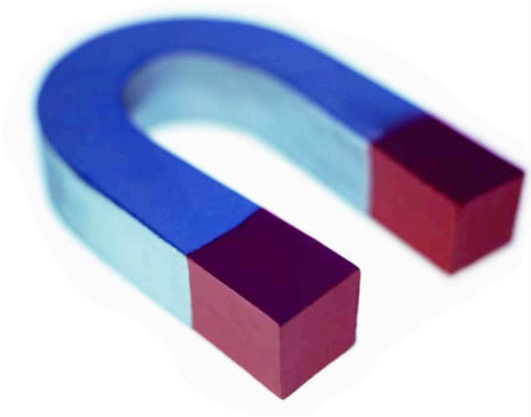
The Simple DC Motor



Prelab

LR Write experiment title, your name and student number at top of the page.

LR **Prelab 1:** Write the objective of this experiment.

LR **Prelab 2:** Write the relevant theory of this experiment.

LR **Prelab 3:** List the apparatus and sketch the setup.

! Have these ready to be checked by lab staff at the door on the day of your lab.

Introduction

In this experiment you will investigate the necessary principles used in a simple DC motor. Using these principles, we will take a very simplistic approach to construct a working motor.

Once constructed, use its properties to determine the direction of the magnetic moment vector for a current carrying loop, determine the orientation of an unknown magnet, and determine the direction of torque on a current carrying loop in a magnetic field.

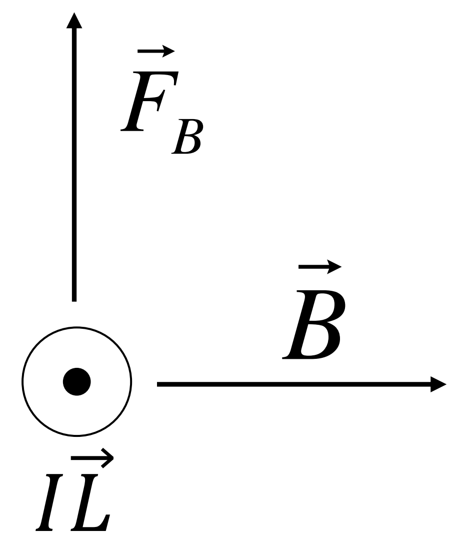
Introduction

A current carrying wire in a magnetic field will experience a force perpendicular to both the field and the current. For example, a wire carrying **current** I out of the page placed in a **magnetic field** $\vec{B}$ to the right will experience a **force** $\vec{F}$ directed up as shown.

The magnetic force is given by:

$$\overrightarrow{F_B} = I\vec{L}\times\vec{B}$$

Use the right-hand rule for cross products to determine the direction of the magnetic force. It should be noted that the current I is not a vector, but instead the length $\vec{L}$; $I\vec{L}$ (directed out of the page in the figure) is taken to be the length in the direction of current, and should have a direction associated.



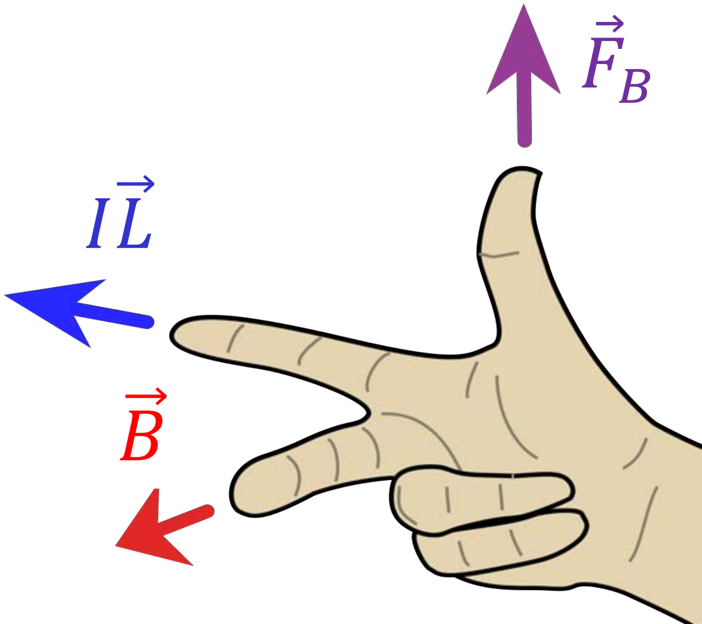
Right Hand Rule

You may find the direction of the force by applying the right hand rule:

- Point your index finger in the direction of the first vector ($I\vec{L}$ in this case).
- Point your second finger (90º) towards the second vector ($\vec{B}$). You may have to twist your wrist.
- Your thumb indicates the direction of the resultant vector ($\vec{F}_B$).

