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Electricity

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The goal of this unit is a fundamental one: to meet the need in our increasingly technological society for a mathematically literate students. The concern is not only or even primarily the gifted students, but also the average student.

The application of electrical technologies is embodied in various mathematical concepts. It is this relationship between electrical technologies and mathematics that this unit will explore.

The major purpose of this unit will be to accumulate the mathematical concepts that are embodied in the study of electricity and to present them to a group of average and below average students.

What is electricity? Can you see it? Can you touch it? Well, if you can't, how do you know it's there? You can't see electricity but you can see the work it does. You can see a lamp light, you can see electric trains run, you can feel electricity if you touch a bare wire and get a shock. One can feel the effect of electricity if burned by an electric hot iron.

There are three important elements of electricity, protons, electrons, and neutrons. Among them they all exhibit known conditions of electric charge, positive, negative, and neutral. The electron is the most important elementary particle in electricity. Electric current is composed of electrons, which move freely through conducting substances, protons are seldom free to move, and neutrons do not take part in electrical effects. Protons gives off a positive charge, electrons gives off negative charge and neutrons remains neutral. The protons in the nucleus of the atom attract the orbital electrons and it is this attraction between the oppositely charged protons and electrons that holds the electrons in their orbits. The electrons in an atom move about the nucleus at very high speed. Without the electrical force of attraction to hold them in their orbits, the electrons would fly off into space (see figure 1).

Electricity is one of the most important forms of energy. We cannot see, hear, or smell electricity, but we know about it by what it does. Electricity produces light and heat, and it provides power for household appliances and industrial machinery. Most of the electricity that we use daily consists of a flow of tiny particles called electrons. Electrons are the smallest units of electricity. Everything around us, including our bodies contains electrons. Therefore everything can be thought of as partly electrical. Some of the effects of electricity may be seen in nature. For example, lightning is a huge flash of light caused by electricity. Energy has many forms and it is involved in all our activities.

Electric power is one of humanity's most useful forms of energy. It serves almost every homes, farm, store and factory throughout the world. Electricity itself is not a source of power. Electric power stations burn coal, or other fuel to make steam and it is this steam that furnishes the energy to run generators that produces electricity. Hydroelectric power stations use the energy of falling water. There are three kinds of power plants, steam-turbine plants which produces about seventy-four percent of the electricity in the United States, Nuclear power plants which provides about nine percent, but this total is increasing. Hydroelectric plants supply most of the remaining power.

People began to learn electricity as early as 600 B.C. Thales, a Greek philosopher, observed that amber, a stone like substance, attracted small bits of straw after being rubbed with cloth. Jerome Cardan distinguished between the properties of amber and those of a magnetic black rock called loadstone. Cardan realized that amber attracted many light objects, but loadstone attracted ion.

William Gilbert discovered that materials such as diamond, glass, sulfur, and wax behaved like amber and he called these materials electrics. In 1646 Sir Thomas Browne devised the word electricity. Stephen Gray discovered that some substances conduct electricity and others do not. Charles DuFay found that glass and other substances charge with "Viterous Electricity" repel one another, but they attracted amber and similar materials charged with "resinous electricity."

Benjamin Franklin experimenting with electricity in 1746 developed a theory that electricity consisted of a single fluid. According to Franklin's theory, a positive object had an excess of this fluid, and a negative object had a deficiency of it. Scientist later proved what Franklin called a positive object actually had a deficiency of electrons and the negative object had in excess of them. Franklin famous experiment of flying a kite during a thunderstorm proved that lightning is electricity. Lightning struck a pointed wire fastened to the kite and travelled down a wet string to a key where it caused a spark between the key and the earth.

Charles A. DeCoulomb formulated the laws of attraction and repulsion between charged bodies.

Allesando Volta built the first battery called a Voltaic pile. It consisted of stacked pairs of metal disks. Each part consisted of one silver and one zinc disk. The disk were separated from one another by paper or cloth that had been moistened with a salt solution. Voltaic piles were the first source of steady electric current.

In 1820 Hans C. Oersted observed that a strong current flowing through a wire could move the needle of a compass and this experiment showed that current has a magnetic effect. Later in the year Audre Marie Ampere measured the effect of two parallel currents on each other. He showed that such currents attract each other if they move in the same direction and repel if they move in the opposite direction.

George S. Ohm worked out the law of electrical resistance that bears his name. Michael Faraday believed that if electricity could produce magnetism, magnetism could produce electricity. In 1831 Faraday found that a moving magnet induced electric current in a coil wire. In the same year Joseph Henry independently discovered the principle that all electric generators and transformers work by means of the induction principal formulated by Faraday and Henry.

James Maxwell worked out the mathematical equations for the laws of electricity and magnetism and these equations indicated that certain electric circuits produced electro-magnetic waves that travelled at the speed of light. In 1880 Heinrich Hertz produced such waves. In 1891 Johnstone Stoney suggested that electric current consisted of very small particles in motion and he called these particles electrons. In 1897 Joseph J. Thompson confirmed Stoney's theory. Thompson also discovered that all atoms contained electrons and in

1913 Robert A. Millikan obtained the exact measurement of the charge of an electron, thus began the electronic age.

In the early 1900's John A. Fleming built a vacuum tube that could detect radio signals, in 1907 Lee DeForest developed a vacuum tube that amplified radio signals. These tubes made radio possible. Other vacuum tubes led to television and radar in the 1920's and 30's and electronic computers in the 1940's. The transistor was invented in 1947 and by the 1960's transistors had largely replaced vacuum tubes in electronic equipment. Later manufacturers found a way to integrate many transistors on one crystal of silicon and this development led to the electronic circuits called integrated circuits.

Every year, the world wide demand for electricity increases. In our country we use about 380 times as much electricity as we did in 1900 and more than 12 times as much in 1940. Today our demands for electricity is increasing even more.

The purpose of the electrical system is to obtain energy. Energy is the capacity to do work, to transfer energy from the source electric current must flow through the electrical path of the circuit. Electrical forces between charged particles are extremely important in electricity. These forces cause electric current to flow.

In simple electric circuit the dry cell (battery) produces a positive (+) electric charge at one end of its terminals and a negative (-) charge at the other. These charges cause electric current to flow. (See Figure 2).

Electric current is a flow of negatively charged electrons. Electrons will flow away from the negative terminal and toward the positive terminal of the dry cell. Like charges repel, so the negative electrons and the negative terminal repel each other. Unlike charges attract, so the negative electrons and the positive terminal attract each other. Both the repulsion and the attraction cause the electrons to move in the same direction through the wires and lamp. (See Figure 3).

Every useful electrical system must meet three basic requirements in order to do work. First it must have a source of electric energy: example, a generating plant or a battery, second it must have a lead, which takes the electric energy provided by the source and puts it to work. Electric irons, motors, and heaters are typical loads. Finally, an electrical system must have a complete, round-trip electrical path through the source, through the load, and back. Whenever a source and a load are connected so that a complete electrical path passes through them both, the resulting system is called a circuit. (See Figures 4 and 5).

Many kinds of loads, including electric lamps, will function equally well, whether the electron flow through them in one direction or the opposite. Such loads oppose electron flow and transform energy just as effectively, no matter which direction the electron flow takes. The important difference between a source and a load; a load passively accepts electron flow in the direction the source dictates. A source that is causing electron flow always sends out electrons through its negative terminal and takes them in through its positive terminal. Reversing the connections of the source in the circuit makes electron flow through the lamp from B to A instead of A to B. (See Figure 6).

Some Fundamental Concepts

An electric current is a system for obtaining, transporting, controlling, and using energy. Every useful circuit has a source of electric energy, a load that uses electric to do some sort of work, and an electrical that permits energy to be carried from the source to the load.

Both sources and load are energy converters. A source converts to electric energy from some other form of energy, a load converts from electric energy to some other form of energy. Electric energy is carried from the source to the load in a circuit by electric current, which consists of a flow of invisibly small particles called electrons.

A source sets up an electromotive force, which tends to cause electrons to flow through the source in a particular direction. The polarity of a source indicates which direction this is. Electrons tend to leave a source through the negative terminal and to enter it through the positive terminal.

LESSON PLANS

Divide students into three groups.

Have one group do a conductor test.

