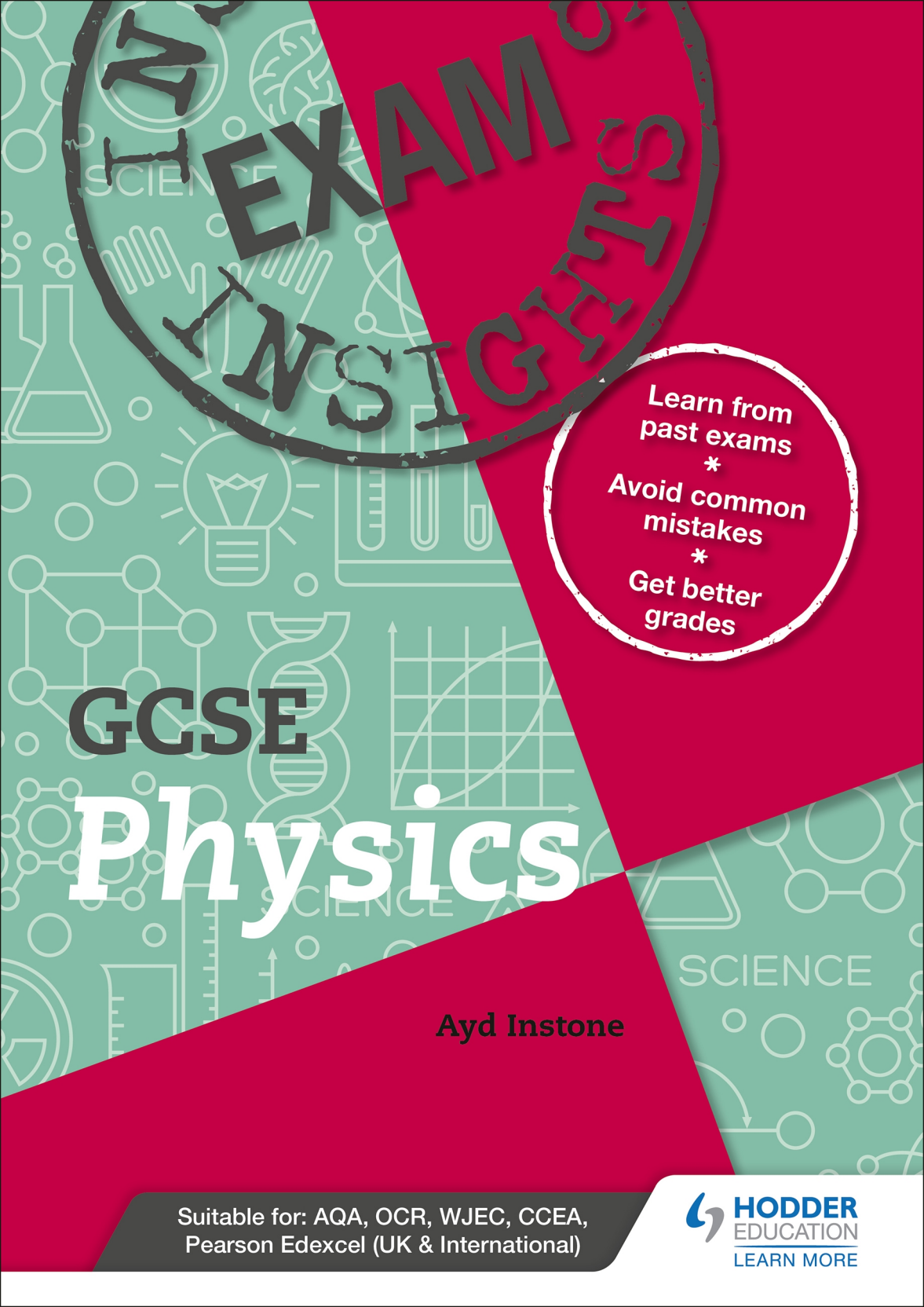
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2 Resistance

Overview

Knowledge recap

- Current, I, is the flow of charge, Q, per second: $I = \frac{Q}{t}$. It is measured in Amperes, A.
- Current is said to flow *from positive to negative*. Electrons actually flow the other way.
- *Potential difference*, V provides the 'push' in a circuit. It is measured in volts, V: $V = \frac{E}{Q}$.
- In a *series* circuit, the *p.d. is shared* between all the components and the *same current* flows through every component. In a *parallel circuit*, the *p.d. across every branch is the same* but the *current is shared* between branches.
- Resistance, R, reduces the current in a circuit. It prevents charges moving easily so they transfer their energy into heat. It is measured in, ohms, Ω.
- Potential difference. is *proportional* to current. If p.d. is increased, current will increase. How much the current will change depends on the resistance. This relationship is shown by Ohm's Law, $V = IR$, which can be rearranged to give $R = \frac{V}{I}$.
- Adding resistors in series increases the total resistance: $R_{Total} = R_1 + R_2 + R_3$
- Adding resistors in parallel allows the current to flow around more than one path decreasing the total resistance: $\frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
- The power, P of a circuit can be expressed as $P = IV$ and $P = I^2R$.

