Your TA will use this sheet to score your lab. It is to be turned in at the end of lab. You must use complete sentences and clearly explain your reasoning to receive full credit.

What are we doing this time?
You will complete two related investigations.

PART A:
Build capacitor circuits on circuit board, investigating current flow and voltages.

PART B:
Build resistor circuits, and measure current and voltage.

Why are we doing this?
Capacitors are almost as ubiquitous as dipoles, showing up almost everywhere there is an insulator. Actually, capacitors have some similarities to dipoles, with equal and opposite charges on the electrodes. That charge has to flow through something to get to the capacitor. The same holds for resistors. The ideas of current flow, current splitting along different paths, and potential differences, are essential ideas in all circuits.

What should I be thinking about before I start this lab?
You should be thinking about the aspects of capacitors you looked at in lecture and discussion. In particular, how the voltage across the capacitor is related to the charge on it, and how the current in a circuit delivers charge to a capacitor. Also how charge moves in a circuit, and that charge must always be conserved – it can be neither created nor destroyed.
For the first part of the lab, you use the circuit board below.

Holes connected by black lines are electrically connected by conducting wires, so all points connected by black lines are at the same electric potential. You build a circuit by plugging in resistors and capacitors across the gap between crosses. The capacitors and resistors are built into plastic blocks with banana-plug connectors that exactly bridge the gaps. After you plug in a block, there will still be unused holes in each cross. You will use the remaining holes to connect the variable voltage source to supply your circuit with charge, and to connect the electrometer (capacitor circuits) or Keithley Digital Multimeter (resistor circuits) to measure potential differences and currents at various points in the circuit.
A. Capacitor circuits.

You use the electrometer and the voltage probes to measure voltages. Connect the red probe to the electrometer ‘input’ connection, and the black probe to the electrometer ‘ground’ input with black coaxial cables (not the banana plug cables). You don’t need any adaptors: the coaxial cable connects directly to the probe and to the electrometer.

1) **Series capacitors**: you will build the circuit below and measure it, but first predict how the 9V provided by the voltage supply will split among the two series capacitors.

\[ V_{\text{across C1}}: \quad V_{\text{across C2}} \]

Build the circuit below (note that the power supply is not connected).

a) First, temporarily short out each capacitor, by plugging it into the metal holder, to make sure there is no charge separation between the plates.

b) Set the voltage supply to 9V. Touch the black and red voltage supply leads across the series circuit, then **disconnect** both the black and red leads from the circuit.

c) Use the electrometer to measure the voltage drops across each capacitor individually with the supply disconnected. Compare these to your prediction.
2) Parallel capacitors.
Here you connect capacitors in parallel to see how they share charge. Start by discharging both capacitors. You first charge up C1 (the 0.47 µF capacitor) to 9V, then disconnect the voltage supply. The electrometer will not measure correctly unless you disconnect the power supply. You then connect the 1 µF capacitor in parallel.
a) Do a calculation here to predict the final voltage across the capacitors.

Now do the experiment:

b) Measure the voltage drop across each capacitor with the electrometer. Remember that the power supply is disconnected here. How does this compare with your predicted value?
B. Resistor circuits.

1) Measuring current and voltage. Build the circuit below using first the resistor labeled 10k\(\Omega\) resistor for R. Then use 20k\(\Omega\) and 100k\(\Omega\). Set the voltage supply to 9V:

![Circuit diagram]

The digital multimeter (DMM) can be configured to measure current, voltage, or resistance. Here you want to measure current. Press the ‘A’ button for amps, then ‘2m’ for a 2 mA scale. The DMM now acts as an ammeter, and it displays how much current flows through it. In this mode it is very low resistance. So it acts like a connecting wire while measuring current, and doesn’t alter the properties of the circuit. Positive current flowing into the red terminal of the DMM and out of the black terminal gives a positive reading on the display.

Which way do the electrons move?

How much work is done by the power supply to move one electron around the circuit?

Complete the following table. The resistor labels are ‘nominal’ values — the actual resistance is likely to be a little different. These resistors are guaranteed to be within 10% of their labeled value.

<table>
<thead>
<tr>
<th>Resistor</th>
<th>Voltage V</th>
<th>Current I</th>
<th>(V / I = \text{Calc. Resistance})</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 k(\Omega)</td>
<td>9.0V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 k(\Omega)</td>
<td>9.0V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 k(\Omega)</td>
<td>9.0V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2) Now build the circuit below, and measure the current. Here the ‘wire’ is a plug-in block that is a metal conductor.

Explain in words whether the measured current will increase, decrease, or stay the same when you remove the 10 kΩ resistor. Then pull it out and see if you were right.

Calculate the value of the current you measured above.
3) *Voltage drops around the circuit, and measuring current with voltage drops.* In part 2) you saw that the DMM can measure current directly, but it must be inserted in the path of the current so that current can flow through it. This makes it difficult to quickly probe current in different parts of the circuit.

Press the ‘V’ button on the DMM so that it displays the electric potential difference between its red and black terminals. In this mode, almost no current at all flows through the DMM – it acts like an extremely large resistor while measuring voltage.

Then press the ‘Auto’ button so that it changes scales automatically.

Explain why you use the DMM to measure the current through a resistor by measuring electric potential difference (voltage drop) between the two ends of the resistor.

Now make the circuit below

![Circuit Diagram]

Use the voltmeter to determine the current through each of the resistors by measuring voltage drops. Write the current below.

Current through R1: _______________  
Current through R2: _______________
In the next step you will put a 20 kΩ resistor (call it R3) in parallel with R2. But before making the circuit, predict whether currents through R1 and R2 will increase or decrease.

Current through R1: 
Current through R2: 

Explain:

Now build the circuit below, and determine the voltages and currents.

Voltage across R1: 
Voltage across R2: 
Voltage across R3: 
Voltage across wire block: 

Current through R1: 
Current through R2: 
Current through R3: 
Current through wire block 

Explain how this agrees or disagrees with your prediction.

Explicitly verify that current is conserved at the node indicated above by showing that the current flowing into the node is the same as the current flowing out.