of the diode. There is some discussion of accuracy and repeatability. Some of the points made are linked together. ***[3-4 marks]***
Level 3: There is a clear and detailed description of a method to investigate the resistance of the diode. The answer includes a full discussion of accuracy and repeatability. The points made are well-linked and the answer has a clear and logical structure. ***[5-6 marks]***

Here are some points your answer may include:
The student should change the output potential difference of the power supply.
For each setting of the power supply he should record the potential difference across the diode and the current through the circuit.
To make his results more accurate and repeatable, he should take repeated readings of current and potential difference for each setting of the power supply, and calculate an average.
He should allow the circuit to cool down between readings, as if the circuit starts to heat up it could interfere with the accuracy and repeatability of his results.
He should plot the average potential difference and current values on a graph of current against potential difference, then draw a line of best fit.
The resistance can be found for any potential difference by reading off the value of current from the line of best fit for that potential difference and then using the equation of resistance = potential difference ÷ current.

Page 215 — Circuit Devices

Warm-up



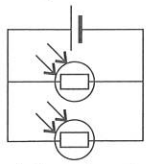
1 a) The resistance decreases ***[1 mark]***.

b) E.g. temperature detectors in thermostats/car engines ***[1 mark]***.

2 a) B *[1 mark]*
b) E.g. when the current increases, so does the temperature of the filament *[1 mark]*. This makes the resistance increase, so the graph is curved *[1 mark]*.

Page 216-218 — Series and Parallel Circuits

1 A *[1 mark]*
2 E.g.



[1 mark for using the correct symbols for an LDR and a cell, 1 mark for correctly drawing the LDRs in parallel]

3 a) $10 + 30 = \mathbf{40\ \Omega}$ *[1 mark]*
b) $V = IR = 0.075 \times 30 = \mathbf{2.25\ V}$
[3 marks for a correct answer, otherwise 1 mark for quoting the correct equation, 1 mark for substituting in the correct values]

4 How to grade your answer:
Level 0: There is no relevant information. *[0 marks]*
Level 1: There is a brief explanation about the effect of adding resistors in series or parallel. The points made are basic and not linked together. *[1-2 marks]*
Level 2: There is a comparison between adding resistors in series and parallel and an explanation of their effects. Some of the points made are linked together. *[3-4 marks]*
Level 3: A logical and detailed comparison is given, explaining why adding resistors in series increases the total resistance but adding them in parallel reduces it. The points made are well-linked and the answer has a clear and logical structure. *[5-6 marks]*
Here are some points your answer may include:
In series, resistors share the potential difference from the power source.
The more resistors that are in series, the lower the potential difference across each one, and so the lower the current through each resistor (as $V = IR$).
Current is the same all around a series circuit, so adding a resistor will decrease the current for the whole circuit.
A decrease in total current means an increase in total resistance.
In parallel, all resistors have the same potential difference as the source.
Adding another resistor in parallel (forming another circuit loop) increases the current flowing in the circuit, as there are more paths for the current to flow through.
An increase in total current means a decrease in total resistance (because $V = IR$).

5 a) Find the equivalent resistance of the circuit:
potential difference = current × resistance so
resistance = potential difference ÷ current = 12 ÷ 0.25 = 48 Ω
This is the resistance of both bulbs, so divide by 2: 48 ÷ 2 = **24 Ω**
[3 marks for the correct answer, otherwise 1 mark for rearranging the equation for resistance, 1 mark for using this to correctly calculate the equivalent resistance of the circuit]
b) i) First find the current through the circuit branch with bulb 3:
potential difference = current × resistance, so
current = potential difference ÷ resistance = 12 ÷ 12 = 1 A
0.5 A is still flowing through the branch with bulbs 1 and 2.
Then find the current through ammeter by adding the currents flowing through each branch:
current = 0.5 + 1 = **1.5 A**
[2 marks for correct answer, otherwise 1 mark for calculating the current for the branch with bulb 3]
The current flowing through the branch with bulbs 1 and 2 on it doesn't change when bulb 3 is added, as the resistance of this branch and the potential difference across it don't change.
ii) Because the potential difference across bulb 3 is the same as the source potential difference, but bulbs 1 and 2 share the source potential difference *[1 mark]*, so the current through bulb 3 is higher *[1 mark]*.
c) i) The current through the ammeter decreases *[1 mark]*.
ii) The brightness of bulbs 1 and 2 doesn't change *[1 mark]*. Bulb 3 gets dimmer *[1 mark]*.
d) Because the bulbs may not have been identical *[1 mark]*. Because the bulbs may have got hotter as the experiment went on, which would increase their resistance *[1 mark]*.

Page 219 — Energy in Circuits

1 D *[1 mark]*
2 a) The heating element *[1 mark]*.
b) In the wires / in the motor *[1 mark]*.
c) The longer the hairdryer is on for, the more the motor/wires heat up *[1 mark]*. This increases the resistance of the wires/ motor *[1 mark]*, meaning less energy is transferred usefully *[1 mark]*.

3 a) $E = I \times V \times t$
so $t = \frac{E}{I \times V} = 355\,000 \div (12 \times 230) = 128.623...$
$= \mathbf{129\ s\ (to\ the\ nearest\ second)}$
[3 marks for correct answer, otherwise 1 mark for correctly rearranging the equation for time, 1 mark for calculating a value of 128.623...s]
b) E.g. that the kettle was 100% efficient / that all the energy transferred to the kettle was used heating the water / that no energy was transferred to heating the wires/surroundings *[1 mark]*.

Page 220 — Power in Circuits

1 a) $E = P \times t = 50 \times 20 = \mathbf{1000\ J}$
[3 marks for correct answer, otherwise 1 mark for using the correct equation, 1 mark for correctly substituting the values into the equation]
b) The power of the car is higher *[1 mark]*. So more energy is transferred away from the chemical energy store of the battery per second *[1 mark]*.