Practice questions

UpGrade
You won't always need all of the information provided to answer a question. *Choose* the information you need.

1 Two identical lamps are placed in series in a circuit. Each one has a resistance of 24 Ω and draws a current of 0.5 A from the power supply. Calculate the total resistance in the circuit. (1)

2 Describe what happens to the total resistance of a circuit, and the current through the circuit, when a second resistor is added in parallel to the existing load. (2)

3 Calculate the charge that flows through a resistor in 6 minutes when the current is 2.5 mA. Give the unit. (3)

4 Draw the circuit symbol for a variable resistor and state what it is used for. (2)

Extended responses

Worked example

1 Explain how length and thickness of a wire affect its resistance. (6)

Plan your answer to this question in the space below. Start by circling the command word, and then highlight or underline any useful information. When writing your plan, consider numbering your points in the order you would write them.

Insight

If a relationship between two changing characteristics needs to be explained, make sure you state the direction – as one gets bigger, does the other get bigger or smaller? Exam reports show that a common mistake is to simply say that one is changing.

Here is a sample answer with expert commentary:

It's unclear what 'it' is here. Always use specific words in answers: in this case, resistance.

This is a correct explanation of the inverse relationship and why a thinner wire has a greater resistance.

It changes as the length of the wire changes because the electrons have more collisions with atoms in the metal. It is inversely proportional to cross-sectional area. As a wire gets thinner its resistance increases because the electrons have less area to flow through so will have more collisions with atoms in the metal.

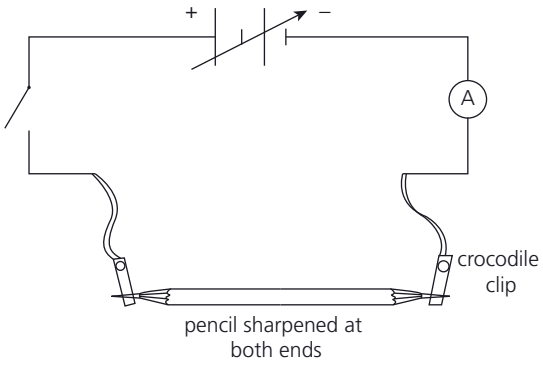
This reasoning is correct, but the statement has not said how changing the length will increase or decrease resistance.

Marks would be awarded here for explaining what causes resistance: the electrons having collisions.

This answer would get 4/6 as it gave good explanations of the inverse relationship between area and resistance, as well as identifying what causes resistance in the first place. The student has dropped marks for not being specific enough in their terminology and because they didn't give the direction of change when discussing the relationship between length and resistance.

Be the examiner

2 The diagram shows a circuit with the graphite lead of a pencil connected in series with a variable power supply (capable of delivering 2 V to 24 V), an ammeter and a switch. Explain why the pencil lead gets hot when the switch is closed. State what happens to the reading on the ammeter as the p.d. supplied is increased. (6)



Read through the sample answer below and comment on what is good and bad about it.

When the switch is closed the circuit is complete and current flows through the pencil. Graphite is a conductor but has a high resistance because it is not a metal with not as many delocalised electrons as copper. This means it is harder for the electrons to move through and there will be more collisions between the electrons and the carbon atoms, transferring their energy as heat. This will cause the graphite to get hot and it may even glow if the voltage is high enough. As the graphite heats up, its resistance increases so the reading on the ammeter will decrease.

Use the mark scheme below to help identify how the student did. Use your comments and what you have checked off to give the answer a mark.

Level descriptors	Marks	
Indicative content • The circuit is now a closed loop, allowing current to flow. • Conductors allow current to flow. • Resistance slows the flow of charge. • Resistance causes components to heat up. • When a component heats up, its resistance increases as charges (the electrons) collide more often with atoms in the material. • $V \propto I$ in an ohmic resistor only when temperature is constant.		☐ ☐ ☐ ☐ ☐ ☐
Level 3: A detailed explanation describing the movement of current from the moment the switch is closed, using correct terminology and with a clear link between cause and effect. Explanations are given for the heating observed and the correct change in the ammeter reading is given. Explanation that the current increases proportionally to the voltage, but only to a point because the heat increases the resistance of the graphite so it no longer follows Ohm's law.	5–6	☐
Level 2: Explanations are accurate but key areas have been missed or don't have enough detail. Statement that as the voltage increases the current increases, but without an explanation of how heat affects resistance.	3–4	☐
Level 1: Resistance is mentioned but answer lacks detail, accuracy or some explanations. For example, an explanation of why the current increase slows down is missing.	1–2	☐

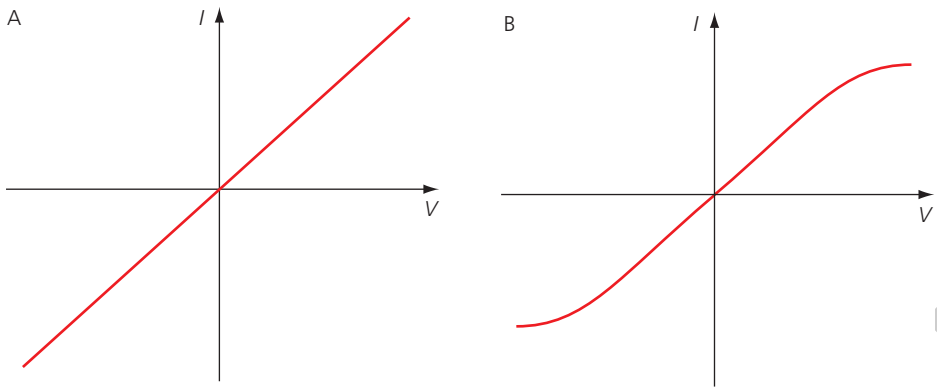
I would give this __/6 because _____

_____

_____

Practice question

3 The two diagrams below show *I*–*V* graphs for two components. Describe and explain what the graphs show, and state what the components could be. (6)



Read through the sample student answer below and make notes on how you would improve it.

Component A shows a diagonal line through zero. As the p.d. increases so too does the current. This looks like a normal resistor. Component B has a curvy line showing the current slows down as the p.d. increases. It is probably a light bulb.

UpGrade
Start by describing exactly what the graphs show and explain what they could mean.

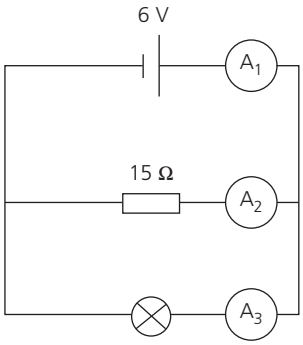
Write an improved response to this question that would get full marks.

Practical Physics

Practice questions

This question is about adding resistors in series and parallel, and the changes the additions make to the overall resistance of a circuit.

1 The circuit below was built with a bulb of unknown resistance.



1–1 Ammeter A_1 gave a reading of 2.4 A. Calculate the total resistance of the circuit. (2)

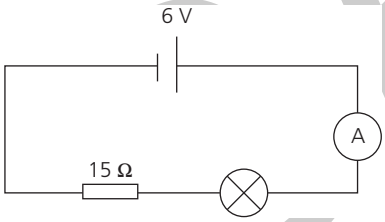
1–2 Calculate the reading on ammeter A_2. (2)

1–3 Calculate the resistance of the bulb. (3)

Insight

Many students leave out the units in their answers. In an exam, there is often a mark for the right unit.

1–4 The components are rearranged to make the series circuit shown below. Calculate the new reading on the ammeter. (3)



1–5 Explain why the current in the second circuit is so much lower than the first even though both contain the same components. (2)

This question is about components whose resistance changes under certain conditions. It tests your understanding of how to use data and present it in a suitable format – a skill that often causes problems.

2 A company wants to use an LDR as a light sensor and needs to know how the resistance of the LDR depends on the brightness of the light shining on it. An engineer wanted to design an experiment to show how the resistance of an LDR varies with the brightness of the light.

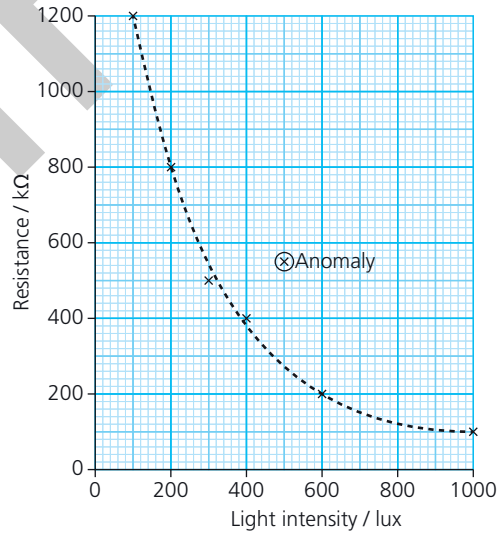
They had the following equipment available: a 6 V battery, the LDR, connecting leads, an ammeter, a voltmeter, a ruler and a high-powered torch.

2–1 On a separate piece of paper, draw a diagram of the setup they could use. (4)

2–2 Explain what readings the engineer would take and how they would use them to see how they LDR responds to light. (3)

2–3 The table shows values of LDR resistance from a component catalogue. (Lux is a measure of light intensity.) Plot a graph of the data, and draw a line of best fit. (4)

Light intensity / lux	Resistance / kΩ
100	1200
200	800
300	500
400	400
500	550
600	200
1000	100



Insight

Reports show that every year students get mixed up about whether a line of best fit should be curved or straight. See if you can line a ruler up to have roughly the same number of points on either side. If not, use a curve.

2–4 Circle the anomalous reading. (1)

2–5 Identify the type of error that could have caused the anomaly. (1)

Mathematics

The questions in this section test your knowledge of the relationship between power, current and resistance which is not given on the formulae sheet. They also test your abilities to choose which values to use and to re-arrange a formula – a task which sometimes trips up students in the exam.

Worked example

1 A hairdryer used in the UK has a power rating of 1.84 kW. Calculate its resistance, giving your answer to three significant figures. (3)

Step 1 *Write a list of what we know in base units:*

$V = 230$ V (UK mains voltage)

$P = 1840$ W (1)

Step 2 *Work out the current:*

Rearrange $P = IV$ *by dividing both sides by* V *to give* $\frac{P}{V} = I$

Substitute numbers in: $1840 \div 230 = 8$ A (1)

Step 3 *Find the resistance:*

Divide both sides of R *by* I^2 *to give* $\frac{P}{I^2} = R$

Substitute numbers in: $\frac{1840}{8^2} = \underline{28.8\ \Omega}$ (1)

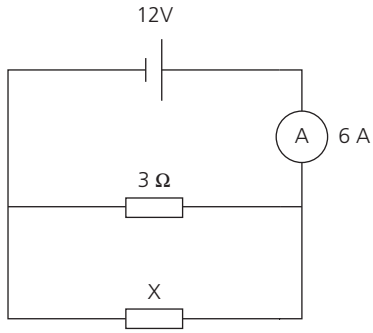
Alternatively

use $V = I\,R$ *rearranged by dividing both sides by* I *to give* $\frac{V}{I} = R$

Substitute numbers in: $230 \div 8 = \underline{28.8\ \Omega}$

Be the examiner

2 What is the resistance of the resistor labelled X? The p.d. supplied is 12 V and the ammeter reads 6 A. (2)



Looking at the three answers below, work out which one is correct and why the two others are incorrect.

A

Total resistance = $12 \div 6 = 2\ \Omega$

$\frac{1}{X} = \frac{1}{2} - \frac{1}{3}$

$\frac{1}{X} = \frac{1}{6}$

$X = \underline{6\ \Omega}$

B

$3 + X = 12$

$12 - 3 = \underline{9\ \Omega}$

C

Total resistance = $12 \div 6 = 2\ \Omega$

$\frac{1}{X} + \frac{1}{3} = 2\ \Omega = \frac{6}{3}$

$\frac{1}{3} - \frac{6}{3} = \frac{1}{X}$

$\frac{-5}{3} = \frac{1}{X}$

$X = \underline{1.67\ \Omega}$

Answer _____ is correct.

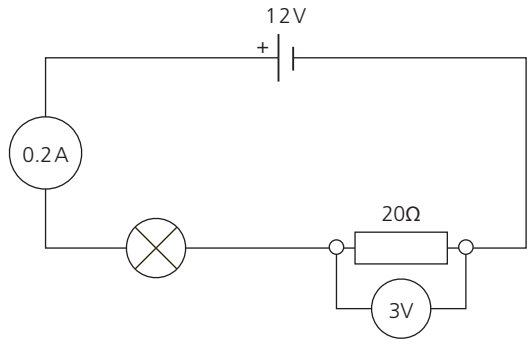
Answer _____ is incorrect because _____

Answer _____ is incorrect because _____

Practice questions

3 A kettle holds 1500 ml of water. It takes 3 minutes to bring it to the boil. The current supplied is 11.5 A and the kettle has a resistance of 20 Ω. If the price of electricity is 15 p per kWh, calculate how much it costs to boil the water. (4)

4 Calculate the resistance of the lamp in this circuit. (2)



UpGrade

List the numbers from each question (with their units) and write down any equations that contain those quantities. This is helpful preparation for questions with multiple steps because you may not be immediately sure which equations you'll need when.

5 A current of 0.2 A flows for an hour. Calculate the charge that flows. Give the unit. (3)

6 Calculate the current at point P and at point Q. (2)