Contents

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Topic 1 — Energy

Page 1 — Energy Stores and Systems

1.1 An object or a group of objects. *[1 mark]*

1.2 Energy is transferred from: apple's gravitational potential energy store / apple's kinetic energy store *[1 mark]*
Energy is transferred to: apple's kinetic energy store / thermal energy store of the apple and surroundings (as the apple hits the ground) *[1 mark]*

1.3 E.g. work being done by the current in the circuit *[1 mark]*.

2 Level 0: There is no relevant information. *[No marks]*
Level 1: There is a brief explanation of one of the energy transfers, with no mention of the forces doing the work. *[1 to 2 marks]*
Level 2: There is a clear description of the energy transfers that take place, as well as the forces that are doing the work. *[3 to 4 marks]*
Here are some points your answer may include:
Gravitational force does work on the bike.
This causes energy to be transferred from the gravitational potential energy store of the bicycle to its kinetic energy store.
Friction force does work between the brake pads and the wheels.
This causes energy to be transferred from the bicycle's kinetic energy store to the thermal energy store of the brake pads.

Page 2 — Kinetic and Potential Energy Stores

1 $E_e = \frac{1}{2}ke^2 = \frac{1}{2} \times 20 \times 0.01^2$ *[1 mark]* = **0.001 J** *[1 mark]*

2 Energy lost from the g.p.e. store = energy gained in the kinetic energy store *[1 mark]*
$E_p = mgh = 0.1 \times 9.8 \times 0.45 = 0.441$ J *[1 mark]*
$E_k = \frac{1}{2}mv^2$
So $v = \sqrt{(2 \times E) \div m} = \sqrt{(2 \times 0.441) \div 0.1}$ *[1 mark]*
$= 2.969...$ *[1 mark]* = **3 m/s (to 1 s.f.)** *[1 mark]*

3.1 $E_e = \frac{1}{2}ke^2 = \frac{1}{2} \times 144 \times 0.10^2$ *[1 mark]* = 0.72 J
It is assumed that all of the energy stored in the elastic potential energy store of the elastic band is transferred to the kinetic energy store of the ball bearing ($E_e = E_k$)
so energy = **0.72 J** *[1 mark]*

3.2 Speed of child A's ball bearing:
$E_k = \frac{1}{2}mv^2 = 0.72$ J
so $v^2 = (2 \times 0.72) \div 0.0100 = 144$ *[1 mark]*
$v = 12$ m/s so child B's ball bearing speed is:
2×12 m/s = 24 m/s *[1 mark]*
$E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.0100 \times 24^2 = 2.88$ J *[1 mark]*
$E_e = \frac{1}{2}ke^2 = 2.88$ J
so $k = (2 \times 2.88) \div 0.10^2$ *[1 mark]*
= 576 = **580 N/m (to 2 s.f.)** *[1 mark]*

Page 3 — Specific Heat Capacity

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

1.1 $\Delta E = mc\Delta\theta$ so $c = \Delta E \div m\Delta\theta$ *[1 mark]*
$= 15\,000 \div (0.3 \times 25)$ *[1 mark]*
Specific heat capacity = **2000** *[1 mark]*

1.2 The current flowing through the immersion heater does work *[1 mark]*, transferring energy electrically *[1 mark]* to the thermal energy store of the immersion heater *[1 mark]*. It is then transferred from the thermal energy store of the immersion heater to the thermal energy store of the liquid *[1 mark]*.

Pages 4-5 — Conservation of Energy and Power

Warm-up
Power is the **rate of** energy transfer or **work done.**
It is measured in **watts.**

1 E.g. energy transferred to a less useful energy store *[1 mark]*.

2.1 Energy can be created.
Energy can be destroyed.
[1 mark for both correct answers, otherwise no marks if more than two boxes have been ticked]

2.2 Useful energy store: e.g. kinetic energy store (of shaver) *[1 mark]*
Wasted energy store: e.g. thermal energy store (of shaver or surroundings) *[1 mark]*

2.3 E.g. it would reduce the battery life of the battery / it would make the battery go flat quicker / it would mean the battery must be recharged more often *[1 mark]*.

3.1 $P = W \div t$ *[1 mark]*

3.2 $W = Pt = 35 \times 600$ *[1 mark]* = **21 000 J** *[1 mark]*

3.3 $P = E \div t$
so $t = E \div P = 16\,800 \div 35$ *[1 mark]* = **480 s** *[1 mark]*

4.1 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]* so the car speeds up more quickly *[1 mark]*.

4.2 The same amount of energy is needed to accelerate the car with both engines. The energy transferred by the old engine:
$P = E \div t$, so $E = P \times t = 32\ 000 \times 9.0$ ***[1 mark]***
$= 288\ 000$ J ***[1 mark]***
The time taken for the new engine to transfer the same amount of energy is:
$P = E \div t$, so $t = E \div P = 288\ 000 \div 62\ 000$ ***[1 mark]***
$= 4.645... =$ **4.6 s (to 2 s.f.)** ***[1 mark]***

Page 6 — Conduction and Convection

1 Convection occurs in **liquids** and **gases**. It is where a change in **density** causes particles to move from **hotter** to **cooler** regions. ***[3 marks for all correct, otherwise 2 marks for 3-4 correct, 1 mark for 1-2 correct]***

2.1 E.g. make sure all of the blocks are the same thickness / make sure the blocks are identical shapes/sizes / measure the time taken for a larger change in temperature / take repeat measurements to calculate an average ***[1 mark]***.

2.2 Energy is transferred by heating to the kinetic energy stores of the particles at the bottom of the block ***[1 mark]***. These particles collide with other particles in the block, and transfer energy mechanically to the kinetic energy stores of other particles ***[1 mark]***. This continues, transferring energy through the whole block ***[1 mark]***.

