PHYS 202

Ch. 5

Capacitance

Chapter 5

Chapter Five

Capacitance

- ***Capacitance***
- ***Calculating the Capacitance***
- ***Capacitors in Parallel and in Series***
- ***Energy Stored in an Electric Field***
- ***Capacitor with a Dielectric***

Capacitance

Capacitance

- Capacitor is an electric device which used for saving energy (electric charge) and enable us to use it later.

- The magnitude of charge q which kept in the capacitor is proportional to the voltage applied across it V.

$$q = CV.$$

where C is the capacitance .

- The SI unit of capacitance is Farad (F).

Capacitance

Example 1:

A capacitor with capacitance of 1.25 pF is charged by applying a voltage of 12 V across its ends. The total charge of the capacitor is:

Solution:

(D)

(A) 12 pC
(B) 13 pC
(C) 14 pC
(D) 15 pC

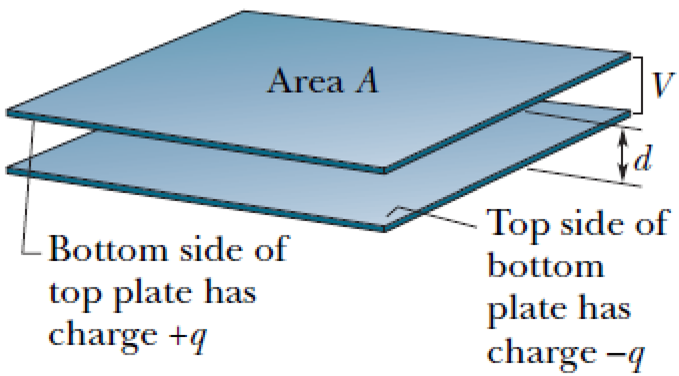
Calculating the Capacitance

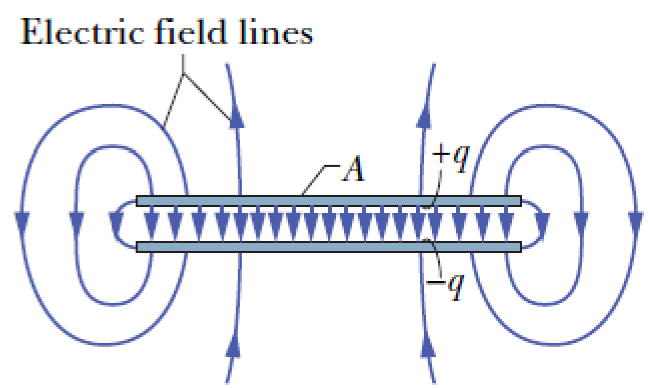
Calculating the Capacitance

A Parallel-Plate Capacitor

- The capacitance for two parallel plates having an equal and opposite charges with plate area *A* and separation distance *d* is:

$$C = \frac{\varepsilon_0 A}{d}$$





Calculating the Capacitance

Example 2:

A parallel-plate capacitor with plate's area 25 cm^2 and separation of 17.7 mm is charged by applying a voltage of 12 V across its ends. The capacitance of the capacitor is:

Solution:

(B)

(A) 0.83 pF
(B) 1.25 pF
(C) 2.73 pF
(D) 3.09 pF

Calculating the Capacitance

Example 3:

A parallel-plate capacitor has a capacitance of 8 μF. Its capacitance if the plate separation is doubled is:

Solution:

(C)

(A) 2 μF
(B) 3 μF
(C) 4 μF
(D) 5 μF

Calculating the Capacitance

Example 4:

Referring to Example 3, if the plate area of the capacitor is doubled. The capacitance will be:

Solution:

(D)

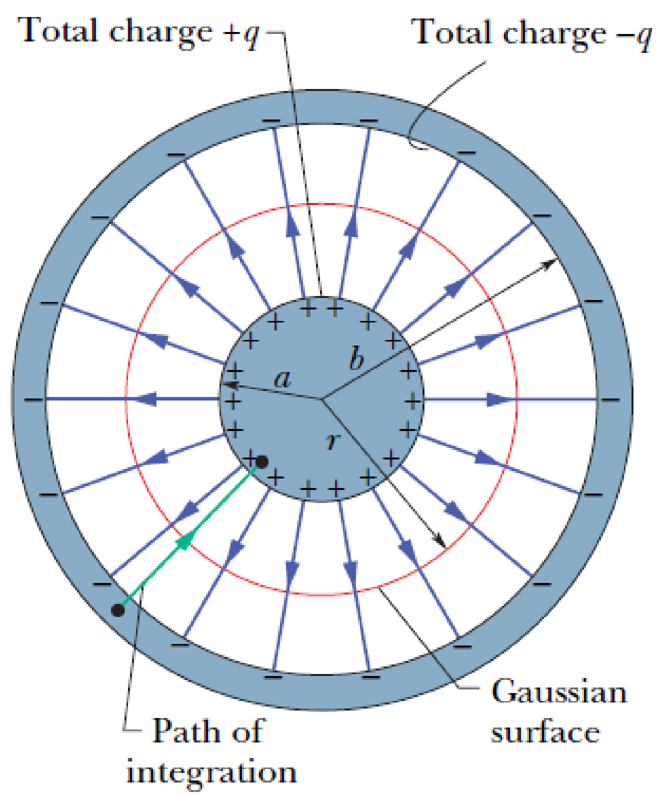
(A) 10 μF
(B) 12 μF
(C) 14 μF
(D) 16 μF

Calculating the Capacitance

A Cylindrical Capacitor

➢ The capacitance for two long coaxial cylinders of length *L* and inner radius *a* and outer radius *b* is:

$$C = 2\pi\varepsilon_0 \frac{L}{\ln(b/a)}$$



Calculating the Capacitance

Example 5:

A coaxial cable of radii 5 mm and 3 mm is connected by a battery of 12 V. If the charge on each cable is 6 nC, the length of the capacitor is:

Solution:

(B)

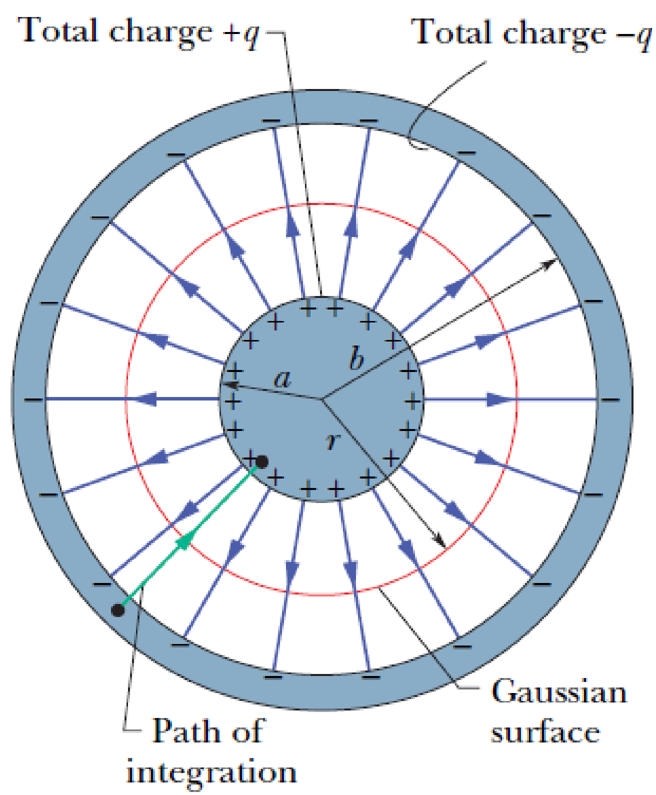
(A) 5.4 m
(B) 4.6 m
(C) 2.9 m
(D) 1.8 m

Calculating the Capacitance

A Spherical Capacitor

- The capacitance for two concentric spheres with inner radius *a* and outer radius *b* is:

$$C = 4\pi\varepsilon_0 \frac{ab}{b - a}$$



Calculating the Capacitance

An Isolated Sphere

- The capacitance for a single isolated spherical conductor of radius R can be assigned by assuming that the "missing plate" is a conducting sphere of infinite radius.

