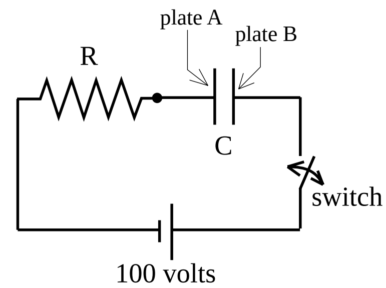
Capacitors -- Conceptual Questions



1.) You have a power supply whose low voltage "ground" terminal is attached to a resistor whose resistance is $R = 10^4$ *ohms*. The resistor is attached to a plate (we'll call it *plate A*) which is next to, but not connected to, a second plate (we'll call it *plate B*). Reiterating, THERE IS NO CONNECTION between *plate A* and *plate B*. There is, additionally, no initial charge on either of the plates. Attached to *Plate B* is a switch. On the other side of the switch is the high voltage "hot" terminal of the power supply. A sketch of the situation is shown. At $t = 0$, the switch is thrown.

a.) Current initially flows between the high voltage terminal and *Plate B*. Why? That is, what's going on?

b.) Current initially flows from *Plate A* through the resistor and back to the ground of the power supply. Why? That is, what's going on?

c.) What is the two-plate device called?

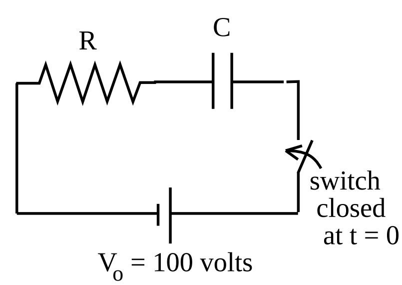
d.) After a while, there is a voltage $V = 10$ *volts* across the plates. At that point in time, there is 10^{-10} Coulombs of charge on *plate B*. The ratio of the *charge to voltage* is 10^{-9}.

i.) How much charge is on *plate B*?

ii.) What is this ratio called?

iii.) At some later point in time, the voltage across the plates is doubled. What is the ratio of *charge to voltage* in that case? Explain.

2.) What do capacitors (often referred to as *caps*) generally do in DC circuits? Give an example.



3.) A 10^{-6} *farad* capacitor is in series with a 10^4 *ohm* resistor, a battery whose voltage is $V_o = 100$ *volts*, and a switch. Assume the capacitor is initially uncharged and the switch is thrown at $t = 0$.

a.) The capacitance value tells you something that is always true no matter what the voltage across the capacitor happens to be. What does it tell you?

b.) What is the initial current in the circuit?

c.) What is the current in the circuit after a long period of time?

d.) How much charge will the capacitor hold when fully charged?

e.) How much energy is wrapped up in the capacitor when fully charged?
f.) Where is the energy stored in the capacitor?
g.) You are told that the time constant for the system is 10^{-2} seconds.
i.) What does that tell you about the system?
ii.) How much charge will be on the capacitor after one time constant?
h.) After a very long time, the switch is opened. What happens to the capacitor? Will it hold its charge forever?

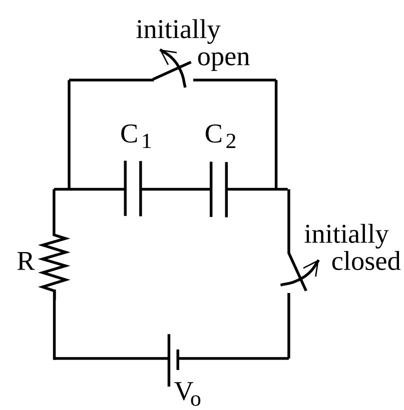
4.) Can you have capacitance if you have only one plate?

5.) You have a series combination of capacitors.
a.) What happens to the equivalent capacitance when you add another capacitor?
b.) What is common to all the capacitors in the series combination?

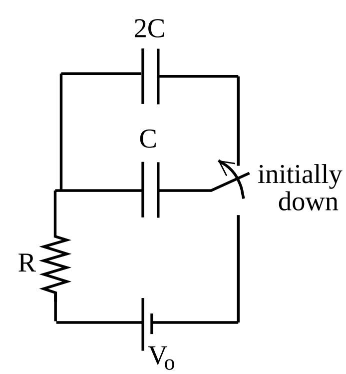
6.) You have a parallel combination of capacitors.
a.) What happens to the equivalent capacitance when you add another capacitor?
b.) What is common to all the capacitors in the parallel combination?

7.) You charge up two single capacitors that are in parallel. You disconnect the battery. What happens to the current in the system when you do this?

8.) You charge up two unequal capacitors that are in series. You disconnect the battery, then reconnect the two capacitors by throwing *both* switches.
a.) What happens to the current in the system when you do this?
b.) Out of curiosity, why was the resistor included in the circuit?



9.) You use a battery whose voltage is V_o to charge up a capacitor C. When fully charged, there is q's worth of charge on the cap. You then disconnect the capacitor from the battery and reconnect it to a second uncharged capacitor whose capacitance is $2C$ (in the sketch, this disconnection, then reconnection, is done with the switch).
a.) What is the voltage across the second capacitor?



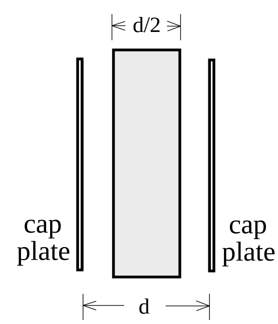
b.) How will the charge redistribute itself? That is, how much charge ends up on the second capacitor?

10.) You charge up a parallel plate capacitor that has air between its plates. Once charged, you disconnect it from the battery, then insert a piece of plastic (an insulator) between the plates. The amount of charge on the capacitor does not change (being disconnected from the circuit, it has no place to go), but the voltage across the capacitor does change.

a.) What is the insulator usually called in these situations?
b.) How and why does the voltage change (up, down, what?)?
c.) What happens to the capacitance of the capacitor?
d.) What happens to the energy content of the capacitor? If it goes up, from whence did the new energy come? If it goes down, where did it go?

11.) You have a parallel plate capacitor with air between its plates hooked up to a power supply whose voltage is V_o. Without disconnecting the battery, you carefully insert a piece of plastic between the plates.

a.) What happens to the voltage across the capacitor?
b.) What happens to the capacitor's capacitance?
c.) What happens to the charge on the capacitor's plates?



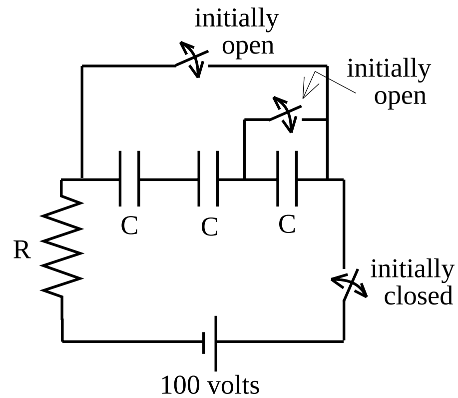
12.) You have two parallel plate capacitors that have air between their plates. Between the plates of the first cap, you insert a dielectric whose thickness is half the plate separation. Between the plates of the second cap, you insert a piece of metal whose thickness is also half the plate separation. The sketch shows a side view of both situations.

a.) Which modified capacitor will end up with the greater capacitance? Justify.
b.) What is the ratio of the two capacitances?

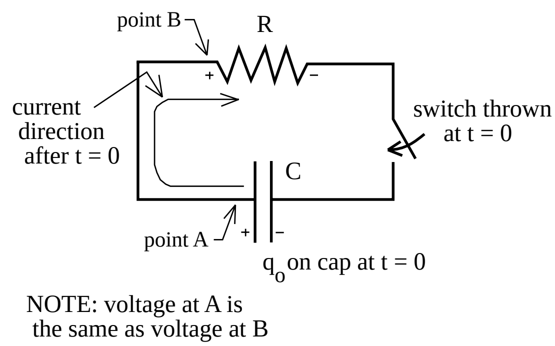
13.) You have a capacitor in series with a switch, a resistor, and a power supply. At $t = 0$, you throw the switch and current begins to flow.

a.) For the amusement of it, draw the circuit.
b.) If the capacitor had been half as big, how would the current have flowed? That is, would the cap has charged faster or slower? Justify your response.

14.) All the capacitors in the circuit have capacitance C. Switch #1 is closed at $t = 0$. Switch #2 is open at $t = 0$. Switch #3 is open at $t = 0$. After the capacitors are charged, all the switches are thrown simultaneously. In terms of the battery voltage and C, how much charge is on each cap after all is said and done?



15) A capacitor of known capacitance C is charged to q_o. The cap is hooked across a resistor R and an open switch. The switch is thrown at $t = 0$.



A student is interested in deriving the time-varying expression for the charge on the capacitor during its discharge. She draws the circuit shown to the right. She knows that the sum of the voltage-changes around the closed loop have to add to zero (i.e., she knows Kirchoff's Laws), so she starts on the right side of the capacitor and traversing clockwise. She observes a voltage increase across the capacitor of q/C and a voltage drop across the resistor of iR (see circuit). With that, she writes:

$$-iR + q/C = 0.$$

She rewrites this equation as $iR = q/C$, replaces i with dq/dt yielding $(dq/dt)R = q/C$, puts all the q parts on the left side of the equation and all the constants on the right side yielding $dq/q = (1/RC)dt$, integrates both sides to get $\ln(q_{final}) - \ln(q_o) = \ln(q_{final}/q_o) = (1/RC)t$, uses the exponential trick to conclude that $q_{final}/q_o = e^{t/RC}$, comes up with an expression that says $q_{final} = q_o e^{t/RC}$, and loudly exclaims YIKES. Why did she say YIKES, and how can she get out of the difficulty?