MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics

8.02 **Spring 2005**

Experiment 6: Magnetic Force on Current-Carrying Wires

OBJECTIVES

1. To predict and verify the nature of the magnetic force acting on a current-carrying wire when the wire is placed in a magnetic field.

INTRODUCTION

The force on a segment $d\vec{\mathbf{s}}$ of a wire carrying current I in a magnetic field $\vec{\mathbf{B}}_{\text{ext}}$ is given by

$$d\vec{\mathbf{F}} = I d\vec{\mathbf{s}} \times \vec{\mathbf{B}}_{\text{ext}} \tag{6.1}$$

where $\vec{\mathbf{B}}_{\text{ext}}$ is the magnetic field produced by an external source somewhere else (*not* the magnetic field caused by the wire segment itself). By performing the necessary integral, which will be a different integral for different situations, you can in principle find the magnetic force on any extended current-carrying wire sitting in any external magnetic field $\vec{\mathbf{B}}_{\text{ext}}$. For a more detailed discussion of the forces on current-carrying wires of different configurations, see the *8.02 Course Notes*, **Section 8.3**.

For the first part of this experiment you need to know the magnetic field due to a permanent magnet. The field lines from this magnet are similar to those you found in the previous experiment, where the field lines due a bar magnet were mapped. For the purposes of making **Predictions 1-5** below, you may assume that the field lines of the rare-earth magnet are similar to those shown for a tightly-wound solenoid, as presented in the *8.02 Course Notes*, **Section 9.4**, and Figure 9.4.1, reproduced here:

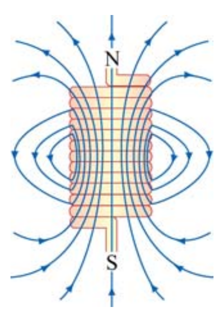

Figure 1 Magnetic Field lines due to a tightly-wound coil.

PREDICTIONS

For this experiment, you are asked to make several predictions regarding the direction of the force on a current-carrying in the field of a permanent magnet. Then, you will be asked to confirm your predictions.

(*Please reproduce your predictions, either words or figures, on the tear-sheet at the end of these instructions*.)

A. Magnetic Force on a Straight Wire

Prediction 1 (*answer on your tear-sheet at the end*): Suppose the rare-earth magnet in your experimental setup has its North magnetic pole on top. If a wire is located above the magnet as shown in the figure, with the current in the wire moving from left to right, predict the direction of the force on the wire, and draw it on Figure 2 and on the tear-sheet.

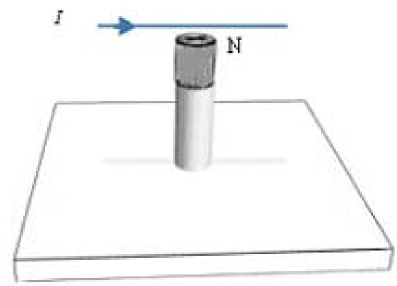

Figure 2 A wire located above the magnet.

Prediction 2 (*answer on your tear-sheet at the end*): Suppose you now place the wire *in front* of the magnet in its midplane, as shown in the figure, with the current in the wire again running from left to right. Now predict the direction of the force on the wire, and draw it on Figure 3 and on the tear-sheet.

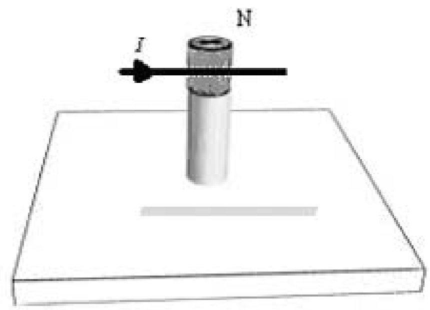

Figure 3 A wire in front of the magnet.

Prediction 3 (*answer on your tear-sheet at the end*): Suppose you place the wire *behind* the magnet in its mid-plane, with the current in the wire again running from left to right. Now what is the direction of the force on the wire? Is it into the page or out of the page?

B. Magnetic Force on a Coil of Wire

Prediction 4 (*answer on your tear-sheet at the end*): Suppose you now place a circular coil carrying current above the magnet and coaxial with it, see Figure 4(a), with the current in the coil running so that current moves *counterclockwise* as seen from above. Will the coil of wire be attracted to or repelled by the permanent magnet, or will it feel no force at all; that is, will the force on the coil be upwards, downwards, or zero? (Remember, the North pole of the magnet is assumed to be on the top.)

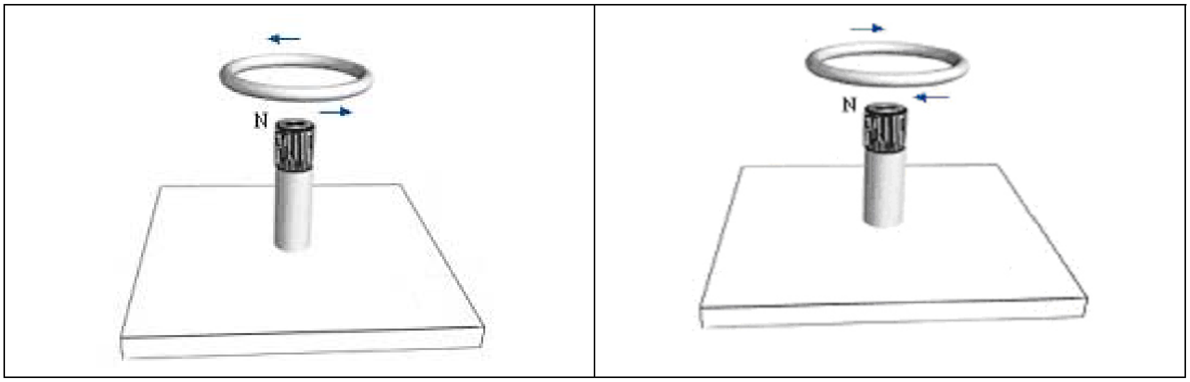

Figure 4 A circular coil placed above the magnet with current running (a) counterclockwise, and (b) clockwise, as seen from the top.

