Object: (a) To study the voltage-time relationship in a charging and discharging capacitor and to measure the circuit's time constant, τ. (b) To use an RC circuit with a neon bulb to measure the capacitance. (c) to study two special RC circuits, the differentiator and the integrator.

Theory:

Determining C with a Neon bulb: When a voltage is applied to a neon bulb, no current will flow until the voltage has been increased to the point where the neon gas has become ionized. The ionizing voltage will be called V_{on}. Once the gas has been ionized it will remain ionized and continue to conduct even though the applied voltage is somewhat reduced. The voltage at which the gas returns to its unionized state and at which the bulb ceases to conduct will be called V_{off} ($< V_{\text{on}}$).

If a neon bulb is connected in parallel with the capacitor in an RC circuit powered by a voltage source as shown in figure 1, the voltage will gradually build up until the ionizing potential of the neon bulb is reached. At this point the bulb suddenly begins to conduct—thereby discharging the capacitor. This is seen as a brief flash in the bulb. After the discharge, the capacitor will begin to charge up again and another flash will occur. This process repeats over and over again causing the bulb to flash or blink at regular intervals. See problem P28.62 in Serway and consider our neon bulb as the voltage-controlled switch. The time between flashes T can be calculated mathematically as follows:

$$V_C = V_0(1 - e^{-t/RC}) \tag{1}$$

$$t = RC \ln\left(\frac{V_0}{V_0 - V_C}\right) \tag{2}$$

$$T = t_{\text{on}} - t_{\text{off}} = RC \ln\left(\frac{V_0 - V_{\text{off}}}{V_0 - V_{\text{on}}}\right). \tag{3}$$

Where t_{on} and t_{off} are the time from the completely uncharged state. This works as long as the resistance of the conducting bulb is negligible, which it is. However, a more complete derivation is patterend after Serway P28.62.

The period T is from one peak to the next and consists of a discharging interval, t_1, and a charging interval, t_2. Then $T = t_1 + t_2$.

During t_1, $V_C(t) = V_{\text{on}}e^{-t/R_BC}$ and continues until $V_C = V_{\text{off}}$. So $V_{\text{off}} = V_{\text{on}}e^{-t/R_BC}$ which gives $t_1 = R_BC\ln(\frac{V_{\text{on}}}{V_{\text{off}}})$.

During t_2, the charging interval, $V_C(t) = V_0 - (V_0 - V_{\text{off}})e^{-t/(R_a+R_B)C}$. When solved for t_2 it yields

$$t_2 = (R_a + R_B)C\ln\left(\frac{V_0 - V_{\text{off}}}{V_0 - V_{\text{on}}}\right) \tag{4}$$

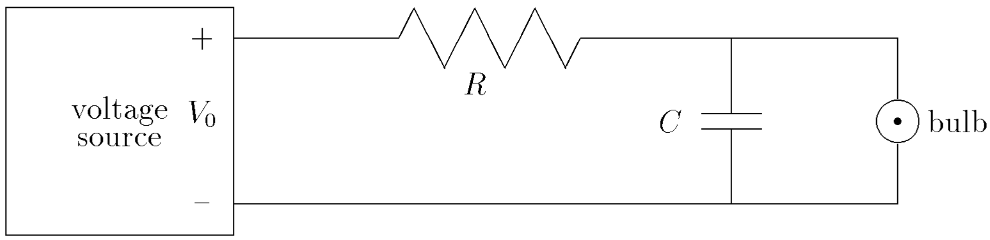

Figure 1: Circuit for determining C with a Neon Bulb

Procedure: Use a breadboard to wire up the circuits (see my website for pictures and explanation).

Determining C with a Neon bulb:

1. First determine V_{on} and V_{off} directly without the capacitor in the circuit. Make sure you have at least a 10 kΩ current-limiting resistor in series with the bulb so as to not blow out the bulb. Use a voltmeter across the bulb to measure V_{on} and V_{off} as you slowly ramp up the voltage on your power supply, then back down again.

2. Connect up an RC circuit with the neon bulb as per figure 1 (V_0 must be greater than V_{on}). Use a resistor with a large R, in the MΩ range, and a capacitor with C in the μF range or slightly lower. Measure the period T by counting the number of flashes in a given time ($T = 1/f$). From the period T, the resistance R, the applied voltage V_0, and the bulb voltages V_{on} and V_{off}, calculate the value of the capacitance used in the circuit, and compare with the stated value. (For time periods that are too short to count visually, use an oscilloscope to display the waveform of the capacitor voltage. The period T can be determined from the oscilloscope display.)

3. Repeat the previous procedure with two capacitors in series or in parallel to see if they obey equations 26.8 and 26.10 in Serway.