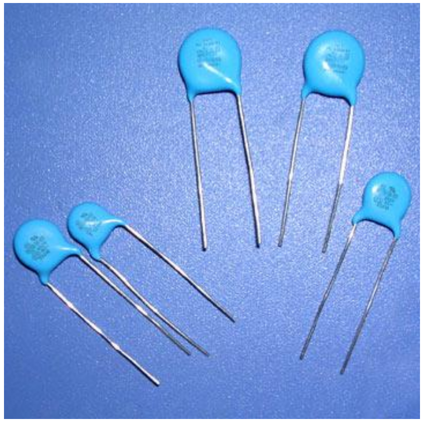
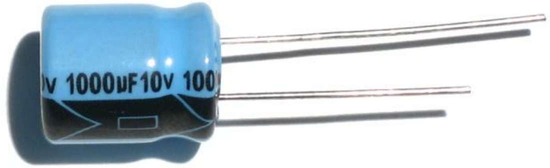
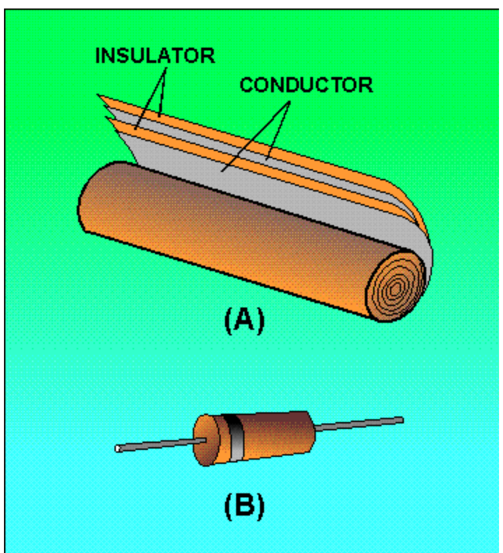
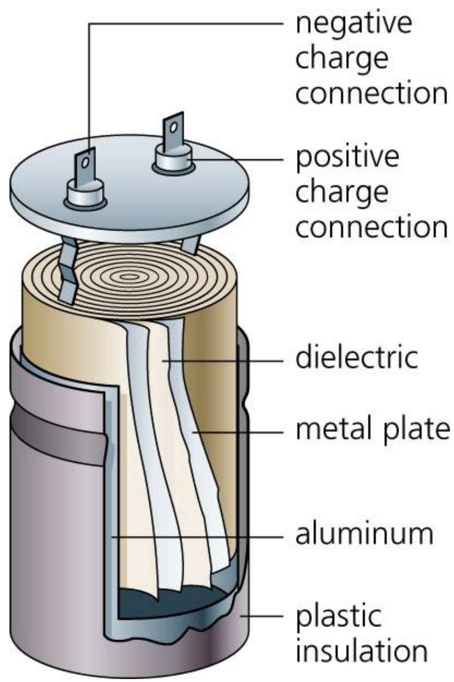
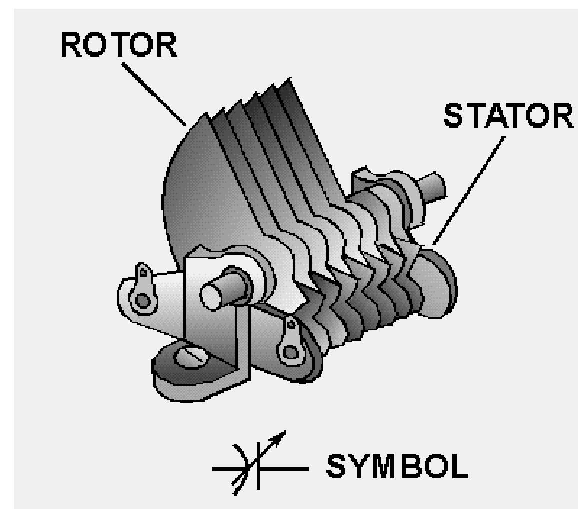




CAPACITANCE – Part 1







A *capacitor* is a device used in a variety of electric circuits.

