UNIVERSITY OF ALABAMA
Department of Physics and Astronomy

PH 102 / LeClair Summer II 2009

Problem Set 7: ac circuits & induction

Instructions:

1. Answer all questions below. Show your work for full credit.
2. Due before the end of the day, 28 July 2009
3. Email: leclair.homework@gmail.com; hard copies: Gallalee 110 or Bevill 228.
4. You may collaborate, but everyone must turn in their own work

1. A cell membrane typically has a capacitance around $1\,\mu\text{F/cm}^2$. It is believed the membrane consists of material having a dielectric constant of $\kappa \sim 3$. Find the thickness this implies. Other electrical measurements have indicated that the resistance of $1\,\text{cm}^2$ of cell membrane is around $1000\,\Omega$. Show that the time constant of such a leaky capacitor is independent of the area of the capacitor. How large is it in this case? What is the resistivity?

2. The rate of flow of a conducting liquid can be measured with an electromagnetic flowmeter that detects the voltage induced by the motion of the liquid in a magnetic field. Suppose that a plastic pipe of diameter $0.10\,\text{m}$ carries beer with a speed of $1.5\,\text{m/s}$. The pipe is in a transverse magnetic field (*i.e.*, perpendicular to the pipe axis) of about $1.5 \times 10^{-2}\,\text{T}$. **(a)** Presume the beer is an ideal conductor. What voltage will be induced between the opposite sides of the column of liquid? **(b)** Does it matter whether the conductivity of the beer is due to mobile positive or negative charges?

3. A technician wearing a conducting bracelet enclosing an area $0.005\,\text{m}^2$ places her hand in a solenoid whose magnetic field is $5.0\,\text{T}$ directed perpendicular to the plane of the bracelet. The resistance around the circumference of the bracelet is $0.02\,\Omega$. A power failure causes the field to drop to $1.50\,\text{T}$ in a time of $20.0\,\text{ms}$. Find **(a)** the current in the bracelet, and **(b)** the power delivered to the bracelet..

4. Any two adjacent conductors can be considered as a capacitor, although the capacitance will be small unless the conductors are close together or long. This (unwanted) effect is termed "stray" or "parasitic" capacitance. Stray capacitance can allow signals to leak between otherwise isolated circuits (an effect called crosstalk), and it can be a limiting factor for proper functioning of circuits at high frequency. A stray capacitance can result when you touch or come close the wires in a circuit - your body provides a capacitive path between the circuit of interest and an adjacent noise source. **(a)** Explain, referencing the figure at right, why the stray capacitance allows unwanted ac signals to couple into the circuit, but does not allow dc signals. **(b)** Suggest a method for minimizing this effect.