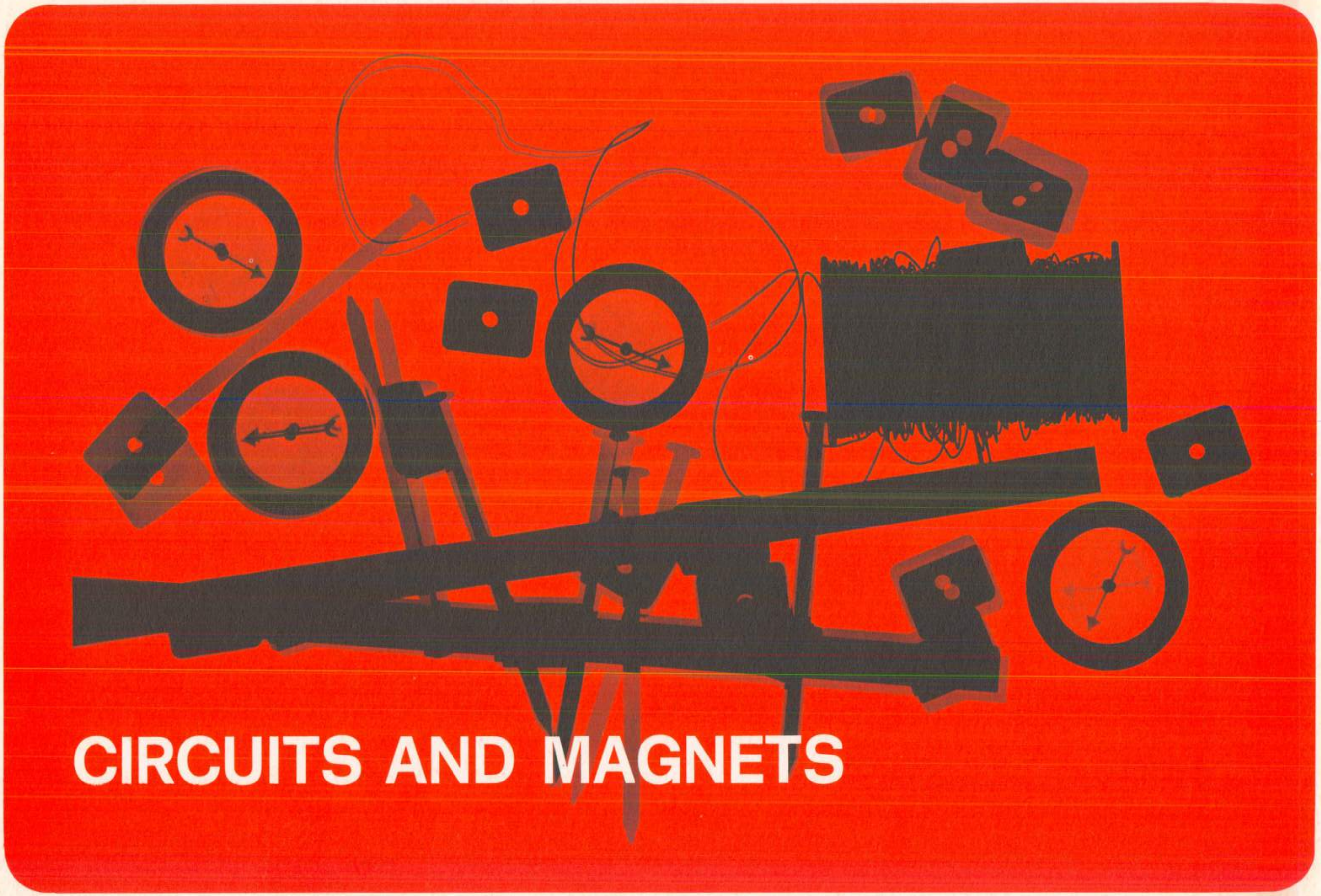
BATTERIES AND BULBS

Book 2



CIRCUITS AND MAGNETS

BATTERIES AND BULBS

Teacher's Guide

Trial Teaching Edition

Book 2

CIRCUITS AND MAGNETS

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CONTENTS OF CIRCUITS AND MAGNETS

INTRODUCTION

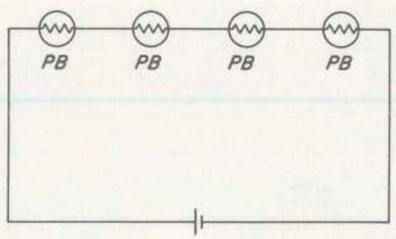
Circuits and Magnets

Circuits and Magnets introduces the children to some of the properties of magnets and to some of the relationships between magnets and circuits.

Questions such as: "What does a compass do?" "Can you use a compass in a circuit?" "What materials will a magnet pick up?" "How can you use a coil of wire in a circuit to act like a magnet?" are answered by children as they explore the characteristics of magnets, compasses and coils in circuits.

In *Circuits I* bulbs had two major functions:
They were an important part of a circuit because they gave light.
They also were an indicating device. The children knew that when a bulb lit it was in a direct path to a battery. If the bulb was left attached to the battery long enough, the battery went "dead" (it would no longer light a bulb). If a bulb did not light, it was *usually* not in a direct path to a battery. That path was not thought of as *affecting* the battery.

But there were some circuits such as this one:

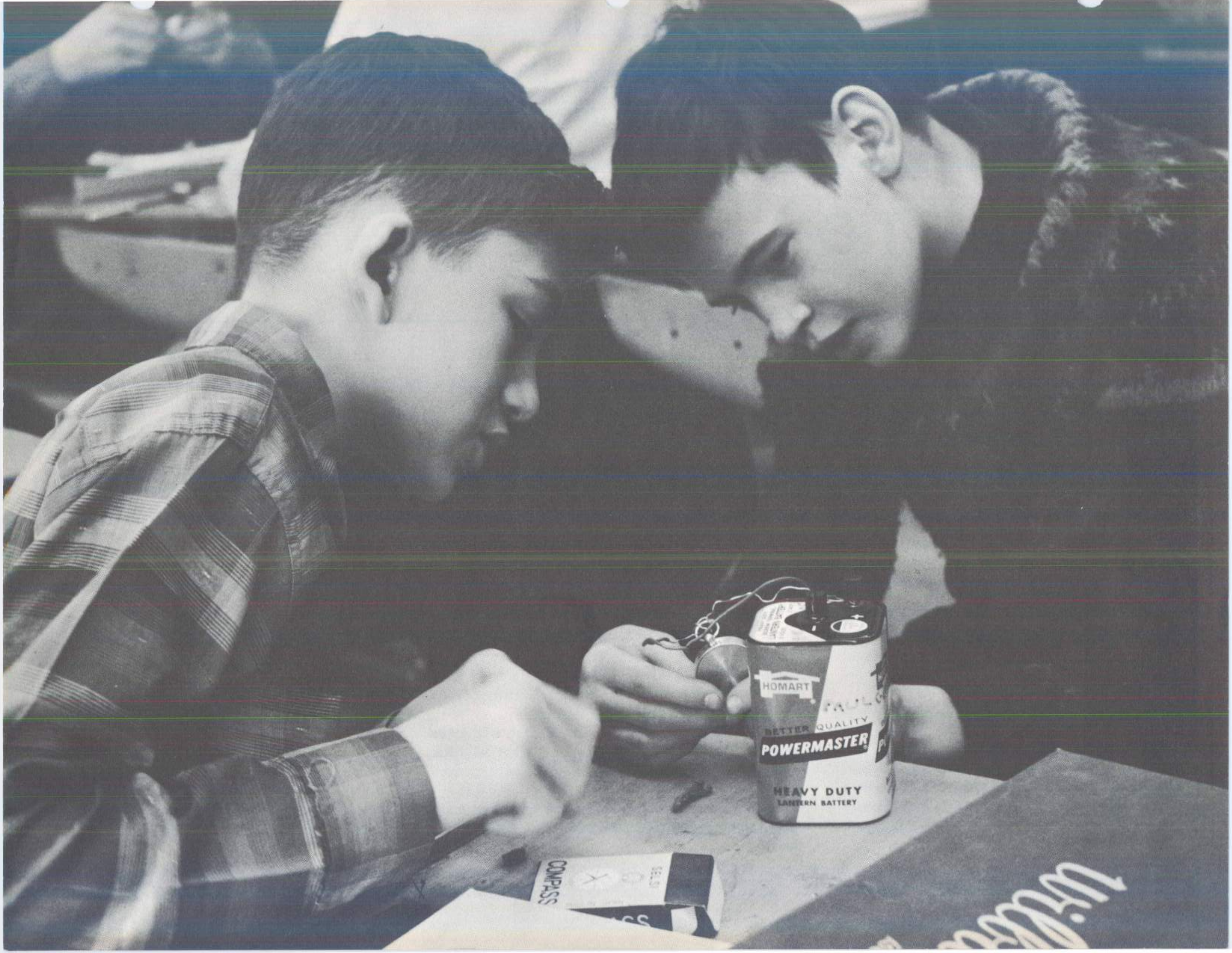


in which none of the bulbs lit, but the battery went dead if left connected to them. There must have been something happening to the circuit to have such effect on the battery!

In *Circuits and Magnets* the children will make a device that will allow them to detect whether some path in a circuit is affecting the battery even if the bulb is out.

Finally the children study some ways that magnets can be used in circuits, such as in a motor and in a buzzer.

You will definitely need to read the Introduction to *Batteries and Bulbs* and work through *Circuits I* before trying *Circuits and Magnets* if you have not previously taught the unit.


HOMART
BETTER QUALITY
POWERMASTER
HEAVY DUTY
LANTERN BATTERY
COMPASS

THE COMPASS

Before Starting to Teach

Materials you will need

2 compasses
Several "D" batteries and holders
Several eight-inch pieces #22 copper wire (plastic-insulated)
1 roll #24 Formvar (enameled copper wire)
Sandpaper
1 roll #22 copper wire
Modeling clay
Cellophane tape
"Junk box"

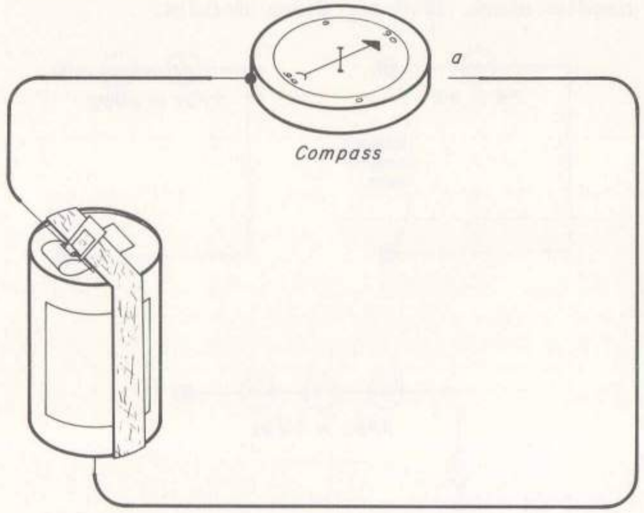
Place a compass on a non-metal surface. Make the needle move, without shaking the compass, by bringing another compass close to it. Bring a nail or paper clip close to the compass needle.

Another way to move the needle is to put the compass in the circuit at the right.

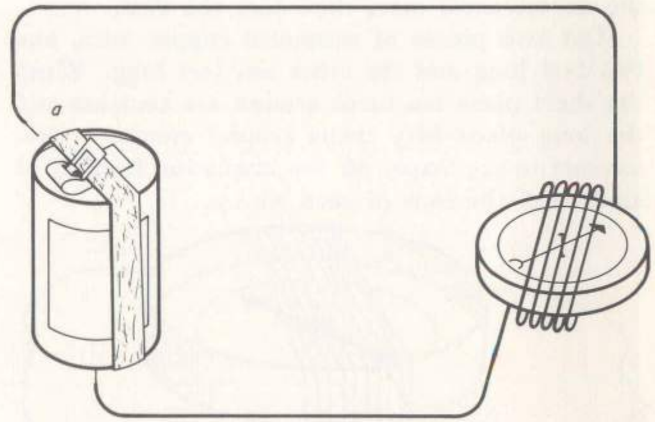
Move the wire at a over the case to see where you must touch the compass to get the needle to move.

Short-circuit a "D" battery with an eight-inch piece of #22 plastic-insulated, copper wire. Move this wire over, under and around the compass.

Does the needle move if the wire is not moved? Lay this wire on the compass case. Quickly connect and disconnect the wire from one side of the battery. You can see that in order to make the needle move you must change something — either by moving the wire or by connecting it to and disconnecting it from the battery.

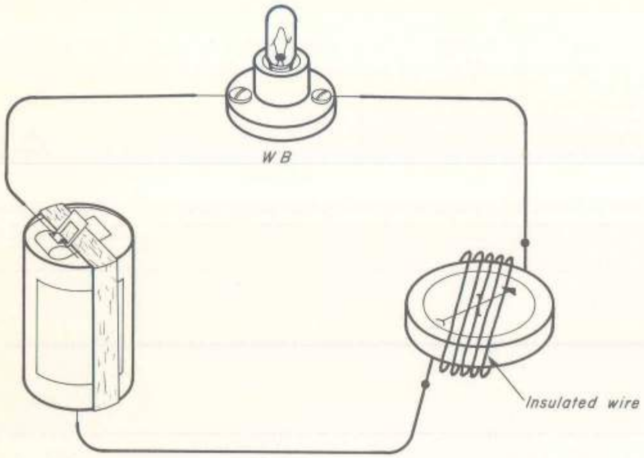


Make a coil by loosely wrapping a two-foot piece of the #22 plastic-insulated, copper wire five times around the circumference of a "D" battery. Remove the coil from the battery. A piece of tape will keep the loops together. Attach one loose end of the coil to the top of the battery and the other to the bottom. Place a compass inside the slightly flattened coil.



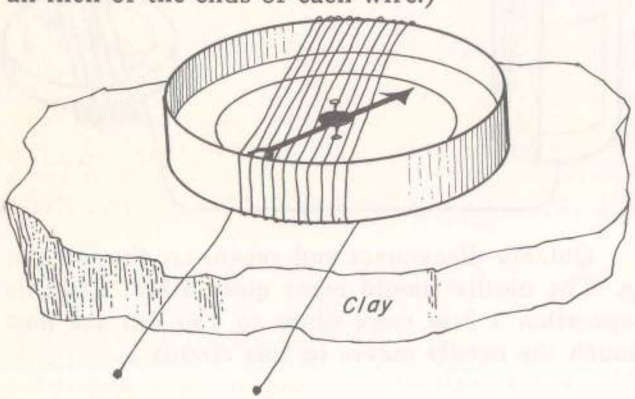
Quickly disconnect and reconnect the wire at a. The needle should move quite a bit. Try this operation a few more times so you can see how much the needle moves in this circuit.

Put a WB in the path to the battery.



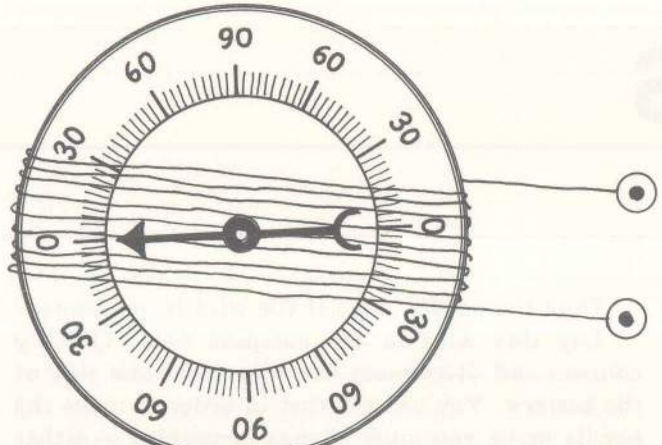
Does the needle move as much now? Repeat, using a PB. Again quickly connect and disconnect the wire ("make" and "break" the circuit) at a. The needle should move most without a bulb, less with a WB, and least with a PB in the path. The bulbs reduce the effectiveness of the path between the battery and the coil. The PB reduces the effectiveness more than does the WB.

Cut two pieces of enameled copper wire, one two feet long and the other ten feet long. Wrap the short piece ten turns around one compass and the long piece fifty turns around another. (Remember to sandpaper off the insulation from ¾ of an inch of the ends of each wire.)

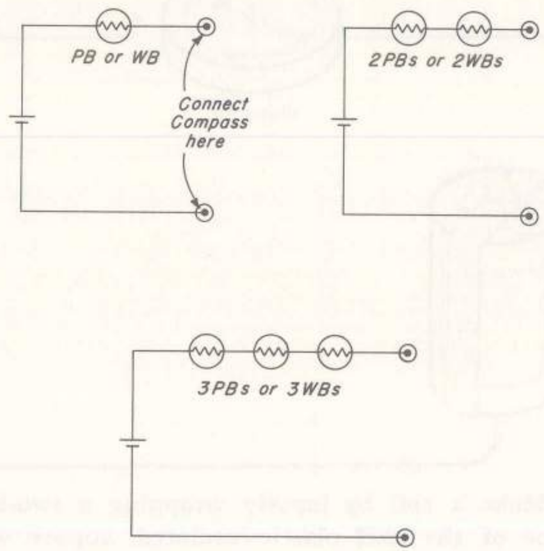


Place each compass and coil on a piece of modeling clay. The clay is used to hold the coil onto the compass and to level the compass so that the needle will not drag on the case.

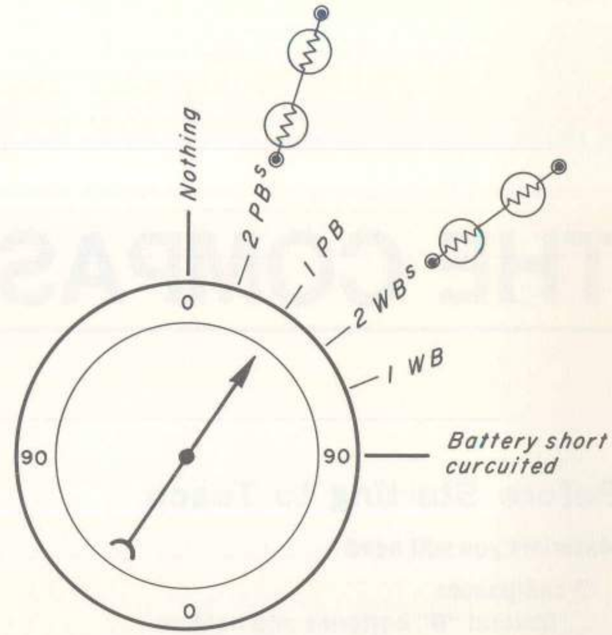
Turn the compasses so that their needles lie *parallel* to the coils and point to a zero on the scale around the edge of each case.



Attach a battery to each coil. Note how far the needles move. Now try these circuits:



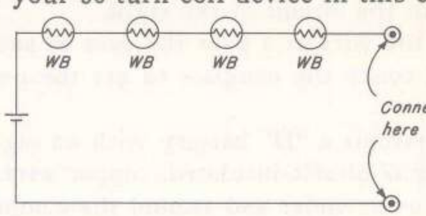
Mark positions like the following on a new scale which is a paper laid under each compass.



Repeat each circuit to make sure your marks are correct. Notice the correlation between the brightness of the bulb and the movement of the compass needle. The brighter the bulbs in a *path* the more movement there is in a compass needle put in that path. (The same type of bulb must of course be used to prove this generalization. A compass needle in the path to a dim WB may move more than a compass needle in the path to a bright PB.)

You now have made a device for determining whether something in a path to a battery has an effect on that battery.

Try your 50-turn coil device in this circuit:



Even though the bulbs *do not light,* the compass needle moves. (Many people consider that four PBs or WBs, such as in the preceding circuit, act like a switch. When there are three bulbs, the light can barely be seen. With four bulbs there is no light. Therefore, they argue, the fourth bulb "turns off" the other bulbs. This statement is proved false by showing with the compass device that this path is still affecting the battery even though no bulbs light.)

The device you have made is called a *galvanometer.* It is a more sensitive indicator than the glow of a bulb in a path.

How does the galvanometer work? The compass needle is in fact a magnet. The coil which is wrapped around the compass is in the path to a battery and is therefore a magnet. These two magnets push against each other and the compass needle moves. (Later, when you study the properties of magnets, this will become clearer.)

A galvanometer is an especially good device for testing what is happening in some path of a circuit because it is made with thick copper wire, which, as you found in *Circuits I,* is a good path to a battery. A galvanometer, therefore, can test whether a path in a circuit is affecting a battery without significantly interrupting the operation of that circuit.

Introducing The Compass in the Classroom

If your class has not investigated the #24 Formvar (enameled copper wire), they should do so before going on with this section. After the children examine the wire carefully, give them sandpaper to remove the enamel insulation from about ¾ of an inch of each end, as they did with other insulated wire.

Give a compass to each child.

Most children discover when they play with compasses that the needle always comes to rest pointing to the same part of the room. If the needle is somehow moved, it will eventually return to this position. (A piece of modeling clay helps children level the compass so that the needle will swing freely and most easily return to its resting position.)

Many of your children have played with compasses before. They know that a compass needle sometimes points to a direction they call "North." They quickly notice there is no North, South, East, West marked on the compass face. Are they to invent their own directional markings? Not really. Because we are not concerned here with a study of these directions or of why the needle points to any of them, we have not indicated them. After some experience with the compass in circuits, North, South, East and West are no longer paramount in children's thinking.

Ask the children if they can make the needle move without shaking or moving the compass case.

If your children have not already done so, ask them if they can use the compass in a circuit. Some may connect wires to the metal case. Some may put bulbs or other things in their circuit. Others may wrap wire around the case.

Somebody will notice that the compass needle moves when it is *near* a wire that is in the path to a battery (short-circuiting a battery).

Further explorations may help the children find that they can put the wire over the compass face or under it and still make the needle move. Meanwhile somebody else may discover that he can keep the needle spinning by "making" and "breaking" a circuit over or beside his compass.

Some children may consider a circuit in which a coil of insulated wire is wrapped around a compass. If a battery is connected to the coil, they discover that the needle spins even more than before. If no one discovers this relationship before all the children have explored their own ideas, you may want to suggest it.

It is tempting to introduce the galvanometer by saying, "Let's build a galvanometer today so we can tell what's happening in a wire." The class would then build their galvanometers according to instructions and proceed to try them out. It is more time consuming, but also more enlightening, to give each child some insulated wire, after he has had sufficient experience with compasses. Then encourage the children to explore the relationships between wire, compasses and batteries.

While children are making their galvanometers they might find real pleasure in learning the name. (It is interesting to note the number of electrical terms named after the people who first defined them: Galvani, Volta, Ampère, Ohm and others.) They will see that a compass put inside a

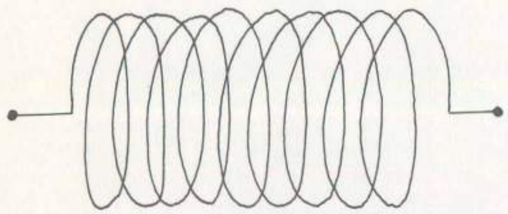
coil can only move the needle if the wires to the battery are disconnected and reconnected rapidly. The children may generalize that they have to move something or "make" and "break" a circuit in order for the needle to move.

After the children have "messed about" with compasses and have a feeling for what they can and cannot do, they probably will seek to consolidate their earlier findings, particularly the children in the 6th and 7th grades. This consolidation is done by using the galvanometer to find out more about what is happening in some paths of circuits.

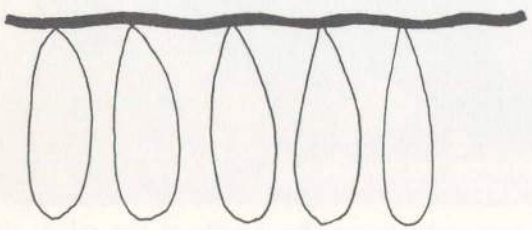
Children usually make coils using both types of insulated wires. They soon see, however, that the enameled copper wire with its smaller diameter is more convenient than the plastic-covered wire for coils with more than ten turns.

Some children will try to make coils out of bare wire of both copper and Nichrome. These coils will work but the loops must not touch or the coil will short-circuit.

A long piece of bare wire touching anywhere on each coil,



is the same as this:



which is the same as a short length of bare wire.

While the children work in groups you may want to suggest that they try coils of, say, ten turns with various circuits such as the ones on Page 4, and then try coils of fifty turns for comparison. If they place their galvanometers in various parts of each of these circuits, they can test whether the needle moves the same amount each time.

Finally, they can reinforce their findings by recording on a piece of paper put under the galvanometer how far the needle moves each time.

You may remind the children that this scale is meaningful only if the same coil is used and the needle is returned to the beginning position each time.

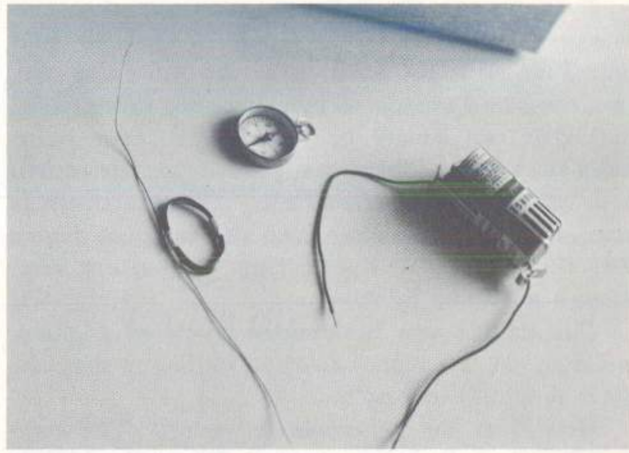
These numbers around the edge of the compass can be used as a numerical expression of the brightness of a bulb in that path of a circuit. If the needle of a compass in a circuit comes to a final rest perpendicular to the coil, (at 90 if it started at 0), you should use a less sensitive coil (one with less turns) so that the final position of the needle is between 0 and 90 on the scale. No name is suggested for the unit of measure. Your class may think of something.

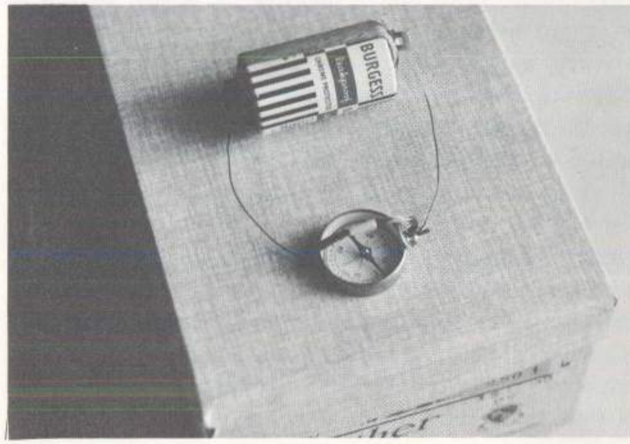
Besides this number as a comparison to the brightness of a bulb in various paths, you should take into account which coil was used. Certainly a reading of 70 using a ten-turn coil is not the same as a reading of 70 using a fifty-turn coil. (Other numbers of turns can also be used.)

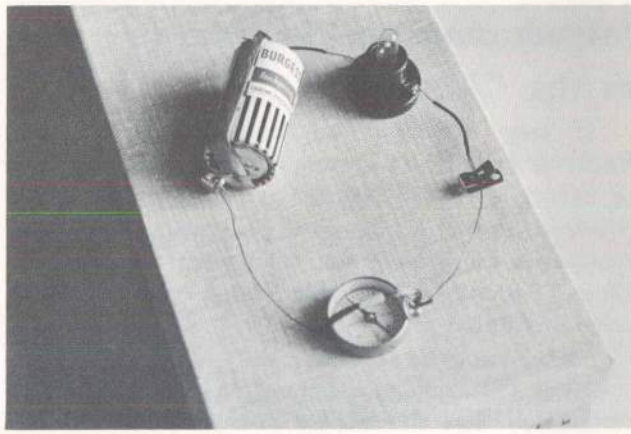
These amounts may be termed:

70 long coil
70 short coil
50 long coil, etc.

Some child may see that there is a consistent ratio between the reading using, say, the fifty-turn coil and the ten-turn coil. The ratio in this example may be found to be 5 to 1. Then a reading of 16 on the short coil would be equivalent to 16 x 5 or 80 on the long coil. (Check in a circuit to verify your ratios.)







NEW MATERIALS FOR THE COMPASS

for the class —

"Junk box"

for each group —

6′ #22 copper wire (plastic-insulated)

20′ #24 Formvar (enameled copper wire)

for each child —

1 compass

1 ball of modeling clay (¾″ dia.)

Activities Children May Try

Use materials such as desk fittings, parts of tools, nails, paper clips, scissors, another compass needle, piece of wood, coins and items in the "junk box" to see what materials will cause a compass needle to move.

Make a chart with two columns: (1) materials that will move the needle; (2) materials that will not move the needle.

See which parts of a compass can be made part of the path from a battery to a bulb.

See how a compass needle moves when wires from a battery are connected to various parts of the compass.

See what happens if the position of the wires is reversed.

Determine whether the compass needle moves more if a wire which is short-circuiting a battery is passed over, under, or to the side of the compass.

