Core practical 2: Determine the electrical resistivity of a material

Objective

- To use a metal wire to determine the resistivity of a metal

Safety

- Voltages and currents are small and so present no specific hazard.
- Disconnect wire between readings as it may get hot.
- Normal laboratory safety procedures should be followed.

Specification links

- Practical techniques 1, 2, 5, 6, 7
- CPAC 2a, 2b, 4a, 4b, 5b

Procedure

1. Attach the crocodile clip to the wire at the 'zero' end of the metre ruler.
2. You will use the 4 mm plug at the free end of the second lead to make contact with different places on the wire. You will record the resistance *R* at that point and the length *l* from the 'zero' end. Place the 4 mm plug approximately 10 cm from the 'zero' end and record *R* and *l*. You will need to press the plug firmly onto the wire to obtain a steady reading on the multimeter.
3. Move the plug along the wire in steps of 10 cm and record *R* and *l* at each step.
4. Measure the diameter of the wire.
5. Estimate the uncertainties in your measurements.

Notes on procedure

- Students should be encouraged to think about the effective length of wire between the clip and the plug.

Answers to questions

1. If students originally used a multimeter that reads to two significant figures, using a voltmeter and an ammeter that reads to three significant figures would provide greater resolution.
2. It makes it easier to spot anomalies and is a good, quick way of finding a weighted average.
3. The resistance is measurable and not very small. For an insulator such as a plastic, the sample should be quite thick and fairly short so that the resistance is again measurable. This is difficult for a good insulating material.
4.
   (a) Contact resistance between wire and plug
   (b) Resistance between crocodile clip and wire at 'zero' end of wire
   (c) Crocodile clip not at 'zero' mark
   These all shift the line of best fit up the graph and do not affect the gradient so the accuracy should be unaffected by these.
5. The wire must not heat up as resistivity is temperature dependent.

Sample data

l/cm	*R*/Ω
10	2.8
20	3.9
30	5.1
40	6.2
50	7.6
60	8.7
70	9.8
80	11.4
90	11.9

This gives a value for $\rho = 5.03 \times 10^{-7}$ Ωm.

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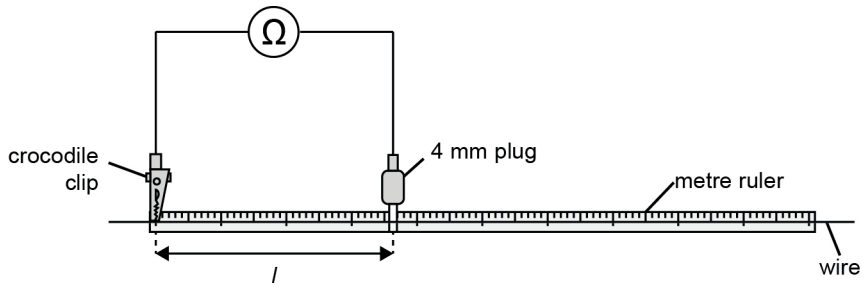
All the maths you need

- Given $\rho = \frac{RA}{l}$ where ρ and A are constant, a graph of R against l should be a straight line through the origin.
- Recognise and use expressions in decimal and standard form.
- Use ratios, fractions and percentages.
- Use an appropriate number of significant figures.
- Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers.
- Substitute numerical values into algebraic equations using appropriate units for physical quantities.
- Translate information between graphical, numerical and algebraic forms.
- Plot two variables from experimental or other data.
- Understand that $y = mx + c$ represents a linear relationship.
- Determine the slope and intercept of a linear graph.

Equipment

- 1.05 m of 34 swg constantan wire
- metre ruler
- 2 leads, one with a crocodile clip on one end
- digital multimeter switched to the lowest ohms scale with both the leads plugged in
- micrometer screw gauge

Diagram



Procedure

1. Attach the crocodile clip to the wire at the 'zero' end of the metre ruler.
2. You will use the 4 mm plug at the free end of the second lead to make contact with different places on the wire. You will record the resistance *R* at that point and the length *l* from the 'zero' end. Place the 4 mm plug approximately 10 cm from the 'zero' end and record *R* and *l*. You will need to press the plug firmly onto the wire to obtain a steady reading on the multimeter.
3. Move the plug along the wire in steps of 10 cm and record *R* and *l* at each step.
4. Measure the diameter of the wire.
5. Estimate the uncertainties in your measurements.

Analysis of results

1. Plot a graph of *R* against *l* and measure the gradient *m*.
2. Use your value of *m* and the diameter *d* to determine a value for the resistivity ρ of the metal. Use $\rho = mA$ where *A* is the cross-sectional area of the wire.
3. Determine a value for the uncertainty in your values for the gradient and A. Hence calculate the uncertainty in your value for the resistivity.
4. Look up a value for ρ from two different sources; one should be online and one from elsewhere. Use the uncertainties you calculated to comment on your measurements.
5. Explain why your graph does not pass through the origin.

Learning tips

- When two metals are in contact, an electromotive force can be established.
- The area of contact between the clip and the wire might be quite small. The area of contact between the plug and the wire is very small.

Questions

1. Explain how you might change the apparatus to calculate your value for the resistivity with greater resolution.
2. Explain why plotting a graph improves your accuracy.
3. Explain why you need to use a wire to find the resistivity of a metal and explain what shape of sample would be suitable for a plastic.
4. Identify the sources of uncertainty in this experiment. Consider the accuracy (percentage difference) of your result and comment on the effect the uncertainties might have had.
5. Explain why the current through the wire should be small.

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• To use a metal wire to determine the resistivity of a metal	• Voltages and currents are small and so present no specific hazard. • Disconnect wire between readings as it may get hot. • Normal laboratory safety procedures should be followed.
Equipment per student/group	**Notes on equipment**
1.05 m of 34 swg constantan wire	This has a resistance of about 12 Ωm^{-1}. Any similar wire is suitable but resistance per unit length should not be less than 10 Ωm^{-1}.
metre ruler	The wire should be secured to the ruler with masking tape and should hang over at each end to enable electrical connections to be made.
2 leads, one with a crocodile clip on one end	These are to make electrical connections to the wire. The moveable connection can be a 4 mm plug pressed horizontally on the wire. An alternative method for the moveable connection is to use a second crocodile clip.
digital multimeter with both the leads plugged in	Used as an ohmmeter
micrometer screw gauge	
Notes	