

615-4585 (10-110) Electromagnet Kit (Gilley Coil)

Warranty

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free by referring to the part numbers above. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse, or normal wear and tear.

Introduction

This apparatus is used to demonstrate induced currents. It consists of two coils, each 210 turns of #20 gauge copper wire and various soft iron magnetic cores. The coils are mounted in plastic saddle blocks enabling them to stand vertically.

No assembly is required. Individual setups are outlined in each experiment.

Other Materials Needed

- 6 volt (or greater) battery
or
- Power supply exceeding 1 amp DC

P/N 24-0110

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Background Ideas and Concepts for Experiments

An electric current is a flow of electrons. The cause of electron flow can vary. They may be made to flow due to electrostatic attraction or repulsion. Electrons in metallic substances are quite mobile and can be induced to flow by the presence of a *magnetic field*.

It is not fully understood what a magnetic field is. We describe it in terms of its effect on materials.

The following properties apply to magnetic fields:

1. Electrons flow only at right angles to the direction of the magnetic field.
2. The electromotive force (EMF) is a measure of a source's ability to cause a current to flow in an electrical circuit. The pressure, or EMF, of the electron flow is proportional to the rate of change of the magnetic field.
3. The number of electrons which respond to the push of the magnetic field depends upon the resistance of the electric circuit including the coil and the counter EMF generated by this flow.

Magnetic Flux

The next basic concept necessary in understanding the idea of induction is *magnetic flux*. In order to induce a coil, we need a **change** in flux.

Magnetic flux is related to the number of lines of magnetic force either entering or leaving a magnetized surface. A magnet with a strong magnetic field produces more lines of flux than does a magnet with a weak field. It is immaterial whether the magnetic flux changes

as a result of the approach or departure of a magnetic field or as a result of the strengthening or weakening of a stationary one. The flow depends on **change**.

In *Experiment 3*, iron filings are used to outline magnetic lines of flux.

If we move a magnet towards a coil (as in *Experiment 1*), the flux linking with the coil is increased. During that time when the magnet is approaching the coil (i.e. flux is changing) an EMF is induced in the coil. The magnitude of the EMF depends on how fast the flux is changing (i.e. how fast the magnet is approaching.) The magnitude of the EMF can be calculated using **Faraday's Law**.

$$\text{Avg induced EMF} = \frac{Nd}{1.01 dt} \quad \text{volts}$$

$$\begin{aligned} N &= \text{\# of turns in coil} \\ d &= \text{change in flux} \\ dt &= \text{change in time} \end{aligned}$$

Another important idea in *Experiment 1* is **Lenz's Law**. Lenz's Law states that *the EMF induced in a coil acts to circulate a current in a direction which opposed the change of magnetic flux which gave rise to the induced EMF*.

In other words, any changes are opposed. Therefore, when we move a magnet (N-pole) towards a coil (as in *Figure 1a*), then the flux entering the left end of the coil is increased. Applying Lenz's Law, the polarity of the EMF produced in the coil must cause a current to flow in the coil such that the flux produced by the coil opposes the flux entering the coil.

In *Experiment 2*, one coil is used to induce another. When two coils are magnetically coupled, the coil which is responsible for producing the flux is known as the *primary* winding. The winding which receives energy is known as the *secondary* winding.

What is an Electromagnet?

A current carrying wire can be looped to form a coil. The coil is called a *solenoid*. By placing a soft iron rod in the core of the coil, we create a magnetic field around the coil.

The coil along with its iron center create what is known as an *electromagnet*.

The strength of an electromagnet depends upon the number of turns (N) in its coil and the material that coil and core are made of. An electromagnet is a temporary magnet. One benefit of a magnet of this type is that the magnetism can be controlled. When the current is shut off, the electromagnet loses most of its magnetism.

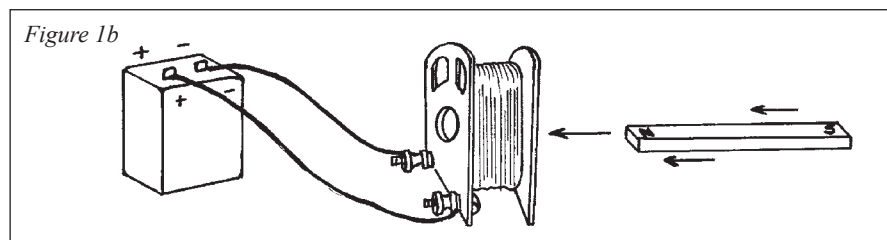
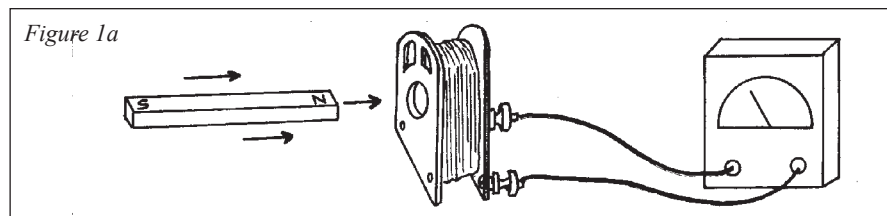
In *Experiment 4*, we create an electromagnet and demonstrate its lifting power.

Additional materials are required. Step-by-step procedures and results accompany each experiment.

Experiment 1 Magnetic Induction in a Coil

Materials Needed:

- One coil
- One bar magnet
- Galvanometer
- 9V battery
- Two (2) clip leads (included)



Objective:

- To demonstrate magnetic induction
- To show the direction of current flow and its potential
- To create a simple electromagnet

Procedure:

Connect one coil to terminals of a galvanometer as shown in *Figure 1a*.

1. Move the N-pole of the bar magnet towards the coil center. Note the direction in which the galvanometer needle moves.
2. Repeat with a departing N-pole, approaching S-pole and departing S-pole. Record your results.
3. Using the n-pole of the magnet, bring the magnet towards the coil first with a slow approach/departure and then with a fast approach/departure. In this case we wish to observe the distance that the pointer moves. This shows the intensity of flow or potential.
4. Knowing that the flow (flux) will continue only as long as the magnetic field is changing, what would you expect to happen if the magnet were to remain stationary:
 - a. To check your result, bring either end of the magnet towards the coil center and record the deflection of the needle after a few seconds. Compare your expectations with the actual outcome.
5. **To form an electromagnet:** Connect the coil to the battery as shown in *Figure 1b*. This will cause the current to flow in the

same direction as that caused by the approaching N-pole in **Step 1**, thus creating an electromagnet.

Next, bring the N-pole of the bar magnet towards the coil.

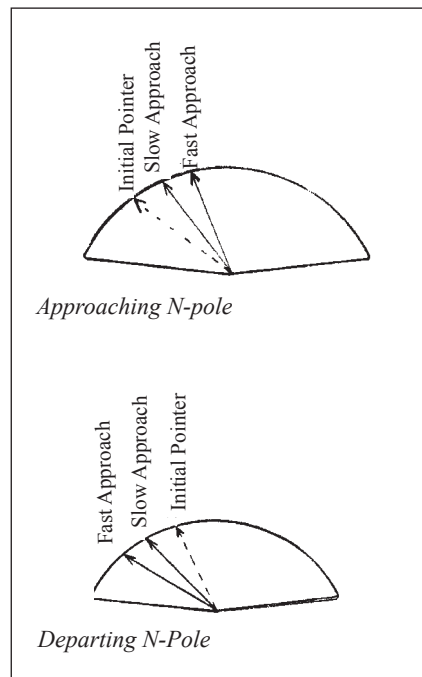
Does the new magnet attract or repel the approaching N-pole? Explain your answer.

Results for Experiment 1

Step 1 & 2: Direction of Current

Pole & Direction of Magnet	Direction of Needle Deflection	Direction of Current
N approach	Pointer right	Clockwise
N depart	Pointer left	Counterclock
S approach	Pointer left	Counterclock
S depart	Pointer right	Clockwise

Step 3: Direction of flow



Step 4:

With a stationary magnet, the change in flux = 0. We would expect no deflection in the needle. Note that this idea corresponds to results in Step 3. The slower approach or departure of the magnet caused a smaller deflection of the needle. A stationary magnet would cause minimum or (zero) movement.

