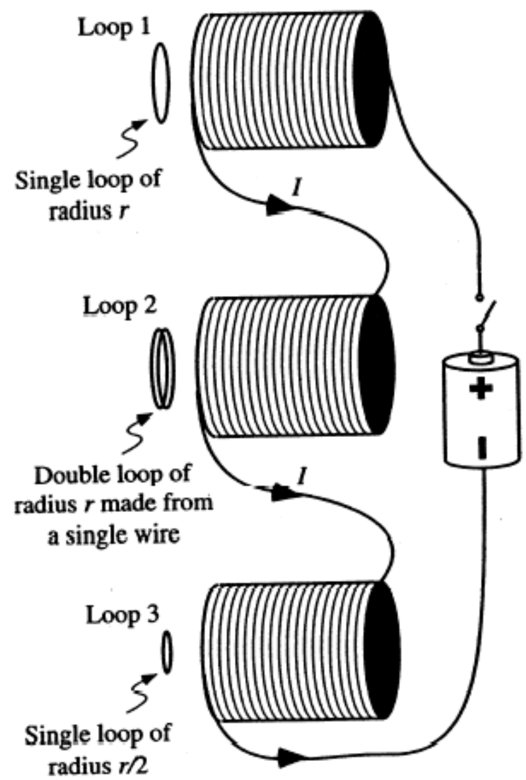
FARADAY'S LAW AND APPLICATIONS

You should try to do this lab, including answering these questions, during the lab period.

Three loops, all made of the same type of wire, are placed near the ends of identical solenoids as shown. The solenoids are connected in series. Assume that the magnetic field near the end of each of the solenoids is uniform.

Loop 2 consists of two turns of a single wire that is twice as long as the wire used to make loop 1. Loop 3 is made of a single wire that is half as long as the wire used to make loop 1.

The following questions concern the period of time just after the switch is closed, just as the current in the loops is reaching a steady state.



1. Let $\mathcal{E}$ represent the induced emf of loop 1. Find the induced emf in each of the other loops in terms of $\mathcal{E}$. Explain your reasoning.

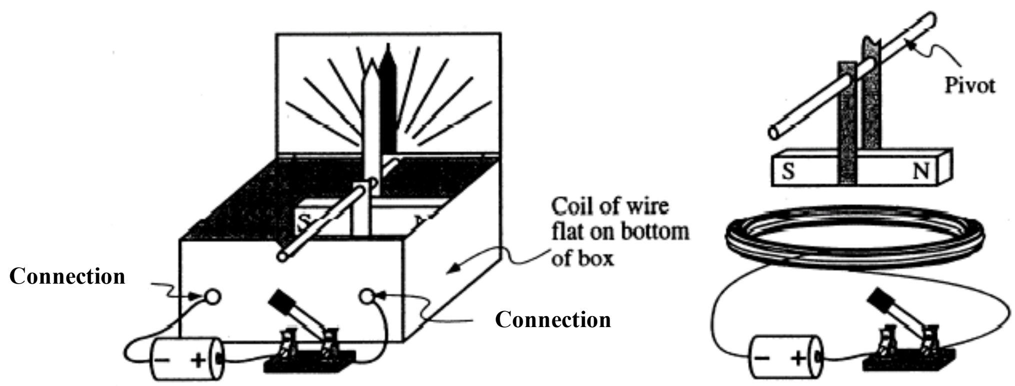
2. Let R represent the resistance of loop 1. Find the resistance of each of the other loops in terms of R. Explain.

3. Find the current induced through the wire of each of the loops in terms of C and R.

Galvanometer

Build a device similar to the one shown below. It contains a coil made of many loops of wire and a magnet suspended so that it is free to swing. A pointer has been attached to the magnet so that a small swing of the magnet will result in a large deflection of the pointer. When there is no current through the coil, the magnet is horizontal and the pointer is vertical.

Before you test this device, predict the deflection of the pointer (if any) when the switch is closed. Explain the reasoning you used to make your prediction.



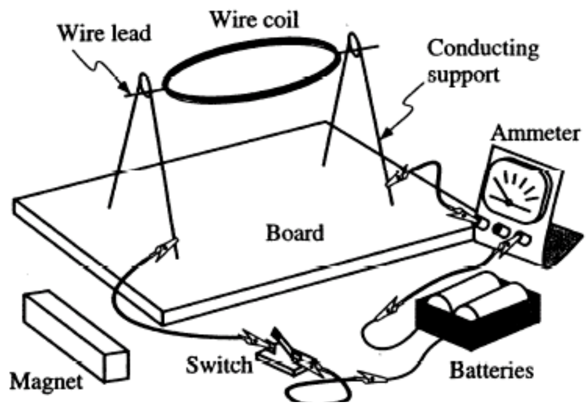
Connect the circuit and observe the deflection of the pointer. If your observation is in conflict with your prediction write why you think it conflicted and what you learned from your observation.

