# OCR A AS Resistivity 2 Practical solutions

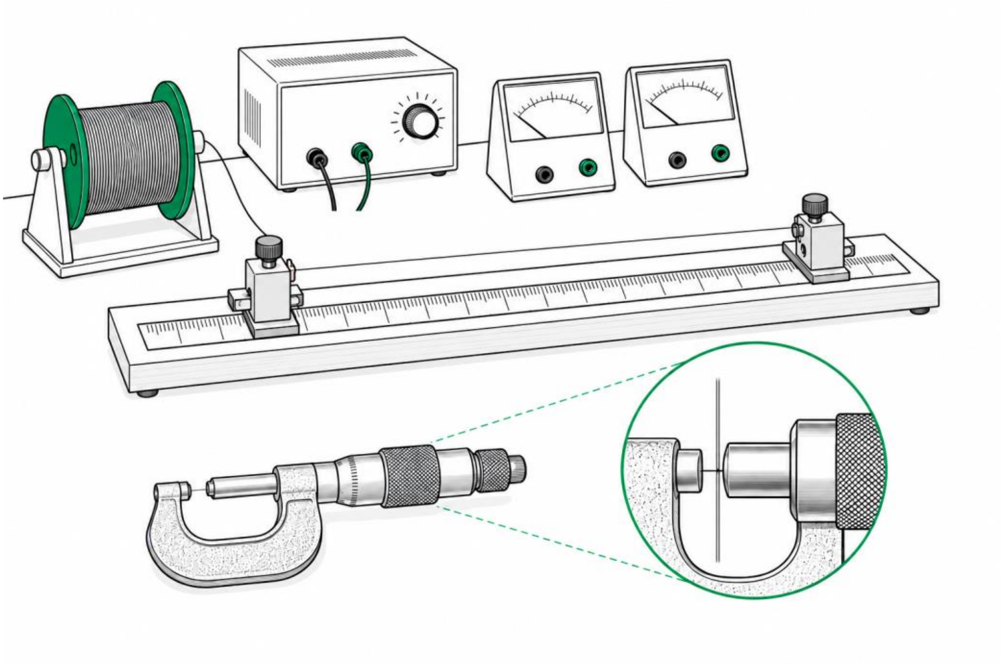
*Matching solutions and teaching prompts for the class review*

## Specification points covered

- 4.2.4(a)(i) Define resistivity using R = ρL / A.
- 4.2.4(a)(ii) Use techniques and procedures to determine the resistivity of a metal.
- 1.1.3(d)(i) Selection and labelling of axes with appropriate scales, quantities and units.
- 1.1.3(d)(ii) Measurement of gradients and intercepts from experimental results.
- 1.1.4(d) Precision and accuracy of measurements and data, including margins of error, percentage errors and uncertainties in apparatus.
- 1.1.4(e) Refining experimental design by suggesting improvements to procedures and apparatus.

**Teaching focus**

The required outcome is ρ from the gradient of R against L, using a reliable mean wire diameter.
Award practical detail only when pupils connect apparatus choices to temperature control, uncertainty or the validity of the gradient.



*Context diagram: precision-wire test bench and micrometer measurement of diameter.*

## 1. Planning the measurements and circuit

**1. State the relation between resistance R, resistivity ρ, length L and cross-sectional area A. State the SI unit of ρ.** **[2 marks]**

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|---|---|
| **Answer / mark points:** $R = \rho L/A$. The SI unit of resistivity is Ω m. | |
| **Teacher prompt / common error:** The unit is Ω m, not Ω/m. Keep ρ distinct from R. | |

**2. The factory varies the tested length of one wire. State the independent variable, the dependent variable and two quantities that should be controlled.** **[3 marks]**

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|---|---|
| **Answer / mark points:** Independent variable: contact separation or wire length L. Dependent variable: resistance R, obtained from V/I. Controls include wire material, diameter or cross-sectional area, and temperature. Any two valid controls score. | |
| **Teacher prompt / common error:** Resistance is calculated from measured V and I; current is not the intended dependent variable when L is varied. | |