The *capacitance*, *C*, of a capacitor is defined as the ratio of the magnitude of the charge on either conductor (plate) to the magnitude of the potential difference between the conductors (plates).

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

Unit: Farad (F)

1 F = 1 C/V

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Unit: Farad (F)

1 F = 1 C/V

F is a large unit, though capacitors of 1 F or more are available.
Commonly used units: μF or pF.

ΔV is the potential difference across a circuit element or device.
V represents the actual potential due to a given charge at a given location.

Parallel-Plate Capacitor

Capacitance depends on the geometric arrangement of the conductors.

For a parallel-plate capacitor whose plates are separated by air: $C = \varepsilon_0 \dfrac{A}{d}$

$A =$ area of one plate $d =$ distance between plates

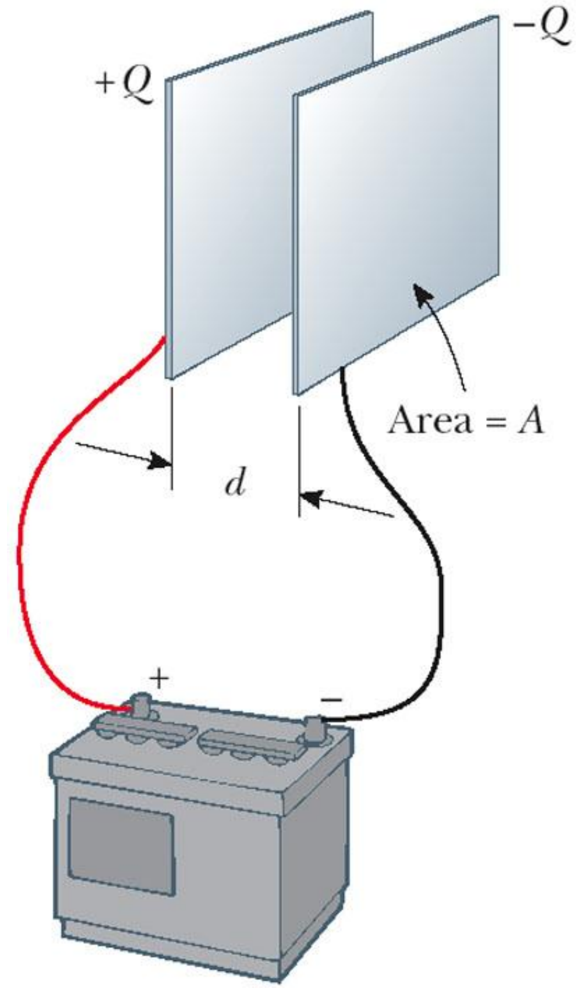
$\varepsilon_0 =$ permittivity of free space

$= 8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$

Parallel-Plate Capacitor, Example

The capacitor consists of two parallel plates, each of area *A*. They are separated by a distance *d* and carry equal and opposite charges. When connected to the battery, charge is pulled off one plate and transferred to the other plate. The transfer stops when

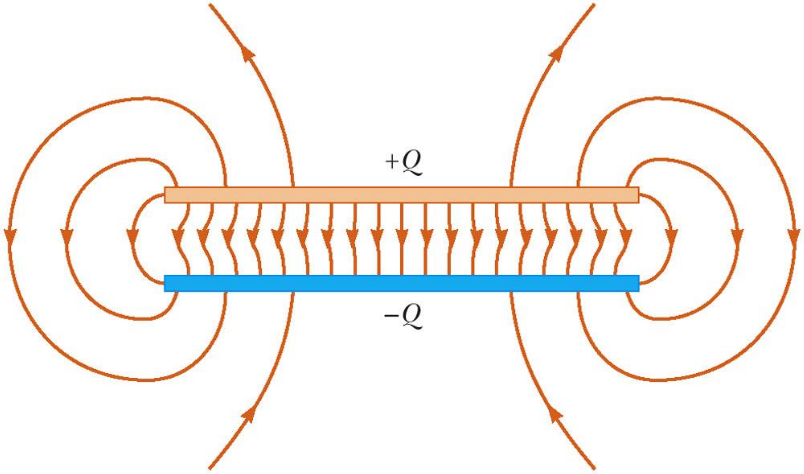
$$\Delta V_{\text{cap}} = \Delta V_{\text{battery}}$$