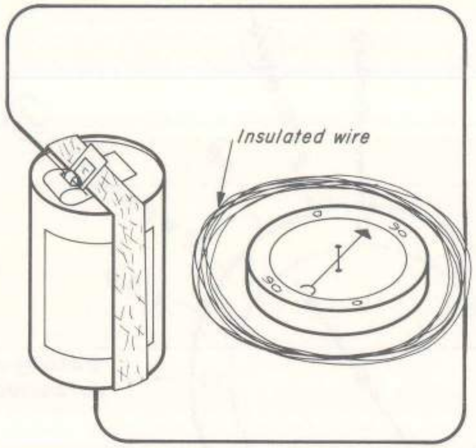
See whether the needle moves more, the same, or less if a wire is wrapped around the compass instead of laid on top or under it.

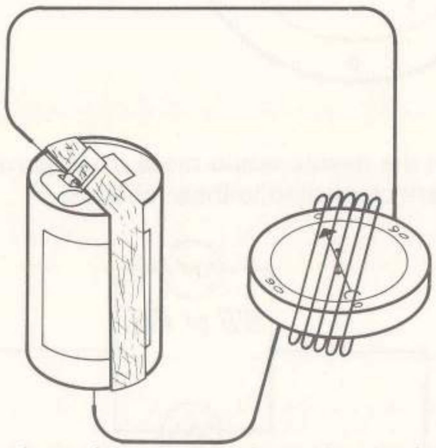
Wrap a ten-turn coil around the compass in many different ways to find which causes the needle to move most.

See what happens to the needle if you reverse the position of the battery.

See what happens if the number of turns in the coil around the compass is increased from ten to fifty.

Find out how much the needle moves if a WB or a PB is put in the path from the battery to the coil. Test a "dead" battery which will no longer light a bulb to see if it really is completely "dead."





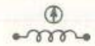
Lay two batteries on a desk so that their tops are touching. Check with a galvanometer to see if they have exactly the same strength. Decide which is stronger.

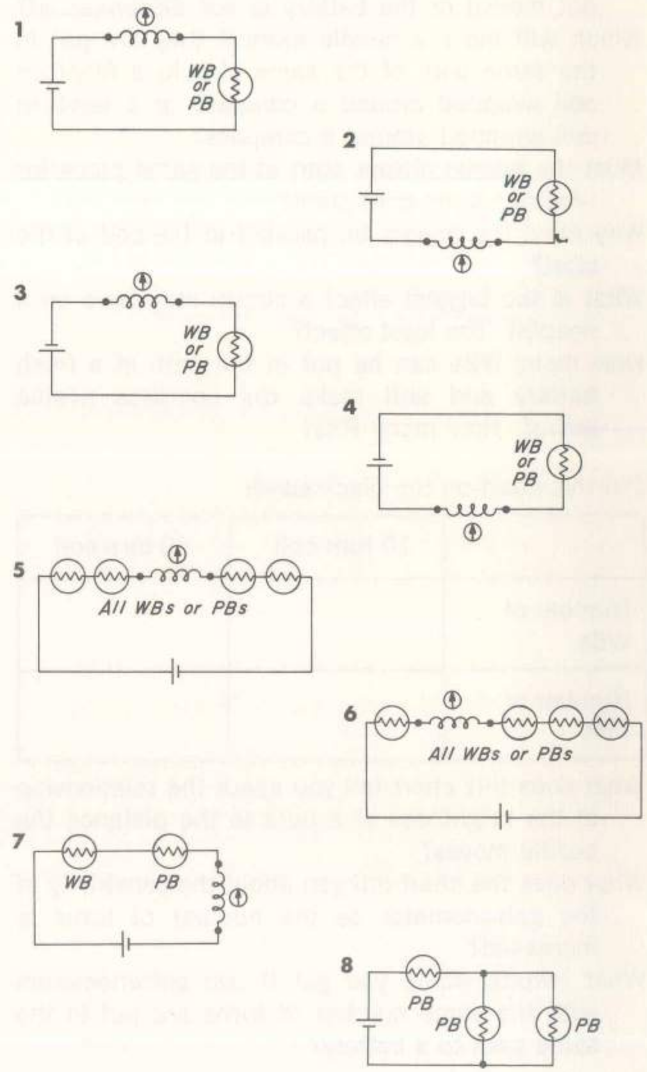
Use a galvanometer in many different circuits to see the effect on the needle.

Try the galvanometer in many different positions in the same circuit.

Mark positions on a piece of paper to make it easier to "read" the galvanometer.

NOTE: The symbol below, combining the symbol for a coil with the symbol for a compass, is used in the following circuits to indicate the galvanometer. Compare the reading of two galvanometers in the same path of each circuit.





Possible Discussion Questions

How can you make a compass needle move?

What effect does one compass have on another compass brought close to it?

Does it matter where you touch wires from a battery to a compass to make the needle move?

Will the needle move when a coil or loop attached to a battery is placed on a compass if the coil is not moved or the battery is not disconnected?

Which will move a needle more if they are put in the same path of the same circuit: a fifty-turn coil wrapped around a compass or a ten-turn coil wrapped around a compass?

Must the needle always start at the same place for readings to be consistent?

Why must the needle be parallel to the coil at the start?

What is the biggest effect a circuit may have on a needle? The least effect?

How many WBs can be put in the path of a fresh battery and still make the compass needle move? How many PBs?

Put this chart on the blackboard:

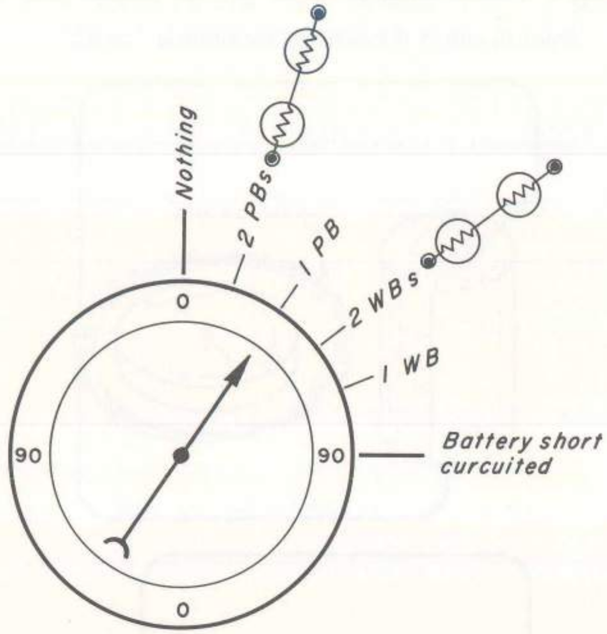
	10 turn coil	50 turn coil
Number of WBs		
Number of PBs		

What does this chart tell you about the relationship of the brightness of a bulb to the distance the needle moves?

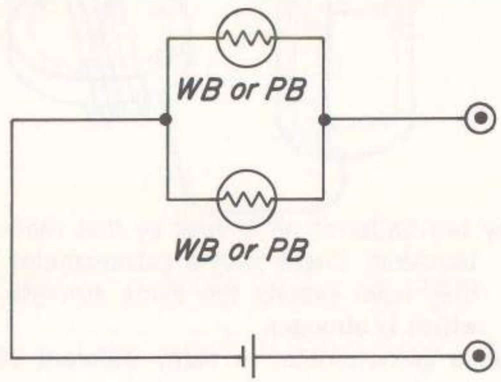
What does the chart tell you about the sensitivity of the galvanometer as the number of turns is increased?

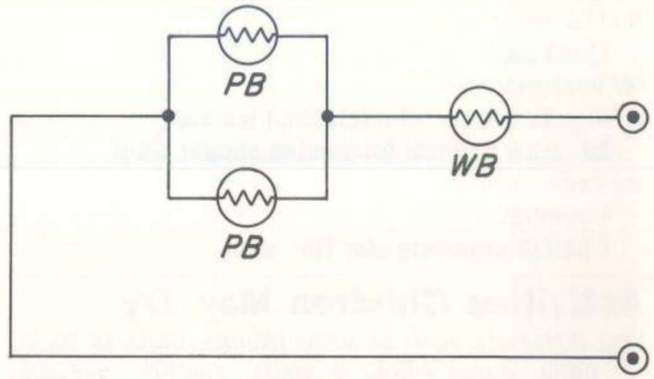
What results would you get if two galvanometers with the same number of turns are put in the same path to a battery?

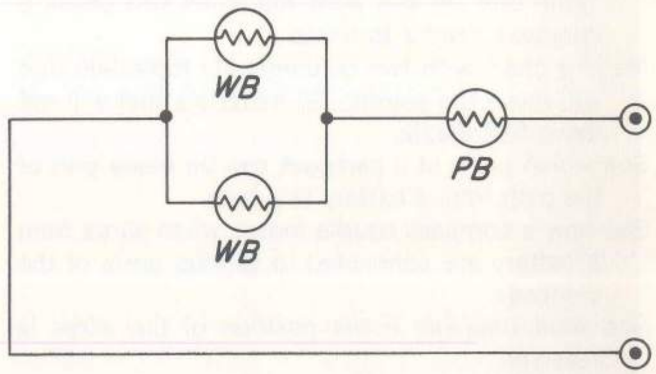
If this is the scale made for a galvanometer, predict



where the needle would move if the galvanometer were connected to these circuits:







Prediction Sheet One

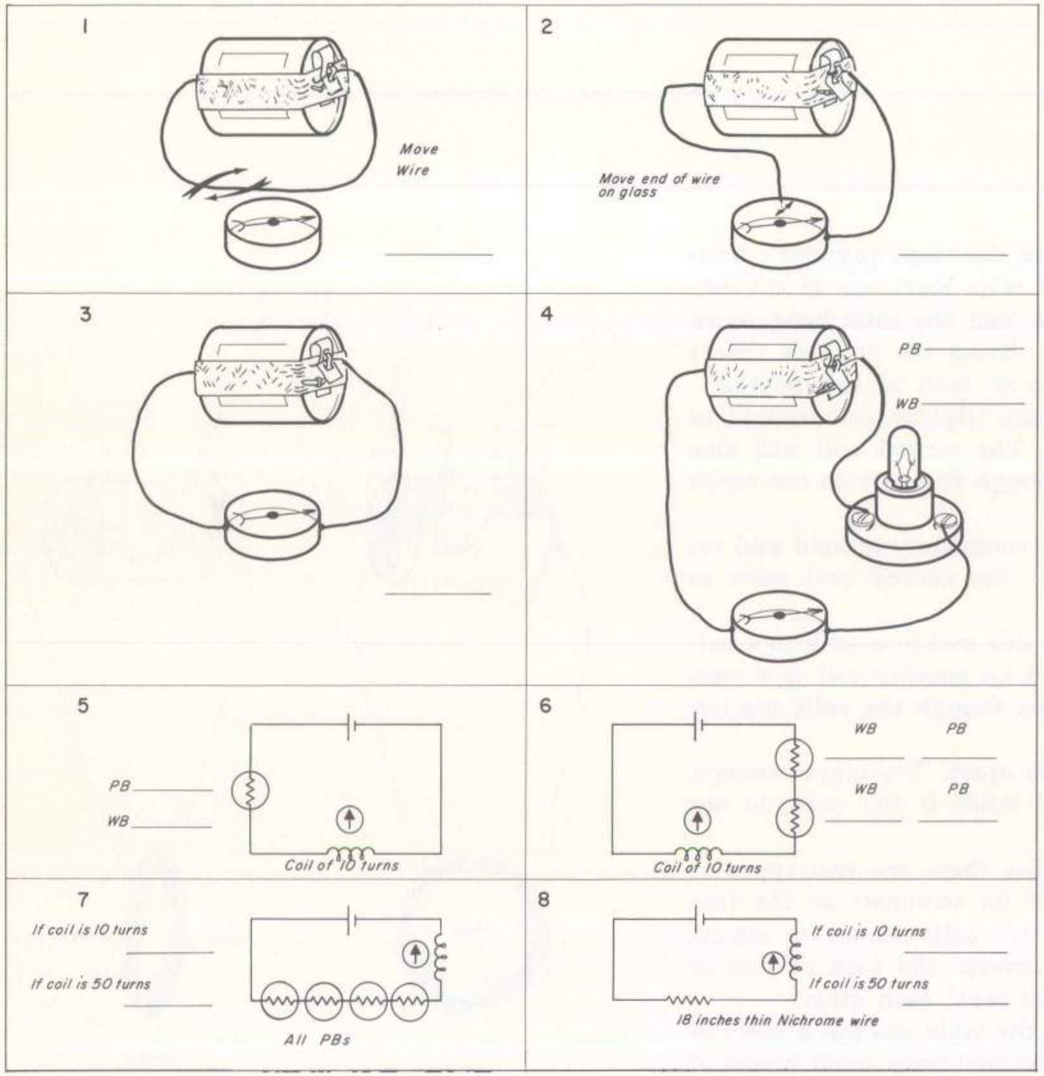
Use this sheet in the same way as the prediction sheets in **Circuits I** were used. It is not a test. The whole class will not necessarily be making their predictions at the same time. In question 8, use various lengths and types of Nichrome and #36 (thin) copper wire. See how much wire makes the needle move as if a WB or a PB was in the path. Check these results with your table in **Circuits I,** page 43. Feel free to add your own circuits to this prediction sheet.

COMPASSES AND MAGNETS

Prediction Sheet One

Mark √ in the blanks where the compass needle will move.

Mark × in the blanks where the compass needle will not move.



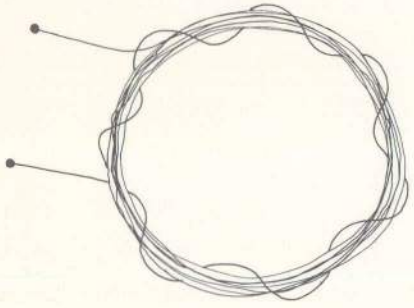
OTHER COILS

Before Starting to Teach

Materials you will need

- **Several "D" batteries in holders**
- **1 roll #24 Formvar (enameled copper wire)**
- **Sandpaper**
- **"Junk box"**
- **Several nails (10d. and 20d.)**
- **Cellophane tape**
- **1 box of paper clips**
- **1 ball of steel wool**
- **1 spool of thread**

Make two coils, each of fifty turns, by wrapping a twelve-foot piece of enameled copper wire loosely around the circumference of a battery. Use tape or wrap one of the loose ends of the wire around the coil to keep the loops together. Connect a battery to each coil. Hold one of the batteries in each hand so that the coils hang down and can swing freely. Bring the flat side (face) of each coil to within an inch of one another.



Set one coil swinging slightly, not enough to touch the other coil. The second coil will also start swinging even though the coils do not touch each other!