2.3 It has a higher thermal conductivity than the other blocks ***[1 mark]***.

Pages 7-8 — Reducing Unwanted Energy Transfers

Warm-up
Wearing a more streamlined helmet

1 Thicker walls decrease the rate of energy lost from a house.
Bricks with a higher thermal conductivity transfer energy at a faster rate.
[1 mark for both correct, no marks if more than two boxes have been ticked]

2.1 through the roof ***[1 mark]***

2.2 E.g. install loft insulation (to reduce convection) ***[1 mark]***

2.3 E.g. use draught excluders (to reduce convection) / install double glazing (to reduce conduction) / hang thick curtains (to reduce convection) / reduce the temperature difference between inside and outside the home ***[1 mark for each sensible suggestion]***

3 Doing work against friction causes energy to be dissipated/wasted (usually to thermal energy stores) ***[1 mark]***. After lubricating the axle, the frictional forces acting on it were reduced ***[1 mark]***. This means that less energy is dissipated as the handle (and axle) is turned and so more energy is transferred to the kinetic energy store of the handle (and axle) and the bucket ***[1 mark]***.

4 Best: C Second best: B Worst: A ***[1 mark]***
The thicker a sample is, the slower the rate of energy transfer through it ***[1 mark]*** so sample B will be a better insulator than sample A ***[1 mark]***. Air has a lower thermal conductivity than glass (so it transfers energy at a slower rate than glass does) ***[1 mark]*** so even though samples B and C are the same thickness, sample C is a better insulator than sample B ***[1 mark]***.

Page 9 — Efficiency

1.1 Efficiency = Useful output energy transfer ÷ Total input energy transfer ***[1 mark]***

1.2 Efficiency = $16\ 000 \div 20\ 000$ ***[1 mark]*** = **0.8** ***[1 mark]***
You'd also get the mark for giving the efficiency as a percentage (80%).

2 Efficiency = 75% = 0.75
Efficiency = Useful power output ÷ Total power input
So Total power input = Useful power output ÷ Efficiency ***[1 mark]***
$= 57 \div 0.75$ ***[1 mark]*** = **76 W** ***[1 mark]***

3.1 Useful output power of the air blower:
Efficiency = Useful power output ÷ Total power input
so Useful power output = Efficiency × Total power input
$= 0.62 \times 533$ ***[1 mark]***
$= 330.46$ W ***[1 mark]***
Useful power output of the turbine:
Efficiency = 13% = 0.13
Total power input = Useful power of air blower
Useful power output = Efficiency × Total power input
$= 0.13 \times 330.46$ ***[1 mark]***
$= 42.9598 =$ **43 W (to 2 s.f.)** ***[1 mark]***

3.2 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 ***[2 marks — 1 mark for each sensible suggestion]***

Pages 10-11 — Energy Resources and Their Uses

Warm-up
Renewable — bio-fuel, solar, tidal, geothermal, wave power, hydroelectricity, 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 can be replenished as it is used ***[1 mark]***.

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

2.2 E.g. generating electricity / burning coal on fires / using gas central heating / using a gas fire / coal in steam trains ***[2 marks — 1 for each correct answer]***

2.3 Bio-fuels are solids, liquids or gases that are produced from plant products or from animal waste ***[1 mark]***.

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

3 E.g. during winter, there are fewer hours of daylight, but the weather is usually more windy ***[1 mark]***, so wind turbines will be able to generate more electricity during winter ***[1 mark]***. However, during the summer, there will be more daylight hours and the weather will be less windy ***[1 mark]***, so solar panels will be more favourable ***[1 mark]***. By installing both, the university will have a more reliable electricity supply throughout the year ***[1 mark]***.

4.1 How to grade your answer:
Level 0: There is no relevant information. ***[No marks]***
Level 1: There is a brief description of the reliability or environmental impact of one of the energy resources. ***[1 to 2 marks]***
Level 2: There is a clear and detailed description of the reliability and environmental impacts of both energy resources, as well as some similarities between them. ***[3 to 4 marks]***
Here are some points your answer may include:
Both energy resources are reliable.
Tides come in and out at known times.
Except in times of drought, there is always water available for a hydroelectric power plant to work.
Hydroelectric power plants require the flooding of valleys, which causes a loss of habitat for any animals living there.
The plants in the valley die during the flood and rot, which releases gases that contribute to global warming.
Using tides to generate electricity creates no pollution, but tidal barrages do alter the habitat of nearby animals.

4.2 How to grade your answer:
Level 0: There is no relevant information. ***[No marks]***
Level 1: There is a brief explanation of an advantage or a disadvantage of fossil fuels. ***[1 to 2 marks]***
Level 2: There is some explanation of both advantages and disadvantages of fossil fuels. ***[3 to 4 marks]***
Level 3: There is a clear and detailed explanation of the advantages and disadvantages of using fossil fuels. ***[5 to 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 are 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.
Acid rain can damage soil and trees. This can damage or destroy the habitats of animals.
Coal mining can spoil the view by damaging the landscape.
Oil spillages kill sea life and birds and mammals that live near to the sea.

Page 12 — Trends in Energy Resource Use

1.1 $35 + 23 + 5 = 63$ %
[2 marks for correct answer, otherwise 1 mark for reading all three values correctly from the graph]

1.2 E.g. the country is using a larger percentage renewable energy resources to generate electricity in 2015 than they were the previous year / overall, they are using a smaller percentage of fossil fuels to generate their electricity in 2015 than they were in 2014 ***[1 mark]***.

