InkPhysics

ANSWER BOOK

# Resistivity and superconductivity

Electricity · Year 12

AQA 3.5.1.3 · CIE 9.3.6, 9.3.8 · OCR A 4.2.4(a)(i), 4.2.4(a)(ii), 4.2.4(b), 4.2.4(c)

18 questions · 58 marks

NAVY EDITION

## SECTION A · Warm-up

**A1** $R = \rho L/A$, where $\rho$ is the resistivity, $L$ the length and $A$ the cross-sectional area (1). Resistivity has the unit ohm metre, Ω m (1). [2]

**A2** $R = \rho L/A = (1.7 \times 10^{-8} \times 2.0)/(1.0 \times 10^{-6})$ (1)
$R = 0.034\ \Omega$ (1) [2]

**A3** Below a critical temperature the resistivity of a superconductor falls to zero (1), so it conducts electricity with no resistance and no energy dissipated (1). [2]

**A4** The resistance falls (steeply) as the temperature rises (1). Used as a temperature sensor, for example in a thermostat, a car engine monitor or an incubator (1). [2]

**A5** 1.6 Ω, since $R \propto L$ and each piece has half the length (1). [1]

## SECTION B · Standard

**B1** (a) $A = \pi(d/2)^2 = \pi \times (0.20 \times 10^{-3})^2$ (1) [4]
$A = 1.26 \times 10^{-7}\ m^2$ (1)
(b) $\rho = RA/L = (0.50 \times 1.26 \times 10^{-7})/1.5$ (1)
$\rho = 4.2 \times 10^{-8}\ \Omega$ m, to the two significant figures the data carry (1)

**B2** $L = RA/\rho$ (1) [3]
$L = (0.10 \times 2.0 \times 10^{-6})/(2.8 \times 10^{-8})$ (1)
$L = 7.14$ m (1)

**B3** Resistance increases by a factor of 4 (1). From $R = \rho L/A$, doubling $L$ doubles $R$ (1), and halving $A$ doubles $R$ again, giving $2 \times 2 = 4$ times the original resistance (1). [3]

**B4** The resistance increases (1). Higher temperature makes the metal ions vibrate more, so the conduction electrons collide with them more often (1), impeding their flow and raising the resistance (1). [3]

**B5** $A = \rho L/R$ (1) $= (1.1 \times 10^{-6} \times 1.2)/15 = 8.8 \times 10^{-8}\ m^2$ (1); $d = \sqrt{(4A/\pi)}$ (1) = 0.33 mm (1). [4]

**B6** (a) $A$ = volume/$L$ = $m$/(density × $L$), with the mass in kg (1); $A = (2.85 \times 10^{-3})/(8930 \times 4.00) = 8.0 \times 10^{-8}\ m^2$ (1). (b) $R = \rho L/A$ (1) $= (1.7 \times 10^{-8} \times 4.00)/(8.0 \times 10^{-8}) = 0.85\ \Omega$ (1). [4]

**B7** $P = I^2R$ (1); $P = 480^2 \times 0.25 = 58$ kW (1); in normal operation the resistance is zero, so the power dissipated is 0 W (1). [3]

## SECTION C · Stretch

**C1** Doubling the diameter multiplies the area by 4 (1) [4]
$R = \rho L/A$, so $R_B = R_A \times 2/4$ (1)
$= 8.0 \times 0.5$ (1)
$R_B = 4.0\ \Omega$ (1)

**C2** $R = \rho L/A = (1.1 \times 10^{-6} \times 5.0)/(2.0 \times 10^{-7})$ (1) [4]
$R = 27.5\ \Omega$ (1)
$P = V^2/R = 230^2/27.5$ (1)
$P = 1924$ W (1)

**C3** As it is cooled to its critical temperature (1) the resistivity suddenly drops to zero (1). Uses include the powerful electromagnets in MRI scanners and particle accelerators, and lossless power transmission cables (1). [3]

**C4** Use of $A = \pi d^2/4$ with the diameters in metres (1); use of $R = \rho L/A$ (1); $R_W = 0.69\ \Omega$, $R_X = 5.0\ \Omega$, $R_Y = 20\ \Omega$, $R_Z = 11\ \Omega$ (1); only X lies between 4.5 and 5.5 Ω, so the student should use wire X (1). [4]

**C5** Metal: the resistance rises (1). The lattice ions vibrate with greater amplitude, so the conduction electrons collide with them more frequently, impeding the drift (1). The number of charge carriers in the metal is (almost) unchanged (1). Thermistor: the resistance falls steeply (1). Heating the semiconductor frees many more charge carriers (1). The increase in carrier numbers far outweighs the extra lattice scattering, so the net resistance drops (1). [6]

**C6** $A = \pi d^2/4 = \pi \times (0.20 \times 10^{-3})^2/4 = 3.1 \times 10^{-8}\ \text{m}^2$ (1); from $R = \rho L/A$ the gradient of R against L is $\rho/A$ (1); $\rho = \text{gradient} \times A = 2.4 \times 3.1 \times 10^{-8}$ (1) $= 7.5 \times 10^{-8}\ \Omega$ m (1). [4]