PHYSICS CLASS XII
CHAPTER – 2 ELECTROSTATIC POTENTIAL AND CAPACITANCE

Q.1. For a given potential difference, does a capacitor store more or less charge with a dielectric than it does without a dielectric.

Ans. A capacitor with a dielectric would store more charge, as its capacity increases.

Q.2. Can ever the whole charge of a body be transferred to the other? If yes, how and if not, why not?

Ans. Yes, the whole charge of a body A can be transferred to the conducting body B, when A is enclosed in B and is connected to it metallic wire. This is because charge resides always on the outer surface of a conductor.

Q.3. The safest way to protect yourself from lighting is to be inside a car. Comment.

Ans. The body of the car is metallic. It provides electrostatic shielding to the person in the car, because electric field inside the car is zero. The discharging due to lighting passes to the ground through the metallic body of the car.

Q.4. A sensitive instrument is to be shifted from the strong electrostate field in its environment. Suggest a possible way.

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

Ans. For this, the instrument must be enclosed fully in a metallic cover. This will provide electrostatic shielding to the instrument.

Q.5. What is a net charge on a charged capacitor?

Ans. Zero, because one plate has positive charge and the other carriers are equal negative charge.

Q.6. How will you obtain maximum capacitance from three given condensers?

Ans. By connecting them in parallel.

Q.7. Why does the electric conductivity of earth's atmosphere increase with altitude?

Ans. This is because of ionisation caused by highly energetic cosmetic ray particles from cosmos, which are hitting the atmosphere of earth.

Q.8. What is the order of capacitances used in power supplies?

Ans. It is usually 1 μF to 10 μF

Q.9. How much work must be done to charge a 24 μF capacitor, when the potential difference between the plates is 500 V?

Ans. Here, C = 24 μF = 24 × 10^{-6}F and V = 500 V

Work done = QV = CV^2 = (24 × 10^{-6}) $(500)^2$ = 6 J

Q.10. A metal plate is introduced between the plates of a charged parallel plate capacitor. What is its effect on the capacitance of the capacitor?

Ans. There will not be any effect on the capacitance of the capacitor.

Q.11. A 12 pF capacitor is connected to a 50 V battery. How much electrostatic energy is stored in the capacitor?

Ans. Given, voltage connected across the capacitor V = 50 V and capacitance of the capacitor

$$C = 12 \text{ Pf} = 12 \times 10^{-12} \text{ F}$$

Energy stored in the capacitor

$E = \frac{1}{2} CV^2 = \frac{1}{2} \times 12 \times 10^{-12} \times 50 \times 50 = 1.5 \times 10^{-8}$ J

Therefore, parallel combination is required for storing greater charge and greater energy.

Q.12. How does an electrically palarised object differ from an electrically charged object?

Ans. The charges of on electrically charged body or object reside on it permanently but the charges on an electrically polarised object reside on then temporarily because these charges will disappear as soon as the charged object causing polarisation is removed.

Q.13. A numbers of spherical conductors of different radii have some potential. How does the surface charge density on them relate to radius?

Ans. We know, $V = \frac{\sigma R}{\varepsilon_0}$

Since V is constant, σR = constant

$\therefore \quad \sigma \propto \frac{1}{R}$

Q.14. A metal foil of negligible thickness is introduced between two plates of capacitor at the centre. What will be the new capacitance of the capacitor?

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

Ans. On introducing a thin metal foil, d is halved. Arrangement is equivalent of two condenser each of capacity 2C in series.

∴ $$\frac{1}{C_s} = \frac{1}{2C} + \frac{1}{2C}$$

or $$\frac{1}{C_s} = \frac{1}{C}$$

$$C_s = C$$

Capacity is unchanged.

Q.15. Calculate the capacitance of a spherical capacitor consisting of two concentric spheres of radii 0.50 m and 0.60 m. The material filled in the space between the two spheres has a dielectric constant of 6?

