Lab 8: Magnetic Dipoles

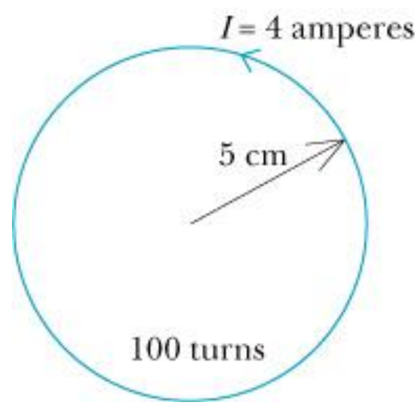
OBJECTIVES

In this lab you will
- Measure the magnetic field of a circular loop of wire and a bar magnet
- Map the magnetic field vectors in the space surrounding the loop and magnet
- Calculate the distance dependence of both the loop and the bar magnet
- Calculate the dipole moment in both the loop and the bar magnet

In lecture you've learned about the magnetic field created by a current loop and about the magnetic field created by a bar magnet. They may seem to be different phenomena, however, after comparing their magnetic field patterns, and distance dependences, you will see that they are in fact very similar. You will then compare these two objects by calculating their dipole moments.

1) Warm-Up Problem:

Problem (1) A thin circular coil of wire of radius 5 cm consists of 100 turns of wire, as shown. If the conventional current in the wire is 4 amperes, and runs in the counter clockwise direction, what are the magnitude and direction of the magnetic field at the center of the coil?



CHECKPOINT 1: Ask an instructor to check your work for credit.
You may proceed while you wait to be checked off

2) The Patterns of Magnetic Field and Measurements

a) **Get out the following items for this lab:**
   - **1 battery with holder**
   - **2 alligator clips**
   - **1 long wire**
   - **1 bar magnet**
   - **1 ruler or meter stick**
   - **1 compass**

b) Put away everything else (except your lab manual), so your table is neat and clear.

c) Take the long insulated wire and wrap a coil of about 20 turns loosely around two fingers. Twist the ends around the coil to hold it together, and remove the coil from your fingers.

d) Attach clip leads so you can connect the coil to one battery but do not make the final connection yet.

You will now take a total of twelve measurements, six for the loop and six for the bar magnet. Before taking each measurement, make sure your compass is aligned with north. When aligning your compass make sure all metallic objects are away from it and **KEEP YOU BAR MAGNET FAR AWAY**.

We will walk you through your first measurement, which will determine d, the distance you will use in all the following measurements. You will then make the rest of the measurements following a similar procedure. We have provided you with blank tables for your data and diagrams on which you can map the magnetic field.

e) Orient the coil perpendicular to the table, with its axis pointing east-west, as shown in the diagram.

f) Place your coil on top of a meter stick to make the distance measurement easier. The meter stick should run east-west.

g) Place your compass far out on the meter stick, and make sure the north tick mark is aligned with north.

Make sure the current will flow as indicated in the diagram. Note that electrons flow from the negative end to the positive end of the battery, so conventional current (I) flows from the positive to the negative end of the battery.

h) Make the final electrical connection and find the location A, along the axis of the coil where the needle of the compass is deflected by 50° (when reading the compass, remember to look straight down on the face).

i) Measure this distance *d* (from the center of the coil to the center of the compass) carefully and record the result.

j) Disconnect the battery from the circuit after each measurement.

Use this value of ***d*** to set the locations of points B – E for the loop. Use the same method to obtain the appropriate value of *d* for the bar magnet. Note it is easier and the measurements are more accurate if you move the coil rather than moving the compass.

k) Take all the necessary measurements

l) Draw arrows to show which way the compass needle pointed at the measurement locations.

m) Draw arrows corresponding to the magnetic fields at the measurement locations.

