GALVANOMETER

OBJECTIVE:

You will understand how an electric current flowing through a coil generates a magnetic field and will demonstrate how this principle is used by making a galvanometer—a device for measuring the size of an electric current.

INTRODUCTION:

The galvanometer measures small electric currents. It is named after what in the nineteenth century was called the galvanic current—the electric current produced from batteries—which in turn was named after Italian scientist Luigi Galvani (1737–1798). The unit of current—the ampere, or amp—is named after French mathematician and physicist André-Marie Ampère (1775–1836).

A galvanometer works on the principle that a wire carrying an electric current produces a magnetic field around the wire. Coiling the wire produces a stronger electromagnetic field, and the coiled wire behaves like a bar magnet, with a north pole and a south pole. The strength of the electromagnetic field is measured by its effect on another magnet—in this case, a magnetized needle. The larger the current flow in the coil, the stronger the electromagnetic field, and the greater the movement (deflection) of the magnetized needle.

This simple type of galvanometer was first developed by Danish physicist Hans Christian Oersted (1777–1851) in 1820. In the 1820s, Italian physicist Leopoldo Nobili (1784–1835) used Oersted's observations and developed the first practical galvanometer with a scale reading. This galvanometer was adopted by many experimenters, enabling them for the first time to quickly, accurately, and sensitively measure the amount of electrical charge flowing through their experimental circuits.

Most present-day laboratory galvanometers are the moving coil type, developed in 1825 by German physicist Johann Schweigger (1779–1857). In these, the coil itself is deflected by the current, while the permanent magnet remains stationary. Today, multimeters—for measuring electric current in amps and measuring potential in volts—are modified galvanometers often used in laboratories. Here you will be constructing a galvanometer similar to the one Nobili designed.

TIME NEEDED:

1 1/2 hours

MATERIALS:

- 2-liter plastic bottle, about 10 cm in diameter (e.g., soft-drink bottle)
- 5 m bell wire
- wire strippers
- steel sewing needle 2–3-in. long
- 20 cm thread
- strong linear magnet (e.g., bar magnet)
- red paint
- sheet of medium-weight cardboard, 9 cm x 9 cm
- sheet of heavyweight cardboard, 12 cm x 12 cm
- pencil
- metric ruler
- electrician's tape
- glue
- DC power pack (able to give an amperage reading in the range of 20mA–1A)
- magnetic compass
- X-acto® knife
- cutting board
- paper clip
- protractor
- tape

