3–17 Capacitance

Capacitors or Charged Plates: Large Q. Capacitors are a way to ***store electrical charge and energy.*** A voltage (potential difference) is needed to create the static electric build up on the plates. The plates can be discharged, releasing energy, by providing a path for the electrons to flow between the plates.

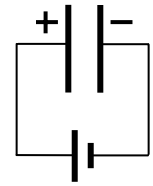

Fig 17.1

Capacitance: C, is the capacity of the capacitor to hold charge. Think of batteries as electrical pumps, and voltage as electrical pressure that makes it all happen. $\boxed{C = \varepsilon_0 \frac{A}{d}}$. Increasing the area increases the space for the charges on each plate. Since each plate holds like charges, that repel each other, increasing the area creates more room for the charges and lowers electrostatic repulsion. If the distance between the plates is lowered then the positive charge on one plate come closer to the negative on the other. The plates attract each other. To keep charges from jumping from one plate to the other an insulating is placed between the plates. For the AP Physics B class the insulating substance will be a vacuum.

Dielectrics: The real formula for capacitance is $\boxed{C = \frac{\kappa \varepsilon_0 A}{d}}$. ε_0 is the permittivity of free space, and κ is the dielectric constant. The dielectric constant varies from substance to substance. $\kappa = 1$ for a vacuum, resulting in the above equation.

$\boxed{C = \frac{Q}{V}}$ is the capacitance C in terms of the charge stored Q and the batteries potential (pressure) V to pump charges onto the plates. Since the charges would prefer to stay evenly distributed and neutral on both plates work must be done to separate the charges. Electrons, which are loosely bound by their atoms, are made to move from one plate to the other, by the potential V. Remember electrons move in a direction that is opposite that of the electric field. They fall upward toward the positive plate and gain potential energy. $\boxed{U_c = \frac{1}{2}QV = \frac{1}{2}CV^2}$ During this process there is a change in energy, or work.

Disconnect the battery and you have stored the charges on the plates. Connect a wire between them and the charge can flow. The quantity of energy that was stored is released and can be used to do an equal quantity of work. You can think of electricity as water. If you pump water up to a water tower it has high potential energy. If you turn off the pump it will flow back to the ground. A capacitor is an electrical water tower where charge is stored temporarily until it is needed. So if the electrical circuit needs to flush all of its toilets simultaneously the capacitor is allowed to discharge. It is then refilled for the next big flush. Q is the water pumped into the tower. V is the pumps pressure. Why is $U_E = qV$ while $U_c = \frac{1}{2}QV$?

Remember Q is the charge of the plates themselves. The first electron moved onto the plate does so easily. But the second is repelled by the first, and the third by the first two. It becomes harder to put more electrons on the plate since repulsion becomes higher with each electron. The positive plate becomes more positive pulling the electrons back as well. The rate of charges moved starts out high and declines to zero. Average the high rate initially with zero at the end and you get half of the initial rate. If you pump water up a water tower it goes fast at first. But, the weight of the water filling the tower begins to make it harder to pump, until the force of the water in the tower pushing down equals the force of the pump pushing water up. Average the fast pumping at the start with zero pumping at the end, and you get half.

Circuits containing Capacitors: Several capacitors in series or parallel, or in combination can add up to act like one capacitor in a similar manner as resistors do. The rules for capacitors in circuits are ***opposite*** the rules for resistors (presented later). However, similar problem solving techniques apply. $\boxed{\frac{1}{C_s} = \sum_i \frac{1}{C_i}}$ $\boxed{C_P = \sum_i C_i}$

Example 17.1: Equivalent Capacitance

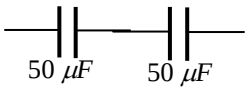

Fig 17.2a

What is the equivalent capacitance of two 50 μC connected in series, Fig 17.2a?

$\boxed{\frac{1}{C_s} = \sum_i \frac{1}{C_i}}$ $\frac{1}{C_s} = \frac{1}{50\mu F} + \frac{1}{50\mu F} = \frac{2}{50\mu F}$ $C_s = \frac{50\mu F}{2} = \boxed{25\mu F}$

Placing capacitors in series creates less capacitance. Sometimes you need a specific amount of capacitance, but can't locate a capacitor with the exact needed value. The battery has a harder time pumping the two capacitors up, in this configuration.

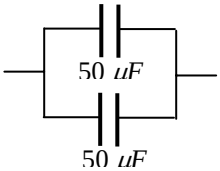

Fig 17.2b

What is the equivalent capacitance of two 50 μC connected in parallel, Fig 17.2b?

$\boxed{C_P = \sum_i C_i}$ $C_P = 50\mu F + 50\mu F = \boxed{100\mu F}$

Placing capacitors in parallel is the same as increasing the area of the plates and therefore increases the capacity of the new combined capacitor

 © R H Jansen

 © R H Jansen