

Resistivity practical and data analysis solutions

AQA AS 7407 and first-year A Level 7408 | OCR A AS H156 and A Level H556

Matching solutions and teaching prompts for the class review

Specification points covered

AQA 7407 / 7408: 3.5.1.3 selected resistivity and metal-wire investigation (Required practical 5); 3.1.2 selected uncertainty and experimental error.

OCR A H156 / H556: 4.2.4(a)(i)–(ii); 1.1.3(d)(i)–(ii), 1.1.4(d)–(e), selected graph analysis, uncertainty and experimental improvement.

Northline precision-wire quality control must verify the resistivity of thin metal wire for temperature-sensor production. Use a measured resistance–length trend to obtain the material property and evaluate whether the measurement method protects its validity. The graph and uncertainty work use the same wire throughout.

1. Planning the wire measurements [5 marks]

Northline varies the tested length of one uniform wire to determine its resistivity at a controlled temperature.

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

(b) 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]

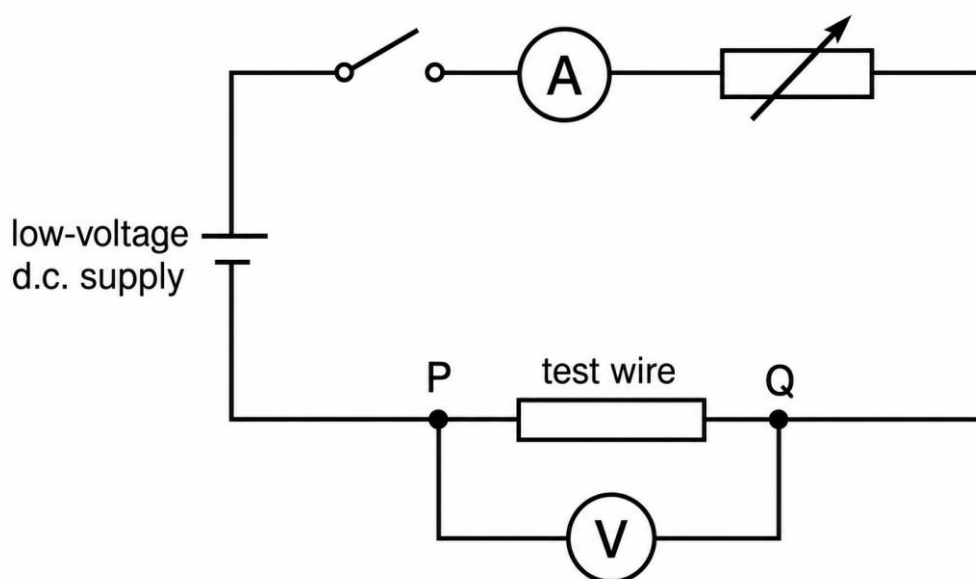
Answer / mark points: (a) $R = \rho L/A$. The SI unit of resistivity is $\Omega \text{ m}$. (b) Independent variable: contact separation or wire length L . Dependent variable: resistance R , obtained from V/I . Controls include wire material, diameter or cross-sectional area, and temperature. Any two valid controls score.

Teacher prompt / common error: Resistance comes from measured V/I ; use length between contacts and keep material, area and temperature controlled.



2. Circuit, temperature and dimensions [9 marks]

Use low-voltage equipment and a small current to avoid appreciably changing the test-wire temperature.



- (a) 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]
- (b) Explain how the variable resistor and switch help to keep the wire at an approximately constant temperature. [2 marks]
- (c) Describe how the separation of the electrical contact points should be measured accurately. [2 marks]
- (d) Describe how a micrometer should be used to obtain a reliable mean diameter for the wire. [2 marks]

Answer / mark points: (a) 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. (b) 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. (c) 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. (d) 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: The solution circuit places A in series and V across only the selected test-wire section. Check zero error and sampling of diameter.

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3. Diameter evidence and uncertainty [5 marks]

The micrometer has resolution 0.001 mm. Remeasurement confirms that one table entry is a recording error, not a real thick section of wire.

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

(a) Identify the anomalous diameter in the table. Calculate the mean from the remaining values, then calculate the cross-sectional area. [3 marks]

(b) Treat the uncertainty in mean diameter as ± 0.001 mm. Calculate the percentage uncertainty in diameter and hence the approximate percentage uncertainty in area. [2 marks]

Answer / mark points: (a) 0.445 mm is anomalous. Mean $d = (0.381 + 0.379 + 0.380 + 0.382 + 0.378)/5 = 0.380$ mm. $A = \pi d^2/4 = \pi(0.380 \times 10^{-3})^2/4 = 1.13 \times 10^{-7} \text{ m}^2$. (b) Percentage uncertainty in $d = (0.001/0.380) \times 100 = 0.263\%$, 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: Investigate an outlier before excluding it; the confirmation in this question justifies omission. Squaring the diameter doubles its percentage uncertainty.

4. Resistance data [2 marks]

The factory records paired voltage and current readings for seven contact separations. The two resistance entries marked with a dash are to be completed.

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

(a) Use $R = V/I$ to calculate the two missing resistance values in the results table. Give each to two decimal places. [2 marks]

Answer / mark points: (a) At 0.30 m, $R = 0.297/0.198 = 1.50 \Omega$. At 0.70 m, $R = 0.647/0.198 = 3.27 \Omega$. The table values are quoted to two decimal places.

Teacher prompt / common error: One mark for each correct missing resistance with the requested decimal precision.

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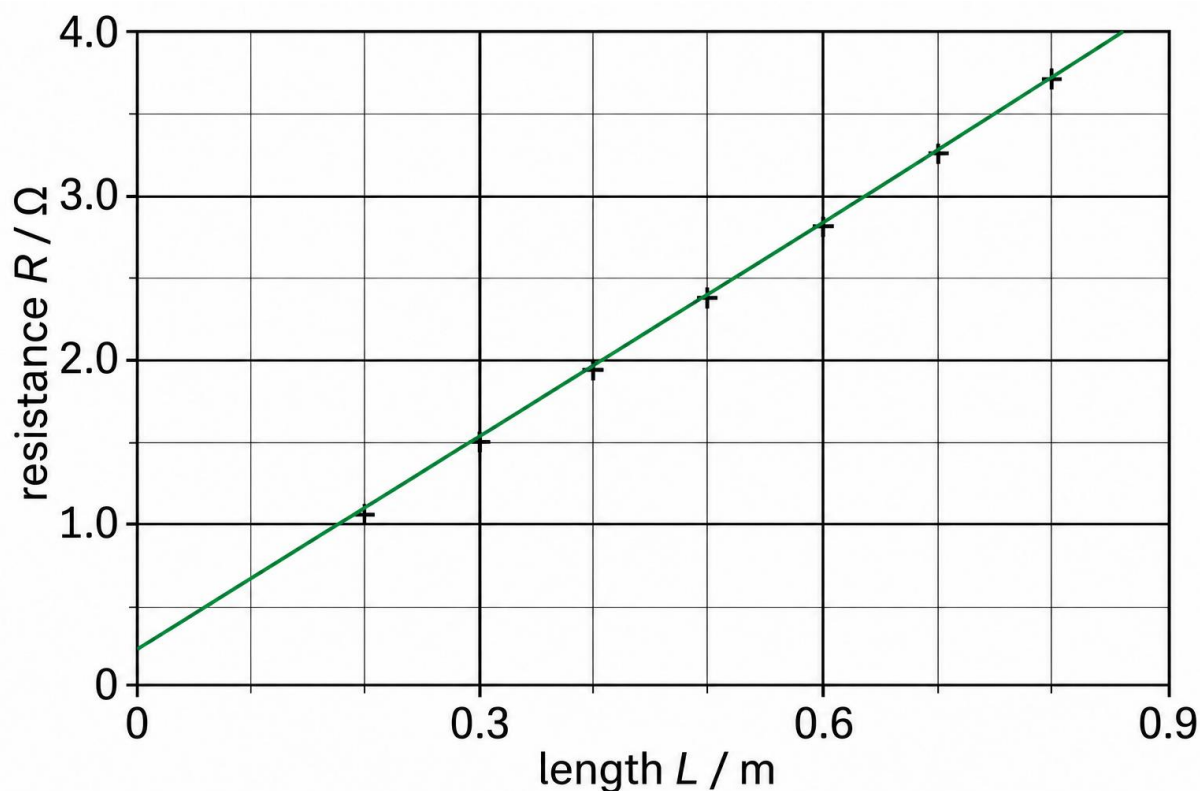
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5. Graph and gradient [5 marks]

Use all seven completed resistance values from Question 4.



(a) 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]

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

Answer / mark points: (a) 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. (b) Using well-separated points on the line, for example (0.10 m, 0.62 Ω) and (0.80 m, 3.71 Ω): gradient = $\Delta R / \Delta L = (3.71 - 0.62) / (0.80 - 0.10) = 4.41 \Omega \text{ m}^{-1}$. Values close to 4.4 $\Omega \text{ m}^{-1}$ are acceptable.

Teacher prompt / common error: Label quantity and unit on both axes, use small crosses and one balanced straight fit, then a large gradient triangle.

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6. Resistivity and the intercept [6 marks]

A small resistance offset may be present in the test rig. Use the gradient, not a single resistance/length ratio.

- (a) Use your graph gradient and the mean area from Question 3(a) to determine the wire resistivity. [2 marks]
- (b) 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]
- (c) For this calculation use gradient = $(4.41 \pm 0.10) \Omega \text{ m}^{-1}$. Estimate the percentage and absolute uncertainty in resistivity, using the area uncertainty from Question 3(b). [2 marks]

Answer / mark points: (a) Because gradient = ρ/A , $\rho = \text{gradient} \times A = 4.41(1.134 \times 10^{-7}) = 5.00 \times 10^{-7} \Omega \text{ m}$. (b) 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 $\rho = \text{gradient} \times A$ remains valid. (c) Gradient uncertainty = $(0.10/4.41) \times 100 = 2.27\%$. For multiplication, percentage uncertainties add: $2.27\% + 0.53\% = 2.80\%$. Absolute uncertainty = $0.0280(5.00 \times 10^{-7}) = 1.4 \times 10^{-8} \Omega \text{ m}$, so $\rho \approx (5.00 \pm 0.14) \times 10^{-7} \Omega \text{ m}$.

Teacher prompt / common error: A constant extra series resistance changes the intercept, not the slope. For $\rho = \text{gradient} \times \text{area}$, add percentage uncertainties.

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7. Evaluation and complete method [9 marks]

Recommend a repeatable quality-control procedure for the same wire material.

- (a) Suggest three specific improvements that would increase the quality of the resistivity result. For each, state the problem it reduces. [3 marks]
- (b) 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: (a) 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. (b) 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: Credit linked practical detail. The six-mark response must connect measurements and controls to a graph-based value of resistivity.

Review: measure between electrical contacts; obtain ρ from the gradient times the mean cross-sectional area; link every improvement to an uncertainty or systematic effect.

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