A HELICAL COIL OF WIRE ACTS AS A BAR MAGNET WHEN CARRYING CURRENT

TOPIC:

Electromagnetism

SCIENTIST:

André-Marie Ampère 1775–1836

INTRODUCTION:

André–Marie Ampère's work on electromagnetism—magnetism produced by an electric current—was stimulated by the chance discovery in 1820 by Danish scientist Hans Oersted (see 1.037) that a wire carrying an electric current deflected a compass needle. After Dominique Arago's (see 1.003) demonstration of Oersted's phenomenon on December 11, 1820, Ampère, like many other scientists, worked frenetically to explain what he had seen. Just one week later he presented a paper putting forward the basic laws of electromagnetism, which he called "electrodynamics." One of his predictions was that a helical coil of wire, which Ampère called a "solenoid," would behave like a bar magnet when an electric current was passed through it. He knew already that a directional compass would point in different directions according to which pole of the bar magnet it was held next to. He used the same technique to prove his prediction about the solenoid, and also went on to show that the polarity of this electromagnet depended on which way the current flowed through it.

TIME NEEDED:

1 hour

MATERIALS:

DC power pack
1 m insulated bell wire
small cardboard tube (*e.g.*, from roll of toilet paper)
piece of cardboard 20 cm x 15 cm
small directional compass
bar magnet (approximately 1 cm x 6 cm)
Fun tak®
iron filings (preferably in an old salt or pepper shaker)
wire strippers
metric ruler
transparent tape
small scissors

Original Materials:

Ampère would have used similar materials except that his battery would have been primitive and he would not have been able to buy insulated wire—he would have had to insulate it himself.

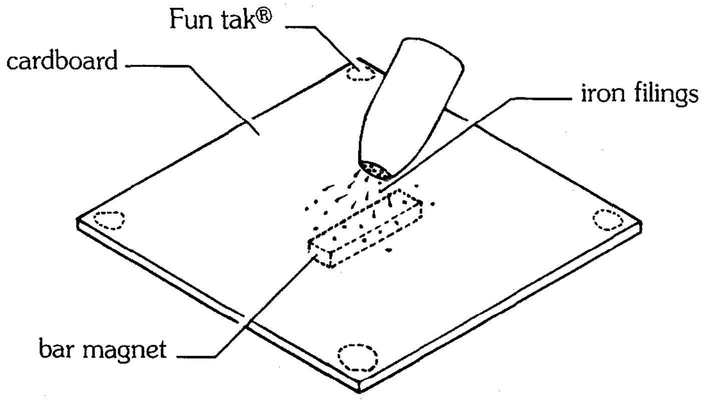
Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Electricity can cause dangerous shocks. Be careful not to expose any live wires.

PROCEDURE:

1. Put the bar magnet flat on the table. Hold the piece of cardboard so that it is just resting on the magnet but parallel to the table (see figure 1). Put a little Fun tak® under each corner to keep it steady. Make sure the cardboard covers the entire magnet.

Figure 1



2. Carefully sprinkle a light dusting of iron filings on the area of cardboard above the bar magnet (see figure 1). (Iron filings show the presence and direction of a magnetic field.) Observe and sketch the pattern of iron filings produced by their orientation in the magnet's magnetic field.

3. Remove the magnet and the Fun tak®. Return the iron filings to their container.

4. Wind the wire around the cardboard tube to make a coil (see figure 2), leaving about 15 cm of wire free at each end. Then remove the tube.

Figure 2

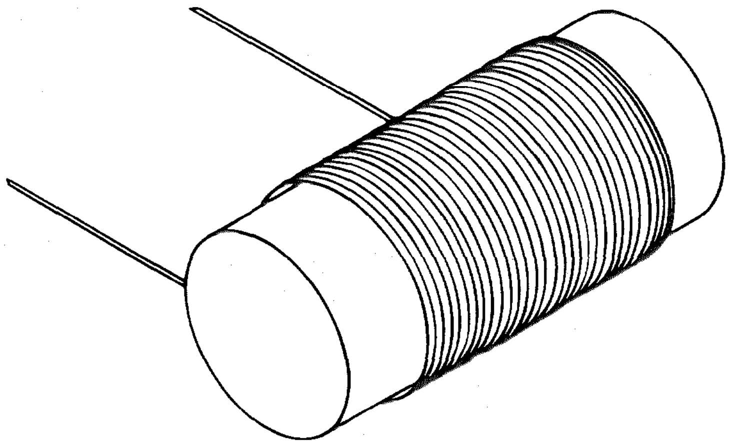
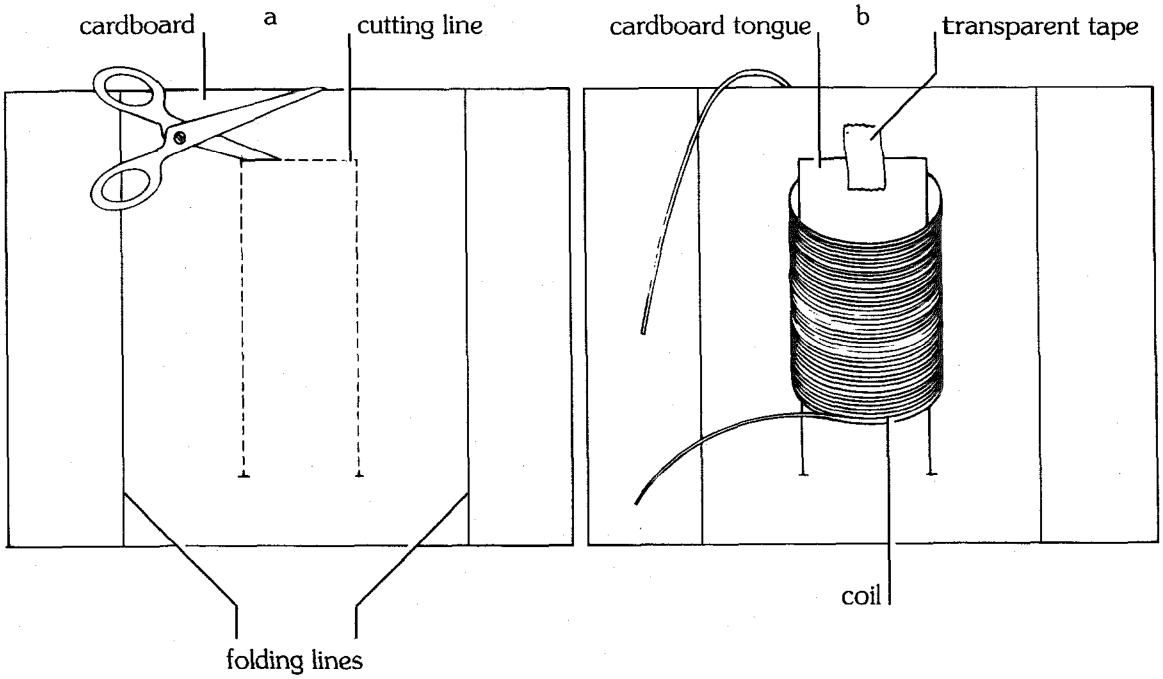


Figure 3

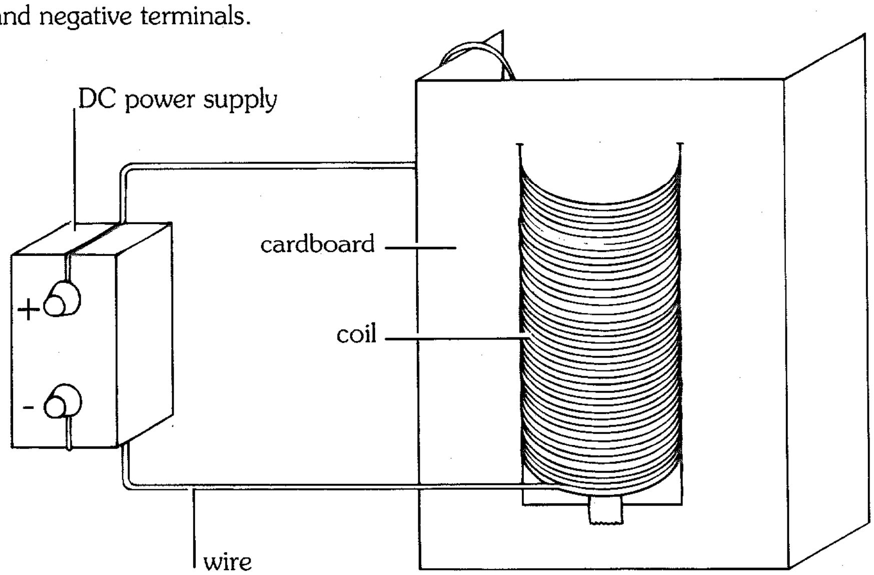


5. Measure and make a note of the length and diameter of the coil you produced. Now take the piece of cardboard and cut out the three sides of a rectangle with the same dimensions in the center of the piece of cardboard. Carefully fold in both sides of the piece of cardboard approximately 5 cm (see figure 3a).

6. Push up the "tongue" of the cardboard. Insert the tongue through the middle of the coil, then push the tongue down (see figure 3b), holding it in place with transparent tape. Then stand the cardboard upright on a table, using the two folded-in sides as supports.

