Due in class Friday September 18. Since this is the week of Exam 1, note that the volume of this problem set has been reduced to a compassionate 6 problems.

To make life easier on the graders:
- Be sure your NAME and ECE MAILBOX NUMBER are prominently displayed on the upper right of what you hand in.
- When appropriate, indicate answers with a box or underline
- Work as neatly as possible
- Be sure answers have UNITS (Amps, Volts, etc.) associated with numerical values

Textbook problems are from Hambley (Sixth Edition)

1. P3.2 (p. 153) [Capacitance concepts]
2. P3.4 (p. 153) [Capacitance concepts]
3. P3.6 (p. 153) [Capacitance concepts]
   Sketch the capacitor voltage vs. time to help visualize the discharging process.
4. P3.8 (p. 153) [Energy storage using capacitor]
   This is why electrical energy for automotive applications is stored in chemical form (battery) rather than in the electric field of a capacitor.
5. In the figure shown below, a 60Hz, 230V peak sine wave is applied to a 4700µF capacitor.

   ![Capacitor Circuit Diagram]

   a) Carefully sketch the capacitor voltage \( v(t) \) and current \( i(t) \) for a time range of 0 to 50ms.
   b) Carefully sketch the power absorbed by the capacitor as a function of time.
   c) Over the 0 to 50ms time interval, during which time periods is the capacitor absorbing power? During which time periods is it delivering power?
   d) What is the average power absorbed by the capacitor over one cycle of the sine wave?
6. In Lab 1 you measured the DC voltage-current characteristic of a 9V battery. The goal was to determine the values of $V_s$ and $R_s$ for a Thevenin model of the battery as shown in Figure 3-6a below. The technique was to first measure the battery voltage with no load, which gives $V_s$ directly since there is no voltage drop across $R_s$ when $i_L=0$. Then, you load down the battery with different values of $R_L$, drawing different load currents $i_L$, and from the data points you plot the $v_L$-$i_L$ characteristic which allows you to determine $R_s$.

![Figure 3-6a](image)

Figure 3-6a

However, a number of people noted a problem with the simple Thevenin model of Figure 3-6a: after removing $R_L$, even with $i_L=0$, the output voltage did not return to the same DC value initially measured! This is inconsistent with the expected behavior for a DC voltage source, which should be constant over time.

Some people correctly noted that this is probably due to the load current discharging the battery. Can we modify our battery model to take this into account? The answer is yes; and the idea of current ($i_L$) causing a voltage that changes over time ($dv_L/dt$) leads naturally to modifying the model as shown in Figure 3-6b. We replace the voltage source with a capacitor $C_b$ charged to an initial condition voltage equal to the first measured value of battery voltage.

![Figure 3-6b](image)

Figure 3-6b

To make the problem a little easier, we imagine that we have a controllable current source available in the lab to run the test. The test and measured waveforms are shown in Figure 3-6c. Voltage $v_L$ is measured using the DVM with 1mV resolution.
With no current drawn for time $t<0$, the output voltage measured on the DVM is 9.272V.

At time $t=0$, the current source is turned on with a DC current of 30mA. The output voltage immediately drops to 8.794V, but as you keep watching the DVM the output measurement continues dropping slowly.

After 100 seconds, the output voltage has dropped to 8.778V.

At $t=100$ seconds, the current source is switched off and the output voltage goes up to 9.256V, a little bit lower than the initial value.

a) From this measured data, determine values for $R_s$ and $C_b$ in the model of Figure 3-6b. Note that $C_b$ is much larger than the typical values of a purely electrical capacitor, due to the much greater volumetric efficiency of charge storage in a chemical mechanism (as you found in problem P3.8).

b) What is the initial charge stored in $C_b$? Sanity check: Does this make sense compared to the nominal battery capacity of 500 mA-hr for the 9V battery we use in lab?