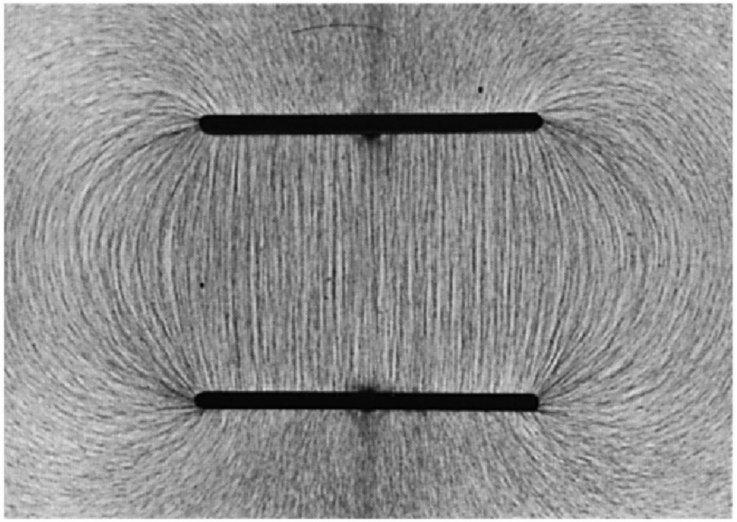


Electric Field in a Parallel-Plate Capacitor

The electric field between the plates is uniform near the center, nonuniform near the edges.

The field *may be taken as constant* throughout the region between the plates.