2 a) $P = I \times V$
so $I = P \div V = 75 \div 230 = 0.3260...$ = **0.33 A (to 2 s.f.)**
[3 marks for the correct answer rounded to 1 or 2 significant figures, otherwise 1 mark for rearranging the equation for current, 1 mark for calculating a value of 0.3260... A]
b) $P = I^2 \times R$ so $R = \frac{P}{I^2} = 2.5 \div 0.50^2 = \mathbf{10\ \Omega}$
[3 marks for correct answer, otherwise 1 mark for rearranging the equation for resistance, 1 mark for substituting in the correct values]
c) i) model A *[1 mark]*
ii) Because it is very noisy *[1 mark]* which means it may be transferring a lot of energy away as sound, making it less efficient *[1 mark]*.

Pages 221-222 — Electricity in the Home

Warm-up
describes the current supplied by a battery — direct current
produced by a voltage that constantly changes direction — alternating current
describes the current supplied by the UK mains — alternating current
produced by a voltage with a constant direction — direct current

1 a) 230 V, 50 Hz *[1 mark]*
b) i) Live: brown
Neutral: blue
Earth: green and yellow
[2 marks for all three correct, otherwise 1 mark for two correct]
ii)

Wires	Potential difference / V
Live wire and neutral wire	230
Neutral wire and earth wire	0
Earth wire and live wire	230

[1 mark for each correct row]

2 No, the radio won't work *[1 mark]*. A closed loop has been formed, where current from the live wire is carried away by the neutral wire *[1 mark]*, so no (or very little) current will flow through the radio *[1 mark]*.

3 a) To stop an electric current from flowing out of the live wire and potentially causing an electric shock (i.e. for safety) *[1 mark]*. To make it easy to identify the live wire *[1 mark]*.

b) The man has an electric potential of 0 V *[1 mark]* and the wire has an electric potential (of 230 V) so a potential difference exists between them *[1 mark]*. This causes a current to flow through the man *[1 mark]*.

c) Yes *[1 mark]*. Although there is no current flowing when it is switched off, there is still a potential difference in the live wire inside the socket *[1 mark]*. Touching it could cause a current to flow through you to the Earth *[1 mark]*.

Page 223 — Fuses and Earthing

1 a) To protect the wiring of the house and prevent fires in the event of a fault *[1 mark]*.

b) Because pennies won't melt like a fuse wire in the event of a current surge, so the circuit won't be broken *[1 mark]*.

c) Advantage: e.g. circuit breakers break the circuit more quickly than fuses / circuit breakers are easier to reset that fuses *[1 mark]*.
Disadvantage: e.g. circuit breakers are more expensive than fuses *[1 mark]*.

2 a) If the live wire comes loose and touches the metal, a large current will flow through the fuse, the live wire and the earth wire *[1 mark]*. This current melts the thin wire in the fuse *[1 mark]*, cutting off the electricity supply to the device *[1 mark]*.

b) The fuse needs to be rated slightly higher than the normal operating current of the device *[1 mark]*, and the electric heater has a higher operating current than the clock radio *[1 mark]*.

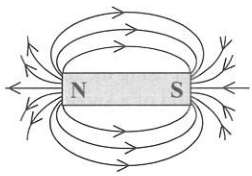
Section 22 — Magnetic Fields

Pages 224-225 — Magnets and Magnetic Fields

Warm-up
T, F, T

1 a) C *[1 mark]*

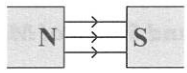
b)



[1 mark for at least two lines between the north and south poles, 1 mark for at least three lines at each pole, 1 mark for at least one arrow in the correct direction with no arrows in the incorrect direction]

c) i) E.g. a uniform field has the same strength everywhere / the field lines are parallel and equally spaced *[1 mark]*

ii)



[1 mark for at least three straight, evenly spaced field lines, 1 mark for at least one arrow in the right direction with no arrows in the incorrect direction]

2 A force is acting on both magnets (due to their interacting magnetic fields) *[1 mark]*. This force is repulsive — the magnetic field lines of both objects are travelling away from each other *[1 mark]*. So the two objects move away from each other *[1 mark]*.

3 a) E.g. the needle of a compass points in the direction of the magnetic field it is in *[1 mark]*. Put the magnet on a sheet of paper and place a compass near to it. Mark where the north pole of the compass is pointing *[1 mark]*. Move the compass so its south pole is next to the mark, and again mark where the north pole of the compass is pointing. Repeat this until you've moved the compass around the entire magnet *[1 mark]*. Join up these marks to create a diagram of the magnetic field lines *[1 mark]*.

b) It would point north *[1 mark]* because it is aligning itself with the magnetic field of the Earth *[1 mark]*.

Page 226 — Permanent and Induced Magnets

1 a) E.g. a permanent magnet produces its own magnetic field at all times *[1 mark]*. An induced magnet only produces a magnetic field when it is close to another magnet *[1 mark]*.

b) Any two from: e.g. iron / steel / cobalt / nickel
[2 marks — 1 mark for each correct answer]

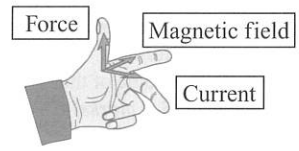
c) E.g. cranes in scrapyards *[1 mark]* use induced electromagnets to pick up, move and put down scrap metal *[1 mark]*.

2 a) The block of cobalt becomes an induced magnet when it is placed in the magnetic field of the bar magnet *[1 mark]*. The magnetic field of the cobalt then makes the paperclip an induced magnet *[1 mark]*, which causes a force of attraction between the paperclip and the cobalt *[1 mark]*.

b) When the bar magnet is removed, the cobalt will quickly demagnetise *[1 mark]*, so the paperclip will become unstuck *[1 mark]*.

