

Electrical Conductors

Learning Aims	
Knowledge	Skills
• Understand the difference between an electrical conductor and insulator • Understand related scientific terminology • Understand different materials have different resistivity to the flow of current • Cross-section area and length are key factors in the resistance of a component • Suitable design can reduce energy losses	• Working collaboratively • Selecting appropriate function on multimeter • Reading digital scales • Using Analogue micrometer • Reading micrometer scales • Using standard form in calculations and presenting figures

Simplifying:

Students may be given one material and conduct tests to measure the effect of increasing length. Class results can be shared for the different materials. Pre-prepared graph axes can be provided.

Normal:

Resistance = resistivity (ohms/m) x length / cross sectional area

Students explore the application of $R = \rho l / A$

where ρ is the coefficient of resistivity
 l is the length of conductor (m)
 A is the cross section area (m²)

Advanced:

Students develop way to determine the coefficient of resistivity graphically

Electrical Conductors

Teaching Guide	
0-5 minutes	Slide 3 Introduce the terminology related to the topic. See suggested narration on Notes page of PowerPoint slide.
0-8 minutes	Slide 4 Review a list of materials and identify which conduct electricity and which don't (i.e. insulators). Notes provided on the notes page of the PowerPoint slide. Metals which are used to make effective conductors of electricity, and that flexibility, toughness, weight and conductivity are all important, but that different applications require different properties. Optional homework task (see word document).
0-5 minutes	Slide 5 Metal is a very good conductor of electricity and is used to make the high-voltage transmission powerlines. The structures that hold up powerlines are called pylons and are made of steel. Insulators are used to separate the high-voltage power lines from the steel structure.
10 minutes	Slide 6 (optional) A faraday cage shows how electricity naturally seeks out an electrical conductor. Ask the class where else this ability of electricity is used. (The answer is lightning conductors on buildings).
2 minutes	Slide 7 Explain electrical resistance and resistivity and the scientific symbols used.
5-10 minutes	Slide 8 Allow students to appreciate the different properties of metals which are used as electrical conductors.
5 minutes	Slide 9 Explain how engineers compare materials and determine the best conductors (lowest resistance).
2 minutes	Slide 10 Calculating cross sectional area. Using the samples of materials you have sourced. A micrometer will be used to accurately measure the diameter of the wire or round bars. This slide shows students how to read a micrometer. Remember to explain the importance of the ratchet to avoid over-tightening
1 minute	Slide 11 A couple of examples to check students understand how to read a micrometer.
10 minutes	Slide 12 Measuring the resistance of the material. Explain how to use a Multimeter. If possible/appropriate, allow students to explore the use of these two instruments to measure the thickness of a hair, or measure the resistance of a pencil lead for example.
	Slide 13 Students use their own measurements to calculate the coefficients of resistivity for several metals. • Option a: Students work with just one metal each and then share results with the class. • Option b: Students measure and calculate for all four materials

Electrical Conductors

	Option c: Students take several measurements at different lengths of each of the wire to determine whether the resistivity is uniform. Further Extension: students could deduce an appropriate graph to plot which would give a gradient equal to the coefficient of resistivity.
30 minutes	Slide 14 With the information obtained by the students have them discuss and explain which is the best material for conducting electricity. Then have them consider and explain specific practical applications and taking into account cost. Students could be asked to write a summary of their findings for homework.
45-55 minutes	Slide 15 Take away the multimeters. The conducting putty has a coefficient of resistivity of 600 Ωm . Students design and then make a rod which will have the specified resistance. Please note: the conducting putty will leave black marks (carbon) on desks and hands which requires soap to remove.
55-60 minutes	Competition: test which team has made the most accurate conducting rod, and discuss whether the lightest or the most robust is best. Ultimately it will depend on the application, but this has not been specified.

Preparation	
Selection of brass / copper / aluminium conductors and pieces of stainless steel	Locally sourced
Multimeters	Maplin
Micrometers	Technology Supplies
Metre rulers	Locally Sourced
Conducting putty	S & C Scichem

Notes:

Very thin wire will give the best results when using 0-200 ohm multimeters, especially for copper which has such a low coefficient of resistivity

- Thin aluminium will be very weak and students may either break the wire, or cause damage with the multimeter probes which could yield unexpected results
- Because the multimeters will use a very low current, there are no electrocution or heating risks

Safety:

Hazard	Likelihood	Injury	Action Recommended
Sharp end of wire scratching eye	likely	Damage to eye or face	Wear goggles when cutting wire lengths for students Students to tape their wire samples to table top or long rulers

Electrical Conductors

Typical Results

Wire thickness (diameter) 0.152mm (38 SWG)

Additional Resistivity Coefficients can be found at http://www.engineeringtoolbox.com/resistivity-conductivity-d_418.html

Material	Diameter (mm)	Diameter (m)	Radius (m)	Area (m ²)	Resistance (Ω)	Length (m)	Coefficient of resistivity (Ωm)
Copper	0.152	1.52×10^{-4}	7.5×10^{-5}	1.81×10^{-8}	0.94	1.000	1.7×10^{-8}
Brass	0.152	1.52×10^{-4}	7.5×10^{-5}	1.81×10^{-8}	1.79	1.000	6.5×10^{-8}
Aluminium	0.152	1.52×10^{-4}	7.5×10^{-5}	1.81×10^{-8}	1.43	0.500	2.6×10^{-8}
S. Steel	0.152	1.52×10^{-4}	7.5×10^{-5}	1.81×10^{-8}	27.55	0.500	100×10^{-8} (1×10^{-6})

Length (m)	Resistance (Ω)
0.100	5.51
0.200	11.02
0.300	16.53
0.400	22.04
0.500	27.55

For the graph, either plot $R \times A$ on the y-axis against l on the x-axis, and the gradient is ρ or plot R against l , and the gradient is ρ/A . The benefit of the graphical method is that random errors are obvious when a line of best fit is added, and systematic errors are more easily identified.

Increasing the length of wire increases resistance, so wire runs need to be as short as possible, and with a large cross section area. However, this does cause the compromise of more weight. Using Aluminium reduces weight, but the wires need to be thicker than copper to give the same resistance

YouTube video links for the Faraday Cage

<https://www.youtube.com/watch?v=RFclcSOigww> (Disney film: "The Sorcerer's Apprentice")

<https://www.youtube.com/watch?v=BTysjWDI-SI>

<https://www.youtube.com/watch?v=fLiji1YqDGU>