Physics 22: Homework 5

The following exercises encompass problems dealing with capacitor circuits.

1. As in Figure 1, consider three identical capacitors—each of capacitance, C—arranged linearly between points a and b. Whereas Figure 1a consider these same capacitors with perfect conductors connecting different parts of the circuit, as shown in Figures 1b and 1c. Determine the equivalent capacitance in each of the arrangements shown in Figure 1.

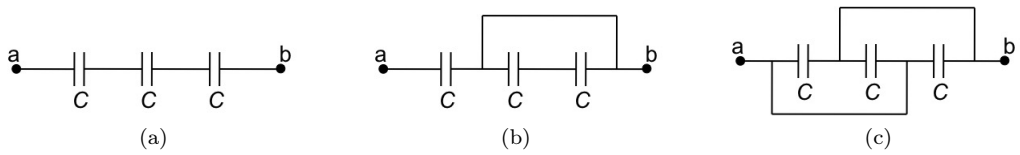

Figure 1: Identical capacitors in a linear arrangement across points a and b. Variations are made in (b) and (c) with ideal conducting wires connecting different parts of the original arrangement shown in (a).

2. Consider the capacitor combination circuits shown in Figures 2, 3, and 4, which serve as individual parts. In these figures, $C_n = nC$ for $n = 1, 2, 3, 4, 6,$ and 8, a battery, of potential V_{ab}, is placed between the points a and b.

   (a)

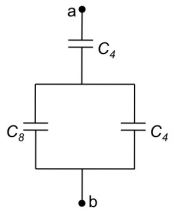

Figure 2: Two capacitors, C_4, are arranged with a single capacitor, C_8, in between electrodes a and b.

   i. Determine the equivalent capacitance, C_{ab};
   ii. Determine the potential difference across each capacitor in the circuit;
   iii. Determine the charge on each capacitor in the circuit;
   iv. Determine the equipotentials in the circuit.
   v. If C_8 is rated for a voltage V, while the C_4 capacitors are rated at $5V$ each, what is the maximum voltage that can be applied between points a and b without generating a breakdown in any of the capacitors?

   (b)

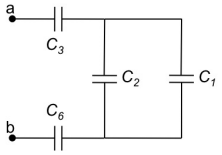

Figure 3: Capacitors C_1, C_2, C_3, and C_6 are arranged in between electrodes a and b.

   i. Determine the equivalent capacitance, C_{ab};
   ii. Determine the potential difference across each capacitor in the circuit;
   iii. Determine the charge on each capacitor in the circuit;
   iv. Determine the equipotentials in the circuit.
   v. Suppose C_1 is disconnected.
      A. Does the energy in C_6 increase or decrease? Apart from your quantitative result, explain the result using a qualitative argument as well.
      B. Does the energy of the entire circuit increase or decrease? Apart from your quantitative result, explain the result using a qualitative argument as well.

(c)

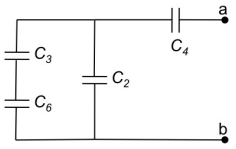

Figure 4: Capacitors C_2, C_3, C_4, and C_6 are arranged in between electrodes a and b.

i. Determine the equivalent capacitance, C_{ab};
ii. Determine the potential difference across each capacitor in the circuit;
iii. Determine the charge on each capacitor in the circuit;
iv. Determine the equipotentials in the circuit.
v. If only C_6 may be replaced with another capacitor, what is the largest possible amount of energy that the circuit can store with the potential, V_{ab}, provided?

3. A 5.0-μF capacitor is charged to 50 V, and a 2.0-μF capacitor is charged to 100 V. The two are disconnected from charging batteries and connected in parallel, with the positive plate of one attached to the positive plate of the other.

   (a) What is the common voltage across each capacitor after they are connected in this way?

   (b) Compare the total electrostatic energy before and after the capacitors are connected. Speculate on the discrepancy.

   (c) Repeat Parts (a) and (b) with the charged capacitors being connected with the positive plate of one attached to the *negative* plate of the other.

4. When a switch is open, there can be a potential difference across it. (Indeed, an open switch effectively acts like a capacitor; although, the capacitance is quite small, particularly because of the relatively small area of the electrodes.) When a switch is closed, charges flow until the two ends of the switch are at the same potential (with the conducting system reaching electrostatic equilibrium). In the circuit shown in Figure 5, point a is grounded and point b is at a voltage of $V_{\text{b}} = +6V$. Also, $C_1 = C$ and $C_2 = 2C$, and the switch is in between points c and d.

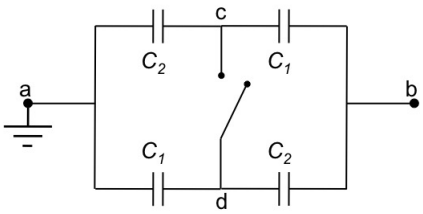

Figure 5: Capacitors C_1 and C_2 are arranged in between two electrodes: a that is grounded, and b that is held at a higher potential. A switch exists between points c and d which is initially open, but then is closed.

   (a) Determine the potentials, with respect to ground, of points c and d when the switch is open.

   (b) Determine the potentials, with respect to ground, of points c and d when the switch is closed.

   (c) How much charge actually flowed through the switch after it was closed?