Pages 227-228 — Electromagnetism and the Motor Effect

Warm-up



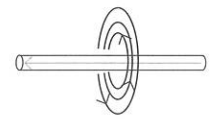
1 a) C *[1 mark]*

Use Fleming's left-hand rule here. Point your first finger in the direction of the field (i.e. from the north pole to the south pole of the magnets). Point your second finger in the direction of the current (shown in the diagram). Your thumb will then show the direction of motion of the wire.

b) The current in the wire creates its own magnetic field *[1 mark]* which interacts with the magnetic field between the poles of the magnets (which results in a force) *[1 mark]*.

c) E.g. the size of the current going through the wire / the strength of the magnetic field that the wire is in / the length of wire inside the magnetic field.
[3 marks — 1 mark for each correct answer]

2 a)



[1 mark for concentric circles around the wire, 1 mark for at least one arrow showing the direction of the field]

b) The direction of the field will also be reversed *[1 mark]*.

c) E.g. increase the current *[1 mark]*.

3 $F = BIl$ so $B = F \div Il$
$B = 1.2 \div (0.4 \times 0.75) = \mathbf{4}$
Unit = **T** or **N/Am**
[4 marks for correct answer, otherwise 1 mark for rearranging, 1 mark for correct substitution, 1 mark for correct numerical value, 1 mark for the correct unit]

Pages 229-230 — Solenoids and Electromagnetic Induction

Warm-up
T, F, T, F

1 C *[1 mark]*

2 a) E.g. a magnet which can be controlled (turned on and off) by an electric current *[1 mark]*.

b) i) E.g. the magnetic field is strong *[1 mark]* and almost uniform *[1 mark]*.

ii) E.g. the magnetic field is weak *[1 mark]* and is a similar shape to that of a bar magnet *[1 mark]*.

3 a) Alternating current *[1 mark]*. As he moves the magnet in, the changing magnetic field induces a potential difference, and so current, in the coil in one direction *[1 mark]*. As he moves it out again, it induces a potential difference, and so current, in the opposite direction *[1 mark]*.

b) Increase the speed that the magnet is moved / use a stronger magnet / have more turns per unit length on the coil.
[3 marks — 1 mark for each correct answer]

4 a) By putting a block of iron in the centre of the solenoid *[1 mark]*.

b) Repelled ***[1 mark]***, because the direction of the current means that the left-hand end of the solenoid acts as a north pole ***[1 mark]***, and like poles repel ***[1 mark]***.

Pages 231-232 — Transformers

Warm-up

Transformers consist of two coils of wire, wrapped around an iron core.
Transformers can change the size of alternating potential differences.
Step-down transformers decrease the output potential difference.
Step-up transformers decrease the output current.

1 $V_p \times I_p = V_s \times I_s$ so $I_s = (V_p \times I_p) \div V_s$
$I_s = (30.0 \times 20.0) \div 40.0 =$ **15 A**
[3 marks for correct answer, otherwise 1 mark for correct rearrangement, 1 mark for correct substitution]

2 How to grade your answer:
Level 0: There is no relevant information. ***[No marks]***
Level 1: There is a brief description of how electromagnetic induction can induce a potential difference. The points made are basic and not linked together. ***[1-2 marks]***
Level 2: There is a more detailed description of how electromagnetic induction in transformers can induce a potential difference. Some of the points made are linked together. ***[3-4 marks]***
Level 3: There is a clear detailed description of how electromagnetic induction is used in transformers to induce a potential difference. There is an explanation as to how the increased number of turns leads to an increased output potential difference. The points made are well-linked and the answer has a clear and logical structure. ***[5-6 marks]***

Here are some points your answer may include:
A step-up transformer has two coils wrapped around a metal (usually iron) core.
Iron is used because it is easy to magnetise.
When a current flows through a wire, it produces a magnetic field around the wire.
The direction of this magnetic field depends on the direction of the current, so when the current is alternating, the magnetic field produced also alternates.
So an alternating current flowing through the primary coil of the transformer creates an alternating magnetic field in the metal core of the transformer.
As the magnetic field in the metal core is alternating, the magnetic field across the secondary coil is always changing.
This change in magnetic field causes a potential difference to be induced in the secondary coil.
In a step-up transformer, there are more turns on the secondary coil than there are on the primary coil.
This means that the potential difference induced in the secondary coil is larger than the potential difference across the primary coil.

3 a) Transformer A: step-up transformer ***[1 mark]***
Transformer B: step-down transformer ***[1 mark]***

b) In the opposite direction to the (changing) magnetic field that caused it ***[1 mark]***.

c) How to grade your answer:
Level 0: There is no relevant information. ***[No marks]***
Level 1: There is a brief description of an advantage of using transformers or high-voltage cables. The points made are basic and not linked together. ***[1-2 marks]***
Level 2: There is a more detailed description of how transferring power at a high voltage results in a lower current and the advantages of this. Some of the points made are linked together. ***[3-4 marks]***
Level 3: There is a clear detailed description of the advantages of using transformers and high-voltage cables, as well as correct equations being used to support the answer. The points made are well-linked and the answer has a clear and logical structure. ***[5-6 marks]***

Here are some points your answer may include:
The national grid needs to transfer a lot of energy each second, so the power transmitted is very high.
Power is the rate of doing work/transferring energy.
$P = E \div t$
Power = current × potential difference / $P = IV$
So for a large output power you need either a large current or a large potential difference.
A high current causes energy to be wasted as it heats the cables.
Using a step-up transformer increases the potential difference of the output electricity.
So increasing the output p.d. reduces the output current.
This reduces the power lost / This makes the national grid more efficient.

