Cambridge Assessment International Education

Teaching Pack

Factors affecting the resistance of a wire

Cambridge IGCSE™

Combined Science 0653

This *Teaching Pack* can also be used with the following syllabuses:

- Cambridge IGCSE™ (9–1) Physics **0972**
- Cambridge IGCSE™ (9–1) Co-ordinated Sciences (Double Award) **0973**
- Cambridge IGCSE™ Physical Science **0652**
- Cambridge O Level Physics **5054**
- Cambridge O Level Combined Science **5129**

Version 2.0

Cambridge Pathway

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Contents

Icons used in this pack:

Briefing lesson

Lab lesson: Option 1 – run the experiment

Lab lesson: Option 2 – virtual experiment

Debriefing lesson

Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note
Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).

There are two options for practising experimental skills. If you have laboratory facilities this pack will support you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Teaching Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed.
It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

↓

Lab lesson (1 hour*)

Option 1 – run the experiment	Option 2 – virtual experiment
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experiment skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experiment skills introduced in the *Briefing lesson*.

↓

Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this *Teaching Pack* you will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: Factors affecting the resistance of a wire

This *Teaching Pack* focuses on factors affecting the resistance of a wire.

Resistance is defined as the ratio of the potential difference across a component or wire to the electric current which flows through it. In this experiment, you will investigate the relationship between resistance and the length or the cross-sectional area of a wire.

This experiment has links to the following syllabus content (see syllabus for detail):

- P5.3 Resistance

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations** (see syllabus for assessment objectives):

- plan experiments and investigations
- make and record observations, measurements and estimates
- interpret and evaluate experimental observations and data.

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- P5.2 Current, potential difference and electromotive force (e.m.f.)
- P5.3 Resistance

Going forward

The knowledge and skills gained from this experiment will be useful for when you teach learners about potential dividers.

Briefing lesson: Making observations and planning

Resources	• Worksheets A, B, C, D and E

Learning objectives	By the end of the lesson: • ***all*** learners should appreciate some factors that affect the resistance of a wire • ***most*** learners should be able to plan an experiment to observe the factors which affect the resistance of a wire • ***some*** learners will be able to plan an experiment to observe the factors which affect the resistance of a wire and explain why.

Timings	Activity
10 min	**Starter/Introduction** Give your learners Worksheet A. This provides three different images which encourage them to think about electrical safety. Ask your learners what they see in these images and what might happen next. They can make notes next to the images on the sheet.
10 min	**Main lesson** Using Worksheet B your learners should be able to demonstrate their understanding of current and potential difference. They should use the equation $R = V/I$ to demonstrate their understanding of Ohm's Law Show your learners the equipment available for the experiment using Worksheet C.
20 min	They should work in small groups to write a plan for an experiment to investigate the effect of wire length and wire thickness on resistance. Their plan should also include a circuit diagram of their equipment set up. They can do this on Worksheet D.
10 min	Once they have completed their own plan, they should swap their work with another group. They should make suggestions of how the experiment plan could be improved and what safety precautions should be taken.
10 min	**Plenary** The learning should be consolidated using the activity on Worksheet E which will help learners focus on the I-V characteristics of a wire and a lamp.

Lab lesson: Option 1 – run the experiment

Resources	• Teacher notes • Worksheets F, G, H, I, J, K and L • Equipment as outlined in the Teacher notes
Learning objectives	By the end of the lesson: • ***all*** learners should be able to describe an experiment to investigate the factors affecting the resistance of a wire • ***most*** learners should be able to carry out an experiment to investigate the factors affecting the resistance of a wire • ***some*** learners will be able to plan and carry out an experiment to investigate the factors affecting the resistance of a wire.

Timings	Activity
10 min	**Starter/Introduction** Your learners should work through Worksheet F which will consolidate their understanding of how cross-sectional area affects resistance.
	Main lesson
10 min	Show your learners the equipment available to them. They should work in small groups to develop the plan they completed last lesson into a detailed method for today's experiment. They can use Worksheet G to help them if they need support.
10 min	Once they have decided on their method your learners can use Worksheet H (most able) and Worksheet I (less able) to record it. Worksheet J gives a completed method for you to refer to as you circulate the classroom to check your learners' work.
15 min	Your learners should collect the equipment and set up the experiment following the diagram on Worksheet J. Make sure you draw their attention to specific things they should be aware of, such as not touching the wire under investigation and ensuring that the potential difference across the wire remains constant. They should follow the method on Worksheet J and make a careful note of the results using Worksheet K.
10 min	Using their data, your learners should draw a graph of the resistance of the wire against the length of the wire and comment on their findings. Particular attention should be given to the direct proportionality between the length of the wire and its resistance. Worksheet L provides a graph outline for less able learners. **Safety** Too much current through a wire can cause overheating and therefore burns and the potential risk of fire. Do not exceed a potential difference of 3V across the wire. Ensure that learners do not touch the wire. Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate.
5 min	**Plenary** The individual groups should give feedback on their findings and discuss the factors that affect the resistance of a wire.

Teacher notes

Watch the *Teacher walkthrough* video and read these notes.

Each group will require:

- two 1.5 V cells, or a power pack.
- two crocodile clips and connecting wires
- a switch
- an ammeter and a voltmeter
- copper-nickel (Constantan) wire of different thickness, e.g. 0.71 mm, 0.46 mm, 0.32 mm and 0.24 mm
- wires of different materials (e.g. steel or copper), but same thickness (e.g. 0.32 mm)
- a metre rule
- insulating tape

