Sismo Learning

GCSE Physics || Paper 1 Foundation

June 2018 || Worked Solutions and Concept Notes

Every question restated with its figure, the key physics explained, full step by step working and a clear final answer. Use it as a mark scheme and as a revision note.

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Answer Summary

Q	Final answer	Marks
01.1	chemical ; kinetic	2
01.2	5760 J	2
01.3	960 J	2
01.4	Increased	1
02.1	0.08 s	1
02.2	Very large current at switch on (cold filament, low resistance) overheats it	1
02.3	36 W	2
02.4	LEDs waste a smaller proportion of input energy	1
03.1	Three 1.5 V cells in series, same direction	2
03.2	7.5 Ω	2
03.3	4.0 Ω	1
03.4	Decreases; parallel total is less than the smallest resistor	2
04.1	Displacement method with a measuring cylinder (or eureka can)	4
04.2	2.7 g/cm^3	2
04.3	Limestone	1
04.4	Water splashed out	1
04.5	Measured volume too small	1
05.1	B: atomic number 94, so a different element	2
05.2	≈ 430 years	1
05.3	≈ 430 years	1
06.1	nucleus ; neutron ; gamma rays	3
06.2	11 power stations	2
06.3	Radioactive waste; risk of accident	2
06.4	Both increase; CO_2 keeps rising steeply but temperature levels off	2
07.1	Rectangle with a line through it	1
07.2	2990 J	2
07.3	Q = I t	1
07.4	3.8 A	3
07.5	358.75 J	2
08.1	Higher	1
08.2	lower ; hot	2
08.3	Higher final temperature ; slow to heat up	2
08.4	0.99	2
08.5	E = P t	1
08.6	814 s	4
09.1	15 000 W	2
09.2	Heating surroundings ; friction	2
09.3	Switches in parallel: either completes the circuit	2
09.4	$E_p = m\ g\ h$	1
09.5	38 000 J	3
10.1	Electrons transferred from carpet to student	2
10.2	Three arrows pointing radially inwards	1
10.3	Electrons flow from student through tap to earth	3
10.4	Copper conducts charge away	2
11.1	13.35 per second	3
11.2	225 000 Bq	2
11.3	1.095 mSv per year, far below 100 mSv	2
11.4	Familiar everyday comparison	1
12.1	Ammeter in series, voltmeter across the wire	3
12.2	Method + risk assessment	6
12.3	Temperature of wire would not change	1
12.4	Accuracy higher ; resolution the same	2
	Total	**100**

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Equations you must know for Paper 1

Quantity	Equation	Units
Kinetic energy	$E_k = \frac{1}{2} m v^2$	J, kg, m/s
Gravitational potential energy	$E_p = m g h$	J, kg, N/kg, m
Power	$P = E \div t$ and $P = W \div t$	W, J, s
Efficiency	useful output ÷ total input	no unit (or %)
Charge flow	$Q = I t$	C, A, s
Potential difference	$V = I R$	V, A, Ω
Electrical power	$P = V I$ and $P = I^2 R$	W, V, A, Ω
Energy transferred	$E = P t$ and $E = Q V$	J, W, s, C, V
Density	$\rho = m \div V$	kg/m³ or g/cm³
Specific heat capacity (sheet)	$\Delta E = m c \Delta\theta$	J, kg, J/kg °C, °C
Specific latent heat (sheet)	$E = m L$	J, kg, J/kg

How to use this booklet

Each question is restated with its figure. Then you will find a **Key concept** box explaining the physics you need, the **numbered steps** a student would write on paper, and the final **ANSWER** box. Read the concept boxes as revision notes: they cover the ideas examiners test again and again, not just this paper.

Rearranging rule used throughout: when a term moves to the other side of the equals sign, its operation changes. Adding becomes subtracting, and multiplying becomes dividing.

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Question 01 Energy stores, kinetic energy and specific heat capacity

01.1 [2 marks]

Figure 1 shows a cyclist riding along a flat road.



Figure 1

Complete the sentence. Choose answers from the box: *chemical*, *elastic potential*, *gravitational potential*, *kinetic*.

As the cyclist accelerates, the _____ energy store in the cyclist's body decreases and the _____ energy of the cyclist increases.

Key concept: energy stores

Energy is never used up. It is **transferred** from one store to another. The main stores at GCSE are: kinetic, gravitational potential, elastic potential, chemical, thermal (internal), magnetic, electrostatic and nuclear.

- **Chemical store:** energy held in food, fuels and batteries. Your muscles release it when you exercise.
- **Kinetic store:** energy an object has because it is moving. Faster means more kinetic energy.
- On a **flat** road the height does not change, so the gravitational potential store does not change.

Step 1: Ask what is being used up

The cyclist's muscles use energy from food stored in the body. That is the **chemical** store, so it decreases.

Step 2: Ask what is increasing

The cyclist is accelerating, which means the speed is increasing. Energy linked to speed is **kinetic** energy.

ANSWER chemical (energy store decreases) ; kinetic (energy increases)

01.2 [2 marks]

The mass of the cyclist is 80 kg. The speed of the cyclist is 12 m/s. Calculate the kinetic energy of the cyclist.

Use the equation: kinetic energy = 0.5 × mass × (speed)^2

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Key concept: kinetic energy

$E_k = ½ m v^2$

E_k in joules (J), m = mass in kilograms (kg), v = speed in metres per second (m/s).

Only the **speed** is squared, so doubling the speed makes the kinetic energy **four times** bigger. Always square the speed first, then multiply.

Step 1: Write the equation

$E_k = 0.5 \times m \times v^2$

Step 2: Substitute the values

$E_k = 0.5 \times 80 \times (12)^2$

Step 3: Square the speed first

$(12)^2 = 144$

$E_k = 0.5 \times 80 \times 144$

Step 4: Multiply

$0.5 \times 80 = 40$

$E_k = 40 \times 144 = 5760$ J

ANSWER **Kinetic energy = 5760 J**

01.3 **[2 marks]**

When the cyclist uses the brakes, the bicycle slows down. This causes the temperature of the brake pads to increase by 50 °C. The mass of the brake pads is 0.040 kg. The specific heat capacity of the material of the brake pads is 480 J/kg °C.

Calculate the change in thermal energy of the brake pads.

Use the equation: change in thermal energy = mass × specific heat capacity × temperature change

Key concept: specific heat capacity

$\Delta E = m c \Delta\theta$

Specific heat capacity (c) is the energy needed to raise the temperature of **1 kg** of a substance by **1 °C**. Here, 480 J/kg °C means 480 J warms 1 kg of brake pad material by 1 °C.

When brakes are used, **friction** transfers energy from the kinetic store of the bike to the **thermal store** of the brake pads, so they get hot.

Step 1: Write the equation

$\Delta E = m \times c \times \Delta\theta$

Step 2: Substitute the values

$\Delta E = 0.040 \times 480 \times 50$

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Step 3: Multiply step by step

$0.040 \times 480 = 19.2$

$\Delta E = 19.2 \times 50 = 960$ J

ANSWER **Change in thermal energy = 960 J**

01.4 **[1 mark]**

How is the internal energy of the particles in the brake pads affected by the increase in temperature? Tick one box: Decreased / Increased / Not affected.

Key concept: internal energy

Internal energy is the total energy of all the particles in a substance: their **kinetic** energy (how fast they vibrate or move) plus their **potential** energy (from the forces between them).

Temperature is linked to the average kinetic energy of the particles. Higher temperature means the particles vibrate faster, so the internal energy goes **up**.

Step 1: Link temperature to particle motion

The temperature of the brake pads rose by 50 °C, so the particles vibrate faster. Their kinetic energy has risen, so the internal energy has risen.

ANSWER **Increased**

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Question 02 Filament lamps, current, power and efficiency

02.1 **[1 mark]**

Figure 2 shows how the current through a filament lamp changes after the lamp is switched on.

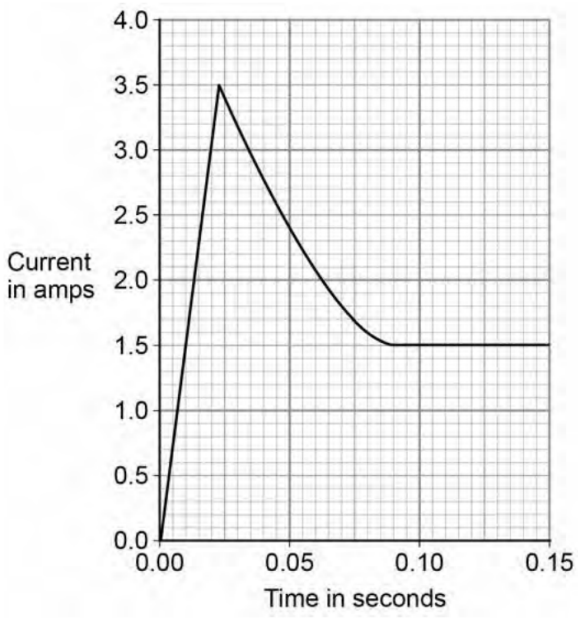


Figure 2

The normal current through the filament lamp is 1.5 A. For how many seconds is the current through the filament lamp greater than 1.5 A?

Tick one box: 0.01 s / 0.08 s / 0.09 s / 0.14 s

Key skill: reading a graph

Find the value on the **y axis** (1.5 A) and follow it across. Mark every point where the curve is **above** that line. Then read the start time and end time from the **x axis** and subtract.

Count the small squares carefully. On this graph one big square across is 0.025 s and each small square is 0.005 s.

Step 1: Find when the current first goes above 1.5 A

The current rises very steeply and passes 1.5 A at about **0.01 s**.

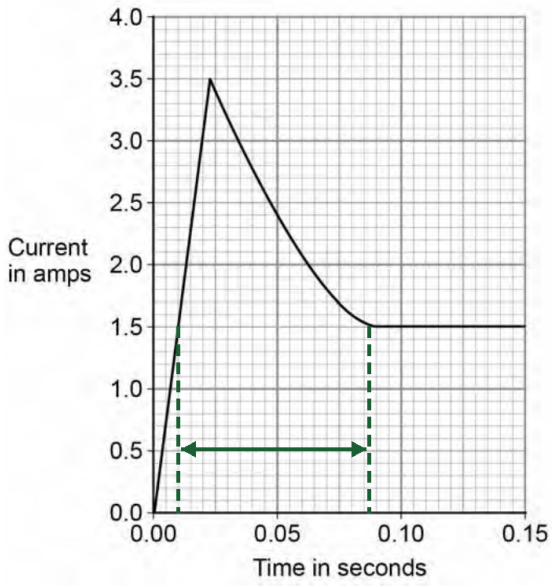
Step 2: Find when it falls back to 1.5 A

The curve comes back down and levels off at 1.5 A at about **0.09 s**.

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Step 3: Subtract to find the time interval

time above 1.5 A = 0.09 − 0.01 = 0.08 s



The dashed lines mark where the current is above 1.5 A

ANSWER **0.08 s**

02.2 **[1 mark]**

Why might the filament inside a lamp melt when the lamp is first switched on?

Key concept: filament lamps and resistance

A filament lamp is a thin metal wire that glows because it is very hot. As the temperature of a metal **increases**, its **resistance increases**, because the metal ions vibrate more and get in the way of the electrons.

When the lamp is first switched on, the filament is **cold**, so its resistance is **low**. A low resistance lets a very **large current** flow (3.5 A on the graph instead of the normal 1.5 A). A large current causes a lot of heating in a very short time.

Step 1: Use the graph

The current briefly reaches 3.5 A, more than double the normal 1.5 A.

Step 2: Link current to heating

A very large current transfers energy to the thermal store of the filament very quickly, so the temperature can rise high enough to melt the wire.

ANSWER **The current is very high when the lamp is first switched on (the cold filament has a low resistance), so the filament heats up too much.**

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02.3 **[2 marks]**

The lamp is connected to a 24 V power supply. The current through the lamp is 1.5 A. Calculate the power of the lamp.

Use the equation: power = potential difference × current

Key concept: electrical power

$$P = V\,I$$

P = power in watts (W), V = potential difference in volts (V), I = current in amps (A). Power is the **rate** of energy transfer: 1 W means 1 joule transferred every second.

Step 1: Write the equation

$$P = V \times I$$

Step 2: Substitute and calculate

$$P = 24 \times 1.5 = 36\ \text{W}$$

ANSWER **Power = 36 W**

02.4 **[1 mark]**

LED lamps are much more efficient than filament lamps. What does this statement mean? Tick one box.

- LED lamps have a similar power output to filament lamps.
- LED lamps waste a smaller proportion of the input energy than filament lamps.
- LED lamps have a higher power input than filament lamps.
- LED lamps waste a larger proportion of the input energy than filament lamps.

Key concept: efficiency

$$\text{efficiency} = \frac{\text{useful output energy transfer}}{\text{total input energy transfer}}$$

Efficiency tells us what **proportion** of the input energy is transferred usefully. A more efficient device **wastes a smaller proportion** of its input energy. A filament lamp wastes most of its energy heating the surroundings. An LED transfers most of its energy as light.

ANSWER **LED lamps waste a smaller proportion of the input energy than filament lamps.**

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Question 03 Cells, series circuits and resistance

03.1 **[2 marks]**

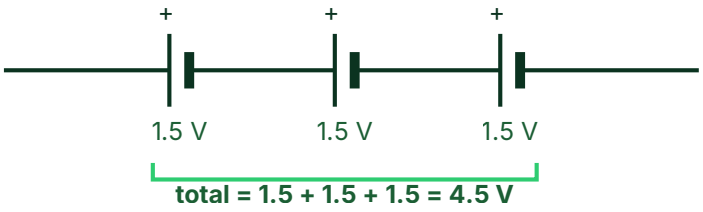
Draw a diagram to show how 1.5 V cells should be connected together to give a potential difference of 4.5 V. Use the correct circuit symbol for a cell.

Key concept: cells in series

A **cell** is drawn as a long thin line (the positive terminal) and a short thick line (the negative terminal).

When cells are joined in **series**, positive to negative, their potential differences **add up**.

$$\text{number of cells} = \frac{4.5\ \text{V}}{1.5\ \text{V}} = 3$$



Three cells in series, each one facing the same way

Exam tip All three cells must face the same way (+ next to −). If one cell is turned around it cancels out another one.

ANSWER **Three 1.5 V cells joined in series, all facing the same way**

A student built the circuit shown in Figure 3.

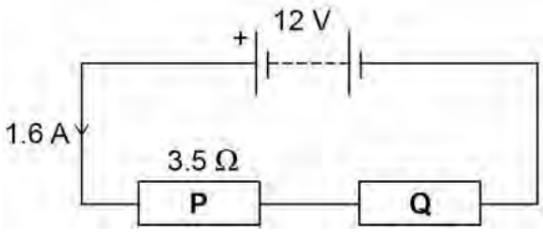


Figure 3

03.2 **[2 marks]**

Calculate the total resistance of the circuit in Figure 3.

Use the equation: $\text{resistance} = \frac{\text{potential difference}}{\text{current}}$

Key concept: resistance

$V = I R$

Resistance (R, in ohms Ω) tells us how hard it is for current to flow. Using the **total** potential difference of the supply (12 V) and the current from the supply (1.6 A) gives the **total** resistance of the whole circuit.