2 How to grade your answer:

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

Level 1: There is a brief explanation why the UK is using more renewable energy resources. ***[1 to 2 marks]***

Level 2: There is some explanation of why the UK is using more renewable energy resources and the factors that restrict the increase in their use. ***[3 to 4 marks]***

Level 3: There is a clear and detailed explanation of why the UK is using more renewable energy resources and the factors that restrict the increase in their use. ***[5 to 6 marks]***

Here are some points your answer may include:

Reasons the UK is using more renewable energy resources:
We understand more about the negative effects that fossil fuels have on the environment, so more people want to use renewable energy resources that have less of an impact on the environment.
Fossil fuel reserves will run out, so we have to find an alternative for them.
Pressure from the public and other countries has lead to government targets for the use of renewable energy resources. This can lead to increased government funding for renewable energy resources.
Pressure from the public and the global community/other countries has also lead to private companies creating more environmentally-friendly products that use renewable energy resources.

Factors that limit the use of renewable energy resources:
Building new power plants to replace existing fossil fuel powered ones costs money.
Some renewable energy resources are less reliable than fossil fuels.
Research into improving renewable energy resources costs money and will take time.
Personal products that use renewable energy resources, like hybrid cars, are generally more expensive than similar ones that use fossil fuels.

Topic 2 — Electricity

Page 13 — Current and Circuit Symbols

Warm-up
A — cell, B — switch, C — filament lamp, D — fuse.

1.1 There is no source of potential difference ***[1 mark]***

1.2 Current is the rate of flow of **charge** ***[1 mark]***.

2.1 0.5 A ***[1 mark]***

Remember that the current is the same at any point in a single closed circuit loop.

2.2 $Q = I \times t$ ***[1 mark]***

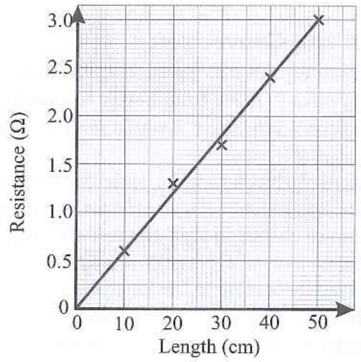
2.3 $t = 2 \times 60 = 120$ s
Charge = 0.5×120 ***[1 mark]*** = **60** ***[1 mark]*** **C** ***[1 mark]***

Page 14 — Resistance and V = IR

1 $V = I \times R$
$V = 3 \times 6$ ***[1 mark]*** = **18 V** ***[1 mark]***

2.1 She could have varied the length of the wire between the crocodile clips ***[1 mark]*** and divided the reading on the voltmeter by the reading on the ammeter to find the resistance for each length ***[1 mark]***.

2.2



[1 mark for resistance on vertical axis and length on horizontal axis, 1 mark for appropriate values labelled on both axes, 1 mark for correctly plotted points, 1 mark for suitable line of best fit.]

2.3 The resistance is proportional to the length ***[1 mark]***. This is shown by the graph being a straight line through the origin ***[1 mark]***.

Pages 15-16 — Resistance and I-V Characteristics

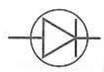
1.1 C ***[1 mark]***

At a constant temperature, the relationship between pd and current is linear — when this is true, the resistor is said to be ohmic.

1.2 *I-V* characteristic ***[1 mark]***

1.3 A resistor at a constant temperature is an example of an **ohmic** conductor. It is also an example of a **linear** component.
[1 mark for each correct answer]

2.1



[1 mark]

2.2 A diode only lets current flow through it in one direction ***[1 mark]***.

2.3 The student put the diode/power supply in the circuit the other way around ***[1 mark]***. The resistance of a diode is very large when current goes through it one way and very small when current goes through in the opposite direction ***[1 mark]***.

3.1 It is used to alter the current ***[1 mark]*** so the potential difference can be measured for each current ***[1 mark]***.

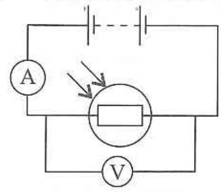
3.2 At 3 A the pd is 12 V ***[1 mark]***
$V = I \times R$
$R = V \div I$ ***[1 mark]*** $= 12 \div 3$ ***[1 mark]*** = **4 Ω** ***[1 mark]***

3.3 The resistance increases as the current increases ***[1 mark]***. This is because the increase in current causes the temperature to rise ***[1 mark]***.

3.4 A resistor is ohmic when the relationship between current and potential difference is linear ***[1 mark]***. The graph is linear until approximately 3.5 V, so the resistor is ohmic in this range ***[1 mark]***.

Page 17 — Circuit Devices

1.1



[1 mark for correct LDR symbol, 1 mark for LDR, ammeter and power supply in series, 1 mark for voltmeter in parallel across LDR.]

1.2 It decreases ***[1 mark]***

1.3 E.g. automatic night lights / burglar detectors ***[1 mark]***

2 As the temperature increases, the resistance of the thermistor decreases ***[1 mark]***. This means the current in the circuit

increases *[1 mark]*. As the current increases, the brightness of the light increases *[1 mark]*. When the cooker's surface is cold, the resistance is high and the current is too small to light the bulb *[1 mark]*.

Page 18 — Series Circuits

1 A *[1 mark]*.

In a series circuit, there should only be one closed loop of wire.