Section 23 — Matter

Pages 233-234 — Density

1 a) i) $\rho = m \div V$ ***[1 mark]***
ii) $\rho = 10\,000 \div 0.5 =$ **20 000 kg/m³**
[2 marks for correct answer, otherwise 1 mark for correct substitution]

b) The density is the same for the whole block,
so $\rho = 20\,000$ kg/m³
$\rho = m \div V$ so $m = \rho \times V = 20\,000 \times 0.02 =$ **400 kg**
[2 marks for correct answer, otherwise 1 mark for correct substitution]

2 volume = area × length = $0.050 \times 0.40 = 0.02$ m³
$\rho = m \div V = 90.0 \div 0.02 =$ **4500 kg/m³**
[3 marks for correct answer, otherwise 1 mark for calculating the volume of the bar, 1 mark for correct substitution into equation for density]

3 $\rho = m \div V$
1 ml of water = 1 cm³
A: $\rho = 5.7 \div 0.30 = 19$ g/cm³. So A is gold.
B: $\rho = 2.7 \div 0.60 = 4.5$ g/cm³. So B is titanium.
C: $\rho = 3.0 \div 0.30 = 10$ g/cm³. So C is silver.
[5 marks for correct answer, otherwise 1 mark for stating 1 ml = 1 cm³, 1 mark for correct substitutions and 1 mark for each correct conclusion]

4 Measure the mass (m_1) of the object using the mass balance ***[1 mark]***. Fill the bottle with a liquid of a known density. Measure the mass of the filled bottle (m_2) ***[1 mark]***. Empty the bottle and place the object inside it. Fill it with the same liquid as before. Measure the mass of the bottle again (m_3) ***[1 mark]***. Calculate the mass of the liquid displaced by the object ($m_2 - [m_3 - m_1]$) ***[1 mark]*** then use this to calculate the volume of the liquid displaced from $V = m \div \rho$, where ρ is the density of the liquid, (which equals the volume of the object) ***[1 mark]***. Use this volume and the mass of the object to calculate its density using $\rho = m \div V$ ***[1 mark]***.

Pages 235-236 — Kinetic Theory and States of Matter

Warm-up

From left to right: liquid, solid, gas

1 condensation — gas to liquid
sublimation — solid to gas
evaporation — liquid to gas
[1 mark for all 3 correct]

2 a) C ***[1 mark]***

b) There is a smaller mass (and so fewer particles) in a given volume of ice than of water ***[1 mark]***. So the water molecules are further apart in ice than they are in liquid water ***[1 mark]***.

Substances are usually more dense as a solid than as a liquid, but water is an exception to this.

3 a) It has evaporated/it has become water vapour ***[1 mark]***.

b) The total mass stays the same ***[1 mark]*** because all of the particles are still in the flask/its a closed system ***[1 mark]***.

As the water is heated, energy is transferred from its thermal energy store to the thermal energy store of the methanol ***[1 mark]***. This means the methanol particles have more energy in their kinetic energy stores ***[1 mark]***, so will move around more — causing the methanol to increase in volume and move the piston ***[1 mark]***. As energy is continuously being transferred to them, some particles gain enough energy to overcome their attraction to each other ***[1 mark]*** and some of the methanol changes state into a gas ***[1 mark]***.

Page 237 — Specific Heat Capacity

Warm-up

The energy needed to raise 1 kg of a substance by 1 °C.

1 a) Measure the mass of the insulated flask and then fill it with the liquid you are testing. Measure the mass of the flask again to find the mass of the liquid ***[1 mark]***. Connect the power supply to the joulemeter and the immersion heater. Place the immersion heater into the liquid ***[1 mark]***. Measure the temperature of the liquid ***[1 mark]*** and then turn on the immersion heater. Turn off the immersion heater once the temperature of the liquid has increased by 10 °C ***[1 mark]***. Read the energy transferred shown on the joulemeter and use $\Delta Q = mc\Delta\theta$ to calculate the specific heat capacity ***[1 mark]***.

b) $\Delta Q = mc\Delta\theta$ so $c = \Delta Q \div m\Delta\theta = 15\,000 \div (0.3 \times 25)$
Specific heat capacity = **2000 J/kg °C**
[3 marks for correct answer, otherwise 1 mark for rearranging, 1 mark for correct substitution]

Pages 238-239 — Specific Latent Heat

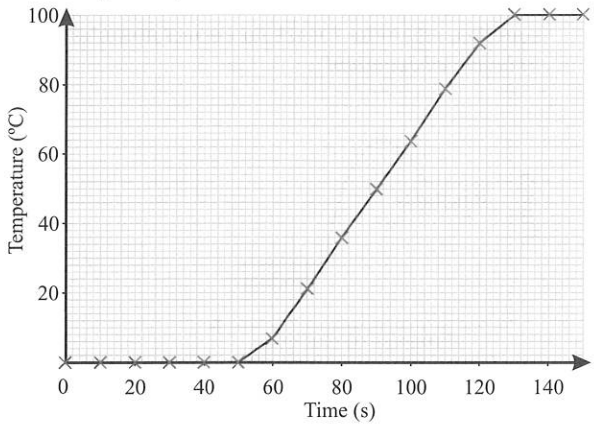
1 D ***[1 mark]***

2 a) The amount of energy required to change the state of one kilogram of a substance with no change in temperature ***[1 mark]***.

b) E.g. specific heat capacity is the energy needed to cause a temperature rise without causing a change of state, but specific latent heat is the energy needed to cause a change of state, where the temperature remains constant ***[1 mark]***.

c) –2 °C ***[1 mark]***

3 a)



[1 mark for all points plotted correctly, 1 mark for a correctly drawn line connecting the points]

b) 500 g = 0.5 kg
$Q = m \times L$ so $L = Q \div m = 1.13 \div 0.5 =$ **2.26 MJ/kg**
[3 marks for correct answer, otherwise 1 mark for rearranging, 1 mark for correct substitution]

c) As the substance is heated, energy is transferred to the kinetic energy stores of its particles ***[1 mark]***. As the substance melts (from 0-50 s), all of this energy is used to break the intermolecular bonds between the particles ***[1 mark]*** so there is no increase in the substance's temperature as it changes state ***[1 mark]***.

Pages 240-241 — Particle Motion in Gases

Warm-up

The particles in a gas are always moving in random directions.
A gas exerts a force on a container due to collisions.
The total force exerted by the particles per unit area is the gas pressure.

1 Absolute zero is the temperature at which particles barely move / the temperature at which particles have the smallest amount of energy possible in their kinetic energy stores ***[1 mark]***.

2 Container A holds the same number of particles, travelling at the same speed, as container B, but in a larger volume ***[1 mark]***. This means the particles hit the walls of container A less often and so exert less pressure ***[1 mark]***.

3 a) 295 – 273 = **22 °C** ***[1 mark]***

b) The pressure of the gas increases ***[1 mark]***. This is because increasing the temperature of the gas increases the speed of the gas particles ***[1 mark]*** so they collide with the walls of the container more often and with more force ***[1 mark]***.

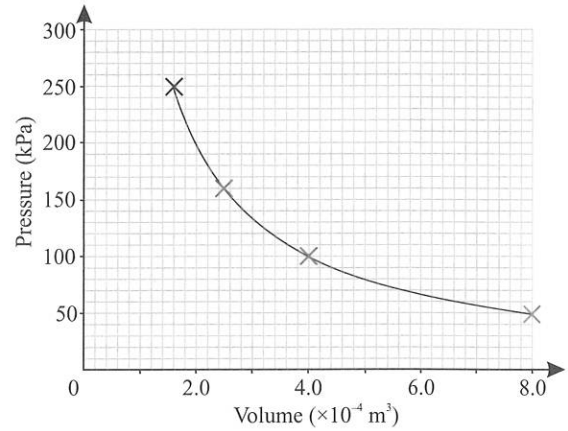
4 D ***[1 mark]***

The volume of each container is the same ($0.04\ m^3 = 40\,000\ cm^3$). Container D has the highest temperature (the temperature of container C is 283 – 273 = 10 °C). A fixed mass and volume of a gas has a higher pressure at a higher temperature.

5 a) $P_1V_1 = P_2V_2$ so $P_2 = P_1V_1 \div V_2$
Use the data from the first row of the table to find the missing pressure:
$P_2 = (50 \times 10^3) \times (8.0 \times 10^{-4}) \div (1.6 \times 10^{-4})$
$= 250\,000 =$ **250 kPa**
[3 marks for correct answer, otherwise 1 mark for correctly rearranging the equation and 1 mark for correctly substituting in values.]

You could have used any row from the table to help you find the missing value — as long as you did the calculation correctly you'd get the marks.

b)



[1 mark for correctly plotted point, 1 mark for a curved line connecting them]

Pages 242-243 — Forces and Elasticity

1 a) Two ***[1 mark]***

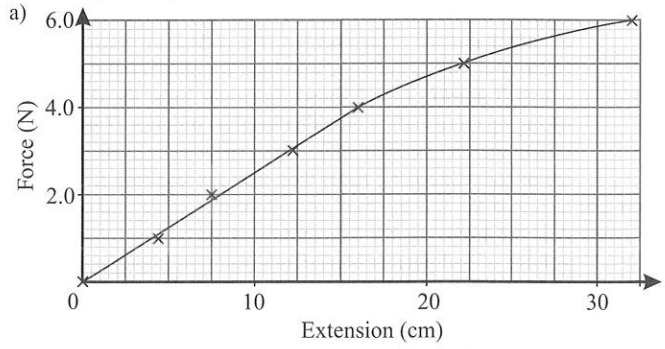
b) An object that has been elastically distorted will go back to its original shape and length when the distorting forces are removed ***[1 mark]***. An object that has been inelastically distorted won't ***[1 mark]***.

c) i) $F = kx$ ***[1 mark]***
ii) $k = F \div x = 20 \div 0.08 =$ **250 N/m**
[2 marks for correct answer, otherwise 1 mark for correct substitution]

d) That stretching the spring by 8 cm doesn't exceed its limit of proportionality ***[1 mark]***.

2 D ***[1 mark]***

3 a)



[1 mark for points plotted correctly, 1 mark for line of best fit showing linear relationship between 0 cm and at least 12 cm, 1 mark for curved line of best fit towards the end of the graph]

b) $F = kx$
so $k = F \div x$ = gradient of the linear section of the graph
$k = 3.0 \div 0.12 =$ **25 N/m**
[2 marks for correct answer between 24 and 26 N/m, otherwise 1 mark for correct calculation]

c) The limit of proportionality is exceeded when the relationship between force and extension becomes non-linear ***[1 mark]***. This is shown by the graph beginning to curve ***[1 mark]***.

d) When he was loading the spring he distorted the spring inelastically ***[1 mark]*** so when the force was removed, the spring didn't return to its original length ***[1 mark]***.

You could also refer to the student exceeding the elastic limit of the spring, which would mean it was inelastically distorted.

Mixed Questions

Pages 244-248 — Biology Mixed Questions

1 a) i) mitochondria ***[1 mark]***
ii) oxygen ***[1 mark]***, carbon dioxide ***[1 mark]***
b) plasma ***[1 mark]***
c) Glucagon is released into the blood ***[1 mark]***, which converts glycogen back into glucose ***[1 mark]***.

2 a) B ***[1 mark]***
b) A ***[1 mark]***
c) i) 40 °C ***[1 mark]***
ii) The enzyme will not work ***[1 mark]*** because the high temperature will change the shape of its active site/denature the enzyme ***[1 mark]*** and the substrate will no longer fit ***[1 mark]***.

3 a) i) C ***[1 mark]***
ii) B ***[1 mark]***
b) The hormone is secreted directly into the blood ***[1 mark]***. It is then carried in the blood to the target organ ***[1 mark]***.
c) It inhibits the secretion of both FSH ***[1 mark]*** and LH ***[1 mark]***.
d) oestrogen ***[1 mark]***, progesterone ***[1 mark]***
e) It causes an egg to mature in one of the ovaries ***[1 mark]***. It stimulates the ovaries to produce oestrogen ***[1 mark]***.

4 a) A non-communicable disease because it is not transmitted between individuals/is not caused by a pathogen ***[1 mark]***.

Remember, communicable diseases are caused by pathogens and can be spread between individuals. Vitamin A deficiency is caused by deficiencies in the diet, so it's non-communicable.

b) It will contain genes not found in normal rice / DNA from a bacterium and a maize plant ***[1 mark]***.
c) E.g. the genes to be used from the maize plant and the soil bacterium were cut out using restriction enzymes ***[1 mark]***. The same restriction enzymes were used to cut open the DNA of a vector ***[1 mark]***. The genes extracted from the maize plant and the soil bacterium were then joined to the vector DNA using ligase enzymes ***[1 mark]***. The recombinant DNA/vector containing the desired genes were then have been inserted into a rice plant to produce Golden Rice ***[1 mark]***.
d) Plants make proteins using nitrogen ***[1 mark]*** from nitrates/nitrogen ions in the fertiliser ***[1 mark]***.

5 a) i) oxygen ***[1 mark]***
ii) light intensity ***[1 mark]***

The foil prevents any light from reaching the algae.

iii) Tube 1 shows that in the dark, the algae are producing more carbon dioxide than they take in ***[1 mark]***. The concentration of carbon dioxide is high because the cells are respiring, but not photosynthesising (as there's no light for photosynthesis to take place) ***[1 mark]***. Tube 2 shows that in the light, the algae are taking up more carbon dioxide than they produce ***[1 mark]***. The concentration of carbon dioxide has reduced because the cells are photosynthesising faster than they are respiring ***[1 mark]***.

Plant cells respire all the time but they can only photosynthesise when it's light.

iv) Any two from: e.g. the temperature of the boiling tubes / the volume of hydrogencarbonate indicator / the concentration of hydrogencarbonate indicator / the number of beads in each tube / the concentration of algal cells in each bead ***[2 marks — 1 mark for each correct answer]***.

b) i) Light intensity ***[1 mark]*** because the rate of photosynthesis is increasing as the light intensity increases ***[1 mark]***.
ii) carbon dioxide concentration ***[1 mark]***

Pages 249-254 — Chemistry Mixed Questions

1 a) calcium + sulfuric acid → calcium sulfate + hydrogen
[1 mark for correct left-hand side, 1 mark for correct right-hand side.]
b) $CaSO_4$ ***[1 mark]***

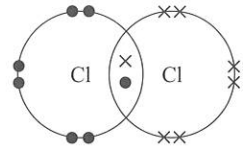
Calcium is in group 2, so it forms 2+ ions. Sulfate ions have a −2 charge (this is one you just need to remember). So, for a neutral compound, you need a ratio of $Ca^{2+} : SO_4^{2-}$ of 1 : 1.

c) insoluble ***[1 mark]***

All sulfates are soluble, except for lead, barium and calcium sulfate.

d) Sodium is above calcium in the reactivity series ***[1 mark]***.

2 a)



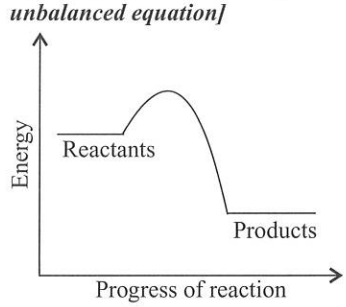
[1 mark for shared pair of electrons, 1 mark for six further electrons in the outer shell of each chlorine atom]
b) C ***[1 mark]***
c) Hold a piece of damp blue litmus paper in the gas ***[1 mark]***. It will be bleached white in the presence of chlorine ***[1 mark]***.
d) liquid ***[1 mark]***

−50 °C is between the melting and boiling points of chlorine, so chlorine would be a liquid at this temperature.

3 a) a piece of (filter) paper ***[1 mark]***
b) R_f of **A** = 4.6 ÷ 12.1 = **0.38** ***[1 mark]***
R_f of **B** = 7.3 ÷ 12.1 = **0.60** ***[1 mark]***
R_f of **C** = 10.6 ÷ 12.1 = **0.876** ***[1 mark]***
c) There is a spot of substance on the baseline / there is a substance with an R_f value of 0 ***[1 mark]***.
d) D ***[1 mark]***
e) A mixture is a substance that contains different compounds or different elements that aren't all part of a single compound ***[1 mark]***.
f) E.g. fractional distillation ***[1 mark]***

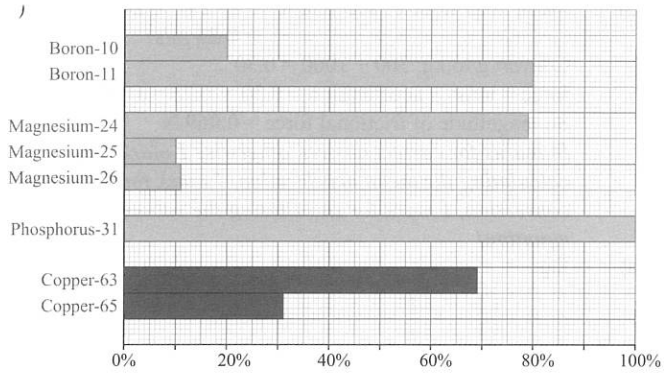
4 a) $2Rb + F_2 \rightarrow 2RbF$
[2 marks for all formulas correct and a correctly-balanced equation, otherwise 1 mark for correct formulas in an unbalanced equation]

b)



[1 mark for showing and labelling reactants and products, with products having less energy than reactants, 1 mark for a correctly-shaped curve joining reactants and products.]

5 a) E.g. wear safety goggles / wear a lab coat / wear gloves / use dilute concentrations of chlorine water ***[1 mark]***.
b) M_r of KI = 39 + 127 = **166** ***[1 mark]***
c) The solution would turn from colourless to brown ***[1 mark]***.
d) Chlorine is more reactive than iodine ***[1 mark]***, so it displaces iodine from the potassium iodide solution ***[1 mark]***.
e) $Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$
[1 mark for correct left-hand side, 1 mark for correct right-hand side]



[1 mark for each correct bar]

b) The relative atomic mass of an element is the average of the mass numbers of all the atoms of that element ***[1 mark]***. Phosphorus only has one isotope, so its relative atomic mass is equal to the mass number of its atoms (31) ***[1 mark]***. Boron, magnesium and copper all have more than one isotope, which exist in different quantities, so the average of their mass numbers won't be a whole number ***[1 mark]***.

c) % Mg-24 = 79%, % Mg-25 = 10%, % Mg-26 = 11%
So, relative atomic mass of Mg =
$[(24 \times 79) + (25 \times 10) + (26 \times 11)] \div 100$
$= 2432 \div 100 =$ **24.32**
[4 marks for a correct answer, but deduct 1 mark if not correctly rounded to 3 s.f.. Otherwise 1 mark for correct % abundances of Mg isotopes and 1 mark for correctly substituting the atomic masses and abundances into an equation to work out relative atomic mass.]

7 B ***[1 mark]***

M_r of $Na_2SO_4 = (2 \times 23) + 32 + (4 \times 16) = 142$
moles of $Na_2SO_4 = 34.08 \div 142 = 0.24$ moles
In one mole of Na_2SO_4 there are 4 moles of oxygen atoms. So, in 0.24 moles of Na_2SO_4 there are $(0.24 \times 4 =)$ 0.96 moles of oxygen atoms.
number of particles in one mole = 6.02×10^{23}, so,
number of atoms in 0.96 moles = $0.96 \times 6.02 \times 10^{23} = 5.7792 \times 10^{23}$
$= 5.779 \times 10^{23}$ atoms (to 4 s.f.)

8 a) Aluminium is reduced and oxygen is oxidised / aluminium gains electrons and oxygen loses electrons ***[1 mark]***.

b) $Al^{3+} + 3e^- \rightarrow Al$ ***[1 mark for correct reactants and products, 1 mark for correct electrons]***

c) $M_r(Al_2O_3) = (2 \times 27) + (3 \times 16) = 102$
moles = mass ÷ M_r
moles of $Al_2O_3 = 40.8 \div 102 = 0.400$ moles
From the balanced equation, 2 moles of aluminium oxide produce 4 moles of aluminium.
So, 0.400 moles of aluminium oxide will produce
$(0.400 \div 2) \times 4 = 0.800$ moles of aluminium.
$A_r(Al) = 27$, so mass of Al $= 0.800 \times 27 =$ **21.6 g**
[4 marks for correct answer, otherwise 1 mark for correctly calculating M_r of Al_2O_3, 1 mark for working out how many moles of Al_2O_3 are in 40.8 g and 1 mark for working out how many moles of Al are made.]

d) Heating with carbon will only reduce metals that are less reactive than carbon ***[1 mark]***. Aluminium is more reactive than carbon, so heating with carbon will not extract aluminium metal from its ore ***[1 mark]***.

e) Any two from: e.g. Recycling reduces waste going to landfill. / Recycling generally requires less energy than extracting metals from their ores. / Recycling is generally cheaper than extracting metals from their ores. / Recycling reduces the need to mine ores, so it therefore reduces damage to the landscape cause by mining. / Recycling preserves natural resources, so it is more sustainable.
[1 mark for each valid advantage.]

9 C ***[1 mark]***

10 a) Order: diamond, poly(propene), butane ***[1 mark]***.
Explanation: Diamond is a giant covalent substance, whilst poly(propene) and butane are molecular ***[1 mark]***. Diamond has the highest melting point as you need to break the strong covalent bonds between the atoms to melt it ***[1 mark]***. Poly(propene) molecules are larger than butane molecules, so poly(propene) has stronger intermolecular forces ***[1 mark]***, which require more energy to break ***[1 mark]***.

b) E.g. diamond would be the best choice ***[1 mark]***. Diamond is strong and hard as it has a rigid structure, held together by strong covalent bonds ***[1 mark]***. These properties make diamond a suitable material to use in drill bits, as it would be able to withstand the forces involved in drilling ***[1 mark]***.

11 a) Any two from: e.g. the only waste product made when hydrogen reacts with oxygen is water/burning hydrogen doesn't produce pollutants (e.g. carbon dioxide, carbon monoxide, sulfur dioxide) / hydrogen can be extracted from a renewable resource (water), but petrol is non-renewable/ hydrogen fuel can be extracted from the waste water made by the cell / fuel cells are more efficient than conventional engines ***[1 mark for each correct answer]***.

b) Bonds broken:
$(2 \times H–H) + O=O = (2 \times 436) + 498$
$= 872 + 498 = 1370$ kJ mol^{-1}
Bonds formed:
$4 \times O–H = 4 \times 463 = 1852$ kJ mol^{-1}
Energy change $= 1370 - 1852 =$ **–482 kJ mol^{-1}**
[3 marks for correct answer, otherwise 1 mark for correct energy value for bonds broken, 1 mark for correct energy value for bonds formed.]

Pages 255-260 — Physics Mixed Questions

1 a) metre ***[1 mark]***
b) B ***[1 mark]***
c) A quantity that has a magnitude/size, but not a direction ***[1 mark]***.

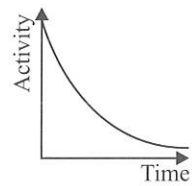
2 a) B ***[1 mark]***
b) work done = force × distance = 5 × 10 = **50 J**
[2 marks for correct answer, otherwise 1 mark for correct substitution]

3 a) A ***[1 mark]***
b) average speed = distance travelled ÷ time
$= 420 \div (5 \times 60) =$ **1.4 m/s**
[3 marks for correct answer, otherwise 1 mark for correct substitution, 1 mark for correct numerical answer, 1 mark for correct unit]
c) B ***[1 mark]***

4 a) E.g. sound / P-waves ***[1 mark]***
b) X-ray: e.g. medical imaging/diagnosing broken bones / airport security scanners ***[1 mark]***.
Gamma rays: e.g. sterilising food/medical equipment / tracers / radiotherapy/treating cancer ***[1 mark]***.
c) A = 99 ***[1 mark]***
B = 0 ***[1 mark]***

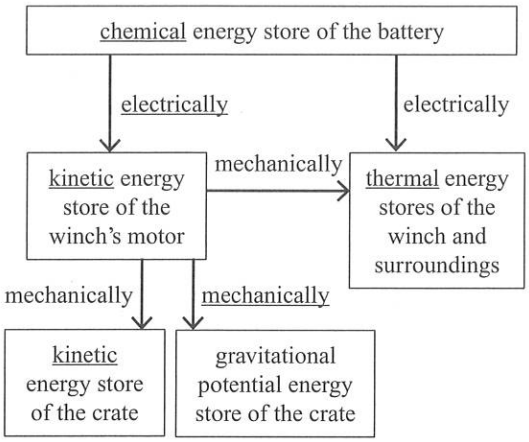
All electromagnetic waves travel at the same speed in a vacuum.

5 a) E.g. photographic film / Geiger-Müller tube ***[1 mark]***
b) alpha particle — a helium nucleus
beta-minus particle — an electron emitted from the nucleus
gamma ray — an electromagnetic wave
[1 mark for all three correct]
c) A ***[1 mark]***
d) i) E.g. the rate at which a radioactive source decays ***[1 mark]***. Its unit is the becquerel/Bq ***[1 mark]***.
ii)



[1 mark for activity decreasing over time, 1 mark for correct shape of the graph]
e) The time taken for the activity to halve ***[1 mark]***.

6 a)



[4 marks for all correct, otherwise 3 marks for five correct, or 2 marks for three or four correct, or 1 mark for one or two correct]

b) $\Delta GPE = m \times g \times \Delta h = 40.0 \times 10 \times 1.1 =$ **440 J**
[4 marks for correct answer, otherwise 1 mark for correct equation, 1 mark for correct substitution, 1 mark for correctly recalling the value of g]

7 a) i) $v = f\lambda$
so $v = (3 \times 10^{14}) \times (1 \times 10^{-6}) = 300\,000\,000 =$ **3×10^8 m/s**
[4 marks for correct answer, otherwise 1 mark for correct equation, 1 mark for correct substitution, 1 mark for answer not in standard form]

ii) 3×10^8 m/s ***[1 mark for answer matching the speed calculated in part a)]***

b) As the wave enters the glass block, it refracts and bends towards the normal ***[1 mark]*** and slows down ***[1 mark]***. As the wave leaves the glass block, it refracts again, this time bending away from the normal ***[1 mark]*** and speeding up ***[1 mark]***.

8 a) Independent variable: Roughness of surface ***[1 mark]***.
Dependent variable: Deceleration / speed of trolley ***[1 mark]***.

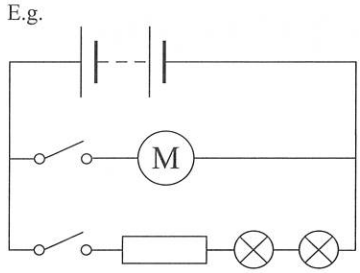
b) Repeat 1 = 0.23 ***[1 mark]*** Repeat 2 = 0.24 ***[1 mark]***
Repeat 3 = 0.22 ***[1 mark]***

Use acceleration = change in velocity ÷ time.

c) Assuming that all of the energy in the spring's elastic potential energy store is transferred to the trolley's kinetic energy store:
Mean speed at light gate 1 = (1.22 + 1.16 + 1.19) ÷ 3 = 1.19 m/s
Use this in the equation for calculating the energy in the kinetic energy store:
$KE = \frac{1}{2} \times m \times v^2 = 0.5 \times 0.50 \times 1.19^2 = 0.354...$ J
So energy in the spring's elastic potential energy store
= **0.35 J (to 2 s.f.)**
[4 marks for correct answer, otherwise 1 mark for equating energy in elastic potential and kinetic energy stores, 1 mark for correct substitution, 1 mark for correct numerical answer]

d) Mean magnitude of acceleration = (0.23 + 0.24 + 0.22) ÷ 3
= 0.23 m/s^2
Convert g to kg: 300 ÷ 1000 = 0.30
force = mass × acceleration = 0.30 × 0.23 = 0.069 N
So magnitude of frictional force = **0.069 N**
[4 marks for correct answer, otherwise 1 mark for calculating the mean acceleration, 1 mark for the correct conversion, 1 mark for substituting the values into the force equation]

9 a) E.g.



[1 mark for filament lamps and resistor in series with each other, 1 mark for motor in parallel with other components, 1 mark for correct placement of switches, 2 marks for all circuit symbols correctly drawn, otherwise 1 mark for 4 symbols correctly drawn]

b) E.g. as current flows through both the resistor and the motor, the charges do work against resistance ***[1 mark]***. This causes energy to be transferred electrically to the thermal energy stores of the resistor and the motor ***[1 mark]***. The motor also does work against friction (as it is moving) which causes energy to be transferred mechanically to the thermal energy store of the motor ***[1 mark]***. A way to reduce this heating would be to lubricate the moving parts inside the motor ***[1 mark]***.

c) $E = V \times I \times t = 6.0 \times (70 \times 10^{-3}) \times (10 \times 60) = 252$ J
3 g = 3 ÷ 1000 = 0.003 kg
$\Delta Q = m \times c \times \Delta\theta = 0.003 \times 400 \times 25 = 30$ J
252 – 30 = 222 J = **220 J (to 2 s.f.)**
[5 marks for correct answer, otherwise 1 mark for correctly stating $E = VIt$, 1 mark for correctly substituting into this equation, 1 mark for correct substitution into $\Delta Q = mc\Delta\theta$, 1 mark for both energies correctly calculated]

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