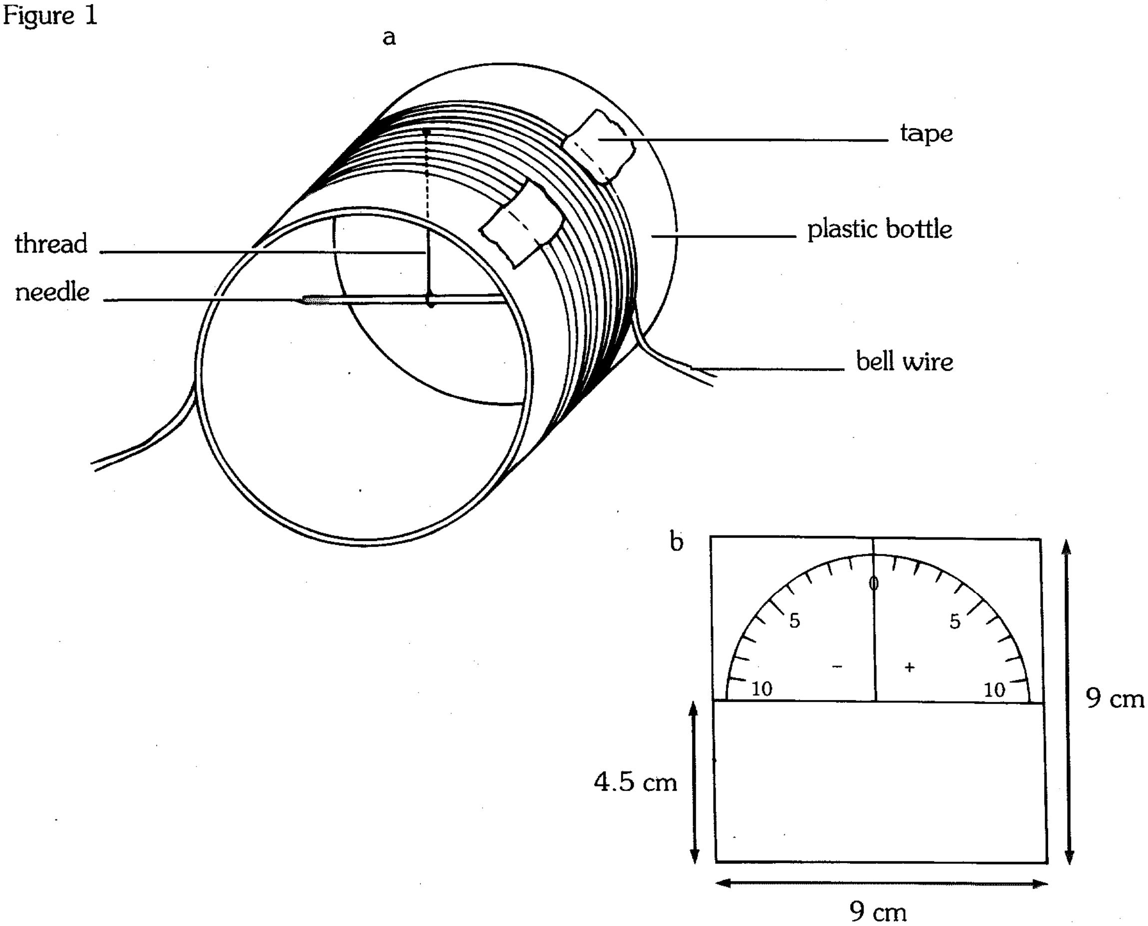
Safety Precautions

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. Take care when using the knife to cut around the plastic bottle.

PROCEDURE:

1. Using the X-acto® knife and working on a cutting board, carefully cut off both ends of the plastic bottle to make a tube 9 cm long.
2. Wind the wire tightly around the tube to form a coil of about ten turns. Hold the wire coil in place by securing it with tape.
3. Magnetize the needle by dropping the flattened end onto the North pole of a magnet. Immediately pull the needle away from the magnet. When you do so, the needle will become magnetized.
4. Check that the needle is magnetized by confirming that it attracts an unmagnetized metal object such as a paper clip and that one end of the needle is repulsed from one pole of the magnet.
5. Dip the sharp end of the needle in red paint. Hold it until it dries.
6. When the paint is dry, tie the cotton thread to the middle of the needle. Add a drop of glue to hold the thread in place against the needle.
7. Using the sharp end of the needle, pierce a small hole in the exact middle of the tube, on the side facing upward, halfway across the tube's diameter and 4.5 cm from one end. Pass the thread through this hole from the inside of the tube and tie a knot in the thread to secure it so that the needle is suspended in the center of the tube, pointing to one side (see figure 1a).
8. Mark out the 9 cm x 9 cm piece of cardboard with a scale drawn using a protractor with marks at 9° intervals (see figure 1b). The scale shows deflection in a positive (clockwise) direction and in a negative (counterclockwise) direction.

Figure 1



9. Attach the tube and coil to the 12 cm x 12 cm piece of cardboard by placing a piece of tape along the base of the tube. Place the cardboard scale inside the tube so that it lies horizontally just below the needle.
10. Use a magnetic compass to align your galvanometer so that the needle points magnetic north–south and the coil east–west.

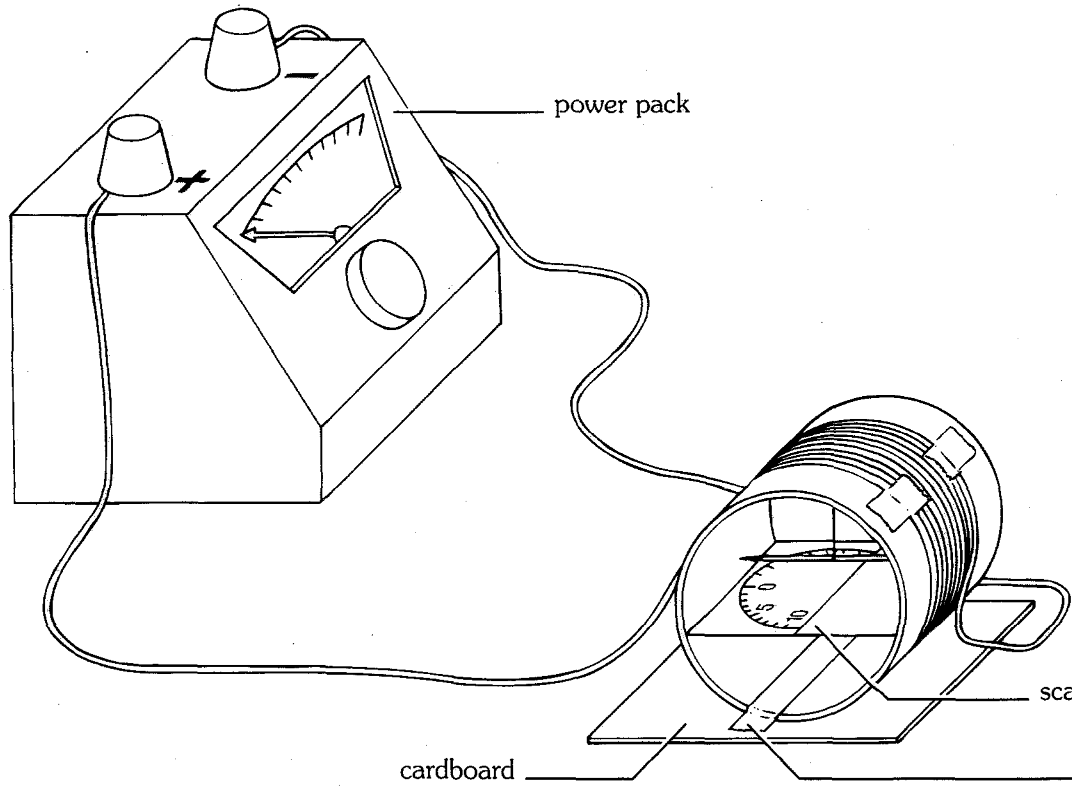
11. Use the wire strippers to remove 3 cm of insulation from each end of the bell wire. Connect the bell wire to the DC power pack (figure 2).

12. Switch on the power pack and deliver a current of 20 mA (milliamps, or 1/1000 amp) through the coil. Note the deflection of the needle against the scale.

13. Increase the current reading to 40 mA and again note the deflection. Repeat this procedure at 20-mA intervals up to 200 mA. Now increase the current at 100-mA intervals, up to a current of 1A, and note the reading in each case. By observing the position of the needle against the scale, note the direction and amount by which the needle swings—this is the deflection.

14. Reverse the connections to the power pack and repeat steps 12 and 13.

Figure 2



ANALYSIS:

1. In step 10, why is the magnetized needle aligned north–south at the start of the experiment?
2. In steps 12–13, in which direction (clockwise or counterclockwise as seen from above) is the needle deflected when the current flows?
3. In step 14, when the connections to the power supply are reversed, in which direction (clockwise or counterclockwise) is the needle deflected?
4. In steps 12–14, is the degree of deflection of the needle proportional to the amount of current flowing through the coil?
5. Examine a commercial moving-coil galvanometer or multimeter. When measuring current using this device, how does the degree of deflection differ from that you observed in your galvanometer?

OUR FINDINGS:

Click on above link to see what we found.

SPECIAL SAFETY NOTE TO INVESTIGATORS

Each invention 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 investigation. 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 when you are constructing or demonstrating a model invention. 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 carrying out the project, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual projects. 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 project 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 carrying out these projects. Be sure to check the individual projects 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 projects
—Read the instructions before you start
—Know the hazards of the procedures and anticipate dangers

PROTECTING YOURSELF:

—Follow the directions step-by-step; do only one project 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 or bench
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders
—Never look directly at the sun with your observation devices

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

Our Findings

VIII. ELECTRICITY

8.04 Galvanometer

1. The magnetized needle will act like the needle of a magnetic compass. To make sure that any deflection of the needle is due to the electric current and not to the earth's magnetic field, the needle must be aligned north–south at the start of the investigation.
2. The needle is deflected clockwise.
3. The needle is deflected counterclockwise.
4. The degree of deflection increases with current, but not in direct proportion. The increase in deflection gets relatively smaller as the amperage increases.
5. In a commercial moving-coil galvanometer or multimeter, the degree of deflection is directly proportional to the amount of current.