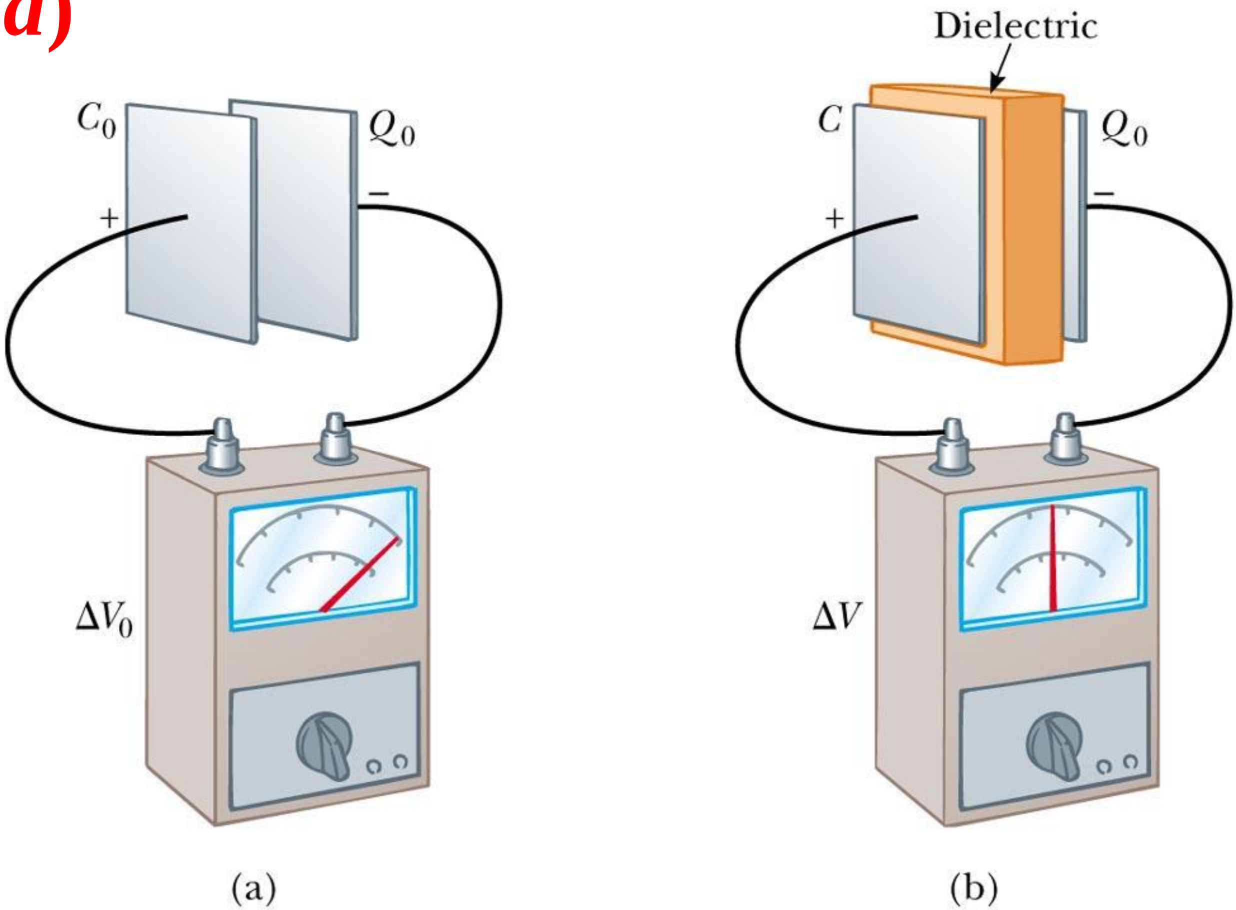


Capacitors with Dielectrics

A dielectric is an insulating material (such as rubber, plastic, or waxed paper) that, when placed between the plates of a capacitor increases the capacitance. For any given plate separation, there is a maximum electric field that can be produced in the dielectric before it breaks down and begins to conduct.
This maximum electric field is called the *dielectric strength*.

The capacitance is multiplied by the factor κ (the *dielectric* constant) when the dielectric completely fills the region between the plates.

$$C = \kappa C_o = \kappa \varepsilon_o (A/d)$$

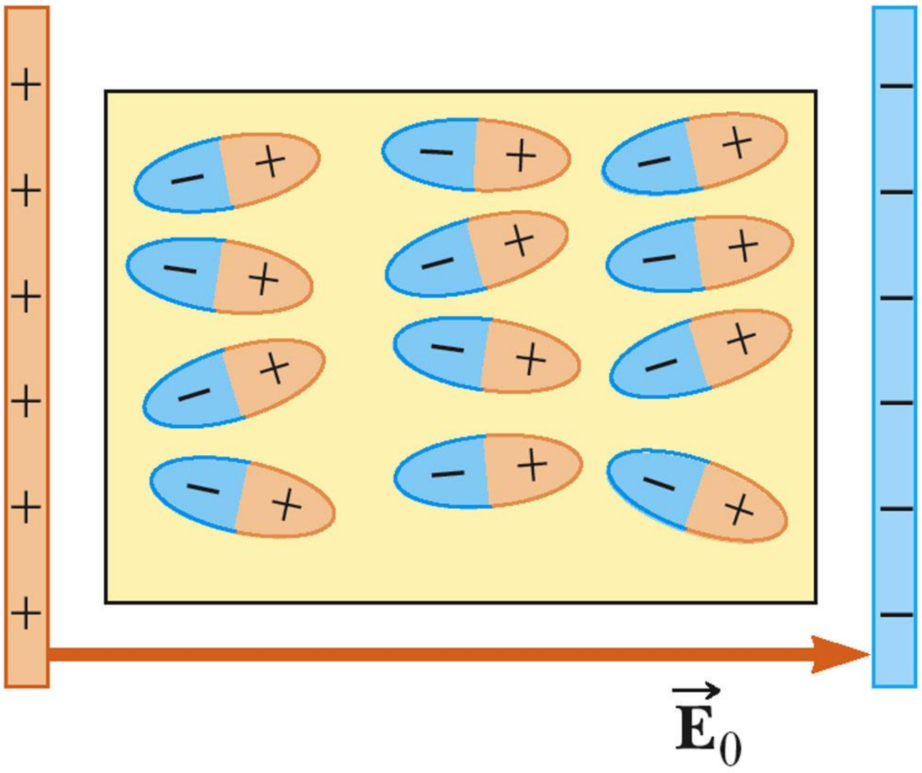


Polarization **occurs when there is a separation between the "centers of gravity" of its negative charge and its positive charge.**

