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Teaching Some Basic Concepts of Electricity

Curriculum Unit 89.07.01
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This curriculum unit is designed to teach a few basic concepts of electricity to middle school students. The teaching methods will include experimentation, demonstrations, analogies, discussion, work sheets and vocabulary review. Supplementary materials such as handouts and vocabulary cards will be presented in the unit. It is believed that all modalities should be used as often as possible in order to enable the students to understand the concepts and to be able to associate the concepts with the appropriate vocabulary. Too often a child does understand a concept but cannot demonstrate that he understands because he doesn't know the correct words to express that the material has indeed been learned. The only source of electricity that will be used in experiments and demonstrations is a pair of 1.5 volt batteries. No matter what other references for experiments are used, batteries should be the only energy supply used by middle school, and possibly older and more experienced, students. The instructor must regularly remind the students that large voltages can be shocking and too often fatal.

Once a lesson is taught, the pertinent vocabulary should be retaught numerous times through the use of flash cards. Most lessons will introduce no more than three new words and their associated concepts. Each new word or term should be written on one side of a piece of construction paper and the definition should be written on the back. The students should be able to provide the term when the definition is shown and the definition when the word or term is shown. It is suggested that the students become thoroughly familiar with the key words and terms through the following use of the flash cards:

1) The teacher or student helper shows one side;

2) the class reads the words aloud
3) and then, the class as a group, reads the second side aloud
4) Individual students should be called on when they feel that they are ready to recite the opposite side of each term and definition.

5) All vocabulary cards should be reviewed at the beginning of each new lesson in this unit. Although this memorizing technique may seem too elementary to some teachers, students enjoy the method and take pride

in being able to quickly associate the appropriate vocabulary word with a concept that they have just learned.

Since most of the classwork is hands on activities and discussion, it may be useful for the students to do the simple work sheets, or similar written reinforcement as a way to review the day's concepts and vocabulary. Students should never be expected to fill in work sheets until the sheets have been reviewed, even answered, in class, even if the material has been thoroughly taught, because the students will not have a textbook or reference book in which they can look up answers on their own.

In a few cases more than one lesson will be devoted to the teaching of a single concept. The reason that this will be done is to make sure that the ideas that seem so simple to some students are really understood by these students and by all the students.

Even when the children have demonstrated that they have understood a lesson, the teacher should always review what was taught the time before. Children should be called upon to discuss the previous lesson, to suggest analogies, and to share the answers on their work sheets.

Included in this unit is a list of all the materials that will be needed to teach all of the lessons. A current price list and local places where the products can be obtained will also be included. It has been my experience that if I am missing that single ingredient for a demonstration, I can never find the time to shop for it, so the demonstration is never presented. It is hoped that this shopping list will encourage teachers to set up their "bag of tricks" in a single day so that they can confidently teach the whole unit with a minimum of wasted time.

Although it would be convenient for the teacher to jump immediately into the teaching of static and then current electricity, there are a few concepts that must be taught before this curriculum unit can be presented. They are the following: What is matter (which will be dealt with below), and what are atoms, elements and compounds? These concepts will be briefly (and therefore, inadequately) introduced in this curriculum unit because of their importance for the understanding of electricity. But because the emphasis here is on electricity, it is strongly recommended that these concepts, i.e., atoms and,less importantly, elements and compounds, be taught before this unit.

Lesson 1: WHAT ARE THE USES OF ELECTRICITY?

The teaching of this curriculum unit will not begin with a definition of electricity but with an attempt to have the students appreciate the importance of it. Demonstration and Discussion: Pull down the shades and turn out the lights in the classroom, and then ask the above question. Leave the lights out a few minutes and ask the following questions. If we didn't have electricity what would you do in the evening as soon as the sun went down? As the students' hands shoot up the teacher should write the following on the board:

Things That We Use That Need Electricity

in the morning during the day at night

This format will encourage the students to list many electrical appliances that should include things that we all tend to take for granted (e.g., the alarm clock, refrigerator, answering machine, radio, t.v., traffic lights, lights, microwave, washing machines etc.) and even battery operated machinery such as cars, radios, etc.

By way of contrasting our life styles in the late twentieth century with that of earlier times (I love mixing disciplines) it would be fun to show the class a reproduction of a painting of domestic life in an earlier century.

Most history books have such reproductions as do calendars of Americana or American Primitive Art. Discuss the simple mechanical utensils (butter churn; fireplace for cooking, heat and light; the taller windows in the kitchens; the fact that the kitchen was also the family room; etc.). Contrast a farmer's hours (dawn to dusk) with the modern businessman's hours. Such discussions would help the children appreciate how radically our lives have changed with the implementation of electricity.