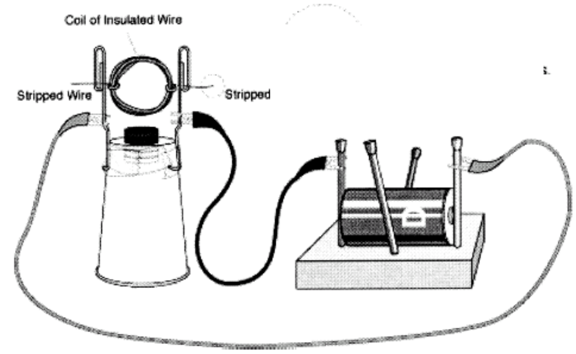
The device above is called a *galvanometer* and can be used to detect current. If the scale on the galvanometer has been calibrated to measure amperes, the device is called an *ammeter.*

A Simple Electric Motor

A coil of wire becomes an electromagnet when current passes through it. The electromagnet interacts with a permanent magnet, causing the coil to spin. Voila! You have created an electric motor.

Build a motor similar to one of the pictures at the right. You will want to use at least two batteries and Styrofoam for support rather than a board or paper cup. The magnets should be placed on the Styrofoam below the loop of wire as shown in the second figure.



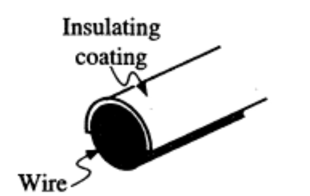


You will need

- About 5 magnets.
- 2 wires, bent to act as clips.
- A piece of Styrofoam.
- A solid enameled or insulated 20-gauge copper wire, about 2 feet (60 cm) long.
- Tape.
- At least 2 batteries or power supply
- Electrical lead wires with alligator clips at both ends.
- Wire strippers (if you are using insulated wire)
- Sandpaper (if you are using enameled wire).
- A black, waterproof marking pen.
- A battery holder.

Wind the copper wire into a coil about 2-3 cm diameter. Wrap the ends of the wire around the coil a couple of times on opposite sides to hold the coil together. Leave about 4 cm projecting from each side of the coil.

1. You will have to configure the wire so that current will not flow through ½ of the revolution of the wire. This can be done by stripping one half of one end of the wire, as shown, or by using a black marker which will act as insulation, and marking one half of the wire, or by sanding the other half of the wire (so that it will conduct). Examine the leads to the wire coil closely, so that you understand which portion of the wire will conduct electricity.



Wire lead half stripped of enamel

   When the wire is in the orientation shown in the figure, do you want the coil wound vertically or horizontally? Explain in writing your reasoning and check with you T.A. that your answer is correct beforc continuing.

Create a loop holder with the metal wires. Rest the ends of the coil in the cradles formed by the wire clips. Adjust the height of the clips so that when the coil spins, it clears the magnets by about 1-2 mm. Adjust the coil and the clips until the coil stays balanced and centered while spinning freely on the clips. Good balance is important in getting the motor to operate well.

Connect the battery or power supply to the metal clips.

Give the coil a spin to start it turning. If it doesn't keep spinning on its own, check to make sure that the coil assembly is well balanced when spinning, that the enamel has been thoroughly scraped off if enameled wire has been used, that the projecting end has been painted with black pen as noted, and that the coil and the magnet are close to each other but do not hit each other. You might also try adjusting the distance separating the cradles: This may affect the quality of the contact between the coil and the cradles.

Keep making adjustments until the motor works.

Answer the following questions to explain the motion of the motor.

3. Draw a picture showing the orientation of the coil and the magnets, as well as the direction of rotation, when there is the maximum current flowing through it. Do the same for when there is no current flowing through it.

4. Draw a picture showing the orientation of the coil and the magnets, as well as the direction of rotation, when there is maximum torque. Do the same for when there is minimum torque.

5. How do your answers to 3 and 4 change if the coil is rotating the other direction? Does the motor still work?

6. Using your answers to 3 and 4 explain how the motor works.

7. Now draw a picture of the coil at different points in its rotation and draw the magnetic moment of the coil. Explain the operation of the motor using the interaction of this magnetic moment with the magnetic field of the external magnets. Explain and show how the interaction will tend to *increase* or to *decrease* the angular speed of the coil.

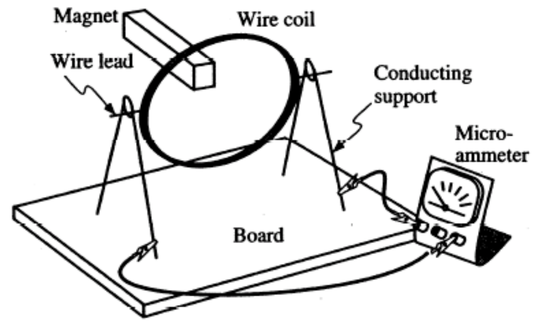
8. Why did you have to make ½ of the wire insulating? What would happen if the both sides of the wire were conducting?

9. Why do you have to use insulated wire? What would happen if the wire wasn't insulated?

10. Predict the effect on the motor of (i) reversing the leads to the battery and (ii) reversing the orientation of the magnet. Check your predictions.

Electric generator

Remove the battery from the circuit you used to make your motor, and set up a situation similar to that shown in the figure. (We don't have microammeters, so use the best you can.)



1. Suppose that the coil is made to spin by an external agent such as yourself. Predict which way the current would move through the ammeter shown in the picture at the right.

How would your prediction change if:

• the coil were made to rotate the other way?

• the poles of the magnet were reversed?

2. Try to check your predictions by gently rotating the coil so that it spins for a little time on its own before coming to a stop. There may not be enough current generated to detect. Comment on your result.

When the coil of the apparatus above is made to spin by an external agent, the apparatus is called an *electric generator*. Comment on the similarities and differences between a motor and a generator.