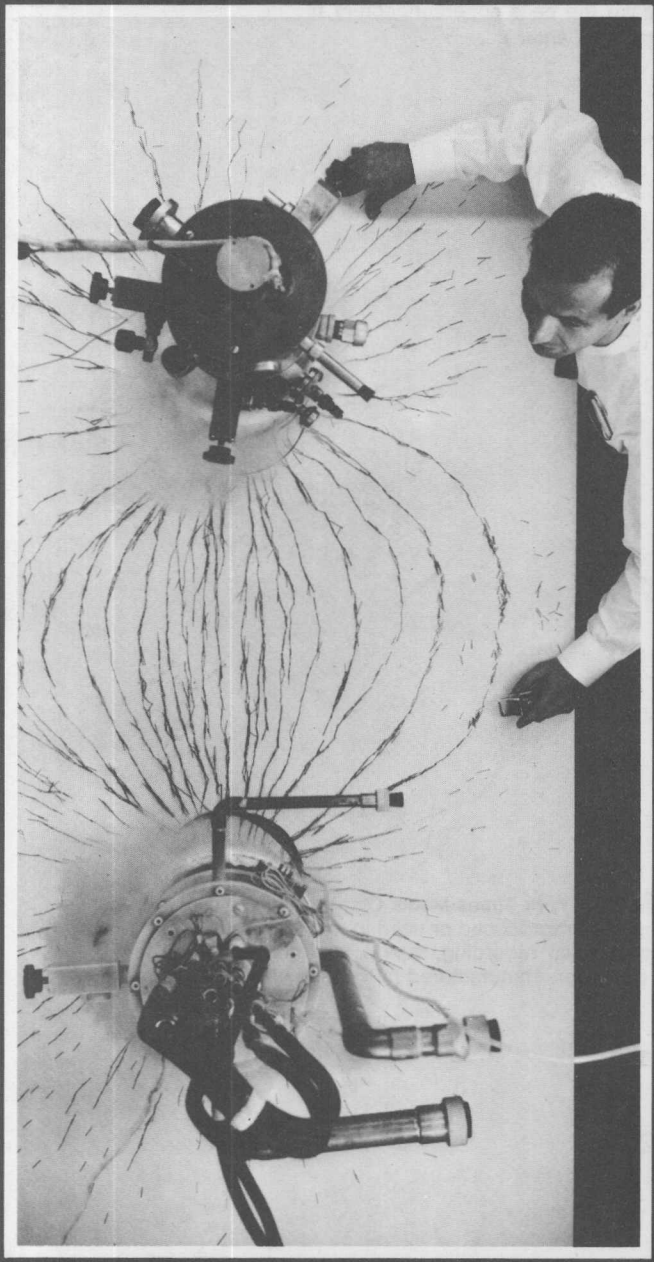
MAGNETISM AND ELECTRICITY



Richard D. Heckathorn

Have you ever seen a flash of lightning? Or have you ever slid your shoes across a rug on a dry day and seen or heard the small spark that jumped between your finger and something you touched?

The bolt of lightning and the small spark are both a form of energy, which we know as **electricity.** Even though no one has ever seen electricity, millions of people all over the world use it every day.

The same is true about **magnetism.** Almost everyone has seen a magnet pick up certain kinds of objects. We use magnets in many ways, at home and in industry. Although scientists know much about using electricity and magnetism, they know little about the real nature of electricity and magnetism.

Benjamin Franklin learned some very interesting things about electricity while flying a kite during a thunderstorm. Since then scientists have discovered many more facts about both electricity and magnetism.

There is hardly an activity that goes on in our modern civilization that does not make use of electricity in some way. Electricity provides us with heat and light. Industry uses it in the operation of machinery. We use it at home for cooking, refrigeration, and air conditioning. Electricity is used in the telephone and telegraph. Electricity provides us with entertainment in the form of radio, television, and motion pictures. Physicians and surgeons use electricity in many ways to

diagnose illnesses and also to help cure patients.

In the activities that follow, you will investigate certain facts about magnetism and electricity which will help you to understand what they are. You will discover for yourself in what ways magnetism and electricity are very much alike, as well as how they are different. You will also discover that electricity can be used to produce magnetism.

Unit Opening Photograph

Carl H. Rosner of the General Electric Research Laboratory used superconducting magnets to perform, on a large scale, the iron filing experiment that you will perform in Problem 7-3 of this unit. Rosner scattered thousands of iron nails on a piece of white plywood surrounding two superconducting magnets. When he tapped the board sharply, the nails formed the classic "picture" of magnetic lines of force. The magnets are inside stainless steel flasks used to maintain a liquid helium temperature of 452 degrees below zero Fahrenheit which is necessary to make the coils superconducters of electricity. (Courtesy of the General Electric Research & Development Center.)

Lab-Inquiry Texts
PHYSICAL SCIENCE

TITLES

Methods of Science
Measurement
Using Line Graphs
Properties of Matter
Force and Motion
Work, Energy and Simple Machines
Magnetism and Electricity
Behavior of Light and Sound

By Sanford M. Eisler and Murray Stock

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problem 7-1

To discover some of the properties of magnetic force given various objects and a bar magnet.

MATERIALS

Wooden dowel	Piece of copper wire
Glass marble	Wire brad
Paper clip	Bar magnet
Iron nail	Beaker or glass jar
Copper penny	Plastic petri dish with cover
Rubber stopper	20 Sheets of paper
Lead sinker	Shaker containing iron filings
Metal washer	

PROCEDURE

1. Place the following objects on the table in front of you: a small wooden dowel, glass marble, paper clip, iron nail, copper penny, rubber stopper, lead sinker and a metal washer. Add any other small objects you may have such as a bobby pin, button, rubber band, etc.

List each of the objects in the first column of Table 7-1.

2. Bring the red end of the bar magnet close to each of the objects.

a. In the second column, place a check (✓) opposite objects that the magnet attracted or picked up.

b. What common property did each of the objects attracted by the magnet have?

_____

_____

3. Repeat Procedure 2 using the unpainted end of the bar magnet instead of the red end.

TABLE 7-1

Objects	Objects Attracted

Was there any difference in the kind of objects attracted by the unpainted end of the magnet?

_____

_____

4. Place the objects that were attracted by the bar magnet into a glass jar or beaker. Move the magnet along the outside of the jar or beaker.

What effect, if any, did the glass have on the objects attracted?

5. Cover a small wire brad with about 20 sheets of paper. With one hand, place the bar magnet on the paper directly over the brad. Hold the magnet in position. With your other hand, gradually lift the paper.

What can you conclude from your observations concerning the effect of glass and paper on magnetic attraction?

6. Using the pointed end of a large iron nail, touch the middle of the bar magnet. Notice the strength of the magnet at this point (Fig. 7-1).

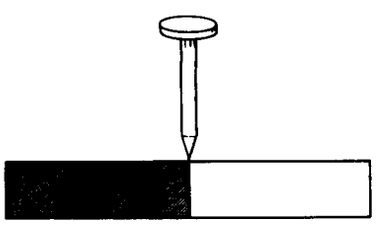


Figure 7-1

Repeat, touching each end of the magnet with the tip of the nail.

a. What did you notice about the strength of attraction at the different parts of the magnet?

b. What can you conclude about the strength of attraction of the different parts of a bar magnet?

7. Place the bar magnet in the center of a white sheet of paper. Cover it with an inverted petri dish. Place the other petri dish over the first dish with the open side up (Fig. 7-2).

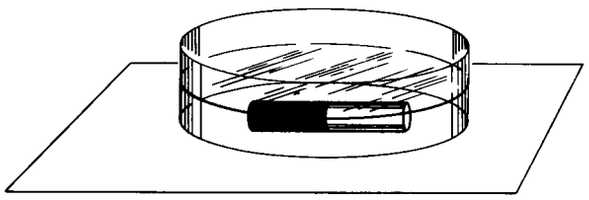


Figure 7-2

8. Lightly sprinkle some iron filings from the shaker into the top petri dish over the magnet. Tap the dish gently until the iron filings form a pattern or design over the magnet. Study the pattern carefully and notice the lines formed.

a. In the space around the drawing of the magnet in Figure 3 sketch the pattern formed by the filings.

Figure 7-3

b. According to the pattern formed by the iron filings, where are the lines closest together? farthest apart?

c. How does the closeness of the lines around the magnet compare to the strength of attraction of the magnet? Refer back to Procedure 6.

9. Instead of using a bar magnet, repeat Procedures 7 and 8, placing objects such as a wooden dowel or a large nail under the petri dish.

What special kinds of objects cause the iron filings to form a pattern of lines?

problem 7-2

To discover the law of magnetic attraction and repulsion.

MATERIALS

2 Bar magnets	Pegboard platform
Single strand thread	Support rod

PROCEDURE

1. Suspend a bar magnet by a single strand thread from a support rod (Fig. 7-4). Allow the magnet to swing freely until it stops moving completely.

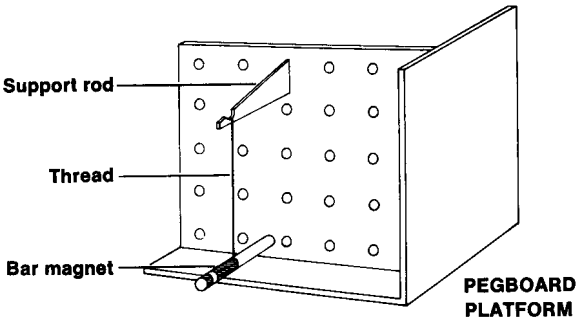


Figure 7-4

In which *geographical* direction does the red end or **pole** of the magnet point?

_____

2. Point the red pole of the magnet in different directions and release it each time. Wait until the magnet stops moving.

a. In which direction does the red pole *always* point when the magnet stops moving?

_____

Call this red end of the magnet the *"north seeking pole."*

3. Slowly bring the north seeking pole of the second bar magnet toward the north seeking pole of the suspended magnet.

Describe what happens.

_____

_____

4. Slowly bring the unpainted pole (south seeking pole) of the second magnet near the north seeking pole of the suspended magnet.

Describe what happens.

_____

_____

5. Now bring the south seeking pole of one magnet near the south seeking pole of the suspended magnet.

Describe what happens.

_____

_____

6. Write a rule which describes what happens when poles of magnets are brought near each other. (Use the words *like, unlike, attract, repel.*)

Rule _____

_____

reference sheet 7-1

Every magnet is surrounded by a **magnetic field,** which is made up of lines of magnetic force. These lines of force surrounding the magnet are invisible. However, the patterns formed by the iron filings sprinkled over the magnet show where these lines of force are.

You have learned that a force must be either a push or a pull. You also learned that all forces must have a *direction* in which to push or pull.

Scientists, by agreement, have decided that the lines of magnetic force *leave* the magnet at the north seeking pole and *enter* at the south seeking pole (Fig. 7-5). In this way everyone will think about these lines of force in the same way. The arrows in Fig. 7-5 show these directions.

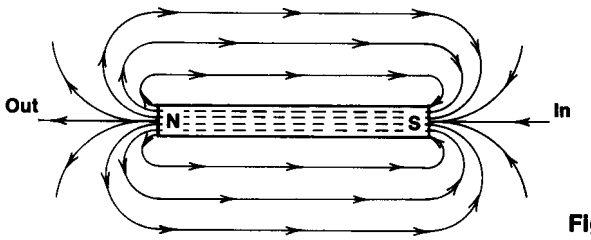


Figure 7-5

Notice that lines of magnetic force do not cross each other as they leave the north seeking pole and enter the south seeking pole. Also notice that the lines of force are closer together or more concentrated at each of the poles. This may explain why the pull of a magnet is strongest at the poles.

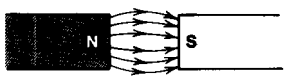


Figure 7-6

Actually, we can think of these lines of force as acting like bunches of stretched rubber bands coming out of the magnets. They tend to want to contract or shorten themselves. If *unlike* poles of two magnets are brought near each other, the lines of force of one magnet enter the other magnet, tending to pull them together. Notice that the lines of force leave the north pole of one magnet and enter the south pole of the other magnet (Fig. 7-6).

Figure 7-7

When like poles of two magnets are brought near each other, something different happens (Fig. 7-7). Instead of going from the pole of one magnet to a pole of the second magnet, the lines of force now push against each other. Lines of force leaving the north pole of a magnet cannot enter the north pole of another magnet. This pushing action tends to cause the magnets to repel each other.

The earth itself is actually a huge magnet. It has two magnetic poles, one of which is located in Northern Canada and the other in Antarctica. These magnetic poles are not to be confused with the north and south *geographic* poles found on maps. Being a magnet, the earth has a huge magnetic field surrounding it which extends far out into space (Fig. 7-8). It is this magnetic field which affects the magnets on the earth's surface and tends to cause them to point in a north-south direction.

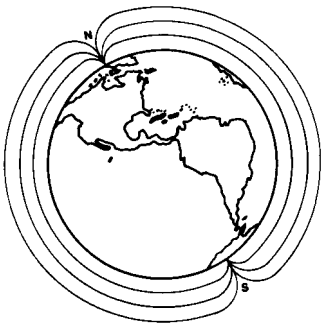


Figure 7-8

problem 7-3

To discover the properties of magnetic lines of force using two bar magnets and iron filings.

MATERIALS

Shaker containing iron filings
Petri dishes
2 Bar magnets

PROCEDURE

1. Study Reference Sheet 7-1.
2. Sprinkle iron filings over one of the magnets as was done in Procedures 7 and 8, Problem 7-1. In the space below, draw the magnet and the pattern formed by the filings around the magnet.

What causes the iron filings to form this pattern?

_____

_____

_____

3. Label the poles of the magnet in your drawing. Use the letter N for the "north seeking pole" (red end) and S for the "south seeking pole."

Draw arrowheads on the lines in your diagram to show the direction of the lines of force as they leave and enter the magnet.

4. Place two magnets under the petri dish so that unlike poles are opposite each other. Keep them far enough apart so that they do not come together (Fig. 7-9).

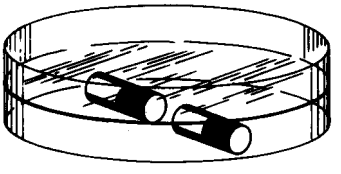


Figure 7-9

Sprinkle the iron filings on top of the petri dish over the magnets and draw the lines of force as they enter and leave the magnets (Fig. 7-10). Place arrows on the lines to show directions of lines of force.

Figure 7-10

5. Repeat Procedure 4, placing *like* poles of the magnets opposite each other. Draw the lines of force (Fig. 7-11). Use arrows to show directions of the lines of force.

Figure 7-11

What happens to the lines of magnetic force:

(1) between unlike poles of two bar magnets?

_____

_____

(2) between like poles of two bar magnets?

_____

_____

6. Complete Worksheet 7-1.

BEYOND THE CLASSROOM

1. Visit any shop that supplies tools for carpenters or electricians. Ask to see a "stud finder." If the clerk is not busy, ask him to explain how it works.

