ELECTRICITY FROM MAGNETISM

TOPIC:

Electromagnetic Induction

SCIENTIST:

Michael Faraday 1791–1867

INTRODUCTION:

Michael Faraday's appetite for electrical investigations was whetted by the chance discovery made by Hans Oersted (see 1.037) in 1820 that a wire carrying an electric current behaves like a magnet. It was not until 1831, however, that Faraday found time to carry out serious research into the topic. He decided to find out (by doing the reverse of Oersted's experiment) whether a magnet could be used to produce an electric current. In August of that year he noted in his diary that he had wound copper wire around a paper cylinder to make a coil, attaching the ends of the coil to a galvanometer. When he pushed the end of a bar magnet into the coil he noticed that the galvanometer needle twitched, indicating that an electric current had, momentarily, flowed through the wire. The same thing happened when the magnet was removed except that the needle twitched in the opposite direction. When the magnet was left inside the coil, however, the galvanometer did not respond. Faraday called this phenomenon "electromagnetic induction," because an electric current had been induced (produced) in the coil by a changing magnetic field. He explained that the current was induced as a result of the coil of wire being "cut by magnetic flux" whenever the magnet moved. Faraday also investigated the effect of the strength of the magnet, the number of turns in the coil, and the effect of plunging the magnet faster or slower into the coil. Faraday's discovery led to the development of the world's first dynamo, forerunner of today's powerful generators that supply most of our electricity.

TIME NEEDED:

1 hour

MATERIALS:

cardboard tube (*e.g.*, from toilet paper roll)
multimeter*
14 m insulated bell wire
sharp scissors or wire cutters
wire strippers
meter ruler
bar magnet, approximately 1.5 cm x 1.5 cm x 8 cm
electrical tape or duct tape

*An analog multimeter is better than a digital multimeter in this experiment.

Original Materials:

In Faraday's time, insulated copper wire was not available, nor were rolls of toilet paper. Instead, he used string to separate the turns of the coil from each other, and wound the coil around a tube made of paper.

Safety Precautions

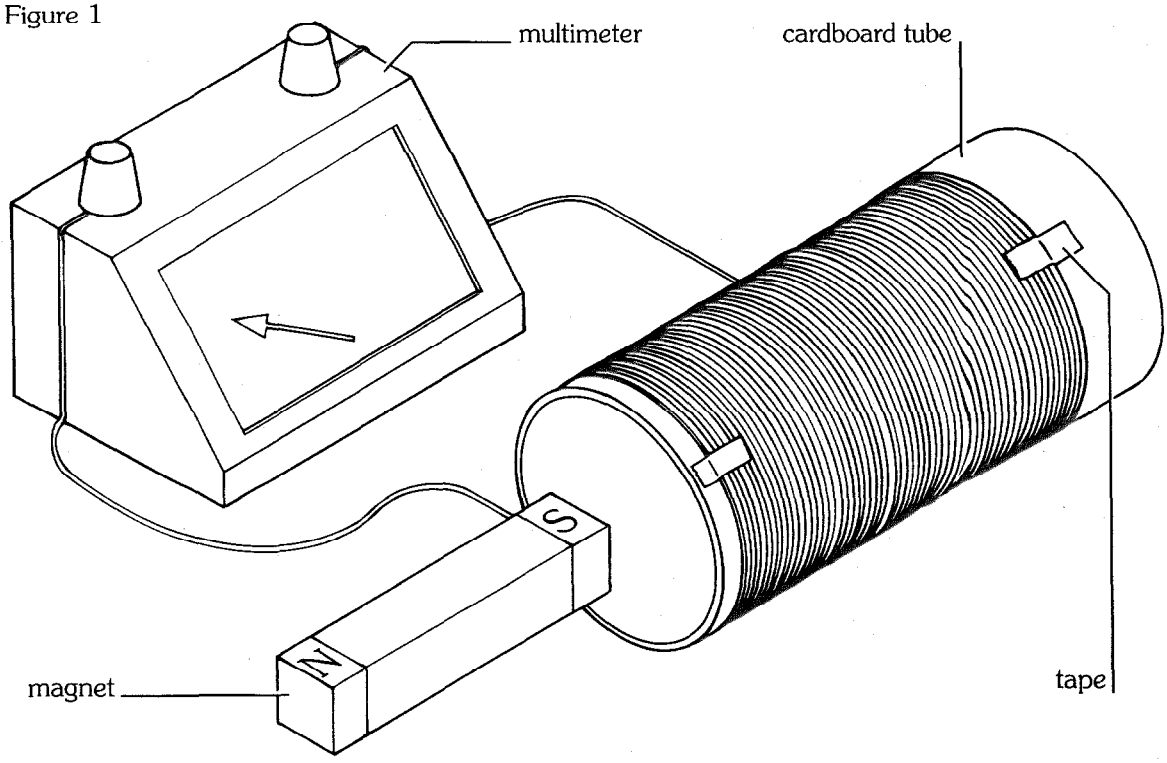
Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. Strip 3 cm of insulation from both ends of the wire.
2. Coil the wire around the cardboard tube. As you do this, push the turns together to produce a tight coil with many turns. Leave 10 cm of wire free at each end.

3. Tape each end of the coil to the cardboard tube so that it does not fall off the roll.
4. Connect the free ends of the wire to the terminals of the multimeter (see figure 1).

Figure 1



5. Hold the tube by one end. Pick up the magnet with your other hand.
6. Keeping one eye on the multimeter scale, push the north pole of the magnet into the tube and leave it there. Record any changes shown by the multimeter.
7. Now pull the magnet out of the coil. Record any changes shown by the multimeter.
8. Repeat steps 5 and 6 with the south pole of the magnet.
9. Repeat steps 5 to 7 but this time push the magnet into, and pull it from, the tube much more rapidly. Record any changes shown by the multimeter.
10. Disconnect the wire from the multimeter. Unwind the wire from the tube. Measure the wire in meters as you unwind it. Cut the wire with scissors when you have measured 7 m (half the length of the wire), leaving 7 m wrapped around the tube.
11. Spread out the remaining wire windings along the tube until they are evenly spaced. Make sure there is 10 cm of wire free at each end as before.
12. Strip 3 cm insulation from the unstripped end of the wire. Repeat steps 4 to 9. Record your observations.

ANALYSIS:

1. What happened to the multimeter reading when you a) pushed the magnet into, b) pulled the magnet from, and c) left the magnet inside the first coil?
2. Did the speed at which you inserted or removed the magnet have any effect on the multimeter reading?
3. What happened to the multimeter reading when you pushed in the south pole instead of the north?
4. What happened to the multimeter reading when you reduced the number of turns in the coil and repeated the insertion and removal of the magnet at different speeds?
5. What overall conclusions can you draw from your observations?

OUR FINDINGS:

Click on above link to see what we found.

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