Step 5:

Because electron flow from the battery is running in the same direction as the electromagnet, it will repel the approach of the N-pole. ("Like" things repel.)

Questions:

1. What is the source of energy which caused the current generated in **Steps 1 and 2?**
2. What determines the amount of current generated:
3. How long does the induced current last? Why?
4. What determines the direction of the induced current?

Answers to Questions:

1. *The source of energy which caused the current generated in the coil is the magnet.*
2. *The amount of current generated depends on the speed at which the electrons are flowing (i.e. how fast the magnet is approaching or departing).*
3. *The induced current does not last very long. There is only current when flux is entering or leaving the coil. Once the magnet becomes stationary, the induced current stops.*
4. *The polarity of the magnet determines the direction of the induced current.*

Experiment 2 Primary/Secondary Coil

Materials Needed:

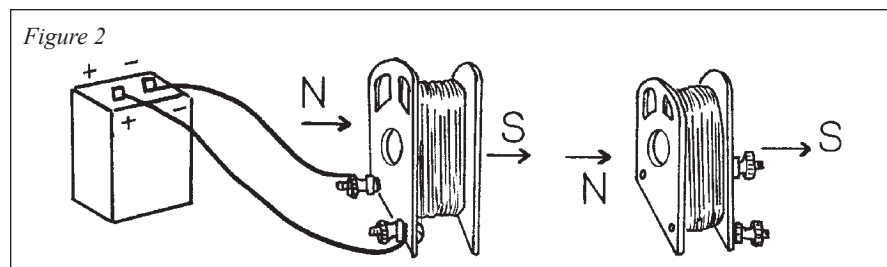
- Galvanometer
- Two (2) coils
- Battery
- Four (4) clip leads
- Iron core

Objective:

- To demonstrate mutual induction

Procedure:

1. Connect primary coil (A) to a battery and the secondary coil (B) to a galvanometer (*Figure 2*). The terminals for each coil should face opposite directions.
2. In what direction does the **galvanometer needle deflect?** In what direction is the flow in the second coil, Coil B? Knowing that electrons flow from the negative electrode of a battery, in what direction is the flow of Coil A? Is the flow in each coil the same or different directions? Why?
3. **Separate Coil A from Coil B by 2 or 3 inches.** Quickly bring Coil A towards Coil B and observe the galvanometer. Does the approach of Coil A give the same direction of deflection as seen in **Step 2?** Why?
4. Repeat **Step 3** with a **departing primary coil**, Coil A.
5. Of the procedures **2 and 3**, which generates a **higher potential?**
6. Repeat **Step 2** using an **iron core** through the center of the coil pair. **Record the degree of deflection** of the galvanometer when the battery is connected and then disconnected. Does the **quantity of magnetic flux** increase or decrease when an iron core is used?



Experiment 3 Magnetic Lines of Force

Materials Needed:

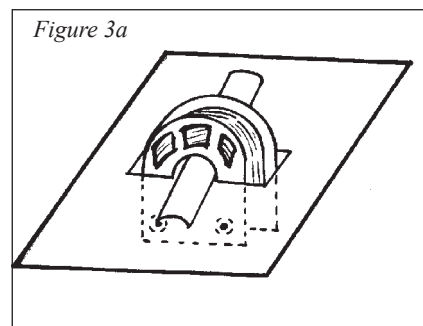
- One coil
- 2 half-round bars
- Stiff paper
- Iron filings
- Battery
- Two (2) clip leads

Objective:

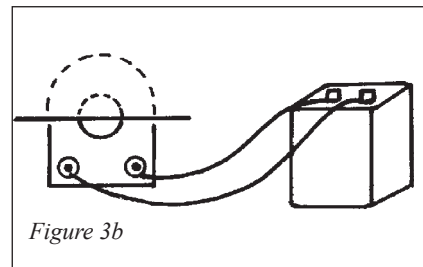
- To outline the magnetic field generated by the current flow.