Materials needed
a dry cell

bell wire

a flashlight bulb fitted into a miniature socket

Directions Cut three pieces of wire each twelve inches long, strip the insulation on all ends about one inch. Attach one end of a wire to one terminal of the dry cell and the other end of the wire to one of the terminals to the socket. Attach one end of the second wire to the other terminal of the dry cell, then attach one end of the third wire to the other terminal of the socket. Take the ends of the free wires and touch them together to complete the circuit and the light should go on. Instead of touching the two ends of wire together touch them to the opposite ends of an iron nail, the bulb will light because the nail is a conductor. Try a piece of wood instead of a nail and answer the question as to whether the wood is a conductor. Any material can be tested this way to see whether or not it is a conductor.
Have the second group construct a switch.

Materials needed
a dry cell

a flashlight bulb in socket

three fifteen inch pieces of bell wire with stripped ends

rulers for measurement

a block of wood

a strip of metal

two nails

a hammer

Directions Nail one end of the metal strip to the blocks of wood, letting the nail stick up a little, hammer the other nail, part of the way into the block of wood under the other end of the metal strip and bend the metal up so that it doesn't touch the nail. Connect a wire from one terminal of the dry cell to one terminal of the socket. Connect the second wire from the other terminal of the dry cell to the nail that holds the metal strip. Connect the third wire to the other terminal of the socket and to the other nail. When the end of the metal strip is not touching the nail, the circuit is open and the bulb does not light. If the strip is pushed down to touch the nail, the circuit is closed and the bulb lights.

Have the third group do an electromagnet.

Materials needed

a dry cell

a switch

a large iron nail

four or five feet of bell wire

tacks

Directions Strip the outer covering from the ends of the wire. Start about one third of the way along the wire, winding it tightly around the nail making as many turns as there is room for. After that, connect one end of the wire to a dry cell terminal and the other end to one of the nails in the switch. Take a short piece of wire, strip the ends and attach it to the other nail in the switch and the other terminal of the dry cell. Close the switch and the large nail with the current flowing in a coil of wire around it will become an electromagnet. Put some tacks underneath, the electromagnet will pick them up and hold them. When the switch is open the tacks will fall off.

Logic circuits

Objectives

To recognize a simple logic circuit

To use and or to find a true and false statements.

Circuits called logic gates control the flow of electricity either by blocking a signal or by letting it pass through.

Below are two kinds of circuit patterns. Electricity will light the light bulb if it can go from the power source to the bulb. If it cannot pass, the bulb will not light.

A closed switch lets an electric signal pass. 1 represents a closed switch.

An open switch blocks an electric signal. 0 represents an open switch.

(figure available in print form)

These two circuit patters are based on the following rules of logic.

AND when and is used between two statements, the whole	OR when or is used between two statements, the whole

statement is true only when both statements are true.	statement is true whenever one of the statements is true.
5 + 2 = 7 and 6 + 3 = 17 is a false statement	5 + 2 = 7 or 6 + 3 = 17 is a true statement.

Provide data and have students construct a table.

The larger the resistance, the smaller the current. The greater the e.m.f. the greater the current.

Current is equal to e.m.f. divided by resistance. In mathematics it can be shown that 8 is divided 4 by writing 8/4. Ohm's law can be shown the same way by writing

electromotive force (e.m.f.)

Current = resistance

Let I stand for current; E for e.m.f.; and R for resistance and the formula is I = E/R. The formula can be changed to read E = IxR and R = E/I.

With Ohm's law students can find out the amount of current, e.m.f. or resistance if they know the amount of any two of them.

Example:
If you have an e.m.f. of 8 volts, and a resistance of 4 ohms, how much current will flow? I = E/R.

I = 8/4 is 2 amperes

If they know that the current is 2 amperes and the resistance is 4 ohms, they can find the e.m.f. with the formula E = I x R or E = 4 x 2 and the answer is 8 volts.

The students can find the resistance if they know that the e.m.f. is 8 volts and the current is 2 amperes. R = E/I or K = 8/2. The resistance is 4 ohms.

Ohm's law is the simple basis for most of all electrical calculations.

Provide data for classes and have them solve the problems.

Have students bring in a copy of their parents electric bill and have them compute the bill based on kilowatt hours used.
Invite speaker from power plant.
Have speaker talk about electricity in general and specific terms.
Plan a field trip to a local power plant.
After field trip have students write a report on their experience.
Have students write two word problems each. Divide the class into groups of twos and have them critique each others work.

CONSUMER PROBLEMS

1. The February electric bill was $134.80 which was twice as much as the January bill. The March electric bill was $50.00 higher than the January bill. What was the total cost of electricity for January, February and March?
2. A microwave oven uses 2.50 kilowatt hours of electricity in thirty minutes. How much electricity is used in 4 hours?
3. In one factory, heat that would normally be lost through the chimney in the process of generating steam is recovered and used. The saving is 1.18 million BTU each hour. At $3.00 per million BTU, how much money is saved (a) 1 day? (b) 1 month? (c) 1 year?
4. The Jackson family electric bill was $1256 for six months. They paid one-half of the bill and they will pay the balance in four installments, what will the payments be?
5. The Hudson's will replace five sockets and four switches. The sockets costs $1.50 each and the circuits costs $2.57 each. What is the total costs?

VOCABULARY-WORDS

Alternating Current —Electric current that reverses the direction of its flow many times a second.
Ampere —The unit of electric current. One ampere is a rate of flow of change equal to one coulomb per second (I=QIT)
Batteries —Charge chemical energy into electricity.
Conductor —A substance that transmits electricity.
Direct Current —Current that flows in only one direction.
Electric Circuit —It is the path or paths followed by an electric current.
Electric Current —It's a flow of electrons or ions.
Electric Field —It is the space around a charged particle in which its charge has an effect.
Electrical Induction —The process by which an electrically charged object charges another object without touching it.
Electrical Resistance —The resistance provided by the structure of a conductor to the flow of electric charges.
Electricity —Electric current used as a source of power.
Electromotive Force —This is a voltage. It is the pressure that pushes electric current through a circuit.

Electron —A particle of an atom that carries one unit of negative charge.
Energy —The capacity for doing work.
Fuse —Prevents too much current from flowing through a circuit.
Generator —Converts mechanical energy into electricity.
Hydroelectric Power —Power that is produced from the conversion of the kinetic energy of water.
Ion —Its an atom that has either gained or lost electrons and is electrically charged.
Kilowatt Hour —A unit of energy equal to a power of one kilowatt (1000w) acting for one hour.
Ohms Law —Current is equal to electromotive force (e.m.f.) divided by resistance.
Proton —One of the fundamental particles located in the nuclei of atoms; each proton has a positive charge equal in amount to that of the negatively charged electron.
Resistance —Is the opposition to the flow of an electric current in a circuit.
Static Electricity —Is electrons or ions that are not moving.
Terminal —A device to which an electrical connection is made. Also, the point at which current enters and leaves an electric circuit.
Transformer —A device that increases or decreases the voltage of

alternating current.

QUIZ

1. What is the purpose of the electrical path of a circuit?
2. What is an electric current?
3. What is energy?
4. Under what conditions will a lamp light?
5. Which of the three elementary particles listed below are the most important in electricity?
   The proton, electron or neutron. Explain your answer.
6. Name the three kinds of particles that make up an atom.
7. Describe Benjamin Franklin's electrical experiment.
8. Name some metals that are conductors of electricity.
9. Name the three basic requirements for every useful electrical system.
10. List the three basic parts of an electrical circuit and describe their functions.

(figure available in print form)

Figure 1. Elementary particles and the atom.

The positive charges in the nucleus, of course, belongs to the protons. The negative charges belong to the orbital electrons. (The neutrons of the nucleus have nothing to do with the distribution of charge in the atom.)

(figure available in print form)

Figure 2. A simple electric circuit.

The dry cell produces a positive (+) charge at one of its terminals and a negative (Ð) charge at the other. These charges cause electric current to flow.

(figure available in print form)

Figure 3. Electron flow in a simple circuit.

(figure available in print form)

Figure 4A. The 3 parts of an electric circuit.

(figure available in print form)

Figure 4B. A simple electric circuit.

(figure available in print form)

Figure 5A. Electron flow with a complete electrical path.

(figure available in print form)

Figure 5B. No electrical flow with a broken electrical path.

(figure available in print form)

Figure 6. Polarity of source establishes direction of electron flow: load passes current in either direction. A source that is causing electron flow always sends out electrons through its negative terminal and takes them in through its positive terminal. Therefore, reversing the connections of the source in the circuit shown makes electrons flow through the lamp from B to A instead of from A to B.

SUGGESTED READING LIST

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SUGGESTED READING LIST FOR STUDENTS

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Gutnik J. Martin, *Simple Electrical Devices* , Franklin Walts, (New York, 1986).

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