Name: ____________________

Period: ____________________

Capacitors

9.6

Capacitors

A battery is like an air pump: it can create pressure. A capacitor is like an air tank: it can only store pressure. Capacitors can only store charges pushed by a battery. Batteries produce a constant voltage from chemicals. Capacitors don't provide steady voltage and don't make their own voltage. Capacitors are used to store large charges (*camera flash*), provide small backup currents (*computer clocks*), or even protect against surges (*like a circuit sponge)*. The most basic capacitors are made of parallel conducting plates.

- Charge of + plate always = charge of − plate (= and opposite Q).
- The net charge of a capacitor (both plates) always = zero.
- A capacitor stops charging when $V_{capacitor} = V_{battery}$.

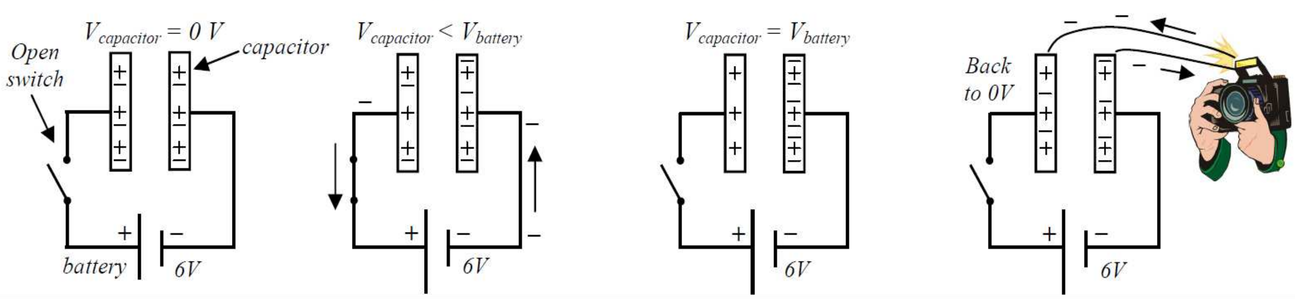
Capacitance

Capacitance (*in Farads [C/V]*) → $C = \frac{|Q|}{\Delta V}$

$|Q|$: Charge on one plate (*in C*)

ΔV: Potential Difference between plates (*in V*)

Circuit symbols:



Before charging *both plates are neutral with an equal number of protons and electrons. V = 0 volts.*

During charging *the battery pushes electrons to the − plate, leaving the other plate more +. V between the plates increases.*

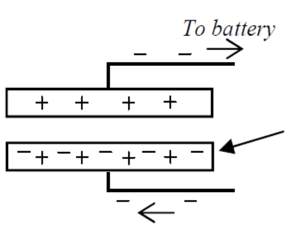
The capacitor is ***fully charged*** *when its voltage equals that of the battery. Its net charge is still zero.*

Discharging*: the plates are connected to a device or each other, release their charge, and each plate returns to neutral.*

Capacitance

A better capacitor can store more charge (more coulombs) with the same voltage. Capacitance is a physical characteristic of a capacitor, like an air tank's volume. A stronger pump (more voltage) does not change the volume of an air tank, just how much air can be forced in. Likewise, more voltage cannot change capacitance, just how much charge it holds.

1. **Increase the plate surface area** so there is more room for the electrons to spread out. It is then easier for the same voltage to push more charge on the plates. This is like a bigger air tank: more air can be pushed in by the pump.
2. **Decrease the distance between the plates.**



As the plates get closer, −'s are attracted and shift toward the + plate, allowing more −'s to be forced onto the − plate with the same voltage.

However, as the plates get closer, less voltage is necessary for the plates to discharge (arc) across each other.

Capacitance from Physical Dimensions

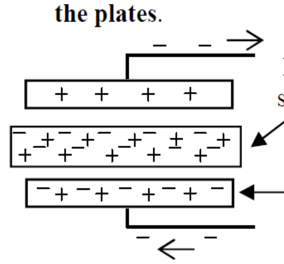
Capacitance (*in Farads*) → $C = \varepsilon_0 \frac{A}{d}$

A: Area of each plate (*in* m^2)

ε_0: Permittivity of a vacuum $= 8.85\times10^{-12}\,C^2/N\cdot m^2$

d: Plate separation between plates (*in m*)

3. **Add a dielectric** (some insulating material) **between the plates.**



Dielectric polarizes: its −'s shift closer to the + plate.

−'s on the − plate are attracted to the polarized dielectric, so more −'s can be added with the same voltage.

A dielectric also allows the plates to be moved closer before arcing occurs.

Potential Energy

If a capacitor can store charge (and voltage), it can store energy. The electrons on the negative plate are pushing against each other, so there are electrical forces between them and electric potential energy. It is important to note that the charge (Q) in the equation is the amount of charge on only one plate.

Electrical Potential Energy on a Charged Capacitor

Electric Potential Energy (*in J*) → $PE = \frac{1}{2}|Q|\Delta V$

ΔV: Potential Difference between plates (*in V*)

$|Q|$: Charge on only one plate (*in C*)

1. A 4 volt battery stores 24 Coulombs of charge. Calculate the capacitance of the capacitor.

2. A capacitor has a rating of 3 Farads. How much voltage is necessary to push 18 Coulombs onto the plates?

3. What does it mean to discharge a capacitor?

4. How much charge is held on one plate of a 15 farad capacitor brought to 6V?

5. A. Calculate the voltage across a 4μF capacitor that holds 12μC of charge on one plate.

   B. How much energy is held by the capacitor?

   C. What is the total charge of the capacitor?

   D. How much charge is there on one plate of the capacitor after it has been discharged?

6. When does a capacitor stop charging?

7. A parallel plate capacitor has .0035 m^2 of area for each plate, which are separated by 6mm.
   A. Calculate the capacitance.

   B. How much voltage is required to separate 2μC of charge?

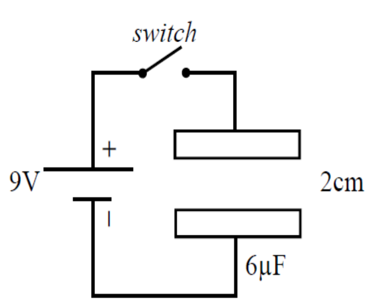
   C. How much potential energy is held on the capacitor?

   D. Give three ways to increase its capacitance.

8. When is the net charge of a capacitor not zero?

9. How does the capacitance change?

   A. If the plate area is doubled.
   B. If the distance between the plates is halved.
   C. If a dielectric is placed between the plates.
   D. If the voltage across the capacitor is doubled.



10. Use the diagram at the left to answer the following.

    A. Draw what will happen to the capacitor when the switch is closed.
    B. Which direction does the electric field point inside the charged capacitor?
    C. Which plate has a higher potential (voltage)?
    D. What is the voltage across the charged capacitor?
    E. What is the total charge of the capacitor?
    F. How much charge does the 6μF capacitor hold on one plate, when fully charged?

    G. How much energy is stored in the capacitor?

    H. Calculate the area of one plate.

    I. If the battery is replaced by a 12v battery, what will be the new capacitance?

    J. With the 12v battery, how much charge is held on the capacitor?