Ans. Here, C = ?, r_a = 0.50 m, r_b = 0.60 m and K = 6

$$C = K\frac{4\pi\varepsilon_0 r_a r_b}{r_b - r_a} = \frac{6}{9\times10^9}.\frac{(0.5)(0.60)}{(0.6)-(0.5)}$$

$$C = 2 \times 10^{-9}\ F$$

Q.16. Net capacitance of three identical capacitors in series is 1 μF. What will be their net capacitance if connected in parallel? Find the ratio of energy stored in the two configurations if they are both connected to the same source.

Ans. If n identical capacitors, each of capacitance C are connected in series combination gives equivalent capacitance,

$$C_s = \frac{C}{n}$$

and when connected in parallel, then equivalent capacitance,

$$C_p = nC$$

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

$\Rightarrow \quad \frac{C_p}{C_s} = \frac{nC}{C/n} = n^2$ or $C_p = n^2 C_s$

Also, for same voltage, energy stored in capacitor given by

$U = \frac{1}{2} CV^2$ (for V = constant)

$U \propto C$

$C = 1\mu F$ and n = 3

In series combination,

$C_s = \frac{C}{n}$

In parallel combination,

$C_p = nC$

According to problem,

$C = nC_s = 3 \times 1\mu F = 3\mu F$

for each capacitor.

In parallel combination,

$$C_p = nC = 3 \times 3 = 9\mu F \; or \; C_p = 9\mu F$$

For same voltage,

$U \propto C$

$\Rightarrow \frac{U_s}{U_p} = \frac{C_s}{C_p} = \frac{C/n}{nC} = \frac{1}{n^2} = \frac{1}{(3)^2} = \frac{1}{9}$

$\Rightarrow \frac{U_s}{U_p} = \frac{1}{9}$ or $U_s : U_p = 1:9$

Q.20. A parallel plate capacitor with air between the plates has a capacitance of 8 pF. The separation between the plates is now reduced by half and the space

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

between them is filled with a medium of dielectric constant 5. Calculate the value of capacitance of the capacitor in the second case.

Ans. Given, capacitance of capacitor

$$C = \frac{\varepsilon_0 A}{d} = 8 \text{ pF}$$

where, A and d are area of each plate and separation between two plates respectively.

Now, $C' = \frac{K\varepsilon_0 A'}{d'}$

$= \frac{5\times\varepsilon_0 A}{(d/2)} = 10\left(\frac{\varepsilon_0 A}{d}\right)$

$C' = 10\left(\frac{\varepsilon_0 A}{d}\right) = 10C$

$= 10 \times 8$ pF $= 80$ pF   or $C' = 80$ Pf

Q.21. A 4 μF capacitor is charged by a 200 V supply. Then, it is disconnected from the supply and is connected to another uncharged 2 μF capacitor. How much electrostatic energy of the first capacitor is lost in the form of heat and electromagnetic radiation?

Ans. Let us consider two capacitors C_1 and C_2. According to the question, C_1 and C_2. According to the question, $C_1 = 4\ \mu F$, $V_1 = 200$ V and $V_2 = 0$

Loss in energy $= \frac{1}{2}\frac{C_1 C_2 (V_1 - V_2)^2}{(C_1 + C_2)}$

$= \frac{1}{2} \times \frac{4\times2\times10^{-12}(200-0)^2}{(4+2)\times10^{-6}} = \frac{8}{3} \times 10^{-2}$J

Loss in energy = 2.67×10^{-2}J

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

This loss in energy is equal to the energy dissipated in the form of heat and electromagnetic radiation.

Q.22. A 12 pF capacitor is connected to 50 V battery. How much electrostatic energy is stored in the capacitor?