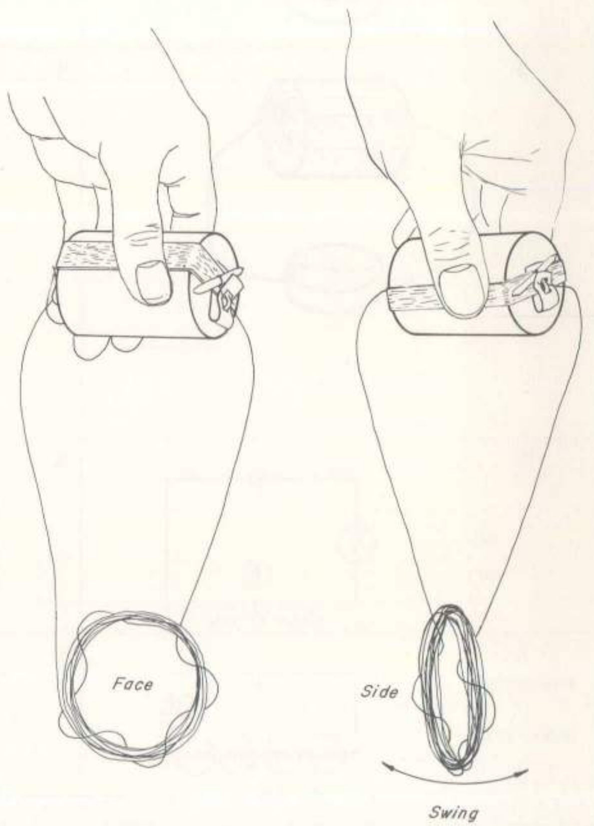
Turn the first coil completely around and repeat the swing. Does the second coil start to swing again?

You see, then, that one coil in a path to a battery can have an effect on another coil in a path to another battery even though the coils are not touching each other.

Try the coils farther apart. Try bigger swings. See if the effect still holds if the coils do not face each other.

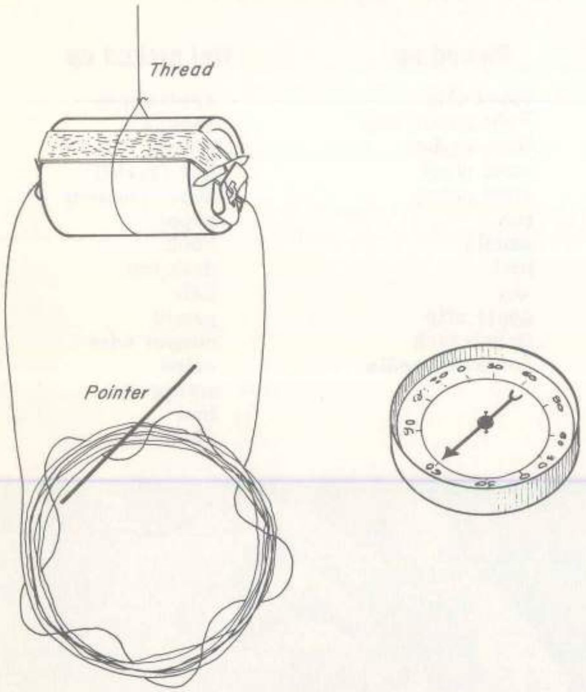
You should find that there are two types of effects. They seem to be strongest at the face of each coil. If the two coils appear to attract each other, you can reverse the face of one of the coils and they will repel each other.

Place a coil flat on the table and put a piece of paper over it. Sprinkle some very small pieces of



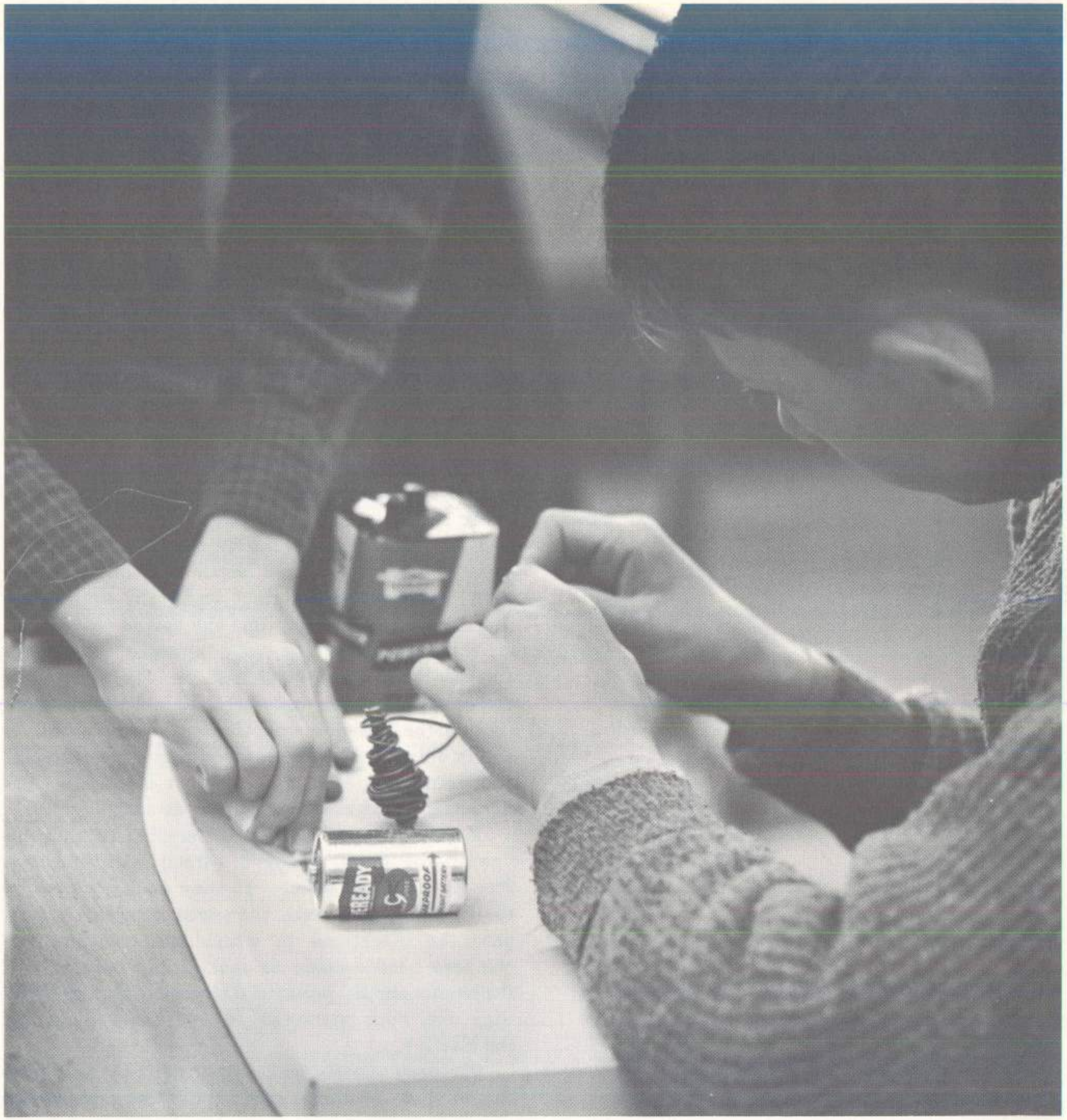
steel wool onto the paper. Move the coil under the paper. The pieces of steel wool move with the coil even though the coil and steel wool do not touch each other!

Hang a "D" battery by a thread so both it and a coil attached to it are free to rotate or swing. Tape a toothpick or a sliver of paper onto the top of the coil and parallel to the floor. After about half an hour compare the direction in which the toothpick is pointing with the direction in which a compass needle is pointing.

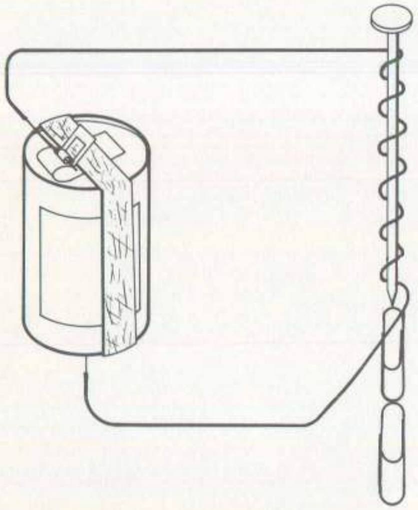


You can now make a coil that will move some larger object such as a metal washer or paper clip.

See what happens when you make more turns in the coil, add another battery, or reduce the diameter of the coil by wrapping it on some smaller object such as a pencil or nail. A nail seems to work best for this purpose. Wrap fifty turns of enameled copper wire around one of the 20d. nails. Attach the ends of the wire to a bat-

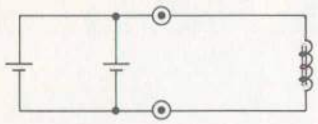


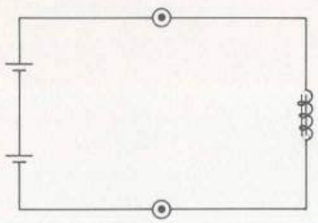
tery. Test some of the objects in your "junk box" to see which will be attracted by this device. See how many paper clips it will lift end to end. Is there any difference in the number of paper clips



which can be lifted by each end? Can they both work at the same time?

Add another battery to the coil in these two ways to see if the coil will lift any more clips:





Remove the nail. Will the coil now lift paper clips?

Any coil of the type you have just made is usually termed an *electromagnet*.

Introducing Other Coils in the Classroom

In the previous study the children found that a coil in the path to a battery could move a compass needle and that one compass needle could affect another compass needle. The children will now see what effect one coil in the path to a battery has on another coil in the path to a battery.

Give about twelve feet of the enameled copper wire to each group. Each group should make two fifty-turn coils. Every child in each group should have a chance to swing one coil near another coil.

Some children will notice that if one of these coils is placed under a piece of paper covered with small pieces of steel wool, the steel wool pieces will move every time the coil is moved and an interesting pattern may appear. The more fragments of steel wool put on the paper, the clearer the pattern becomes. This happens even though the coil does not touch the steel wool.

By this time many children think that the coil acts something like a magnet. It is usually sufficient to leave the explanation at that.

A few groups might be interested in hanging one of the batteries by a thread with the coil free to rotate or swing. If they attach a pointer to the top of the coil, they will be able to compare the directions in which the coil and the compass needle come to rest. (The pointer and the needle should point in the same direction since they are both attracted to the same place on the Earth.)

Children usually make other coils by changing the number of turns around the compass or by wrapping it around some other material. Pass out a few nails and ask the children if they can make a coil that will move heavier objects. You may want to use *Project Sheet One* (*Making a Stronger Electromagnet*, page 14) to help the children in this study.

Bring out the "junk box" at this time so that the children can explore the lifting property of the coil. Have children come up to the board to write which materials will or will not be picked up.

The class list may look like this:

Picked up	Not picked up
paper clip	eyedropper
Fahnestock clip	sponge
iron washer	plastic
steel wool	key (brass)
steel penny	paper fastener
pin	paper
needle	book
nail	desk top
key	hair
paper clip	pencil
thumb tack	copper wire
compass needle	coins
	string
	box
	aluminum tray

NEW MATERIALS FOR OTHER COILS
for the class —
"Junk box" and more wire available.
for each group —
12′ #24 Formvar (enameled copper wire)
Fragments of steel wool
18 to 20 paper clips
2′ thread
1 10d. nail
1 20d. nail

Activities Children May Try

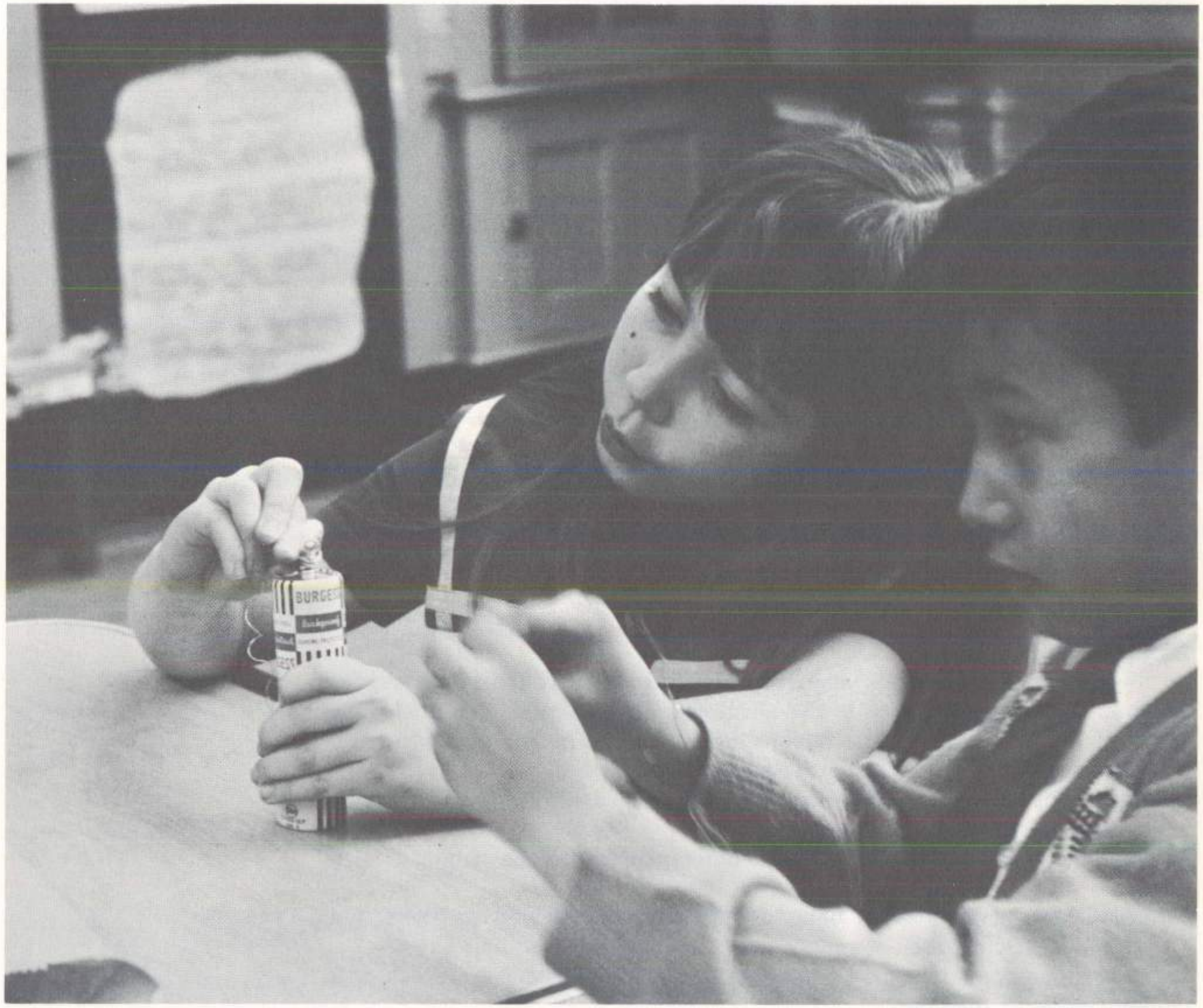
Make one coil in the path to a battery move a similar coil.
Find out in what position this effect is greatest.
Determine that there are really two types of effect.
When a coil in the path to a battery is hung by a thread, see if it comes to rest in the same direction as a compass needle.
Find out some of the materials that will be attracted to an electromagnet. Make a list of these materials.
See how the list compares with other lists, such as the one which showed materials that completed the path to a battery. (See **Circuits I,** page 39.)
Study the characteristics of an electromagnet by changing its size and materials to make it lift heavier objects. **(Project Sheet One)**

Possible Discussion Questions

What happens as you increase the distance between the two fifty-turn coils and then set one swinging? What happens if the coils are not facing each other?
Is there any change in the effect if the swing is made bigger? If the distance between the coils is changed?
Why does a compass needle point in the same direction at rest as does a coil hanging from a battery held by a thread?
What materials do electromagnets attract?
What things can you change in an electromagnet to make it pick up heavier objects?

