Electricity

Model answers and marking points

GCSE science 6-mark questions

This topic online

1 Mateusz connects a filament lamp to a variable power supply. He slowly increases the potential difference across the lamp from 0 V to 12 V and records the current each time.

He finds that when the potential difference doubles, the current goes up by much less than double.

Explain this result. Include what happens inside the filament. (6 marks)

Model answer

Resistance = potential difference / current. When the p.d. doubled the current rose by less than double, so the ratio of p.d. to current went up, which means the resistance of the lamp increased. The current is not directly proportional to the p.d., so the lamp is not an ohmic conductor. On an I-V graph this would show as a curve that gets less steep as the p.d. increases.

The resistance increases because of what happens to the filament. As the current through it increases, more energy is transferred to the thermal store of the filament, so its temperature rises and it glows brighter.

The filament is a metal made of a lattice of ions. As the temperature rises, the ions vibrate more. The free electrons that carry the current then collide with the ions more often. These collisions make it harder for the electrons to flow through the wire, so the resistance increases. The hotter the filament gets, the higher its resistance, which is why the current rises more and more slowly as the p.d. is increased.

Marking points (credit any 6 relevant points, linked in a sensible order)

- resistance = potential difference / current
- if current rose by less than double when p.d. doubled, the resistance of the lamp has increased
- so the lamp is not an ohmic conductor and the current is not directly proportional to the p.d.
- as the current increases, energy is transferred to the thermal store of the filament
- the filament gets hotter as the current increases
- the metal ions in the filament vibrate more as the temperature rises
- the moving electrons collide with the vibrating ions more often
- this makes it harder for charge to flow, so resistance increases
- the I-V graph is a curve that becomes less steep at higher p.d.

How it is marked

- 5-6 marks: states that resistance increases, links rising current to rising temperature, and explains this in terms of ions vibrating and electrons colliding more often.
- 3-4 marks: states that the resistance increases because the filament gets hotter, but the explanation of why heating raises resistance is missing or unclear.
- 1-2 marks: states that the resistance changes or that the lamp gets hot, with no linked explanation.

What loses marks

- saying the resistance decreases because more current flows
- saying the electrons themselves vibrate rather than the ions
- describing the graph without explaining the cause

Free for classroom and home use: print, photocopy and share. Not for resale or re-hosting.

2 Amara is making two sets of decorative lights, each with four identical lamps and a 6 V battery. In set A the lamps are connected in series. In set B each lamp is connected in parallel with the battery.

Compare the two sets of lights. Refer to current, potential difference, resistance, brightness and what happens if one lamp breaks.

(6 marks)

Model answer

In set A the lamps are in series, so the same current flows through every lamp. In set B the lamps are in parallel, so the current from the battery splits between the branches and the total current is the sum of the branch currents.

In series the 6 V is shared between the four lamps, so each gets about 1.5 V. In parallel every lamp gets the full 6 V of the battery.

The total resistance of the series set is the sum of the four lamp resistances. In parallel the total resistance is smaller than the resistance of just one lamp, so set B draws a much bigger current from the battery.

Because each parallel lamp has a larger p.d. and a larger current through it, the lamps in set B are brighter than those in set A. However, set B transfers energy from the battery faster, so its battery will go flat sooner.

If one lamp breaks in set A, there is a gap in the only loop, so no current flows and all the lamps go out. If one lamp breaks in set B, the other branches are still complete, so the other three lamps stay lit.

Marking points (credit any 6 relevant points, linked in a sensible order)

- in series the current is the same through every lamp; in parallel the total current is the sum of the currents in each branch
- in series the 6 V is shared between the lamps, about 1.5 V each; in parallel each lamp has the full 6 V
- in series the total resistance is the sum of the four resistances; in parallel the total resistance is less than the resistance of any one lamp
- the parallel set draws a larger total current from the battery
- each lamp in the parallel set is brighter because it has a bigger p.d. and current
- if one lamp breaks in series, the circuit is broken and all the lamps go out
- if one lamp breaks in parallel, the other branches are still complete and stay lit
- the parallel set transfers energy from the battery faster, so the battery runs down sooner
- lamps in parallel can be switched separately; lamps in series cannot

How it is marked

- 5-6 marks: compares the two sets on at least four of the listed features, using correct rules for current, p.d. and resistance, and links these to brightness and to a broken lamp.
- 3-4 marks: gives two or three correct comparisons, for example the broken-lamp effect and the p.d. rule, with some errors or gaps.
- 1-2 marks: makes one correct statement, such as all the series lamps going out if one breaks.

What loses marks

- saying current is shared in series and the same in parallel, which is the wrong way round
- saying adding lamps in parallel increases the total resistance
- describing each circuit separately without comparing

Free for classroom and home use: print, photocopy and share. Not for resale or re-hosting.

3 A metal toaster is connected to the mains using a three-core cable and a plug.

Describe the job of each of the three wires and how the earth wire and fuse together protect someone if the live wire comes loose and touches the metal case. (6 marks)

Model answer

The UK mains supply is alternating, at about 230 V and 50 Hz.

The brown live wire carries the alternating potential difference from the supply into the toaster. The blue neutral wire completes the circuit and is at or close to 0 V. The green and yellow earth wire is a safety wire. It is at 0 V and is connected to the metal case of the toaster. Normally no current flows in it.

If the live wire comes loose and touches the metal case, the case would be at 230 V. Because the case is connected to the earth wire, there is now a path of very low resistance from the live wire, through the case, to earth. A very large current flows along this path.

The fuse is fitted in the live wire. The large current heats the thin wire inside the fuse until it melts, which breaks the circuit. The live wire is then disconnected from the toaster, so the case is no longer at a high voltage. If someone touches the case they will not get an electric shock.

Marking points (credit any 6 relevant points, linked in a sensible order)

- UK mains is an alternating supply at about 230 V and 50 Hz
- the live wire (brown) carries the alternating potential difference from the supply, about 230 V
- the neutral wire (blue) completes the circuit and is at or close to 0 V
- the earth wire (green and yellow) is a safety wire at 0 V that only carries current if there is a fault
- the earth wire is connected to the metal case of the toaster
- if the live wire touches the case, a large current flows from live through the case and down the earth wire
- this low-resistance path means a very large current flows
- the large current melts the thin wire in the fuse, which is in the live wire, breaking the circuit
- the case is no longer connected to the live supply, so a person touching it does not get an electric shock

How it is marked

- 5-6 marks: gives the role of all three wires and describes the full fault sequence: live touches case, large current through earth wire, fuse melts, live disconnected, no shock.
- 3-4 marks: describes the roles of at least two wires and part of the fault sequence, for example the fuse melting, but with a step missing.
- 1-2 marks: names the wires or their colours, or says the earth wire stops shocks, with little description.

What loses marks

- saying the fuse is in the earth or neutral wire
- saying the earth wire carries current all the time
- missing the step that the large current is what melts the fuse

Free for classroom and home use: print, photocopy and share. Not for resale or re-hosting.

4 Ellie, aged six, slides down a long plastic slide at a soft play centre. At the bottom her hair is standing on end. When she touches a metal hand rail she feels a small shock and hears a crack.

Explain these observations.

Separate science only

(6 marks)

Model answer

As Ellie slides down, her clothes rub against the plastic slide. This friction transfers electrons from one material to the other. If electrons move onto Ellie she becomes negatively charged, and if they move off her she becomes positively charged. Plastic is an insulator, so the charge cannot flow away and it builds up on her.

The charge spreads over her body, including along each of her hairs. All the hairs now carry the same type of charge. Like charges repel, so each hair is pushed away from the hairs next to it and from her head. This is why her hair stands on end.

The metal hand rail is a good conductor and is connected to the earth. When Ellie's hand gets very close to it, the charge on her flows very quickly between her and the rail, so electrons move suddenly through her hand. This sudden current is the small shock she feels. Just before she touches, the charge can jump across the tiny air gap as a spark, and this is what makes the crack. Afterwards she is no longer charged.