$$C = 4\pi\varepsilon_0 \frac{ab}{b - a}$$

- Then by rewriting this equation as

$$C = 4\pi\varepsilon_0 \frac{a}{1 - a/b}$$

- If we then let $b \rightarrow \infty$ and substitute R for a, we find

$$C = 4\pi\varepsilon_0 R$$

Calculating the Capacitance

Example 6:

Two concentric spherical shells of radii 4 cm and 3 cm has a charge of 5 nC. The potential difference across the capacitor is:

Solution:

(B)

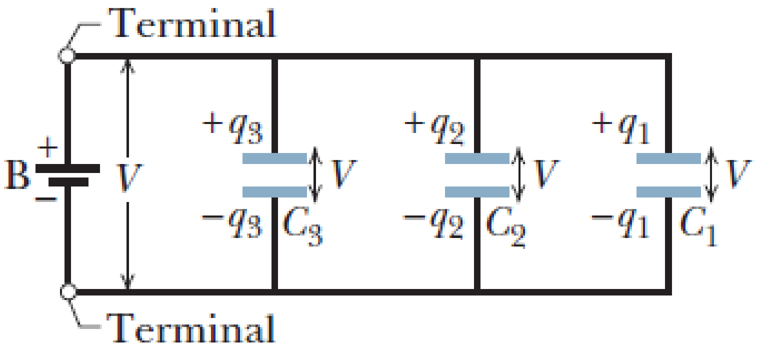
(A) 0.083 KV
(B) 0.375 KV
(C) 1.124 KV
(D) 2.361 KV

Capacitor in Parallel and in Series

Capacitors in Parallel and in Series

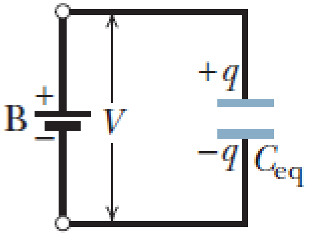
Capacitors in Parallel

- If capacitors connected in parallel, the voltage across each capacitor is the same as the total voltage, but the charge on each is different.



- The equivalent capacitance of a group of capacitors connected in parallel is

$$C_{eq} = \sum_{j=1}^{n} C_j$$



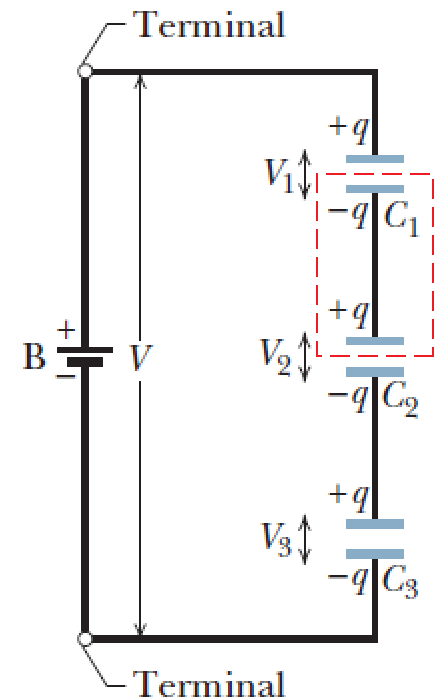
Capacitor in Parallel and in Series

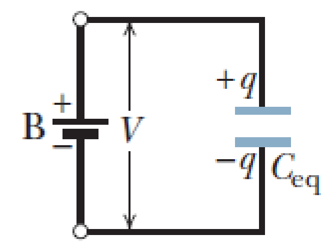
Capacitors in Series

- If capacitors connected in series, the charge on each capacitor is the same as the total charge, but the voltage across each is different.

- The equivalent capacitance of a group of capacitors connected in series is

$$\frac{1}{C_{eq}} = \sum_{j=1}^{n} \frac{1}{C_j}$$





Capacitor in Parallel and in Series

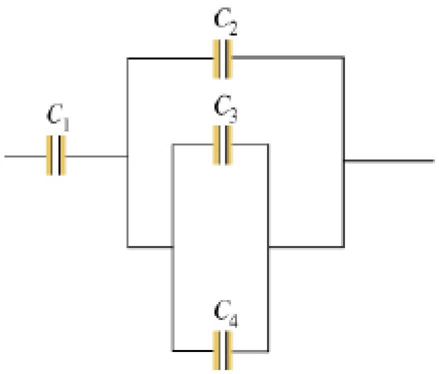
Example 7:

As shown in the figure, C_1= 6μF and C_2= C_3= C_4= 2μF. The equivalent capacitance is:

Solution:

(B)

(A) 4 μF
(B) 3 μF
(C) 2 μF
(D) 1 μF



Energy Stored in an Electric Field

Energy Stored in an Electric Field

- The electric potential energy of a charged capacitor is the work needed to charge it

$$U = \frac{q^2}{2C}$$

$$U = \frac{1}{2}CV^2$$

- The energy density is the potential energy per unit volume

$$u = \frac{1}{2}\varepsilon_0 E^2$$

where its unit is J/m^3

Energy Stored in an Electric Field

Example 8:

An isolated conducting sphere whose radius R is 6.85 cm has a charge q = 1.25 nC. The potential energy stored in the electric field of this charged conductor is:

Solution:

(D)

(A) 9.33×10^{-7} J
(B) 6.48×10^{-7} J
(C) 3.72×10^{-7} J
(D) 1.03×10^{-7} J

Energy Stored in an Electric Field

Example 9:

Referring to Example 8, the energy density at the surface of the sphere is:

Solution:

(C)

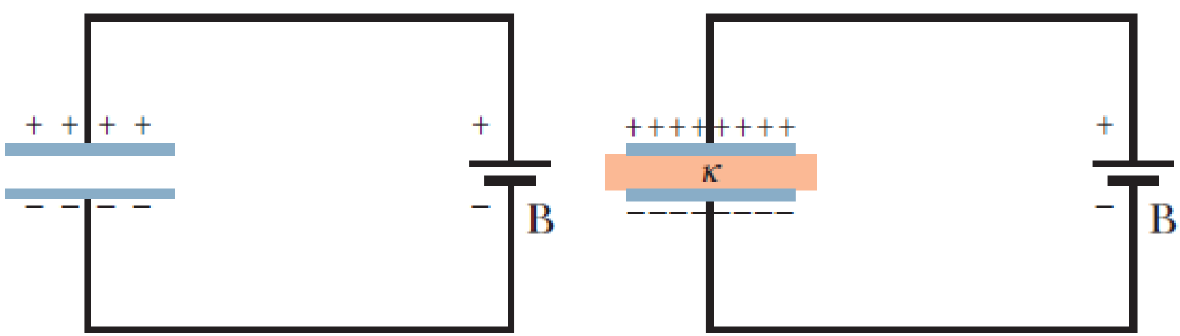
(A) 8.74×10^{-5} J/m^3
(B) 5.89×10^{-5} J/m^3
(C) 2.54×10^{-5} J/m^3
(D) 1.58×10^{-5} J/m^3

Capacitor with a Dielectric

Capacitor with a Dielectric

- In a region completely filled by a dielectric material of dielectric constant κ, all electrostatic equations containing the permittivity constant ε_0 are to be modified by replacing ε_0 with $\kappa\varepsilon_0$.

$$C = \kappa C_{\text{air}},$$



Capacitor with a Dielectric

Example 10:

A parallel-plate capacitor whose capacitance C is 13.5 pF is charged by a battery to a potential difference $V = 12.5$ V between its plates. The potential energy of the capacitor–slab device after a porcelain slab ($\kappa = 6.50$) is slipped between the plates is:

Solution:

(B)

(A) 43 pJ
(B) 162 pJ
(C) 383 pJ
(D) 561 pJ