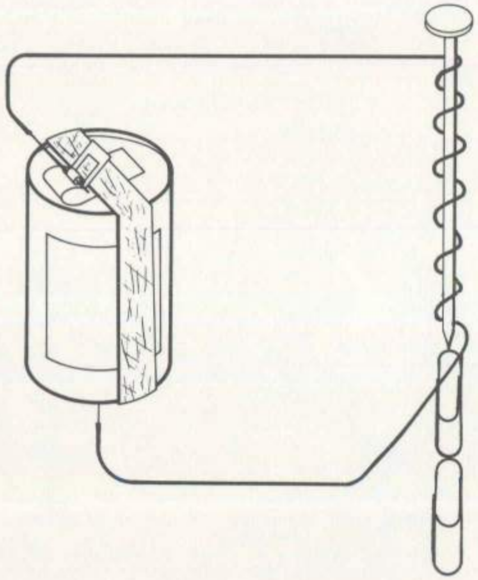
NOTE: The symbol for an electromagnet made by wrapping insulated wire on a piece of iron, such as a nail, is this: 

Not all the children will want to work with **Project Sheet One,** nor should they all. If most of the class is working with the sheet at one time, suggest a contest to see who can make the strongest electromagnet. A small prize (like a compass) might be given to the winner(s).



PROJECT SHEET ONE

Making a Stronger Electromagnet



How can you make your electromagnet lift more objects or heavier objects?

The following questions may help you test some of the parts of your electromagnet. As a measure of the electromagnet's strength, see how many paper clips it will pick up. The paper clips should be picked up end to end to make a test that can be done the same way each time.

1. What happens when more than one battery is used in the path to the electromagnet?
2. Does the type of wire used make a difference? Does the length of wire make a difference?
3. Which type of material is best to wrap your coil around to make it a strong electromagnet?
4. What differences do you find between wrapping your coil on a thick or a thin piece of material?
5. Where is the best place on the magnet to pick up the paper clips?

MAGNETS

Before Starting to Teach

Materials you will need

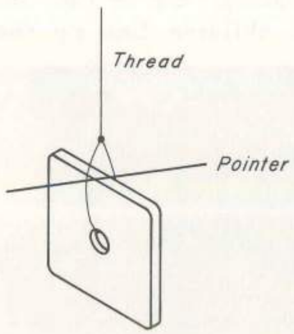
5 or 6 magnets
Compass
1 spool of thread
"Junk box"
1 piece of chalk
Cellophane tape

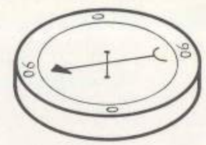
Find out which sides of the magnets attract and which sides repel each other. Mark with a piece of chalk those sides which seem to contain the same property. A rule you may go by is that *like sides repel, unlike sides attract.*

Test materials in your "junk box" to see which ones are attracted to a magnet. Compare a list of these materials with the list of materials that are attracted to an electromagnet.

Bring a magnet near a compass to see if it will affect the needle.

Suspend a magnet from a thread in the way you suspended a coil in the last section. Add a pointer to the top of the magnet with tape or glue. Compare the direction to which this magnet points with the direction to which a compass





needle at rest points.

The compass is a magnet and so is the Earth. For that reason a compass needle is attracted to the magnetic poles of the Earth. The north magnetic pole and the south magnetic pole *generally* have more effect on magnets and compasses than any other places on the Earth.

Notice that some iron or steel objects that have been in contact with a magnet are now magnets themselves! By now you should realize that magnets must be made of particular materials such as: iron or steel; aluminum-nickel-cobalt alloys; and ceramic suspensions of iron powder. The following list indicates some ways that magnets can be *made* or *destroyed:*

Made by:

1. stroking or rubbing with other magnets.
2. electromagnetic coil

Destroyed by:

1. dropping
2. extreme heat
3. placing two magnets of same kind together
4. time

You should also realize that a magnet's influence on another magnet lessens as the distance between them increases. To test this principle, see how far away from a suspended magnet you can move another magnet and still influence the suspended one.

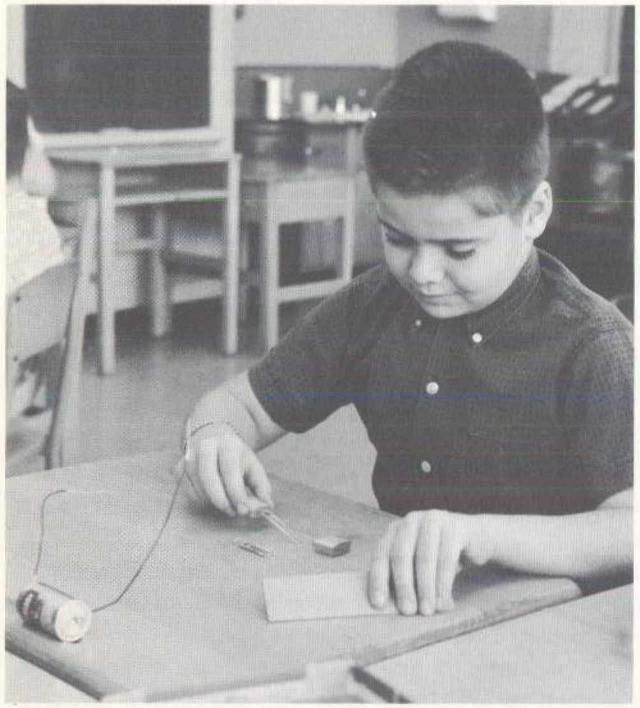
Bring one of the fifty-turn coils which is in the path to a battery near the suspended magnet. You will notice the same movements that two magnets or two coils make when they are suspended near each other.

You can test the strength of the magnet by seeing how many paper clips put end to end it will lift. How does this compare to the number lifted by the strongest electromagnet you or your children made?

Finally, make thirty mystery cards according to the directions on page 19.

Introducing Magnets in the Classroom

No child is at a loss for something to do when he is first given a magnet. He will pick up something with it, he will stick it to something, or he may make another magnet move or hop. Many children, however, have never gone much beyond this stage.

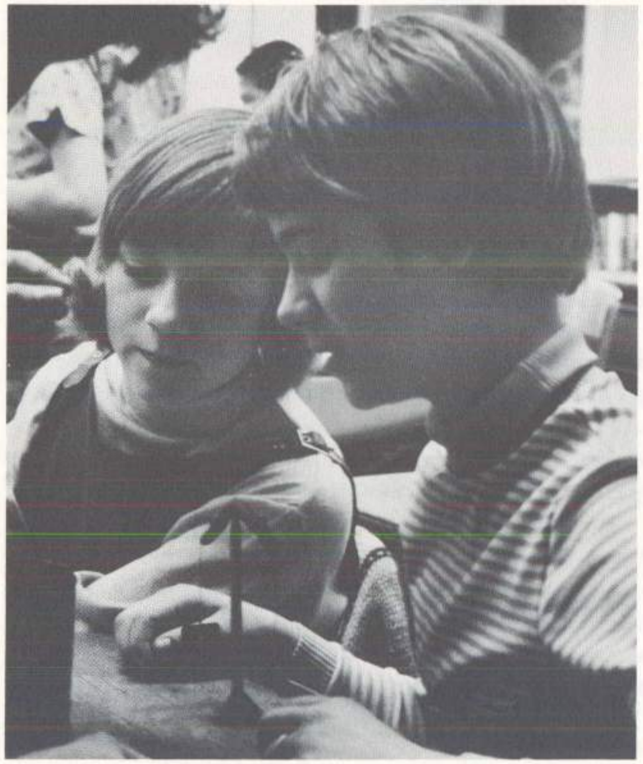


Some children may try to make a magnet out of a nail, a screwdriver blade, a needle, or a paper clip. They may put a book, page by page between a magnet and another magnet, a compass needle, or some steel wool to see through how many pages the magnet will attract the other objects. The children may want to see what happens if a magnet is put in the path between a battery and a bulb.

Children realize very soon, if they do not know already, that not all sides of magnets act the same. Some sides repel each other, some sides attract each other, some have no effect on each other. Many children discover that a compass needle can be used to verify that sides of a magnet which act the same, that is, attract the same end of the compass needle, repel each other. Sides of a magnet which act differently (attract opposite ends of a compass needle) attract each other.

When children are trying to find which ends of their magnets are "alike," it will occur to someone to mark them. Encourage every child to do this. No child's marking scheme is wrong as long as he is consistent in it.

A group of neighboring children may decide to mark all of theirs according to the same scheme. If they do, then "train-making" can be fun. Several different groups of children line up their



"trains," engine to caboose. Do some have to go engine to engine?

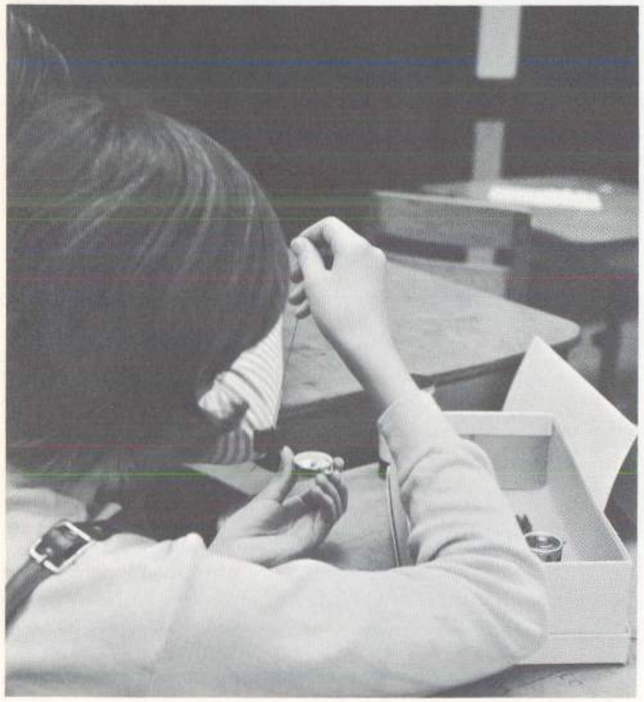
Children will test all the things around them to see what reactions they get with their magnet. During one class you can list on the blackboard the materials a magnet will attract and those it will not. The children can compare this list to the lists of materials that affect or do not affect a compass, materials that are or are not attracted

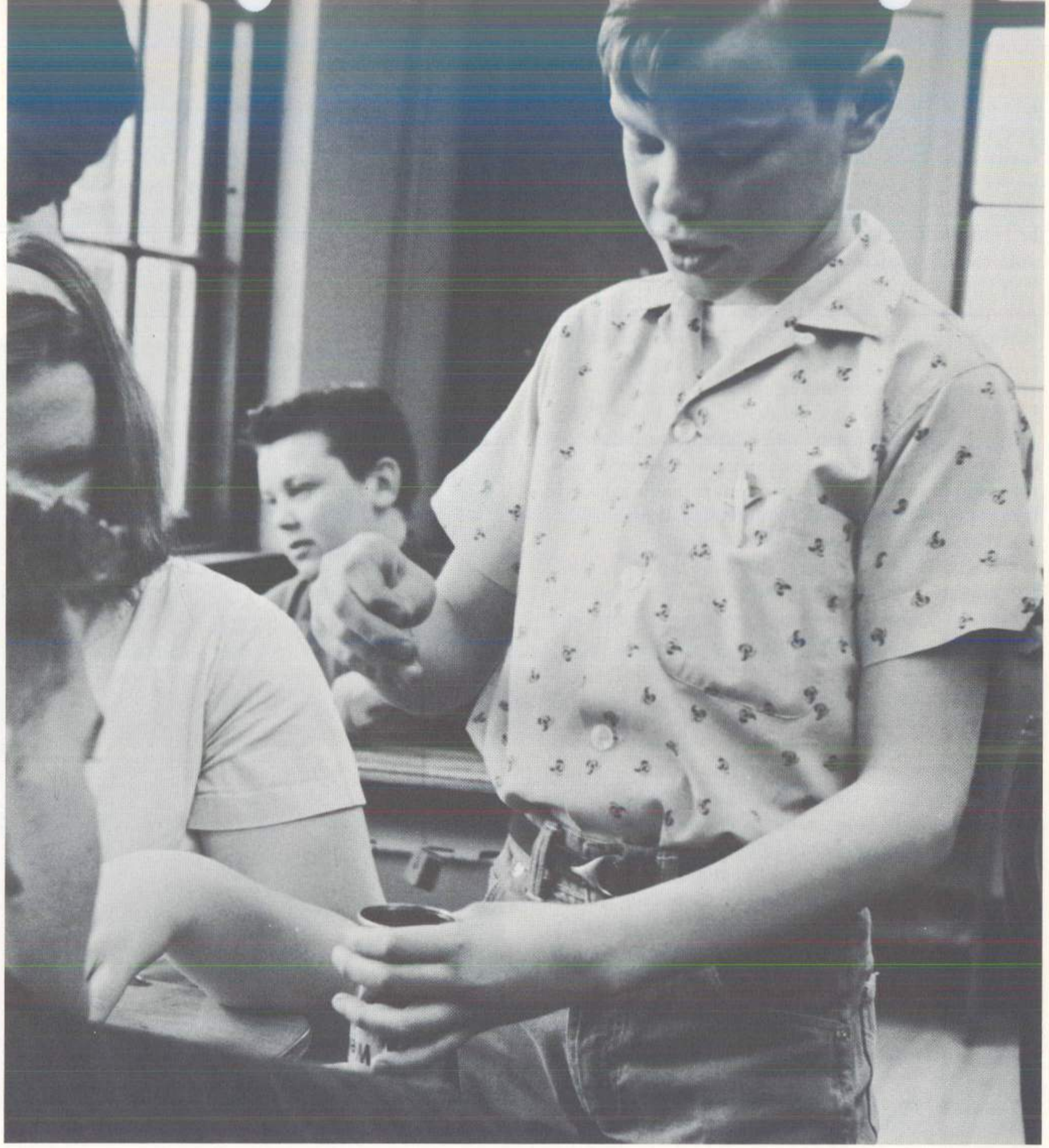
to an electromagnet and materials which can and cannot be put in the path from a battery to a bulb without extinguishing the bulb. You can put all the lists on the blackboard or keep a summary chart for the easiest comparison. Discuss the comparisons. Why are some lists identical?