2.1 10 + 30 = **40 Ω** *[1 mark]*

2.2 $V = I \times R$

$V = 75 \times 10^{-3} \times 30$ *[1 mark]* = **2.25 V** *[1 mark]*

3 The potential difference across the 8 Ω resistor is:

6 – 2 = 4 V *[1 mark]*

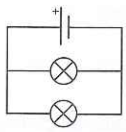
$V = I \times R$, so the current through the 8 Ω resistor is:

$I = V \div R = 4 \div 8$ *[1 mark]* = 0.5 A *[1 mark]*

This is the same as the current through R, so the resistance of R is: $R = V \div I = 2 \div 0.5$ *[1 mark]* = **4 Ω** *[1 mark]*

Page 19 — Parallel Circuits

1



[1 mark]

2.1 6 V *[1 mark]*

Potential difference is the same across all components in parallel.

2.2 $V = IR$ so $I = V \div R$ *[1 mark]*

A_1: $I = V \div R = 6 \div 4$ *[1 mark]* = **1.5 A** *[1 mark]*

A_2: $I = V \div R = 6 \div 12$ *[1 mark]* = **0.5 A** *[1 mark]*

2.3 The current from the supply splits into 1.5 A and 0.5 A.

So A_3 reads 1.5 + 0.5 = **2 A** *[1 mark]*

3 How to grade your answer:

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

Level 1: There is a brief explanation about the effect of adding resistors in series or parallel. *[1 to 2 marks]*

Level 2: There is a comparison between adding resistors in series and parallel and an explanation of their effects. *[3 to 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. *[5 to 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 for each one, and so the lower the current for each one.

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.

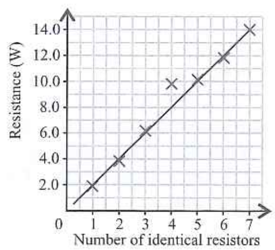
In parallel, all resistors have the same potential difference as the source.

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 $V = IR$).

Page 20 — Investigating Resistance

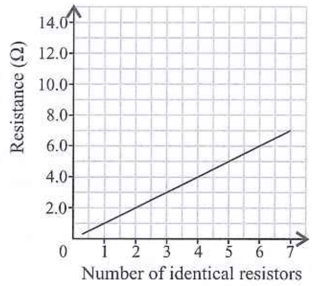
1.1



Resistance = **8.0 Ω**

[1 mark for a straight line of best fit that excludes the point plotted for 4 resistors, 1 mark for correct prediction of resistance]

1.2



[1 mark for a straight line of best fit with a positive gradient, 1 mark for the gradient of the line being half of the gradient of the line drawn in 1.1]

2 How to grade your answer:

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

Level 1: There is a brief description of the techniques used to measure resistance of the circuit. The steps mentioned are not in a logical order. *[1 to 2 marks]*

Level 2: There is a good description of the techniques used to measure resistance of the circuit. Most steps are given in a logical order and they could be followed to produced valid results. A correct circuit diagram may be included. *[3 to 4 marks]*

Level 3: A logical and detailed description is given, fully describing the method for investigating the effect of adding resistors in parallel. The method could easily be followed to produce valid results. A correct circuit diagram may be included. *[5 to 6 marks]*

Here are some points your answer may include:

Connect a battery or cell in series with an ammeter and a fixed resistor.

Measure the source potential difference using the voltmeter.

Measure the current through the circuit using the ammeter.

Calculate the resistance of the circuit using $R = V \div I$.

Connect a second identical resistor in parallel with the first resistor.

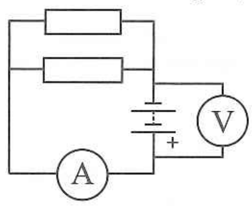
Do not connect the second resistor across the ammeter.

Measure the current and use this to calculate the resistance of the circuit.

Repeat this for several identical resistors.

Plot a graph of number of identical resistors against overall resistance of the circuit.

A correct circuit diagram, similar to:



So long as you draw a correct diagram with at least two resistors in parallel, you would get the marks. You could also draw your circuit with several resistors in parallel, all separated with switches.

Page 21 — Electricity in the Home

Warm-up

The live wire is **brown** and is at a potential difference of **230** V.

The earth wire is **green and yellow** and is at a potential difference of **0** V.

1.1 230 V *[1 mark]*

50 Hz *[1 mark]*

1.2 How to grade your answer:

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

Level 1: There is a brief explanation of the function of the live and neutral wires and some attempt at explaining why the toaster would not work. *[1 to 2 marks]*

Level 2: There is a good explanation of the function of the live and neutral wires and why the fault would not

allow a current to flow through the toaster.
[3 to 4 marks]

Here are some points your answer may include:
The purpose of the neutral wire is to complete the circuit.
Current flows into the toaster via the live wire, through the toaster, and out of the device by the neutral wire.
The fault means that a closed loop/low-resistance path has been formed between the live and neutral wire before the current in the live wire has reached the toaster.
So no (or very little) current will flow through the toaster.
This means that the toaster will not work.

2.1 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]***.

2.2 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]***.

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

Page 22 — Power of Electrical Appliances

1 The **power** of an appliance is the energy transferred **per second**. Energy is transferred because the **current** does work against the appliance's resistance. ***[1 mark for each correct]***

2.1 $E = P \times t$ ***[1 mark]***

2.2 $E = 50 \times 20$ ***[1 mark]*** = **1000 J** ***[1 mark]***

2.3 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]***.

3.1 Energy is transferred electrically from the power source ***[1 mark]*** to the thermal energy store of the water ***[1 mark]*** and the kinetic energy store of the motor ***[1 mark]***.

3.2 Work done = power × time ($E = P \times t$)
Work done = 400 × 60 ***[1 mark]*** = **24 000 J** ***[1 mark]***

3.3 Time of economy mode = 160 × 60 = 9600 s
Energy transferred in economy mode
= power × time = 400 × 9600 = 3 840 000 J ***[1 mark]***
Time of standard mode = 125 × 60 = 7500 s
Energy transferred in standard mode = 600 × 7500
= 4 500 000 J ***[1 mark]***
Energy saved = 4 500 000 – 3 840 000 ***[1 mark]***
= **660 000 J** ***[1 mark]***

Page 23 — More on Power

Warm-up

A power source supplies **energy** to a charge. When a charge passes through a component with **resistance**, it does **work**, so the charge's energy **decreases**.

