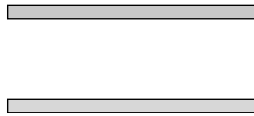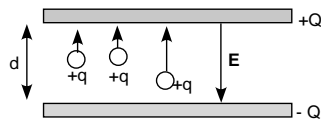## *CAPACITORS*

A capacitor is an electronic device used to *store charge* and thus to *store energy* as well. Here are different types of capacitors:

What is a capacitor and how can a capacitor store energy? A capacitor can be formed by two conductors separated by an insulator (vacuum, plastic, wax paper). The simplest form of a capacitor is the parallel plate capacitor.

To see how these two conductors can store energy let's assume that the plates are initially uncharged. Let's suppose that you now transfer +charges from one plate to the other.

$$W = \Delta U = q\Delta V$$
$$V = \Delta V = Ed$$
$$E = \frac{\sigma}{\varepsilon_o}$$
$$\sigma = \frac{Q}{area}$$

Thus, the work that is done in charging capacitor is stored as electric potential energy in the capacitor. We will see later that we can think of these energy as being stored in the electric field within the capacitor.

Let's see what happens to E and V on the capacitor during the charging process.
As Q increases $\rightarrow$ σ = Q/area increases $\rightarrow$ E = σ/ε_o increases $\rightarrow$ V=Ed increases.

Thus,

$$Q \; \alpha \; V$$

The proportionality constant is called the capacitance C.

$$Q = CV$$

$$\boxed{C = \frac{Q}{V}}\ \text{Capacitance}$$

Note that for a given voltage V, the larger the capacitance C, the larger the charge Q on the plates of the capacitor, and thus the larger the stored energy. Therefore:

Capacitance is a measure of how much charge (energy) a capacitor can store.

As we will see shortly, the capacitance of a capacitor will depend on the geometry of the conductors forming the capacitors.
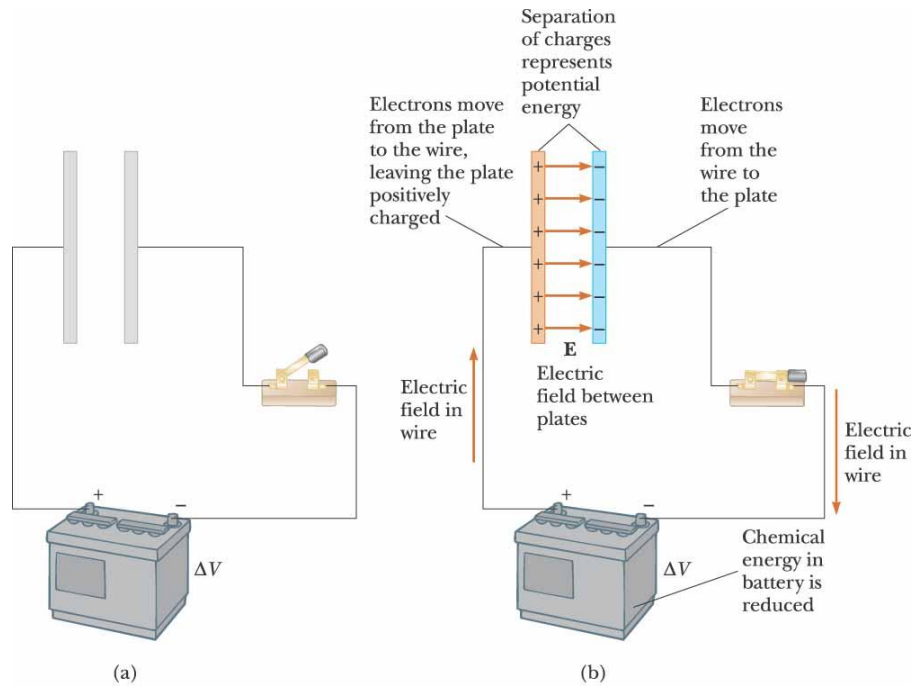
The SI unit of capacitance is the Farad (F):

1F = 1C/V

1F is a very large unit of capacitance. Typical values range from 1μF to 1pF.

If a capacitor is rated at 4 pF, then it can store 4 pC of charge for each volt of potential difference between the conductors. If it is rated at 10 pF, then it can store 10 pC of charge for each volt of potential difference between the conductors.

A capacitor can be charged by connecting both plates to the terminals of a battery by a conducting wire. Let's look at the process of how the plates of a capacitor are charged.

Separation of charges represents potential energy

Electrons move from the plate to the wire, leaving the plate positively charged

Electrons move from the wire to the plate

E

Electric field in wire

Electric field between plates

Electric field in wire

Chemical energy in battery is reduced

ΔV

ΔV

(a)

(b)

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1. Initially the plates are uncharged and the switch is open.
2. When the switch is closed the battery does work to transfer electrons from the left plate to the right plate. This leaves the left plate positively charged and the right plate negatively charged.
3. The transfer of charge will continue until the potential difference across the plates is equal to the potential difference across the battery.
4. The work done by the battery to charge the capacitor is equal to the potential energy stored in the capacitor.
5. Thus, a capacitor stores energy as well as charge.

Most practical applications of capacitors make use of their ability to store energy and release it in a controlled manner (Ex. camera flashes, pulse lasers …) Other applications include: producing E-fields, controlling voltage variations in circuits, tuning a radio or receiver…..

Finding Capacitance

1. Use Gauss's Law to find **E** between conductors.
2. Use **E** to find V between conductors:

$$V_B - V_A = -\int_A^B \vec{E} \bullet d\vec{\ell}$$

3. Calculate $C = \dfrac{Q}{V}$

Recall: $Q = |Q|$ and $V = |V_B - V_A|$