

TEACHER'S GUIDE

SCIENCE KEY CONCEPTS SERIES:

ELECTRIC CURRENT, VOLTAGE, AND CIRCUITS

17 minutes

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FOR USE IN: Physics

LEVEL: Grades 9-12

EDUCATIONAL ADVISOR: Dr. O. Roger Anderson, Columbia University, Professor Natural Sciences, Teachers College; and Senior Research Scientist, Lamont-Doherty Earth Observatory

EDUCATIONAL OBJECTIVES:

To help the student understand these key concepts:

Current / voltage / series and parallel circuits / resistance and Ohm's Law / ohmic and non-ohmic conductors / factors which affect resistance: type of metal; length and thickness of wire; and temperature.

CONTENT SUMMARY

The program introduces electric current and voltage and measures these in series and parallel circuits. An experiment to measure resistance is demonstrated and results are shown graphically. Resistance is introduced and calculated from the gradient of $V-I$ graphs. Ohm's Law is discussed and the $V-I$ graph for a light bulb is plotted. Resistance is shown to depend on the type of metal, the length of a wire, the thickness of a wire and on the temperature, concluding with a demonstration of a superconductor. Animations of positive ions and free electrons explain the observed behaviour.

Chapter 1 Current, Voltage, and Circuits 6 min Small electrical devices require a source of electrical energy, a path for current to flow and a component to work. Electric current is a flow of electrons. An animated model is shown in which an escalator is the source of energy (this is analogous to a battery giving electrons electrical energy). It gives balls (electrons) potential energy by lifting them to a higher level. The balls move around the circuit and a paddle wheel represents a component. The balls turn the wheel giving it kinetic energy and then fall to a lower level, losing potential energy. Current is the amount of charge passing a point in one second. It is measured with an ammeter. Voltage is the amount of potential energy the electrons are carrying. The voltage between two points in a circuit is measured with a voltmeter. Components can be connected in a continuous loop called a series circuit. They can also be connected in a parallel circuit in which each component is connected directly across the power supply

and there is more than one path around the circuit. As more bulbs are added in a series circuit the brightness decreases. As more bulbs are added in a parallel circuit the brightness is unchanged.

The current is measured in a series circuit. With one bulb it is 0.4A with two bulbs the current is halved and with three bulbs it is reduced to 0.13A. In a parallel circuit, with one bulb the current either side of the bulb is 1.5A. When a second bulb is added in parallel the current from the power supply is doubled to 3.0A, each bulb is taking 1.5 A. When three bulbs are in parallel the total current is 4.5A. The voltage is measured across components in a series circuit and the sum of the voltage across each component is the same as the total supply voltage. In a parallel circuit the voltage across each component is the same as the voltage across the battery.

Chapter 2. Ohm's Law 5 min. A bulb is connected to a power supply and an ammeter measures current while a voltmeter measures voltage. As the voltage is increased, the current increases. More energy is transferred to the bulb, which gets brighter. To investigate this effect, the bulb is replaced by a fine wire. Voltage is increased by regular amounts and current is measured. In general, current increases as voltage increases, but to investigate in more detail a graph is plotted of voltage against current. The graph gives a straight line through the origin showing that voltage is directly proportional to current. The gradient of the straight line is R so $V = RI$.

The experiment is repeated with the wire replaced by a resistor. This graph is plotted on the same axes, giving a steeper straight line. The value of R is calculated and shown to be 5.0 for the wire and 14.7 for the resistor. R is then explained to be the resistance of the wire or resistor, measured in ohms (symbol Ω). Resistance is a measure of how difficult it is for electrons to flow through a circuit.

The escalator and paddle wheel model is used to describe increasing resistance by changing the paddle wheel for a larger heavier wheel. This wheel is more difficult for the electrons to turn, so they move more slowly and so the current is reduced.

As the $V-I$ graphs are straight lines through the origin the wire and the resistor obey Ohm's Law, which states that, at constant temperature, voltage and current are directly proportional. The graph for a light bulb is then plotted. This graph is a curve so the bulb does not obey Ohm's Law. Devices like this are said to be non-ohmic.

Chapter 3. . Factors Affecting Resistance 6 min Two bulbs are shown. The energy from the power supply is the same, but one is brighter than the other and so they must have different resistance.

Two wires made of different metal, but of the same thickness and length, are compared. An ohmmeter is used to measure resistance. One is made of nichrome and has a resistance of 5W. The other is made of tinned copper with a resistance of 0.2W.

An animation of the positive metal ions making up the lattice in a sea of free electrons is shown. When a voltage is applied some of the free electrons will move, forming a current. In a low resistance metal, the electrons will move easily giving a higher current. A different metal with fewer free electrons will have a higher resistance. As the electrons collide with the metal ions energy is transferred, so the metal will heat up. A tungsten light bulb will heat up so much that it glows. At a high enough current the filament melts.

The effect of changing the length of wire is demonstrated. If the length is halved, what happens to the resistance? It also halves, from 1.4W to 0.7W. If the length is increased the resistance increases. A variable resistor is a long coil of wire. Sliding the handle changes the length of the wire in the circuit. The bulb is brighter with less wire in the circuit because there is less resistance.

With two wires there is double the thickness of metal for electrons to flow through so the resistance is lower. This is shown with the lattice animation of a thick wire and a thin wire. Finally the effect of lowering temperature is investigated. The wire is put in liquid nitrogen. The resistance is less. The animation shows that as the positive ions vibrate less it is easier for the free electrons to pass through the lattice. Some materials become superconductors at very low temperatures. In superconductors, the positive ions hardly vibrate at all so there is little or no resistance.

A superconductor is put into liquid nitrogen with a magnet on top. The magnet causes a small current in the superconductor and as it cools further this current increases and the magnet levitates. The superconductor produces a magnetic field strong enough to repel the magnet.

AFTER VIEWING THE VIDEO These are some suggested questions to help stimulate student discussion.

Current, Voltage, and Circuits

1. What happens to the brightness of light bulbs as more are added:
a) in series? b) in parallel?
2. What happens to the total current flowing from the power supply as more bulbs are added: a) in series? b) in parallel?
3. What is the relationship between the supply voltage and the voltage across each component: a) in a series circuit? b) in a parallel circuit?

Ohm's Law

1. If a graph of the voltage across a wire is plotted against the current flowing through it: a) What shape is the graph? b) What does the gradient of the graph tell you about the wire? c) What law does the graph show is true for a wire?
2. What shape is a graph of voltage against current for a light bulb?

Factors Affecting Resistance

1. If pieces of wire are the same length and thickness, but made of different metal, will their resistance be the same or different?
2. The resistance of a piece of wire is measured. If a longer piece of the same wire is tested will it have: a) the same resistance? b) lower resistance? c) higher resistance?
3. Draw a diagram of a metal lattice showing the positive ions and the electrons flowing through the lattice when an electric current flows through the metal:
a) for a wire b) for a thicker wire, which has lower resistance
4. What happens to the resistance of a wire as it is cooled?
5. Explain your answer to question 4 by describing what happens to the lattice of positive ions and the sea of free electrons.

USEFUL LINKS

<http://www.geocities.com/thesciencefiles/electric/circuits.html> These pages showing circuits were made using the 'crocodile clips' circuit building package.

<http://www.gcse.com/electricity.htm> This contains encyclopedia style information about electricity and circuits.

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569 NORTH STATE ROAD, BRIARCLIFF MANOR, NY 10510

TEL: 914/762-3838, 1/800-438-5564 FAX: 914/762-3895

email benchmedia@aol.com website www.benchmarkmedia.info