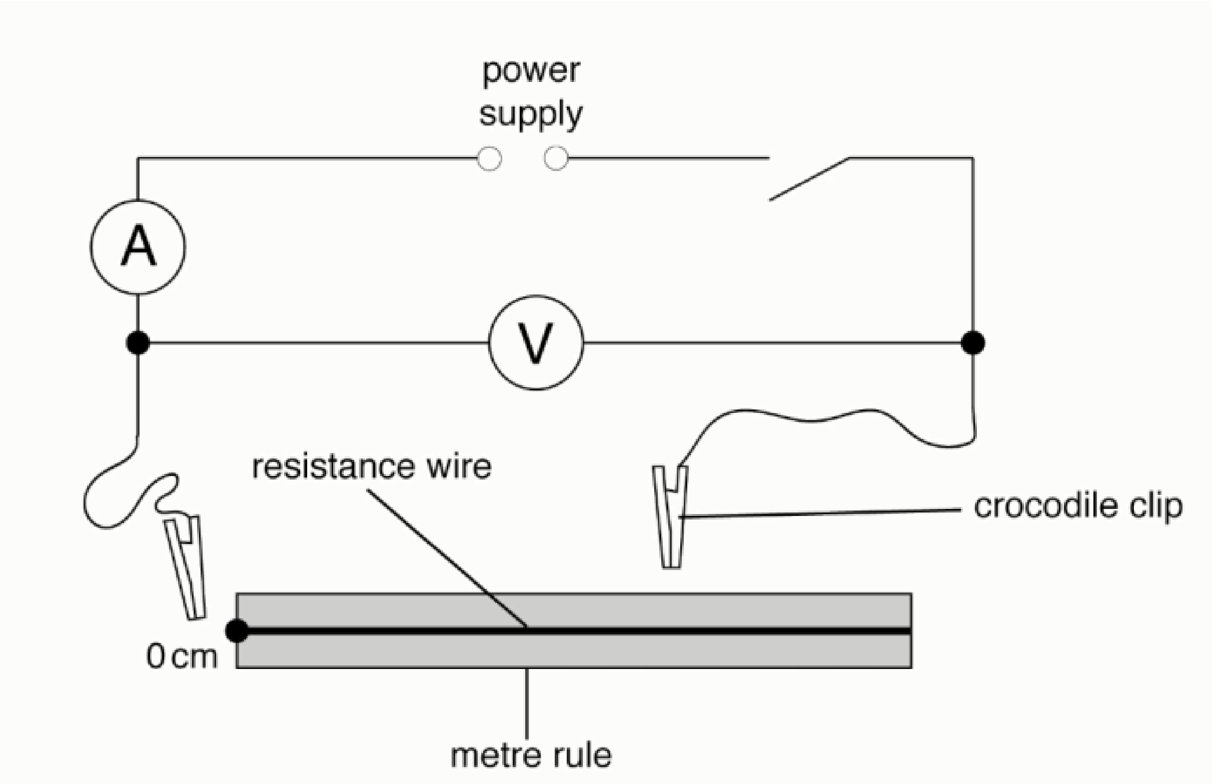
Safety

The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Substance	Hazard	First aid
—	Electrocution	**If casualty is in contact with live electricity supply:** break contact by switching off or removing the plug. If this is not possible, use a wooden broom handle or wear rubber gloves to pull the casualty clear. See a doctor. If the casualty is unconscious, check that airways are clear and that the casualty is breathing and has a pulse. If so, place the casualty in the 'recovery position'. If a pulse is found but the casualty is not breathing, artificial ventilation is necessary. If no pulse is found and the casualty is not breathing, cardio-pulmonary resuscitation is necessary.
—	Burns	Flood burnt area with water for at least 10 minutes. For serious injuries see a doctor.

Experiment set-up



Teacher method

This is your version of the method for this experiment that accompanies the *Teacher walkthrough* video.

Do not share this method with learners. Give them Worksheet J.

Before you begin

Plan how you will group your learners during the experiment session.

Think about:

- the number of groups you will need (group size 2–4 learners)
- the amount of equipment required
- whether you are investigating more than one variable

Experiment

Circulate during the experiment in case learners encounter any difficulties.

Step	Notes
1. Learners should collect the equipment they need from the front of the class.	
2. Learners should set up the circuit and ensure that the equipment is working properly before taking readings.	*Learners should ensure that they have chosen the correct range on the multimeter if they are substituting that for an ammeter*
3. Learners need to use a metre rule to measure the wire	
4. Learners should cut the wire using the wire cutters provided and attach the wire to the metre rule using insulating tape	*Cut the wire slightly bigger than the required size and use insulating tape to attach it to the metre rule.* *Learners should take care using wire cutters. Make sure the tape does not cover the wire at the 0cm point.*
5. Learners should record readings of potential difference and current for different lengths by moving the crocodile clip to different points on the metre rule.	
6. This should be repeated several times and the results carefully recorded.	
7. Learners can investigate further and use wires of different cross-sectional area or different materials	*Provide wire of different materials and cross-sectional area to enable learners to investigate further.*
8. Learners calculate the resistance for different lengths and plot a graph.	

Clear-up

After the experiment, learners should:

- switch all the equipment off and return it to the front of the class
- tidy up their work space.

Lab lesson: Option 2 – virtual experiment

Resources	• Virtual experiment video • Worksheets F, G, H, I, J, K and L

Learning objectives	By the end of the lesson: • ***all*** learners should be able to describe an experiment to investigate the factors affecting the resistance of a wire • ***most*** learners should be able, with help, to plan an experiment to investigate the factors affecting the resistance of a wire • ***some*** learners will be able to plan an experiment to investigate the factors affecting the resistance of a wire.

Timings	Activity
10 min	**Starter/Introduction** Your learners should work through Worksheet F, which will consolidate their understanding of how cross-sectional area affects resistance.
10 min 10 min 10 min 10 min	**Main lesson** Your learners should refer back to the experiment plan they completed last lesson. They should use Worksheet H (most able) and Worksheet I (less able) to record a detailed method. Worksheet J provides a completed method for you to refer to as you circulate the classroom to check your learners work. Worksheet G can be used to help learners if they need it. There are three levels of support on the worksheet Your learners will need a table of results. The independent variable i.e. the length of the wire, should go in the first column and the dependent variable, i.e. the resistance of the wire in another column They can either create this table themselves or there is a blank one on Worksheet K. Show your learners the first part of the virtual experiment video and ask them to compare the method used to their own. They should note the differences and for each difference decide which method is best. They should justify their opinion. As they watch the remainder of the virtual experiment, your learners should complete their results table. Learners should draw a graph of the resistance of the wire against the length of the wire and comment on their findings. They should pay particular attention to the direct proportionality between the length of the wire and its resistance. Worksheet L provides a graph outline for less able learners.
10 min	**Plenary** Ask your learners to give feedback on the results and discuss how factors affect the resistance of a wire. Ask them to work in groups to consider the answers to the following questions: 1. What effect does doubling the length of the wire have on the resistance? 2. What effect does halving the length of the wire have on the resistance?

Debriefing lesson: Variables

Resources	• Worksheets M and N

Learning objectives	By the end of the lesson: • ***all*** learners should be able to identify the factors that affect the resistance of a wire • ***most*** learners should be able to explain how the experimental technique could be changed to improve reliability • ***some*** learners will be able to evaluate the role of cost and availability in the choice of wire for use in different applications.

Timings	Activity
10 min	**Starter/Introduction** Using classroom discussion, make sure that your learners can identify that the length, material and cross-sectional area of a wire are all variables that can be controlled or independent depending on which factors are being investigated. All of your learners should be able to explain that it is important to have only one independent variable when carrying out an investigation. If there is more than one, it may be difficult to interpret the results and identify what is causing the changes observed.
20 min 20 min	**Main lesson** Your learners should use the data on Worksheet M to draw a bar chart of the resistance of identical lengths of wire made from different materials. Following this, they can calculate the resistance of different diameters of 1m lengths of copper wire and then plot a graph of the resistance against the cross-sectional area. Learners can use Worksheet N to help them discuss which materials should be used for wires in a variety of situations. They will need to recognise that, although some materials are very good conductors, their cost and availability also have to be considered.
10 min	**Plenary** Learners should be able to discuss whether the experiment they saw or completed last lesson produced reliable results. They should then suggest ways in which the experiment could have been improved. They should pay particular attention to how they could improve the reliability of the data.

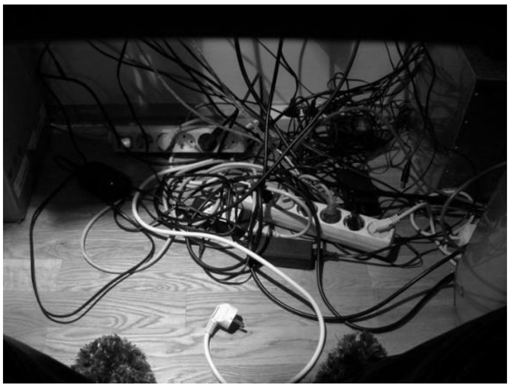
Worksheets and answers

Worksheet A: Observations

Work in pairs and look at the images below. Ask yourselves the following questions and make a note of your ideas:

- What do you notice about each picture?
- What do you think could happen next?
- What observations can you make about electrical safety?
- Give feedback on your observations to the rest of the class

Notes



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Worksheet B: Ohm's Law

Read the following information and complete the questions below.

The electrical **resistance** of a wire is a measure of how difficult it is to pass an electric current through that wire; the higher the resistance, the smaller the current. Resistance is measured in ohms (Ω).

The resistance of a component can be found by measuring the current flowing through it, and the *potential difference* across it.

Below is the relationship between potential difference, current and resistance:

$$V = I \times R$$

V is the potential difference in volts (V)
I is the current in amperes (amps, A)
R is the resistance in ohms (Ω)

To find the resistance the equation can be rearranged:

$$R = \frac{V}{I}$$

For example:
If a current of 6 A flows through a 240 V lamp, what is the resistance of the lamp?