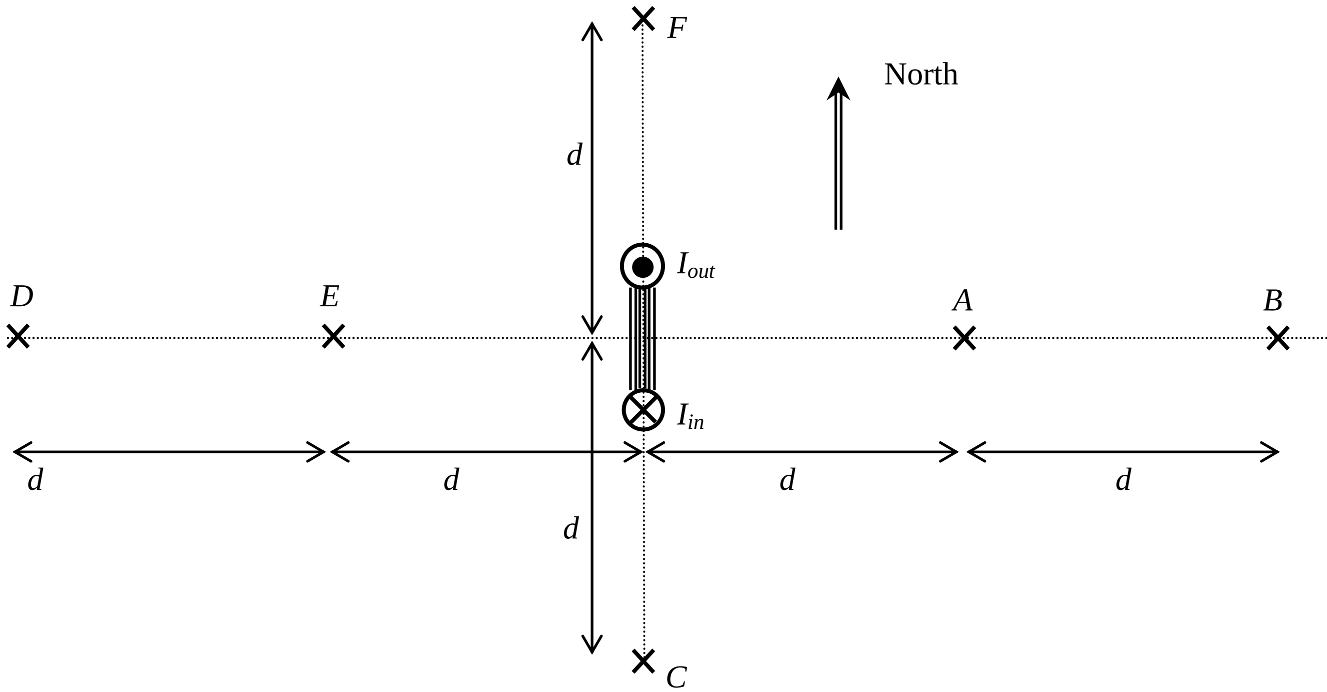


Table 1 Current Carrying Loop			
Location	**Deflection (degrees)**	**Direction (East or West)**	**Magnetic Field Magnitude (T)**
A	**50**		
B			
C			
D			
E	**50**		
F			

