University of Alabama
Department of Physics and Astronomy

PH 126 LeClair | Fall 2011

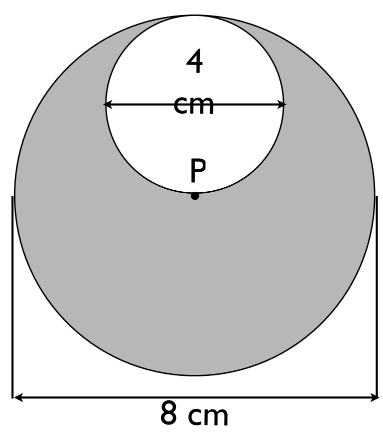
Problem Set 6

Instructions:

1. Answer all questions below. Show your work for full credit.
2. All problems are due 14 October 2011 by 11:59pm.
3. You may collaborate, but everyone must turn in their own work.

1. One way to produce a very uniform magnetic field is to use a very long solenoid and work only in the middle section of its interior. This is often convenient, but wasteful of space and power. Can you suggest ways in which two short coils or current rings might be arranged to achieve good uniformity over a limited region? *Hint: consider two coaxial current rings of radius* a *separated axially by a distance* b*. Investigate the uniformity of the field in the vicinity of the point on the axis midway between the two coils. Determine the magnitude of the coil separation* b *which for a given coil radius* a *will make the field in this region as nearly uniform as possible.*

2. A long copper rod 8 cm in diameter has an off-center cylindrical hole, as shown below. This conductor carries a current of 900 A flowing in the direction into the page. What is the direction and magnitude of the magnetic field at point P on the inner axis of the outer cylinder?



3. Consider the magnetic field of a circular current ring, at points on the axis of the ring (use the exact formula, not your approximate form above). Calculate explicitly the line integral of the magnetic field along the ring axis from $-\infty$ to ∞, and check the general formula

$$\int \vec{B} \cdot d\vec{l} = \mu_o I_{encl} \tag{1}$$

Why may we ignore the "return" part of the path which would be necessary to complete a closed loop?

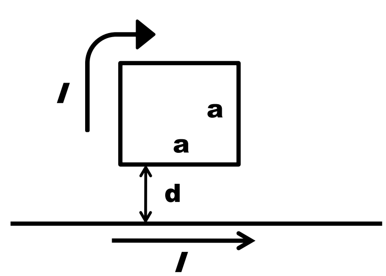
4. A sphere of radius R carries the charge Q which is distributed uniformly over the surface of the sphere with a density $\sigma = 4\pi R^2$. This shell of charge is rotating about an axis of the sphere with angular velocity ω, in radians/sec. Find its magnetic moment. (Divide the sphere into narrow bands of rotating charge, find the current to which each band is equivalent and its dipole moment, and integrate over all bands.)

5. Consider two solenoids, one of which is a tenth-scale model of the other. The larger solenoid is 2 m long, and 1 m in diameter, and is wound with 1 cm-diameter copper wire. When the coil is connected to a 120 V dc generator, the magnetic field at the center is exactly 0.1 T. The scaled-down version is exactly one-tenth the size in every linear dimension, including the diameter of the wire. The number of turns is the same in both coils, and both are designed to provide the same central field.

(a) Show that the voltage required is the same, namely, 120 V
(b) Compare the coils with respect to the power dissipated, and the difficulty of removing this heat by some cooling means.

6. You want to confine an electron of kinetic energy 3.0×10^4 eV by making it circle inside a solenoid of radius 0.1 m under the influence of the force exerted by the magnetic field. The solenoid has 12000 turns of wire per meter. What minimum current must you put through the wire if the electron is not to hit the wall of the solenoid?

7. Find the force on a square loop (side a) placed as shown below, near an infinite straight wire. Both loop and wire carry a steady current I.



8. I have input signals of voltage V_a, V_b, and V_c. I want an a circuit that outputs $V_a + 2V_b - 3V_c$. Design a circuit that does this, making sure to note all component values and supply voltages. Presume that the signals are essentially constant, i.e., do not worry about frequency response.[i].

[i] If you can add, you can do any other kind of math based on that, so you have in principle the basis for a simple computer

9. A *pulse height discriminator* (a.k.a., *amplitude discriminator*) is a device one often encounters in physics experiments. It is essentially a circuit that produces a specified output pulse when and *only when* it receives an input pulse whose amplitude exceeds an assigned value. Design on that will produce output pulses if and only if the input is greater than 100 mV. Make sure to note all component values and supply voltages, and presume the frequency of pulses is well within the range of your components. *Hint: You will probably want to use a comparator, though one can do it passively with only a diode, capacitor, and resistor.* [ii]

[ii] You will be building one of these in the next few weeks as part of your mid-semester project ...