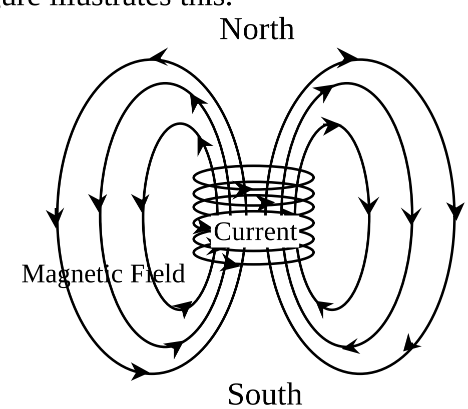
Electromagnetic Induction

Electromagnetism is the physical phenomenon by which changing electric fields produce magnetic fields and vice versa. For instance, a current (moving charges) through a straight wire produces a magnetic field around the wire. To find the direction of this magnetic field, one uses the **right-hand rule**. If the thumb of the right-hand is placed such that it points in the direction of the electrical current, then the fingers will coil in the direction of the magnetic field formed around that current. A wire can be formed into a loop or a spiral called a **solenoid**. Applying the right-hand rule to the solenoid will yield the direction of the magnetic field through the solenoid. Such an arrangement will behave as a bar magnet. In addition, the poles (north and south) will depend on the direction of the current. The following figure illustrates this.



The magnetic field pictured above is produced by moving charges. In addition, through the process of **electromagnetic induction**, a changing magnetic field can produce an electric field. Whenever a conducting loop lies in a changing magnetic field or whenever a conductor passes through a magnetic field, an **electromotive force** is induced in the conductor. **Faraday's law** states that the induced emf in the conductor is directly proportional to the time rate of change of the magnetic field. That means that the faster the magnetic field changes (increases or decreases in strength), the greater will be the resulting emf. **Lenz's law** states that the current produced by this emf will flow in a direction such that the magnetic field produced by this emf opposes the change in the external field.

These laws can be tested experimentally using various coils and magnets. A device called a **galvanometer** (or multimeter) can be used to detect the presence and direction of currents produced in the experiment. In this laboratory, we will be using the galvanometer, various coils and magnets to test the validity of Faraday's law, Lenz's law, and the right-hand rule.

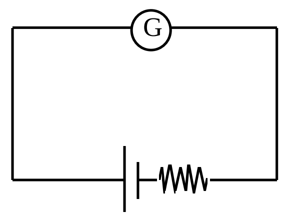
Equipment:

Galvanometer or mulitmeter, permanent magnet, two coils of wire, iron rod, dry cell (battery), compass.

Procedure:

Part One: Calibration

Since we will be using the galvanometer to test for the presence and direction of currents in the coils, we will first need to calibrate it to known currents and directions. We will be sending a current of known direction through the galvanometer and noting the direction of the deflection.



The above figure demonstrates the circuit necessary to calibrate the galvanometer. The voltage source will be a dry cell. Since the galvanometer is very sensitive, choose a very large resistance (10K Ohm or more) so the current will be very small. We know that current flows from the positive (center) terminal to the negative (outside) terminal of the cell. Observe into which binding post on the galvanometer the current flows and from which post it leaves. Correlate the direction of current flow with the direction of needle deflection of the galvanometer. Reverse the polarity of the circuit and test this again. Does the deflection go in to opposite direction?

Disconnect the cell.

Part Two: Electromagnetic Induction

Two coils are provided, one with many turns of fine wire called the secondary coil (S) and one with fewer turns of coarse wire called the primary (P) coil.

1. Connect the secondary coil directly to the galvanometer.
2. Use a compass to determine the poles of a permanent magnet. Remember that the north pole of the compass points to the south pole of the magnet.
3. Move the N-pole of the magnet quickly into coil-S and observe the direction and magnitude of the deflection on the galvanometer. Reverse the motion and observe the deflection again.

4. Repeat 3. moving the magnet slowly this time.
5. Repeat 3 and 4 using the S-pole of the magnet.
6. Hold the magnet stationary and move the coil onto the magnet. Use both poles of the magnet and record all observations.

Questions:

Does the galvanometer show a reading when the magnet and coil are at rest with respect to one another?

What is the effect of the speed of the motion?

How is the deflection dependent on the pole of the magnet used?

How does the deflection with insertion compare to that with withdrawal of the magnet?

Part Three: Electromagnetism

1. Turn the power supply off and set it to 0V. Connect the primary coil to the power supply. Observing the direction of the windings in the wire, and given that current flows from the positive to negative terminals of the power supply, use the right-hand rule to make a prediction about which end of coil-P will be the north pole. Record this prediction.
2. Turn on the power supply and test your prediction using a compass. Did the right-hand rule predict correctly? Reverse the current and observe any changes.
3. Adjust the power supply to about 4V. Move coil-P in and out of coil-S. Record your observations as you did in part two.
4. Reverse the current in coil-P and repeat step 3.
5. Repeat part three with the iron core inserted. Note your findings on the lab form.

Question:

What general conclusion about the magnetic field from the permanent magnet and from the energized coil-P can be reached from this demonstration?

What effect was produced by the iron core? Why do you think it had an effect?

Electromagnetic Induction

Name:______________________Section:_________

Abstract:

Data/Observations:

Part Two: Electromagnetic Induction

Condition	Observation
1. N-pole of Magnet moved rapidly into coil-S.	
2. N-pole of Magnet removed rapidly from coil-S.	
3. N-pole of Magnet moved slowly into coil-S.	
4. N-pole of Magnet removed slowly from coil-S.	
5. S-pole of Magnet moved rapidly into coil-S.	
6. S-pole of Magnet removed rapidly from coil-S.	
7. S-pole of Magnet moved slowly into coil-S.	

8. S-pole of Magnet removed slowly from coil-S.	
9. Magnet held stationary and coil-S moved rapidly onto N-pole.	
10. Magnet held stationary and coil-S removed rapidly from N-pole.	
11. Magnet held stationary and coil-S moved rapidly onto S-pole.	
12. Magnet held stationary and coil-S removed rapidly from S-pole.	
13. Both Magnet and coil-S held stationary.	

Conclusions:

Part Three: Electromagnetism
Data/Observations:

1. Observe the direction of coil-P's wire winding and the direction of current from the voltage source. Use the right-hand rule to predict which end of coil-P is a N-pole. Test with a compass. You may wish to draw a picture.

2. Reverse the current direction and test with the compass. What did you find?

Condition	Observation
3. N-pole of coil-P inserted into coil-S.	
4. N-pole of coil-P removed from coil-S.	
5. Reverse I. S-pole of coil-P inserted into coil-S.	
6. S-pole of coil-P removed from coil-S.	

Conclusions: