

Unit 24 Homework Problems**Learning Goals:**

- F.24 Identify the variables that affect the capacitance and how each affects the capacitance.
A.24 Quantitatively analyze the time-dependent behavior of an RC circuit.

24-1) Capacitance:

- (a) What is the physical description of a capacitor?
(b) What is the mathematical definition of capacitance?
(c) Based on the physical description of capacitance, why would you expect a plate to hold more excess charge on each of its conducting surfaces when the voltage difference between the two pieces of conductor increases?

24-2) Consider the attraction and repelling of different types of charge.

- (a) Explain why you expect to find that the amount of charge a battery can pump onto a parallel plate capacitor will double if the area of each plate doubles.
(b) Explain why you expect to find that the amount of charge a battery can pump onto a parallel plate capacitor will be cut in half if the distance between each plate doubles.

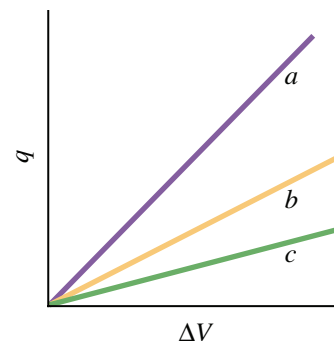
24-3) *Capacitors in parallel:* Look over the prediction and observations you made in Activity 24.5.1. Give as clear an explanation as possible as to why it is physically reasonable to expect that two identical parallel plate capacitors placed in parallel ought to have twice the capacitance as one capacitor. **Hints:** What happens to the effective area of capacitors wired in parallel? What does the fact that like charges repel each other have to do with anything?

24-4) *Capacitors in series:* Look over the prediction and observations you made in Activity 24.5.2. Give as clear an explanation as possible as to why it is physically reasonable to expect that two identical parallel plate capacitors that are placed in series ought to have half the capacitance as one capacitor. **Hints:** What happens to the effective spacing between the first plate of capacitor 1 and the second plate of capacitor 2 when they are wired in series? What does the fact that like charges repel each other have to do with anything?

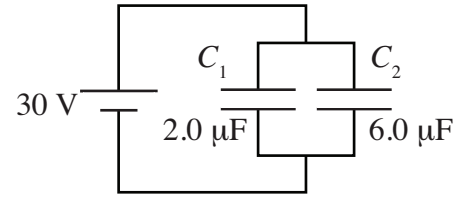
24-5) Suppose you have three capacitors as follows:

- Capacitor 1: Area A , spacing d
Capacitor 2: Area $2A$, spacing d
Capacitor 3: Area A , spacing $2d$

The three graph lines (labeled a, b and c) represent data for the magnitude of charge on the plates of each capacitor as a function of the voltage across it. Which capacitor {1, 2, or 3} belongs to which line {a, b, and c}? **Explain** your reasoning carefully.



24-6) Two capacitors are connected to a 30V battery as shown in the circuit to the right. Using text equations to show your work (For example, $C = Q/\Delta V$), find:

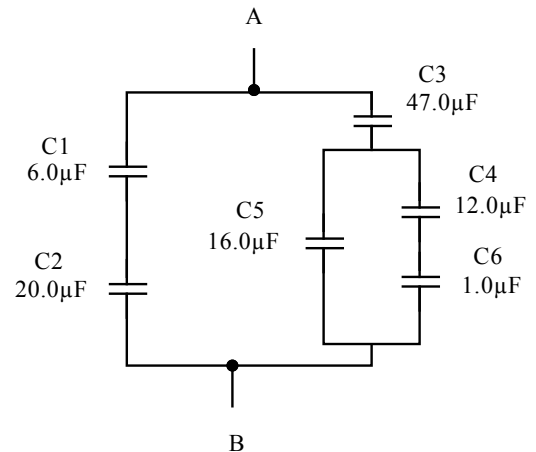


- (a) the equivalent capacitance in the circuit,
- (b) the voltage across each of the capacitors,
- (c) the excess charge on each of the capacitors.
- (d) Which plate on C_1 has excess negative charge on it, the top one or the bottom one? Explain.