**3. Draw a complete circuit for measuring the p.d. across and current through a chosen length of the test wire. Include a low-voltage d.c. supply, switch, ammeter, voltmeter and variable resistor.** **[3 marks]**

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| **Answer / mark points:** Use the supply, switch, variable resistor, ammeter and chosen wire length in one series loop. Connect the voltmeter in parallel across only the selected wire length. Standard circuit symbols and correct junctions are required. | |
| **Teacher prompt / common error:** The ammeter must be in series and the voltmeter across the selected wire length, not across the whole supply-plus-resistor circuit. | |

## 2. Temperature, length and diameter

**4. Explain how the variable resistor and switch help to keep the wire at an approximately constant temperature.** **[2 marks]**

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|---|
| **Answer / mark points:** Set the variable resistor to limit current. Close the switch only while readings are taken and open it between readings. This reduces $I^2R$ heating, so temperature and therefore resistivity stay approximately constant. |
| **Teacher prompt / common error:** Identify heating as the problem and link it to a changing temperature and resistivity. |

**5. Describe how the separation of the electrical contact points should be measured accurately.** **[2 marks]**

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| **Answer / mark points:** Measure between the actual contact points using a millimetre ruler fixed parallel and close to the wire. Use a sharp sliding contact, read perpendicular to the scale to avoid parallax, and record to the ruler resolution. |
| **Teacher prompt / common error:** The relevant length is between electrical contacts, not the full physical wire on the bench. |

**6. Describe how a micrometer should be used to obtain a reliable mean diameter for the wire.** **[2 marks]**

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| **Answer / mark points:** Check and correct any micrometer zero error. Measure gently at several positions along the wire and in two perpendicular orientations, then calculate a mean after checking for anomalies. |
| **Teacher prompt / common error:** Several positions test non-uniform diameter; two orientations test whether the wire is circular. |

## 3. Processing the measurements

**7. The micrometer has resolution 0.001 mm. Use the table to identify the anomalous reading, calculate the mean diameter from the remaining readings, and calculate the cross-sectional area.** **[3 marks]**

| Position along wire / m | Diameter in direction 1 / mm | Diameter in direction 2 / mm |
|---|---|---|
| 0.10 | 0.381 | 0.379 |
| 0.45 | 0.380 | 0.382 |
| 0.80 | 0.378 | 0.445 |

**Answer / mark points:** 0.445 mm is anomalous. Mean d = (0.381 + 0.379 + 0.380 + 0.382 + 0.378)/5 = 0.380 mm. $A = \pi d^2/4 = \pi(0.380 \times 10^{-3})^2/4 = 1.13 \times 10^{-7}\ m^2$.

**Teacher prompt / common error:** Do not include the obvious anomaly in the mean. Convert millimetres to metres before squaring.

**8. Use R = V/I to calculate the two missing resistance values in the results table. Give each to two decimal places.** **[3 marks]**

