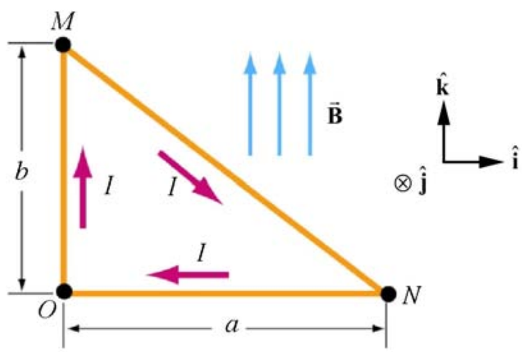
Magnetic Dipoles
Challenge Problems

Problem 1:

Circle the correct answer.

Consider a triangular loop of wire with sides a and b. The loop carries a current I in the direction shown, and is placed in a uniform magnetic field that has magnitude B and points in the same direction as the current in side OM of the loop.



At the moment shown in the figure the torque on the current loop

a) points in the $-\hat{\mathbf{i}}$-direction and has magnitude $IabB/2$.

b) points in the $+\hat{\mathbf{i}}$-direction and has magnitude $IabB/2$.

c) points in the $-\hat{\mathbf{j}}$-direction and has magnitude $IabB/2$.

d) points in the $+\hat{\mathbf{j}}$-direction and has magnitude $IabB/2$.

e) points in the $-\hat{\mathbf{i}}$-direction and has magnitude $IabB$.

f) points in the $+\hat{\mathbf{i}}$-direction and has magnitude $IabB$.

g) points in the $-\hat{\mathbf{j}}$-direction and has magnitude $IabB$.

h) points in the $+\hat{\mathbf{j}}$-direction and has magnitude $IabB$.

i) None of the above.

Problem 2:

A wire ring lying in the *xy*-plane with its center at the origin carries a counterclockwise current I. There is a uniform magnetic field $\vec{\mathbf{B}} = B\hat{\mathbf{i}}$ in the +*x*-direction. The magnetic moment vector $\vec{\boldsymbol{\mu}}$ is perpendicular to the plane of the loop and has magnitude $\mu = IA$ and the direction is given by right-hand-rule with respect to the direction of the current. What is the torque on the loop?

Problem 3:

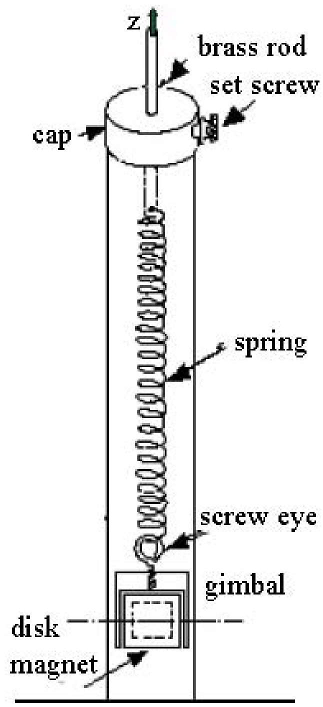
1. Force on a Dipole in the Helmholtz Apparatus

The magnetic field along the axis of a coil is given by

$$B_z(z) = \frac{N\,\mu_0\,I\,R^2}{2}\frac{1}{(z^2+R^2)^{3/2}}$$

where z is measured from the center of the coil.

Consider a disk magnet (a dipole) suspended on a spring, which we will use to observe forces on dipoles due to different magnetic field configurations.



(a) Assuming we energize only the top coil (current running counter-clockwise in the coil, creating the field quoted above), and assuming that the dipole is always well aligned with the field and on axis, what is the force on the dipole as a function of position? (HINT: In this situation $F_z = \mu_z \; dB_z/dz$)

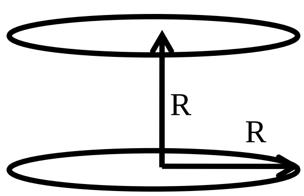
(b) The disk magnet (together with its support) has mass *m*, the spring has spring constant *k* and the magnet has magnetic moment μ. With the current on, we lift the brass rod until the disk magnet is sitting a distance z_0 above the top of the coil. Now the current is turned off. Does the disk magnet move up or down? Find the displacement Δz to the new equilibrium position of the disk magnet.

(c) At what height(s) is the force on the dipole the largest?

(d) What is the force where the field is the largest?

(e) Our coils have a radius *R* = 7 cm and *N* = 168 turns, and the experiment is done with *I* = 1 A in the coil. The spring constant *k* ~ 1 N/m, and μ ~ 0.5 A m^2. The mass m ~ 5 g is in the shape of a cylinder ~ 0.5 cm in diameter and ~ 1 cm long. If we place the magnet at the location where the spring is stretched the furthest when the field is on, at about what height will the magnet sit after the field is turned off?

2. Motion of a Dipole in a Helmholtz Field



In Part I of this experiment we will place the disk magnet (a dipole with moment μ) at the center of the Helmholtz Apparatus (in Helmholtz mode). We will start with the disk magnet aligned along the x-axis (perpendicular to the central z-axis of the coils), and then energize the coils with a current of 1 A.

Recall that a Helmholtz coil consists of two coils of radius *R* and *N* turns each, separated by a distance *R*, as pictured above. The field from each coil is given at the beginning of the previous problem.

(a) The disk magnet will experience a torque. Will it also experience a force? Explain why or why not.

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