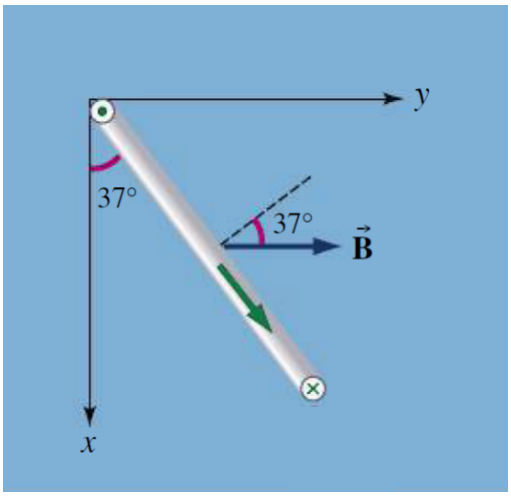
General Physics: Electromagnetism, Problem Set 9

Exercise 1 :

A rigid wire loop of square shape has sides of length 20 cm. It has fives turns and is carrying a current of 2 A (indicated by green arrow). The normal to the loop makes an angle of 37° with a uniform magnetic field $B = 0.5\hat{y}$ T.



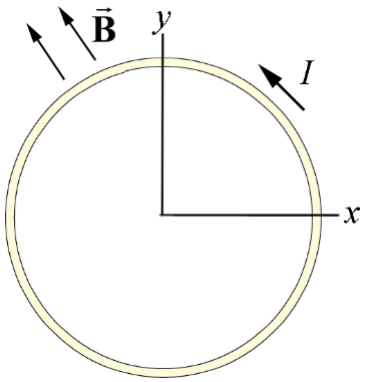
a) Find the magnetic dipole moment.

b) Find the magnitude and direction of the torque acting on the loop.

c) Find the work that an external agent must provide to rotate the frame from its position of minimum energy to the given position.

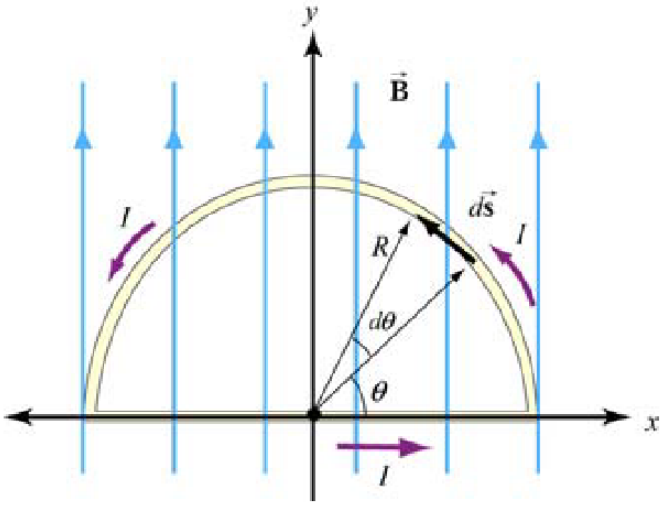
Exercise 2 :

A wire ring lying in the xy-plane with its center at the origin carries a counterclockwise current I. There is an external uniform magnetic field $B = B_x\hat{i} + B_y\hat{j}$ such that $B_y > 0$ and $B_x < 0$.The magnetic moment vector $\vec{\mu}$ 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 direction and magnitude of the torque on the loop?



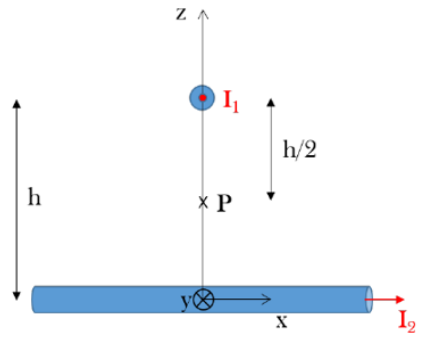
Exercise 3 :

Consider a closed semi-circular loop lying in the xy plane carrying a current I in the counter-clockwise direction, as shown in the figure below. A uniform magnetic field pointing in the $+y$ direction is applied. Find the magnetic force acting on the straight segment and the semicircular arc.