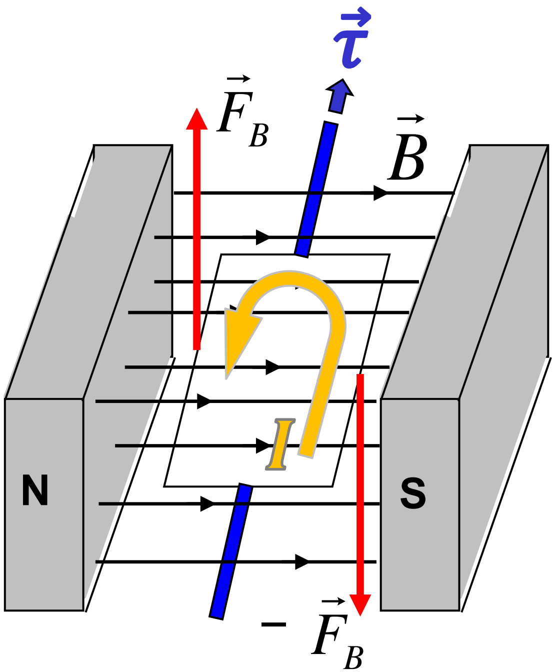
If the current and magnetic field are parallel, the force is zero!

This method applies to **all cross products**.



Introduction

The right hand rule may be applied to each segment of a loop to determine the force on each segment.



The image at right is a simple DC motor.

The two magnetic forces $\vec{F}_B$ and $-\vec{F}_B$ produce a torque on the loop, tending to rotate it about its central axis. The other two sides of the loop do not experience a force since the current and magnetic field are parallel.

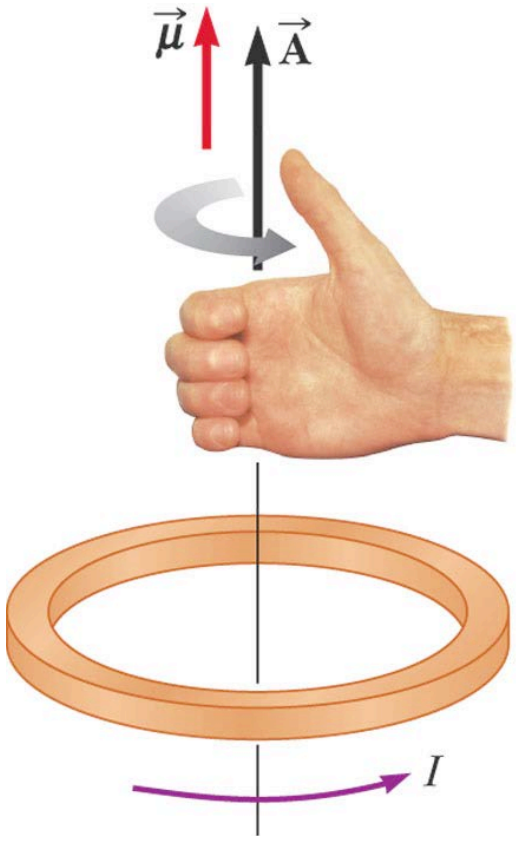
The force vectors may be added to determine the net force.

Magnetic Dipole Moment

A current carrying coil has a **magnetic dipole moment** $\vec{\mu}$. This vector points in the direction normal to the plane of the coil and has magnitude $\vec{\mu} = NIA$ where N is **number of turns**, I is **current**, and A is the coil **area**.

The figure at right shows a right-hand rule for finding the direction of $\vec{\mu}$:

Point or curl the fingers of your right hand in the direction of current at any point on the loop. Your extended thumb then points in the direction of the magnetic dipole moment.