Marking points (credit any 6 relevant points, linked in a sensible order)

- as Ellie slides there is friction between her clothes and the plastic slide
- electrons are transferred from one material to the other
- Ellie becomes charged; plastic is an insulator so the charge cannot flow away
- the material that gains electrons becomes negative and the one that loses electrons becomes positive
- the charge spreads over Ellie, including over each hair
- every hair has the same type of charge, and like charges repel
- the hairs push away from each other and from her head, so they stand on end
- the metal rail is a conductor connected to earth
- when she gets close to the rail, electrons flow suddenly between her and the rail, which is felt as a shock
- the charge can jump across the air gap as a spark, which makes the crack

How it is marked

- 5-6 marks: explains charging by friction as electron transfer, explains the hair using like charges repelling, and explains the shock as charge flowing to earth through the conducting rail.
- 3-4 marks: explains two of the three observations, or all three with some vague steps such as 'static builds up'.
- 1-2 marks: says Ellie has static or that charges repel, with no linked explanation.

What loses marks

- saying positive charges or protons are transferred
- saying unlike charges repel
- not mentioning that the rail is a conductor connected to earth

Free for classroom and home use: print, photocopy and share. Not for resale or re-hosting.

5 A small solar farm in Cornwall sends 1,000,000 W of electrical power along overhead cables to a nearby town. The cables have a total resistance of 5.0 ohms. Engineers compare sending the power at 25,000 V with sending it at 400,000 V.

Use the data to calculate the current and the power wasted in the cables for each voltage. Use your answers to explain why the National Grid uses step-up and step-down transformers. (6 marks)

Model answer

Power = potential difference x current, so current = power / potential difference.

At 25,000 V: I = 1,000,000 / 25,000 = 40 A.
At 400,000 V: I = 1,000,000 / 400,000 = 2.5 A.

The power wasted in the cables is $P = I^2R$.

At 25,000 V: $P = 40^2 \times 5.0 = 1600 \times 5.0 = 8{,}000$ W.

At 400,000 V: $P = 2.5^2 \times 5.0 = 6.25 \times 5.0 = 31$ W (2 s.f.).

Sending the same power at the higher voltage gives a much smaller current. Because the power wasted depends on the current squared, cutting the current by 16 times cuts the losses by 256 times. The wasted power heats the cables and is dissipated to the surroundings, so less heating means far more of the energy reaches the town.

This is why the National Grid uses step-up transformers at power stations to increase the potential difference to very high values for transmission, which makes the system efficient. Near homes, step-down transformers lower the potential difference to 230 V, because very high voltages would be far too dangerous to use in houses.

Marking points (credit any 6 relevant points, linked in a sensible order)

- power = potential difference x current, so current = power / potential difference
- at 25,000 V, current = 1,000,000 / 25,000 = 40 A
- at 400,000 V, current = 1,000,000 / 400,000 = 2.5 A
- power wasted = current squared x resistance
- at 25,000 V, power wasted = 40 squared x 5.0 = 8,000 W
- at 400,000 V, power wasted = 2.5 squared x 5.0 = about 31 W
- a higher voltage gives a lower current for the same power, and losses depend on current squared, so they fall greatly
- wasted power heats the cables and is dissipated to the surroundings
- step-up transformers raise the voltage for transmission to make the system efficient; step-down transformers lower it to a safe value, such as 230 V, for homes

How it is marked

- 5-6 marks: correctly calculates both currents and both power losses and uses them to explain that high voltage cuts the current and therefore the heating losses, naming the roles of step-up and step-down transformers.
- 3-4 marks: calculates the currents or the losses correctly and gives a partial explanation of why high voltage is used.
- 1-2 marks: calculates one value or states that high voltage reduces energy losses without using the data.

What loses marks

- using P = VI with the transmission voltage to work out the loss in the cable
- forgetting to square the current
- saying high voltage reduces the power sent rather than the current

Free for classroom and home use: print, photocopy and share. Not for resale or re-hosting.