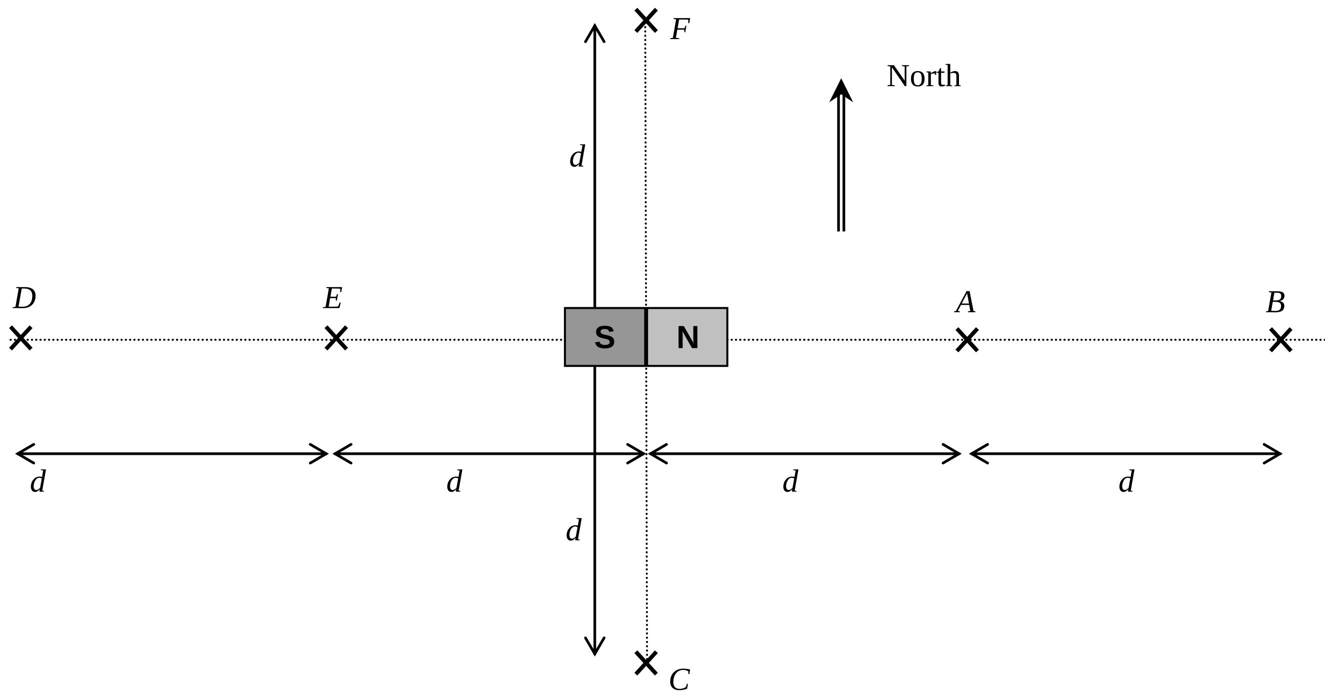


Table 2 Bar Magnet			
Location	**Deflection (degrees)**	**Direction (East or West)**	**Magnetic Field Magnitude (T)**
A			
B			
C			
D			
E			
F			

CHECKPOINT 2: Ask an instructor to check your work for credit.
You may proceed while you wait to be checked off

2) The Distance Dependence of the Magnetic Field

In order to calculate the distance dependence of the magnetic field we will do a procedure involving logarithms, similar to last week's lab. Look at your measurements from points A and B. Point B is twice as far from the source as point A. If you assume the field follows the same general form you used in the previous lab,

$$\left|\vec{B}\right| = Kr^n$$

then at location A: $r = d$

and at location B: $r = 2d$

You can write two equations for the magnetic fields at these points:

$$\left|\vec{B}_A\right| = K(d)^n$$
$$\left|\vec{B}_B\right| = K(2d)^n$$

Divide these equations by each other and take the natural log of both sides.

$$\frac{\left|\vec{B}_A\right|}{\left|\vec{B}_B\right|} = \frac{Kd^n}{K(2d)^n} = 2^{-n}$$
$$ln\left(\frac{\left|\vec{B}_A\right|}{\left|\vec{B}_B\right|}\right) = ln(2^{-n}) = -nln(2)$$
$$-\frac{\ln\left(\frac{\left|\vec{B}_A\right|}{\left|\vec{B}_B\right|}\right)}{\ln(2)} = n$$

a) **Now calculate n.**

i. *To what type of distance relation does your value of n correspond?*

ii. *How do your values for the bar magnet and loop compare?*

iii. *By how much do your values of n disagree with the expected result?*

3) The Dipole Moments

The magnetic field on the axis of the current loop or on the axis of the bar magnet is given by:

$$B_{axis} = \frac{\mu_0}{4\pi}\frac{2\mu}{r^3}$$

Hopefully you found the third power in the previous section. μ is the magnetic dipole moment. It is an intrinsic and fixed quantity for the bar magnet, but can be increased with increased current for the current loop.

a) **Calculate μ for both the bar magnet and the current carrying loop.**

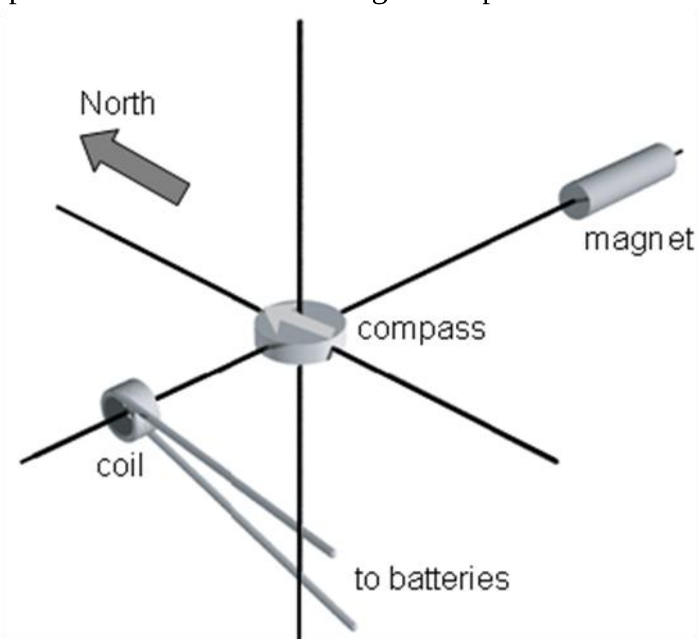
i. *Is the one you expected to be larger actually larger?*

ii. *Why did you expect it to be larger?*

CHECKPOINT 3: Ask an instructor to check your work for credit.
You may proceed while you wait to be checked off

4) Final Problem

Problem (2) A coil of wire with 12 turns of radius 0.01 m is connected to a battery. A conventional current of 6 A runs through the coil. The coil is 0.11 m away from a compass (see diagram). A bar magnet lies along the opposite axis with its center 0.25 m from the compass. The compass needle points north. What is the magnetic dipole moment of the bar magnet?



CHECKPOINT 4: Ask an instructor to check your work for credit.