2. Use an ordinary magnetic compass to find the position of the studs in the walls of a room in your home. Studs are the upright posts in the framing of a wall to which wall boards, paneling, etc. are attached.

worksheet 7-1

1. Since you cannot see the magnetic field around a magnet, by what method can you show it is present?

_____

_____

2. In what ways are the force of gravity and magnetic force similar?

_____

_____

3. Suppose you sawed a steel magnet in half (Fig. 7-12). What would be the polarity of the pieces? Fill in the blank spaces above the magnets to show the poles.

Figure 7-12

4. The ends of 4 bar magnets are positioned as in Figure 7-13 below. Draw the lines of magnetic force as they leave one magnet and enter the other. Use arrows to show direction. (Refer to Reference Sheet 7-1 if necessary.)

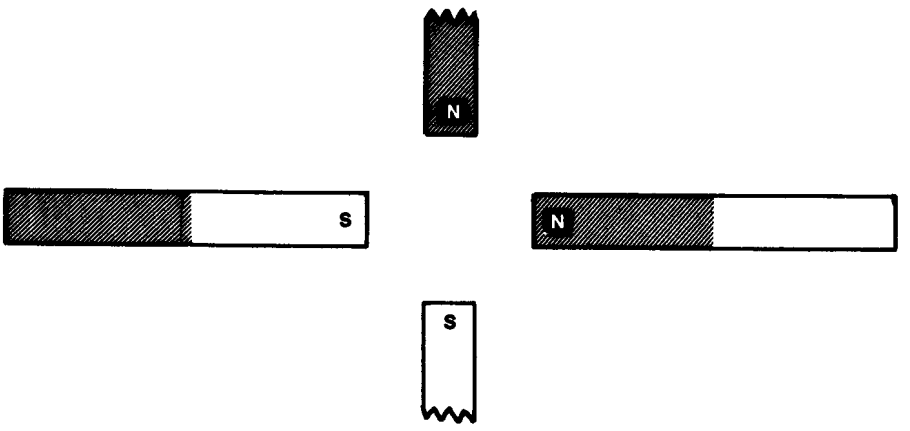


Figure 7-13

5. Four bar magnets are positioned with their ends as shown in Figure 7-14. Draw the lines of force as they leave one magnet and enter the other. Use arrows to show the direction of the lines.

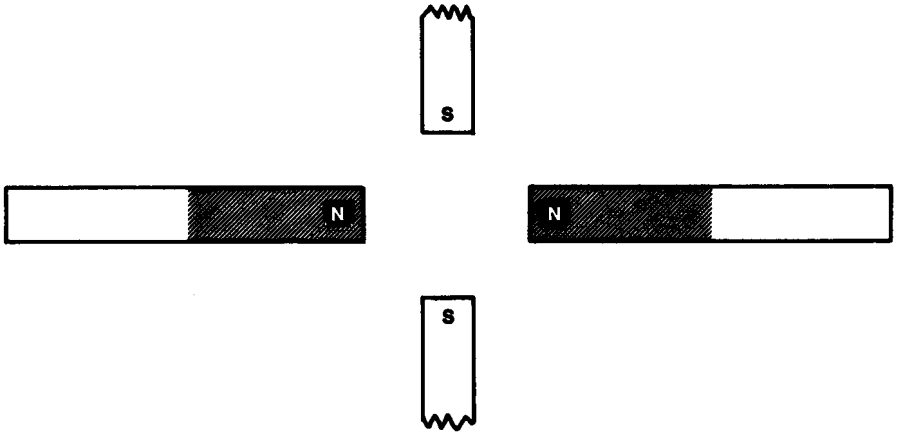


Figure 7-14

6. Suppose that all you had were two steel bars. They had the same shape, size, color, and weight. How could you tell which of the bars was a magnet?

_____

_____

7. How far do you think the magnetic field extends from the magnet?

_____

_____

8. Why is the north geographic pole actually the south magnetic pole?

_____

_____

problem 7-4

To measure indirectly the magnetic force between two magnets.

MATERIALS

Pegboard support
Short support rod
2 Magnets
Broom straw
Ruled notebook paper
Metric plastic ruler
Masking tape or scotch tape
Thread
Graph paper
Compass

PROCEDURE

1. Use a compass to line up the pegboard support so that it is located in an east-west direction (Fig. 7-15).

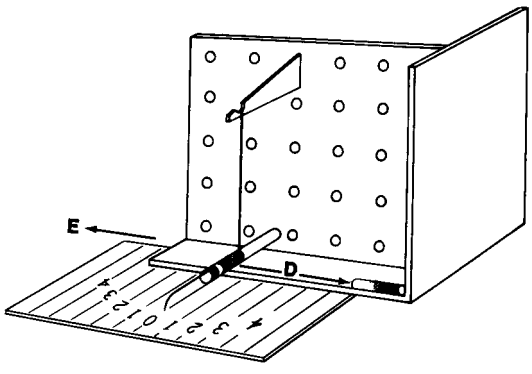


Figure 7-15

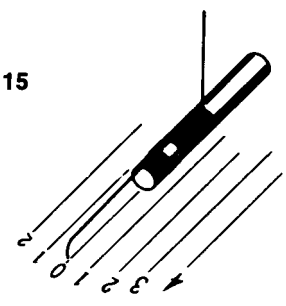


Figure 7-16

2. Attach a broom straw about 15 cm long to the north seeking pole of a magnet with a piece of scotch or masking tape. Bend the end of the broom straw downward slightly (Fig. 7-16).

3. Suspend the magnet by a thread from the support rod inserted in the pegboard. The tip of the broom straw should be about one millimeter above a sheet of graph paper placed under one end of the pegboard support (Fig. 7-15). Adjust the thread supporting the magnet so that the magnet is suspended in a horizontal position and swings freely.

4. When the magnet stops swinging, place a 0 on the line on the graph paper directly under the tip of the broom straw. Number each line 1, 2, 3, etc., in *both* directions away from the 0 line (Fig. 7-16).

5. Place the second magnet at the other end of the base of the pegboard support with the south seeking pole pointed toward the suspended magnet. Place this magnet at the *outer edge* of the base (Fig. 7-15).

What effect did placing the magnet on the pegboard base have on the suspended magnet? Why?

_____

_____

6. Measure the distance D from the end of the second magnet to a point directly under the suspended magnet. Record this distance in Table 7-2. Also record the position of the tip of the broom straw pointer on the ruled paper. Read this position accurately—estimate to a tenth of the space between the ruled lines.

TABLE 7-2

Distance Between Magnets (D)	Position of Pointer

7. Move the magnet along the edge of the base toward the suspended magnet in 3 cm steps. Record in Table 7-2 the distance D, and the position of the pointer over the ruled paper for each step. (Be sure to keep the magnet at the edge of the base as you change its position.) Move the magnet through a *total* distance of about 24 to 27 cm along the base.

Describe what happens to the suspended magnet as the other magnet moves closer and closer.

_____

_____

8. From the data in Table 7-2, plot a series of points on Practice Sheet 7-1, showing how the position of the pointer changes as the distance D between the magnets changes. Draw a straight line passing as close as possible to all of the points.

a. Which is the independent variable?

_____

_____

b. From your graph explain what happens to the amount of force acting on two magnets as they move closer together.

_____

9. Repeat Procedures 5, 6 and 7, reversing the second magnet so that the north seeking pole will point toward the north seeking pole of the suspended magnet. Record values in Table 7-3.

TABLE 7-3

Distance Between Magnets	Position of Pointer

Using the same graph as in Procedure 8, plot the points in Table 7-3. Draw another straight line passing close to these points. (Draw this line with colored ink or pencil if possible.)

a. Compare the curves of both graphs. What does each describe?

_____

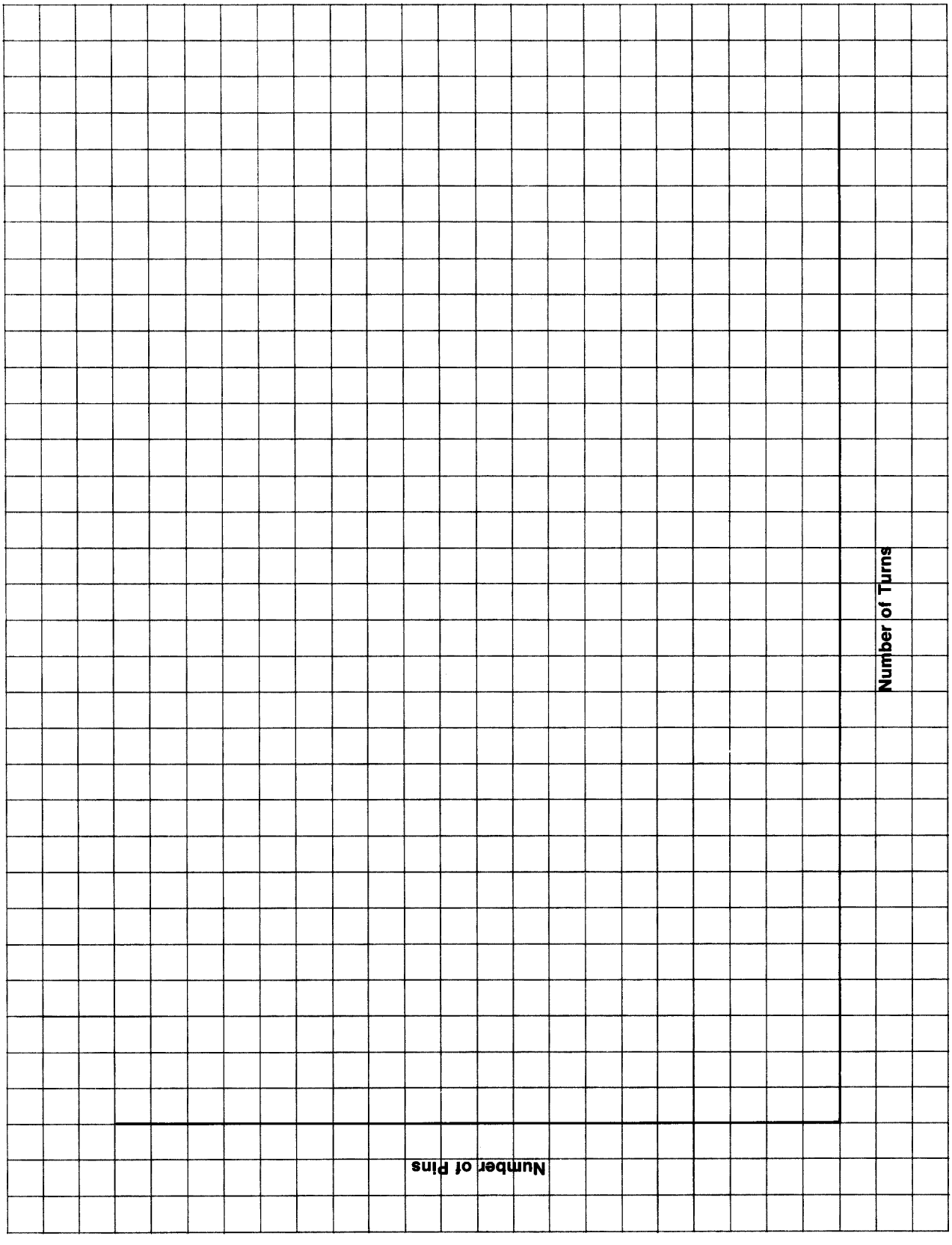
_____

b. What is the relationship between the attractive force of two magnets and the distance between them?

_____

_____

PRACTICE SHEET 7-1



reference sheet 7-2

Many years ago it was discovered that atoms are electrical in nature. According to the atomic theory, all substances are made up of tiny particles called **atoms.** In turn, these atoms themselves are made up of many different kinds of even smaller particles.

The particles in which we are most interested for our study of electricity are the **electron** and the **proton.**

Electrons are very small particles charged with *negative* electricity. The electron is represented by a minus sign (–) which indicates a negative charge. Electrons are found in all substances, spinning like little tops. In addition to spinning, electrons also revolve around the center or *nucleus* of each atom. They revolve in regular orbits very much like the planets revolve around the sun (Fig. 7-17).

The nucleus in the center of the atom contains the protons. Protons are much heavier than electrons and are charged with *positive* electricity. The proton is represented by a plus sign (+), which indicates a positive charge (Fig. 7-17). The terms "negative" and "positive" were introduced by Benjamin Franklin who, among other things, was famous for his experiments with static electricity. The nucleus of the atom also contains particles called **neutrons** which have no charge at all.

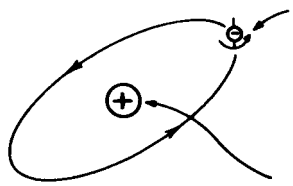


Figure 17

Atoms of different substances have different numbers of electrons and protons. Hydrogen, for example, has only one electron revolving around *one* proton which makes up the nucleus (Fig. 7-17).

Carbon has six electrons revolving around six protons in the nucleus (Fig. 7-18). In each of these atoms, notice that the number of electrons equals the number of protons. This is the natural condition in all atoms. When the total negative charges of the electrons cancel out the positive charges of the protons in the nucleus, the atom is said to be electrically *neutral.*

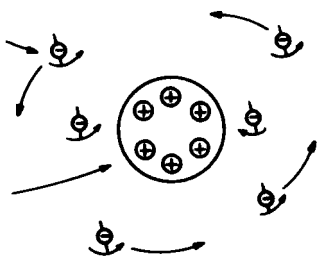


Figure 18

Protons and electrons attract each other. This is similar to the attraction between the north and south poles of a magnet. This attraction is the force which keeps the revolving electron in its orbit as it moves around the nucleus.

When certain objects made of plastic or hard rubber are rubbed with substances such as wool or animal fur, electrons are rubbed off the wool and transferred onto the plastic. This results in the presence of extra negative electrons on the plastic. Because the plastic has more electrons than protons, it is said to be *negatively* charged (Fig. 7-19). Since the wool or fur has lost negative charges from its neutral atoms, it has an excess of protons and it becomes positively charged.

When glass is rubbed by silk, electrons are *removed* from the glass by the silk. This leaves the glass with more protons than electrons. The glass then has a *positive* charge (Fig. 7-20). Since electrons have been transferred from the glass to the silk, the silk has more electrons than protons and is negatively charged.

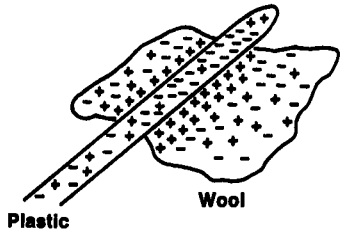


Figure 7-19

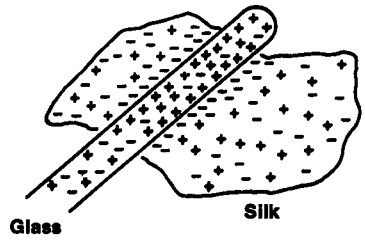


Figure 7-20

Many substances can be charged electrically by rubbing them against something. When this happens, the object is said to be charged with **static electricity.** The word "static" means "standing still" and is the result of either negative or positive charges building up in an object. Static electricity is electricity that is not moving. In later activities you will learn about **current** or "moving" electricity.

For many years scientists have tried to explain why some materials can be made magnetic and others cannot. As you have just learned the electrons within an atom are always spinning very rapidly, like little tops. Scientists now think that as the electrons spin they become little magnets. Some of these electrons spin to the left and others spin to the right (Fig. 7-21). In most materials, about the same number of electrons in an atom spin to the left as to the right. Because of this, they sort of wipe out each other's magnetism. Copper, glass, wood, etc. are substances which have electrons spinning this way. However in certain special materials such as iron, nickel, and cobalt, it seems that most of the electrons in the atoms can be made to spin in the same general direction (Fig. 7-22). When they do this, they combine their magnetism and form a stronger magnet.

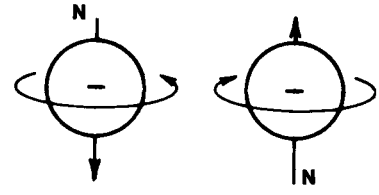


Figure 7-21

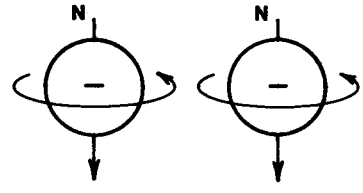


Figure 7-22

Scientists think that in these easily magnetized materials, the electrons form in groups called **domains** (doe-manes). Each domain is made up of millions of atoms whose electrons are all spinning in the same direction. These atoms are bunched together making many tiny magnets throughout the material. When a piece of iron for instance, is *not* magnetized the domains in the iron are pointed in many different directions (Fig. 7-23).

Figure 7-23

However, when you stroke a piece of iron in one direction with a strong magnet, the iron becomes magnetized. This is because all the little bunches of atom magnets, or domains, line themselves up in the same direction and work together to form one large magnet (Fig. 7-24).

Figure 7-24

The positions of the magnetic domains in soft iron are more easily changed from one direction to another. Magnets made of soft iron *lose* their magnetism quite rapidly. The positions of the magnetic domains in steel, on the other hand, are not easily shifted. Magnets made of steel *keep* their magnetism for a long time.

problem 7-5

To charge a plastic rod and a piece of glass with static electricity.

MATERIALS

Tissue paper
Piece of wool cloth
Plastic or rubber rod
Small glass test tube
Piece of silk cloth

PROCEDURE

1. Study the first three paragraphs of Reference Sheet 7-3.

2. Cut 15 to 20 pieces of tissue paper into small squares each about .5 cm square. Rub the plastic or rubber rod vigorously with the piece of wool cloth for about 10 seconds. Place the rubbed end of the rod near the small squares of tissue.

a. Describe what happens when you bring the rod near the square of tissue.

b. What charge was placed on the rod?

3. Rub the same end of the plastic rod across the palm of your hand for about 10 seconds. Again place the rod near the tissue squares.

a. Compare the number of squares of tissue the plastic rod picked up in Procedure 2 with Procedure 3.

b. What do you think happened to the charge on the rod?

4. Rub a small test tube vigorously with a piece of silk cloth for about 10 seconds. Place the rubbed end of the test tube near the small squares of tissue. (It is best to do this on a very dry day.)

a. Describe what happens.

b. What charge has been placed on the test tube by rubbing it with the silk?

5. Roll the test tube between the palms of your hands for about 10 seconds. Place the test tube near the squares of tissue again.

a. Did the test tube pick up as many squares of tissue as before?

_____

_____

b. What happened to the charge on the test tube by rubbing it in your palms?

_____

_____

c. Compare the action of the plastic rod and the test tube with the way magnets act.

_____

_____

_____

d. List as many similarities between the behavior of magnets and static electricity as you can.

_____

_____

e. List as many differences as you can.

_____

_____

BEYOND THE CLASSROOM

1. Rub a fluorescent lamp bulb briskly with a piece of wool cloth in a darkened room. Notice how the bulb glows. (Be careful not to break the bulb.)

2. Find out why static electricity can light this type of bulb and not the ordinary filament type.

problem 7-6

To investigate the forces of attraction and repulsion resulting from static electric charges.

MATERIALS

Pegboard platform	Glass test tube
Support rod	Wool cloth
Plastic covered wire	Silk cloth
Thread	Second plastic rod
Plastic rod	Second glass tube

PROCEDURE

1. Cut a piece of plastic-covered wire about 12 cm in length. Form it in the shape of a stirrup to support a plastic rod or test tube (Fig. 7-25). Suspend the stirrup from a support rod by a piece of thread.

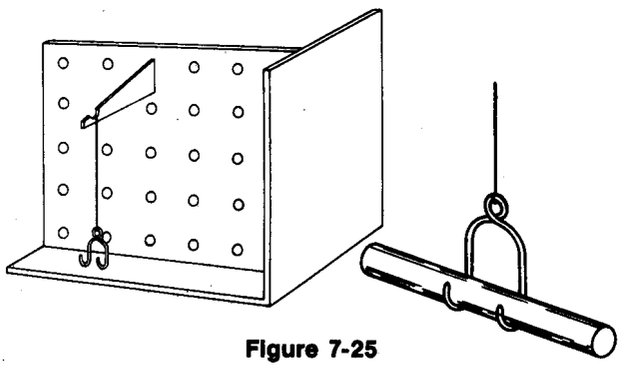


Figure 7-25

2. Rub the plastic rod with a piece of wool cloth for about 10 seconds. Place the rod in the stirrup. Immediately, rub a glass test tube with a piece of silk for about 10 seconds. Bring the test tube near one end of the suspended charged plastic rod. *Do not touch the rod with the test tube* (Fig. 7-26).

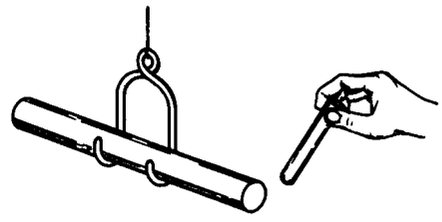


Figure 7-26

a. Describe what happens when the two charged objects are brought near each other.

_____

_____

b. What charge, (+) or (–), did the plastic rod have after rubbing with wool? Refer to Reference Sheet 7-3.

_____

c. What charge did the wool have after rubbing the plastic rod?

_____

d. What charge did the glass tube have after rubbing with the silk cloth?

_____

e. What charge did the silk cloth have after rubbing the glass tube?

_____

3. Rub the test tube again with the silk cloth. Bring the charged tube close to the other end of the suspended plastic rod.

a. Describe what happens.

_____

_____

b. How does this action differ from the way a magnet acts?

_____

_____

4. Remove the plastic rod from the stirrup. Recharge it by rubbing it again with a piece of wool for about 10 seconds. Replace it in the stirrup. Rub a second plastic rod with a piece of wool for the same length of time. Bring it close to either end of the suspended plastic rod.

a. Describe what happens when the second charged rod is brought close to the end of the first charged rod.

_____

_____

b. What charge, (+) or (–), did each of the plastic rods have?

_____

5. Charge a glass test tube by rubbing it with a piece of silk cloth for about 10 seconds. Suspend it in the stirrup. Charge a plastic rod by rubbing it with a piece of wool and bring its end close to each end of the suspended test tube.

a. Describe what happens when the end of the charged plastic rod is brought close to either end of the charged test tube.

_____

_____

b. What charge did the test tube have?

_____

c. What charge did the plastic rod have?

_____

d. What does this show about the behavior of objects with unlike static electric charges?

_____

_____

6. Remove the glass test tube from the stirrup and recharge it by rubbing it with the silk cloth. Suspend it in the stirrup. Charge a second glass test tube by rubbing it with silk cloth. Bring the end of the tube close to each end of the suspended glass tube.

