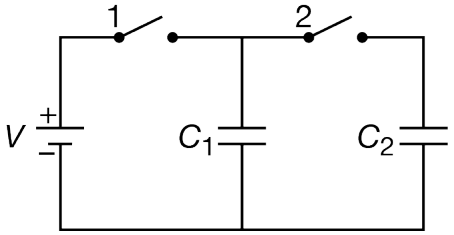
PHYS 1120 Discussion 4:
Capacitance, Resistivity, and Drift Speed

Problems

As usual, there is no room on this sheet. Use scratch paper.

1. Two capacitors are connected in a circuit with a voltage source and two switches, as illustrated below.



   a. Switch 1 is closed, so that voltage V is across capacitor 1. What is the charge Q_1 of capacitor 1?

   b. What is U_1, the energy stored in capacitor 1?

   c. Suppose V = 12.0 V and C_1 = 30 μF. What are Q_1 and U_1?

   d. Switch 1 is then opened, so that Capacitor 1 is charged and isolated. Afterwards, switch 2 is closed, so that capacitors 1 and 2 are together in a circuit. Charge will flow from capacitor 1 to capacitor 2 until they equilibrate at the same voltage.

      i. What is their new voltage?

      ii. What are the charges on the two capacitors?

      iii. What is the total energy stored in the two capacitors?

   e. Suppose C_2 = 90 μF, and the other quantities are as given in part c. What is the voltage across the capacitors, what are their charges, and what is the total energy stored in them?

2. A capacitor with capacitance C is charged to voltage V.

   a. What is the charge on the capacitor?

   b. What is the energy stored in the capacitor?

   The capacitor is disconnected from the voltage source while it is still charged. The gap between its plates is filled with a dielectric of dielectric constant κ, changing its capacitance to κC.

   c. What is the voltage across the capacitor now? Express in terms of κ and V.

   d. What is the energy stored in the capacitor? Express in terms of κ, C, and V.

The capacitor, with the dielectric, is reconnected to the voltage source so that it is charged to voltage V.

e. What is the charge on the capacitor now?

f. What is the energy stored in the capacitor?

3. A 1000-Ω resistor is connected to a 1.5 V voltage source.

   a. What is the current through the resistor?

   b. In most circuits, the charge carriers are electrons. Each electron has a charge of 1.602×10^{-19} C. In one second, how many electrons pass a given point in the circuit?

   c. Suppose that the resistor is constructed of a very thin copper wire wrapped around an insulator so that the length of the wire occupies a small volume. If the resistor has a cross sectional radius of 10^{-6} m, how long is the thin wire that makes up the resistor? $R = \rho L/A$, where $\rho = 1.68\times10^{-8}$ Ωm is the resistivity of copper, L is the length of the wire, and A is its cross-sectional area.

   d. Copper has one conduction electron per copper atom; the other electrons are bound to the nucleus and are not mobile in the circuit. What volume of copper contains the number of electrons you found in part b? The number density of copper is 8.5×10^{28} atoms/m^3.

   e. What length of wire contains the volume you found in part d?

   f. The *drift speed* is the average transport speed of the electrons moving through the wire. The length of wire containing the number of electrons passing by a point in one second is the distance a single electron must travel in one second. What is the drift speed?

   g. If a single electron is accelerated from rest by a voltage of 1.5 volts, what is its speed? The mass of an electron is 9.1095×10^{-31} kg.

   h. How does the speed of the accelerated electron compare to its drift speed in the wire?