Capacitors

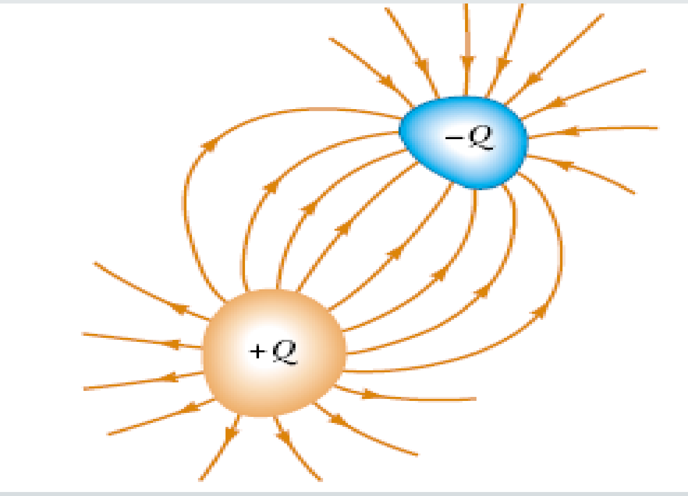
Capacitors—devices that store electric charge. Capacitors are commonly used in a variety of electric circuits. For instance, they are used to

- tune the frequency of radio receivers,
- as filters in power supplies,
- to eliminate sparking in automobile ignition systems, and
- as energy-storing devices in electronic flash units.

Consider two conductors carrying charges of equal magnitude but of opposite sign, as shown in Figure. Such a combination of two conductors is called a capacitor. The conductors are called *plates. A potential difference V exists between* the conductors due to the presence of the charges.

The **capacitance** C of a capacitor is the ratio of the magnitude of the charge on either conductor to the magnitude of the potential difference between them:

$$C \equiv \frac{Q}{\Delta V} \tag{26.1}$$



CALCULATING CAPACITANCE

Parallel-Plate Capacitors

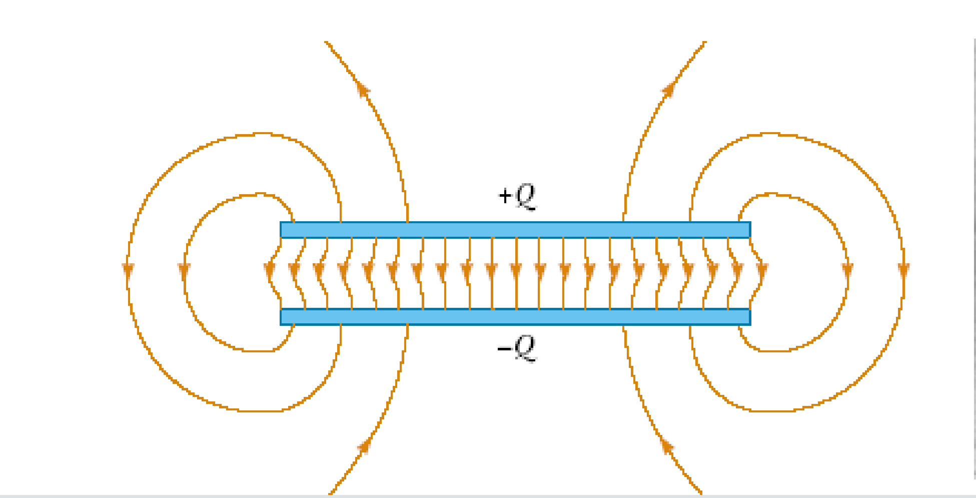
Two parallel metallic plates of equal area *A are separated by a distance d, as shown* in Figure. One plate carries a charge Q , *and the other carries a charge Q.*

The value of the electric field between the plates is

$$E = \frac{\sigma}{\epsilon_0} = \frac{Q}{\epsilon_0 A}$$

$$\Delta V = Ed = \frac{Qd}{\epsilon_0 A}$$

$$C = \frac{Q}{\Delta V} = \frac{Q}{Qd/\epsilon_0 A}$$



$$C = \frac{\epsilon_0 A}{d}$$

the capacitance of a parallel-plate capacitor is proportional to the area of its plates and inversely proportional to the plate separation,

