Chapter 26

Capacitance and Dielectric

26.1 Definition of capacitance

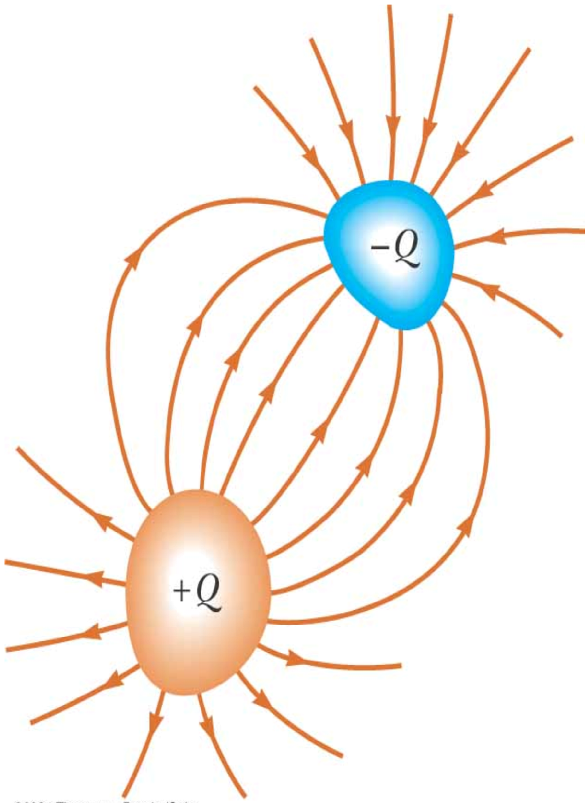
In the front figure, you can see two conductors. Such system is called a capacitor. Due to the different charge at the two plates, difference in potential ΔV exists between the two plates. It has been found that,

$$q \propto \Delta V$$

So, $$q = C \quad \Delta V \qquad 26.1$$

Where C is the capacitance. The capacitance is defined as the ratio between the charge and the difference potential.

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

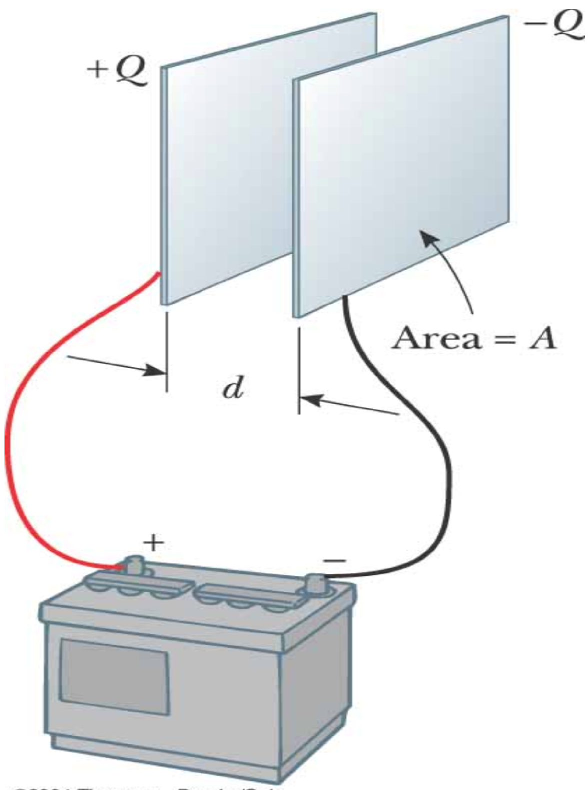


The unit of the capacitance is Farad (F). In practical, the devices have capacitance ranging from microfarad ($\mu F = 10^{-6}$ F) to picofarad ($pF = 10^{-12}$ F).

26.2 Calculating Capacitance

- **Parallel-plate capacitors:**

In the figure, two parallel plates carry different type and equal charges (±Q) and separated distance d. As we discussed in chapter 24, the surface charge σ is $\frac{q}{A}$. Then, the electric field between the two plates is given by:



$$E = \frac{\sigma}{\varepsilon_0} = \frac{q}{\varepsilon_0 \ A} \qquad 26.2$$

Also, the electric potential can be written as,

$$V = \int_0^d E \ dx = E \ d \qquad 26.3$$

Comparing Eq. (26.2) and (26.3), we can derive an expression for the capacitance of the parallel-plate as follows,

$$V = \frac{q}{\varepsilon_0 \ A} d = \frac{d}{\varepsilon_0 \ A} q$$

$$q = \frac{\varepsilon_0 \ A}{d} V \qquad 26.4$$

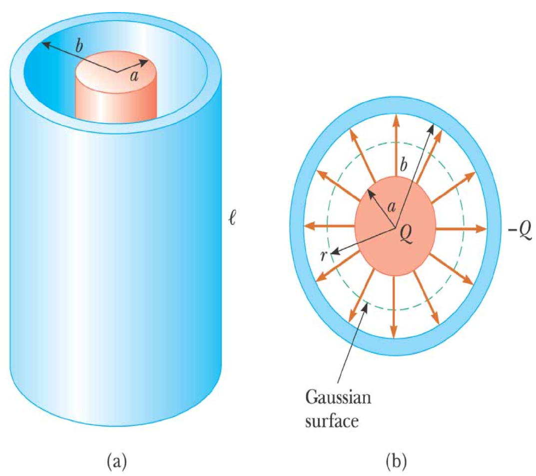
==➔ $$C = \frac{\varepsilon_0 \ A}{d} \qquad 26.5$$

Then, the capacitance of the parallel plate depends on:

1- The distance between the two plates,
2- The area of each plate, and
3- The material between the two plates.

❖ Cylindrical Capacitors:

$$C = 4\pi\epsilon_0 \frac{l}{\ln(\frac{b}{a})} \qquad 26.6$$



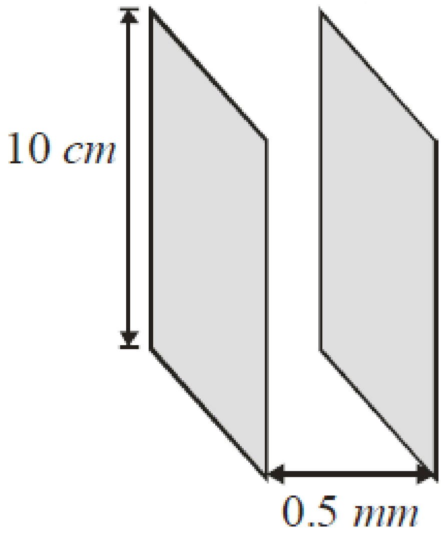
- **Spherical Capacitor:**

$$C = 4\pi\varepsilon_o \frac{ab}{(b-a)} \qquad 26.7$$

Examples:

Example1:

What is the capacitance of the capacitor shown below, knowing that the plates are square in shape?



Example2:

An electric field of 4×10^{6} V/m is set up between two oppositely charged parallel circular plates. If the magnitude of the charge on either of the circular plates is 4×10^{-6} C, the radius of the plate is: