Physics 313 assignment 4 for Tuesday, September 8, 2009:

Reading:
Handout on scope probe
Handout on capacitor markings; also look at p. 354 on capacitor markings
Semiconductor technology, 4.1
Diodes, 4.2 (through 4.22, p. 419)

Problems:
Note: in all “design” problems, choose reasonable component values (don’t specify, for example, 1 F capacitors or 0.001 Ω resistors).

1) a) You want to design a high-pass RC filter that has its cutoff frequency at 600 Hz. You have a 560 pF capacitor and a large selection of resistors. Draw the appropriate circuit and label the values of its components. Be sure to show where $V_{out}$ should be taken.

b) Use the formula for $V_{out}/V_{in}$ to make a graph (preferably using software such as Mathematica or Excel) of $V_{out}/V_{in}$ vs. the frequency (in Hz) for your circuit over a frequency range large enough to show the behavior. Label the cutoff frequency and the corresponding value of $V_{out}/V_{in}$ on your graph. Linear scales are fine.

c) If $V_{in}$ is a 5.0 V (amplitude) sine wave of frequency 200 Hz, what is $V_{out}$? Also calculate the voltage attenuation in dB at this frequency.

d) If $V_{in}$ is a 5.0 V sine wave of frequency 1200 Hz, what is $V_{out}$? Also calculate the voltage attenuation in dB at this frequency.

e) Make a table like the one below and fill it with the appropriate answers for this type of filter:

<table>
<thead>
<tr>
<th></th>
<th>$V_{out}/V_{in}$ ($=0, 1/\sqrt{2}, \approx 1$)</th>
<th>$V_{out}$ phase shift relative to $V_{in}$ ($=0, 45, \approx 90^\circ$)</th>
<th>$V_{out}$ leads or lags $V_{in}$?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f &lt;&lt; 600$ Hz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$f = 600$ Hz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$f &gt;&gt; 600$ Hz</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2) a) A designer wants to build an RC filter that will work the same way as does the RL circuit in Fig. 3.91 (p. 381), circuit B (that is, pass high frequencies and have the same cutoff frequency). Show what the RC circuit would look like, and find appropriate component values for R and C.

b) Using reasoning similar to what we used in class to find the attenuation for RC filters, find an expression for the attenuation (or gain) $V_{out}/V_{in}$ for an RL high-pass filter in terms of R, L, and the frequency.

c) Use your result from b) to show that the cutoff frequency is what Fig. 3.91 claims it is.

3) Design a simple bandpass filter (a filter that attenuates low and high frequencies, while passing frequencies in between) by putting a low-pass filter in series with a high-pass filter (that is, make $V_{out}$ from one filter serve as $V_{in}$ for the other one). Sketch the circuit diagram. Design the filter to pass only signals between about 15 kHz and 25 kHz. Also, choose component values such that the resistance of the second filter doesn’t load down the first filter too much (remember the 10x rule). Finally, specify a minimum power rating for the resistors (1/8 W, ¼ W, ½ W, …) if input voltages of up to 15 V can be expected.