Step 1: Write the equation

$$R = \frac{V}{I}$$

Step 2: Substitute the values from Figure 3

$$R = \frac{12}{1.6}$$

Step 3: Calculate

$R = 7.5\ \Omega$

ANSWER **Total resistance = 7.5 Ω**

03.3 **[1 mark]**

The resistance of P is 3.5 Ω. Calculate the resistance of Q.

Key concept: resistors in series

$R_{total} = R_1 + R_2$

In a **series** circuit there is only one path, so the total resistance is the **sum** of the individual resistances. The current is the same everywhere in a series circuit.

Step 1: Write the series rule

$R_{total} = R_P + R_Q$

Step 2: Substitute

$7.5 = 3.5 + R_Q$

Step 3: Carry 3.5 over to the other side (+ becomes −)

$R_Q = 7.5 - 3.5$

$R_Q = 4.0\ \Omega$

ANSWER **Resistance of Q = 4.0 Ω**

03.4 **[2 marks]**

The student connects the two resistors in Figure 3 in parallel. What happens to the total resistance of the circuit? Tick one box: It decreases / It increases / It does not change. Give a reason for your answer.

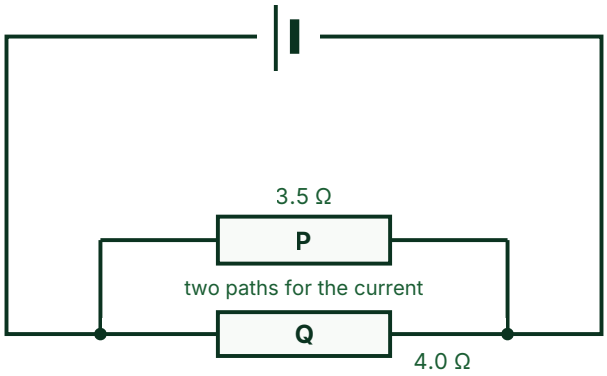
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Key concept: resistors in parallel

In **parallel**, each resistor is on its own branch, so the current has **more than one path**. More paths make it easier for charge to flow, so the total resistance goes **down**.

Rule to remember: the total resistance of resistors in parallel is always **less than the smallest** single resistor. Here that means less than 3.5 Ω.

(Extension check: $\frac{1}{R} = \frac{1}{3.5} + \frac{1}{4.0}$ gives R = 1.86… Ω, which is less than 3.5 Ω)



P and Q in parallel: the current can split between two paths

ANSWER **It decreases. The total resistance of resistors in parallel is less than the smallest individual resistance, because there are more paths for the current.**

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Question 04 Density practical

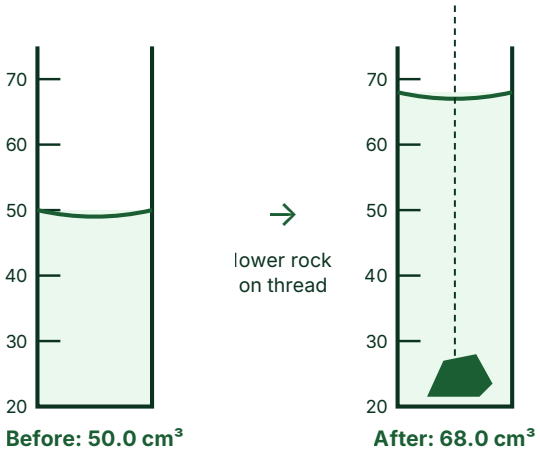
04.1 **[4 marks]**

A student wanted to determine the density of a small piece of rock. Describe how the student could measure the volume of the piece of rock.

Key concept: volume by displacement

A rock has an **irregular shape**, so we cannot use length × width × height. Instead we use **displacement**: when an object is fully under water it pushes aside (displaces) a volume of water **equal to its own volume**.

Two methods: a **measuring cylinder** (read the rise in water level) or a **displacement (eureka) can** (collect and measure the water that overflows).



Volume of rock = 68.0 − 50.0 = 18.0 cm³

Step 1: Part fill a measuring cylinder

Pour water into a measuring cylinder so that there is enough to cover the rock completely. Read the volume at the bottom of the meniscus, with your eye level with the water surface.

Step 2: Lower the rock in

Tie the rock to a thin thread and lower it gently into the water so it is **fully submerged** and no water splashes out.

Step 3: Read the new volume

Read the new water level at eye level.

Step 4: Subtract

volume of rock = final reading − starting reading

Exam tip For 4 marks, give four separate clear points: water in cylinder, read initial volume, fully submerge the rock, read final volume and subtract. The eureka can method also scores: fill the can to the spout, lower the rock in, collect the overflow in a measuring cylinder, and the overflow volume is the volume of the rock.

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ANSWER **Measure an initial volume of water in a measuring cylinder; fully submerge the rock; measure the new volume; volume of rock = new volume − initial volume.**

04.2 **[2 marks]**

The volume of the piece of rock was 18.0 cm^3. The student measured the mass of the piece of rock as 48.6 g. Calculate the density of the rock in g/cm^3.

Use the equation: density = $\frac{\text{mass}}{\text{volume}}$

Key concept: density

$$\rho = \frac{m}{V}$$

Density is the mass in each unit of volume. It tells us how tightly packed the mass is. Because the mass is in g and the volume in cm^3, the density comes out in **g/cm^3**.

Step 1: Write the equation

$$\rho = \frac{m}{V}$$

Step 2: Substitute

$$\rho = \frac{48.6}{18.0}$$

Step 3: Calculate

$\rho = 2.7\ g/cm^3$

ANSWER **Density = 2.7 g/cm^3**

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04.3 **[1 mark]**

Figure 4 shows the densities of different types of rock.

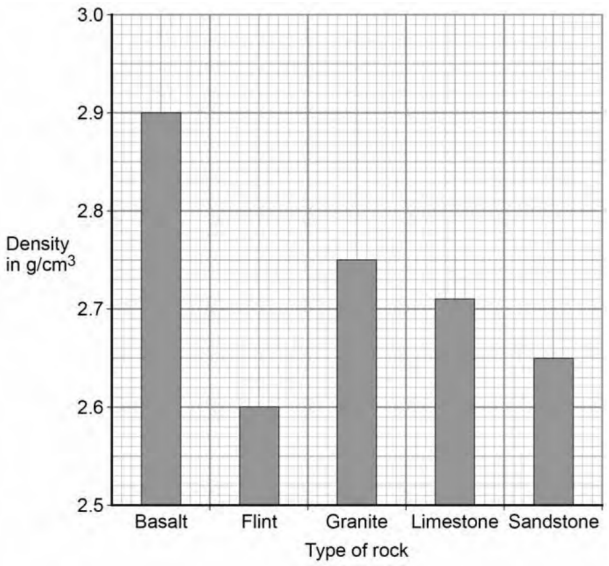


Figure 4

What is the most likely type of rock that the student had? Tick one box: Basalt / Flint / Granite / Limestone / Sandstone.

Step 1: Read each bar

Basalt ≈ 2.90, Flint ≈ 2.60, Granite ≈ 2.75, Limestone ≈ 2.71, Sandstone ≈ 2.65 g/cm^3.

Step 2: Compare with 2.70 g/cm^3

The closest bar to 2.70 g/cm^3 is limestone (2.71 g/cm^3).

Key idea

Density is a property of a material, so measuring it lets us **identify** the material, even when two objects look alike.

ANSWER **Limestone**

04.4 **[1 mark]**

Give one source of error that may have occurred when the student measured the volume of the rock.

04.5 **[1 mark]**

How would the error you described in question 04.4 affect the measured volume of the rock?