Ans. Here, C = 12 pF, C = 12 × 10^{-12}F

V = 50 V, U = ?,

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

$U = \frac{1}{2}(12 \times 10^{-12})(50)^2 = 1.5 \times 10^{-8}$ J

∴ $\frac{Q_1}{Q_2} = \frac{C_1}{C_2}$ [From Eqs. (i) and (ii)]

Putting the values of C_1 and C_2, we get

$\frac{Q_1}{Q_2} = \frac{4\pi\varepsilon_0 a}{4\pi\varepsilon_0 b} = \frac{a}{b}$

$\frac{Q_1}{Q_2} = \frac{a}{b}$ ……(iii)

Charge density on sphere (1), $\sigma_1 = \frac{Charge}{Surface\ area}$

$\sigma_1 = \frac{Q_2}{4\pi a^2}$

Charge density on sphere (2), $\sigma_2 = \frac{Charge}{Surface\ area}$

$\sigma_2 = \frac{Q_2}{4\pi b^2}$

∴ $\frac{\sigma_1}{\sigma_2} = \frac{b^2}{a^2} \cdot \frac{Q_1}{Q_2} = \frac{b^2}{a^2} \cdot \frac{a}{b}$ [From Eq. (iii)]

or $\frac{\sigma_1}{\sigma_2} = \frac{b}{a}$ …..(iv)

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

The ratio of electric field on both spheres

$$\frac{E_1}{E_2} = \frac{\sigma_1}{\sigma_2} = \frac{b}{a} \qquad \text{[From Eq. (iv)]}$$

As, charge density is inversely propotional to radius. Thus, for flatter portions, the radius is more and at pointed ends radius is less, thus the charge density is more at pointed or sharp ends.

Q.23. A capacitor of 200 pF is charged by a 300 V battery. The battery is then disconnected and the charge capacitor is connected to another uncharged capacitor of 100 pF. Calculate the difference between the final energy stored in the combined system and the initial energy stored in the single capacitor.

Ans. Given, C = 200 pF = 200 × 10^{-12}F

V = 300 V

The energy (initial) stored by the capacitor is

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

$$= \frac{1}{2} \times 200 \times 10^{-12} \times 300 \times 300$$

$$= 9 \times 10^{-6} \text{J}$$

The charge on the capacitor when charged through 300 V battery is

$$Q = CV = 200 \times 10^{-12} \times 300$$

$$= 6 \times 10^{-8} C = 60 \text{ nc}$$

When two capacitors are connected, they have their positive plates at the same potential and negative plates also at the same potential. Let V' be the common

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

potential difference. By charge conservation, charge would distribute but total charge would remain constant.

Thus, $\qquad$ Q = $q + q'$

$$\frac{q}{C} = \frac{q'}{C'}$$

$$\frac{q}{200} = \frac{q'}{100}$$

$$q = 2q'$$

Thus $\qquad$ Q = $2q'$ + q' = $3q'$

So, $\qquad$ q' = $\frac{Q}{3}$

$$= \frac{60nC}{3} = 20nC$$

And $\qquad$ q = 2q = 40 nC

Thus, final energy

$$U_f = \frac{q^2}{2C} + \frac{q'^2}{2C'}$$

$$= \frac{1}{2} \times \frac{(40\times10^{-9})^2}{200\times10^{-12}} + \frac{1}{2} \times \frac{(20\times10^{-9})^2}{100\times10^{-12}}$$

$$= 4 \times 10^{-6} + 2 \times 10^{-6} = 6 \times 10^{-6} J$$

Difference in energy = Final energy – Initial energy

$$= U_f - U_i$$

$$= 6 \times 10^{-6} - 9 \times 10^{-6} \text{ J}$$

Thus, difference in energy is 3×10^{-6} J.

Q.24. 27 drops of same size are charged at 220 V each. They coalesce to form a bigger drop. Calculate the potential of bigger drop.

Ans. Here, n = 27, V = 220 V

V = ?

