UNIVERSITY OF ALABAMA
Department of Physics and Astronomy

PH 106-4 / LeClair Fall 2008

Problem Set 7: Magnetism, Induction

Instructions:

1. Answer all questions below. Show your work for full credit.
2. Due at the end of **Friday** 24 Oct. 2008
3. You may collaborate, but everyone must turn in their own work

1. 10 points. Very large magnetic fields can be produced using a procedure called *flux compression.* A metallic cylindrical tube of radius R is placed coaxially in a long solenoid of somewhat larger radius. The space between the tube and the solenoid is filled with a highly explosive material. When the explosive is set off, it collapses the tube to a cylinder of radius $r < R$. If the collapse happens very rapidly, induced current in the tube maintains the magnetic flux nearly constant inside the tube, even though the area shrinks. If the initial magnetic field in the solenoid is $2.50\,\mathrm{T}$, and $R/r = 12.0$, what is the maximum field that can be reached?

2. 5 points. Coaxial cables are used to shield conductors carrying small signals from stray electric fields by creating a *Faraday cage* around the central conductor. In order to shield extremely sensitive signals from stray *magnetic* fields, a Faraday cage will not work. Instead, so-called "twisted pair" wiring is used. Explain how this works. How would you shield a signal from *both* electric and magnetic interference?

3. 5 points. One common way to make a resistor is simply to wind a coil of high resistivity wire of the appropriate length - for a wire radius r and resistivity ϱ, the resistance of a coil of wire of total length l is $\varrho l/\pi r^2$. This is known as a "wire wound resistor," not surprisingly. Another common method for constructing resistors is to use thin, patterned metal films instead of wires, reducing the cross-sectional area and allowing useful values of resistance. Why might one have a preference for which type of resistor is used when designing circuits, for example, audio amplifiers?

4. 10 points. What is the maximum voltage induced across a coil of 4000 turns, average radius $12\,\mathrm{cm}$, rotating at 30 revolutions per second in the earth's magnetic field, where the field is approximately $5 \times 10^{-5}\,\mathrm{T}$?

5. 5 points. A superconducting solenoid designed for whole-body imaging by nuclear magnetic resonance is $0.9\,\mathrm{m}$ in diameter and $2.2\,\mathrm{m}$ long. The field at the center is $0.4\,\mathrm{T}$. Estimate roughly the energy stored in the field of this coil, in Joules.

6. 10 points. Consider two solenoids, one of which is a tenth-scale model of the other. The larger solenoid is $2\,\mathrm{m}$ long, and $1\,\mathrm{m}$ in diameter, and is wound with $1\,\mathrm{cm}$-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.

7. 10 points. A long coaxial cable consists of two concentric conductors. The inner conductor is a cylinder of radius a, and it carries a current I uniformly distributed over its cross section. The outer conductor is a cylindrical shell with inner radius $b > a$ and outer radius c. It carries a current I that is also uniformly distributed over its cross section, and that is opposite in direction to the current on the inner conductor. Calculate the magnetic field $\vec{\mathbf{B}}$ as a function of the distance r from the axis, and plot the field strength as a function of r.

8. 15 points. A long wire is bent into a hairpin, like the shape shown below. find an exact expression for the magnetic field at point P which lies at the center of the half-circle.

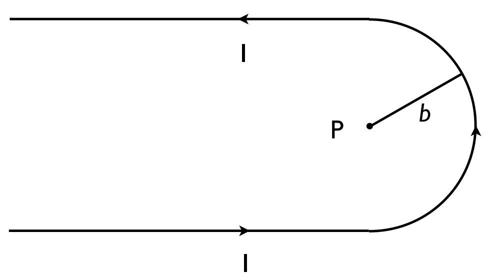

Figure 1: *Problem 8*

9. 5 points. What is the induced EMF between the ends of the wingtips of a Boeing 737 when it is flying over the magnetic south pole? Use your google-fu for the numbers you require.

10. 10 points. A flat circular disk with radius R carries a uniform surface charge density σ. It rotates with an angular velocity ω about the z-axis. Find the magnetic field $B(z)$ at any point z along the rotation axis.