1.1 $E = V \times Q$ ***[1 mark]***

1.2 $E = 6 \times 2$ ***[1 mark]*** = **12 J** ***[1 mark]***

1.3 Multiplying the potential difference by the current gives the power ***[1 mark]***. In 1.2 the energy was transferred by the two coulombs of charge in one second ***[1 mark]***. This is the same as the power ***[1 mark]***.

2.1 $P = I \times V$
so $I = P \div V = 75 \div 230$ ***[1 mark]*** = 0.3260...
= **0.33 A (to 2 s.f.)** ***[1 mark]***

2.2 $P = I^2 \times R$
so $R = P \div I^2 = 2.5 \div 0.50^2$ ***[1 mark]*** = **10 Ω** ***[1 mark]***

Page 24 — The National Grid

1.1 Potential Difference ***[1 mark]***, Current ***[1 mark]***

1.2 A step-up transformer increases the potential difference, a step-down transformer decreases it ***[1 mark]***.

2.1 Transformer A = step-up transformer ***[1 mark]***
Transformer B = step-down transformer ***[1 mark]***

2.2 How to grade your answer:
Level 0: There is no relevant information. ***[No marks]***
Level 1: There is a brief explanation of the function of the step-up transformer and how this results in smaller energy losses. ***[1 to 2 marks]***
Level 2: There is a good explanation of the function of the step-up transformer and how reducing the energy lost increases the efficiency of the national grid. ***[3 to 4 marks]***

Here are some points your answer may include:
Transformer A increases the potential difference.
This decreases the current at a given power.
This decrease in current decreases energy lost to the thermal energy stores of the cables and surroundings.
Efficiency is useful output energy transfer ÷ total input energy transfer, so reducing the energy lost to thermal stores makes the transmission of electricity more efficient.

2.3 The potential difference across the power cables is very high and too large for domestic devices ***[1 mark]***. Transformer B reduces the potential difference to lower, usable levels ***[1 mark]***.

Page 25 — Static Electricity

1.1 The charges are alike ***[1 mark]***. The balloons are repelling each other ***[1 mark]***.

1.2 The balloons were rubbed against something, e.g. clothing/hair ***[1 mark]***.

This wouldn't work if the balloons were rubbed against each other, as that would charge them up with opposite charges

2.1 Electrons ***[1 mark]*** are removed from the dusting cloth and transferred to the polythene rod ***[1 mark]***.

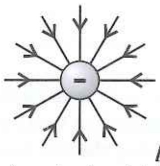
2.2 The student could bring the dusting cloth towards one end of the rod ***[1 mark]***. The rod should turn towards the cloth ***[1 mark]***.

3.1 The man is charged, so there is a potential difference between him and the rail ***[1 mark]***. When the potential difference is high enough, electrons jump across the gap to the rail, producing a spark ***[1 mark]***.

3.2 Negatively charged ***[1 mark]***. Only negative charges/electrons can move ***[1 mark]*** and they will move from an area of negative charge to an earthed area ***[1 mark]***.

Page 26 — Electric Fields

1.1



[1 mark]

1.2 A region in which a charged object will experience a force ***[1 mark]***.

1.3 It decreases ***[1 mark]***.

1.4 The second sphere is not charged ***[1 mark]***.

2.1 The size of the force increases ***[1 mark]***.

2.2 The negative charges are attracted towards the positive sphere, while the positive charges are attracted towards the negative sphere ***[1 mark]***. So parts of the particle are pulled away from each other ***[1 mark]***. When the potential difference is high enough, the force becomes large enough to break the particle apart ***[1 mark]***.

Topic 3 — Particle Model of Matter

Pages 27-28 — Density of Materials

Warm-up

From left to right: liquid, solid, gas

1.1 $\rho = m \div v$ ***[1 mark]***

1.2 $\rho = 10\,000 \div 0.5$ ***[1 mark]*** = **20 000 kg/m³** ***[1 mark]***

1.3 The density is the same for the whole block, so ρ = 20 000 kg/m³
$\rho = m \div v$ so $m = \rho \times v$ ***[1 mark]***
= 20 000 × 0.02 ***[1 mark]*** = **400 kg** ***[1 mark]***

2 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.

3.1 How to grade your answer:
Level 0: There is no relevant information. ***[No marks]***
Level 1: There is a brief description of how to measure the mass of the object and how to use this along with its

volume to calculate its density. *[1 to 2 marks]*

Level 2: There is a clear description of how to measure both the mass and volume of the object and how to use these values to calculate its density. *[3 to 4 marks]*

Here are some points your answer may include:
First measure the mass of the object using a mass balance.
Then submerge the object in the water.
Measure the volume of water displaced using the scale on the measuring cylinder.
The volume of the displaced water in the measuring cylinder is equal to the volume of the object.
Use density = mass ÷ volume to calculate the density of the object.

