Homework Assignment #1
Due Friday April 10 by 4:30 pm

Please note that the exercise numbers given here are from the 2nd Edition of the textbook. The bookstore did not notify me that they were changing to the 3rd Edition, and so far I do not have a copy of it.

1. Exercise 1.7 in Horowitz and Hill. What will a 20,000 ohm/volt meter read, on its 1 volt scale, when attached to a 1 volt source with an internal resistance of 10kohm? What will it read when attached to a 10k-10k voltage divider driven by a “stiff” (zero source resistance) 1 volt source? Hint: in the case of the voltage divider, replace it by its Thevenin equivalent. (Note that the DVMs used in the lab are not like the meter assumed in this exercise. Rather, they are of the type discussed above this exercise, with very high input impedance, probably the order of a billion ohms, which is achieved through amplifier feedback techniques that we will study later in the course.)

2. a) Find the Thévenin equivalent of this circuit. Be sure first to calculate the open-circuit voltage and then the short-circuit current and use the recipe in Section 1.05 or from the Lecture-1 notes.

![Circuit Diagram]

b) Find the Norton equivalent of a voltage divider composed of a 10 V supply and two 10 kohm resistors (as in Additional Exercise #1 of Chapter 1).

3. Additional Exercise 4 of Chapter 1. Design a “scratch filter” for audio signals (3dB down at 10 kHz). Assume zero source impedance (perfect voltage source) and a 10 kohm (minimum) load impedance. It is not enough just to get the time constant right! You must also consider this load impedance and choose your filter components appropriately such that when the load varies from 10 kohm up to infinity (open circuit) the time constant does not change significantly (say more than 10%).

4. Additional Exercise 6 of Chapter 1. Design a bandpass filter as illustrated in the figure on the same page. Take the low and high 3dB points to be $f_1 = 10$ Hz and $f_2 = 10$ kHz, and assume a minimum load impedance of 10 kohm. Use two stages, one high pass and one low pass. But take seriously load impedance (as in the previous exercise) and the requirement not to load down the first stage too much, as that is the principal point of this exercise. Put the high pass filter first (closest to the input).

5. Additional Exercise 8 of Chapter 1. Design an oscilloscope “×10 probe” to use with an oscilloscope whose input impedance is 1 Mohm in parallel with 20 pF. Assume that the cable between probe and oscilloscope adds an additional 100 pF and that the probe components are placed at the tip end (rather than at the scope end) of the cable.
The resultant network should have 20 dB attenuation at all frequencies, including DC. The reason for using a $\times 10$ probe is to increase the load impedance seen by the circuit under test, which reduces loading effects and errors. What input impedance ($R$ in parallel with $C$) does your $\times 10$ probe present to the circuit under test, when used with the oscilloscope? Note that the Appendix A shows exactly how to do this, so the purpose of this exercise is just to push you to take a look at how a probe works and why we use the $\times 10$ probe.

6. For the 2-loop circuit shown here:
   a. What is the complex impedance of the network of resistors, capacitor, and inductor at the given frequency, as seen by the source? To keep it simple, work out the numerical (complex) impedances of the reactive components at the given frequency before calculating the network impedance.
   
   ![2-loop circuit diagram]

   b. Find the magnitude and phase of the current flowing through the source, assuming that the phase of the source is zero. Does the current lead or lag the voltage at this frequency?

   Be sure to make use of the concept of complex impedance. It is probably easiest to do this by adding series and parallel combinations (combine the 4-ohm resistor and inductor in series, then combine that result in parallel with the capacitor, and then combine that result in series with the 6-ohm resistor). It may be helpful to refer to my posted handout on using complex numbers (i.e. phasors) in circuit analysis. This is the only problem of this type that we will do in this course, as we will normally rely on PSpice to do these tedious sorts of calculations.

7. Go through the PSpice tutorial that I wrote and simulate the circuit of the previous problem. You must include with your homework solutions answers to my questions plus printed plots of your schematic and of the PSpice output. Make sure that your schematic isn’t a copy of your friend’s schematic. I want every one of you to go through the whole exercise, because you need to learn how to use the program. As always, I’m available to help you in or out of my office hours. If you are not able to install the program on your own computer, there are three new PCs in the lab that have the program installed.
   a. Do an AC sweep (frequency-domain) analysis showing the current through the source and the voltage across the inductor as a function of frequency from 1 Hz to 1 MHz. How does the resonance peak compare with $\omega = 1/\sqrt{LC}$? (Remember the factor of $2\pi$ between frequency versus angular-frequency.) At resonance, what happens to the impedance of the circuit (as seen by the voltage source)?
   b. Do a transient (time-domain) analysis showing the voltage across the inductor in response to a square-wave input with 1 ms period and 0.05 ms rise and fall times.