# SHIKSHA CLASSES

**Subject : Physics** **BOARD ANSWER PAPER** **Total Marks : 20**
**Class : XII** **Topic: 8. Electrostatics**

### Section (A)

**Q.1 : A) Select and write the most appropriate answer from given alternatives in each sub-question.** **[5]**

**1) There are two charges $+1\,\mu C$ and $+5\,\mu C$ the ratio of the forces acting on them will be..**

**Ans. :** b) 1:1

$q_1 = 1\mu C \qquad q_2 = 5\mu C$

$$F_1 = \frac{1}{4\pi\in_0}\frac{\left(1\times10^{-6}\right)\left(5\times10^{-6}\right)}{r^2} \quad \text{---(i)}$$

$$F_2 = \frac{1}{4\pi\in_0}\frac{\left(5\times10^{-6}\right)\left(1\times10^{-6}\right)}{r^2} \quad \text{---(ii)}$$

divide eqn (i) by eqn (ii)

$\frac{F_1}{F_2} = \frac{1}{1}$ but direction of $F_1$ and $F_2$ is different.

**2) A capacitor of capacity C has a charge Q and stored energy is W. If the charge is increased to 2Q. the stored energy will be…**

**Ans. :** c) 4W

Energy stored $W = \frac{Q^2}{2C}$

$\therefore W \propto Q^2$ (if C is constant)

$W \propto Q^2 \qquad ---(i)$

$W' \propto (2Q)^2 \qquad ---(ii)$

$$\frac{W}{W'} = \frac{Q^2}{(2Q)^2} = \frac{Q^2}{4Q^2} \qquad \boxed{W' = 4W}$$

**3) The energy stored in a condenser is in the form of**

**Ans. :** b) Potential energy

**4) A metal plate of area 0.5 m$^2$ is given a charge of $50\mu C$. The mechanical force acting on the metal plate is**

**Ans. :** c) 565 N/m$^2$

**5) In n condensers each of capacity C are connected in series, effective capacity of combination is**

**Ans. :** a) $\frac{C}{n}$

**Q.1 : B) Very short answer type question.** **[2]**

**1) A wire is bent in a circle of radius 20 cm. it is given a charge of 200 $\mu C$. Which spread on it uniformly. What is electric potential at the centre?**

**Ans. : Given :**

$q = 200\mu C = 200\times10^{-6}\,C$

$R = 20\text{ cm} = 2\times10^{-2}\text{m} \; V = ?$

As $V = \frac{1}{4\pi\in_0}\frac{q}{r}$

$$= \frac{9\times10^9\times \overset{100}{\cancel{200}}\times10^{-6}}{\cancel{2}\times10^{-2}}$$

$= 9\times10^9\times10^2\times10^{-6}\times10^2$

$= 9\times10^{13-6} = 9\times10^7$ Volt

**2) Explain the concept of potential.**

**Ans. : Concept of Potential :** The potential energy is the work done against the electrostatic forces to achieve a certain configuration of charges in a given system. Since every system tries

Consider a positive charge Q fixed at some point in space. For bringing any other positive charge close to it, work is necessary. This work is equal to the change in the potential energy of their system.

Thus, work done against a electrostatic force - Increase in potential energy of the system.

$\therefore \vec{F} d\vec{r} = dU,$

Where dU is the increase in potertial energy when charges is displaced through $d\vec{r}$ and $\vec{F}$ is the force exerted on the charge.

## Section (B)

**Q.2 : Attempt any THREE. [6]**

**1] Define : i) Electric flux**

**ii) Capacitance**

**Ans :** i) **Electric flux :** The number of lines of force passing through per unit area is called electric flux, S.I. unit - Vm. a given area around a point in an electric field is called electric flux.

ii) **Capacitance :** The capacitance of a capacitor is the ratio of magnitude of charge on either of conductor to the magnitude of potential difference between two conductors.

**2] Define capacity of a condenser and state its S.I. unit.**

**Ans :** The capacitance of a capacitor is the ratio of magnitude of charge on either of conductor to the magnitude of potential difference between two conductors.

$C = \frac{Q}{V}$ where C = Capacity, Q = Charge,

V = potential difference.

S.I. unit is farad.

A capacitor has a capacitance of one farad, if the potential difference across it rises by 1 volt, when 1 coulomb of charge is given to it.

**3] Calculate the surface density of charge on a metal sphere of diameter 10 cm situated in air, if electric intensity at a point of 15 cm is 2 x $10^4$ N/C.**

**Ans : Given :**

D = 10 cm, R = 5 cm = $5 \times 10^{-2}$ m

k = 1, r = $15 \times 10^{-2}$ m, E = $2 \times 10^4$ N/c

To find $\sigma = ?$

$$E = \frac{\sigma R^2}{\varepsilon_0 r^2}$$

$$\sigma = \frac{k\varepsilon_0 r^2 E}{R^2}$$

$$= \frac{1 \times 8.85 \times 10^{-12} \times (15 \times 10^{-2})^2 \times 2 \times 10^4}{(5 \times 10^{-2})^2}$$