Describe what happens.

_____

_____

7. Review what happened in Procedures 1 through 6.

Write a general rule which tells what happens when objects charged with static electricity are brought close to each other.

_____

_____

8. Complete Worksheet 7-2.

BEYOND THE CLASSROOM

Gather together various non-metallic items that you find around the house such as a comb, pencil, etc. Rub them with wool cloth and with silk cloth. See if they become electrically charged by testing them with small bits of tissue paper.

worksheet 7-2

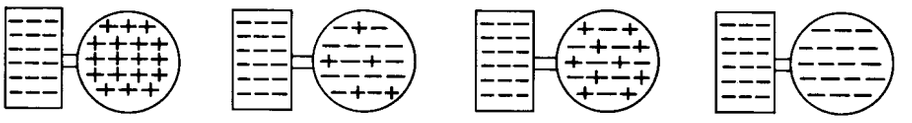
1. Explain why most atoms are usually electrically neutral; that is, have no electrical charge.

2. What causes an atom to become electrically charged?

3. A plastic rod becomes negatively charged when rubbed with a piece of wool cloth. What is the charge on the wool? Why?

4. When an object becomes charged with static electricity, which atomic particle is either added to or removed from the object?

5. Below are diagrams of four sets of charged objects. In which direction will the electrons move if the objects in each set touch each other? Use an arrow to show the direction.



6. In what ways are the forces of magnetism and static electricity similar?

7. In what ways are the forces of magnetism and static electricity different?

8. Why does an object charged with static electricity eventually lose most of its charge?

9. Why do gasoline trucks often have a piece of chain that drags on the ground?

10. When pairs of magnets are stored, they should be placed next to each other so that their opposite poles are in contact with each other. Why?

reference sheet 7-3

As was mentioned in Reference Sheet 7-2, when certain materials are rubbed, electrons are transferred and the materials become charged with static or non-moving electricity. The charge on the material is considered *negative* electricity if electrons are *added* to it. If electrons are *removed* from the material by rubbing them off, the material becomes charged with *positive* electricity.

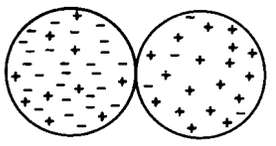


Figure 7-27

What do you think would happen if a negatively charged object with too many electrons touched a positively charged object that was short of electrons (Fig. 7-27)? If you said that electrons would move from the negatively charged object to the positively charged object, you would be correct. After a while, each atom in the object would have the same number of electrons as protons and, therefore, each object would then be *neutral* and have no electric charge (Fig. 7-28). *Electrons always tend to move from a place where there are too many electrons to a place where there is a shortage of electrons.*

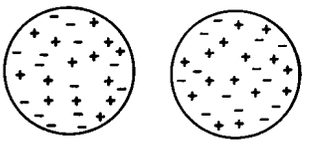


Figure 7-28

When many electrons are able to move in a continuous flow in the same direction, from one atom to another, the electricity is no longer "static" or standing still. It is now "moving," or **current electricity.** Current electricity, therefore, results from the movement of electrons from one atom to another (Fig. 7-29).

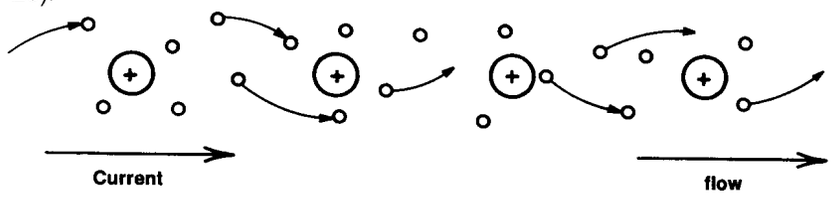


Figure 7-29

If the objects in Figure 7-29 above, were connected with a piece of copper wire instead of just being allowed to touch, electrons would move from atom to atom through the copper wire. This movement of electrons would take place in a fraction of a second. It would stop when enough electrons were transferred to make both objects electrically neutral. Electrons move through copper quite easily because copper is a good **conductor** of electricity. Other materials such as glass, wood, etc. are poor conductors of electricity since electrons do not move through them easily. Materials that are poor conductors of electricity are called **insulators.**

If many electrons can be made to move in the same direction in a conductor, an electric current flows through the conductor (Fig. 7-30).

To cause electrons to move continually through a conductor, a force is needed. This force is called **electromotive force** or EMF for short. The common term for EMF is **voltage.** This electromotive force can be developed in many different ways. Batteries provide electromotive force or voltage through chemical action.

Huge generators in electric power plants provide enough electromotive force by mechanical action to supply the electric current for an entire city. In both cases, electrons are forced through conductors by an electromotive force so that an electric current flows. For an electric current to flow continually, both an electromotive force and a complete path or closed **circuit** are necessary (Fig. 7-30).

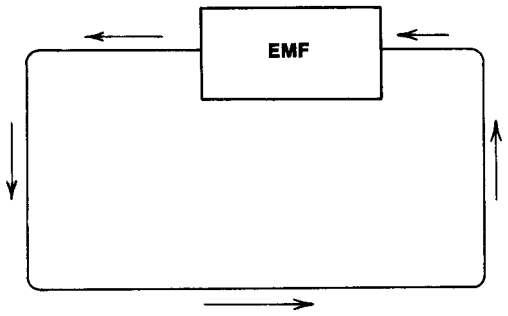


Figure 7-30

Sometimes we wish to measure electrical current, which is the *rate* of flow of electrons. Electric current is usually measured in units called **amperes.**

As you continue to study the physical sciences, you will learn more about how EMF, or voltage, and the amount, or amperes, of electric current that flow through a circuit are measured. You will also learn how the combination of EMF and amperes determine the amount of electrical energy being used in a circuit.

problem 7-7

To investigate the properties of an electric circuit.

MATERIALS

Dry cell (flashlight battery)	Lamp socket
Flashlight bulb	Cell holder
Enameled wire	Knife switch
Sandpaper	Small screwdriver

PROCEDURE

1. Study Reference Sheet 7-3 carefully.
2. Examine the dry cell or flashlight "battery." Notice that it has a metal post in the center (A). It also has a metal base (B) (Fig. 7-31).

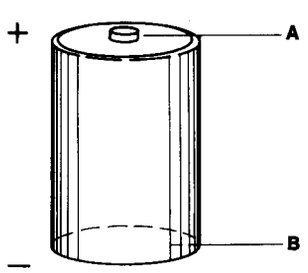


Figure 7-31

Because of chemical action within the dry cell, millions of electrons are set free and forced to the base of the battery. The electrons forced to the base of the battery originally came from the center post. The center post, therefore, is lacking millions of electrons.

a. What do you think would happen to the electrons if you connected the center post to the base with a conductor?

_____

b. Examine the label on the battery. What is its EMF or voltage?

_____

_____

3. Examine the light bulb very carefully. Compare it with the diagram in Fig. 7-32. Notice that it has a base made of metal. Also notice the bottom tip of the bulb, which is separated from the base by a black material (insulator). If you look very closely, you should be able to see two thin wires, coming up out of the base. Connecting these two wires is the **filament** of the lamp. The filament is a very fine wire.

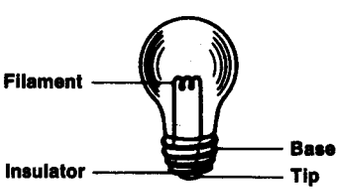


Figure 7-32

4. Take approximately 40 cm of enamel covered copper wire and remove about 6 cm of the brown enamel from each end of the wire with a piece of sandpaper. Be sure all the enamel is completely off and that the ends are shiny copper. Wrap one end of the bare wire tightly around the metal base of a flashlight bulb (Fig. 7-33). Do not allow this end of the wire to touch the metal tip of the bottom of the bulb. Touch the bottom tip of the bulb to the center part of

the dry cell and the other bare end of the wire to the base of the dry cell.

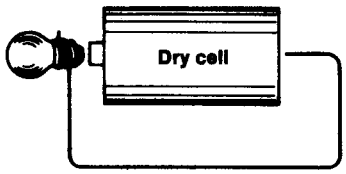


Figure 7-33

a. Describe what happens when the wire touches the base.

_____

_____

b. What do you think is moving through the wire?

_____

_____

c. Why is this a closed circuit?

_____

_____

5. Using arrows, show the direction of the electric current flow through the wire on the diagram (Fig. 7-33).

What is flowing through the filament of the bulb?

_____

_____

6. Hold the tip of the bulb against the post of the dry cell. Remove the other end of the wire from the base of the cell.

Why does the light go out?

_____

_____

7. Remove the wire from the base of the bulb. Screw the bulb tightly into the lamp socket. Examine Figure 7-34 carefully and trace the circuit through the lamp and the socket.

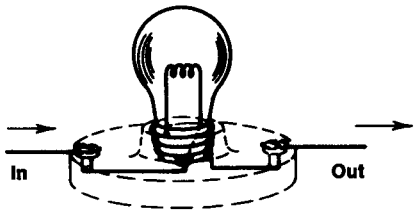


Figure 7-34

Is this a closed circuit? Explain.

_____

_____

8. Place the dry cell in the cell holder. (The cell holder makes it easier to attach wires to each end of the dry cell.) Connect the dry cell, the lamp socket and knife switch (Fig. 7-35). Be sure all connections are tight. Use a screwdriver wherever necessary. Wherever connections are made with wire, the brown enamel insulation must be removed from the ends of the wire with sandpaper.

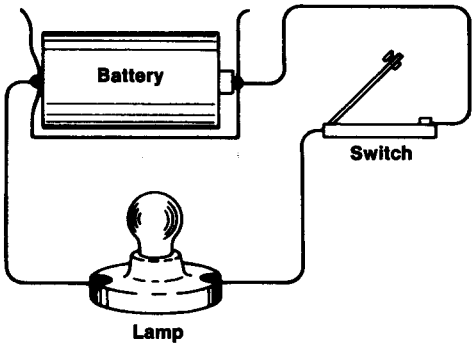


Figure 7-35

Close and then open the knife switch.

a. Describe what happens as you open and close the switch.

_____

_____

b. What is the purpose of the switch?

c. Why must all wire connections be tight?

d. If the light bulb is unscrewed in its base, why does the light go out?

e. Why is it necessary that the inside of the dry cell be a good conductor of electricity?

As you use the dry cell, the chemicals in it are used up. When this happens, the cell is no longer able to produce electricity. *To preserve the dry cell, do not keep the switch closed for more than a few seconds at a time in any of the activities.*

BEYOND THE CLASSROOM

1. Examine an ordinary household light bulb. Compare its construction with the flashlight bulb used in the previous activity.

2. With a hacksaw carefully cut a worn out flashlight battery in half. Cut it lengthwise. Examine one of the cross sections and describe the interior of the battery.

3. Visit a local electric generating plant and see how the large quantities of electricity used in a city or town are produced.

problem 7-8

To investigate the relation between an electric current and magnetic force.

MATERIALS

Compass	Wire
Dry cell and holder	Switch

PROCEDURE

1. Examine a magnetic compass carefully. The needle of the compass is a small magnet. Set the compass down on the table and slowly rotate it.

a. In what geographical directions do the ends of the compass needle always tend to point?

_____

_____

b. Is the dark or light end of the compass needle the north seeking pole?

_____

_____

c. Why must a magnetic compass be kept away from large objects made of iron?

_____

_____

2. Connect a dry cell in the circuit with the switch in the open position (Fig. 7-36). Place the compass *under* the wire. Arrange the compass so that the north and south seeking poles of the needle line up with the north and south markings on the face of the compass.

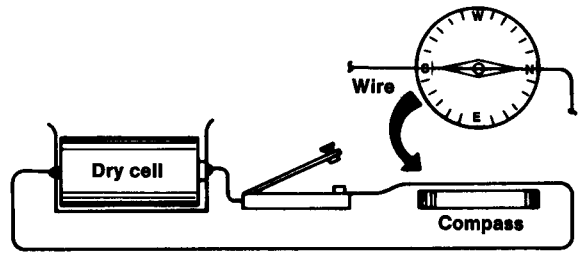


Figure 7-36

Complete the circuit by closing the switch for just a second and then opening it.

a. Describe what happened to the compass needle.

_____

_____

b. In what direction did the north seeking pole of the compass needle move when the switch was closed and the current was flowing?

_____

c. What is the direction of the lines of force *under* the wire if the north seeking pole of a magnet tends always to point in the direction of the lines of force?

_____

_____

3. Repeat Procedure 2 but place the compass *over* the wire.

a. In what direction did the north seeking pole move when the switch was closed this time?

b. What is the direction of the lines of force *above* the wire?

4. Repeat Procedures 2 and 3 but place the wire so that it crosses the compass in the east and west direction instead of north and south (Fig. 7-37).

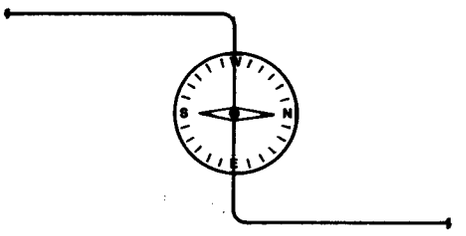


Figure 7-37

What happened to the compass needle with the wire in this position when you closed the switch?

Remember that the compass needle lines itself up with the lines of magnetic force. From what you have observed in this activity draw what you think is the direction of the magnetic lines of force around a wire carrying an electric current. Use the drawing of the wires in Figure 7-38, and place arrowheads on the lines to show the direction of the lines of force.

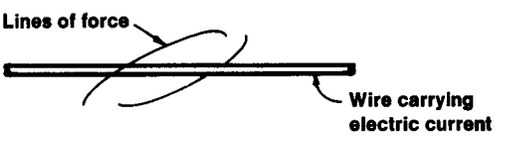


Figure 7-38

5. Repeat Procedure 2, but this time reverse the dry cell in the holder.

a. What effect does reversing the dry cell have on the direction of the electric current?

b. In what direction did the north seeking pole of the compass move this time when the switch was closed, east or west?

c. How does this compare to the direction the needle moved when you used the original Procedure 2?

d. Does the direction of current flow affect the direction of the lines of force around a wire? Explain.

BEYOND THE CLASSROOM

1. In 1819, a Danish scientist named Oersted, discovered an interesting fact concerning the relationship of electrical currents to magnetic fields. Using a reference book find out what Oersted's discovery was.

2. Bring a compass near the battery cable under the hood of an automobile. Have someone step on the starter and notice the effect on the compass needle.

problem 7-9

To investigate the properties of electromagnetism.

MATERIALS

Dry cell and holder	Enamel-covered wire
Wire	Sandpaper
Knife switch	Soft iron rod
Steel pins	Masking tape

PROCEDURE

1. In the previous activity you discovered that when an electric current flows through a wire there is a magnetic field around the wire.

Connect the dry cell in a circuit as shown in Fig. 7-39. Allow an electric current to flow in the wire.

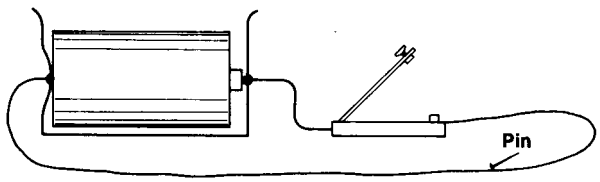


Figure 7-39

Place a small steel pin near any part of the wire.

What happens to the pin as the electric current flows through the wire? Give a reason why this takes place.

_____

_____

2. Cut a 1.5 meter length of thin enamel-covered copper wire. With a piece of sandpaper rub off about 3 cm of the brown enamel covering from each end of the wire. Be sure that all the enamel is off and that the ends are shiny copper.

3. Wind one end of the wire around the soft iron rod. Leave about 20 cm of wire before you start winding (Fig. 7-40). Be careful not to kink the wire.

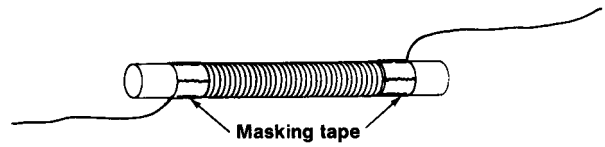


Figure 7-40

Wrap a small piece of masking tape around the wire after you wind 10 turns. This is to keep the wire from unwinding. Continue to wind the wire around the rod until you have a total of 60 turns. Wrap a small piece of masking tape around your last few turns.

4. Connect the windings to the dry cell (Fig. 7-41). Be sure to include the switch in the circuit and make sure that all connections are tight.

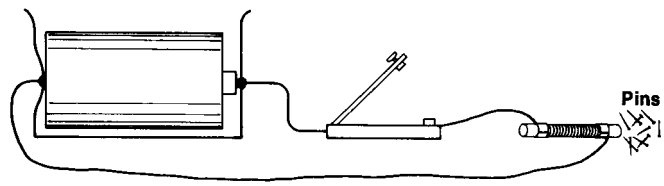


Figure 7-41

Place one end of the rod next to about 15 steel pins and close the switch for about three seconds. Then open the switch.

a. Describe what happened when you closed the switch.

b. Describe what happened when you opened the switch.

c. About how many pins were picked up? Compare this to what happened to the pin in Procedure 1.

d. What effect does winding the wire around an iron core have on the strength of the magnetic force surrounding the wire?

5. An iron rod with many turns of wire wound around it becomes an **electromagnet** when an electric current is passed through the wire.

How is an electromagnet different from the regular bar magnet you used in the other activities?

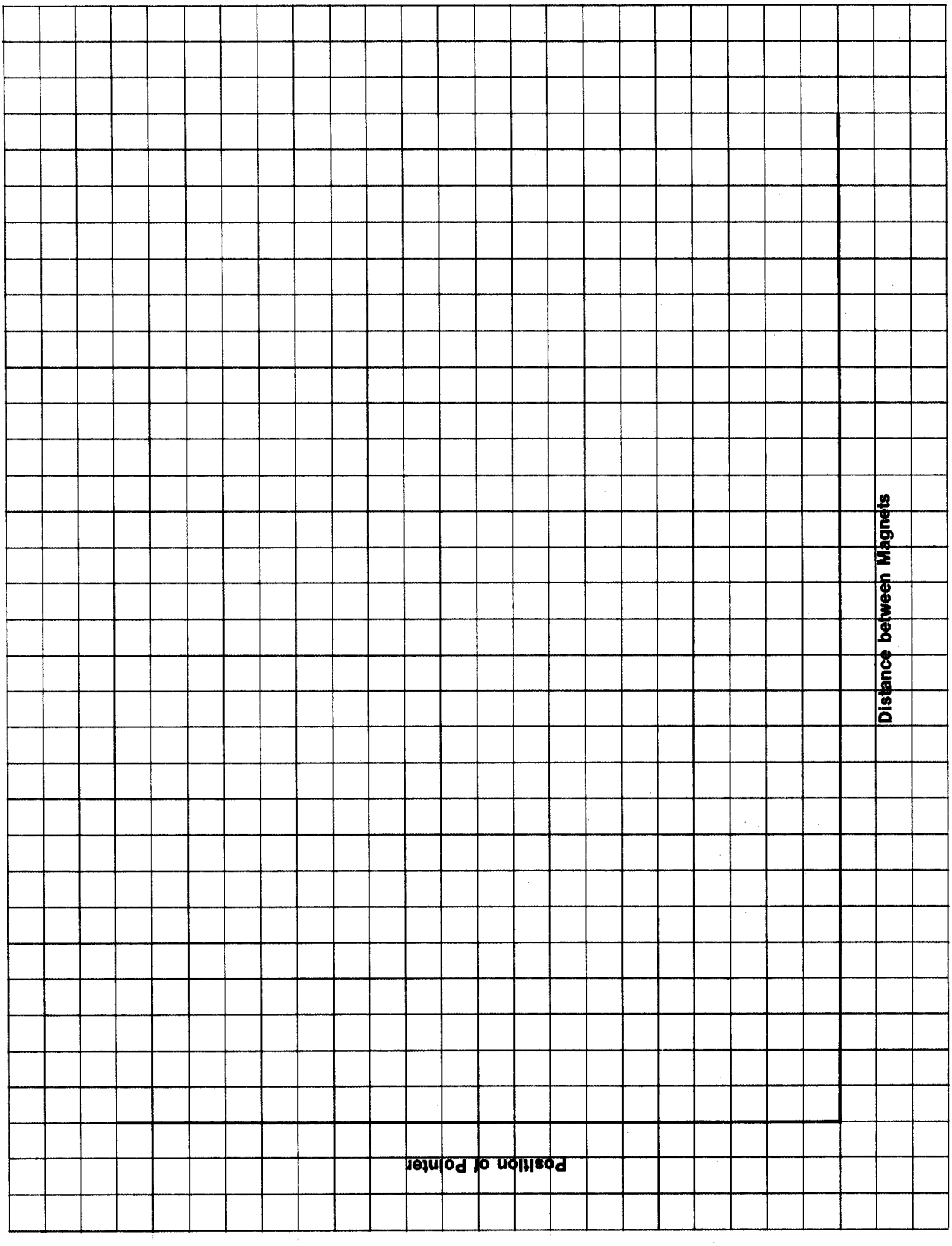
6. Repeat Procedure 4, but unwind 10 turns of the wire from one end of the rod. Record in Table 7-4 the number of turns of wire on the rod and the number of pins picked up by the electromagnet. Continue to remove 10 turns of wire from the rod each time. Count the number of pins picked up each time. Record data in Table 7-4.

TABLE 7-4

Number of Turns of Wire	Number of Pins

7. On Practice Sheet 7-2 make a graph showing how the strength of an electromagnet depends on the number of turns of wire. Use values in Table 7-4 to construct the graph.

PRACTICE SHEET 7-2



worksheet 7-3

1. An electric current in a wire is similar (but not the same) as water flowing through a pipe. Below are two columns of terms. The left column of terms refers to flow of water through a pipe. The other refers to flow of electrons through a wire. Draw a line connecting terms in one column with a matching term in the other column. For example ELECTRONS moving through wire compares to WATER flowing through a pipe.

Water flow	non-conductor
Pipe	voltage
Pump	electron current
Faucet	switch
Frozen line	wire
Pressure	battery

2. Clouds often develop very large electrical charges during a thunderstorm. What does the lightning represent?

_____

_____

3. Name at least three ways in which the bar magnet and electromagnet are similar.

_____

_____

_____

4. Name three ways in which bar magnets differ from electromagnets.

_____

_____

_____

5. An electromagnet with 100 turns picks up 20 brads. About how many brads would an electromagnet with 200 turns pick up?

_____

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