Key concept: errors in measurement

A **random error** makes readings scatter unpredictably (for example misreading a scale). A **systematic error** pushes every reading the same way (for example always reading the top of the meniscus). Your answer to 04.5 must match the error you gave in 04.4.

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Error in 04.4	Effect in 04.5
Water splashed out when the rock was dropped in	Final level too low, so measured volume too **small**
Air bubbles trapped on the rock	Final level too high, so measured volume too **large**
Rock absorbs some water (porous rock)	Final level too low, so measured volume too **small**
Volume of the thread also under water	Measured volume slightly too **large**
Meniscus read from above or below eye level	Reading could be too high or too low

ANSWER

04.4: Water splashed out of the measuring cylinder when the rock was added.
04.5: The measured volume of the rock would be smaller than the true volume.

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Question 05 Isotopes and half life

05.1 **[2 marks]**

Americium 241 ($^{241}_{95}Am$) is an isotope of americium. Which of the isotopes given in Table 1 is not an isotope of americium? Give a reason for your answer.

Isotope	Mass number	Atomic number
A	243	95
B	243	94
C	242	95

Key concept: atomic number, mass number and isotopes

Atomic number (bottom number) = number of protons. It decides **which element** the atom is. Every americium atom has 95 protons.

Mass number (top number) = protons + neutrons.

Isotopes are atoms of the **same element**: same number of protons, but a **different number of neutrons**, so a different mass number.

Step 1: Check the atomic numbers

A and C have atomic number 95, the same as americium, so they are americium isotopes. B has atomic number 94.

Step 2: Conclude

B has 94 protons, so it is a different element (plutonium), not americium.

ANSWER **B, because its atomic number (number of protons) is 94, not 95, so it is a different element.**

Figure 5 shows how the number of americium 241 nuclei in a sample changes with time.

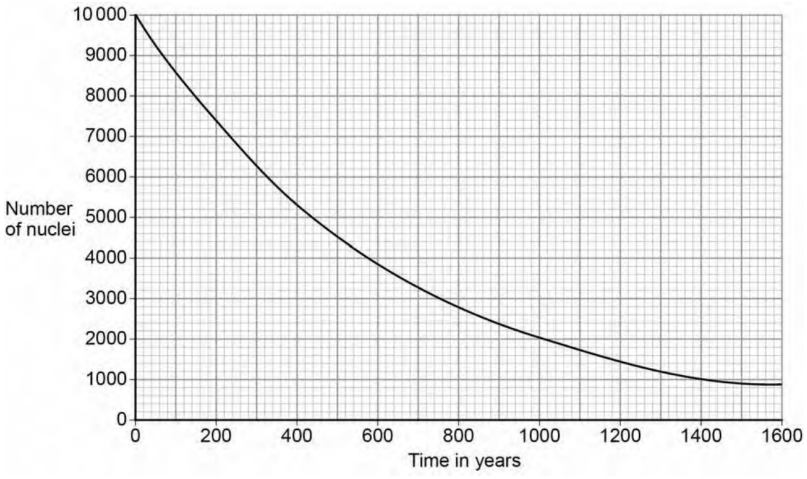


Figure 5

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05.2 **[1 mark]**

How many years does it take for the number of americium 241 nuclei to decrease from 10 000 to 5000?

05.3 **[1 mark]**

What is the half life of americium 241?

Key concept: half life

The **half life** of a radioactive isotope is the time it takes for the **number of unstable nuclei** in a sample to **halve** (or for the activity to halve). Decay is **random**, but over large numbers the half life is always the same.

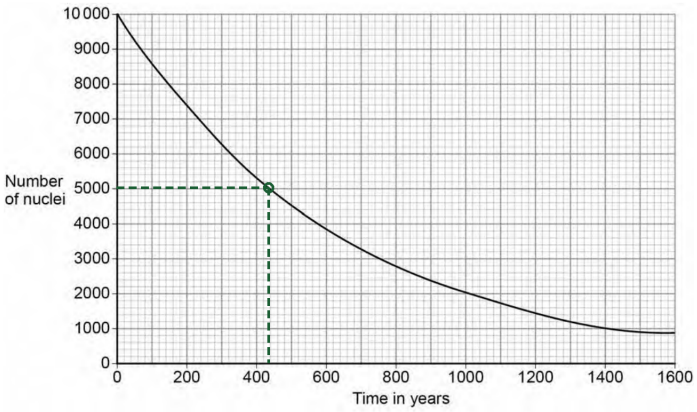
Going from 10 000 to 5000 is exactly halving, so the answer to 05.2 **is** the half life.

Step 1: Go across from 5000

Start at 5000 on the y axis and draw a line across to meet the curve.

Step 2: Drop down to the time axis

From the curve, go straight down and read the time: about 430 years.



Reading the half life from the graph

Step 3: Check with a second halving

From 5000 to 2500 takes from about 430 to about 860 years, another 430 years. The half life is constant.

ANSWER

05.2: Time ≈ 430 years
05.3: Half life ≈ 430 years

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Question 06 Nuclear fission and generating electricity

06.1 **[3 marks]**

Nuclear power can be used to generate electricity through nuclear fission. Figure 6 shows the process of nuclear fission.

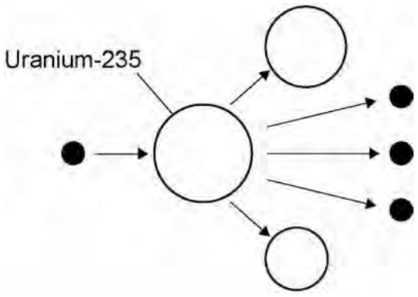


Figure 6

Complete the sentences. Choose answers from the box: *gamma rays*, *light rays*, *proton*, *neutron*, *nucleus*, *X rays*.

During the process of nuclear fission a uranium _____ absorbs a _____. Electromagnetic radiation is released in the form of _____.

Key concept: nuclear fission

Fission means splitting. A large unstable **nucleus** (uranium 235) **absorbs a neutron**. It becomes even more unstable and splits into two smaller nuclei (daughter nuclei), releasing two or three more **neutrons** and energy. Energy is also released as **gamma rays**.

The released neutrons can be absorbed by more uranium nuclei, starting a **chain reaction**. In a power station this is controlled.

In Figure 6: the small black dots are neutrons, the large circle is the uranium nucleus and the two medium circles are the daughter nuclei.

ANSWER **nucleus ; neutron ; gamma rays**

06.2 **[2 marks]**

The UK needs at least 25 000 000 kW of electrical power at any time. A nuclear power station has an electrical power output of 2 400 000 kW. Calculate how many nuclear power stations are needed to provide 25 000 000 kW of electrical power.

Step 1: Divide the total power needed by the output of one station

$$\text{number} = \frac{25\,000\,000}{2\,400\,000}$$

Step 2: Calculate

number = 10.4166...

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Step 3: Think about what the answer means

You cannot build 0.4 of a power station. 10 stations would only give 24 000 000 kW, which is **not enough**. The question says **at least** 25 000 000 kW, so we must round **up**.

Exam tip When the answer is a number of whole objects needed (buses, boxes, power stations), always round up, even if the decimal is small.

ANSWER **11 power stations**

06.3 **[2 marks]**

State two environmental issues caused by generating electricity using nuclear power stations.

Key concept: nuclear power, pros and cons

Nuclear power does **not** release carbon dioxide while generating electricity, and it is reliable. Its problems are:

- It produces **radioactive waste** that stays dangerous for a very long time and must be stored safely.
- There is a risk of a major **accident** releasing radioactive material into the environment (for example Chernobyl or Fukushima).
- Uranium is a **non renewable** resource that must be mined.

ANSWER

1. Produces radioactive waste that must be stored safely for a very long time.
2. Risk of an accident that releases radioactive material into the environment.

06.4 **[2 marks]**

The UK currently generates a lot of electricity by burning natural gas. This process releases carbon dioxide into the atmosphere. Figure 7 shows how the concentration of carbon dioxide in the atmosphere has changed over the past 115 years. Figure 8 shows how the global temperature has changed over the past 115 years.

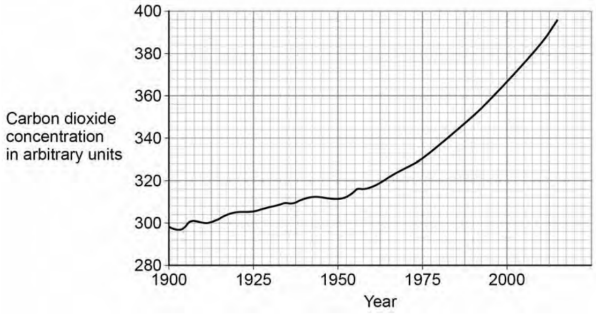


Figure 7

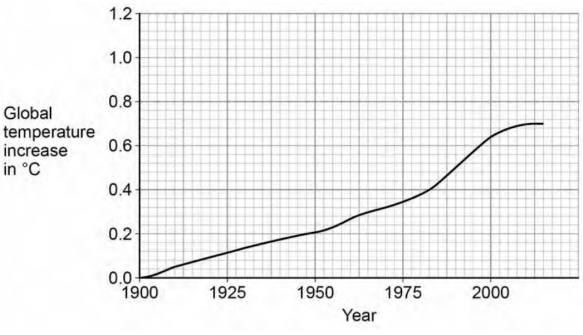


Figure 8

Give one similarity and one difference between the data in Figure 7 and Figure 8.

Key skill: comparing two graphs

A **similarity** is a pattern both graphs share. A **difference** is something one graph does that the other does not. Always describe what the **data** show (trend, rate of change, shape), and quote years or values to support it.

Remember: two graphs having a similar shape shows a **correlation**. It does not prove on its own that one causes the other.

Step 1: Look at the overall trend

Both graphs go up from 1900 to the present day. Both rise more steeply after about 1975.

Step 2: Look for where they disagree

Carbon dioxide dips slightly around 1940 to 1950, while temperature keeps rising. At the very end, the temperature levels off (after about 2010) while carbon dioxide is still rising steeply.

ANSWER

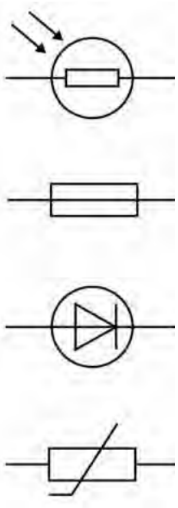
Similarity: both carbon dioxide concentration and global temperature increase over the 115 years.
Difference: carbon dioxide still rises steeply at the end, but the temperature levels off (or: carbon dioxide dips around 1940 to 1950 but temperature does not).

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Question 07 Fuses, charge and specific latent heat

07.1 **[1 mark]**

The plug of an electrical appliance contains a fuse. What is the correct circuit symbol for a fuse? Tick one box.



The four symbols, from top to bottom

Key concept: circuit symbols

Symbol (top to bottom)	Component
1. Resistor in a circle with two arrows pointing in	Light dependent resistor (LDR)
2. Rectangle with a line running through it	**Fuse**
3. Triangle and bar in a circle	Diode in a circle (used for light emitting diodes)
4. Rectangle with a diagonal line and a flat foot	Thermistor

The line through the fuse rectangle represents the thin **fuse wire** inside it.



Fuse symbol

ANSWER **The second symbol: a rectangle with a line running through it**

07.2 **[2 marks]**

The appliance is connected to the mains electrical supply. The mains potential difference is 230 V. Calculate the energy transferred when 13 C of charge flows through the appliance.

Use the equation: energy transferred = charge flow × potential difference

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Key concept: potential difference and energy

$E = Q\,V$

Potential difference is the energy transferred **per coulomb** of charge. 230 V means each coulomb of charge transfers 230 J. So 13 coulombs transfer 13 times as much.

Step 1: Write the equation

$E = Q \times V$

Step 2: Substitute and calculate

$E = 13 \times 230 = 2990\ J$

ANSWER **Energy transferred = 2990 J**

Figure 9 shows the structure of a fuse.

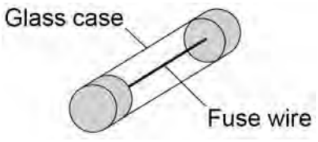


Figure 9

07.3 **[1 mark]**

Write down the equation that links charge flow, current and time.

Key concept: current

Current is the **rate of flow of charge**: how many coulombs pass a point each second.

$Q = I\,t$

Q = charge flow in coulombs (C), I = current in amps (A), t = time in seconds (s).

ANSWER **charge flow = current × time (Q = I t)**

07.4 **[3 marks]**

The fuse wire melts when 1.52 coulombs of charge flows through the fuse in 0.40 seconds. Calculate the current at which the fuse wire melts.

Step 1: Write the equation

$Q = I \times t$

Step 2: Substitute

$1.52 = I \times 0.40$

Step 3: Carry 0.40 over (multiplying becomes dividing)

$$I = \frac{1.52}{0.40}$$

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Step 4: Calculate

I = 3.8 A

Why a fuse works

If the current gets too large (here 3.8 A), the thin fuse wire heats up and **melts**. This breaks the circuit and stops the current, protecting the appliance and the cable from overheating and catching fire.

ANSWER **Current = 3.8 A**

07.5 **[2 marks]**

The mass of the fuse wire is 0.00175 kg. The specific latent heat of fusion of the fuse wire is 205 000 J/kg. Calculate the energy needed to melt the fuse wire. Use the Physics Equations Sheet.

Key concept: specific latent heat

E = m L

Specific latent heat is the energy needed to **change the state** of 1 kg of a substance **without changing its temperature**. **Fusion** means melting (solid to liquid). **Vaporisation** means boiling (liquid to gas).

Do not confuse this with specific heat capacity, which is about changing temperature. Latent heat is about changing state.

Step 1: Choose the equation from the sheet

E = m × L

Step 2: Substitute

E = 0.00175 × 205 000

Step 3: Calculate

E = 358.75 J

ANSWER **Energy = 358.75 J (≈ 359 J)**

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Question 08 Thermal conductivity, insulation, efficiency and power

08.1 **[1 mark]**

Figure 10 shows a hot water tank made of copper.

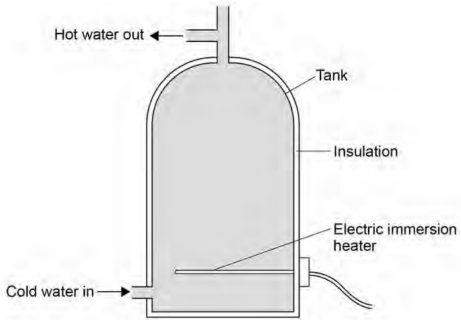


Figure 10

Copper has a higher thermal conductivity than most metals. How does the rate of energy transfer through copper compare with the rate of energy transfer through most metals? Tick one box: Higher / Lower / The same.

Key concept: thermal conductivity

Thermal conductivity tells us how quickly energy is transferred through a material by conduction. The **higher** the thermal conductivity, the **higher** the rate of energy transfer.

The rate of energy transfer through a wall also depends on its **thickness** (thicker means slower) and the **temperature difference** across it (bigger difference means faster).

ANSWER **Higher**

08.2 **[2 marks]**

The tank is insulated. When the water is hot, the immersion heater switches off. Complete the sentences.

Compared to a tank with no insulation, the rate of energy transfer from the water in an insulated tank is _____. This means that the water in the insulated tank stays _____ for longer.

Key concept: insulation

Insulating materials have a **low thermal conductivity**. They reduce the rate of energy transfer from the hot water to the cooler surroundings, so less energy is wasted and the water stays hot longer.

ANSWER **lower (reduced) ; hot (warm)**

Figure 11 shows how temperature varies with time for water in a tank heated with an immersion heater.
Figure 12 shows how temperature varies with time for water in a tank heated with a solar panel.

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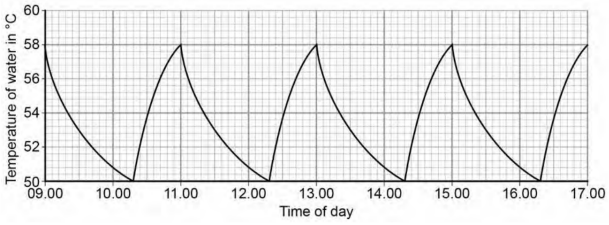


Figure 11: immersion heater

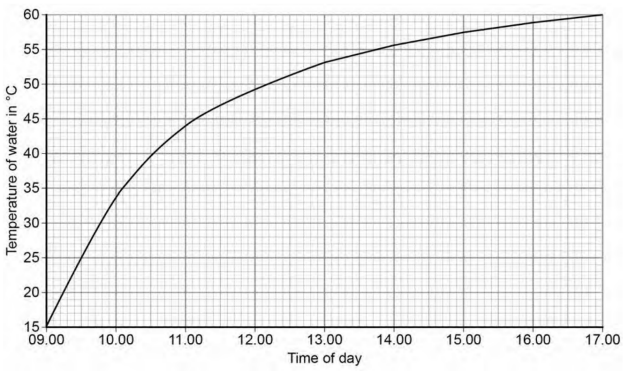


Figure 12: solar panel

08.3 **[2 marks]**

Give one advantage and one disadvantage of heating the water using solar panels rather than an immersion heater. Use only information from Figure 11 and Figure 12.

Key skill: using only the data given

When a question says **use only information from the figures**, do not write general facts (such as "solar is renewable" or "it is free"). Those score nothing here. Write what the graphs **show**.

Figure 11: the water stays between 50 °C and 58 °C all day, switching on and off. Figure 12: the water starts at 15 °C, heats slowly, and only reaches 50 °C at about 12.00, ending at 60 °C.

ANSWER

Advantage: the water reaches a higher maximum temperature (60 °C compared with 58 °C), and its temperature does not keep falling.
Disadvantage: the water takes a long time to heat up (it is below 50 °C until about 12.00), so there is no hot water early in the morning.

08.4 **[2 marks]**

During one morning, a total of 4 070 000 J of energy is transferred from the electric immersion heater. 4 030 000 J of energy are transferred to the water. Calculate the proportion of the total energy transferred to the water.

Key concept: proportion and efficiency

A proportion is a part divided by the whole. Here, it is the same as the **efficiency** of the heater.

$$\text{proportion} = \frac{\text{energy to water (useful)}}{\text{total energy transferred}}$$

Efficiency is a decimal between 0 and 1 (or a percentage up to 100 %). It can never be more than 1.

Step 1: Write the proportion

$$\text{proportion} = \frac{4\,030\,000}{4\,070\,000}$$

Step 2: Calculate, keeping the full value

$$\text{proportion} = 0.990171\ldots$$

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Step 3: Round at the end

proportion = 0.99 (2 d.p.)

As a percentage this is about 99 %.

ANSWER **Proportion = 0.99 (2 d.p.)**

08.5 **[1 mark]**

Write down the equation that links energy transferred, power and time.

Key concept: power and energy

$E = P\,t$

E = energy transferred in joules (J), P = power in watts (W), t = time in seconds (s). Power is energy transferred per second.

ANSWER **energy transferred = power × time (E = P t)**

08.6 **[4 marks]**

The power output of the immersion heater is 5000 W. Calculate the time taken for the immersion heater to transfer 4 070 000 J of energy. Give the unit.

Step 1: Write the equation

$E = P \times t$

Step 2: Substitute

$4\,070\,000 = 5000 \times t$

Step 3: Carry 5000 over (multiplying becomes dividing)

$$t = \frac{4\,070\,000}{5000}$$

Step 4: Calculate and give the unit

t = 814 s

Using power in W and energy in J gives time in **seconds**. (814 s is about 13.6 minutes.)

Exam tip "Give the unit" means one of the marks is for the unit. Always write s for seconds.

ANSWER **Time = 814 Unit: seconds (s)**

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Question 09 Work, power, efficiency, parallel switches and gravitational potential energy

09.1 **[2 marks]**

Figure 13 shows a lift inside a building (a photograph of people standing inside a lift).

The motor in the lift does 120 000 J of work in 8.0 seconds. Calculate the power output of the motor in the lift.

Use the equation: power output = $\frac{\text{work done}}{\text{time}}$

Key concept: work done and power

Work done is energy transferred when a force moves an object (1 J of work = 1 N moving 1 m). **Power** is how fast the work is done.

$$P = \frac{W}{t}$$

Step 1: Write the equation

$$P = \frac{W}{t}$$

Step 2: Substitute

$$P = \frac{120\,000}{8.0}$$

Step 3: Calculate

$$P = 15\,000 \text{ W}$$

ANSWER **Power output = 15 000 W**

09.2 **[2 marks]**

The power input to the motor is greater than the power output. Tick two reasons why.

- Energy is transferred in heating the surroundings.
- Friction causes energy to be transferred in non useful ways.
- The motor is connected to the mains electricity supply.
- The motor is more than 100% efficient.
- There are only four people in the lift.

Key concept: wasted energy

No real machine is 100 % efficient. Some input energy is always **dissipated** (wasted): **friction** in moving parts and electrical **resistance** in wires heat the motor and the **surroundings**, and some energy is transferred as sound.

So input power = useful output power + wasted power. Input is always bigger than useful output. Nothing can be more than 100 % efficient.

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ANSWER

✓ **Energy is transferred in heating the surroundings.**
✓ **Friction causes energy to be transferred in non useful ways.**

09.3 **[2 marks]**

Figure 14 shows part of the circuit that operates the lift motor.

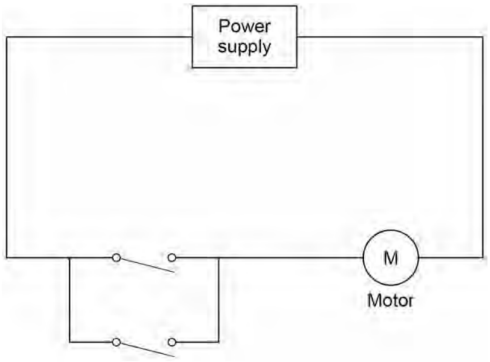


Figure 14

The lift can be operated using either of the two switches. Explain why.

Key concept: switches in parallel

A current only flows when there is a **complete loop** (closed circuit). The two switches are connected in **parallel**: each one is on its own branch.

Closing **either** switch gives the current a complete path through the motor, so the lift works. This is useful in a lift: there is a button inside and a button outside.

ANSWER

The switches are connected in parallel, so closing either switch completes the circuit and current can flow through the motor.

09.4 **[1 mark]**

Write down the equation that links gravitational field strength, gravitational potential energy, height and mass.

Key concept: gravitational potential energy

$E_p = m\ g\ h$

E_p in J, m = mass in kg, g = gravitational field strength in N/kg (9.8 N/kg on Earth), h = height in m. Lifting an object higher stores more energy in its gravitational potential store.

ANSWER

gravitational potential energy = mass × gravitational field strength × height ($E_p = m\ g\ h$)

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09.5 **[3 marks]**

The lift goes up 14 m. The total mass of the people in the lift is 280 kg. Gravitational field strength = 9.8 N/kg. Calculate the increase in gravitational potential energy of the people in the lift. Give your answer to 2 significant figures.