Prediction 5 (*answer on your tear-sheet at the end*): Suppose that the current in the coil runs so that current moves *clockwise* as seen from the top, see Figure 4(b). Will the coil of wire be attracted or repelled by the permanent magnet, or will it feel no force at all?

PROCEDURE

The source of the external field $\vec{\mathbf{B}}_{ext}$ will be a strong "Rare-Earth" magnet and the current in the wires will be provided by two 1.5-volt batteries.

THE RARE EARTH MAGNET IS EXTREMELY STRONG, STRONG ENOUGH TO WIPE YOUR CREDIT CARDS, STOP YOUR WATCH, OR DO SERIOUS DAMAGE TO YOUR COMPUTER, IF IT COMES CLOSE ENOUGH TO ANY OF THESE.

DO NOT REMOVE THE MAGNET FROM ITS PROTECTIVE PLASTIC CASE!

You will use the AC/DC Electronics Board to mount two 1.5-volt batteries, which will provide the current for the wires. You will use a piece of wire about 60 cm (2 ft) in length and a coil of wire with 22 turns (different coils might have a different number of turns). You will compare your above predictions by finding the directions of the forces you find acting on the wires (**Predictions 1-5**) in the various configurations.

EXPERIMENT

Direction of the Forces

Perform the five experiments needed to verify **Predictions 1-5** above, using the only batteries, your length of wire, and coil of wire to see if reality agrees with your predictions. Use leads to and from the "switch" on the AC/DC board, indicated by the red button. This will allow you to make the connections without having the current run until you're ready to find the force direction. ***Since we are directly shorting out the***

batteries to get a high current, it is important that you USE THE SWITCH TO PULSE THE SYSTEM MOMENTARILY so that our batteries don't run down rapidly.

In looking for the force on a small piece of wire, bend your long wire into a long U shape so that there is plenty of length of wire to allow movement of the wire due to the magnetic force. You should be able to hold the leads (the alligator clips) to the wires on the board with the magnet, in such a way that a portion of the wire is near but not touching the plastic casing. This way, you'll be able to see the wire deflect and so determine the direction of the force.

For the coil, the direction of the force is much easier to determine. In fact, with the proper direction of the current and position of the wire, you might even be able to get the coil to almost levitate (stable levitation is known to be impossible when only magnetic forces and gravity are acting).

Question 1 (*answer on your tear-sheet at the end*): If any of your Predictions 1-5 were incorrect, briefly explain why.

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Tear off this page and turn it in at the end of class.

Note:
Writing in the name of a student who is not present is a Committee on Discipline offense.

Experiment Summary 6: Magnetic Force on Current-Carrying Wires

Group and Section ___________________________ **(e.g. 10A, L02: Please Fill Out)**

Names ___________________________________

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A. Magnetic Force on a Straight Wire

Prediction 1: With the current in the wire moving from left to right, predict the direction of the force on the wire, and draw it on Figure 2 _________________________

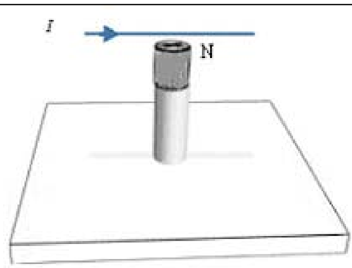


Figure 2 A wire placed above a magnet

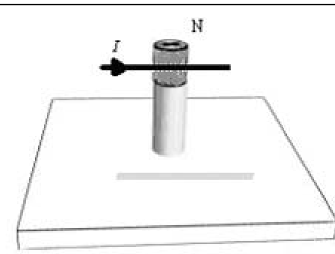


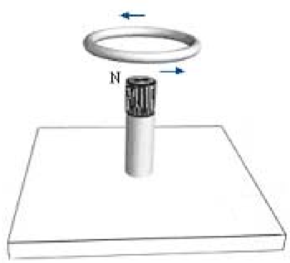
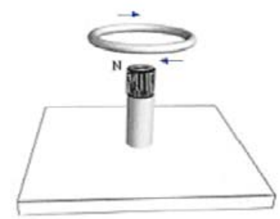
Figure 3 A wire placed in front of a magnet

Prediction 2: Now place the wire *in front* of the magnet in its midplane, with the current in the wire again running from left to right. Now predict the direction of the force on the wire, and draw it on Figure 4 ________________________________

Prediction 3: Suppose you place the wire *behind* the magnet in its mid-plane, with the current in the wire again running from left to right. Now what is the direction of the force on the wire, that is, is it into or out of the page? ____________________

B. Magnetic Force on a Coil of Wire

Prediction 4: You now place a coil above the magnet, with the current in the coil running *counterclockwise* as seen from above. Will the coil be attracted to or repelled by the permanent magnet, or will it feel no force at all? ___________________________

	**Figures 5** Circular coils placed above the magnet	

Prediction 5: The current in the ring now runs *clockwise* as seen from the top. Will the coil of wire be attracted or repelled by the permanent magnet, or will it feel no force?

Question 1: Now do the actual measurements. If any of your predictions were incorrect, briefly explain why.