**Objective:** to investigate the charging and discharging of capacitors, and to see what this behavior can tell us about different electrical meters.

**Equipment:** epoxy capacitor (10 µF, 100 V), Simpson multimeter, digital electronic multimeter, GLX Xplorer lab datalogger, battery (9 volt), stopwatch, red and black leads (alligator to banana)

The numbers written on the capacitor are 106 K and 100V. The 106 is to be interpreted as 10 x 10^6 picofarads. This equals 10 x 10^6 x 10^-12 farads = 10 x 10^-6 farads = 10 micro farads = 10 µF. The K means that the accuracy of this item is 10%. The 100V means that this item can withstand up to 100 volts across its two legs, but no more than that.

**Background:**
Define farad:

Define “time constant” of exponential decay:

State the “time constant” of a circuit with a capacitor and a resistor. T =

Two primary issues are related in this lab. The first idea is capacitor charge and discharge.

The second idea is the internal resistance of the three devices which we will use to discharge the capacitor. By carefully measuring the “time to discharge to almost zero” with a stopwatch we can work backwards and calculate the internal resistance of each of the three devices.

**Procedure:**

1. **Mathematical model of exponential decay**
   Open an Excel spreadsheet to calculate the expected values of voltage from a capacitor which is discharging from some initial value, say 9 volts. Let the time constant T be 2 seconds.
   In the main table let the time range from 0 to 15 seconds in increments of half a second.
   In the next column calculate the voltage as V =

   Plot V vs. time
   In the next column label the times which are T, 2T, 3T, etc.
   In the next column calculate the ratio V / V initial.
   Are these ratios what you expected?
   We will take 5T as representing “time to discharge to almost zero,” OK?
2. **The first experiment: a standard Simpson multimeter.**

It is important that the meter be set up as pictured and that the capacitor is connected to the meter before it is charged with the 9V battery. Please be careful to avoid bending the capacitor leads any more than is absolutely necessary.

Use the red lead to connect the red mark (by the K in 106 K) on the capacitor to the DC V terminal on the Simpson meter. Place the red mark (plus end) on the 9V battery aligned with the red mark on the capacitor. As a brief test, momentarily touch the leads of the capacitor to the battery. The meter should read 9V on the 10V scale as long as you keep the battery connected. The instant you disconnect the battery, the meter will start to return toward zero.

With the stopwatch measure the time the meter takes to return to zero after the battery is disconnected. After each part of the experiment you should fully discharge the capacitor by shorting the leads with a small wire. Repeat three more times and record these times in your spreadsheet.

Calculate the average of your four discharge times. __________________

The time constant \( T \) is 1/5 of this “time to discharge to almost zero” = ____________
We can use this time constant $T$ to calculate the resistance $R$ of the meter itself by $R = T/C$ where $C = 10 \, \mu F$, so $R = \underline{\underline{}}$ for the Simpson meter.

3. The second experiment: digital electronic multimeter
Setup the circuit pictured, with the knobs in the indicated positions. Do not connect the meter until the knob positions are set and do not move them for any reason as damage to the meter can easily occur. Also do not charge the capacitor at this point.

With the stopwatch measure the time the meter takes to return to zero after the battery is disconnected. After each part of the experiment you should fully discharge the capacitor by shorting the leads with a small wire. Repeat three more times and record these times in your spreadsheet.

Calculate the average of your four discharge times. \underline{\underline{}}

The time constant $T$ is 1/5 of this “time to discharge to almost zero” = \underline{\underline{}}}
We can use this time constant $T$ to calculate the resistance $R$ of the meter itself by $R = \frac{T}{C}$ where $C = 10 \, \mu F$, so $R = \frac{T}{10 \, \mu F}$ for the digital electronic meter.

4. **The third test: using the Xplorer GLX handheld datalogger**

Turn on the GLX by holding the power button (lower right) for a couple of seconds.
Wait for it to boot-up to the “home screen.”

Plug-in the Voltage probe and note that the screen changes to the view with the zeros (0.00).

We will want a graph so press the home key, and again you will see the home screen. Using the arrow keys move the highlighted area to the lower left Graph screen, then select it with the check key (It is surrounded by the arrow keys).
You should now see a Voltage vs. Time graph as shown here.

Make the physical connections as shown in the first picture in this section. The triangular “play” key will start and stop the recording of voltage data, but do not use it until you make the physical connections. Be mindful of the red dots, as before. As a brief test momentarily touch the leads of the capacitor to the battery. Press the play key. The Xploer GLX meter should read 9V on the graph as long as you keep the battery connected. The instant you disconnect the battery the GLX graph will start to return to zero. Also note that the changing time and voltage are displayed near the top of the graph.

With the stopwatch measure the time the meter takes to return to zero after the battery is disconnected. After each part of the experiment you should fully discharge the capacitor by shorting the leads with a small wire. Repeat three more times and record these times in your spreadsheet.

Calculate the average of your four discharge times. __________________

The time constant T is 1/5 of this “time to discharge to almost zero” = ___________

We can use this time constant T to calculate the resistance R of the meter itself by $R = \frac{T}{C}$ where $C = 10 \ \mu F$, so $R = _________________________$ for the GLX Xplorer.

5. **Summary**

<table>
<thead>
<tr>
<th>Type of meter</th>
<th>T, time constant (s)</th>
<th>R, meter’s resistance (ohm)</th>
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</thead>
</table>

Conclusions:

6. **Future work:**