Let R be the radius of big drop and r be the radius of each small drop. As volume remains unchanged, therefore,

$$\frac{4}{3}\pi R^3 = 27 \times \frac{4}{3}\pi r^3 \quad \text{or} \quad R = 3r$$

If q is charge on each small drop, then charge on one big drop, q' = 27 q

Capacity of big drop

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

$$C' = 4\pi\varepsilon_0 (3r)$$

Potential of big drop,

$$V = \frac{q'}{C} \quad \text{or} \quad V = \frac{27q}{4\pi\varepsilon_0(3r)}$$

$$V' = 9 \times V = 9 \times 220 = 1980 \text{ V}$$

Q.25. (i) How is the electric field due to a charged parallel plate capacitor affected when a dielectric slab is inserted between the plates fully occupying the intervening region?

(ii) A slab of material of dielectric constant K has the same area as the plates of a parallel plate capacitor but has thickness ½ d, where d is the separation between the plates. Find the expression for the capacitance when the slab is inserted between the plates.

Ans. (i) The total charge of the capacitor remain conserved on introduction of dielectric slab.

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

Also, the capacitance of capacitor increases to K times of original values.

∴ CV = $C'V'$

CV = (KV)V'

⇒ $V' = \frac{V}{K}$

∴ New electric field

$$E' = \frac{V'}{d} = \left(\frac{V/K}{d}\right) = \left(\frac{V}{d}\right)\frac{1}{K}$$

$$E' = \frac{E}{K}$$

∴ On introduction of dielectric medium new electric field E' becomes $\frac{1}{K}$ times of its original value (decrease).

(ii) ∵ Capacitance of a parallel plate capacitor partially filled with dielectric medium is given by

$$C = \frac{\varepsilon_0 A}{(d-t)(t/K)}$$

where t is the thickness of dielectric medium.

Here, $t = \frac{d}{2}$

$$C = \frac{\varepsilon_0 A}{d-\frac{d}{2}+\frac{d}{2K}} = \frac{\varepsilon_0 A}{\frac{d}{2}\left(1+\frac{1}{k}\right)}$$

∴ $C = \frac{2\varepsilon_0 AK}{(K+1)d}$

⇒ $\frac{V_S^2}{V_p^2} = \frac{C_p}{C_s} = \frac{2C}{\left(\frac{C}{2}\right)}$

$\frac{V_S^2}{V_P^2} = 4$

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

$\Rightarrow \quad \frac{V_s}{V_p} = 2$

$V_s : V_p = 2 : 1$

Q.26. The two plate of a parallel plate capacitor are 4 mm apart. A slab of dielectric constant 3 and thickness 3mm is introduced between the plates with its faces parallel to them. The distance between the plates is so adjusted that the capacitance of the capacitor becomes (2/3)rd of its original value. What is the new distance between the plates?

Ans. Before introduction of slab

d_1 = 4mm = 4 × 10^{-3} m

Plate area = A

∴ Capacitance $C_1 = \frac{\varepsilon_0 A}{d_1}$

Suppose after introduction of slab, the new distance between the place is d_2.

Plate area of each plate = A

K = 3

Thickness of slab t = 3 mm = 3 × 10^{-3} m

Capacitance $C_2 = \frac{\varepsilon_0 A}{(d_2 - t + t/K)}$

According to the question,

$\frac{2}{3} C_1 = C_2$

$\frac{2}{3} \cdot \frac{\varepsilon_0 A}{d_1} = \frac{\varepsilon_0 A}{d_2 - t + t/K}$

Substituting the values (given in question)

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

$$\frac{2}{3d_1} = \frac{1}{d_2 - t + t/K}$$

$$\frac{2}{3\times4\times10^{-3}} = \frac{1}{(d_2 - 3 + 3/3)\times10^{-3}}$$

[d_2 is in mm]

$$\frac{1}{6} = \frac{1}{(d_2 - 2)}$$

$\Rightarrow$ d_2 - 2 = 6 $\Rightarrow$ d_2 = 8 mm

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co