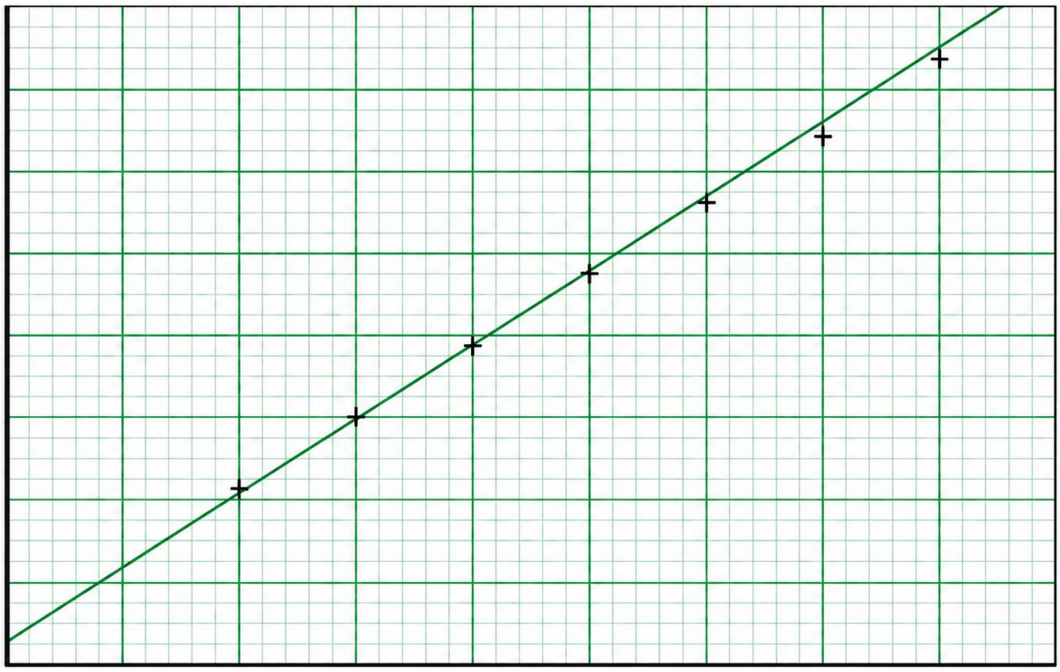
| Length L / m | p.d. V / V | Current I / A | Resistance R / Ω |
|---|---|---|---|
| 0.20 | 0.212 | 0.200 | 1.06 |
| 0.30 | 0.297 | 0.198 | — |
| 0.40 | 0.392 | 0.202 | 1.94 |
| 0.50 | 0.476 | 0.200 | 2.38 |
| 0.60 | 0.557 | 0.197 | 2.83 |
| 0.70 | 0.647 | 0.198 | — |
| 0.80 | 0.734 | 0.198 | 3.71 |

**Answer / mark points:** At 0.30 m, R = 0.297/0.198 = 1.50 Ω. At 0.70 m, R = 0.647/0.198 = 3.27 Ω. The table values are quoted to two decimal places.

**Teacher prompt / common error:** Use V/I for each row and follow the table's two-decimal-place precision.

## 4. Graph and gradient

**9. On the graph grid, label the horizontal axis length L from 0.0 to 0.9 m and the vertical axis resistance R from 0.0 to 4.0 Ω. Plot all seven points and draw a straight line of best fit.** [3 marks]



*Solution plot: seven points and a straight best-fit line.*

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| **Answer / mark points:** Award for sensible axis labels and stated scales, seven accurately plotted small points, and one straight best-fit line with points balanced about it. The line is approximately $R = 0.18 + 4.41L$ and should not be a point-to-point join. |
| **Teacher prompt / common error:** Axes must include quantity and unit. Use small crosses and a single best-fit line, not a join-the-dots curve. |

**10. Use two well-separated points on your line of best fit to determine its gradient, including a unit.** [2 marks]

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| **Answer / mark points:** Using well-separated points on the line, for example (0.10 m, 0.62 Ω) and (0.80 m, 3.71 Ω): gradient = $\Delta R/\Delta L = (3.71 - 0.62)/(0.80 - 0.10) = 4.41\ \Omega\ m^{-1}$. Values close to $4.4\ \Omega\ m^{-1}$ are acceptable. |
| **Teacher prompt / common error:** Use points on the line, separated by at least half its useful length, not one raw data point divided by its length. |

## 5. Resistivity and uncertainty

**11. Use your gradient and the mean area from Question 7 to determine the resistivity of the wire. [2 marks]**

**Answer / mark points:** Because gradient = $\rho/A$, $\rho$ = gradient × A = $4.41(1.134 \times 10^{-7}) = 5.00 \times 10^{-7}\ \Omega$ m.

