University of Alabama
Department of Physics and Astronomy

PH 102-2 / LeClair — Spring 2008

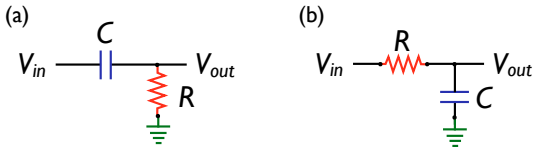
Problem Set 8: ac Circuits

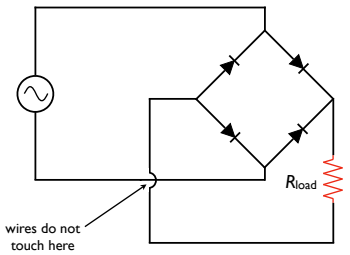
Instructions:

- Answer all questions below. Show your work for full credit.
- Due before 5pm, 24 Mar 2008 *i.e.,* right after spring break
- 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. Using capacitors, resistors, and inductors, sketch a circuit to split an audio signal composed of many frequencies in to a low frequency part and a high frequency part, for distribution to speakers. That is, filter the incoming signal into separate low frequencies and high frequencies to send to a woofer and tweeter, respectively. Such a circuit is known as an "audio crossover." You do not need to specify the values of your components.

2. 15 points. Two filters are constructed, as shown below, both using a resistor of $R = 1.0\,\mathrm{k\Omega}$ and a capacitor of $0.01\,\mu\mathrm{F}$. **(a)** Determine which filter is a low-pass, and which is a high-pass. Explain your reasoning. **(b)** Sketch the frequency response of each filter, and calculate the 3dB "cutoff" frequency of each. **(c)** Assume now that these filters are applied in series, one after the other. What would be the frequency response of the combined filter?





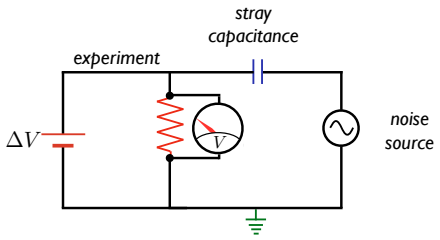
3. 10 points. The circuit at right is known as a full-wave bridge rectifier - an ac source is connected to two opposite ends of a diode "bridge," and a load resistor is connected to the other two ends. If the ac voltage source is sinusoidal, sketch the voltage and current across the load resistor as a function of time. Refer to the previous problem to determine the current flow through the diodes.

4. 10 points. An electricity-generating station needs to deliver energy at a rate of 20 MW to a city 1.0 km away. **(a)** If the resistance of the wires is $2.0\,\Omega$ and the energy costs about 10¢/kWh, estimate what it costs the utility company for the energy converted to internal energy in the wires during one day. A common voltage for commercial power generators is 22 kV, but a step-up transformer is used to boost the voltage to 230 kV before transmission. **(b)** Repeat the calculation for the situation in which the power plant delivers the energy at its original voltage of 22 kV.

5. 10 points. 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

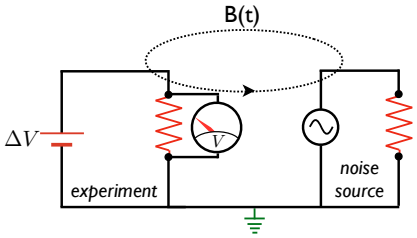
close the wires in a circuit - your body provides a capacitive path between the circuit of interest and an adjacent noise source.

(a) Explain, referencing the figure below, 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 (*hint: last week's homework*).



6. 10 points. The previous problem dealt with unintentional capacitive coupling. A similar phenomena is *inductive* coupling, and the basis for this effect is illustrated in the figure at left. Time-varying magnetic fields (for instance, due to the 60 Hz current present all around you!) can couple the circuit of interest to a nearby circuit, inducing an unwanted signal.

(a) Explain, referencing the figure below, why inductive coupling also allows unwanted ac signals to couple into the circuit, but does not allow dc signals. **(b)** Suggest a method for minimizing this effect (*hint: last week's homework*).



7. 10 points. An audio amplifier delivers to a speaker alternating voltage at audio frequencies. If the source voltage has an amplitude of 15.0 V and an internal resistance of 8.20 Ω, and the speaker can be considered equivalent to a 10.4 Ω resistor, what is the time-averaged power transferred to it? The source, its internal resistance, and the speaker are in series.

8. 5 points. Why does a capacitor act as a short circuit at high frequencies? Why does it act as an open circuit at low frequencies?

9. 5 points. Why does an inductor act as a short circuit at low frequencies? Why does it act as an open circuit at high frequencies?

10. 10 points. A current source I is used to drive a large inductor (say, a wound wire electromagnet) as shown at right. Driving inductive loads can be problematic - what happens when you open the switch providing current to an inductor in circuit **(a)** Why does adding a diode across the inductor, circuit **(b)**, add protection? Recall diodes only allow current through in one direction, as shown in **(c)**.