As you have seen in lecture and lab, it is useful to think of electric current as a flow. More specifically, the flow of charged particles through the wires, light bulbs, and other materials that make up a circuit.

I. Visualizing resistivity and Ohm’s law

As charged particles move through matter, they encounter “obstacles” along the way. Materials with more obstacles have a larger resistivity. Use your phone to google “phet resistivity,” and open the simulation. The simulation is called “Resistance in a Wire” and is at the URL https://phet.colorado.edu/en/simulation/resistance-in-a-wire

First, play with the simulation until you have a feel for what is going on. Adjust the various sliders and see how they affect the picture and the resistance.

A. Now think about how quantities are related:
   1. What happens to the resistance of the piece of wire if the length of the wire is doubled, while the resistivity and the cross-sectional area are held constant? Does the resistance double as well?

   2. What happens to the resistance if the cross-sectional area is doubled?

   3. What happens to the resistance if the resistivity is doubled?

   4. Is it possible for the length to double, but the resistance to stay constant? If so, how could that happen?

Resistivity is a property of a particular material, which characterizes how that material conducts electricity. The resistivity depends on temperature. The resistivity of a small piece of a material (say, aluminum) has the same value as the resistivity of a large piece at the same temperature. The resistance $R$ of a particular circuit component depends on the length of the component and on its cross-sectional area, as well as the resistivity of the material of which it is made. Metals usually obey Ohm’s Law, which means that the resistivity is independent of the electric field, so that $E$ is directly proportional to the current density $J$. 
B. Think of an analogy to the scenario in the PhET simulation. Analogies you might use are:

- cars driving along a street through a succession of traffic lights, or
- water flowing through a section of pipe.

Discuss the analogy with your partner. Try to make it as “tight” as possible – by connecting each aspect of the analogy to a corresponding aspect of the flow of charge through a wire. Once you have worked out your analogy:

1. Describe the change in the analogy system that corresponds to an increase in resistivity.

2. Describe the change in the analogy system that corresponds to an increase in cross-sectional area.

II. Resistors in series and parallel

Four identical resistors are attached to a sea of electrons in the two configurations shown. On the left they are attached together end to end, and on the right, side by side. The other ends of the resistors are connected to a positively charged plate with a conducting rod. (Assume the rod has zero resistance.)

A. In which configuration will it be easiest for the electrons to flow to the positively charged plate?

B. In which configuration will the number of electrons that flow in a given unit of time (say, one second) be greatest?

C. Explain in words your choices in terms of what you observed in the simulation.
III. Quantitative analysis of resistors in parallel

Two resistors, \( R_1 = R_2 = R \), are connected in parallel in a circuit. A portion of the circuit is shown at right.

A. Rank the currents \( I \) at the labeled points (\( A – F \)). Explain.

B. Is the voltage drop \( V_1 \) across \( R_1 \) greater than, less than, or equal to the voltage drop \( V_2 \) across \( R_2 \)? Explain in words.

C. If this network were connected directly to a 4.0 V battery and \( R_1 = R_2 = 4 \) \( \Omega \), what current \( I \) would flow through each of the labeled points? Show your work and provide correct units.

IV. Quantitative analysis of resistors in series

Two resistors, \( R_1 = R_2 = R \), are connected in series in the following circuit.

A. Rank the currents \( I \) at the labeled points (\( A – C \)). Explain.

B. Is the voltage drop across \( R_1 \) greater than, less than, or equal to the voltage drop across \( R_2 \)? Use Ohm’s law to support your answer.

C. This network is connected directly to a battery and the current through point \( A \) is found to be \( I_A = 0.5 \) A. If \( R_1 = R_2 = 4 \) \( \Omega \), determine the voltage \( V \) of the battery with correct units. Discuss your reasoning with your partners.