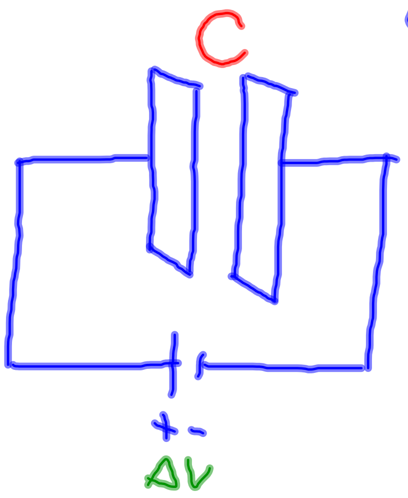
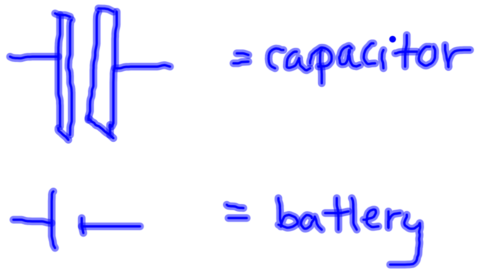
17.2 Capacitance

capacitance - the ability of a conductor to store energy in the form of electrically separated charges

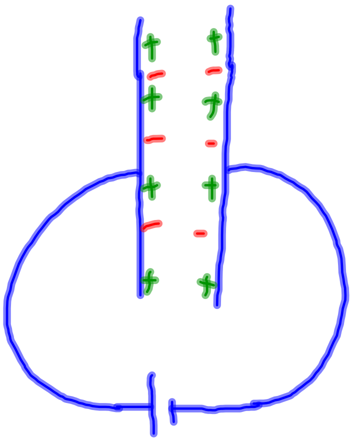




Think of a capacitor like a spring. When the spring is stretched, it stores potential elastic energy similar to how a capacitor will store electric potential energy.

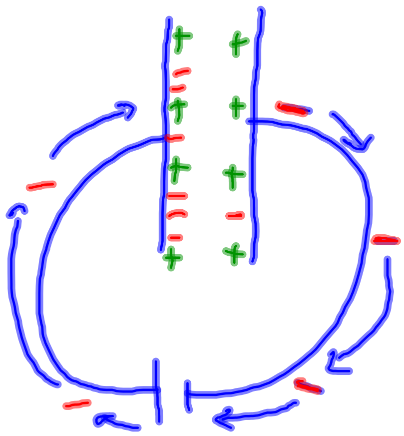
In both cases, work must be done for the energy to be stored (ie: work to stretch the spring).

Capacitors also help to stabilize the flow of electrons so that the supply of energy is continuous. (see online diagram)

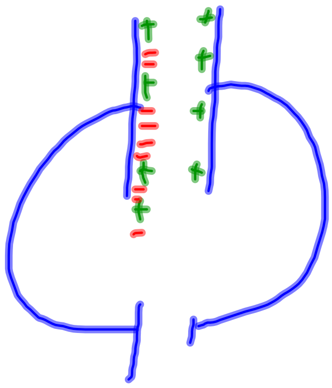


Before

No net charge - Both plates are neutral

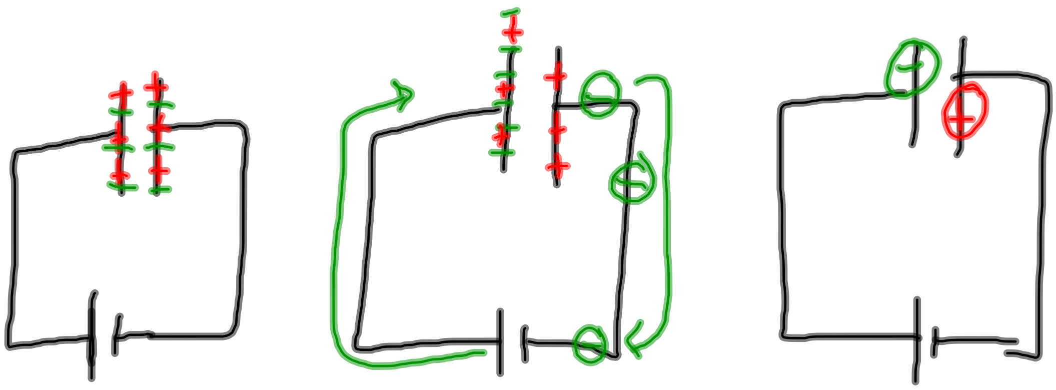


During charging - Electrons leave the one plate, traveling through the wire to the other plate



After

Net charges - plates have opposite charges



Before

No net charge - Both plates are neutral

During charging - Electrons leave the one plate, traveling through the wire to the other plate

After

Net charges - plates have opposite charges

$$C = \frac{Q}{\Delta V}$$

$$\text{capacitance} = \frac{\text{amount of charge stored}}{\text{potential difference}}$$

(F)
↑
farad
=
$\frac{C}{V}$

*Capacitance is dependent of the geometry (shape) of the capacitor.

