Lab 3 – Electric Motors & Generators

Part 1: Applications of Torque on a Magnetic Dipole

We have already seen that a magnetic dipole (e.g. a compass) will experience a torque that tends to line the dipole up with an external magnetic field. Here we consider two applications of that.

1) Galvanometer

Place the cylindrical magnet attached to the white plastic axle above the large wooden framed coil of wire. The magnet is suspended so that it is free to swing above the coil. 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. Attach the coil to the DC power supply.

DC Power Supply: With the power supply OFF, set it up as follows

- Readout switch should be set to read AMPS
- The voltage dials should be turned all the way to maximum (CLOCKWISE).
- The current dials should be turned all the way to minimum (COUNTER-CLOCKWISE)
- **<u>The High/Low button should be OUT in the HIGH setting.</u>**

When there is no current through the coil, the magnet is horizontal and the pointer is vertical.

a) Predict the deflection of the pointer (if any) when the power supply is turned on.

b) Turn on the power supply and slowly increase the current using the "**<u>FINE</u>**" current dial. How does your prediction compare to your observations?

c) What happens to the pivot as the current through the coil is varied?

d) With the current at some setting, would you say the magnet is lined up with the coil's magnetic field? If so, why does the pivot move when the current is varied? If not, why not?

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

2) Electric Motor

A small coil of wire is suspended above a magnet by two copper bars resting on support posts. One of the copper bars has a non-conductive coating on half of its surface. On one side of the plastic spool of the coil is an arrow. This arrow shows the direction current will flow around the coil when it comes in that side's copper bar.

DC Power Supply : With the power supply OFF, set it up as follows

- Disconnect all wires from power supply, then turn supply ON
- Turn current dials all the way CLOCKWISE to maximum.
- **<u>The HIGH/Low button should be OUT in the HIGH position</u>**
- Move digital readout switch to "Volts" and adjust voltage to 3.5 V.
- **<u>Do NOT adjust voltage dial after this point.</u>**
- Move the digital readout switch to "Amps"
- Turn power supply OFF.

Using the wires and alligator clips, attach the positive terminal (RED) of the power supply to the bottom of the support post on the arrow side of the coil. Attach the negative terminal (BLACK) to the bottom of the other support post.

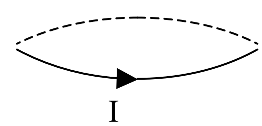
Warning: Do NOT hold the coil fixed in one place with the power supply ON and current flowing for more than 2-3 seconds or you could damage the power supply.

Turn the supply OFF when not experimenting with the coil.

a) Predict what orientations of the coil (during one complete revolution) will allow a current to flow through it when the power supply is on. Sketches may be helpful.

b) Check your prediction by turning on the supply and rotating the coil manually through one complete revolution. How does your prediction compare to your observations?

c) During the time that there is a current through the coil, draw the magnetic field due to the coil. Indicate which side will act like a north pole and which side will act like a south pole?



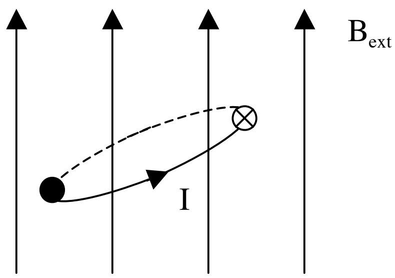
<u>The magnet glued to the base provides an external magnetic field that points vertically upwards.</u>

d) Now allow the coil to move freely, predict how the coil will behave when the power supply is turned on.

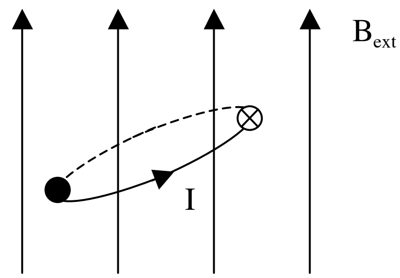
e) Check your prediction by turning on the supply. Note: If the coil does not begin to spin, gently rotate the coil to start it spinning. How does your prediction compare to your observations?

When current is flowing through the coil, the direction of the torque can be thought of in two ways. Either as the result of the forces on current carrying wires, or as a magnetic dipole moment trying to line up with an external field (e.g. like a compass). Note: the magnetic moment of a coil points in the direction of the coil's magnetic field at the center of the coil.

f) For the orientation of the coil below, show these two ideas give the same direction of torque. (Note: You are looking down the axis of the copper bars)



Forces



Magnetic Moment

g) During the portions of the cycle that there is a current through the coil, the current results in a magnetic moment that interacts with the external magnetic field. Will the resulting torque tend to increase or decrease the angular speed of the coil? Explain.

h) During the portions of the cycle that there is no current through the coil will the angular speed of the coil tend to increase, decrease or stay the same? Explain.

i) Summarize g) and h) with sketches showing the orientation and magnetic moment of the coil as it rotates (e.g. CLOCKWISE). Start with the first position where current flows through the coil. Include a couple intermediate positions, in particular the position when the current stops flowing. Be sure to show ONE COMPLETE REVOLUTION.

j) Manually start the coil spinning so that it rotates in the opposite direction. During the portions of the cycle that there is a current through the coil, the current results in a magnetic moment that interacts with the external magnetic field. Will the resulting torque tend to increase or decrease the angular speed of the coil? Explain.

k) How would the motor behave if both copper bars on the coil were completely bare? Explain.

l) What effect will reversing the wires to the power supply have on the motor? Explain. Try it.

m) **(Do NOT try this, the magnet is GLUED in place)** What effect would reversing the orientation of the magnet have on the motor? Explain.

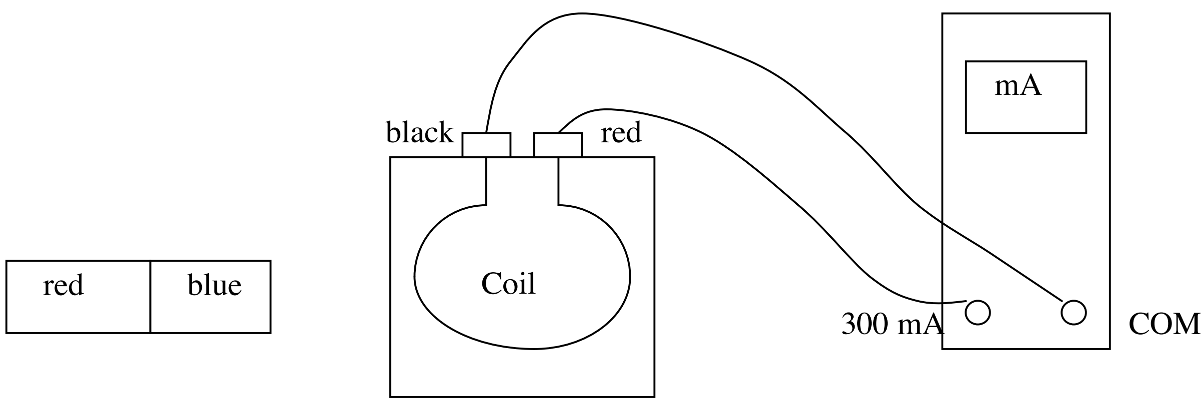
The device above is a form of electric motor. By using stronger magnets or larger currents, it is possible to make motors that can drive machines and perform various tasks. In some motors, the coils are held stationary and the magnet spins.

Part 2: Electromagnetic Induction

1) Faraday's and Lenz's Laws

   Connect the large wooden framed coil to the multimeter (set to read mA in ammeter mode) as shown. Only one turn of the coil is shown, but that is sufficient to tell which way the coil is wrapped. Attached as shown, a positive reading on the ammeter means current came out of the coil's red plug, i.e. current was COUNTER-CLOCKWISE around the coil.

   Hold the bar magnet outside the coil with the BLUE end facing the coil as shown.



   a) Move the magnet into the coil. Is there a current induced in the coil

      - As the magnet is held stationary outside the coil?
      - As the magnet is moving into the coil?
      - As the magnet is held stationary inside the coil?

   b) For the period of time that there is a current induced through the coil, find the direction (CW or CCW) of the current in the coil?

c) Move the magnet out of the coil. Is there a current induced in the coil

- As the magnet is held stationary inside the coil?
- As the magnet is moving out of the coil?
- As the magnet is held stationary outside the coil?

d) For the period of time that there is a current induced in the coil, find the direction (CW or CCW) of the current in the coil?

e) Very slowly move the magnet into the coil. For the period of time that there is a current induced in the coil, how does the amplitude of the current compare to when you moved it quickly in part a)?

f) Very slowly move the magnet out of the coil. For the period of time that there is a current induced in the coil, how does the amplitude of the current compare to when you moved it quickly in part c)?

g) Turn the magnet 90°, so the center of the magnet is over the opening of the coil. (The magnet won't fit IN the coil, but can still be moved TOWARD the coil) Move the magnet toward and away of the coil. For the period of time that there is a current induced in the coil, how does the amplitude of the current compare to when you moved the end of the magnet toward the coil?

h) If you positioned the magnet with the RED end facing into the coil, how would your answers to the questions above differ?

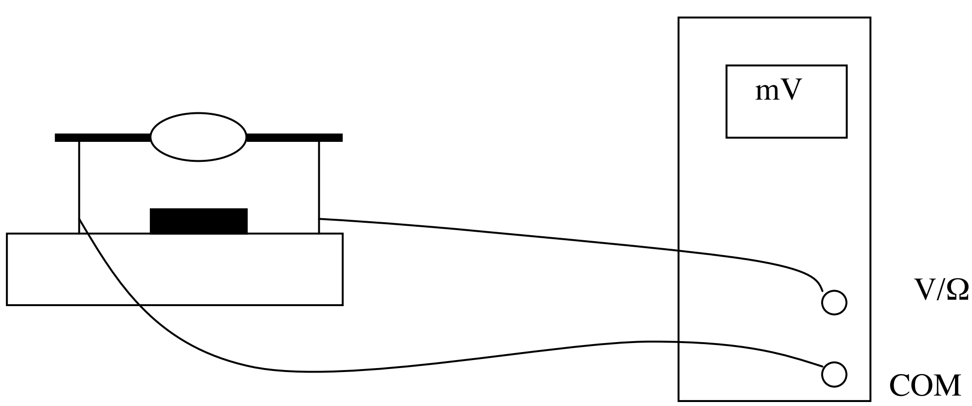
i) Based on your answers and on the winding of the coil, determine which end of the magnet is a north pole?

j) Suppose that the coil were replaced with a wooden loop. Would there still be an emf in the loop? Would there still be a current induced in the loop?

These results are consistent with the idea that a change in the magnetic flux through the surface of a loop results in an emf in that loop. If there is a conducting path around the loop, i.e. a wire, there will be a current. The emf is independent of the material of which the loop is made; the current is not. It is found by experiment that the induced emf is proportional to the rate of change of the magnetic flux through the loop. This relationship is called Faraday's Law. The direction of any induced current is given by Lenz's law.

2) Electric Generator

Attach the small coil of wire suspended above the magnet to the multimeter (set to read mV in voltmeter mode).



Suppose the coil were made to rotate by some external agent (e.g. YOU)

a) Predict the variation in voltage for a complete revolution of the coil.

b) Check your prediction by gently rotating the coil so that it spins for a little time on its own before coming to a stop. How does your prediction compare to your observations?

NOTE: the multimeters used in this lab can't display quickly changing voltages, so instead they display an "average" value. Make sure you understand how the voltage is really varying. Ask your GSI if you are still unsure. You will see be able to see rapidly changing voltages in the next lab using oscilloscopes.

c) Predict the variation in voltage if the coil were made to rotate the other way.

d) Check your prediction. How does your prediction compare to your observations?

When the coil of the apparatus above is made to spin by an external agent, the apparatus is called an electric generator, i.e. mechanical energy is converted into electrical energy. AC (alternating current) generators transfer energy for electrical transmission to supply electricity to our homes and offices. In commercial power plants, the energy required to rotate the loop can be derived from a variety of sources such as water in a hydroelectric plant, or burning coal in a coal-fired plant.