Lesson II: WHAT IS MATTER?

Materials
a jar of water

a balloon

any solid objects in the room, e.g. a book, a pencil ***Discussion*** Matter is anything that occupies, or takes up, space. Is this book matter? They will give you an easy "yes." Is orange juice matter? Again, they will answer easily. Now fill your cheeks with air and then ask is your cheeks are filled with matter. (You might get into a discussion of forces such as heat, gravity, etc. These do not occupy space).

Demonstration of solid matter Have a student sit on a chair. Ask a passive type student to sit in the same chair. The first student probably won't move, and the standing one will just look lost. The more aggressive children will suggest that the standing student push the seated child out of the chair. Being careful to avoid any accidents, discuss the point that only one person can occupy a single place at any one time.

Conclusion A person is a solid, or clearly shaped, form of matter. Only one solid can be in a single place at a single time.

Demonstration of liquid matter Have a child hold up a capped bottle or jar of water (possibly with a drop of food coloring to make it more visible to the group). Have the child turn the bottle to demonstrate that the shape of the liquid is determined by its position in the bottle—thin and flat when the bottle is on its side; cylindrical when the bottle is upright.

Conclusion Another form of matter is liquid. Liquids take the form or the shape of their container. They can be poured.

Demonstration of gases, the third type of matter Ask the students if they know of another form that matter can take if it isn't solid or liquid.

Discussion What form of matter is ice? Yes, it is solid. And if it is melted? Yes, it is liquid. What happens if the water is put in a pot and boiled? Ask the children if they have ever boiled water in a pot with a lid so that they can tell you about steam. If they boiled water long enough so that it completely evaporated, they will enthusiastically share their red hot pot, and exploded egg stories with you.

Conclusion Ice, water and steam are examples of the three different forms of matter. They are made up of the same parts. They all taste, smell, and are basically the same thing but they take different forms. Ice, water and steam are compositionally, or chemically the same, that is they are the same compound. Ice, water and steam are examples of the three forms of matter.

Demonstration that gases occupy space Have some students blow up some balloons. Discuss that they are filling the balloons with the third type of matter, gas.

Discussion Gases are matter, whether we can see them or not, because they occupy space.

Definition MATTER is stuff that occupies space. The three forms of matter are solids, liquids and gases.

This vocabulary word should be made into a flash card,as should all new vocabulary words, with the word or terms on one side and the definition and qualifiers on the other side.

Lesson III: WHAT ARE ATOMS?

The next step would be to teach about the smallest components of all matter, the ATOMS. None of the following lessons on electricity can be taught without a basic understanding of the atom. Any text book dealing with middle school science, electricity or chemistry will have a unit on the atom. Two such texts are included in bibliography of this curriculum unit.

Lesson IV: WHAT IS STATIC ELECTRICITY?

Although this is treated as one lesson, it will require at least two class periods, and it is worth spending the time. The concepts of atoms, charge, electrons and static electricity are essential for an understanding of the nitty-gritty of electricity, which is current electricity.

Materials

rug remnants
metal of a door knob or of a pencil sharpener
Needed: a dry, cool day

Procedure Have each student rub his or her feet on the rug while reaching toward the metal object.

Observation A spark will move through the air or a shock will be felt by the student as he or she touches the metal.

Although it is probable that the children have already seen this demonstration of static electricity or have experienced it personally, they probably do not understand what is actually occurring.

Discussion The following questions may be asked: Why was there a spark or a flow of charge? The children will not be able to answer this question, so ask the following: Did charge come from the person or the doorknob? Another blank will be drawn. If the person were to just sit on a rug and touch a metal object, would he or she feel a shock? They will know the answer here. Okay—a beginning.

It is the actual movement of the feet rubbing on the rug that causes the charge to be separated. In other words, the rubbing is work; work that is being done to separate charge. Work? Charge? It is time to bring in the construction paper to make vocabulary flash cards.

Discussion and Demonstration Have a student place his or her hands on the wall and push until he or she either breaks into a sweat or is too tired to continue. Ask the class if work has been done. Explain that in scientific terms (Definition:) WORK is only done when an object moves across some distance. It doesn't matter how much energy is exerted; work is done only when force is exerted on an object that moves because of the force exerted. How much work is done is measured by the formula:

WORK = force x distance, or

W=F x d

Have a student lift a pile of textbooks. Explain that the force is the weight of the books and the distance is the height that the books were lifted.

The above formula for work should not be taught to fifth or sixth graders, while the concept of work being force times distance traveled should be taught to all students.

The concept of electric charge should be introduced at this point.