$R = \frac{V}{I}$

$R = \frac{260}{6}$

$R = 40\ \Omega$

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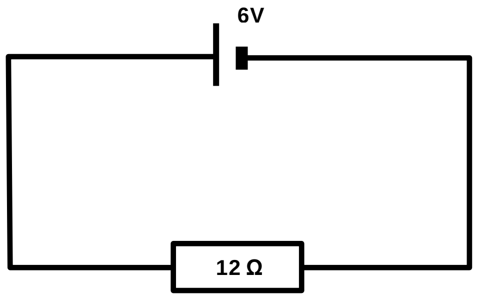
Worksheet B: Ohm's Law

1. Calculate the current in the circuit below:



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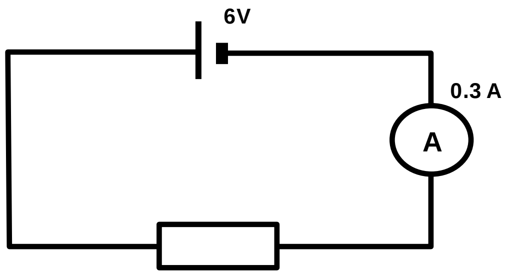
2. Calculate the resistance in this circuit:



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3. A 50 Ω resistor has a current of 3 A flowing through it. Calculate the potential difference across the resistor.

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4. A 600 Ω resistor has a current of 0.8 A flowing through it. Calculate the potential difference of the circuit.

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5. In a cell phone the keyboard circuit has a resistance of 4000 Ω. The potential difference applied across the circuit is 1.6 V. What is the current in the keyboard circuit?

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6. Calculate the resistance of a small torch if the current is 0.75 A and the voltage is 6 V.

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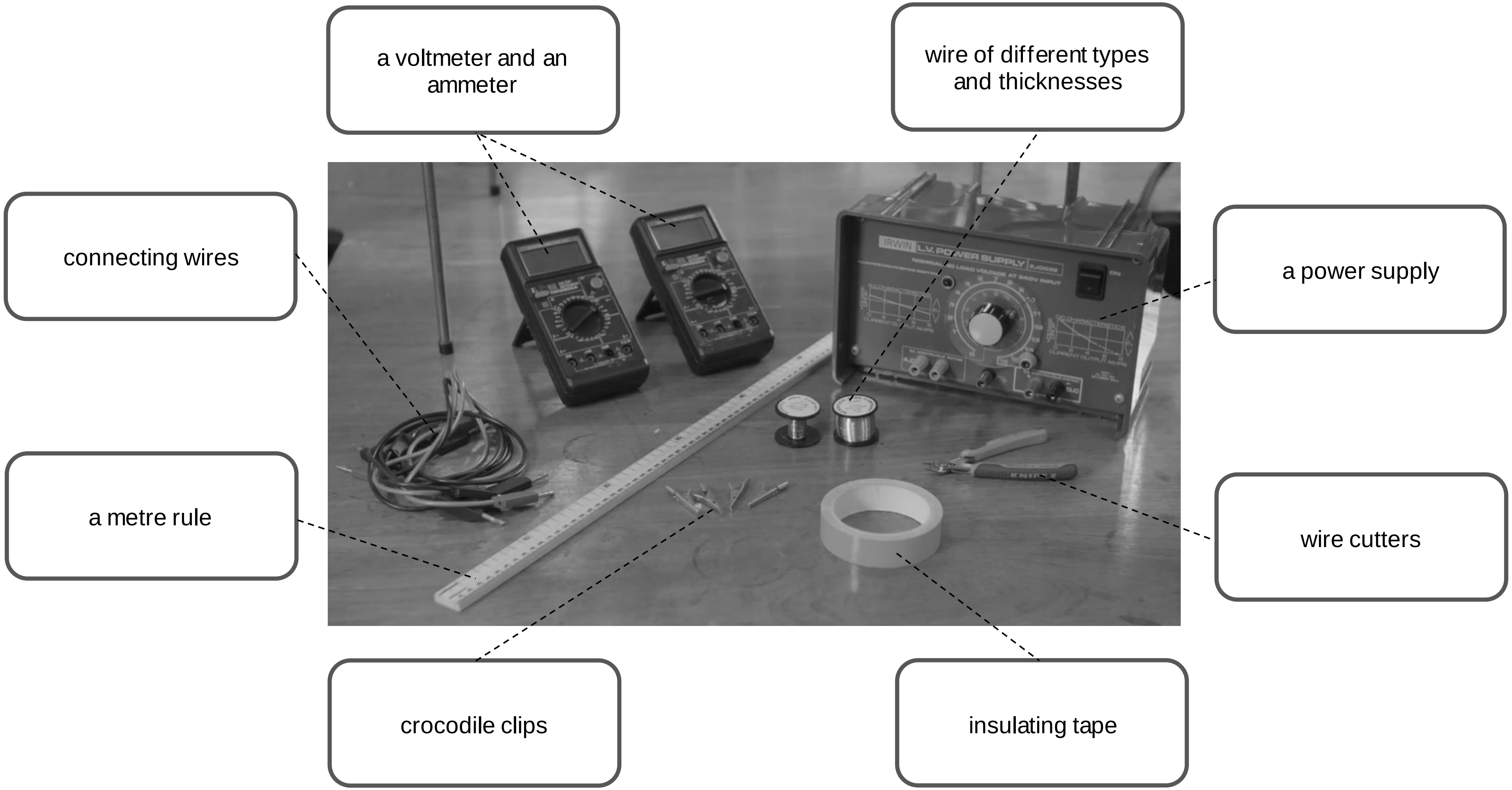
Worksheet C: Available equipment



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Worksheet D: Experiment plan

Use the space below to plan your experiment to investigate the factors that affect the resistance of a wire.

Circuit diagram	Independent and dependent variables:	Safety considerations
	....	....
	....	....
	....	....
	....	....
	....	....

Brief outline of how the experiment will be carried out:

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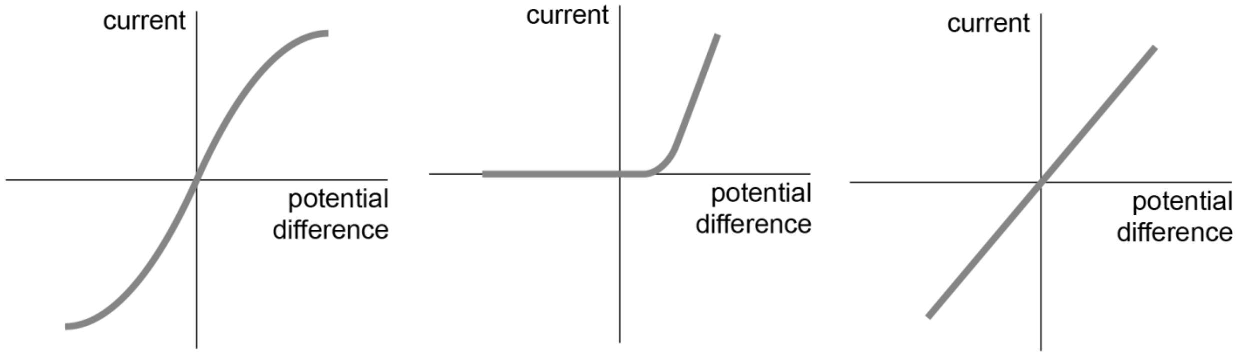
Worksheet E: Electrical characteristics

The graphs below display the electrical characteristics of a diode, a resistor and a lamp.



1. Discuss the features of each graph and use the spaces to identify each graph. Use the following labels:
   a. diode
   b. resistor
   c. lamp
2. Describe each graph in detail, commenting on what happens to the resistance

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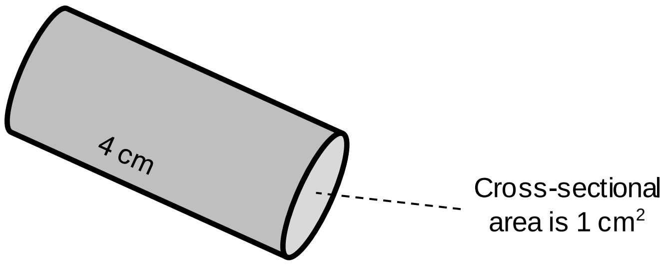
Worksheet F: Estimating the resistance

In the following examples, you are going to consider the effects of cross-sectional area on resistance.