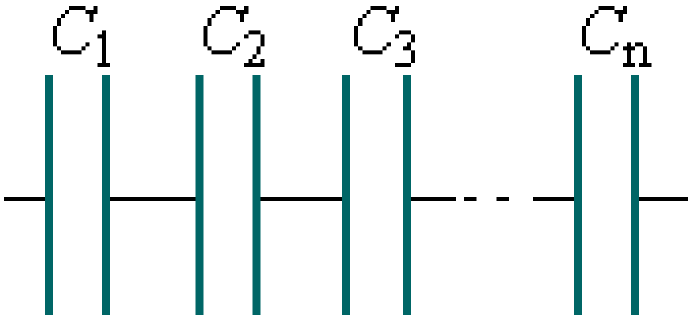
In a capacitor, the dielectric becomes polarized because it is in an electric field that exists between the plates.

An atomic/molecular view

The presence of the positive charge on the dielectric effectively reduces some of the negative charge on the metal. This allows more negative charge on the plates for a given applied voltage. The capacitance increases.



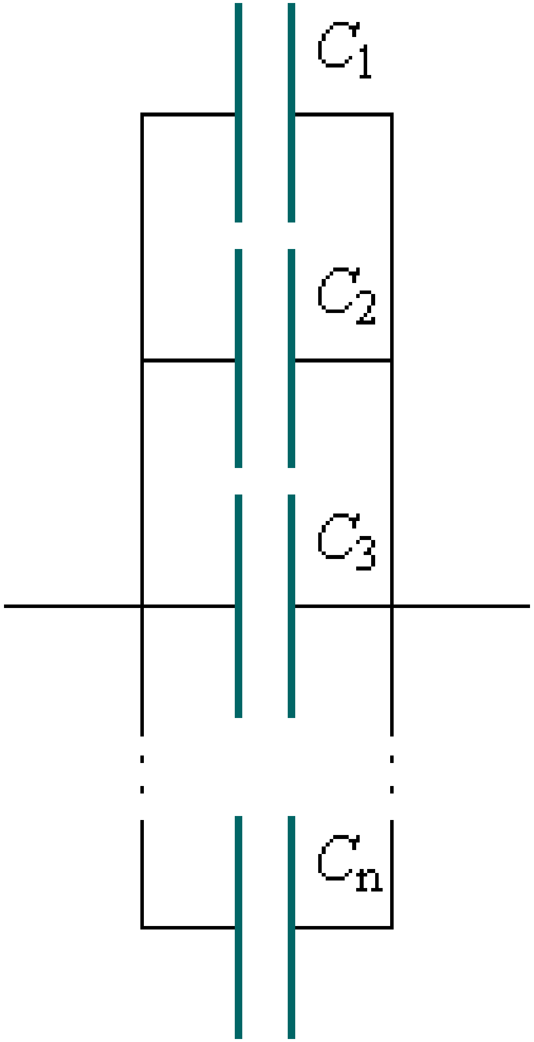
Capacitors in Series



The equivalent capacitance is smaller than the smallest capacitance of the combination. The charge on each capacitor is the same as the charge on the combination.

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots + \frac{1}{C_n} = \sum_{i=1}^{n} \frac{1}{C_i}$$

Capacitors in Parallel



The equivalent capacitance is larger than the largest capacitance of the combination. The potential difference across each capacitor is the same as the potential difference across the combination.

$$C_{eq} = C_1 + C_2 + C_3 + \cdots + C_n = \sum_{i=1}^{n} C_i$$

Energy Stored in a Charged Capacitor

(Stored charge, $Q = C\Delta V$)

$$\text{Energy stored} = \frac{1}{2}Q\Delta V = \frac{1}{2}C\left(\Delta V\right)^2 = \frac{Q^2}{2C}$$