Homework #3 (Due 04/19 at the beginning of lecture)

1. (10%) Figure 3-1 shows a wood cylinder of mass m = 0.250 kg and length L = 0.100 m, with N = 10.0 turns of wire wrapped around it longitudinally, so that the plane of the wire coil contains the long central axis of the cylinder. The cylinder is released on a plane inclined at an angle θ to the horizontal, with the plane of the coil parallel to the incline plane. If there is a vertical uniform magnetic field of magnitude 0.500 T, what is the least current i through the coil that keeps the cylinder from rolling down the plane?

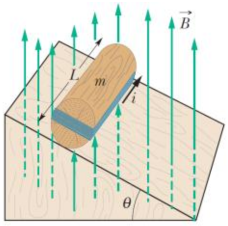

Figure 3-1

2. (10%) In Fig. 3-2, a metal wire of mass m = 24.1 mg can slide with negligible friction on two horizontal parallel rails separated by distance d = 2.56 cm. The track lies in a vertical uniform magnetic field of magnitude 73.5 mT. At time t = 0, device G is connected to the rails, producing a constant current i = 9.13 mA in the wire and rails (even as the wire moves). At t = 61.1 ms, what are the wire's (a) speed and (b) direction of motion (left or right)?

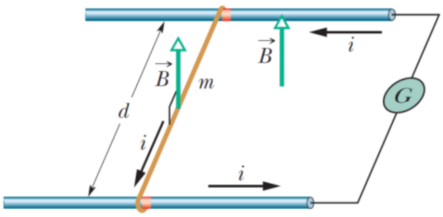

Figure 3-2

3. (10%) In Fig. 3-3*a*, two concentric coils, lying in the same plane, carry currents in opposite directions. The current in the larger coil 1 is fixed. Current i_2 in coil 2 can be varied. Figure 3-3*b* gives the net magnetic moment of the two-coil system as a function of i_2. The vertical axis scale is set by $\mu_{net,s} = 2.0 \times 10^{-5}\ \mathrm{A \cdot m^2}$, and the horizontal axis scale is set by i_{2s} = 10.0 mA. If the current in coil 2 is then reversed, what is the magnitude of the net magnetic moment of the two-coil system when i_2 = 7.0 mA?

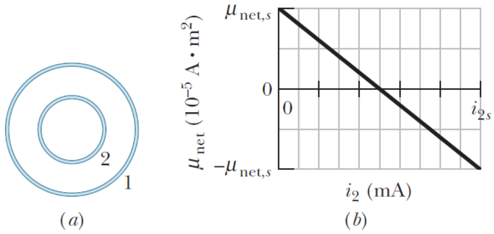

Figure 3-3

4. (10%) In Fig. 3-4, an electron with an initial kinetic energy of 5.0 keV enters region 1 at time t = 0. That region contains a uniform magnetic field directed into the page, with magnitude 0.010 T. The electron goes through a half-circle and then exits region 1, headed toward region 2 across a gap of 25.0 cm. There is an electric potential difference ΔV = 2000 V across the gap, with a polarity such that the electron's speed increases uniformly as it traverses the gap. Region 2 contains a uniform magnetic field directed out of the page, with magnitude 0.020 T. The electron goes through a half-circle and then leaves region 2. At what time t does it leave?

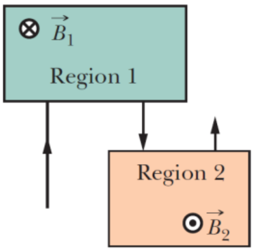

Figure 3-4

5. (10%) Figure 3-5*a* shows a length of wire carrying a current i and bent into a circular coil of one turn. In Fig. 3-5*b* the same length of wire has been bent to give a coil of two turns, each of half the original radius. (a) If B_a and B_b are the magnitudes of the magnetic fields at the centers of the two coils, what is the ratio B_b/B_a? (b) What is the ratio μ_b/μ_a of the dipole moment magnitudes of the coils?

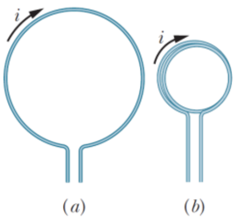

Figure 3-5

6. (10%) In Fig. 3-6, a long straight wire carries a current i_1 = 30.0 A and a rectangular loop carries current i_2 = 20.0 A. Take a = 1.00 cm, b = 8.00 cm, and L = 30.0 cm. In unit vector notation, what is the net force on the loop due to i_1?

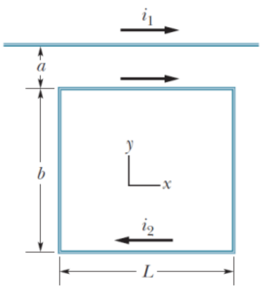

Figure 3-6

7. (10%) In Fig. 3-7, a long circular pipe with outside radius R = 2.6 cm carries a (uniformly distributed) current i = 8.00 mA into the page. A wire runs parallel to the pipe at a distance of 3.00R

from center to center. Find the (a) magnitude and (b) direction (into or out of the page) of the current in the wire such that the net magnetic field at point P has the same magnitude as the net magnetic field at the center of the pipe but is in the opposite direction.

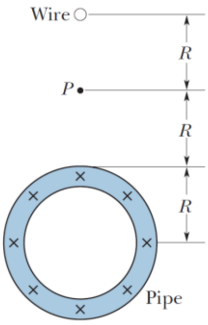

Figure 3-7

8. (10%) Figure 3-8 shows two current segments. The lower segment carries a current of $i_1 = 0.40$ A and includes a semicircular arc with radius 5.0 cm, angle 180°, and center point P. The upper segment carries current $i_2 = 2i_1$ and includes a circular arc with radius 4.0 cm, angle 120°, and the same center point P. What are the (a) magnitude and (b) direction of the net magnetic field $\vec{B}$ at P for the indicated current directions? What are the (c) magnitude and (d) direction of $\vec{B}$ if i_1 is reversed?

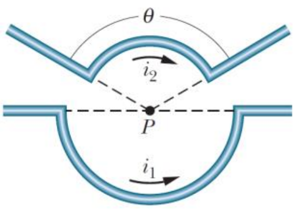

Figure 3-8

9. (20%) A uniformly charged, with a charge density ρ, nonconducting cylindrical shell has length L, inner and outer radii R_1 and R_2, respectively. Assume it rotate with an angular velocity ω about its central axis. What is the magnetic dipole moment of the cylinder?

10. (20%) A pair of identical coils, each having a radius of 30 cm, are separated by a distance equal to their radii, i.e., 30 cm, as shown in Figure 3-10 below. It is called Helmholtz coils. They are coaxial and carry equal currents in directions such that their axial fields are in the same direction. A feature of Helmholtz coils is that the resultant magnetic in the region between the coils is very uniform. Assume the current in each coil is 15 A and there are 250 turns for each coil. Please calculate and graph the magnetic field as a function of x, the distance from the center of the coils along the common axis, for -30 cm < x < +30 cm. Over what range of x does the field vary by less than 20%? Hint: For the magnetic field calculation and graph, you could either use Microsoft Excel to do the spreadsheet calculation or simply use Python to do the calculation.

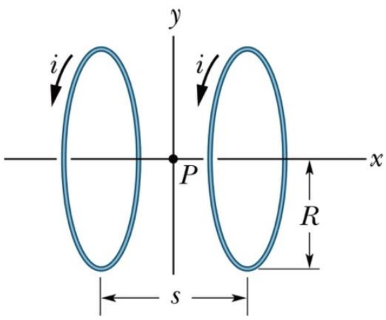

Figure 3-10

11. (20%) It is impossible to have a uniform magnetic field without any fringing field no matter how you arrange the coils, as shown in Figure 3-11. Please use Ampere's law with the rectangular curve shown by the dashed lines to show it. Note that this is a simple problem but will give you the idea of how powerful the Ampere's law (or Gauss's law) can be for some quick / simple concept checks.

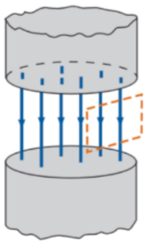

Figure 3-11