3.2 $\rho = m \div v$
1 ml of water = 1 cm^3 *[1 mark]*
A: $\rho = 5.7 \div 0.30 = 19$ g/cm^3. So A is gold. *[1 mark]*
B: $\rho = 2.7 \div 0.60 = 4.5$ g/cm^3. So B is titanium. *[1 mark]*
C: $\rho = 3.0 \div 0.30 = 10$ g/cm^3. So C is silver. *[1 mark]*

4 Volume of empty aluminium can
= volume displaced by full can – volume of cola
= 337 – 332 = 5 ml *[1 mark]*
5 ml = 5 cm^3 *[1 mark]*
$\rho = m \div v = 13.5 \div 5$ *[1 mark]* = **2.7 g/cm³** *[1 mark]*

Page 29 — Internal Energy and Changes of State

1 When a system is heated, the internal energy of the system **increases**. This either increases the **temperature** of the system or causes a change of state. During a change of state the temperature and **mass** of the substance remain constant.
[2 marks for all correct, otherwise 1 mark for two correct]

2.1 Gas to liquid: condensing
Liquid to gas: evaporating/boiling
[1 mark for both correct]

2.2 E.g. a change where you don't end up with a new substance / you end up with the same substance in a different form *[1 mark]*.

3.1 E.g. the energy stored in a system by its particles. / The sum of the energy in the particles' kinetic and potential energy stores *[1 mark]*.

3.2 Any two from: mass, specific heat capacity, total energy transferred to the system *[2 marks]*

4 10 g *[1 mark]* E.g. because when a substance changes state, its mass doesn't change. So the mass of the water vapour equals the mass of the water originally in the container *[1 mark]*.

Page 30 — Specific Latent Heat

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

1.2 $E = mL$ so $L = E \div m$ *[1 mark]*
$L = 1.13 \div 0.5$ *[1 mark]* = **2.26 MJ/kg** *[1 mark]*

2.1 The substance is melting *[1 mark]*.

2.2 As the substance is heated, its internal energy increases *[1 mark]*. As the substance melts (during 3-8 minutes), all of this energy is used to break apart intermolecular bonds *[1 mark]* so there is no increase in the substance's temperature as it changes state *[1 mark]*.

2.3 Melting point = –7 °C *[1 mark]*
Boiling point = 58 °C *[1 mark]*

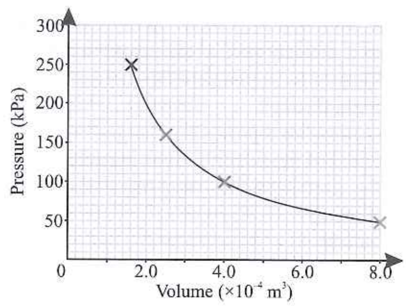
Pages 31-32 — Particle Motion in Gases

Warm-up
They are constantly moving in random directions at random speeds.

1 When the temperature of a gas increases, the average energy in the **kinetic** energy stores of the gas molecules increases. This **increases** the **average** speed of the gas molecules. If the gas is kept at a constant volume, increasing the temperature **increases** the pressure.
[3 marks for all correct, otherwise 1 mark for two correct or 2 marks for three correct]

2.1 pV = constant
$8.0 \times 10^{-4} \times 50 \times 10^3 = 40$ *[1 mark]*
So $p = 40 \div (1.6 \times 10^{-4})$ *[1 mark]* = 250 000 = **250 kPa** *[1 mark]*

2.2



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

3 E.g. a gas is made of particles *[1 mark]*. The particles collide with each other and the sides of the container they are in, which exerts a force on the sides of the container *[1 mark]*. The total force per unit area exerted on the container is the gas pressure *[1 mark]*. As the volume is increased, the gas particles spread out more *[1 mark]*. This means that there are fewer collisions with the sides of the container in a given time, so the pressure is lower *[1 mark]*.

4 How to grade your answer:
Level 0: There is no relevant information. *[No marks]*
Level 1: There is a brief explanation of how work is done on the air. *[1 to 2 marks]*
Level 2: There is some explanation of how doing work on the air increases its temperature. *[3 to 4 marks]*
Level 3: There is a clear and detailed explanation of how doing work on the air transfers energy to the particles in the air and how it causes an increase in temperature. *[5 to 6 marks]*

Here are some points your answer may include:
To compress the air, work must be done.
This work is done against the force caused by the pressure of the air in the piston.
Doing work causes a transfer of energy.
Energy is transferred to the internal energy of the system.
So energy is transferred to the kinetic energy stores of the air particles in the system.
This increases the temperature of the air/gas.
Because temperature of a gas is related to the average energy in the kinetic energy stores of the gas molecules.
So doing work on the gas increases its temperature.

Topic 4 — Atomic Structure

Pages 33-34 — Developing the Model of the Atom

Warm-up
1×10^{-10} m
10 000

1.1 Our current model shows that the atom can be broken up (into protons, neutrons and electrons) *[1 mark]*.

1.2 The plum pudding model *[1 mark]*. This was where an atom was thought to be a sphere of positive charge, with electrons spread throughout it *[1 mark]*.

1.3 The neutron *[1 mark]*.

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

2.2 ion *[1 mark]*

2.3 Positive (or +1) *[1 mark]*

An atom is neutral. Losing an electron takes away negative charge, so the remaining ion is positive.

3 Level 0: There is no relevant information. *[No marks]*
Level 1: There is only one correct discovery mentioned with a brief description of the observation that led to it. *[1 to 2 marks]*
Level 2: Two correct discoveries are given with a detailed description of how observations led to them. *[3 to 4 marks]*

Here are some points your answer may include:
Discovery: The atom is mostly made up of empty space / most of the atom's mass is concentrated at the centre in a tiny nucleus.
Observation: Most of the alpha particles fired at the thin gold foil passed straight through.
Discovery: The atom has a positively charged central nucleus.
Observation: Some of the positive alpha particles were deflected back towards the emitter, so they were repelled by the nucleus.

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

4.2 The protons and neutrons are in the central nucleus ***[1 mark]*** and the electrons surround the nucleus (arranged in shells) ***[1 mark]***.