Remember: $V = I \times R$

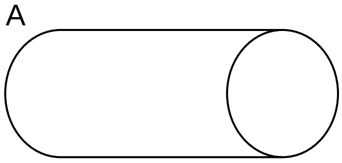
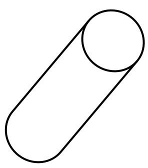
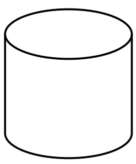
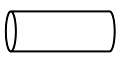
V is the potential difference in volts (V)
I is the current in amperes (amps, A)
R is the resistance in ohms (Ω)

The shape below has been connected to a simple circuit. It has a potential difference of 2 V and 0.2 A current.



Calculate the resistance in Ω ……………………..

If the voltage stays constant estimate what you think the resistance would be across the shapes below.

Shape	Cross-sectional area / cm^2	Length / cm	Estimated resistance / Ω
A 	1	8	
B 	1	16	
C 	2	8	
D 	0.5	8	

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Worksheet G: Planning an experiment

Use the suggestions below to help you decide how you could use the apparatus you have been shown to investigate the factors that affect resistance in a wire.

Depending on how confident you feel about planning your method, choose the column that gives you the right level of support.

Low-level support	Mid-level support	High-level support
What readings do we need to take if we are going to measure the resistance of a wire?	What equipment do we need to use to take these readings?	How can we calculate the resistance of the wire after we have taken the readings? Hint: look at Ohm's Law
What lengths of wire should we use to investigate how the resistance of a wire varies with length?	Ensure that you do not change the material that the wire is made out of, or the cross sectional area of the wire if you are going to vary the length of the wire. How can we measure the cross-sectional area of the wire?	What will happen when we turn the power on?
How is electricity conducted by means of free electrons?	How does electricity flow through a wire?	Hint: Free electrons are given energy and as a result, move and collide with neighbouring free electrons. This happens across the length of the wire. The longer the wire, the more collisions there will be.

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Worksheet H: Writing a method

Use the space below to record your method.

An investigation to study the factors affecting resistance in a wire

Equipment	Method
…………………………………………………	…………………………………………………………………………………
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Don’t forget to consider safety precautions

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Worksheet I: Writing a method with support

Use the space below to record your method.

An investigation to study the factors affecting resistance in a wire

Equipment	Method
	Think about these questions: 1. What will you use to find the resistance? 2. What will you use to measure the current and voltage? 3. How long will the length of wire be? How many readings are you going to take? Why? 4. Are you going to repeat the readings? Why?

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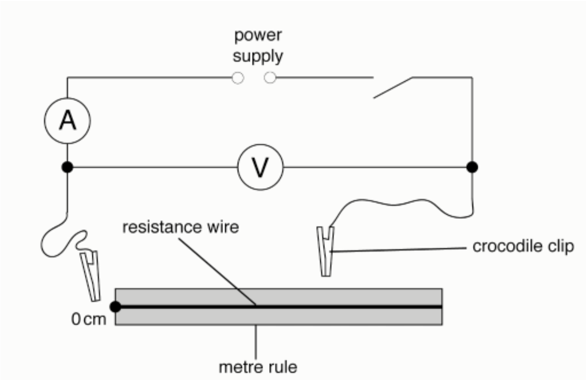
Worksheet J: Method

Connect the apparatus together as shown in the diagram below:



Measure and cut a 110 cm length of the 0.32 mm copper-nickel wire.

Attach the wire to the metre rule using insulating tape. Ensure that the wire is straight and there are no twists, knots or bends.

The tape should not cover the end of the metre rule; make sure it is a few centimetres from the end.

Connect one crocodile clip to the 0 cm point on the ruler.

Connect the second crocodile clip to the wire at the 10 cm mark. By doing this, you are effectively making the wire in the circuit 10 cm long.

Before you switch on your circuit, check that it is set up as shown in the diagram and make sure that you have a results table ready so that you can record your data.

Turn on the power and record the readings from the ammeter and voltmeter for the 10 cm length of wire.

Now move the crocodile clip from the 10 cm to the 30 cm point. You should notice that the potential difference shown by the voltmeter does not change, but that the current through the wire decreases as the length increases. Record the readings for the 30 cm mark.

Move the crocodile clip again and record the readings for the 50 cm mark and then keep recording the data as you move the crocodile clip along the wire in 20 cm increments.

If you have different wire thicknesses or wire types, you can use these to change the variables in the experiment to see how they affect the resistance in the wire.

Once all of the data has been collected, you can draw a graph of the results. Make sure your independent variable (the length) is plotted on the *x*-axis and your dependent variable (the resistance) on the *y*-axis. Label each axis and evenly space the units so that you make the best use of the space on your graph paper. Join the points using a straight line of best fit.

Make sure any additional data is plotted as a separate line and is carefully labelled.

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Worksheet K: Table of Results

Experiment 1

Wire type used:			
Wire thickness:			
Wire length (cm)	**Potential difference (V)**	**Current (A)**	**Resistance (Ω)**
10cm			
30 cm			
50 cm			
70 cm			
90 cm			

Experiment 2

Wire type used:			
Wire thickness:			
Wire length (cm)	**Potential difference (V)**	**Current (A)**	**Resistance (Ω)**
10cm			
30 cm			
50 cm			
70 cm			
90 cm			

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Worksheet L: Plotting graphs

Use the outline below to plot a graph of your results.

If you add more than one line, make sure you create a key.

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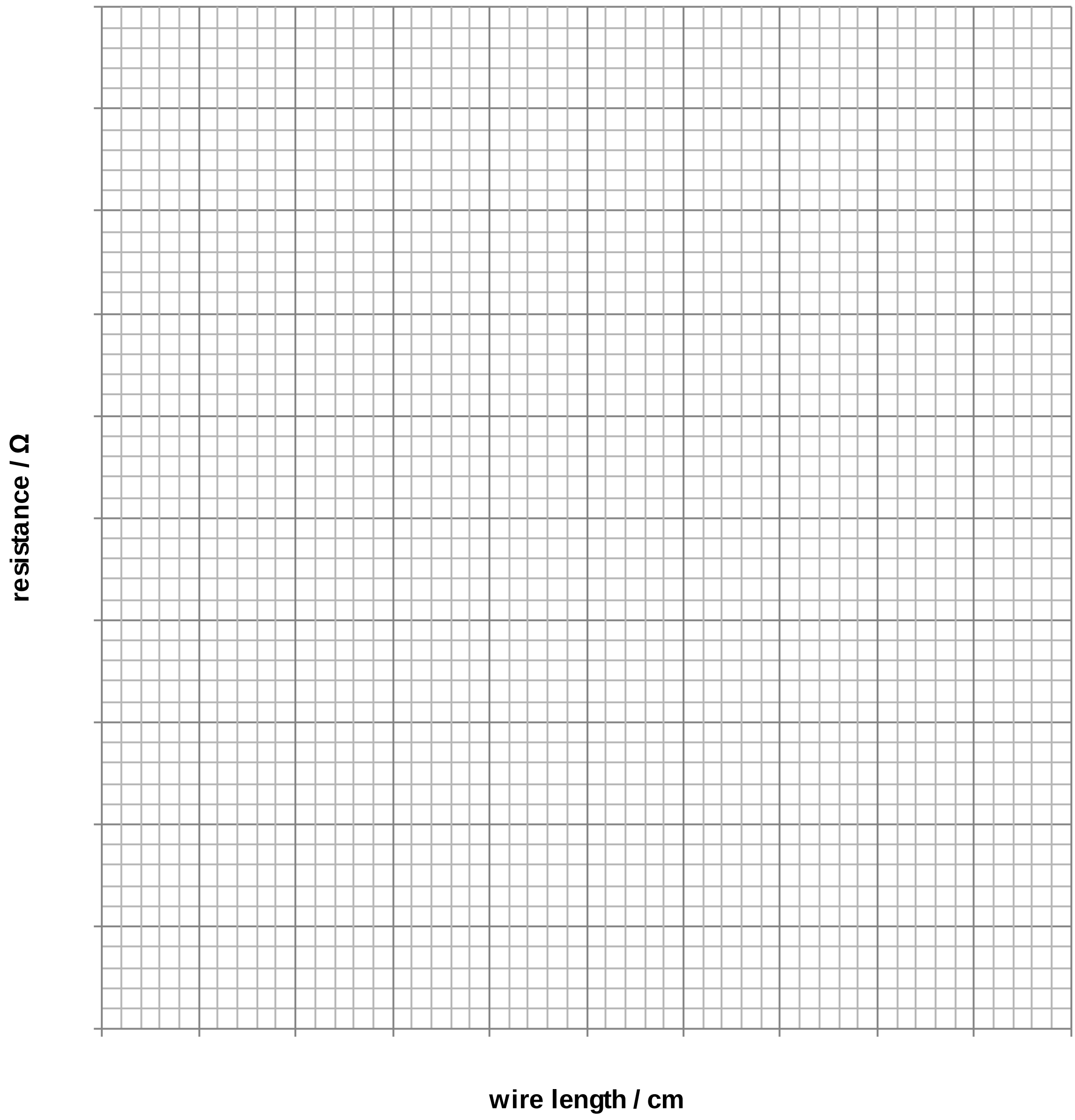

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Worksheet M: Variables

The table below shows the resistance of a 1 m length of seven different materials. Each material has the same cross-sectional area.

Plot a bar chart of the resistance of each material to show how this varies.

Material	Resistance / × 10^{-8} Ω
Silver	1.59
Copper	1.68
Aluminium	2.65
Tungsten	5.6
Iron	9.71
Platinum	10.6
Lead	22

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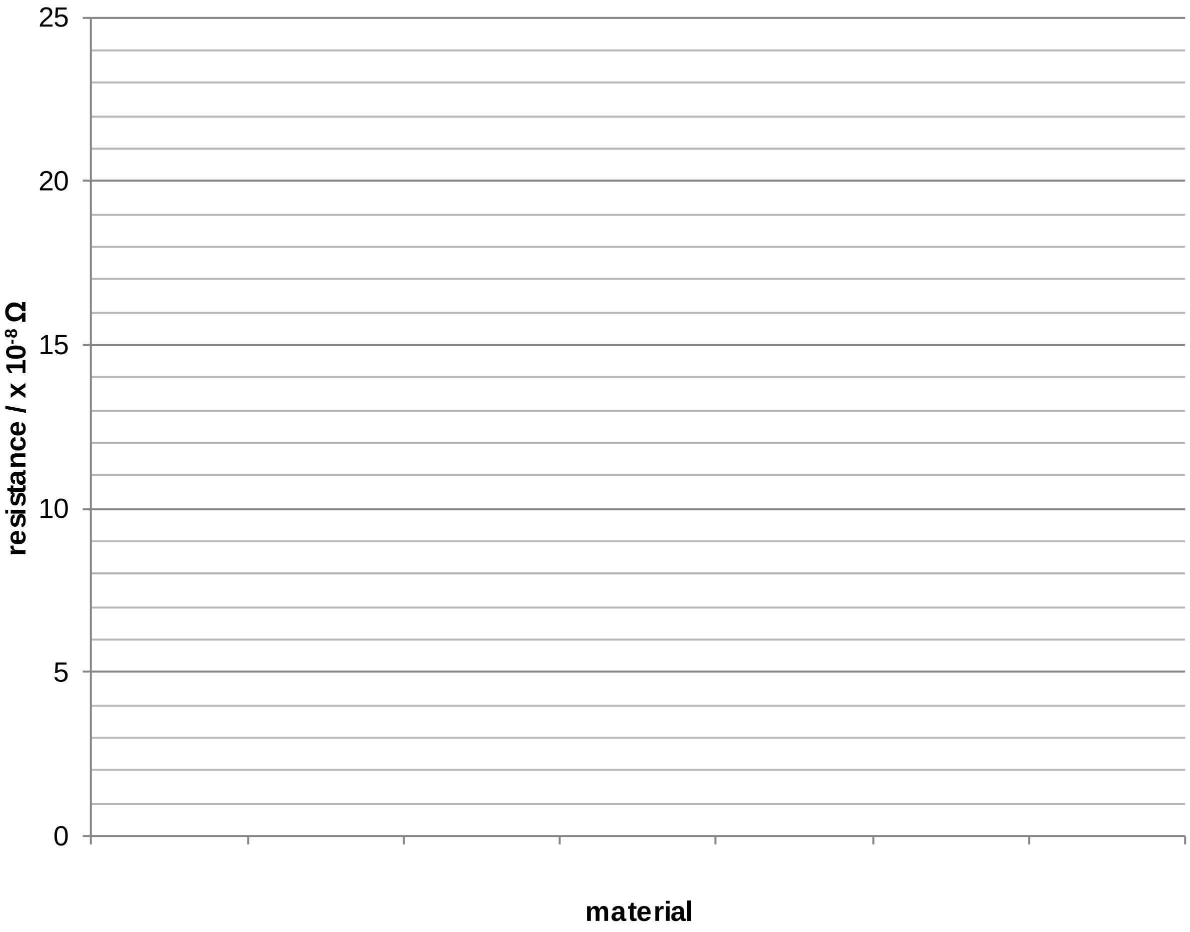

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Worksheet M: Variables

Below is a table of data for different diameters of 1 m lengths of copper wire.

1. Determine the cross-sectional area of each wire. Remember:
   Cross-sectional area = πr^2
2. Plot a graph of the resistance against the cross-sectional area

Diameter / mm	Radius / mm	Cross-sectional area	*Resistance / Ω*
2.642			
1.626			
0.914			
0.559			
0.376			
0.274			
0.193			

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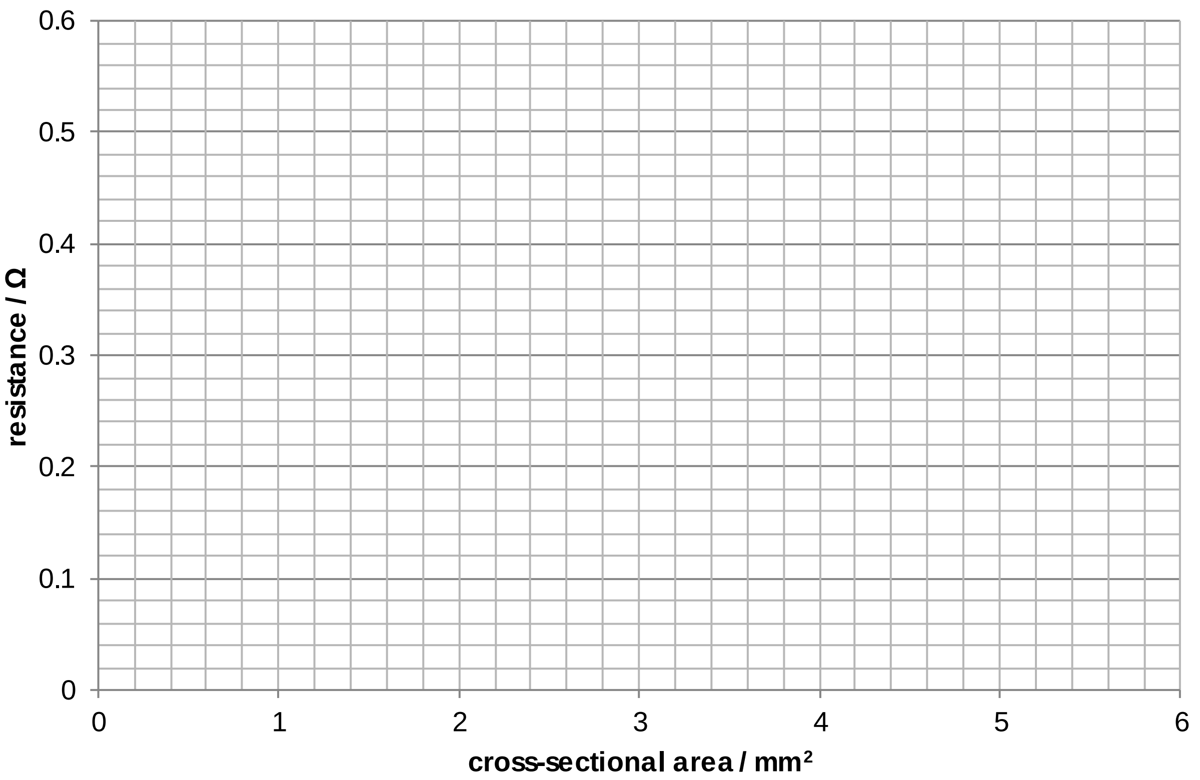

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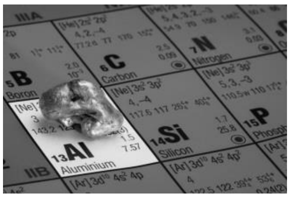
Worksheet N: The best wire for the job

Using the table below, discuss which wire or material would be the best for the following jobs:

1. Power cables which have to cover long distances
2. Wiring in houses
3. Wires for speakers
4. Electrical contacts in a car air bag

Wire type and wire material	Characteristics
Solid wire 	• low surface area, so less likely to corrode • strong and rigid • likely to break if bent repeatedly • not good for high voltages
Stranded wire 	• lots of smaller wires twisted together • the air spaces between the smaller wires mean there are high resistance levels in stranded wire • greater conductivity than solid wire • more durable and flexible than solid wire • more expensive than solid wire
Copper and aluminium  	• not the best conductors • abundant and low cost
Gold 	• resistant to corrosion • an excellent conductor • not abundant and the cost is high
Steel-reinforced aluminium cable 	• aluminium strands are wrapped around a steel centre wire • the steel centre wire is simply there for strength, meaning the wire can be used in long lengths • aluminium is cheaper than copper and does not corrode

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Worksheet A: Answers

Work in pairs and look at the images below. Ask yourselves the following questions and make a note of your ideas:

- What do you notice about each picture?
- What do you think could happen next?
- What observations can you make about electrical safety?
- Feedback your observations to the rest of the class.

Notes

Overloaded sockets are dangerous. If too many appliances draw power from one socket it can start overheating and catch fire.

Damaged wires may expose live connections. This leads to a risk of electrocution and potential fires if sparks are produced.

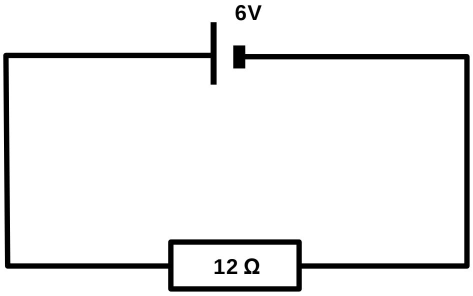
Wires should be checked carefully and any damaged sections replaced.

Fairy lights often use LED bulbs. These are preferable as they remain cool and also require lower voltages.

They are less likely to cause electrocution as there is no way to remove separate bulbs and expose live connections. This is often the case with incandescent fairy lights.

Worksheet B: Answers

1. Calculate the current in the circuit below:

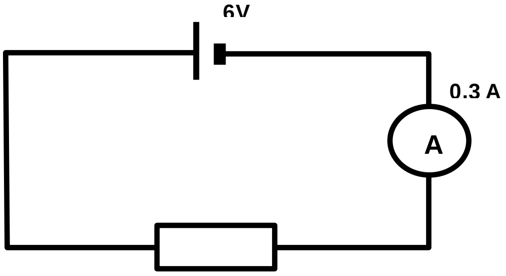


$I = V/R$

$I = 6/12$

$I = 0.5A$

2. Calculate the resistance in this circuit:



$R = V/I$

$R = 6/\ 0.3$

$R = 20\ \Omega$

3. A 50 Ω resistor has a current of 3 A flowing through it. Calculate the potential difference across the resistor.

$V = I \times R$

$V = 3 \times 500$

$V = 1500\ V$

4. A 600 Ω resistor has a current of 0.8 A flowing through it. Calculate the potential difference of the circuit.

$V = I \times R$

$V = 600 \times 0.8$

$V = 480V$

5. In a cell phone, the keyboard circuit has a resistance of 4000 Ω. The potential difference applied across the circuit is 1.6 V. What is the current in the keyboard circuit?

$I = V/R$

$I = 1.6\ /\ 4000$

$I = 0.00004A$

6. Calculate the resistance of a small torch if the current is 0.75 A and the voltage is 6 V.

$R = V/I$

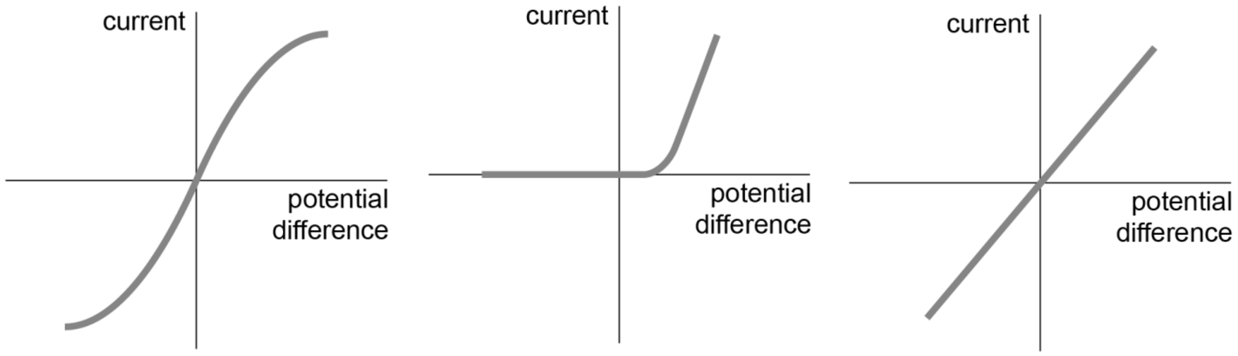
$R = 6/0.75$

$R = 8\ \Omega$

Worksheet E: Answers

The graphs below display the electrical characteristics of a diode, a resistor and a lamp.

The graphs below display the electrical characteristics of a diode, a resistor and a lamp.



Lamp	*Diode*	*Resistor*

1. Discuss the features of each graph and use the spaces to identify each graph. Use the following labels:
   a. diode
   b. resistor
   c. lamp
2. Describe each graph in detail, commenting on what happens to the resistance

A filament lamp contains a thin coil of wire called the filament. The filament heats up when an electric current passes through it, and as a result light is produced. The resistance of a lamp increases as the temperature of its filament increases. Therefore, the current flowing through the lamp is not directly proportional to the voltage across it.

A diode is a component which can be used to control the potential difference in a circuit and it is usually used to make logic gates. A diode has a very high resistance in one direction which means that the current can't flow and much lower resistance in the other direction so that current can only flow in that direction.

In a resistor the current flowing through it at a constant temperature is directly proportional to the potential difference across it and therefore the graph is a straight line through the origin.

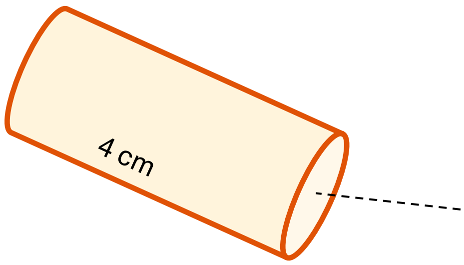
Worksheet F: Answers

In the following examples, you are going to consider the effects of cross-sectional area on resistance.

Remember: $V = I \times R$

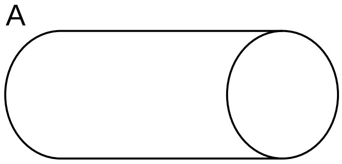
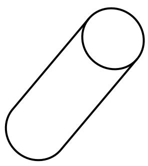
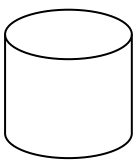
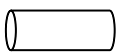
V is the potential difference in volts (V)
I is the current in amperes (amps, A)
R is the resistance in ohms (Ω)

The shape below has been connected to a simple circuit. It has a potential difference of 2 V and 0.2 A current.



Calculate the resistance in Ω

If the voltage stays constant estimate what you think the resistance would be across the shapes below.

Shape	Cross-sectional area / cm^2	Length / cm	Estimated resistance / Ω
A 	1	8	20
B 	1	16	40
C 	2	8	10
D 	0.5	8	40

Worksheet K: Answers

This data is collected from the *Virtual Experiment*

Experiment 1

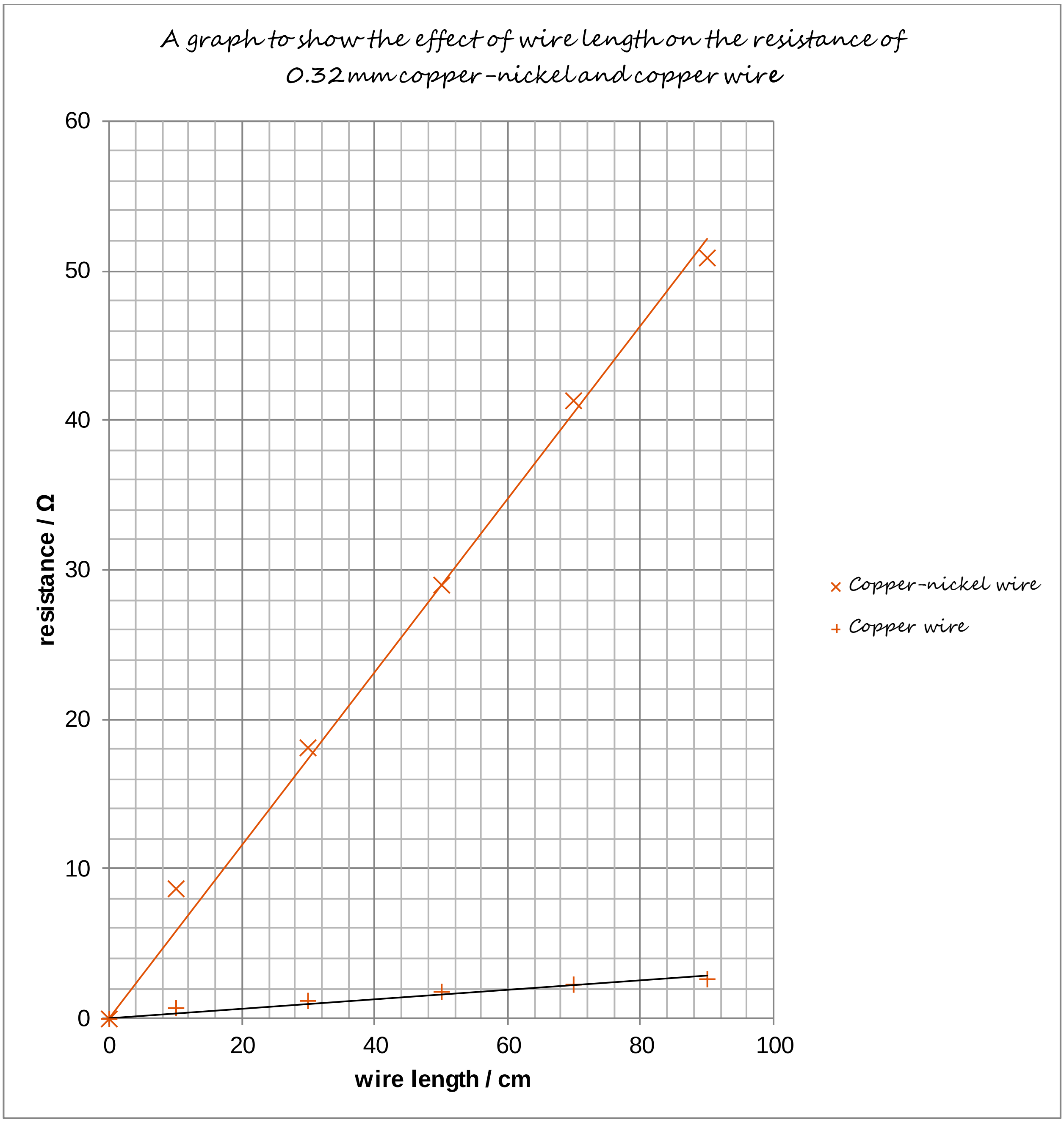
Wire type used:	copper-nickel wire		
Wire thickness:	0.32 mm		
Wire length (cm)	**Potential difference (V)**	**Current (A)**	**Resistance (Ω)**
10 cm	2.80	0.323	8.67
30 cm	2.54	0.140	18.14
50 cm	2.70	0.093	29.03
70 cm	2.77	0.067	41.34
90 cm	2.80	0.055	50.91

Experiment 2

Wire type used:	copper		
Wire thickness:	0.32 mm		
Wire length (cm)	**Potential difference (V)**	**Current (A)**	**Resistance (Ω)**
10 cm	0.90	1.340	0.672
30 cm	1.25	1.072	1.166
50 cm	1.51	0.868	1.740
70 cm	1.68	0.740	2.270
90 cm	1.80	0.686	2.624

Worksheet L: Answers

The graph below is plotted using the data from the *Virtual Experiment* video.