Discussion As we have learned, matter is made up of atoms that are electrically neutral. Each atom has a nucleus that is made up of protons (positively charged) and neutrons (no charge). There is an electron cloud (negatively charged particles) around the nucleus which exactly balances the number of protons electrically. The electrons are relatively free to move under the influence of an outside force whether it is physical or electrical. The electrons are held relatively loosely in materials that are conductors, such as metals, but are more tightly held in the case of insulators, such as glass, plastic, wood. (The next lesson will explain insulators and conductors more fully). If some of the electrons are removed from an atom, the atom, and therefore the object made up of the atoms, has a net positive charge.

Definition CHARGE = too many electrons, or too few electrons around atoms of an object causing the object to have a negative (excess electrons) or a positive (too few electrons) charge

Definition ELECTRONS = tiny negatively charged particles that when separated from their atoms form electricity

The freed electrons are the stuff of which electricity is made.

An example of a force that would cause electrons to be separated from their atoms is rubbing or friction (types of work) as in feet rubbing across a rug, a comb being pulled through hair, or a piece of silk being rubbed along a glass rod. Because the glass rod or the plastic comb are insulators the charge remains static, that is, in one place.

Definition STATIC ELECTRICITY = charge that stays on a nonconductive material

If a metal rod were to be rubbed with silk, no charge would build up because the metal is a conductor. The charge, in the case of a conductor, would return to the other atoms within the conducting material itself.

It should here become apparent to the reader that many concepts are being introduced simultaneously to explain closely related ideas. The difficulty is that as adults we are not aware of how alien most of these ideas are to our students. For this reason it is worth doing several demonstrations of the same principle in the hope that the revisualization and varied descriptions of the same concept may enable the students to begin to understand static, and then current, electricity.

Further Demonstrations of the Law of Electric Charge

Materials to produce a negative charge:

a rubber rod

a piece of fur

Materials to produce a positive charge:

a glass rod

a piece of silk

and for both experiments:

a piece of dowel inserted into a piece of wood

two ping pong balls covered with aluminum paint,

or two pith balls

a string to suspend the balls

Method

1) Rub (emphasize the word rub = work done to separate charge) the rubber rod with fur. We are thereby forming a negative charge on the surface of the rubber rod.
2) Touch the balls with the charged rod. The balls will become negatively charged and will repel each other, and they will repel the rod.
3) Immediately after this, rub the piece of silk on the glass rod to produce a positive charge.
4) Move the glass toward the balls, that are still negatively charged, and the pith balls will move toward the glass rod. Negative and positive, or oppositely charged, particles will attract.

(figure available in print form)

Discussion The concept that particles that are oppositely charged will attract each other is in itself a difficult one. The topic is explained well in both of the science texts cited in the bibliography under the chapters that deal with chemistry.

Because it will take the balls a moment to pick up the charge, whether positive or negative, the balls may be momentarily attracted to the charged rod. As soon as they pick up the charge of the rod they will behave as predicted. Both the balls and the tiny pieces of tissue may initially be attracted to the charged objects, rods or comb. Uncharged objects tend to be attracted to charged ones because of the redistribution of charges within the object that brings the opposite charges close to the charging source. This is called induction.

Lesson V: WHAT ARE ELECTRIC CURRENT AND VOLTAGE? HOW ARE CURRENT AND VOLTAGE MEASURED?

An analogy for the discussion of current and voltage: Current electricity is often thought of as a fluid that flows in the way that water flows through pipes. If there is a lot of water in a tank that is attached to a pipe, there is more pressure for the water to be pushed through the pipe. The voltage of a battery or a live wire might be compared to the height of the water in the tank since the voltage exerts pressure on the electrons to flow through the wire. The water that flows through the pipe helps us to understand how electricity flows along wires to the load.

Definition VOLTAGE = (think the height of the water in a tank) the source pressure that pressures electrons to flow through a wire or other conductor

Discussion We generally hear of the word “voltage” used to refer to batteries such as the standard d-cell that provides 1.5 volts, or to power lines in homes that are 110 to 220 volt wires. In these cases we are referring to the voltage source which is either a battery or the voltage delivered to buildings through wires from the generator in a central power plant. We think of this type of voltage as the pressure applied that pushes electricity through the circuit.

The word “volts” is also seen on light bulbs, and in this case there is a different meaning implied. What this means is the voltage *rating* of the bulb, that is, the voltage needed to make the bulb light up. This will lead us to the next lesson, Ohm’s Law, which is defined as:

Voltage = current x resistance, or

V=I x R

Definition CURRENT = (think flows like water) the flow of electrons through conductive materials such as a circuit

Students should always think of current as a *through* quantity, that is, current flows through a wire. Voltage is an *across* quantity, that is, a voltage exists across a circuit.