4.3 26 electrons ***[1 mark]***. Atoms are neutral ***[1 mark]***. Protons and electrons have equal but opposite charges. For these charges to cancel, there must be the same number of each ***[1 mark]***.

Pages 35-36 — Isotopes and Nuclear Radiation

Warm-up
Gamma — weakly ionising, alpha — strongly ionising, beta — moderately ionising.

1.1 radioactive decay ***[1 mark]***

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

1.3 An atom losing (or gaining) at least one electron ***[1 mark]***.

1.4 Alpha decay ***[1 mark]***

2 E.g. Alpha particles have a small range in air and will be stopped by a thin sheet of material ***[1 mark]***. So the alpha radiation inside the detector cannot escape the detector ***[1 mark]***.

3.1 23 ***[1 mark]***

Remember that the mass number is the little number in the top-left. It's the total number of protons and neutrons in the nucleus.

3.2 23 – 11 = 12 neutrons ***[1 mark]***

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

3.3 $^{24}_{11}Na$ ***[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).

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

4 How to grade your answer:
Level 0: There is no relevant information. ***[No marks]***
Level 1: There is a brief explanation of the method of locating the leak and of the radiation used. ***[1 to 2 marks]***
Level 2: There is some explanation of the method of locating the leak and of the radiation used. ***[3 to 4 marks]***
Level 3: There is a clear and detailed explanation of the method of locating the leak and of the radiation used. ***[5 to 6 marks]***

Here are some points your answer may include:
The isotope travels along the pipe.
If there is no leak, the radiation doesn't escape the pipe/not much radiation can escape the pipe/some of the radiation is blocked by the pipe.
If there is a leak, the isotope escapes the pipe and some/more radiation can reach the detector.
This causes the count-rate to increase.
An increase in count-rate indicates a leak.
The isotope could be beta-emitting because beta radiation would be blocked by the pipe but would not be blocked by the small amount of ground above the pipe.
OR The isotope could be gamma-emitting because it can escape the pipe and reach the detector, and more gamma radiation would get to the detector if there was a leak.

Page 37 — Nuclear Equations

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

1.2 The atomic number increases ***[1 mark]*** but the mass number stays the same ***[1 mark]***. This is because emitting an electron (beta decay) involves a neutron turning into a proton ***[1 mark]***.

Remember that a neutron turns into a proton in order to increase the positive charge on the nucleus. (Because emitting the electron has taken away some negative charge.)

1.3 No effect ***[1 mark]***

When an electron moves to a lower energy level, it loses energy in the form of an EM wave, which doesn't change the charge or mass of the nucleus.

2.1 The atomic numbers on each side are not equal ***[1 mark]***.

2.2 $^{0}_{-1}e$ ***[1 mark]***

The other particle must be an electron (a beta particle), as this will balance the equation.

2.3 $^{226}_{88}Ra \longrightarrow \,^{222}_{86}Rn + \,^{4}_{2}He$

[3 marks in total — 1 mark for each correct symbol]

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.

2.4 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 38-39 — Half-life

1.1 E.g. the time taken for the count-rate of a sample to halve ***[1 mark]***.

1.2 75 seconds ***[1 mark]***

The initial count-rate is 60 cps. Half of this is 30 cps, which corresponds to 75 seconds on the time axis.

1.3 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 calculating the number of decayed/undecayed nuclei after one half-life]

1.4 After 2 half-lives, there are 200 undecayed nuclei.
The ratio is 200:800,
which simplifies to **1:4** ***[1 mark]***

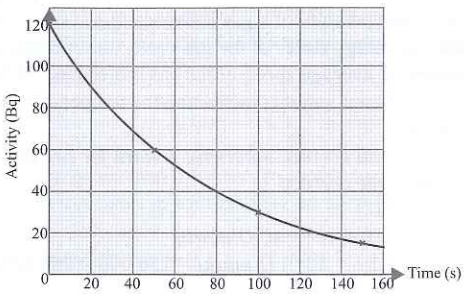
You don't even need the numbers to work out this ratio. For any radioactive isotope, after two half lives, the initial number of undecayed nuclei will have halved and then halved again. It will be one quarter of the original number, so the ratio is always 1:4.

2 Isotope 1, because more nuclei will decay per second ***[1 mark]***.

3.1 It takes a total of 2 hours and 30 minutes for the activity to halve from 8800 Bq to 4400 Bq,
so its half-life = (2 × 60) + 30 = **150 minutes** ***[1 mark]***

3.2 Check how many half-lives pass during 6 hours and 15 minutes:
6 hours and 15 minutes = (6 × 60) + 15 = 375 minutes
375 ÷ 150 = 2.5 half-lives
The activity can only be worked out if a whole number of half-lives have passed, so calculate how many half-lives have passed from the time when activity = 6222 Bq:
1 hour 15 minutes = 60 + 15 = 75 minutes
375 – 75 = 300 minutes
300 ÷ 150 = 2 half-lives.
So now you can calculate the activity after 2 half-lives, with an initial activity of 6222 Bq:
After 1 half-life, the activity will be 6222 ÷ 2 = 3111 Bq
After 2 half-lives, the activity will be 3111 ÷ 2 = 1555.5 Bq
1555.5 = **1600 Bq (to 2 s.f.)**
[2 marks for correct answer, otherwise 1 mark for finding how many half-lives will have passed between 1 hour and 15 minutes and 6 hours and 15 minutes]

4.1



[3 marks in total — 2 marks for all points plotted correctly, otherwise 1 mark for three points plotted correctly, 1 mark for smooth curve.]

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.

4.2 70 Bq (accept between 68 Bq and 72 Bq) ***[1 mark for correct value from your graph]***

4.3 After 200 s, 15 ÷ 2 = 7.5 Bq
After 250 s, 7.5 ÷ 2 = **3.75 Bq** ***[1 mark]***
E.g. radioactive decay is random ***[1 mark]*** and the effect of randomness on the activity will be greater for lower activities ***[1 mark]***.

Pages 40-41 — Background Radiation and Contamination

Warm-up
E.g. cosmic rays / rocks

1 Any two from: e.g. using shielding / working in a different room to the radioactive source / using remote-controlled arms to handle sources / wearing protective suits ***[2 marks]***

2.1 Low-level radiation which is around us all of the time. ***[1 mark]***

2.2 Systematic error ***[1 mark]***. If she doesn't subtract the background radiation, her results will all be too large by the same amount ***[1 mark]***.

This assumes that the background level is constant for the duration of her experiment. This is a reasonable assumption, as long as she carries out the experiment in the same location under the same conditions each time.

2.3 Radiation dose ***[1 mark]***

2.4 E.g. Where you live / your job ***[1 mark for both correct]***

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

3.2 E.g. keeping the sample in a protective box / standing behind a protective barrier ***[1 mark]***

3.3 Any two from: e.g. wearing protective gloves / using tongs / wearing a protective suit or mask ***[2 marks]***.

4 How to grade your answer:
Level 0: There is no relevant information. ***[No marks]***
Level 1: There is a brief explanation of the dangers of contamination or radiation. ***[1 to 2 marks]***
Level 2: There is some explanation of the dangers and risks of contamination and radiation. ***[3 to 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 be more concerned about contamination. ***[5 to 6 marks]***

Here are some points your answer may include:
Alpha particles are strongly ionising.
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, close to his skin. 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.
This means that the alpha particles can do lots of damage to nearby tissue or organs.
So he should be more concerned about contamination.

Page 42 — Uses and Risk

Warm-up
Radiation can cause cells to **mutate** or **die**, which can cause cancer or radiation sickness. Radiation can also be used to treat **cancer** and to **diagnose** illnesses.

1.1 Gamma ***[1 mark]***

1.2 E.g. the gamma rays could cause damage to healthy cells ***[1 mark]***. Rotating the beam ensures healthy cells nearby get a lower dose of radiation ***[1 mark]***.

2.1 Iodine-123 could be injected into or swallowed by the patient, where it would be absorbed by their thyroid ***[1 mark]***. The iodine would then decay, giving off radiation that could be detected outside the body ***[1 mark]***. The amount of radiation detected could then be used to find how much iodine has been absorbed by the thyroid, to check whether or not the thyroid is overactive ***[1 mark]***.

2.2 Because alpha radiation would be too dangerous inside the body ***[1 mark]*** and it would not be detectable outside the body, as it cannot penetrate tissue ***[1 mark]***.

2.3 A short half-life means the activity will quickly drop, so the patient will not be exposed to radiation for too long ***[1 mark]***.

Page 43 — Fission and Fusion

1 Both statements are true ***[1 mark]***.

2 Similarity: E.g. they both release energy ***[1 mark]***.
Difference: E.g. fission is the splitting of a large nucleus to form a smaller nuclei, whereas fusion is the joining of smaller nuclei to form a larger one ***[1 mark]***.

3.1 How to grade your answer:
Level 0: There is no relevant information. ***[No marks]***
Level 1: There is a brief explanation of nuclear fission and that a neutron can start the fission reaction. ***[1 to 2 marks]***
Level 2: There is a detailed explanation of how a neutron starts a forced fission reaction, what a fission reaction is and how this leads to a chain reaction. ***[3 to 4 marks]***

Here are some points your answer may include:
Absorbing a neutron makes the nucleus more unstable.
The unstable nucleus undergoes fission.
Fission is the splitting of an unstable nucleus into two lighter elements and releasing two or three neutrons.
These neutrons can be absorbed by other nuclei, causing more fission.
Each decay can cause another decay to happen, which is a chain reaction.

3.2 E.g. each fission decay releases energy ***[1 mark]*** so an uncontrolled chain reaction would release lots of energy, which could lead to reactor meltdown/an explosion ***[1 mark]***.

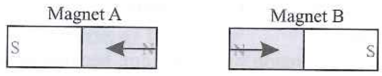
Topic 5 — Forces

Page 44 — Contact and Non-Contact Forces

Warm-up
Scalar — mass, time, temperature
Vector — acceleration, weight, force

1 Vector quantities have both magnitude and direction. ***[1 mark]***

2 Contact force: e.g. friction / tension / normal contact force / air resistance ***[1 mark]***
Non-contact force: e.g. weight / gravitational force ***[1 mark]***

3.1


[1 mark for correct arrow length, 1 mark for correct direction]

3.2 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]***.

Page 45 — Weight, Mass and Gravity

1 **Mass** is the amount of matter in an object. **Weight** is a force due to gravity. Mass is measured **kilograms** whilst weight is measured in **newtons**. The weight of an object is **directly** proportional to its mass. ***[3 marks for all correct, 2 marks for 3-4 correct, 1 mark for 1-2 correct]***

2 A point at which you can assume the whole mass of an object is concentrated. / The point from which the weight of an object can be assumed to act. ***[1 mark]***

3.1 $W = mg$ ***[1 mark]***

3.2 $W = 350 \times 9.8$ ***[1 mark]*** = **3430 N** ***[1 mark]***

3.3 New mass = 350 – 209 = 141 kg ***[1 mark]***
$W = mg = 141 \times 3.8$ ***[1 mark]*** = 535.8
= **536 N (to 3 s.f.)** ***[1 mark]***