

Introduction

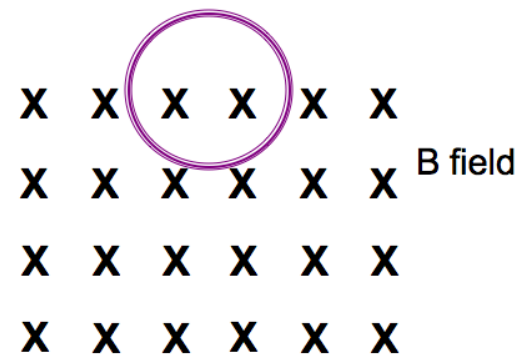
Electricity in circuits can produce light, heat, sound, and magnetic effects. Magnets attract and repel each other and certain kinds of other materials. Electricity and magnetism are two aspects of a single electromagnetic force. The applications of how energy can be converted via electricity and magnetism have greatly affected our daily lives. We are going to explore two of the main applications of electricity and magnetism with the simple motor and the generator.

To understand how motors and generators work, you will need to review much of what you have learned this quarter in 1B. In particular, you will need to be familiar with current (sections 17.1-17.4), magnetic fields (sections 19.3-19.4), torque (section 19.5), and electromagnetic induction (sections 20.1-20.4). Please review those sections of the text (along with section 20.5) before coming to class to be prepared for the lab and the reading quiz.

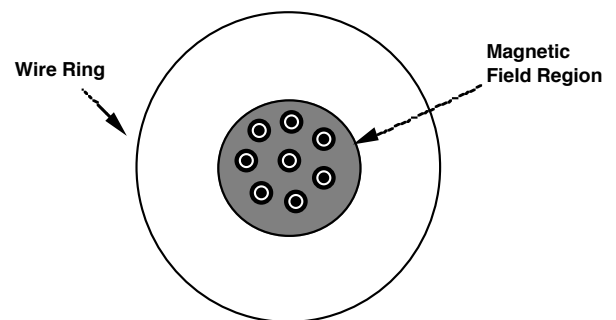
CAUTION: the magnets used in this lab are very strong (about 500 times the earth's magnetic field). The strongest fields are concentrated between the magnets' poles. Keep your credit cards etc. more than 3 feet away from the magnets. Do not place ferromagnetic materials near the magnets. If you have a heart pace maker, you should **NOT** do this lab, but see your TA for advice. There is otherwise no danger associated with strong magnetic fields.

Pre-lab Questions:

1. A circular loop of wire is positioned half in and half out of a square region of constant uniform magnetic field directed into the page, as shown to the right. State at least three things you can physically do to this wire or the magnetic field to induce a counterclockwise current in this loop (Hint: What does electromagnetic induction depend on?).



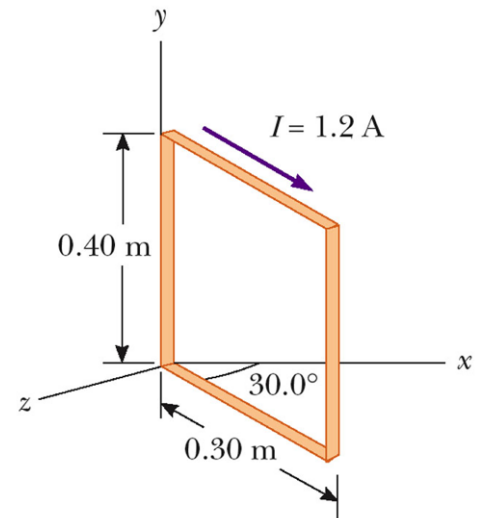
2. A uniform magnetic field is confined to a cylindrical volume of radius 8 cm, as shown to the right. The field is directed out the plane of the paper and is increasing at a constant rate of $\Delta B/\Delta t = 0.22 \text{ T/sec}$. Calculate the magnitude and direction of the current induced in a circular ring of radius 16 cm and resistance 3.7Ω that encircles the magnetic field region.



3. Write "I checked my grades online". (Please, actually check them on webct.ucsd.edu. And if you have some problems then it would be better to solve them with your TAs during the last lab instead of emailing them during finals week.)

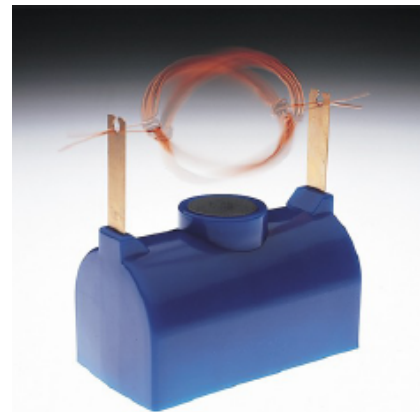
Group Activity:

A rectangular loop consists of 100 closely wrapped turns and has dimensions 0.40 m by 0.30 m. The loop is hinged along the y -axis, and the plane of the coil makes an angle of 30.0° with the x -axis (as shown in the figure to the right). What is the magnitude of the torque exerted on the loop by a uniform magnetic field of 0.80 Teslas directed along the x -axis when the current in the windings has a value of 1.2 A in the direction shown in the figure. What is the expected direction of rotation?

**Experiment A: The World's Simplest Motor**

In this experiment you will be exploring different aspects of how a simple motor works. The equipment consists of a coil of wire, a permanent magnet, a battery, and a plastic housing with two metal contacts.

- A1.** Assemble the equipment into the motor as shown in the figure to the right. If you are unable to do this, ask the TA for help or equipment. Verify the coil is able to spin properly before continuing to the next part.
- A2.** Remove the coil of wire from the motor (so that it is no longer spinning).
 - Use the compasses to find the direction of the magnetic field due to the permanent magnet at the place where the coil used to be.
 - Is the magnetic field uniform (in terms of direction) at this location? If so, what is the direction of the magnetic field? (Up? Down? Horizontally left? Horizontally right? At some angle?) If the magnetic field is not uniform at the location of the coil, sketch the direction of the magnetic field due to the permanent magnet in your lab notebook.
 - Next, flip the magnet. Check to see how the magnetic field has changed due to this flipping.
- A3.** Put the coil of wire back where it belongs in the setup, but now remove the permanent magnet from the setup and place it off to the side (so that the coil of wire is no longer spinning).
 - Make sure the wire loop is horizontally flat. Use the compasses to find the direction of the magnetic field inside the coil of wire.
 - Is the magnetic field uniform (in terms of direction) at this location? If so, what is the direction of the magnetic field? (Up? Down? Horizontally left? Horizontally right? At some angle?) If the magnetic field is not uniform at the location of the coil, sketch the direction of the magnetic field due to the permanent magnet in your lab notebook.
 - Slowly turn the coil and see how the magnetic field due to this coil of wire changes (in terms of direction). Does the magnetic field due to the coil always have the same orientation with respect to the coil? Is there an orientation where the magnetic field disappears?



- A4.** Properly reassemble the motor so that it spins again (as in **A1**).
- Note the direction of the spinning coil of wire. Will the direction of spinning change if you were to remove the wire and reinsert the coil flipped (such that each wire touches a different contact with the apparatus)? Will the direction of spinning change if you flip the permanent magnet? Perform both of these experiments to verify your predictions.
 - Estimate the angular velocity of the loop in units of revolutions per second. Next, convert that angular velocity to radians per second.
 - Can you think of any ways to increase this angular velocity? Attempt one of these methods and see if you can increase the angular velocity of the coil. If you are successful show your TA how you accomplished this.
 - The permanent magnet creates a torque on the wire loop to create this angular velocity. In what orientation does the wire loop have the maximum torque on it? How are the orientations of the magnetic field due to the permanent magnet and the magnetic field due to coil related when you are maximum torque?
 - Is there ever an orientation of the wire loop that will have zero torque due to the permanent magnet? If so, why doesn't the wire loop just stop at this location?
- A5.** Converting energy between different forms is very useful for our daily lives. A motor is an excellent example of this.
- Where is the energy coming from to rotate this coil of wire?
 - Did the permanent magnet have to be present for the coil to rotate?

Experiment B: The Generator

In this section we will explore how you turn mechanical energy in electrical energy. In the middle table there should be a large device labeled "Motor/Generator."

- B1.** The TA will demonstrate this device for you in the generator mode by spinning it, which creates current that lights a small light bulb.
- If you initially spin the generator faster, will it lead to a brighter bulb? Or is the brightness of the light bulb not dependent on how fast the coils are spinning?
 - Was the light bulb continuously on during this process? Or did it have periods that it would rapidly flash on and off?
 - How does this compare to the simple motor in Experiment A in terms of which energy systems are involved? What is gaining energy and what is losing energy?

- B2.** Next to the Motor/Generator there should be a device called a Hand Crank Generator that has a large light bulb attached.

- Try to light the large light bulb by turning the crank. How hard is it to turn that crank at a reasonable speed?
- Next, remove the light bulb. Now try to turn the crank at the same speed that you used to light the large light bulb. Was it easier to turn without the light bulb attached?
- How does this compare to part B1 in terms of which energy systems are involved? What is gaining energy and what is losing energy? Do the magnets need to be present in this Hand Crank Generator in order for it to light the bulb?