The formula for current is current equals voltage (or the measure of source pressure) divided by resistance (or things that offer resistance to the flow of electricity):

Current = voltage/resistance, or

I=V/R

The unit used to measure current is the ampere.

Analogy for discussion of amperes: An ampere is a specific number of electrons (that is one coulomb of charge) that moves past a given point in one second. An analogy that might enable us to better understand what an ampere is is to think of someone standing on a bridge over a highway and counting the number of cars that pass beneath him in a given amount of time. The ampere measures flow of current as the counting person measures the flow or traffic—units per time.

Lesson VI: WHAT ARE INSULATORS AND CONDUCTORS?

Any combination of the following materials would be useful for this lesson.

Materials

a metal pot (copper, aluminum, steel)
aluminum foil
a pane of glass or a large piece of plastic (part of a toy, a
food storage container, etc.)
a down jacket or a piece of fiberglass in a plastic bag
a heat emitting device such as a light bulb or a hair dryer
or the radiator in the room, but nothing hotter or with an open element

Method Hold the conductors and then the nonconductors in front of the heat source and ask the students if they can feel any heat coming from the heat source.
Have the children find things in the room that they can test, in this way, as conductors or as insulators.

Discussion Heat and electricity are both forms of energy. We are here using heat to illustrate a property that these two energies have in common. Metals such as copper, silver, iron and steel are excellent conductors of both heat and of electricity. In order to demonstrate this fact it is useful to work with the conduction of heat through these materials because it is both easier and more familiar to the students through their life experiences. Experiments with the conduction of electricity and with nonconductors or insulators will be done in the lessons on circuitry.

On a hot summer’s day, if you were wearing shorts, would you sit on the hood of a car that has been in the sun? Would you sit on the same car if you had a thick pile of newspapers or a pillow under you?

Those things that are good heat conductors are good conductors of electricity. Things that are poor conductors of heat are also poor conductors of electricity. Another way to think of a material that is a poor conductor of electricity is that it is a good insulator.

Things that are good insulators are things that are good at keeping heat or electricity from moving. We can think of insulators at things that fight against or resist the flow of electricity.

Demonstration of resistance A demonstration might be useful to make the concept of resistance clear that will also relate to the analogy that will be drawn between current and water. Have a student shoot a water pistol at a good sport—if you will be the good sport, the students will never forget this demonstration. Then, hold up a single layer of cloth in front of yourself and see if you are hit with less water. Of course, as the layers of the material are increased, the less water you will be hit with. The more resistance, the less the flow of water.

Definition RESISTANCE = is a measure of how hard it is for electric current to move through a material

For more inquisitive or advanced students you can tell them that resistance (in amperes) is the proportionality factor defined by voltage (measured in volts) over current (measured in ohms), which is Ohm's Law. This will be redefined and explained further in lesson VII. At this point you can refer the more advanced students to the appropriate texts in the bibliography.

Finer tuning of our understanding of conductors vs. insulators: No conductor of electricity is the perfect conductor because all things offer some resistance to the flow of electrons. No one material is a perfect insulator either. Generally, the more resistance a material puts up against the flow of electricity, the better and insulator it is.

Suggestion for a great subject for a science fair project:

Things that are the best conductors of electricity, the worst and in between: a continuum.

Definitions INSULATOR = anything that electricity cannot move easily through; anything that offers a lot of resistance to electric flow

CONDUCTOR = a thing electricity can easily pass through; metals and electrolytes (The word "electrolytes" should be memorized in this context even if time doesn't allow more than the defining of this word).

ELECTROLYTE = a liquid or moist substance that can conduct electricity

A handout on this material is included at the end of this paper. I found that although the children had little difficulty with the concepts of conduction and insulation, they did have trouble remembering the words themselves. The tricks in the handout helped them as did the use of the above described flash card usage.

Further Discussion Why do you think the space shuttle has a ceramic tile outer layer? Why do many pots have built-in plastic or wooden handles? Do you think that metal-soled shoes would be a good idea? Would aluminum foil jackets be a smart thing to manufacture? Why do electricians wear rubber gloves?

Testing Materials for Conductivity in a simple Circuit

Materials

a size D battery lamp fixture (socket)
1.5 volt bulb bell wire (gauge)
electric tape a straight pin
a scissors a pencil
a variety of pocket objects: key, plastic or wooden key ring

Method

1) Cut three 30 cm (=1ft) pieces of wire. Strip the plastic about 1 cm (=1/2 inch) from the ends of each piece.
2) Connect the end of the first wire to the socket. Push its other end through a piece of electric tape and then tape it to the positive (+) end of the battery (= the button end). This method of slipping the wire through the tape will keep the wire from slipping off the button-like + end.
3) Connect the second wire to the other side of the socket.
4) Connect the third wire to the negative (-) end (flat end) of the battery.
5) Place each object between the two open ends of the wires to see which ones complete the circuit (= a pathway for electricity) and which ones don't.

(figure available in print form)

This circuit was designed to test various materials for their ability to conduct electricity. At the same time we have introduced the parts of a circuit that will be used and reused in future experiments.

Definition CIRCUIT = the pathway through which electricity flows

Lesson VII: WHAT IS OHM'S LAW?

We have already mentioned Ohm's Law in the above lessons in its three forms: V = I x R, I = V/ R, and R = V/ I. This means that there is a linear relationship between the voltage, V, and current, I, in a circuit, and the proportionality constant is the resistance, R. The first equation means that in any circuit, the current is equal to the voltage divided by the resistance:

voltage (volts)

current (amperes) = resistance (ohms)

This is the way in which Ohm's Law is most often presented, and the definitions of voltage and resistance are derived from this one. One example of this law is if the voltage across a resistor is doubled, the current through it must also be doubled. Ohm's Law can be used to derive the currents and voltages in series and parallel circuits, as will be seen below.

Lesson VII: WHAT IS AN ELECTRIC CIRCUIT?

Definition cards to be reviewed at the beginning of this lesson:

conductors	circuit	electrons
insulators	charge	resistance

current voltage

Discussion of Circuit A circuit is a series of conductors, or things through which electricity can flow. It is a closed circuit when all of its parts are connected by conductive materials. It is an open circuit when there is either an opening in the pathway or there is a non-conductive material in the pathway such as plastic, air, or any electricity resistant material. A circuit must have the following parts:

1) a source of electric current such as a dry cell, a battery or electricity from a wall socket. This source of electricity is called the source.
2) a load = the thing that works because of the current such as a light, a bell, a motor, etc.
3) one wire that goes
   a) from the source to the load and
   b) a second wire that goes from the load to the source.

A circuit may have more than one source and more than one load and any number of wires to complete the pathways between them, but every circuit must have one of each of these three elements.

Definitions SOURCE = the source of electricity; the place where work is done to separate charge; a battery or current from the wall
LOAD = the thing that works because of the flow of electricity; a light, a bulb, a buzzer, a motor, etc.

CIRCUIT = (think "circle" or "circulatory system"); the pathway through which electric current flows; made up of conductive materials

A) CLOSED CIRCUIT = a complete, circle-like pathway through which electricity moves
B) OPEN CIRCUIT = a circuit with either a break in it (from an open switch or a loose wire etc.) or with a nonconductor interrupting the pathway through which electricity normally flows

Demonstration of the fact that electricity flows through a simple circuit:

Materials

a pocket compass a galvanized (iron) nail
bell wire a lemon

a piece of copper wire or a copper nail or a penny

Method

1) Wind the wire approximately twenty times around the body of the compass.
2) Strip the plastic off the last 1 cm of each end of the wire.
3) Connect one of the ends of the wire to the galvanized nail and the other end to the copper element (whichever copper element you choose).
4) Roll the lemon on the table while pushing down on it to break up some of its insides.
5) Making sure that the two different types of metals don't touch each other, push them through the lemon skin.
6) Watch to see if the compass needle moves. [1]

(figure available in print form)

Discussion Why does the needle of the compass move? The electric current passing through the wire creates a magnetic field. In this experiment which thing is the source? The source is the lemon. What is the load? The load is the coiled wire. Why do we wind the wire around the compass? We do this to create a magnetic field. Why do we roll the lemon on the table? We roll the lemon to break down some of its fibers so that it forms an electrolyte. What kind of conductor or source is the lemon? Is the lemon more like the current from the wall or from a battery? The lemon is like a battery.

Definition BATTERY = an electrochemical source of electricity

The lemon acts like a battery because it provides the electrolyte (the source of free ions) in which two half reactions take place. The galvanized nail is plated with zinc which accepts the electrons and the copper which provides the electrons.

Demonstration of a more conventional circuit

Discussion and Review At this point all the vocabulary words should be reviewed and the concepts and experiments already done should be discussed. Listed here are all the vocabulary words:

atoms		electron	charge		conductors
insulators	resistance	work		current	
voltage	circuit		source		load

Briefly, the discussion should include the following material: Work is done to separate electrons from atoms. This work is either done by the battery, or by a huge generator in a power plant and the electric current is brought through wires into our homes through the walls to the outlets on the walls. When we push a plug into the outlet and turn on the switch we are converting that electrical energy into light, heat or mechanical energy that is done by either a motor or a light or some kind of electric appliance. Because the energy that comes from a wall outlet is so powerful, that is, it is of such high voltage, we will use another source or supplier of electrical energy in all our experiments in the classroom. This source is the battery.

This circuit was designed to test various materials for their ability to conduct electricity. At the same time we have introduced the parts of a circuit that will be used and reused in future experiments.

Definition CIRCUIT = the pathway through which electricity flows

The two types of circuits: Introducing Lessons X and XI

There are two kinds of circuits. One is a single pathway circuit called a series circuit. The second is called a parallel circuit. The two should be shown in separate lessons and demonstrations of two types can be done by the students during student directed labs.

Lesson X: WHAT IS A SERIES CIRCUIT?

This lesson will take a short time because the concept is an easy one. The next lesson, schematics, actually deals with the same material as it lets the students do the designs and the implementation of the series circuit. Thus, this lesson and a good part of the next should be taught during the same period.

Definition A SERIES CIRCUIT = a single pathway through which electricity can flow

As we saw in the demonstration of the lemon and the compass as well as in our circuit that tested materials for their ability to conduct electricity, a series circuit is made up of

1) a power source (a dry cell, battery, or outlet)
2) a load (a light, a bell, any kind of a motor, etc.)
3) and two wires between the source and the load.

A series circuit can have more parts in it but its definitive characteristic is that all its parts are in a single loop, one thing lined up after the other, with the last wire returning to the power source.

Lesson XI: WHAT IS A CIRCUIT DRAWING OR A SCHEMATIC?

Discussion Physicists and electricians use several symbols to draw circuits. Circuits are drawn before they are actually built in the same way that recipes are made before bakers bake, or plans are made before architects, or designers of buildings, have their buildings built. The symbols are easy to draw. Once rules for putting the symbols together are learned, circuits can be designed easily and quickly, and the actual circuits can be built so that we can get our hoped for and expected results.

DEFINITION: A CIRCUIT DRAWING OR A SCHEMATIC = a drawing or blueprint for an electric circuit

Method: The teacher should be sure to practice the symbols from the Designing Circuits Handout (which is at the end of this paper) before putting them on the board. Simply use the handout to introduce each of the symbols separately. Have the children practice each symbol on the board after they doodle a few times on a blank sheet of paper. The handouts should only be distributed and worked on when the children begin to feel that they have associated the symbols with their terms. These symbols should be the alphabet of circuit drawing. Like the printed and the cursive alphabet, the students have to develop ease in using the "letters" or the writing of "sentences," that is, the designing of circuits.

(figure available in print form)

As soon as the children have been introduced to the symbols, they should practice drawing at their desks and on the board, the simplest circuit: source—wire—load—wire. The simple exercise in drawing the design will reinforce the concepts and the appropriate vocabulary (circuit, series circuit, source, load).

(figure available in print form)

The next step is that the children should work in groups of two or three to design other possible circuits and to try to predict what will happen. The handout has the suggested components for some basic designs and asks leading questions so that other designs can be designed and then tried.

Further discussion about circuits and circuit drawing: The following questions will suggest possible designs to the children. (The results can be discovered by the students as they implement their circuit designs).

Does it matter where you place the buzzer? the bell? the switch? What happens if you wire two lights, one after the other? What happens if you wire a light and a buzzer? What would happen if one light in the series circuit were to burn out or if one didn't light because it was not screwed in correctly?

Demonstration of some simple circuits:

Materials Each group should be given

three batteries	three sockets
three light bulbs	electric tape

8 wires with the plastic stripped from the ends

Once each team or small group of students has put some basic designs on paper, it should be given supplies to actually build each circuit. No boards are needed because as soon as a light lights or a buzzer sound a different circuit should be designed and implemented.

Discussion As the children wire up their circuits they will be surprised by some of the results. When they see that each of two lights in a series circuit burn half as bright as a single light they will be ready to calculate the voltages in the circuit. For example, if you use two 1.5 volt batteries in series, meaning the source provides 3.0 volts, each bulb will use 1.5 volts. Review lessons V and VII. If one of the bulbs is disconnected or burns out there would be a break in the circuit and it would be an open circuit.

Lesson XII: WHAT ARE PARALLEL CIRCUITS?

As usual, review all the vocabulary cards taught so far in the described way.

None of the children in my class came upon a parallel circuit in their playing with their drawings or with their actual building of circuits. Nor were they able to figure out why all the lights in the classroom don't go out when one light bulb is burned out; but it did get them into an excited discussion about the need for a different method of wiring. So the next step was the introduce parallel circuits.

The reason that electricity works separately on the loads of a parallel circuit is that in a parallel circuit the voltage across each path is the same. Since the voltage across each path is the same, the current splits at its forking pathways. It splits in proportion to the resistance in each path. On the other hand, in a series circuit, the current through each element is the same, while the voltage splits in proportion to the resistance of each element.

Discussion As we have discussed and discovered, if lights are lined up one after the other in a circuit in a single path we have a series circuit. A series circuit is useless when we need to light more than one light that has a single source of power and is controlled by a single switch because if one light blows the circuit is no longer closed, and none of the lights will light.

Instead of series circuits, we use parallel circuits when there is more than one load. Strings of Christmas lights or the rows of lights around a make-up mirror are two examples that clearly illustrate the need for circuits that can still work if a single light goes out.

Definition A PARALLEL CIRCUIT = a circuit in which there is more than one pathway through which electricity can flow

If one part of the circuit doesn't work, the electricity can still follow a circular path because there are other ways through to different loads and back to the source. In other words, in a parallel circuit there is a source and wires leading away from it that fork to separate loads. It is at the *fork* that the current splits. The current that would pass through one load never reaches the other loads, so a failure of one load doesn't create a break in the circuit. (In a series circuit, each load in the single pathway is part of the circuit of conductors for each other load).

Analogy to a parallel circuit: A good way to make this concept clear to the students through analogy is to compare a parallel circuit to a day's chores done by a working mother who has to drop her children off at day-care, drop off her suits at the cleaner, go to work, pick up the children and return home. If there is a detour (a part of her normal route is closed), so that the cleaner's is unreachable, she can still make it to her other destinations because there are alternative, other possible, roads that can take her there, and allow her to return home too.

Demonstration and Experimentation: At this point a couple parallel circuits should be drawn on the board by the teacher. Then a few children should try to reproduce them once they are erased. As before the children should work in small groups to make circuit drawings and then to implement their designs.

(figure available in print form)

CONCLUSIONS: Electricity is becoming a more important factor in our lives every day as more and better inventions are manufactured. We are presently teaching students who have been growing up with computerized toys, innumerable electric appliances and user friendly computers everywhere in their lives. All of these products use the above seeds of circuitry as their cores. We must be able to understand the fundamental principles of electricity so that we don't feel like complete incompetents in a rapidly changing world. We must be able to teach our children at least these basics so that they can take over from where we leave off.

Electricity Handout

Conductors vs. Insulators

Conductors

CONDUCTORS are things that electricity easily passes through; things that do not resist the flow of electricity

copper	silver
aluminum	gold
steel	electrolytes

thick, short wires . . . . why?

> Memory trick: Think “train conductor.” Train conductors keep the trains moving as electric conductors keep the current moving.

Not all metals conduct electricity equally well.

Insulators

INSULATORS resist the flow of electricity; things that electricity does not easily pass through

plastic	wood
rubber	cloth
air	glass

thin, long wires . . . . why?

> Memory trick: Think “insulated jacket,” or “house insulation.” Both keep the heat in.

No material can be a perfect insulator. Some materials are better insulators than others.

> Directions: Read the list of materials and objects below. Put them under the conductors list or under the insulators list.

ceramic tiles	plastic bags	wooden boxes
metal shoes	salt water	a chain fence
asbestos tiles	wool blankets	a jump rope
an aluminum can	water	lemon juice

Conductors	Insulators

Electricity Handout

Circuit Symbols and Circuit Design

word symbol practice . . . . .
source = battery

bell or buzzer

light, bulb or socket

wire crossing wire

switch

(figure available in print form)
(figure available in print form)
(figure available in print form)
(figure available in print form)
(figure available in print form)

Some Simple Circuits

1) single source
   single load
2) single source
   single load
   switch
3) single source
   two bulbs
   switch
4) double source
   two loads
   switch

Electricity Handout

Comparing An Electric Circuit to the Circulatory System

The Human Circulatory System	A Closed Circuit
pump = the heart	pump = the source = a battery or electric current
substance that flows = blood	flow = electrons
carriers of the fluid that leave the heart = arteries	carries the electrons to the load = wires
the load = the cells	the load = a bulb, a buzzer, a bell, a motor, etc .

