THE UNIVERSITY OF BRITISH COLUMBIA

Science 1 Physics Assignment # 16:

MAGNETIC FIELDS

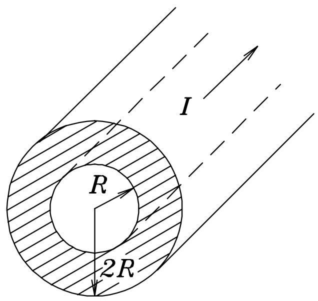
Wed. ♡ 14 Feb. 2001 ♡ — finish by Mon. 26 Feb.

1. **FRICTION** *vs.* **THE LORENTZ FORCE:** A 2.0-kg copper rod rests on two horizontal rails 2.0 m apart and carries a current of 100 A from one rail to the other. The coefficient of static friction between the rod and the rails is $\mu_s = 0.50$. What is the smallest magnetic field (not necessarily vertical) that would cause the bar to slide?

2. **CYCLOTRONS:** (Neglect any relativistic effects.) Suppose that we want to build a small cyclotron for protons using a magnet with a uniform field over a region 1.0 m in radius such that the protons reach a maximum kinetic energy of 20 MeV at the outer radius of the magnet. *(a)* What magnetic field must the magnet produce? *(b)* At what frequency must the "dee" voltage oscillate?

Now suppose we want to build a cyclotron to accelerate electrons *without a magnet*, using the Earth's magnetic field (assume $B = 5 \times 10^{-5}$ T) to keep the electrons moving in circles. *(c)* What is the radius of the electron orbit at 100 eV? *(d)* What is the frequency (in Hz) of the RF electric field we must supply to the cyclotron "dees?"

3. **HOLLOW CYLINDRICAL CONDUCTOR:** A thick-walled hollow conducting cylinder carries a uniformly distributed current I. The (centred) hole in the middle has a radius of R and the outer radius of the conductor is $2R$. Derive an expression for the strength of the magnetic field B as a function of radial distance r from the cylinder axis, in the range from $r = R$ to $r = 2R$; then *plot* (*i.e.* sketch, showing axis labels, scales and values at key points) $B(r)$ in the range from $r = 0$ to $r = 4R$.



. . . *and* Tipler (4th Edition)

Ch. **28**: problems **53**, **69**, **85** and **91**

Ch. **29**: problems **17**, **33**, **50**, **99** and **114**

Challenge Problems:

1. **MOTION OF AN ELECTRON IN A MAGNETIC FIELD:** An electron has a kinetic energy of 400 eV as it moves through a region containing a uniform magnetic field $\vec{\boldsymbol{B}} = B\hat{k}$ of magnitude $B = 4 \times 10^{-4}$ T. At $t = 0$ it is at the origin of coordinates $(x = 0, y = 0, z = 0)$ and has velocity components $v_y = 0$ and $v_x = v_z > 0$. Find the position of the electron (x, y and z) one millionth of a second later.

2. **FORCE ON A CURRENT-CARRYING CONDUCTOR:** A long, rigid conductor, lying along the x axis, carries a current of 6.0 A in the $-\hat{\imath}$ direction. A magnetic field $\vec{\boldsymbol{B}} = 3.0\hat{\imath} + 6.0x^2\hat{\jmath}$ (with x in m and B in mT) is present. Calculate the vector force on the 3.0-m segment of the conductor that lies between $x = 1.0$ m and $x = 4.0$ m.

3. **AMPÈRE'S LAW:** A wire carrying a current of 2000 A coming out of the page, as shown, emerges from the centre of the square ABCD whose side is 3.0 m in length. *(a)* Using Ampère's Law, find the average value along AB of the magnetic field component parallel to AB. *(b)* Find the magnitude and direction of the magnetic field at the midpoint of the line AB.