**Teacher prompt / common error:** For a plot of R against L, the gradient is $\rho/A$, so multiply by area.

**12. The line of best fit has a small positive intercept on the resistance axis. Explain one likely cause and why the gradient method still gives a valid wire resistivity. [2 marks]**

**Answer / mark points:** Lead resistance and contact resistance add an approximately constant resistance at every length, producing a positive intercept. A constant added resistance changes the intercept but not the gradient, so $\rho$ = gradient × A remains valid.

**Teacher prompt / common error:** A constant extra resistance affects the intercept. It does not change the rate at which R increases with L.

**13. Treat the uncertainty in mean diameter as ±0.001 mm. Calculate the percentage uncertainty in diameter and hence the approximate percentage uncertainty in cross-sectional area. [3 marks]**

**Answer / mark points:** Percentage uncertainty in d = (0.001/0.380) × 100 = 0.263%, about 0.26%. Since A is proportional to $d^2$, percentage uncertainty in A is about 2(0.263%) = 0.53%.

**Teacher prompt / common error:** Because diameter is squared, double its percentage uncertainty to estimate the area uncertainty.

**14. The gradient is $4.41 \pm 0.10\ \Omega\ m^{-1}$. Estimate the percentage uncertainty and absolute uncertainty in the final resistivity. Use your area uncertainty from Question 13. [2 marks]**

**Answer / mark points:** Gradient uncertainty = (0.10/4.41) × 100 = 2.27%. For multiplication, percentage uncertainties add: 2.27% + 0.53% = 2.80%. Absolute uncertainty = $0.0280(5.00 \times 10^{-7}) = 1.4 \times 10^{-8}\ \Omega$ m, so $\rho \approx (5.00 \pm 0.14) \times 10^{-7}\ \Omega$ m.

**Teacher prompt / common error:** Add percentage uncertainties for the product gradient × area, then convert the percentage to an absolute uncertainty.

## 6. Evaluation and complete method

**15. Suggest three specific improvements that would increase the quality of the resistivity result. For each, state the problem it reduces. [3 marks]**

**Answer / mark points:** Any three linked suggestions: reduce current and open the switch between readings to reduce heating; repeat V and I readings and calculate means to reduce random uncertainty; use more lengths over a wide range to strengthen the best-fit gradient; use a sharp sliding contact and read the ruler without parallax to reduce length uncertainty; measure diameter at several positions and orientations to reduce sampling error; check zero errors before use.

**Teacher prompt / common error:** Each suggestion must identify what is improved; vague phrases such as 'use better equipment' are not enough.

**16. Write a complete six-mark-style method for determining the resistivity of the wire. Use the prompts: circuit and controls; length and diameter measurements; repeated V and I readings; graph and gradient; calculation of ρ; uncertainty and evaluation. [6 marks]**

**Answer / mark points:** Indicative content for Level 3 (5–6 marks): connect the supply, switch, variable resistor, ammeter and test wire in series, with a voltmeter across the selected length; keep current low and open the switch between readings to limit heating; measure L between contact points with a ruler; use a zero-checked micrometer at three or more positions and two orientations, reject anomalies, find mean d and calculate $A = \pi d^2/4$; vary L over a wide range, record repeated V and I readings and calculate $R = V/I$; plot R on the y-axis against L on the x-axis and draw a best-fit line; calculate its gradient using well-separated points; use $\rho = \text{gradient} \times A$; discuss diameter uncertainty, contact/lead resistance, anomalies and suitable improvements. Level 2 (3–4 marks) gives a workable procedure with some analysis. Level 1 (1–2 marks) gives limited procedure or limited analysis.

**Teacher prompt / common error:** A high-level response must link measurements to the graph gradient and final ρ, while controlling temperature and addressing diameter uncertainty.

### Language and method check

Say 'measure between the contact points', not simply 'measure the wire'.
Say 'draw a line of best fit with points balanced about it', not 'join the points'.
A positive intercept can represent lead or contact resistance; it does not by itself invalidate the gradient.