The Cylindrical Capacitor

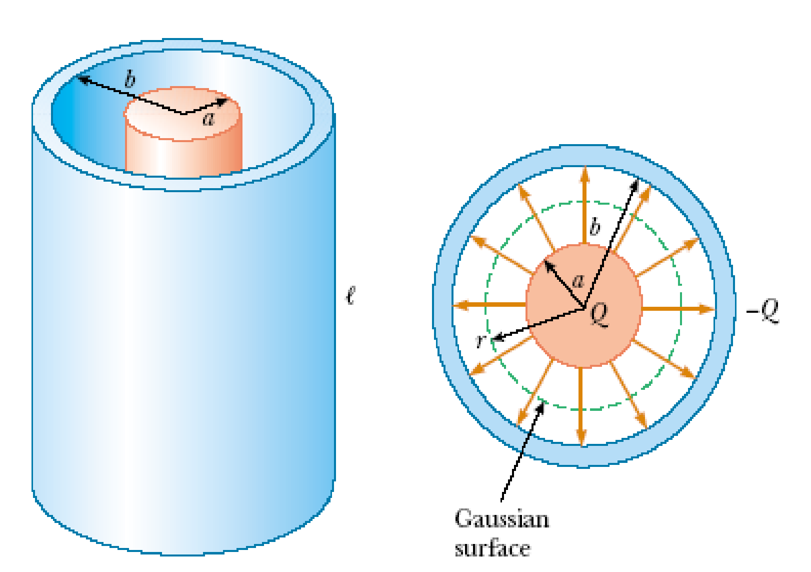
Not very important

A solid cylindrical conductor of radius a and charge Q is coaxial with a cylindrical shell of negligible thickness, radius $b > a$, and charge $-Q$

First calculate the potential difference between the two cylinders,

$$V_b - V_a = -\int_a^b \mathbf{E} \cdot d\mathbf{s}$$

$$E_r = 2k_e\lambda / r$$



$$V_b - V_a = -\int_a^b E_r\, dr = -2k_e\lambda \int_a^b \frac{dr}{r} = -2k_e\lambda \ln\left(\frac{b}{a}\right)$$

$$C = \frac{Q}{\Delta V} = \frac{Q}{\frac{2k_e Q}{\ell}\ln\left(\frac{b}{a}\right)} = \frac{\ell}{2k_e \ln\left(\frac{b}{a}\right)}$$

$$\frac{C}{\ell} = \frac{1}{2k_e \ln\left(\frac{b}{a}\right)}$$

the capacitance per unit length

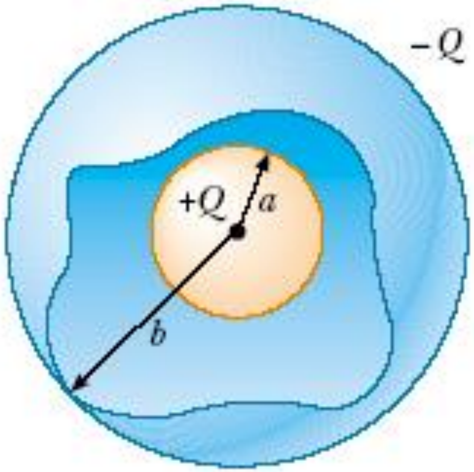
The Spherical Capacitor

Not very important

A spherical capacitor consists of a spherical conducting shell of radius b and charge $-Q$ concentric with a smaller conducting sphere of radius a and charge Q

$$V_b - V_a = -\int_a^b E_r\,dr = -k_eQ\int_a^b \frac{dr}{r^2} = k_eQ\left[\frac{1}{r}\right]_a^b$$

$$= k_eQ\left(\frac{1}{b} - \frac{1}{a}\right)$$



$$\Delta V = |V_b - V_a| = k_eQ\frac{(b-a)}{ab}$$

$$C = \frac{Q}{\Delta V} = \boxed{\frac{ab}{k_e(b-a)}}$$

COMBINATIONS OF CAPACITORS

Parallel Combination

The individual potential differences across capacitors connected in parallel are all the same and are equal to the potential difference applied across the combination.

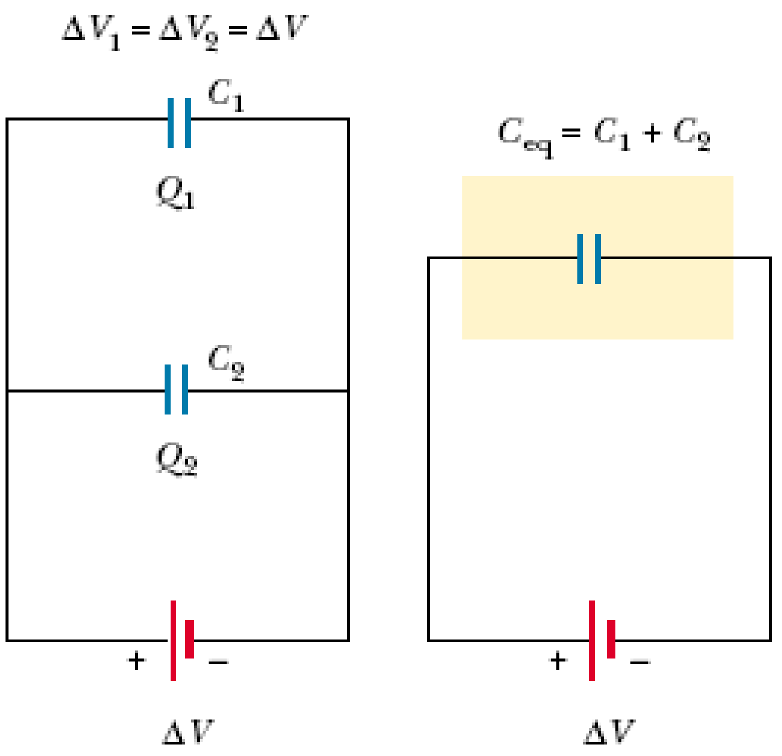
The *total charge* Q stored by the two capacitors is

$$Q = Q_1 + Q_2$$

$$Q_1 = C_1 \Delta V \qquad Q_2 = C_2 \Delta V \qquad Q = C_{eq} \Delta V$$

$$C_{eq} \Delta V = C_1 \Delta V + C_2 \Delta V$$

$$C_{eq} = C_1 + C_2 \qquad \left(\begin{array}{l}\text{parallel}\\ \text{combination}\end{array}\right)$$



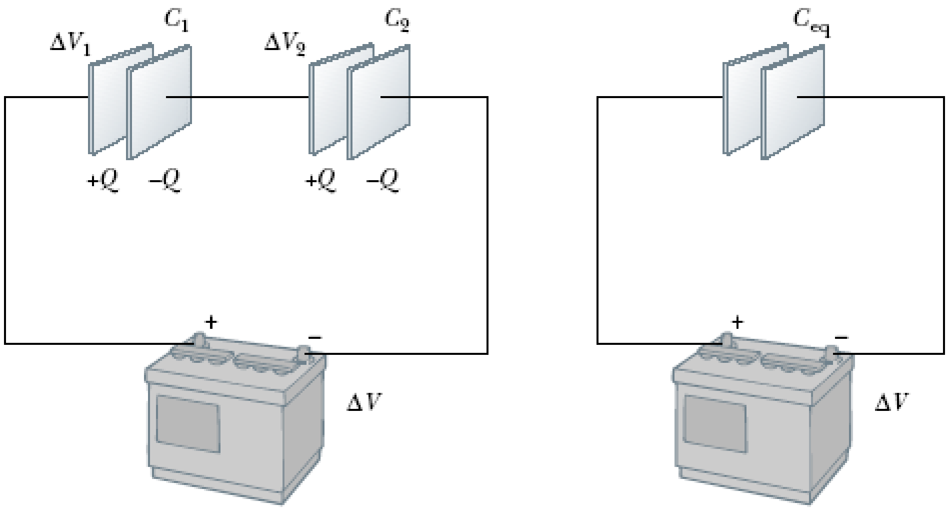
$$C_{eq} = C_1 + C_2 + C_3 + \cdots \qquad \text{(parallel combination)}$$

COMBINATIONS OF CAPACITORS

Series Combination

$$\Delta V = \Delta V_1 + \Delta V_2$$

$$\Delta V_1 = \frac{Q}{C_1} \qquad \Delta V_2 = \frac{Q}{C_2} \qquad \Delta V = \frac{Q}{C_{eq}}$$



$$\frac{Q}{C_{eq}} = \frac{Q}{C_1} + \frac{Q}{C_2}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} \qquad \left(\begin{array}{l}\text{series}\\ \text{combination}\end{array}\right)$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots \qquad \left(\begin{array}{l}\text{series}\\ \text{combination}\end{array}\right)$$

This demonstrates that **the equivalent capacitance of a series combination is always less than any individual capacitance in the combination.**