If a magnet is hung by a foot-long thread, the children can experiment to see what objects, when held at a distance from it, will make it move. Also, they can find out whether these objects have to be held beside, underneath, or at an angle to have the greatest effect. They may wonder whether or not they can prevent the magnet from being moved by putting things between the object and the suspended magnet. Are there any materials that might "cut off" the magnetic effect?

The children can also tape a sliver of paper to the top edge of a magnet which is hung by a thread to see which way the paper comes to rest. Make sure there is nothing iron or magnetic near it. The children can compare the direction in which the paper points to the direction in which a compass needle at rest points. This project should be started early in the class period so that the magnet has ample time to come to rest.

Some children may realize a similarity in some of the experiments they have done. This is exciting for those who realize the Earth is a large magnet, but do not push this generalization if the children do not think of it.





Children generally use "magnetic" in two senses: to mean that something is *attracted* to a magnet and that something *is* a magnet. Mystery cards can help focus on this difference. Taped between two cards are various small objects: some magnets, some things attracted by magnets (such as iron washers) and things not attracted by magnets (wood, plastic, cardboard). Have the children sort the cards into piles, but do not specify at first how many piles to make. Work with some groups while the others are doing the previous activities. Discourage the children from feeling the cards as a means of determining what is inside.

The children's first tendency will be to divide things into the same two categories they did earlier, magnetic (in both its senses) and non-magnetic. They will soon start running into trouble, however, when they realize that magnets are themselves a third kind of thing.

It will take some careful work, but in the end the children will have three piles. Their conclusions can be compared and once again any disagreements can be resolved by going back to the materials and checking the results.

Then a new problem can be posed. If they have only one magnet and one card which they don't know anything about, is there a way to find out whether there is a magnet inside the card or not, just by using this one magnet? The children might hang several cards from strings and test each one separately by bringing a magnet near. Can they tell just by whether the card moves if it has a magnet in it? Can they tell by *the way* it moves whether it has a magnet in it?

To relate the characteristics of magnets to electromagnets, children can suspend a magnet on a thread near a suspended coil attached to a battery. They can move one slightly as before. The result is the same as when two coils were used. What does this tell about the characteristics of the magnetism from a coil and those from a magnet?

Children will now be in a position to find out how strong one of the magnets is compared to the strongest electromagnet the class has made. Your children have already determined the strength of the electromagnet by seeing how many paper clips it would pick up end to end. They can now see how many paper clips the magnet will pick up.

In one seventh-grade class two girls made a "magnet-testing machine." This machine consisted of a compass and two magnets to be compared. The compass was laid on a wooden table. One magnet was brought up to one side of the compass, the other magnet to the opposite side. One magnet was moved around the circumference of the compass. If the needle followed this magnet, it was the stronger of the two. This device also worked well in comparing magnets with electromagnets.

NEW MATERIALS FOR MAGNETS

for the mystery cards —

75 plain white cards (3″ x 5″)

Cellophane tape

10 1″ squares of thick cardboard (as from a cardboard box), wood, or plastic

10 steel or iron washers (1″ dia.)

for each child —

2 magnets

2′ thread

Make thirty mystery cards, ten with magnets, ten with cardboard, ten with washers. Wrap each object with a piece of card ½″ by 1½″. Tape the object in the middle of one 3″ x 5″ card. Place another 3″ x 5″ card over this card. Tape all edges shut. Mark similar cards with the same notation — all magnet cards with an I or an X, etc.

Activities Children May Try

Investigate ways two magnets do and do not hold together.

Make lists of materials magnets will attract and those which they will not attract.

Compare these lists to previous lists in **Circuits I** and **Circuits and Magnets,** perhaps by means of a class chart.

Make magnets out of other materials.

Compare the strength of a magnet with the strongest electromagnet in the class.

Test how the ends of two magnets react with one end of a suspended magnet.

Compare the magnetic properties of a magnet with those of a coil in the path to a battery by hanging them near each other and noting the interactions.

Work with mystery cards to consolidate some ideas about magnetism.

Possible Discussion Questions

How many magnets can you hold together without any falling off?

Can two magnets put together lift twice as many paper clips as one?

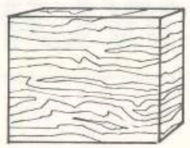
Does an electromagnet have two kinds of effect, as a magnet does?

Do you think magnets are always stronger than electromagnets?

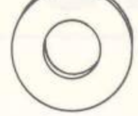
What ways are electromagnets like magnets?

What ways are they different?

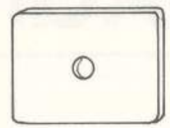
HOW TO MAKE A MYSTERY CARD



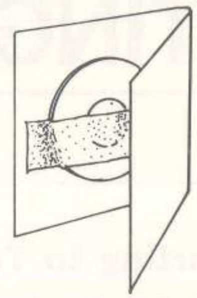
Wood block



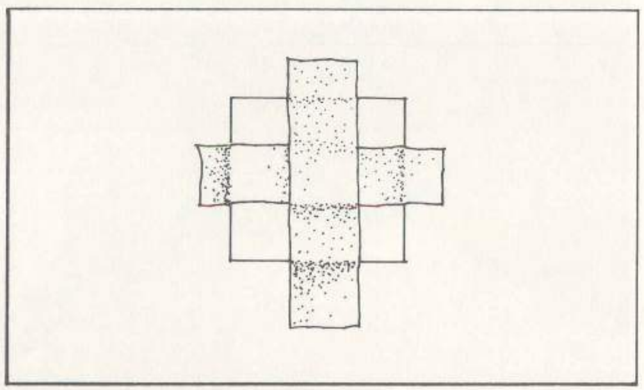
Iron washer



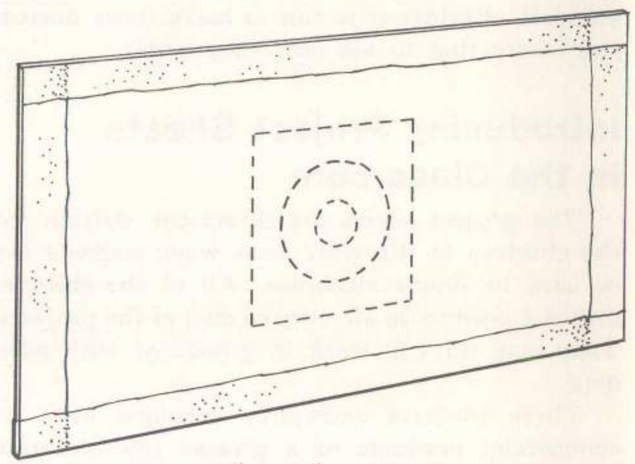
Magnet



Washer taped into piece of folded card $1\frac{1}{2}'' \times 1\frac{1}{2}''$



Card taped to inside of 3″X5″ Card



Two 3″X5″ cards taped together

PUTTING MAGNETS TO WORK

Before Starting to Teach

You should follow the commentary about each project and then make the device from the directions on the project sheet so that you will see some of the challenges the children will meet. You will also be able to ask the children more appropriate questions if you have done the work yourself. Besides it is fun to make these devices and interesting to see how they work.

Introducing Project Sheets in the Classroom

The project sheets are directions written for the children to illustrate some ways magnets can be used in simple machines. All of the children may not want to do all, or even any, of the projects. They may want to work in groups or with partners.

These projects exemplify concepts basic to commercial products of a greater sophistication but which operate on the same simple principles illustrated here. You or your children will probably think of some additional projects to pursue after completing these. Several children may want to bring from home examples of magnets in circuits such as a toy telegraph, a model telephone, a buzzer system, a motor in a small car. This should be encouraged. A trip to a company which uses big electrical machines or to a generating plant might be interesting.

Activities Children May Try

1. Looking at a Buzzer

(See Project Sheet Two)

MATERIALS FOR LOOKING AT A BUZZER

for each child or pair—

- 1 metal strip
- 2 Fahnestock clips
- 1 shoe box
- 1 10d. nail
- 1 20d. nail
- 1 paper fastener
- 6′ insulated wire (either kind)
- 2 "D" batteries and holders

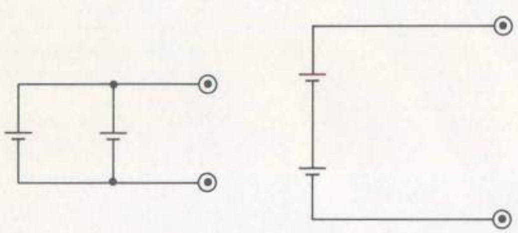
Special Comments

Sometimes the metal strip will be a better path to the battery if some of the blue outside coating is sanded off the tip where the Fahnestock clip is touched and underneath where it touches the nail.

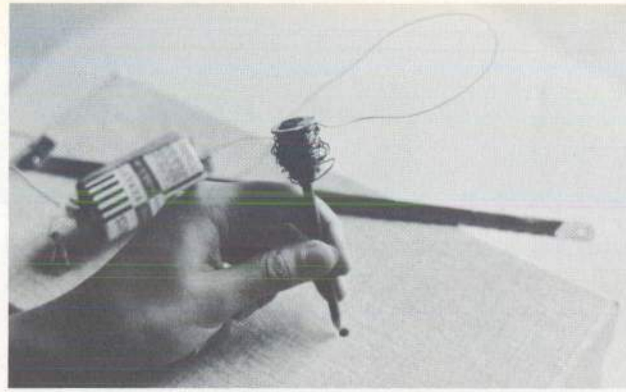
Encourage the children to use the battery holders so that both hands are free to experiment.

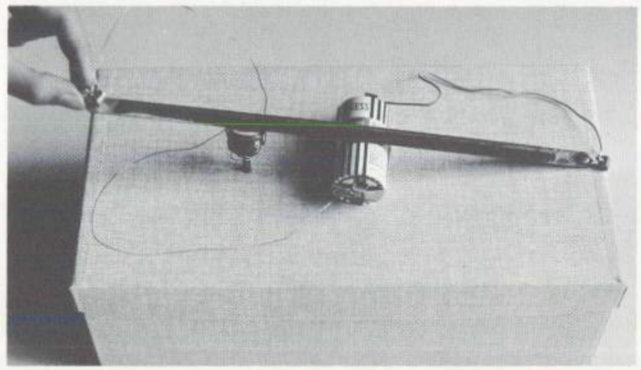
Some students will want to use both types of insulated wire for comparison. If they are using the enameled copper wire, be sure the enamel covering is completely removed where connections are made.

Two batteries sometimes work best to start with until the buzzer is adjusted to work easily. These batteries can be connected in either of these ways:



The nail may become so loose in its hole in the top of the box that it must be held in place with





cellophane tape. A new position for the nail may be tried.

Here are some further questions your children might explore:

Can you keep the buzzer going by itself?

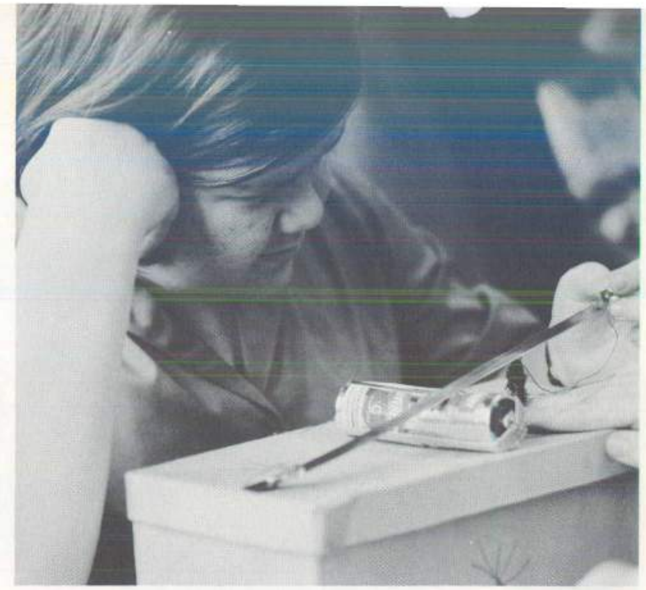
Does raising or lowering the height of the nail make any changes in the working of the buzzer?

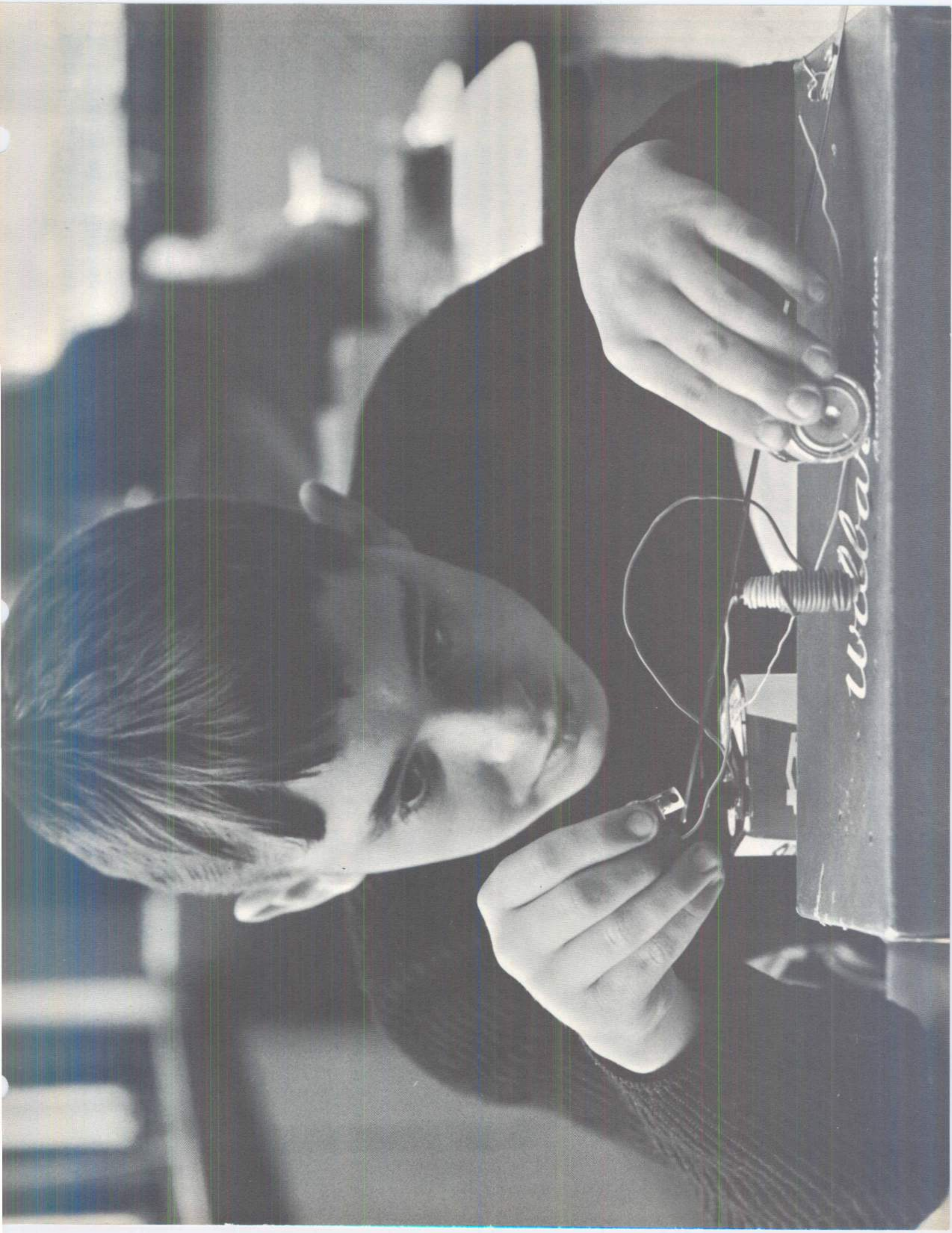
If you touch the metal strip anywhere with the Fahnestock clip, does the buzzer still work? Does it work as well?