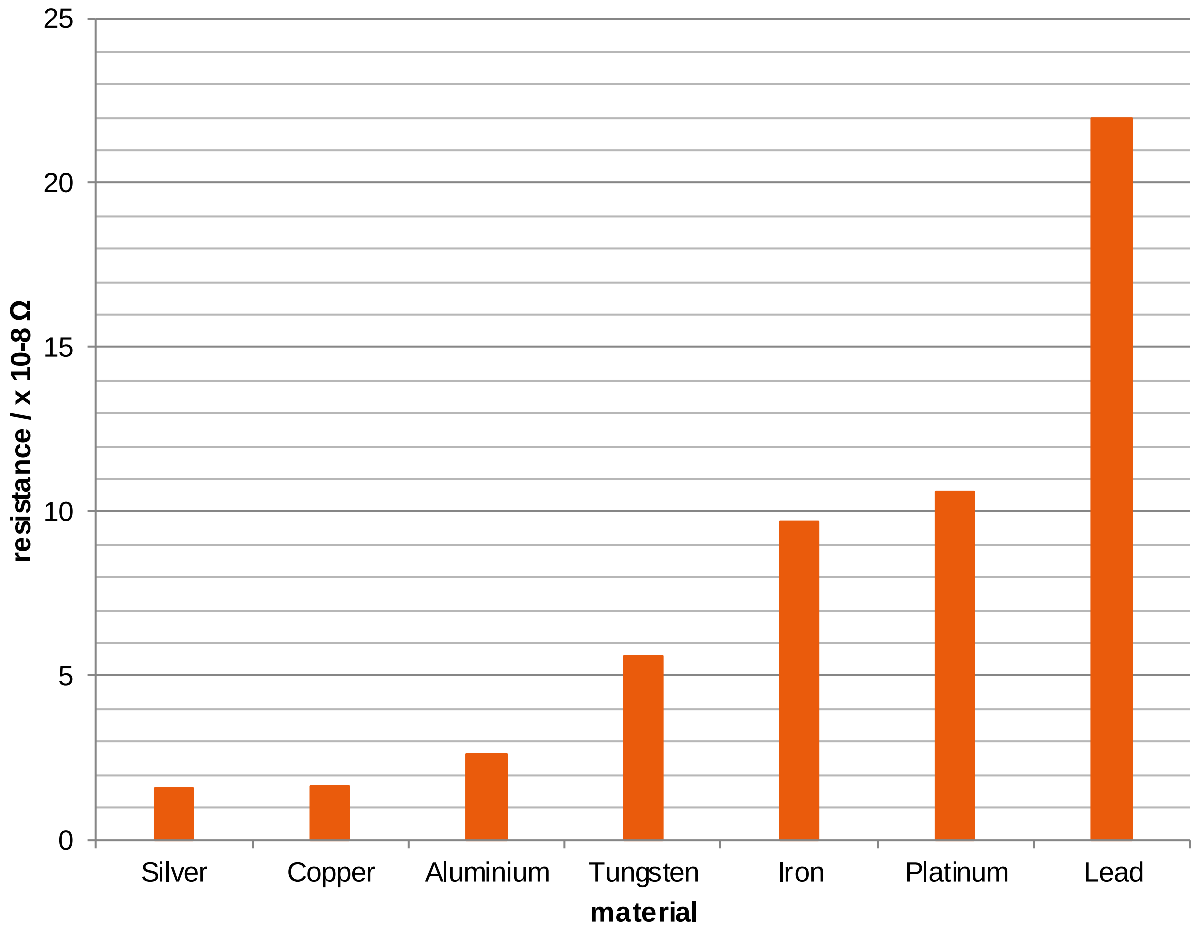
Worksheet M: Answers

The table below shows the resistance of a 1m length of seven different materials. Each material has the same cross-sectional area.

Plot a bar chart of the resistance of each material to show how this varies.

Material	Resistance / $\times 10^{-8}\ \Omega$
Silver	1.59
Copper	1.68
Aluminium	2.65
Tungsten	5.6
Iron	9.71
Platinum	10.6
Lead	22

A graph to show the resistivity of different 1m lengths of different materials

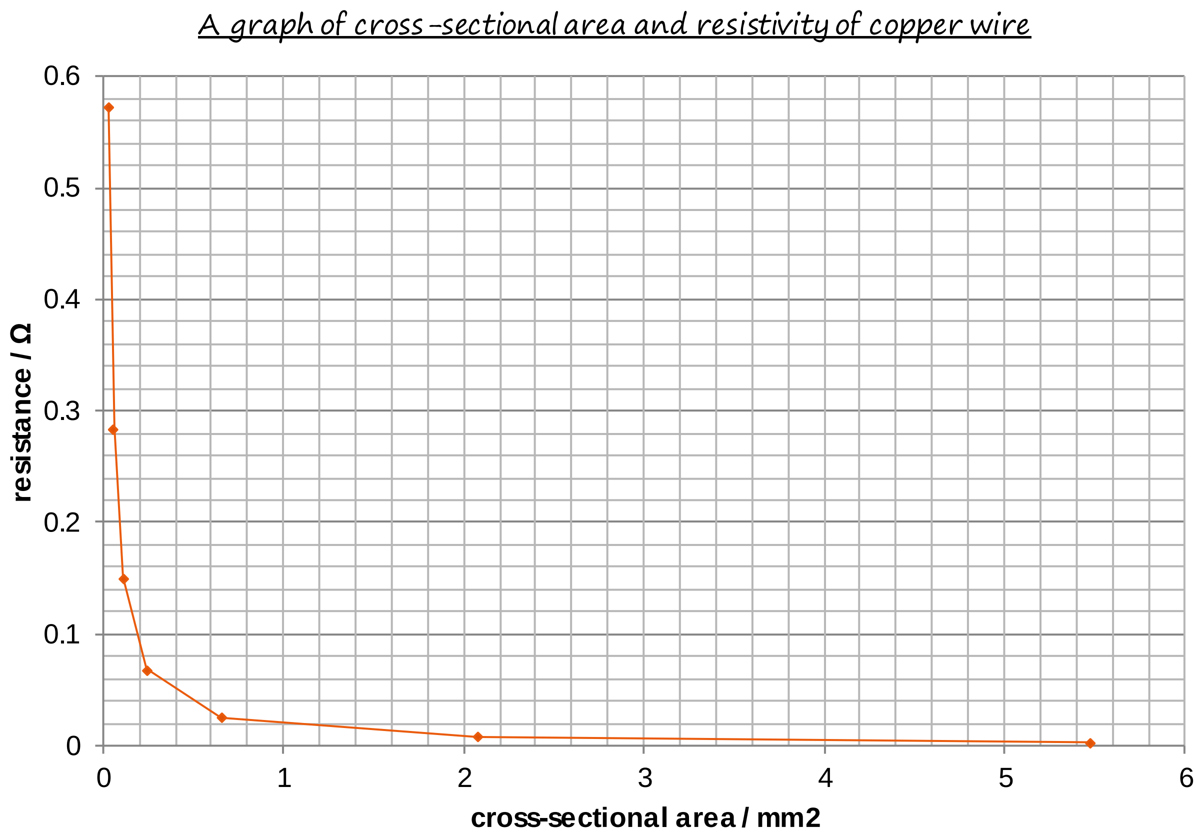


Worksheet M: Answers

Below is a table of data for different diameters of 1m lengths of copper wire.

1. Determine the cross-sectional area of each wire. Remember:
   Cross-sectional area = πr^2
2. Plot a graph of the resistance against the cross-sectional area

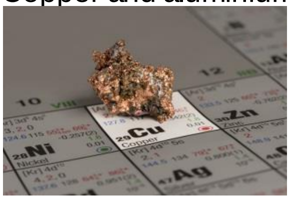
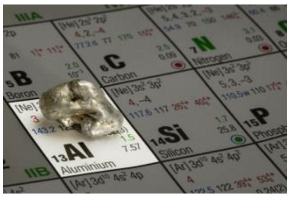
Diameter / mm	Radius / mm	Cross-sectional area	Resistance / Ω
2.642	1.321	5.479429	0.00306
1.626	0.813	2.075443	0.00808
0.914	0.457	0.655786	0.02557
0.559	0.2795	0.245298	0.06837
0.376	0.188	0.11098	0.15112
0.274	0.137	0.058935	0.28458
0.193	0.0965	0.02924	0.57357



Worksheet N: Answers

Using the table below, discuss which wire or material would be the best for the following jobs.

1. Power cables which have to cover long distances
   Steel-reinforced aluminium cable is best – it does not corrode and the added strength from the steel means it can cover long spans.
2. Wiring in houses
   Solid wire is best – relatively low cost, not likely to corrode and does not have to flex or bend.
3. Wires for speakers
   Stranded wire, as it is flexible. Long lengths are not needed which reduces the cost.
4. Electrical contacts in a car air bag
   Gold is used in this case as it is resistant to the effects of the elements meaning the parts are reliable. The relative importance of the item outweighs the cost involved.

Wire type and wire material	Characteristics
Solid wire 	• low surface area, so less likely to corrode • strong and rigid • likely to break if bent repeatedly • not good for high voltages
Stranded wire 	• lots of smaller wires twisted together • the air spaces between the smaller wires mean there are high resistance levels • greater conductivity than solid wire • more durable and flexible than solid wire • more expensive than solid wire
Copper and aluminium  	• not the best conductors • abundant and low cost
Gold 	• resistant to corrosion • an excellent conductor • not abundant and the cost is high
Steel reinforced aluminium cable 	• aluminium strands are wrapped around a steel centre wire • the steel centre wire is simply there for strength, meaning the wire can be used in long lengths • aluminium is cheaper than copper and does not corrode

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