Step 1: Write the equation

$E_p = m \times g \times h$

Step 2: Substitute

$E_p = 280 \times 9.8 \times 14$

Step 3: Calculate in stages

$280 \times 9.8 = 2744$

$E_p = 2744 \times 14 = 38\,416$ J

Step 4: Round to 2 significant figures

The first two significant figures are 3 and 8. The next digit is 4, which is less than 5, so we round down.

38 416 → 38 000 J (2 s.f.)

Key skill: significant figures

Count significant figures from the **first non zero digit**. After rounding, fill the remaining places with zeros so the number keeps its size: 38 416 becomes 38 000, not 38.

ANSWER **Increase in gravitational potential energy = 38 000 J (2 s.f.)**

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Question 10 Static electricity and electric fields

10.1 **[2 marks]**

Figure 15 shows a student walking on a carpet (a photograph of feet in socks on a carpet). The student becomes negatively charged because of the friction between his socks and the carpet. Explain why the friction causes the student to become charged.

Key concept: charging by friction

When two insulating materials rub together, **electrons** (which are negatively charged) are transferred from one material to the other. Only electrons move. Protons stay in the nuclei.

- The object that **gains** electrons becomes **negatively** charged.
- The object that **loses** electrons becomes **positively** charged.

ANSWER **Friction causes electrons to be transferred from the carpet to the socks (student). The student gains electrons, so becomes negatively charged.**

10.2 **[1 mark]**

The student's head is represented by the sphere in Figure 16. The student is negatively charged. The arrow shows part of the electric field around the student's head. Draw three more arrows on Figure 16 to complete the electric field pattern.

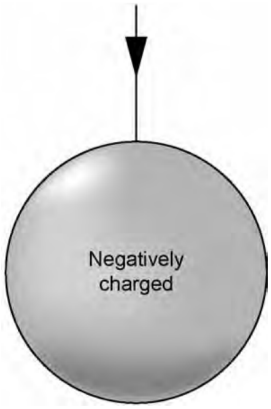


Figure 16

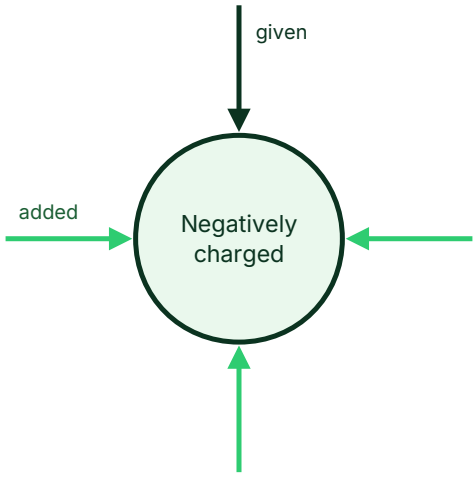
Key concept: electric field patterns

An electric field is the region around a charged object where another charge feels a force. Field lines show the direction of the force on a **positive** charge.

- Around a **positive** sphere, field lines point **outwards**.
- Around a **negative** sphere, field lines point **inwards**, towards the centre.

The lines are **radial** (like spokes of a wheel) and meet the surface at right angles. The field is strongest close to the sphere.

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Three arrows added (left, right and bottom), all pointing in towards the centre

ANSWER **Three arrows, evenly spaced around the sphere (left, right and bottom), each pointing radially inwards towards the sphere**

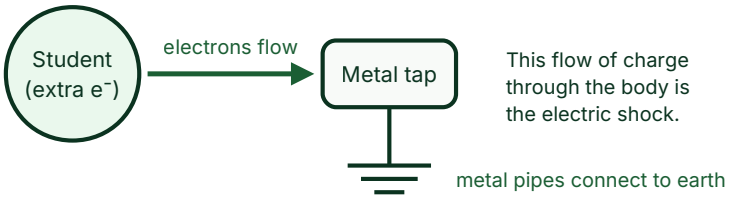
10.3 **[3 marks]**

The negatively charged student touches a metal tap and receives an electric shock. Explain why.

Key concept: discharge and sparks

As charge builds up on the student, the **potential difference** between the student and the earth increases. Metal is a **conductor**, and metal taps are connected to earth through the water pipes.

When the student touches the tap, the extra **electrons flow** from the student through the tap to **earth**. This sudden flow of charge (a current) through the body is the shock.



Electrons flow from the student, through the tap, to earth

ANSWER **There is a large potential difference between the student and the tap. The tap is a conductor connected to earth, so electrons flow from the student through the tap to earth. This flow of charge (current) through the student is the shock.**

10.4 **[2 marks]**

Some carpets have thin copper wires running through them. The student is less likely to receive an electric shock after walking on this type of carpet. Suggest why.

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Key concept: preventing charge build up

Charge only builds up on **insulators**. Copper is a good electrical **conductor**, so any charge produced is **conducted away** (to earth) instead of building up on the student.

ANSWER

Copper is a conductor, so the charge (electrons) is conducted away through the wires (to earth). Charge does not build up on the student, so there is no large discharge when he touches the tap.

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Question 11 Radioactivity, activity and radiation dose

11.1 **[3 marks]**

A teacher used a Geiger Muller tube and counter to measure the number of counts in 60 seconds for a radioactive rock. The counter recorded 819 counts in 60 seconds. The background radiation count rate was 0.30 counts per second. Calculate the count rate for the rock.

Key concept: count rate and background radiation

Count rate is the number of decays detected per second (or per minute).

$$\text{count rate} = \frac{\text{number of counts}}{\text{time}}$$

Background radiation is always around us (rocks, cosmic rays, food, medical uses). The counter detects it as well as the rock, so we must **subtract** it to find the count rate from the rock alone. This is called a **corrected count rate**.

Step 1: Find the measured count rate

$$\text{count rate} = \frac{819}{60} = 13.65 \text{ counts per second}$$

Step 2: Subtract the background count rate

$$\text{count rate for rock} = 13.65 - 0.30$$

Step 3: Calculate

$$\text{count rate for rock} = 13.35 \text{ counts per second}$$

Exam tip Another valid route: background counts in 60 s = 0.30 × 60 = 18; 819 − 18 = 801 counts; $\frac{801}{60}$ = 13.35 per second. Same answer.

ANSWER **Count rate = 13.35 per second (≈ 13.4)**

11.2 **[2 marks]**

A householder is worried about the radiation emitted by the granite worktop in his kitchen. 1 kg of granite has an activity of 1250 Bq. The kitchen worktop has a mass of 180 kg. Calculate the activity of the kitchen worktop in Bq.

Key concept: activity

Activity is the rate at which unstable nuclei decay, measured in **becquerels (Bq)**. 1 Bq = 1 decay per second. More granite means more unstable nuclei, so the activity scales with mass.

Step 1: Multiply activity per kg by the mass

$$\text{activity} = 1250 \times 180$$

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Step 2: Calculate

activity = 225 000 Bq

ANSWER **Activity = 225 000 Bq**

11.3 **[2 marks]**

The average total radiation dose per year in the UK is 2.0 millisieverts. Table 2 shows the effects of radiation dose on the human body.

Radiation dose in millisieverts	Effects
10 000	Immediate illness; death within a few weeks
1000	Radiation sickness; unlikely to cause death
100	Lowest dose with evidence of causing cancer

The average radiation dose from the granite worktop is 0.003 millisieverts per day. Explain why the householder should not be concerned about his yearly radiation dose from the granite worktop. One year is 365 days.

Key concept: radiation dose

Radiation dose (measured in sieverts, Sv, or millisieverts, mSv) measures the **risk of harm** to the body from radiation. 1 Sv = 1000 mSv. To judge a risk, always calculate the dose and **compare** it with a known value.

Step 1: Calculate the yearly dose

yearly dose = 0.003 × 365 = 1.095 mSv

Step 2: Compare with Table 2

The lowest dose with evidence of causing cancer is 100 mSv. 1.095 mSv is far below this (about 1 % of it).

ANSWER **Yearly dose = 0.003 × 365 = 1.095 mSv, which is much smaller than 100 mSv, the lowest dose with evidence of causing cancer. (It is also less than the UK average yearly dose of 2.0 mSv.)**

11.4 **[1 mark]**

Bananas are a source of background radiation. Some people think that the unit of radiation dose should be changed from sieverts to Banana Equivalent Dose. Suggest one reason why the Banana Equivalent Dose may help the public be more aware of radiation risks.

Key idea: communicating risk

Scientific units like millisieverts are hard for most people to picture. Comparing a dose with something **familiar** and everyday, like eating a banana, helps people understand how big or small a risk really is.

ANSWER **People are familiar with bananas, so it is easier to understand and compare the size of a dose (and see that small doses are common and low risk).**

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Question 12 Required practical: resistance of a wire

12.1 **[3 marks]**

A student investigated how the resistance of a piece of nichrome wire varies with length. Figure 17 shows part of the circuit the student used.

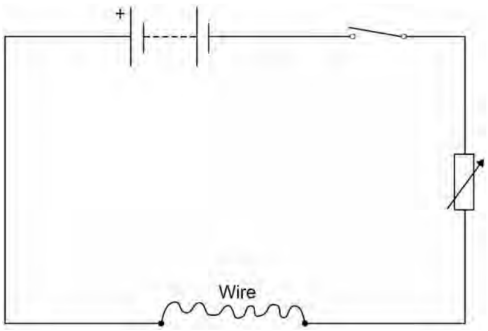
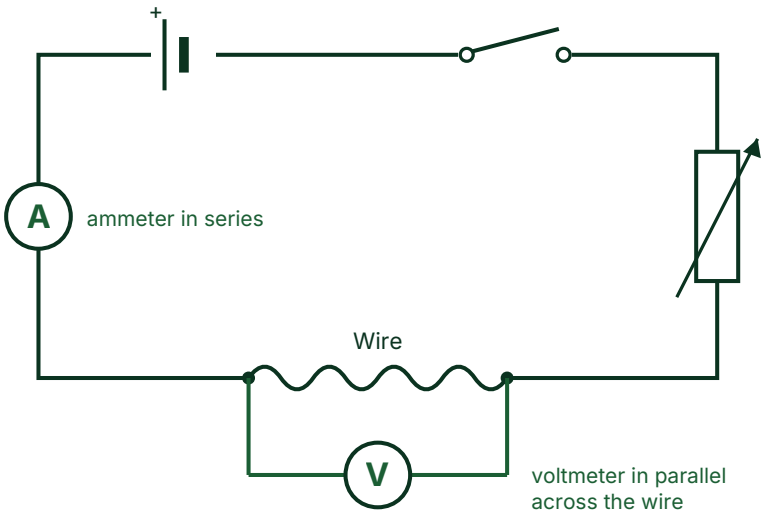


Figure 17

Complete Figure 17 by adding an ammeter and a voltmeter. Use the correct circuit symbols.

Key concept: ammeters and voltmeters

- **Ammeter** (circle with A): measures current. It goes in **series**, in the main loop, so the same current flows through it as through the wire.
- **Voltmeter** (circle with V): measures potential difference. It goes in **parallel**, connected across the two ends of the wire being tested.



Completed circuit

ANSWER **Ammeter symbol (A in a circle) in series in the main loop; voltmeter symbol (V in a circle) connected in parallel across the wire**

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12.2 **[6 marks]**

Describe how the student would obtain the data needed for the investigation. Your answer should include a risk assessment for one hazard in the investigation.

Key concept: the resistance of a wire practical

Independent variable: length of wire. **Dependent variable:** resistance (found from V and I). **Control variables:** same wire material, same thickness (diameter), same temperature, same supply settings.

$$R = \frac{V}{I}$$

Expected result: resistance is **directly proportional** to length. Doubling the length doubles the resistance, because the electrons have twice as far to travel through the metal ions.

Step 1: Set up

Tape the wire along a metre ruler. Attach one crocodile clip at the 0 cm mark.

Step 2: Set the first length

Attach the second crocodile clip so that the length of wire between the clips is, for example, 10 cm.

Step 3: Take readings

Close the switch. Record the reading on the ammeter (current) and the voltmeter (potential difference). Open the switch straight away.

Step 4: Calculate the resistance

Use $R = \frac{V}{I}$ for each length.

Step 5: Change the length

Move the clip to give lengths of 20, 30, 40, 50 cm and so on (at least five different lengths), taking readings each time.

Step 6: Repeat and average

Repeat the readings for each length and calculate a mean. Keep the current small using the variable resistor so the wire does not heat up.

Step 7: Risk assessment

Hazard: the wire can get very hot. **Risk:** burns to the skin. **Control:** use a low current, switch off between readings, and do not touch the wire while the circuit is on.

Exam tip Six mark questions are marked by level. To reach the top level, give a clear logical sequence: what you measure, how you change the length, how you calculate R, and a full risk assessment (hazard, risk and how to reduce it).

ANSWER

Connect clips to give a measured length; close switch; record V and I; calculate R = V ÷ I; repeat for at least five different lengths; repeat and average; risk: hot wire may burn, so use a low current and switch off between readings.

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12.3 **[1 mark]**

Why would switching off the circuit between readings have improved the accuracy of the student's investigation? Tick one box.

- The charge flow through the wire would not change.
- The potential difference of the battery would not increase.
- The power output of the battery would not increase.
- The temperature of the wire would not change.

Key concept: temperature and resistance

Current heats the wire. As the wire gets hotter, its **resistance increases**. Temperature is a **control variable**: if it changes, the resistance changes for a reason other than length, which makes the results less accurate. Switching off lets the wire cool.

ANSWER **The temperature of the wire would not change.**

12.4 **[2 marks]**

The student used crocodile clips to make connections to the wire. They could have used a piece of equipment called a 'jockey'. Figure 18 shows a crocodile clip and a jockey in contact with a wire.

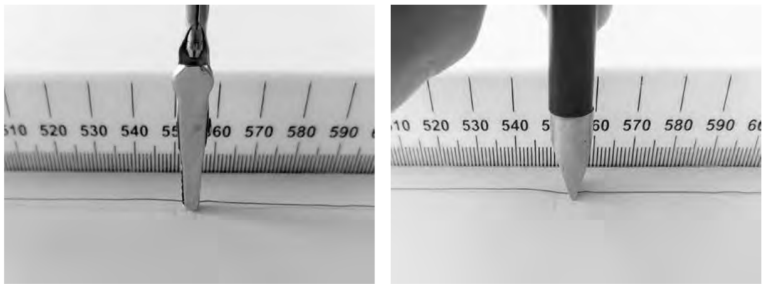


Figure 18

How would using the jockey have affected the accuracy and resolution of the student's results compared to using the crocodile clip? Tick two boxes.

Key concept: accuracy and resolution

- **Accuracy**: how close a measurement is to the **true value**.
- **Resolution**: the **smallest change** a measuring instrument can show (for a ruler, 1 mm).

The crocodile clip is wide, so it is hard to tell exactly where it touches the wire. The jockey has a sharp point, so it touches the wire at an exact point and the length is closer to the true value: **accuracy is higher**. The **same ruler** is used in both cases, so the **resolution is the same**.

ANSWER
- ✓ **The accuracy of the student's results would be higher.**
- ✓ **The resolution of the length measurement would be the same.**

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