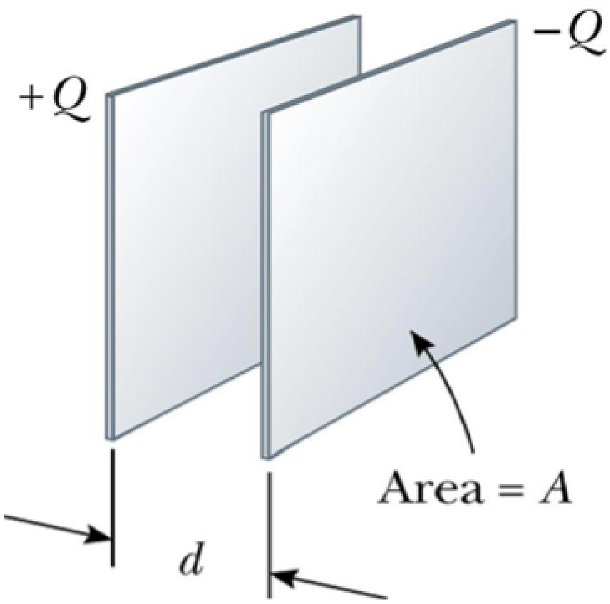
For parallel plates:

$$C = \frac{\varepsilon_0 A}{d}$$

A = area of the capacitor

d = distance between plates

$$\varepsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$$



Example 1:

A capacitor, when connected to a 15V supply, carries a charge of 5 μC. Find the capacitance of the capacitor.

$$C = \frac{Q}{\Delta V} = \frac{5E-6}{15} = \boxed{3.3E-7\ F}$$

Example 2:

A parallel plate capacitor of area 0.015 m^2 and a plate separation of 0.02 m is connected to a 9V supply.

a) Find the capacitance.

$$C = \frac{\varepsilon_0 A}{d} = \frac{(8.85E-12)(0.015)}{0.02}$$

$$\boxed{C = 6.64 \times 10^{-12}\ F}$$

b) Find the charge stored on the capacitor.

$$C = \frac{Q}{\Delta V} \rightarrow Q = C\Delta V$$

$$= (6.64E-12)(9V) = \boxed{5.97 \times 10^{-11}\ C}$$

Example 3:

A rectangular plate of sides 5 cm x 4 cm is separated by a distance of 0.5 cm from the same rectangular plate.

a) Find the capacitance.

$$C = \frac{\varepsilon_0 A}{d} = \frac{(8.85E{-}12)(.05 \times .04)}{.005} = \boxed{3.5 \times 10^{-12}\ F}$$

b) The capacitor above is connected to a 1.5 V battery. Find the charge stored on the capacitor.

$$C = \frac{Q}{\Delta V} \rightarrow Q = C\Delta V$$

$$= (3.5E{-}12)(1.5V) = \boxed{5.31 \times 10^{-12}\ C}$$

Potential Energy Stored in a capacitor :

$C = \frac{Q}{\Delta V}$

$Q = C\Delta V$

* $PE = \frac{1}{2} Q \Delta V$

$= \frac{1}{2}(C\Delta V)\Delta V$

$= \frac{1}{2} C \Delta V^2$

$\Delta V = \frac{Q}{C}$

$= \frac{1}{2} Q \cdot \frac{Q}{C}$

$PE = \frac{Q^2}{2C}$

Find the energy stored in a 5 μF capacitor connected to a 9V supply

$C = 5 \times 10^{-6} F$

$\Delta V = 9V$

$PE = \frac{1}{2} C (\Delta V)^2$

$= \frac{1}{2} (5E{-6}) (9)^2$

$= 2.03 \times 10^{-4} J$

Homework (pg. 607 Practice B)

1. A 4.00 μF capacitor is connected to a 12 V battery
   a) What is the charge on each plate of the capacitor?
   b) If this same capacitor is connected to a 1.50 V battery, how much electrical potential energy is stored?

2. A parallel-plate capacitor has a charge of 6.0 μC when charged by a potential difference of 1.25 V.
   a) Find its capacitance.
   b) How much electrical potential energy is stored when this capacitor is connected to a 1.5 V battery?

3. A capacitor has a capacitance of 2.00 pF.
   a) What potential difference would be required to store 18.0 pC?
   b) How much charge is stored when the potential difference is 2.5 V?

4. You are asked to design a parallel-plate capacitor having the capacitance of 1.00 F and a plate separation of 1.00 mm. Calculate the required surface area of each plate. Is this a realistic size for a capacitor?