Chapter.2

Electrostatic Potential and Capacitance
Class – XII
Subject – Physics

2.1 Two charges 5×10^{-8} C and -3×10^{-8} C are located 16 cm apart. At what point(s) on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero.

Sol.

Given:
$Q1 = 5x10^{-8}$ C
$Q2 = 3x10^{-8}$ C
r = 16 cm

We know

potential, $V = \frac{Q}{4\pi\epsilon_o r}$

Let the point P be at distance x from Q1 and 16-x from Q2 where the electric potential is zero.

Solving for cancellation of potential due to given charges

$$\frac{1}{4\pi\epsilon_o}\left[\frac{5 \times 10^{-8}}{x \times 10^{-2}} - \frac{-3 \times 10^{-8}}{(16-x) \times 10^{-2}}\right] = 0$$

Or, (5 / x) + (3 / 16-x) = 0

Or, x = 40 cm from positive charge towards negative charge on extended line.

Again, in between charges

(5 / x) + (3 / x-16) = 0

Or, x = 10 cm from positive charge towards negative charge.

2.2 A regular hexagon of side 10 cm has a charge 5 μC at each of its vertices. Calculate the potential at the centre of the hexagon.

Sol.

Given:
Six charges = 5 μC
Side of hexagon = 10 cm
Distance between center to vertex = 10 cm
Now, we know

$$V = \frac{Q}{4\pi\epsilon_o r}$$

Substituting the given values
$V = (9\text{x}10^{9}).(5\text{x}10^{-6}) / (10\text{x}10^{-2})$
Or, $V = 4.5\text{x}10^{5}$ V

Since all six charges are of equal magnitude and sign, therefore
Net potential at the centre = $6\text{x}(4.5\text{x}10^{5}) = 2.7\text{x}10^{6}$ V

2.3 Two charges 2 μC and –2 μC are placed at points A and B 6 cm apart

a) Identify an equipotential surface of the system.

b) What is the direction of the electric field at every point on this surface?

Sol.

Given:
Q1 = 2 μC
Q2 = -2 μC
r = 6 cm

a) Since both charges are equal and opposite, they will cancel out each other's effect at the centre of line joining them, and the plane passing through it will have equal potential (i.e. zero).

b) Normal to the plane in the direction AB.

2.4 A spherical conductor of radius 12 cm has a charge of 1.6×10^{-7}C distributed uniformly on its surface. What is the electric field

a) inside the sphere

b) just outside the sphere

c) at a point 18 cm from the centre of the sphere?

Sol.

Given:
$Q = 1.6 \times 10^{-7}$ C
r = 12 cm

a) Zero.

b) We know

$$E = \frac{Q}{4\pi\epsilon_o r^2}$$

Substituting the values
E = 100000 N / C

c) Now, r' = 18 cm
Using the above formula
$E = 4.4 \times 10^{4}$ N / C

2.5 A parallel plate capacitor with air between the plates has a capacitance of 8 pF (1pF = 10–12 F). What will be the capacitance if the distance

between the plates is reduced by half, and the space between them is filled with a substance of dielectric constant 6?

Sol.

Given:
C = 8 pF
d' = d / 2
K = 6

We know $C = \in_o . \frac{A}{d}$
$8x10^{-12} = (8.85x10^{-12}).A / d$
Or, d = (1.10625).A
Since, d = d / 2
d = 0.55 A
$Co = \in_o . \frac{A}{d'} = 1.6x10^{-11}$ F (this value is valid for vacuum)
With dielectric
C = KCo'
Or $C = 6x1.6x10^{-11} = 9.6x10^{-11}$ F

2.6 Three capacitors each of capacitance 9 pF are connected in series.
 a) **What is the total capacitance of the combination?**
 b) **What is the potential difference across each capacitor if thecombination is connected to a 120 V supply?**

Sol.

Given:
C1 = C2 = C3 = 9 pF

a) For series combination

$1 / C = (1 / C1) + (1 / C2) + (1 / C3)$

Or $C = 3$ pF

b) Potential drop is equal for every capacitor

$3V = 120$

$V = 40$ volts

2.7 Three capacitors of capacitances 2 pF, 3 pF and 4 pF are connected in parallel.

a) What is the total capacitance of the combination?

b) Determine the charge on each capacitor if the combination isconnected to a 100 V supply.

Sol.

Given:

C1 = 2 pF

C2 = 3 pF

C3 = 4 pF

a) For parallel configuration

$C = C1 + C2 + C3$

$C = 9$ pF

b) $Q = CV$

Therefore $Q1 = 2x10^{-12}x100 = 2x10^{-10}$ C

$Q2 = 3x10^{-10}$ C

$Q3 = 4x10^{-10}$ C

2.8 In a parallel plate capacitor with air between the plates, each plate has an area of 6 × 10–3 m2 and the distance between the plates is 3 mm. Calculate the capacitance of the capacitor. If this capacitor is connected

to a 100 V supply, what is the charge on each plate of the capacitor?

Sol.

Given:
$A = 6x10^{-3}\ m^2$
d = 3 mm
V = 100 V
We know

$$C = \epsilon_o . \frac{A}{d}$$

Or $C = 1.8x10^{-11}$ F

Now with supply connected
$Q = CV$
Or $Q = 1.8x10^{-11}x100 = 1.8x10^{-9}$ C

2.9 Explain what would happen if in the capacitor given in Exercise2.8, a 3 mm thick mica sheet (of dielectric constant = 6) were inserted between the plates,

a) While the voltage supply remained connected.

b) After the supply was disconnected.

Sol.

Added detail:
K = 6
d = 3 mm

a) With supply connected
$C' = KC$

Or $C' = 6x1.8x10^{-11}$
$C' = 1.08x10^{-10}$ F

And $Q' = C'V = 1.08x10^{-8}$ C

b) With supply disconnected
$C'' = C' = 108$ pF

Electric field when dielectric is not inserted
$E = V / d$
Or $E = 100 / 3x10^{-3}$
Or $E = 33333.33$ N / C
When dielectric sheet is inserted
$E'' = E / K$
Or $E'' = 33333.33 / 6$
Or $E'' = 5555.55$ N / C

So
$V'' = E''.d$
Or $V'' = 55555.55 \text{ x } 3 \text{ x } 10^{-3}$
Or $V'' = 16.6$ V
Then
$Q'' = C''V''$
Or $Q'' = (1.08x10^{-10}).(16.6)$
Or $Q'' = 1.8x10^{-9}$ C

2.10 A 12pF capacitor is connected to a 50V battery. How much electrostatic energy is stored in the capacitor?

Sol.

Given:
C = 12 pF
V = 50 V

Energy stored = $CV^2 / 2 = 1.5x10^{-8}$ J

2.11 **A 600pF capacitor is charged by a 200V supply. It is then disconnected from the supply and is connected to another uncharged 600 pF capacitor. How much electrostatic energy is lost in the process?**

Sol.

Given:
C = 600 pF
V = 200 V
C' = 600 pF

Initial energy, $U = CV^2 / 2$
$= 1.2 \times 10^{-5}$ J

Since half of energy initially stored is lost in the form of heat and electromagnetic radiation, therefore
Energy lost = $U / 2 = 6 \times 10^{-6}$ J