Introduction

A current carrying coil experiences a torque that is related to both the magnitude and direction of the $\vec{\mu}$ and $\vec{B}$ vectors. This vector relation is written as

$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

Torque direction may be found in one of two ways:

1. If you know the directions of μ and B, you may use the right hand rule. Point your fingers in the direction of μ. Bend your fingers towards B. Your thumb indicates the direction of torque.
   If μ and B are parallel, the torque is zero!
2. If you know the direction of rotation, curl your fingers in the directions of rotation. Your thumb points towards torque.

This torque is the basis for the operation of a DC motor.

Apparatus and Setup

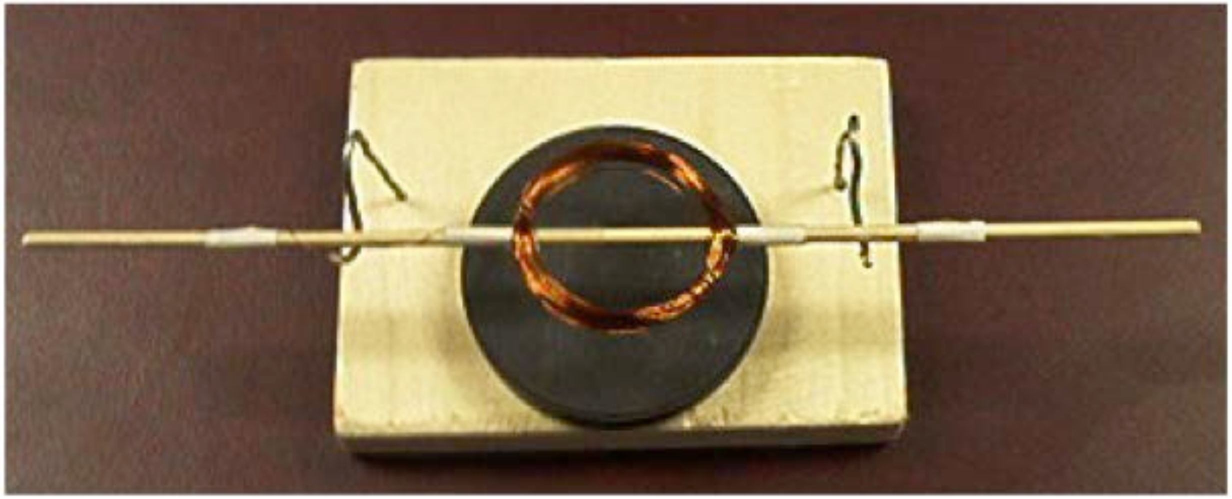
You have been provided with the following:

- Wooden base
- DC power supply
- Wires and connectors
- 2 Magnets
- Wooden stick
- Length of insulated copper wire
- Wire stands
- Sandpaper
- 200 g mass

Apparatus and Setup

To build the motor successfully, the coil must be balanced and attached to the wooden stick so they can rotate smoothly on the wire stands. There are many elements required to build the motor and for it to operate successfully.

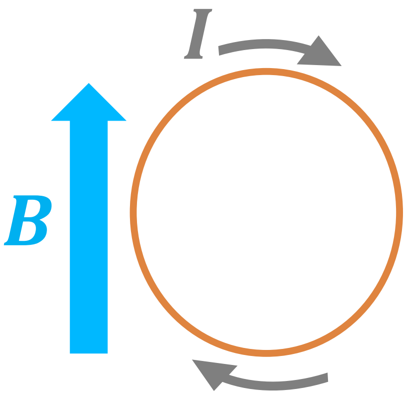
Pay close attention to the structural details, as well as the physics necessary to produce a torque.



Understanding the Apparatus

The magnetic field produced by the magnets in this setup is either pointing up, towards the coil, or down towards the benchtop. To build your DC motor properly will take careful thought and attention to details.

Lab Report 1:
Given the figure at right, indicate the direction of the magnetic force on top and bottom of the loop.



Lab Report 2: Based on the figure, in which direction is the magnetic moment $\vec{\mu}$? Which direction is the torque? Use a sketch as part of your explanation.

Lab Report 3: While the coil rotates, should you have current running through the coil at all times, or only when oriented in a particular arrangement? Explain.

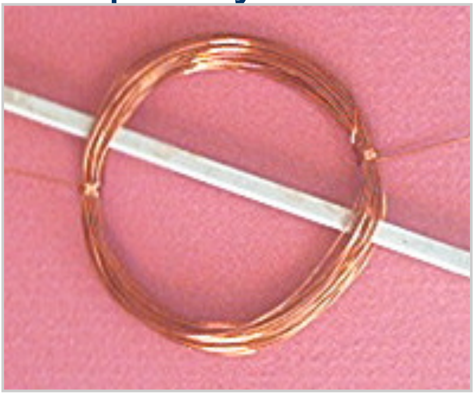
Apparatus and Setup

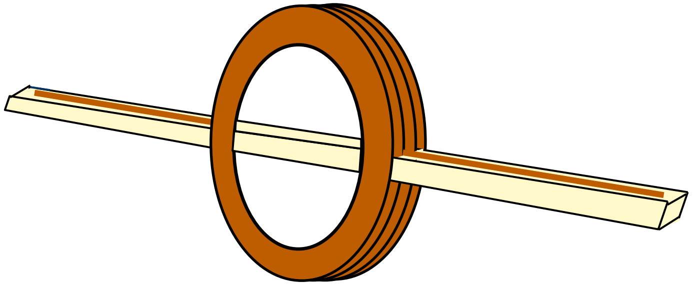
Begin assembling your coil. You may use the 200g mass as a base to keep your coil round.

To obtain a sufficient magnetic moment vector, it is recommended that you have a **minimum of 15 turns** in your coil.

Apparatus and Setup

You have been given a small wooden stick which may be used to hold the loops. Be sure the loop is symmetric on the stick.





When securing the ends of the coil to the stick, think carefully about the current flow and orientation of the coil in the magnetic field: Where must the wires be secured to ensure current will flow in the correct orientation?

Apparatus and Setup

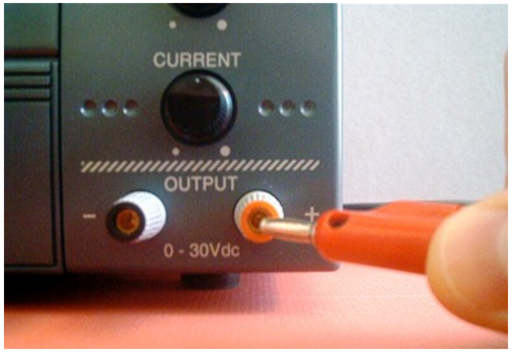
The thin copper wire provided has a very thin enamel coating that prevents it from short circuiting (current unintentionally flowing between coils). Part of producing enough torque to rotate the coil as desired means there needs to be a number of coils.

You have been given a **piece of sandpaper to remove the coating**. Once the enamel insulation is **removed where the coil leads contact the bent wire stands**, it should be able to flow current. The copper wire is bright and shiny in colour, underneath the enamel coating.

Current **will only flow** from the wire stands to the coil if this coating has been removed at the point of contact.

Apparatus and Setup

Use the power supply, leads, and alligator clips to connect a circuit with your DC motor.



Adjust current and voltage knobs so that $\sim 12V$ is applied to the motor. You will likely need to adjust the voltage, once you test your motor.

Carefully check that your motor will flow current by gently turning the coil to spin. If no current flows when coil leads touch wire stands, check that coating is removed at point of contact.

Experiment and Troubleshoot

You will need to give the loop a nudge with your finger to get it spinning. The motor should rotate smooth and even. If there are sparks, you may decrease the voltage a little. *These sparks will not hurt you*.

!

DO NOT run your motor for more than **a minute continuously**.
The coil can get very HOT!

CP

Before proceeding, have an instructor see your running motor and sign your lab report.

LR

Lab Report 4: Based on the direction of current and rotation of your motor, determine which pole of your magnet is facing up. Explain your answer. Provide a sketch and indicate these directions.

CP

Before proceeding, have an instructor check your answer with a labelled bar magnet to confirm.

Analysis

LR **Lab Report 5:** What would happen to your motor if you switch the direction of the current? Why? Test your prediction and confirm.

LR **Lab Report 6:** What would happen to your motor if you increase the current? Why? Test your prediction and confirm.

Think about the orientation of your coil relative to the magnet. In particular, consider the moment when the current is flowing through the coil.

Summary & Conclusion

LR **Lab Report 7**: Briefly summarize your experiment, in a paragraph or two, and include any experimental results.

LR **Lab Report 8**: Are there any sources of experimental uncertainty and classify them as random or systematic. Explain

! **Include your prelab, printed data, and all analysis with your report.**