things that complete the circuit or the return to the source:

the veins	wires

Materials List

Lesson Number	Materials	Source	Cost
I	a few balloons	any store where you get party supplies	$ .05 ea
	a glass jar	an empty mayo jar	free
IV	rug remnant	any carpet store	2.00 to 5.00
	piece of silk	a scarf or a blouse you no longer need	free
	a piece of fur	an old fur collar, a remnant from a furrier	free
	a glass rod	a fluorescent light from your kitchen	free
	a wooden dowel	any lumber supply store; cut a piece off a broom handle	under 2.00 or free
	a piece of wood	a chunk of 2 x 4 from any lumber yard scrap heap	free
	ping pong balls	Herman’s	1.00
VI	a metal pot	your kitchen	free
	aluminum foil	” ”	”

a pane of glass	from an old picture frame or window pane	”
a winter coat	borrow from a student	free

VII a lemon	the supermarket	.79
a pocket compass	first see if one of your kids has one; else, Bradlee’s	6.99
a galvanized nail	Grossman’s .	05
a copper nail	”	”

The following materials are reusable for all the circuit designs and are available at any Radio Shack for the prices quoted below:

2 size D batteries Extra Life .59 ea
per group of students

3 2.5 volt bulbs E-10 threaded .99 ea
per group of students

3 lamp fixtures E-10 screw-base .79 ea
per group of students

electrical tape .99/roll

100 feet #22 solid wire (substitute for bell wire) 2.99/roll

a wire stripper (or a scissors will do) 2.59 ea

3 buzzers, 1..5 volt 1.99 ea

3 motors, 1.5 volt .89 ea

3 toggle switches (or use an opened paper clip) 1.29 ea
per group of students

Notes

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1. Blecha, Milo K., Peter C. Gega, and Muriel Green, *The New Exploring Science* , Green Book (Laidlaw Brothers, Publishers, River Forest, Illinois, 1982), page 102.

Annotated Bibliography

Blecha, Milo K., Peter C. Gega and Muriel Green. *The New Exploring Science* (Laidlaw Brothers, Publishers, River Forest, Illinois, 1982).

Great for explaining electricity to fourth through sixth graders because it includes explanations of power plants through how everyday electric appliances such as phones, hair driers and t.v.s work. Good, inexpensive and simple circuit projects. Weak in the explanations of electric theory and frustratingly over-simplified in explanations, such as how static electricity works.

Brockway, Carolyn Sheets, Robert Gardner and Samuel F. Howe. *General Science* (Allyn and Bacon, Inc., Newton, Massachusetts, 1985).

An excellent seventh grade science text. See Chapter 7: Atoms and Molecules. Excellent illustrations and photographs.

Carelse, X.F. *Making Science Laboratory Equipment: A Manual for Students and Teachers in Developing Countries* (John Wiley and Son Limited, Chichester, 1983).

Illustrations of simple tools such as wire strippers and various kinds of batteries, LED's, etc. Excellent for the person who needs step-by-step in circuit design and assembly.

Dibner, Bern. *Ten Founding Farthers of the Electrical Science* (Burndy Corporation, Norwalk Connecticut, 1954)

Nice outline of the development of electricity through some of the founding fathers.

Kaufman, Milton, J. A. Wilson. *Basic Electricity: Theory and Practice* (McGraw Hill Book Company, New York, 1973).

Thorough explanations and analogies for numerous concepts. One of those programmed learning texts that were so big in the 70's, thus, nice test questions for yourself and your students.

Sharlin, Harold I. *The Making of the Electrical Age from the Telegraph to Automation* (Abelard-Schuman, London, 1963).

Nice book for pleasure reading. Historical and anecdotal.

Talsenick, Irwin. *Idea Bank Collation: A Handbook for Science Teachers* (Science Supplies and Services Company, Limited, Kingston, Ontario, Canada, 1984).

Fun to leaf through. Some invaluable suggestions, such as a fuse made out of aluminum foil, and a simple home-made switch.

Vergara, William C. *Electronics in Everyday Things: 113 Searching Questions and Authoritative Answers About the Major Role Electronics Plays in Our Daily Lives* (Barnes and Noble, New York, 1972). Good for many appliances, but of course, dated.

Wilson, J. A."Sam" and Milton Kaufman. *Learning Electricity and Electronics Through Experiments* (McGraw Hill Book Company, Gregg Division, New York, 1979).

The book for the student who just has to go on and build dozens of things. Great explanations for the hands on type.

Winkler, Alan, Leonard Bernstein, Martin Schachter and Stanley Wolfe. *Concepts and Challenges in Science* , Second Edition (CEBCO, Allyn and Bacon, Inc., Newton, Massachusetts, 1984).

Excellent section on physics for fifth and sixth graders. One of the two textbooks referred to in the unit for

good explanations of atoms, molecules, charge, etc.