

TAP 109- 1: Electrical characteristics

Introduction

In this set of activities you are going to find out about the way circuit components conduct electricity.

A potential difference maintained across a conductor drives a current through that conductor. You will measure the size of the current for different applied potential differences and plot the results on a graph. The behaviour of the conductor as shown by an I – V graph is called its characteristic.

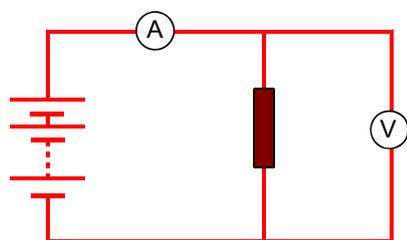
Apparatus

- ✓ 100 Ω carbon film resistor 1 W or even 0.5 W
- ✓ filament lamp 12 V, 24 W SBC (6 V 300 mA MES might be more convenient)
- ✓ diode – 1N4001 (NB: max current 1 A) with a protective resistor $\sim 50 \Omega$ or greater
- ✓ clip component holder
- ✓ 4 mm leads
- ✓ heatproof mat
- ✓ 2 multimeters
- ✓ power supply, 0–12 V d.c. (continuously variable if possible)
- ✓ rheostat (e.g. 50 Ω 1W) only needed if power supply has stepped output

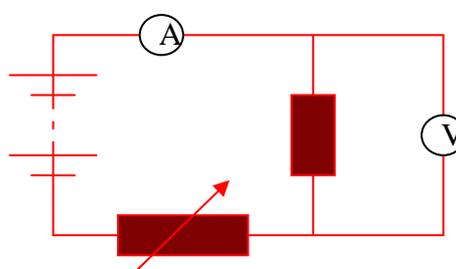
Experiment 1: Carbon film

1. Mount the carbon resistor in the clip holder.
2. Set up the basic circuit. Connect up the ammeter and resistor in series with the variable power supply. Place a heatproof mat under the resistor, although you should not let the resistor get too hot. Switch off the supply or disconnect the resistor when not making a measurement!
3. Connect a voltmeter in parallel with the resistor. You will need to select a range that will measure up to 5 V. At this stage your teacher may wish to check your circuit for you.
- 4.

If power supply continuously variable:



If power supply stepped output:



5. Switch on the circuit and adjust the supply so that the voltmeter reads 4 V. Quickly note the ammeter reading and voltmeter readings. Switch off for a few seconds, to prevent the resistor heating up and then switch on again to take repeat readings. Switch off while you lower the supply voltage slightly. Switch on again to take the new set of readings. Do not worry about setting the voltage to a particular value – just aim

Label the x-axis as 'potential difference / V' and the y-axis as 'current / A'. When the resistor is reversed you can show that the potential difference and the current are reversed by using a negative sign.

When you have finished plotting your results draw a best-fit line through the points.

A straight line graph through the origin shows that the current is proportional to the potential difference. This result is known as Ohm's law, which applies to metal or metal-like wires as long as their temperature remains constant.

For any point on the graph the resistance R can be found by calculating V/I . If the graph is a straight line then the resistance is constant – the same for every value of current or potential difference. Under these conditions finding the $1/\text{gradient}$ gives the average resistance of the wire. (Graphs using best-fit lines are often the best way of averaging results.)

The resistance is the same in both directions.

Further experiments

Experiment 2: Filament bulb

Set up the basic circuit but using the bulb in a holder instead of the carbon resistor.

This time the bulb can be left on between measurements. Repeat/check readings can be obtained by repeating the whole experiment but you will need to take care to reproduce (exactly) the voltage reading across the bulb.

Experiment 3: Semiconductor diode

Wire up the basic circuit substituting the diode. There must be a protective resistor in series with the diode to prevent damage by too large a current.

The diode is a one-way device and you may find that you cannot record a current as you increase the voltage up to 4 V. In this case reverse the diode in the holder. If in doubt ask your teacher.

Even in forward bias (conducting), the current through the diode will be very small so you may find the ammeter is not sensitive enough to show the change in current. Use a milliammeter or a digital multimeter set to read current but make sure the range of the milliammeter is greater than the maximum current through the diode.

Repeat/check readings can be obtained by repeating the whole experiment but you will need to take care to reproduce (exactly) the voltage reading across the diode.

If you want to explore the reverse bias of the diode you will need to use a microammeter to measure the tiny current.

Graphs for experiments 2–3

Either draw graphs with four quadrants choosing appropriate scales, or enter data on a spreadsheet and produce one or more appropriate graphs. Make the graph look as good as you can, to communicate its message as clearly as possible.

Give each one a caption which expresses the message of the graph. What is it saying?

Is the component well described by Ohm's law?

Remember that the filament of the lamp is designed to run white hot. At high temperatures metals conduct less well than at low temperatures.

Practical advice

Where you start on this activity depends on the experience and confidence of your students. The characteristics of the wire/resistor and the filament lamp are now part of many pre-16 specifications.

You can divide the further experiments up amongst groups of students. Each group can then produce the graph, research the behaviour of the component to explain the characteristic and then give a presentation to the rest of the class. Photocopies of the graphs can be distributed to members of the class.

Encourage students to use the higher range from a meter, selecting more sensitive ranges when they have an estimate for the highest reading. Digital meters are more robust, easier to read and even the 0–10 A scale is reasonably sensitive. If you do have to use moving coil instruments you will need to check that the meter is correctly inserted in the circuit and the range is suitable.

Experimental data and graphs on I / V characteristics of a filament lamp, a neon lamp and a silicon diode are on the CD-ROM Advancing Physics.

Technician's note: the specified ranges are indications only. It may be necessary to run through the experiment yourself to make sure your components and meter ranges are compatible.

Alternative approaches

These experiments can be easily adapted for datalogging and the graphs drawn automatically by the software, e.g. Insight.

Similarly results obtained manually can be keyed into a spreadsheet package such as Excel or Insight and the graphs obtained. These spreadsheets will give an analysis of the shape of the graph.

External references

This activity is taken from Advancing Physics, Chapter 2, 150E