UNIVERSITY OF ALABAMA
Department of Physics and Astronomy

PH 106-4 / LeClair Fall 2008

Problem Set 6: Magnetic Fields

Instructions:

1. Answer all questions below. Show your work for full credit.
2. Due at the end of **Monday** 13 Oct. 2008
3. You may collaborate, but everyone must turn in their own work

1. Protons having a kinetic energy of 5.00 MeV are moving in the positive x direction and enter a magnetic field $\vec{\mathbf{B}} = 0.0500\,\hat{\mathbf{k}}\,\mathrm{T}$ directed out of the plane of the page and extending from $x = 0$ to $x = 1.00\,\mathrm{m}$, as shown below. **(a)** Calculate the y component of the protons' momentum as they leave the magnetic field. **(b)** Find the angle α between the initial velocity vector after the beam emerges from the field. Note that $1\,\mathrm{eV} = 1.60 \times 10^{-19}\,\mathrm{J}$.

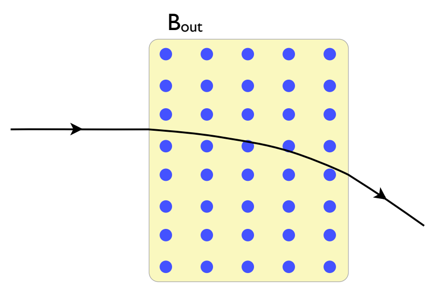

Figure 1: *Problem 1*

2. Consider an electron orbiting a proton and maintained in a fixed circular path of radius $R = 5.29 \times 10^{-11}$ m by the Coulomb force. Treating the orbiting charge as a current loop, calculate the resulting torque when the system is in a magnetic field of 0.400 T directed perpendicular to the magnetic moment of the electron.

3. A wire lying along the x axis carries a current of 30 A in the $+x$ direction. A proton at $\vec{\mathbf{r}} = 2.5\,\hat{\mathbf{y}}$ has instantaneous velocity $\vec{\mathbf{v}} = 2.0\,\hat{\mathbf{x}} - 3.0\,\hat{\mathbf{y}} + 4.0\,\hat{\mathbf{z}}$, where $\vec{\mathbf{r}}$ is in meters and $\vec{\mathbf{v}}$ in meters per second. What is the instantaneous magnetic force on this proton?

4. The electric field of a long, straight line of charge with λ coulombs per meter is

$$E = \frac{2k_e\lambda}{r}$$

where r is the distance from the wire. Suppose we move this line of charge parallel to itself at speed v. **(a)** The moving line of charge constitutes an electric current. What is the magnitude of this current? **(b)** What is the magnitude of the magnetic field produced by this current? **(c)** Show that the magnitude of the magnetic field is proportional to the magnitude of the electric field, and find the constant of proportionality.

5. A metal crossbar of mass m slides without friction on two long parallel rails a distance b apart. A resistor R is connected across the rails at one end; compared with R, the resistance of the bar and rails is negligible. There is a uniform field $\vec{\mathbf{B}}$ perpendicular to the plane of the figure. At time $t = 0$, the crossbar is given a velocity v_o toward the right. What happens then? **(a)** Does the rod ever stop moving? If so, when? **(b)** How far does it go? **(c)** How about conservation of energy? *Hint: first find the acceleration, and make use of an instantaneous balance of power.*

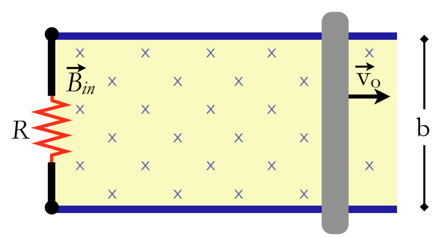

Figure 2: *Problem 5*

6. A uniform magnetic field of magnitude $0.150\,\mathrm{T}$ is directed along the positive x axis. A positron (a positively-charged electron) moving at $5.00 \times 10^6\,\mathrm{m/s}$ enters the field along a direction that makes an angle of 85° with the x axis. The motion of the particle is expected to be a helix in this case. Calculate the pitch p and radius r of the trajectory.

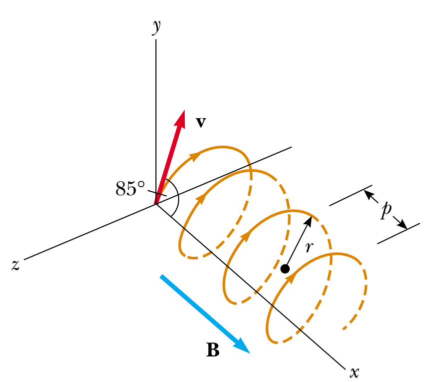

Figure 3: *Problem 6*