inkPhysics

ANSWER BOOK

Current–voltage characteristics

Electricity · Year 12

AQA 3.5.1.2 · CIE 9.3.2, 9.3.3, 9.3.4, 9.3.5 · OCR A 4.2.3(a), 4.2.3(b), 4.2.3(c)(i)

19 questions · 58 marks

NAVY EDITION

SECTION A · Warm-up

A1 For a metallic conductor at constant temperature (1), the current through it is directly proportional to the potential difference across it, $I \propto V$ (1). [2]

A2 $R = V/I = 4.0/0.20$ (1)
$R = 20\ \Omega$ (1) [2]

A3 A straight line passing through the origin, current proportional to voltage (1), with the same gradient for positive and negative pd (1). [2]

A4 Ideal ammeter: zero resistance (1). Ideal voltmeter: infinite resistance (1). [2]

A5 R is the ratio V/I of the coordinates at that point, not the gradient of the curve (1). [1]

A6 A straight line through the origin (1). The gradient is V/I, which for an ohmic conductor is its (constant) resistance (1). [2]

SECTION B · Standard

B1 The curve is S-shaped through the origin (1) and gets shallower as the voltage rises: for a given increase in V the current increases less (1). As current rises the filament heats up, so its resistance increases, curving the graph away from a straight line (1). [3]

B2 In forward bias almost no current flows until about 0.6 V (1), after which the current rises steeply (1). In reverse bias only a negligible current flows, so the diode conducts in only one direction (1). [3]

B3 At 2.0 V: $R = 2.0/0.40$ (1)
$R = 5\ \Omega$ (1)
At 8.0 V: $R = 8.0/0.80 = 10\ \Omega$ (1)
The resistance has increased, because the filament is hotter at the higher voltage (1) [4]

B4 $R = V/I$ for each pair (1)
$2.0/0.10 = 4.0/0.20 = 6.0/0.30 = 20\ \Omega$ in every case (1)
The resistance is constant, so $I \propto V$ and the component is ohmic (1) [3]

B5 Use of $R = V/I$ with the currents converted to amperes (1); forward: $R = 0.62/0.035 = 18\ \Omega$ (1); reverse: $R = 5.0/(1.0 \times 10^{-6}) = 5.0 \times 10^{6}\ \Omega$ (1); the resistance is millions of times larger in reverse, so the diode conducts in one direction only (1). [4]

B6 Both are straight lines through the origin, since each is measured at a constant temperature (1). The 80 °C line is shallower on an I–V graph: less current at every pd, so a higher resistance (1). At the higher temperature the metal ions vibrate with greater amplitude, so the electrons collide with them more frequently (1). [3]

B7 The filament's heating, and therefore its resistance, depends only on the size of the current, not its direction (1), so reversing the pd reverses the current and traces the same shaped curve (1). A diode conducts only in forward bias, beyond a threshold of about 0.6 V; in reverse it passes almost no current, so the two directions give completely different curves (1). [3]

SECTION C · Stretch

C1 Its resistance decreases as temperature rises (1). Heating releases many more free charge carriers, electrons, in the semiconductor (1), so more current flows for a given voltage (1); this effect outweighs the increased vibration of the lattice, so the resistance falls (1). [4]

C2 (a) R = 12/2.0 = 6 Ω (1) [4]
(b) P = VI = 12 × 2.0 (1)
P = 24 W (1)
When barely lit: R = 1.0/0.50 = 2 Ω, much lower, as the filament is cool (1)

C3 Ohm's law requires constant temperature (1). As the pd increases, the filament current heats it, raising its temperature and hence its resistance (1), so the current is not proportional to the voltage and the component is non-ohmic (1). [3]

C4 P: R = 2.0/0.40 = 5.0 Ω and R = 6.0/1.00 = 6.0 Ω (1); Q: R = 2.0/0.100 = 20.0 Ω and R = 6.0/0.294 = 20.4 Ω (1); P's resistance rises by 20% but Q's by only about 2% (1); Q meets the 5% requirement and P does not, so Q should be chosen (1). [4]

C5 Connect the lamp in series with an ammeter and a variable supply (1). Use a potential divider arrangement so the pd across the lamp can be varied from zero up to the maximum, with a voltmeter connected across the lamp (1). Record pairs of V and I readings over the whole range (1). Reverse the connections to the supply to obtain negative values of V and I (1). Plot I against V for both polarities (1). The graph is a curve through the origin that flattens at larger pds as the filament heats and its resistance rises (1). [6]

C6 Resistance is the ratio $R = V/I$ (1). Below the threshold the pd is non-zero while the current is almost zero, so the ratio V/I is extremely large, not zero (1). The diode's resistance is therefore very high (it behaves as an open switch), the opposite of 'no resistance' (1). [3]