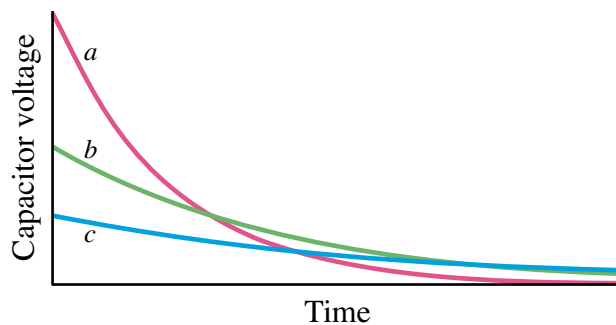
24-7) Physicists claim that charge never flows *through* an ideal capacitor. Yet when an uncharged capacitor is first placed in series with a resistor and a battery, current flows through the battery and the resistor. Explain how this is possible.

24-8) What is the *net* charge on a capacitor in a circuit? Is it ever possible for the charge on one conductor to be different than the charge on the other conductor? Explain.

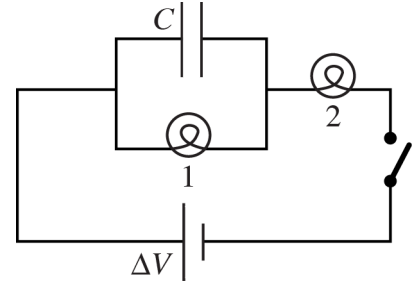
24-9) Use appropriate equations such as $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$ or $C = C_1 + C_2$ to find the equivalent capacitance of the network between points A and B shown in the figure to the right. You must show your work.



24-10) The figure below shows plots of voltage, $\Delta V(t)$, across a capacitor as a function of time for three different capacitors that have each been separately discharged through the same resistor. Rank the plots according to the capacitances, listing the greatest first. Explain the reasons for your rankings.

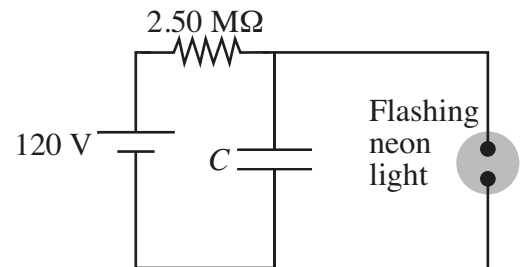


- 24-11) R-C Circuit Behavior** Consider a circuit with two bulbs, a switch and a capacitor connected to an ideal battery in the arrangement shown on the right. What do you think will happen to the brightness of each of the two bulbs from the time the switch is first closed to a long time afterwards?
Hint: What will the voltage across C be when the switch is first closed? How about after a long time?



- 24-12)** Suppose a capacitor of $C = 3.0 \mu F$ with no excess charge on it is suddenly connected in series with a resistor of $R = 457 \Omega$, and an ideal battery of voltage $\Delta V = 30 \text{ V}$. How long will it take for the capacitor to gain 80% of the charge it will eventually have when current stops flowing through the battery?
- 24-13)** Suppose a capacitor having a capacitance of C is fully charged to a voltage ΔV and then discharged through a resistor R . Derive the equation (in terms of C , ΔV , and R) that shows how long a time the capacitor will take to lose 40% of its charge. (Be sure to read that last sentence a couple of times, and also make sure you know what information you are finding with the RC discharge equation.)

- 24-14)** Intense flashing lights are often found at highway construction sites. The circuit used to create a flashing light often has a capacitor in parallel with a neon light as shown in the diagram below. This type of circuit is known as a relaxation oscillator. The neon light acts like a switch that is open until it reaches a breakdown voltage. At the point where the voltage across the capacitor is at breakdown the light conducts and has almost no resistance and the capacitor, C , discharges through the lamp in a tiny fraction of a second. The light flashes and switches off very rapidly and the battery starts charging the capacitor once more.



Suppose, your engineering group has the task of designing a highway relaxation oscillator that flashes twice a second. If the break down voltage of your neon lamp is 90.0 V and you have a $2.50 \text{ M}\Omega$ resistor, what value of capacitance should the capacitor have?