Procedure:

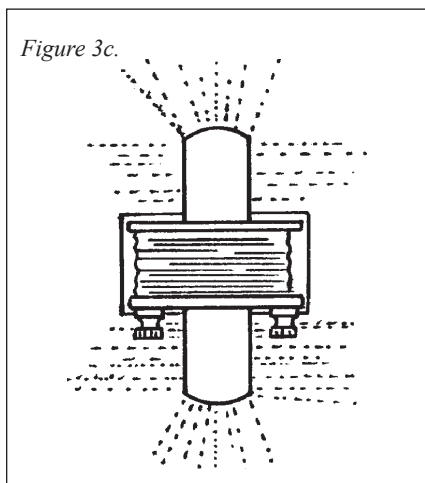
1. **Place a half round bar through one coil flat side up.** Place the plastic card over the coil and rest it against the half round iron bar. Lay the second half round bar on top of the plastic card and slide it through the coil center. This secures the coil. *Figure 3a.*



2. **Sprinkle iron filings on the plastic card.** For best results, scatter the filings over the entire card.
3. **Connect the coil to the battery terminals** (see *Figure 3b*) using two of the clip leads.



4. Tap the card lightly. **Observe the pattern which the filings create** (See *Figure 3c*, below.)



Note that lines of magnetic flux never intersect each other!

More Experiments Illustrating Magnetic Lines of Force

1. Repeat above procedure with **both coils close together** and current flow in the **same direction** - and then in **opposite directions**.
2. Repeat above procedure **without using the iron core**. How does the pattern differ from your results in the original experiment? Why?

Experiment 4 Electromagnetism

Materials Needed:

- Two coils
- U-shaped core
- Battery
- Three (3) clip leads
- Flat core
- Magnet or compass
- Two (2) hex nuts (included)

Objective:

- To create an electromagnet and test its lifting power

Procedure:

1. **Place the two coils on each end of the "U"-shaped core** as shown in *Figure 4*, below. *[Note: Coil terminals face opposite directions.]*
Secure coils to each end of the U-shaped core by screwing on two hex-shaped nuts provided.
2. **Complete the series** by connecting one terminal of each coil to a battery and the two remaining terminals to each other using 3 clip leads. See *Figure 4*.
3. **Test the lifting power of the magnet** by grasping the U-shaped core and trying to lift the flat core. *[Note: The coils may move around on the U-shaped cores as you lift it. Their position is irrelevant. Our demonstration only shows that the core becomes magnetized.]*
4. Use a compass or magnet to test the

polarity in each core end.

5. Remove either coil and **reverse the direction of the current**. (That is, return the coil to the U-shaped core now facing the same direction as the other coil.) Test the lifting power as before.
6. Which magnet was stronger? Why?

How To Teach With Electromagnet Kit

Concepts Taught: Solenoid; Ampere's Rule; Electromagnetic attraction and repulsion; Magnetic permeability; Electromagnetic polarity; Flux density; Mutual inductance (transformer effect); Induced current and induced magnetic field.

Curriculum Fit: PS/ Electricity and Magnetism. *Unit: Moving Charge and Magnets* **Grades 9-10**

Related Products

The following products can be ordered from your distributor; or, if unavailable, from manufacturer Science First.

- **615-0300 Lifting Magnet -**
Weights two pounds, lifts two hundred pounds. Striking display of electromagnetic power. Precision machined magnet with alligator clip leads and battery holder, instructions. *Needs 1 1/2 volt D cell battery.*
- **615-4650 Primary Secondary Coil -**
Excellent for electromagnetic induction and transformer effects. Contains two coils, both with binding posts and plastic mounts. Soft iron keeper and instructions included. *Needs voltmeter.*
- **615-4685 Toy Motor Kit**
Construct a working DC motor at a price your entire class can afford. All parts provided, including two coils copper wire; base; field pole; armature core; brushes; all fasteners, battery clips, instructions. *Needs AA battery.*

