

AQA AS Resistivity thermistors and superconductivity

35–40 minutes independent practice + 15–20 minutes review | 51 marks

Specification points covered

• 3.5.1.3 Resistivity: $\rho = RA/L$; temperature effects in metal conductors and NTC thermistors; thermistors as temperature sensors and R–temperature graphs.

• 3.5.1.3 Superconductivity: zero resistivity at/below a material-specific critical temperature; strong magnetic fields and reduced transmission losses. Required practical 5: wire resistivity using a micrometer, ammeter and voltmeter.

Scenario Relay medical-delivery aircraft

An electric aircraft delivers refrigerated medical supplies. Engineers choose its power leads, test a spare wire and calibrate the cargo sensor. They also assess a superconducting ground charging link. Show working, units and sensible significant figures. Resistivities quoted for cable comparisons are at the same temperature; assume uniform circular wires.

Choosing the aircraft power leads

1. Use $\rho = RA/L$ to obtain the SI unit of resistivity. [1 mark]

2. A copper power lead has a circular cross-section of diameter 2.40 mm. Calculate its cross-sectional area in m^2 . [2 marks]

3. The lead in Question 2 is 3.00 m long. Copper has resistivity $1.72 \times 10^{-8} \Omega \text{ m}$ at the test temperature. Calculate the resistance of this lead. [1 mark]

4. A replacement copper lead is 4.50 m long and has diameter 3.60 mm. Both leads are at the same temperature. Calculate the ratio $R(\text{replacement})/R(\text{original})$, showing how both dimensions affect the result. [2 marks]

5. An engineer says, ‘Making the copper lead thicker reduces the copper’s resistivity.’ Correct this statement, distinguishing resistance from resistivity. [2 marks]

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Equal resistance does not mean equal mass

Table 1 Cable-material data at the comparison temperature. Density is mass per unit volume.

Material	Resistivity / $\Omega \text{ m}$	Density / kg m^{-3}
Copper	1.72×10^{-8}	8960
Aluminium	2.82×10^{-8}	2700

6. The aircraft team considers an aluminium lead with the same length and resistance as the copper lead in Question 3. Use Table 1 to calculate the aluminium lead's cross-sectional area and diameter. [3 marks]

7. The aircraft needs two identical leads, each 3.00 m long. Calculate the total mass of metal for (a) the copper design and (b) the aluminium design from Question 6. Which design gives the lower mass for this equal-resistance comparison? Use mass = density $\times$ cross-sectional area $\times$ total length. Ignore insulation and connectors. [3 marks]

8. After a sustained flight, the copper leads are hotter and their resistance has increased. Explain this increase in terms of lattice ions and conduction electrons. [2 marks]

9. A spare alloy wire is tested at room temperature. The measured length is 0.800 m and its diameter is 0.400 mm. The current is 0.800 A and the potential difference across that length is 0.384 V. Calculate the wire's resistivity. [3 marks]

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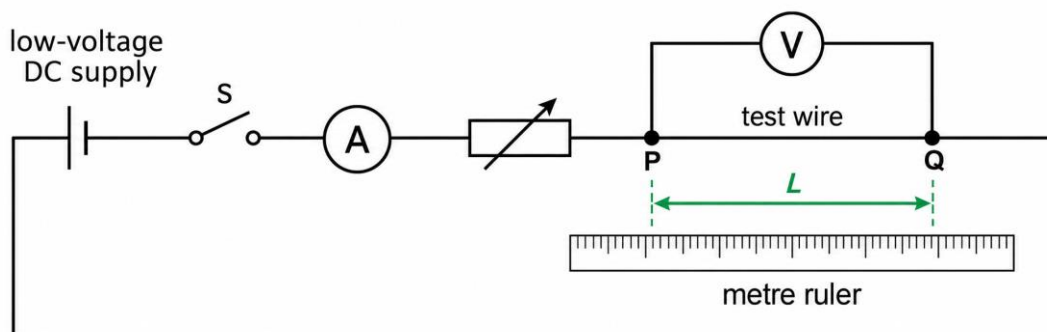
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Required practical 5 Measuring wire resistivity

10. Figure 1 shows the bench circuit used to test the spare wire. Explain why the voltmeter is connected between P and Q. State which length must be used in $\rho = RA/L$. Switch S is closed while taking readings. [2 marks]



11. A micrometer gives zero-corrected diameters of 0.398 mm, 0.402 mm and 0.400 mm at different positions along a uniform wire. Calculate its mean diameter and the cross-sectional area to use in the resistivity calculation. [2 marks]

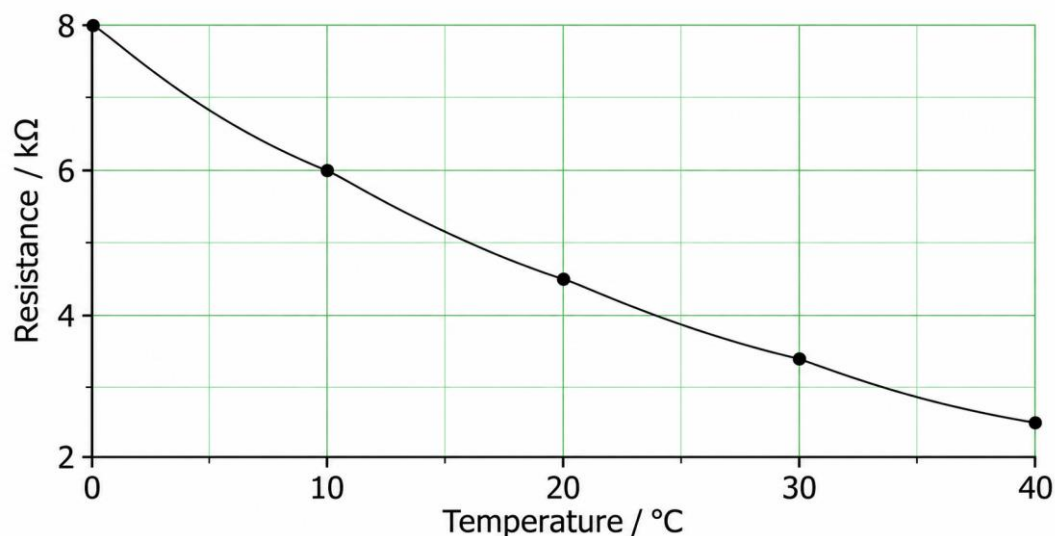
12. A technician forgets to correct a micrometer zero error and uses 0.420 mm instead of the true diameter 0.400 mm. The current, potential difference and length are correct. Calculate the percentage error in the calculated resistivity and state whether it is too high or too low. [2 marks]

13. Write a method to determine the resistivity of a uniform metal wire using the apparatus in Figure 1 and a micrometer. Scaffold your six-mark-style response under these headings: wire dimensions; electrical measurements; temperature control and reliability; calculation or graph analysis. Explain how the measurements give resistivity, not just resistance. [6 marks]



Calibrating the refrigerated cargo sensor

14. An NTC thermistor monitors the refrigerated medical-cargo pod. Figure 2 shows its calibration. Describe how its resistance changes as temperature increases, including whether the relationship is linear. [2 marks]



15. At 20 °C the potential difference across the thermistor is 0.0900 V. Read its resistance from Figure 2 and calculate the current through it. [2 marks]

16. The pod's alarm should activate when its temperature exceeds 8 °C. The thermistor resistance is 5.0 kΩ. Estimate the temperature from Figure 2 and decide whether the alarm should activate, giving a reason. [2 marks]

17. Describe how to obtain an R–temperature calibration for this thermistor using a water bath. Include paired measurements, thermal equilibrium and a precaution against self-heating. [3 marks]

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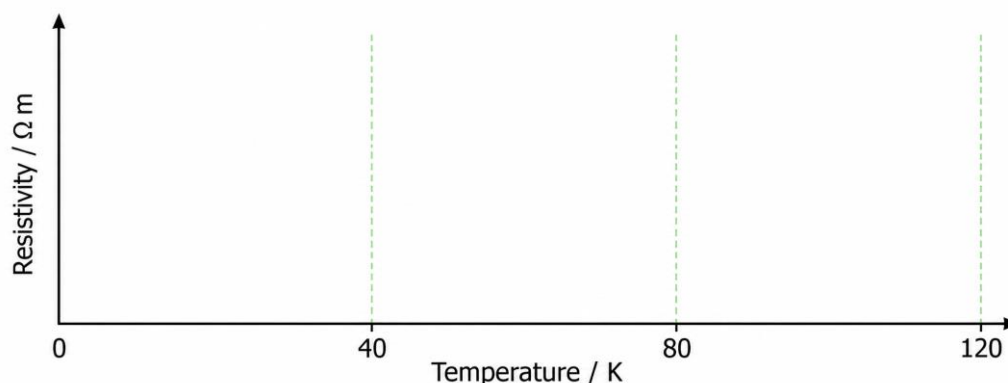
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A superconducting ground charging link

18. For a proposed ground charging link, material S has a critical temperature of 80 K. Sketch its qualitative resistivity–temperature graph on Figure 3 from 0 to 120 K. Show clearly what happens at and below 80 K and immediately above 80 K. [2 marks]



19. Two alternative materials have critical temperatures of 90 K and 35 K. Both are cooled to 77 K. State which, if either, is superconducting and justify your choice. [2 marks]

20. Superconducting coils are used to produce strong magnetic fields. Explain why superconductivity permits a large current with no resistive heating in the superconducting coil itself. [2 marks]

21. A conventional ground charging cable has resistance $0.0400\ \Omega$ and carries 500 A. Its heating loss is given by $P(\text{loss}) = I^2R$. A replacement superconducting cable has zero resistance but requires a cooling plant using 2.00 kW. Calculate the reduction in total power loss and explain why the whole system is not loss-free. Ignore all other losses. [3 marks]

22. An engineer suggests replacing the aircraft's copper power leads with superconducting leads. Give two practical difficulties that must be considered even if the superconducting leads have zero resistivity. [2 marks]

Review and improve

Check one diameter-to-area conversion and one graph reading.

Correct any statement that confuses resistance with resistivity or claims that a superconducting system needs no cooling energy.

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