7. Take the two ends of the wire extending from the coil and bend them as shown in figure 4. Strip 3 cm of insulation from each end of the wire. Connect the ends to the terminals of the power pack (see figure 4). Make a sketch showing which way the wires are connected to the positive and negative terminals.

Figure 4



8. Hold the compass next to one end of the coil, then the other. Record what happens to the compass needle.

9. Reverse the terminals—disconnect the wires and attach to the negative terminal the wire that was attached to the positive terminal, and to the positive terminal the wire that was attached to the negative terminal Repeat step 8.

10. Hold the north pole of the magnet next to one end of the coil, then the other. Record anything you feel.

11. Reverse the terminals. Repeat step 10.

12. Disconnect the circuit. Sprinkle iron filings on the card inside and around the coil.

13. Reconnect the circuit. Look at and sketch what happens to the iron filings around the coil.

ANALYSIS:

1. Describe what happened when the compass was placed next to the end of the coil. Did the response of the compass change when the wires were changed to opposite terminals?

2. Do some research. Explain what you described in your answer to question 1. (Clue: If the terminals are reversed, the direction of current flow through the wire is reversed.)

3. Describe what happened when the north pole of the magnet was placed next to the end of the coil. Did the response change when the wires were changed to opposite terminals?

4. Do some research. Explain what you described in your answer to question 3.

5. Describe what happened in step 2 when you sprinkled iron filings on the cardboard placed above the magnet.

6. Compare what happened in step 2 with what happened in step 13 when you sprinkled iron filings around the coil. Is it the same or different?

7. Do you think the coil behaves in the same way as a bar magnet. Why?

OUR FINDINGS:

Click on above link to see what we found.

Figure 2

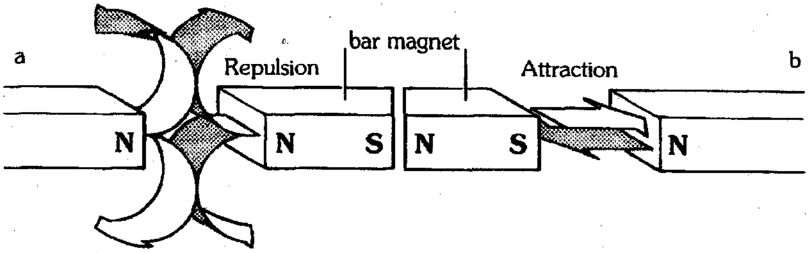
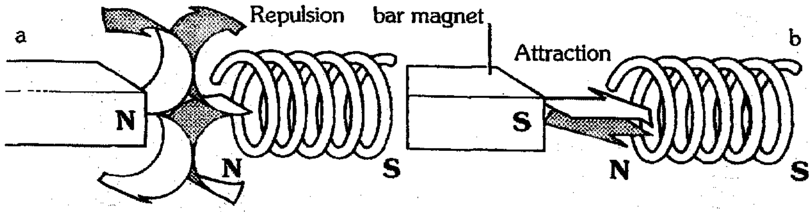
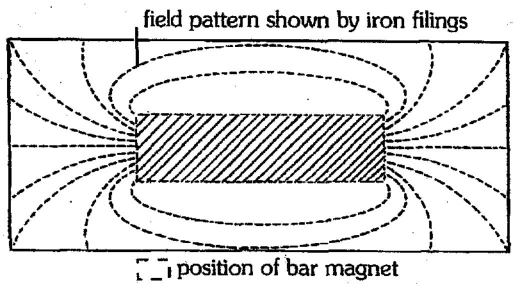


Figure 3



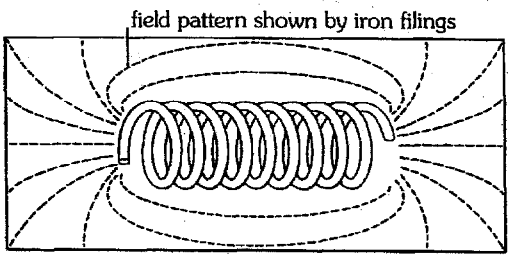
5. The appearance of the iron filings is as shown in figure 4.

Figure 4



6. The coil and the bar magnet behave in similar ways with the iron filings (see figure 5).

Figure 5



7. The coil does behave in the same way as a bar magnet. The magnetic field pattern is the same for the coil as for a bar magnet. Also, the bar magnet reacts to the coil as it would to another bar magnet.

SPECIAL SAFETY NOTE TO EXPERIMENTERS

Each experiment includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are performing the experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each experiment you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:
—Clear all surfaces before beginning experiments
—Read the instructions before you start
—Know the hazards of the experiments and anticipate dangers

PROTECTING YOURSELF:
—Follow the directions step-by-step; do only one experiment at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Don't use your mouth to pipette; use a suction bulb
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not use reflected sunlight to illuminate your microscope
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES