3.5 Electricity: 30-minute Pack

AQA 7408 · Calculator allowed · about 30 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 This question tests core definitions in electricity.

(a) Define the electromotive force (EMF) of a source. **(1)**

(b) Define the resistivity of a material. **(1)**

(c) State Kirchhoff's second law. **(1)**

(Total for Question 1 is 3 marks)

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2 A wire in a circuit carries a steady current of 0.85 A for 12 minutes.

(a) Calculate the charge that flows through the wire in this time. **(2)**

(b) Calculate the number of electrons that pass a point in the wire during this time (charge of an electron = 1.60×10^{-19} C). **(2)**

(Total for Question 2 is 4 marks)

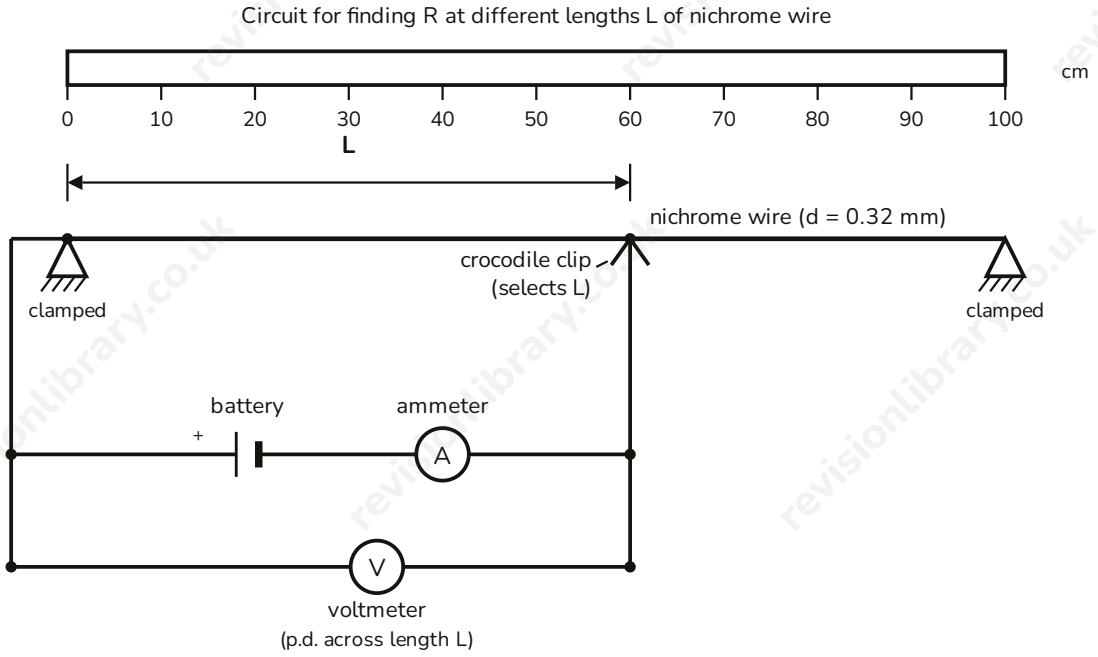
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3 Compare and explain the I-V characteristics of three components: a metal wire resistor at constant temperature, a filament lamp, and a silicon diode. Your answer should refer to the effect of temperature (where relevant) and the behaviour of charge carriers in each case.

(Total for Question 3 is 6 marks)

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4 Required practical: a student determines the resistivity of a sample of nichrome resistance wire of diameter 0.32 mm. The student measures the resistance R of different lengths L of the wire, using a crocodile clip to select each length, and plots a graph of R against L.



(a) Describe how the student should carry out this experiment to obtain a reliable set of R and L measurements, including how the diameter of the wire is measured. **(5)**

(b) Two of the student's results are: at L = 0.200 m, R = 2.80 ohm; at L = 1.000 m, R = 13.60 ohm. Show that the gradient of the graph of R against L is approximately 13.5 ohm per metre. **(2)**

(c) Calculate the resistivity of the nichrome wire, using the gradient found in part (b) and the diameter of the wire (0.32 mm). The gradient of R against L is equal to resistivity/A, where A is the cross-sectional area of the wire. **(3)**

(d) Suggest two reasons why using the gradient of a graph of R against L gives a more accurate value of resistivity than calculating resistivity from a single pair of R and L readings. **(2)**

(Total for Question 4 is 12 marks)

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Mark scheme · 3.5 Electricity: 30-minute Pack

Question 1

(a) the (total) energy transferred (from chemical or other forms) to electrical energy per unit charge that passes through the source oe **B1**

(a) Answer: The energy transferred to electrical energy per unit charge that passes through the source.

(b) a property of a material equal to RA/L, the resistance of a sample per unit cross-sectional area per unit length oe **B1**

(b) Answer: Resistivity is a property of a material, defined by resistivity = RA/L, where R is resistance, A is cross-sectional area and L is length.

(c) the sum of the EMFs around any closed loop in a circuit equals the sum of the potential differences (voltage drops) around that loop oe **B1**

(c) Answer: The sum of the EMFs around any closed loop equals the sum of the potential differences around that loop.

Question 2

(a) Q = I t = 0.85 x (12 x 60) **M1**

(a) Q = 612 C cao **A1**

(a) Answer: 612 C

(b) n = Q / e = 612 / (1.60 x 10^{-19}) **M1**

(b) n = 3.83 x 10^{21} cao **A1**

(b) Answer: 3.83 x 10^{21}

Question 3

Level 3 A full, coherent comparison of all three components, correctly describing each I-V characteristic (straight line through the origin for the resistor; curve of decreasing gradient for the lamp; negligible current until a threshold voltage then a rapid rise for the diode) and explaining the underlying physics for each (constant lattice vibration/collision rate at constant temperature; increased lattice vibration and collision rate with the drift electrons as the filament heats up; charge carriers only crossing the p-n junction in significant numbers once forward biased beyond the threshold voltage), using accurate specialist terminology throughout. **5-6**

Level 2 A correct description of the I-V behaviour of at least two of the three components, with a partial physical explanation (for example, linking temperature change to resistance change for the lamp, or describing the diode's threshold behaviour) for at least one. The answer has some logical structure and is mostly clear. **3-4**

Level 1 Basic, largely descriptive statements about the shape of one or two of the I-V graphs, with little or no physical explanation in terms of charge carriers or lattice vibration. The answer may lack clarity. **1-2**

Level 0 No relevant content, or the answer does not relate to the question. **0**

Indicative content:

- A metal wire resistor kept at constant temperature gives a straight-line I-V graph through the origin, showing that current is directly proportional to pd (Ohm's law); resistance is constant because temperature is constant, so the lattice ions vibrate with the same amplitude and the collision rate with drifting electrons does not change.
- A filament lamp gives a curve whose gradient decreases as I and V increase, so resistance increases with current; as current increases, the filament's temperature rises, the lattice ions vibrate with greater amplitude, and this increases the rate of collision between the ions and the drifting electrons, increasing resistance.
- A silicon diode carries almost no current in reverse bias, and negligible current in forward bias until a threshold (turn-on) voltage of around 0.6-0.7 V is reached; beyond this threshold, current increases very rapidly for a small further increase in pd.
- The diode's behaviour arises because charge carriers only cross the p-n junction in significant numbers once the forward bias is large enough to overcome the potential barrier at the junction; below threshold, effectively no charge carriers have enough energy to cross, so almost no current flows.
- Unlike the resistor and the lamp, the diode's I-V characteristic is not symmetrical about the origin, reflecting the fact that it allows current to flow easily in only one direction.

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Question 4

(a) measure the diameter of the wire using a micrometer (or digital calliper) at several points along the wire and at different orientations, then calculate a mean, oe **B1**

(a) clamp the wire straight along a metre ruler so it is taut but not stretched, to allow accurate length measurement **B1**

(a) use a crocodile clip to select each length L of wire in the circuit, with an ammeter (in series) and voltmeter (in parallel across the length in circuit) to find R at each L **B1**

(a) keep the current low, or switch off the circuit between readings, so the wire does not heat up (which would change its resistance/resistivity) **B1**

(a) repeat each measurement of R (at each L) and calculate a mean to reduce random error / improve reliability **B1**

(a) Answer: Measure the wire's diameter with a micrometer (mean of several readings); clamp it taut against a ruler; use a crocodile clip and ammeter/voltmeter to find R at each L; keep current low to avoid heating; repeat readings for reliability.

(b) gradient = (13.60 - 2.80)/(1.000 - 0.200), oe **M1**

(b) cso: gradient = 10.80/0.800 = 13.5 ohm/m **A1**

(b) Answer: 13.5 ohm per metre (shown)

(c) correct area from diameter: $A = \pi(0.16 \times 10^{-3})^2 = 8.0 \times 10^{-8}$ m^2 **M1**

(c) resistivity = gradient x A, ft from (b) **M1**

(c) 1.1×10^{-6} ohm metre, awrt 2 sf, cao (ft) **A1**

(c) Answer: 1.1×10^{-6} ohm metre

(d) using the gradient removes the effect of a constant systematic error, such as contact resistance at the crocodile clip, because this appears as a y-intercept rather than affecting the gradient, oe **B1**

(d) plotting several points and drawing a line of best fit averages out random errors in individual readings, oe **B1**

(d) Answer: The gradient method removes constant systematic errors (e.g. contact resistance, which shows up as an intercept), and averaging several points via a line of best fit reduces the effect of random error.

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