Does the buzzer work as well if the strip is not directly over the nail?

How long will the buzzer work on one battery? How long on two batteries?

What happens if the nail is moved toward the tip or toward the attached end of the strip? Do you have to move the battery?

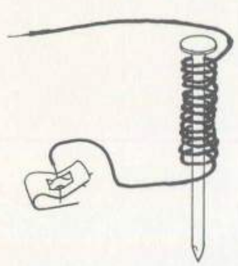


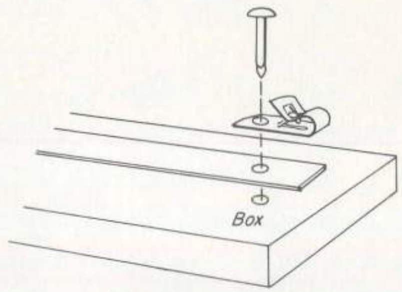


PROJECT SHEET TWO

Looking at a Buzzer

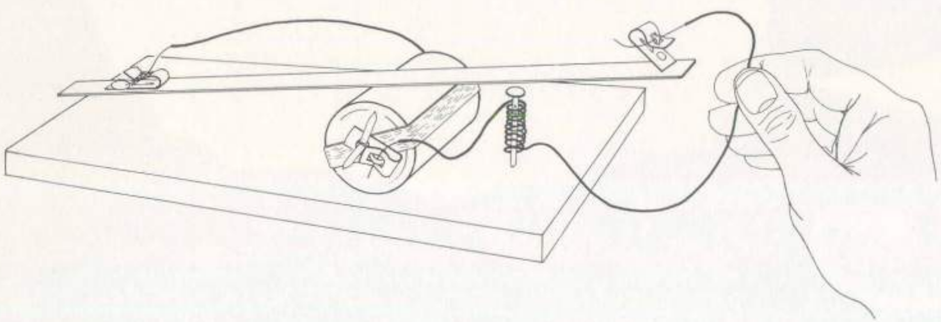
Wind about one hundred turns of insulated wire close to the head of a nail. Leave eight inches of loose wire on both ends of the coil. Be sure to remove insulation where connections are to be made. Put a Fahnestock clip on one of these ends.





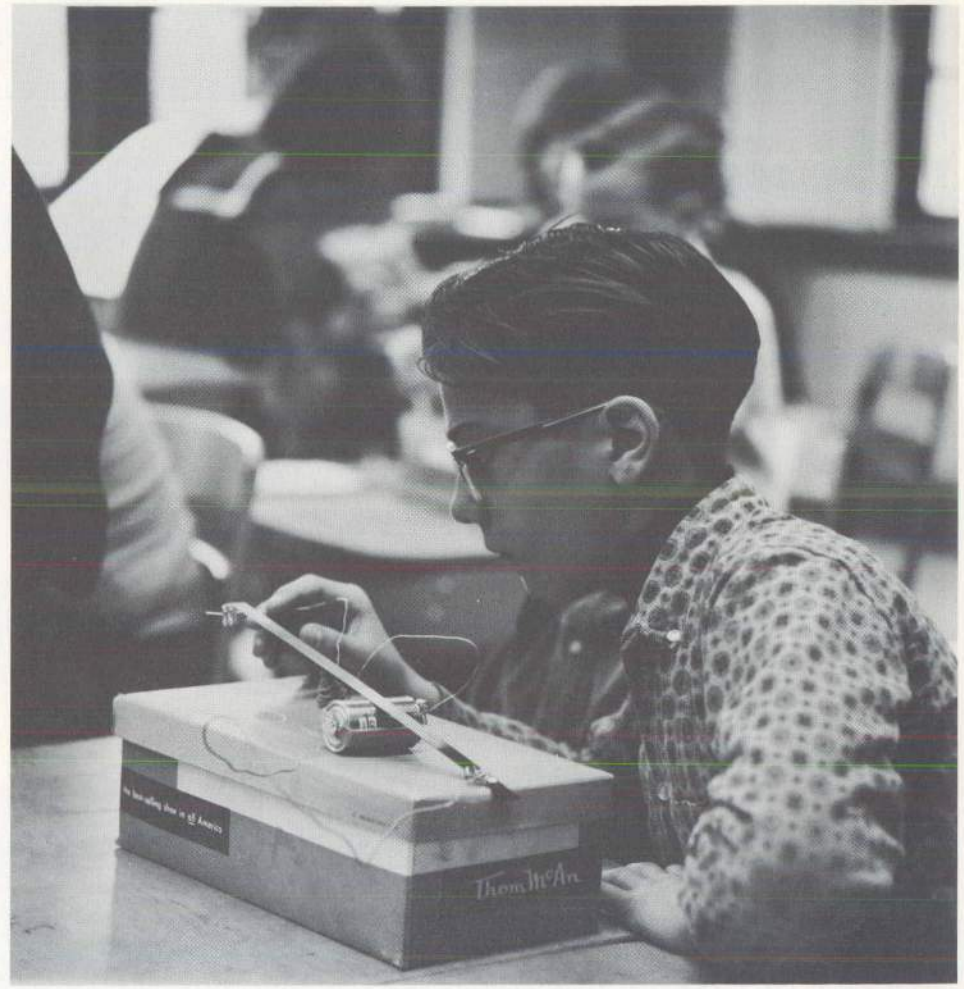
Connect the metal strip to the top of your shoe box by putting a paper fastener through a Fahnestock clip, through the metal strip and then through the box. Push the nail part of the way into the box, under the strip.

Connect one end of a battery to one side of the coil and the other end to the Fahnestock clip which is at the end of the metal strip. Use a battery holder. The battery can be placed under the metal strip so that the metal strip is about a quarter inch above the head of the nail. Hold the wire with the Fahnestock clip attached about two inches from the clip. Touch the Fahnestock clip to the top of the metal strip at its loose end.



Here are some questions you may have. A study of the buzzer will help answer them for you.

1. How does the buzzer work?
2. Where is the path to the battery?
3. How can you make the sound higher? How can you make the sound lower?
4. What happens when more batteries are added?
5. Do you see any difference in the buzzer if you add more turns of wire to the coil? Take away turns?
6. If you use different wire or a different-sized nail, do you notice any change in how the buzzer works?




EVEREADY
Flashlight BATTERIES
EVEREADY
GUARANTEED
Power to Spare!

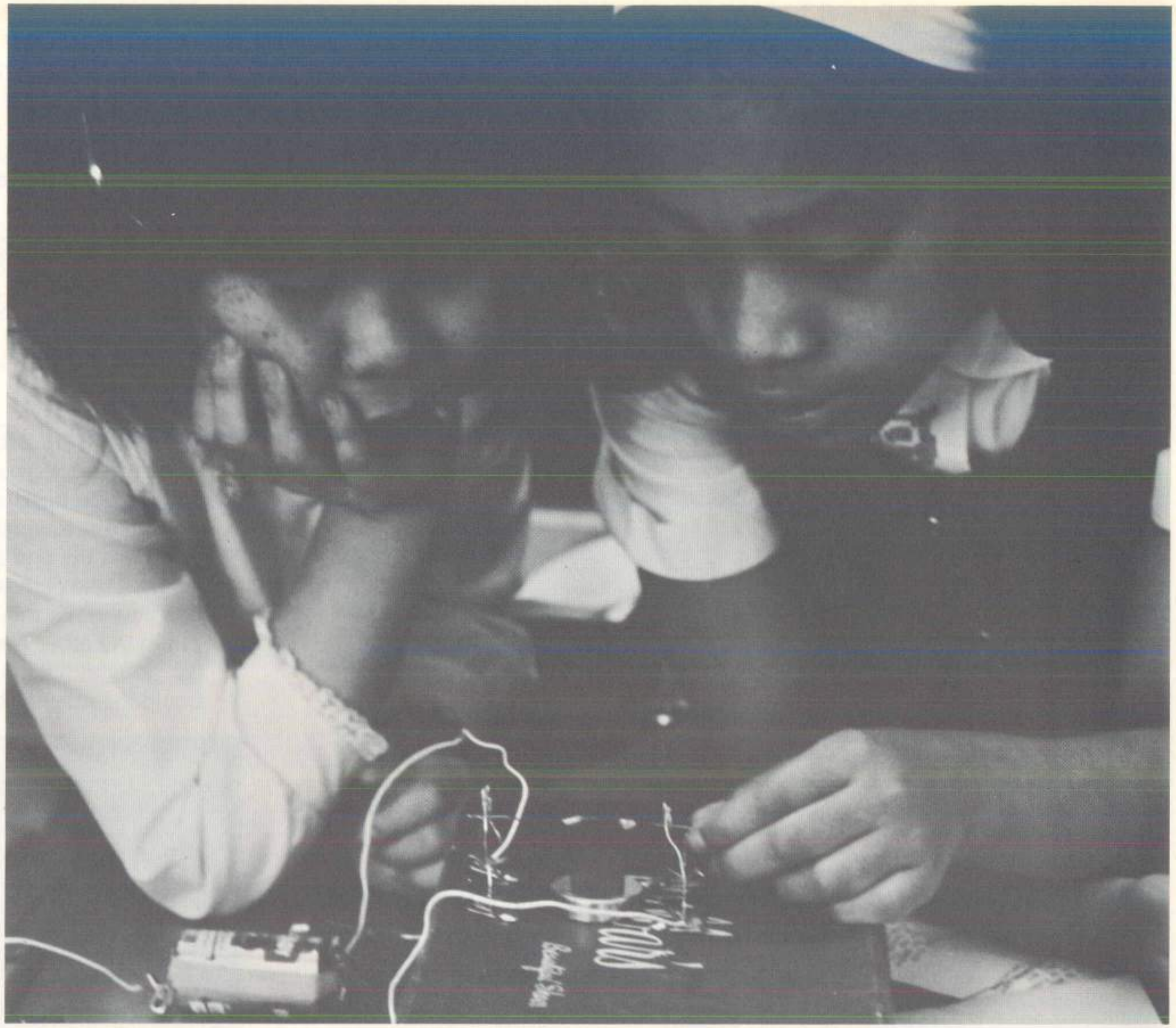
2. Making and Testing a Motor

(See Project Sheet Three)

MATERIALS FOR MAKING AND TESTING A MOTOR

for each child or pair—

- **10″ #Formvar (enameled copper wire)**
- **2 four-inch pieces #20 (thick) bare copper wire**
- **1 roll cellophane or masking tape (¼″ preferred)**
- **4 paper fasteners**
- **2 Fahnestock clips**
- **2 "D" batteries and holders**
- **Insulated wire for connections**
- **2 magnets**
- **Shoe box**



Special Comments

As an introduction to making and testing a motor, your students should have explored these questions:

1. Can you make your compass needle spin by using just a magnet? Can you keep it spinning?
2. Can you make your compass needle spin using a piece of insulated wire attached to a battery? Can you keep the needle spinning?
3. Can you make a galvanometer needle spin? Can you keep the needle spinning?
4. In the same manner as on page 19 of **Circuits and Magnets** attach a battery to a ten-turn coil. If you hold the battery with your fingers so that the coil hangs freely, can you make the coil move with a magnet?

These are some further questions you can ask the children about their motors as you circulate around the room.

How does a motor work? What parts are needed for a motor?

How would you make the motor do some work? Where would you attach anything you wanted the motor to work upon?

What happens if the coil is made with more turns? Less turns? Bigger turns? Different wire?

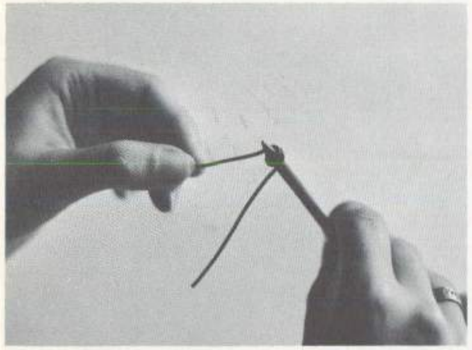
How does the action of the motor change if more than two batteries are used? If only one battery is used? How long do you think the motor would run with one battery? Two batteries? More than two batteries?

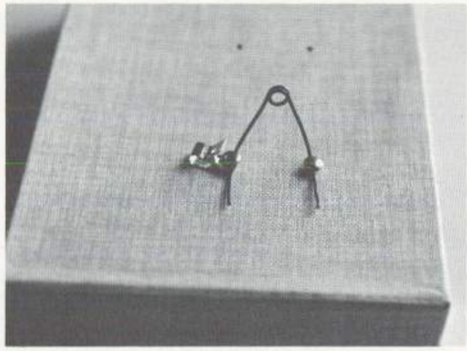
What happens if you bring a second magnet near the coil of a motor when it is running?

PROJECT SHEET THREE

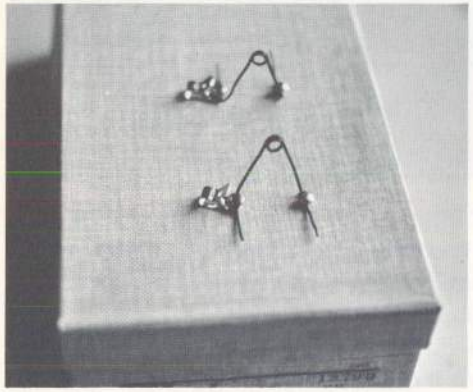
Making and Testing a Motor

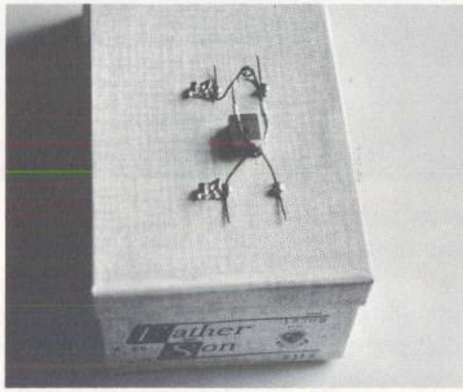
A stand for your motor can be made from two four-inch pieces of bare wire, four paper fasteners and two Fahnestock clips. Make a loop in the middle of each wire by wrapping it once around a pencil. Use paper fasteners to attach these wires — about two inches from each other — to the top of your shoe box. At one end of each wire put a paper fastener through a Fahnestock clip before attaching it to the box.



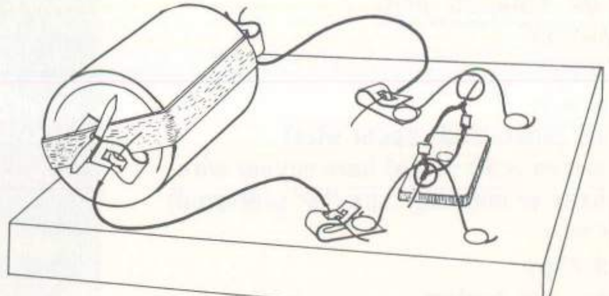


The moving coil can be made from a piece of enameled copper wire about ten inches long. This piece is wrapped three times around the width of a ruler. Leave enough extra wire on both sides to be bent out straight away from the coil. Tape the coil in two places to keep the loops together. Clip the straight wires off so that the whole coil is about three inches long. Use sandpaper to take the enamel insulation off the last three-quarters of an inch of each straight wire.



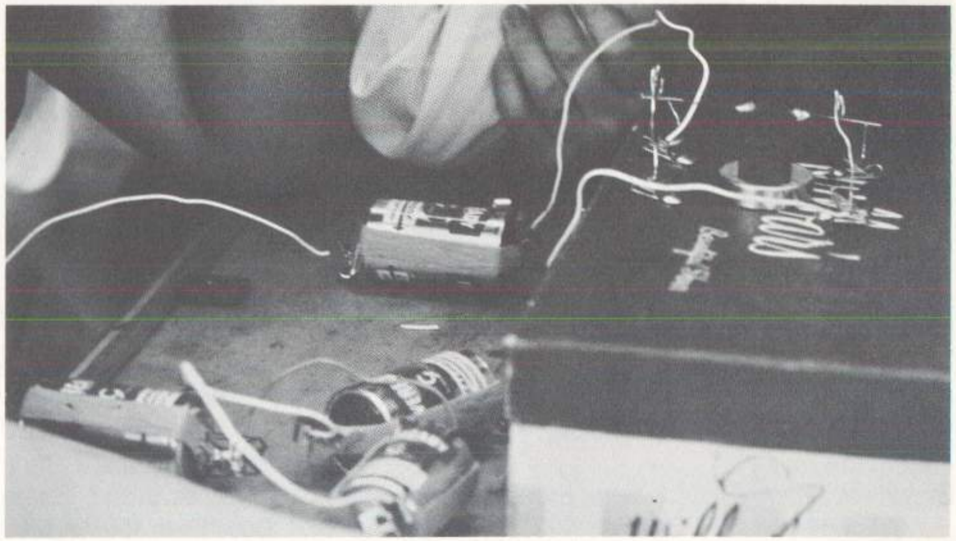


Place one magnet on the box under the coil. Connect two batteries between the Fahnestock clips. You may have to give the coil a slight turn by twisting the **end** between your thumb and forefinger.



Here are some questions you might want to study and answer for yourself.

1. What will make your motor go faster? Will it work on only one "D" battery?
2. Why do you need a magnet? Can you use two magnets? Where can you place these magnets?
3. How does the end of the coil work as a switch?
4. Where is the path to the battery?
5. Can you make the motor turn the other way? What happens if the coil is put in the other way around?
6. Can you get the motor to start by itself?
7. Could the magnet be replaced by an electromagnet?



3. Another Testing Device

(See Project Sheet Four)

MATERIALS FOR ANOTHER TESTING DEVICE

for each child or pair —

- **1 half-pint milk carton with top cut off**
- **2 paper clips**
- **1 straw**
- **2 magnets**
- **9′ #24 Formvar (enameled copper wire)**
- **Small piece of modeling clay**
- **1 6-inch piece #20 (thick) bare copper wire**

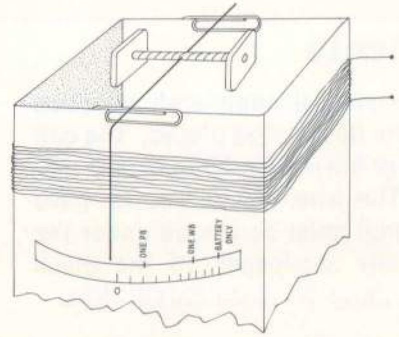
Special Comments

Be sure the magnets balance well on the bare copper wire and straw. You may need a piece of tape where the wire goes through the straw to keep the joint from slipping.

PROJECT SHEET FOUR

Another Testing Device

Wrap fifty to a hundred turns of insulated wire near the top of a half-pint milk carton. Take off the insulation on the last ¾ of an inch of each wire. Place two paper clips on opposite top edges of the carton. Push a 5-inch piece of thick copper wire through a piece of drinking straw 1½ inches long. Push a magnet onto each end of this straw. (The magnets will hold to the straw if the holes in each magnet are first filled with clay.) Two sides which attract each other should be facing away from each other. Level the straw with a small piece of clay.



Here are some questions about this new testing device you may want to answer.

1. What happens if you connect a battery to the two wires?
2. Why does the straw swing if the coil is part of the path to a battery?
3. What kind of scale can you make to show how much the needle would swing if a PB bulb, say, is put in the path between the coil and battery?
4. Can you make the needle swing the other way?
5. How can the needle be made to move if the meter is put in this circuit?
6. In what ways is this device better than the galvanometer you made?
7. Try this device in some of the circuits you used to study the galvanometer for a comparison with that instrument.

4. The Jiggler

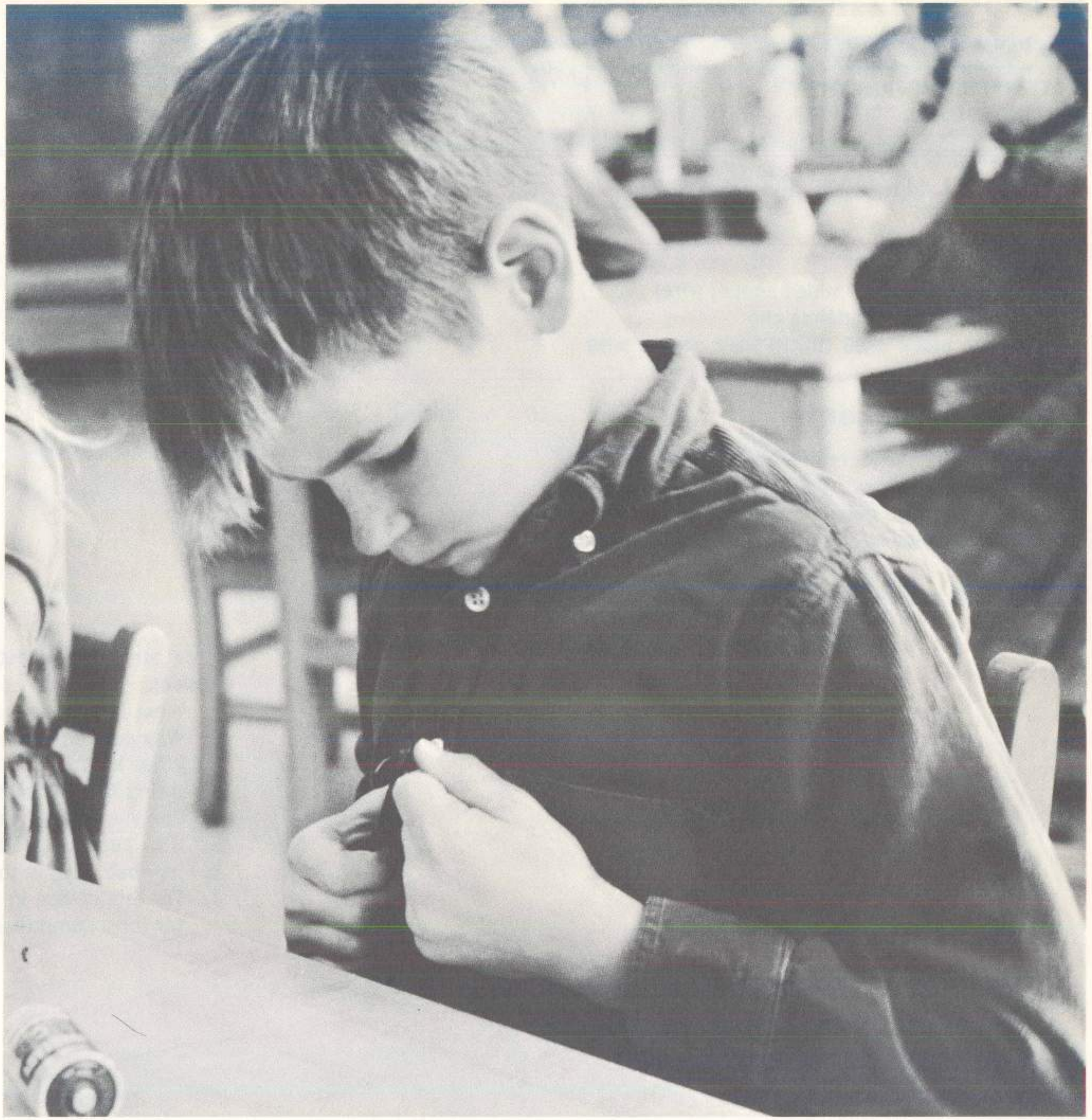
(See Project Sheet Five)

MATERIALS FOR THE JIGGLER

for each child or pair —
- 1 20d. nail
- 1 10d. nail
- Cellophane tape
- 12′ #24 Formvar (enameled copper wire)
- 1 corner of cardboard box (see diagram)
- 2 "D" batteries and holders
- 1 piece of sandpaper
- 3 thumb tacks

Special Comments

Be sure that the enamel is completely removed with sandpaper from the designated places. The coil may have to be raised or lowered to increase the efficiency of operation. The wire that is free to move (either **A** or **B** in drawing) must be placed under the falling nail. Periodically sandpaper off the black substance that accumulates on these bared wires.



PROJECT SHEET FIVE

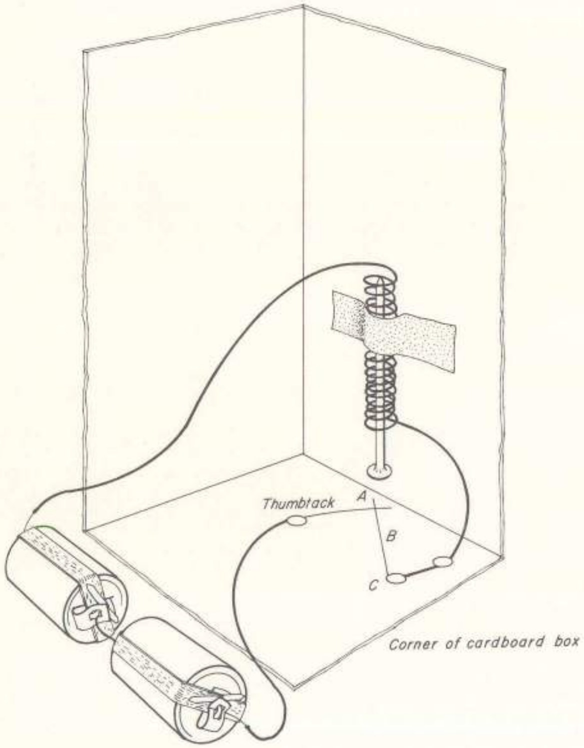
The Jiggler

Loosely wrap about one hundred fifty turns of enameled copper wire around the larger of your two nails. The nail should easily slip out of this coil. Remove 1½ inches of insulation from the loose wire on each end of the coil with sandpaper.

Remove 1½ inches of insulation from each end of an eight-inch piece of this type of wire.

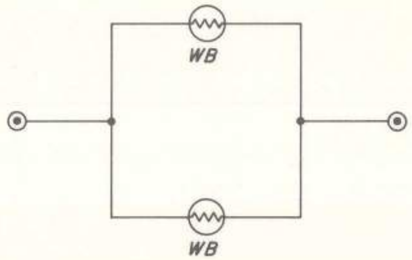
Assemble the Jiggler by taping the coil inside a corner of a cardboard box. (Insert the smaller nail into the coil before it is taped to the box.) The bottom of the coil should be about an inch above the bottom of the box.

Arrange the other wires as shown in the diagram, making sure the wire **A** lies flat on the cardboard and the wire **B** is raised an eighth inch above **A.** These wires should cross just under the spot where the nail will fall. Attach two "D" batteries as shown. Lift the nail and let it drop where the two wires cross.

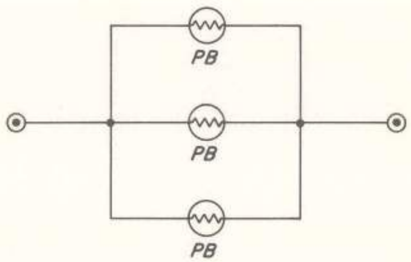


Here are some questions about the Jiggler you may want to answer.

1. Why does the nail keep bouncing up and down?
2. What happens to the number of bounces in a minute if wire **A** is moved toward the thumb tack **C**? (Keep wire **B** touching the cardboard.)
3. How can you stop the Jiggler from working?
4. Will the Jiggler work with only one battery? Three batteries?
5. What happens if a smaller nail is used?
6. Will an aluminum or brass nail work in place of the iron one?
7. Do you get the same results with only fifty turns of wire on the coil?
8. What happens if a WB is put in the path to the coil? Two WBs connected like this?



9. How many PBs, if they are connected in the path to the coil, like this, will it take to make the Jiggler bounce?



10. What is the black substance that forms on the bare wires at **A** and **B**?