Exercise 4 :

Two long wires of radius a are perpendicularly oriented as shown in figure below. The upper wire has a current I_1 in the $\hat{y}$ direction and the lower cable has a current I_2 in the $\hat{x}$ direction.



(a) Find the magnetic field along the z axis, between $z = a$ and $z = h$. Use the fact that the magnitude of the magnetic field around a straight wire carrying current I is given by $B = \frac{\mu_0 I}{2\pi r}$, where r is the perpendicular distance from the wire.

(b) For $I_1 = 100$ A and $I_2 = 150$ A, with the distance $h = 2.5$ cm, what is the magnitude of the magnetic field at point P?

(c) Describe the direction of the compass needle placed in point P.
Hint: The magnetic field of Earth is about $5 \cdot 10^{-5}$ T.

Exercise 5 :

Consider two infinitely long wires carrying currents are in the x direction.

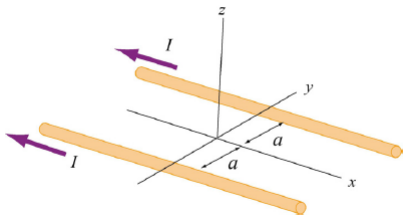


Figure 1: Non-uniform current density

(a) Draw a schematic of the magnetic field pattern in the yz-plane.

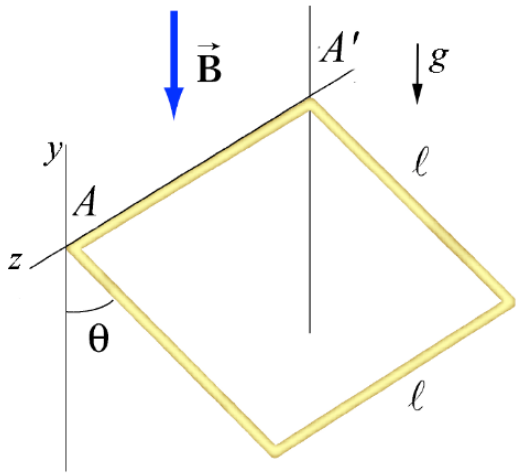
(b) Find the distance d along the z-axis where the magnetic field is maximum. Use the fact that the magnitude of the magnetic field around a straight wire carrying current I is given by $B = \frac{\mu_0 I}{2\pi r}$, where r is the perpendicular distance from the wire.

Exercise 6 :

Find the minimum diameter of the wires d that can transmit $P = 225$ MW of electricity with only a 2.0% loss. Their length is $l = 185$ km. Assume there are two wires to make a complete circuit (the length is thus doubled). The wires are to be made of aluminum ($\rho = 2.6 \cdot 10^{-8}\ \Omega \cdot m$) and the voltage is $V = 660$ kV.

Exercise 7 :

A square loop of wire, of length l on each side, and mass m, pivots about an axis AA' that corresponds to a horizontal side of the square, as shown in the figure on the left below. The external magnetic field $\vec{B}$ of magnitude B is directed vertically downward, and uniformly fills the region in the vicinity of the loop. A current I flows around the loop. The gravitational torque on the loop and the magnetic torque on the loop sum to zero when the loop makes an angle θ with the z -axis. The magnitude of the gravitational field is $g = 9.8$ m s^{-2} .



a) In what direction does the current need to flow in order that the magnetic torque acts in an opposite direction from the gravitational torque?

b) Calculate the magnitude of the magnetic torque on this loop of wire in terms of the quantities given.

c) Suppose that the mass of the loop $m = 0.4$ kg and the length of a side is $l = 1.0$ m . Suppose that when current in the loop is $I = 2.0$ A , the torques on the loop balance when $\theta = 45°$. What is the magnitude of the magnetic field?