University of Alabama
Department of Physics and Astronomy

PH 102-2 / LeClair Spring 2008

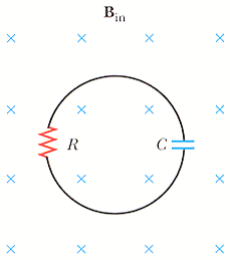
# Problem Set 7: Induction

**Instructions:**

- Answer all questions below. Show your work for full credit.
- Due before 5pm, 10 Mar 2008
- Problem sets may turned in *via* email or hard copy
- Hard copies may be left in Dr. LeClair's mailbox (Gallalee 206) or office (Bevill 228)
- You may collaborate, but everyone must turn in their own work

**1. 15 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 T, and $R/r = 12.0$, what is the maximum field that can be reached?

**2. 10 points.** In the figure below, a uniform magnetic field *decreases* at a constant rate $\Delta B/\Delta t = -K$, where $K$ is a positive constant. A circular loop of wire of radius $a$ containing a resistance $R$ and a capacitance $C$ is placed with its plane normal to the field. **(a)** Find the charge $Q$ on the capacitor when it is fully charged. **(b)** Is the upper or lower plate of the capacitor at a higher potential? Show your work for full credit.




**3. 15 points.** A technician wearing a brass bracelet enclosing an area $0.00500\,\text{m}^2$ places her hand in a solenoid whose magnetic field is 5.00 T directed perpendicular to the plane of the bracelet. The electrical resistance around the circumference of the bracelet is $0.0200\,\Omega$. A power failure causes the field to drop to 1.50 T in a time of 20.0 ms. Find **(a)** the current in the bracelet, and **(b)** the power delivered to the bracelet. *Hint:* don't wear metal jewelry when working with strong magnetic fields.

**4. 10 points.** Calculate the resistance in an $RL$ circuit in which $L = 2.50$ H and the current increases to 90% of its final value in 3.00 s.

**5. 10 points.** An inductor in the form of a solenoid contains 420 turns, is 16 cm in length, and has a cross-sectional area of $3.00\,\text{cm}^2$. What uniform rate of decrease of current through the inductor induces a voltage of $175\,\mu$V?

**6. 10 points.** Considerable scientific work is currently underway to determine whether weak oscillating magnetic fields such as those found near outdoor power lines can affect human health. One study indicated that a magnetic field of magnitude $\sim 10^{-3}$ T, oscillating at 60 Hz, might stimulate red blood cells to become cancerous. If the diameter of a red blood cell is $8.2\,\mu$m, determine the maximum voltage that can be generated around the perimeter of the cell if the magnetic field strength is $1.4 \times 10^{-3}$ T.

**7. 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?

**8. 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 $\varrho$, 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?

**9. 10 points.** A step-down transformer is used for recharging the batteries of portable devices, such as cell phones or mp3 players. The turns ratio inside the transformer is 13:1 and it is used with a 120 V household outlet. If a particular ideal transformer draws 0.350 A from the house outlet, what are **(a)** the voltage, and **(b)** the current supplied to a cell phone from the transformer?

**10. 10 points.** A magnetic field of 0.200 T exists within a solenoid of 500 turns and a diameter of 10 cm. How rapidly (*i.e.,* in what period of time) must the field be reduced to zero, if we want the average induced voltage within the coil during this time interval to be 10 kV? Presume that the field reduces uniformly.