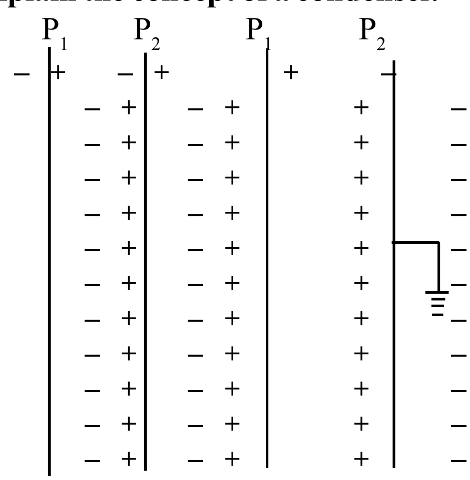
$$= \frac{8.85 \times 10^{-12} \times \overset{9}{\cancel{225}} \times \cancel{10^{-4}} \times 2 \times 10^4}{\cancel{25} \times \cancel{10^{-4}}}$$

$$= 8.8 \times 9 \times 2 \times 10^{-8}$$

$$\boxed{\sigma = 1.593 \times 10^{-6} \, C/m^2}$$

**4] Explain the concept of a condenser.**

**Ans :**




Consider a metal plate $P_1$ having area A. Let positive charge Q be the charge on insulated metal plate $P_1$., when it is fully charged let its potential is V.

$\therefore C_1 = \frac{Q}{V}$ .... (1)

Now another identical metal plate $P_2$ is kept near and parallel to plate $P_1$. The inner surface metal $P_2$ acquires charge –Q and outer surface of metal plate $P_2$ acquires + Q charge by methodof induction. The induced negative charge lowers the potential of $P_1$, while the positive charge raises its potential. However negative charge is nearer to plate $P_1$ than positive charge. Therefore there is net decrease in potential of plate $P_1$.

If outer surface of P is connected to the connected to the earth, the unbound positive charge + Q escapes to the earth.

Let $-V_1$ be the electric potential due to charge – Q on plate $P_2$.

Hence, the net electric potential of system $= V + (-V_1) = V - V_1$

∴ The capacity in this case =

$$C_2 = \frac{Q}{V - V_1} \qquad ..... (2)$$

Form equation (1) and (2) , $C_2 > C_1$. Thus, if an earth connected conductor is brought near a charged conductor, its capacity increases. This is the principle of condenser.

## Section (C)

**Q. 3. Attempt any one** **[3]**

1. **Derive the formula for effective capacity of three condensers connected in series.**

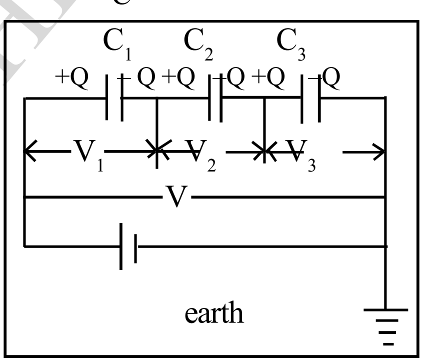
**Ans :** Consider three condenser of capacities $C_1$, $C_2$, and $C_3$ are connected in series as shown in the figure.

Let V be the P. D. applied across the combination. Let the P.D. across $C_1$, $C_2$ and $C_3$ is $V_1$, $V_2$, and $V_3$ respectively.

Let Q be the total charge supplied by the cell.

$V = V_1 + V_2 + V_3$ ........ (1)

But $V = \dfrac{Q}{C}$.




$$\therefore\ V_1 = \frac{Q}{C_1},\ V_2 = \frac{Q}{C_2},\ V_3 = \frac{Q}{C_3}$$

Putting the values of $V_1$ , $V_2$ and $V_3$ in equation (1), we get :

$$V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$V = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right] \qquad ..... (2)$$

Let the effective capacity be = $C_s$

∴ P.D. across $C_3$ i.e. $V = \dfrac{Q}{C_s}$ .... (3)

From (2) and (3),

$$\frac{Q}{C_s} = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$$

$$\therefore\ \frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

i.e. reciprocal of effective capacity is the sum of reciprocals of individual capacities.

2] **A condenser of capacity of 100 mF is charged up to a potential of 500 V. If the area of each plate of the condenser is 20 cm² and the distance between the plates is 1 mm. Find the energy density of the space between the plates.**

**Ans :** Given : $C = 100mF = 100 \times 10^{-3} F = 10^{-1} F$,

V = 500 Volt,

$A = 20\text{cm}^2 = 20\times10^{-4}\text{m}^2$, d = 1mm $10^{-3}$ m

**To Find :** Energy density = ?

i) Total Energy $E = \dfrac{1}{2}CV^2$

$$E = \frac{1}{2}\times10^{-1}\times(500)^2$$

$$\therefore E = \frac{25}{2}\times10^{-1}\times10^4$$

$$\therefore E = 12.5 \times 10^3 \text{ J}$$

ii) Energy density =

$$\frac{\text{Total Energy}}{\text{Volume of the space between the plates}}$$

$$= \frac{E}{A.d} = \frac{12.5\times10^3}{20\times10^{-4}\times10^{-3}} = \frac{12.5}{2}\times10^6\times10^3$$

$= 6.25 \times 10^9$ J/$m^3$

**Section (D)**

**Q. 4. Attempt any one** **[4]**

**1) a. Derive the formula for energy stored in a charged condenser.**

**Ans :** Consider a capacitor of capacity C.

Let the initial charge on the condenser be zero, so the potential of condenser will be zero.

In the process of charging, let the charge and potential be $q$ and $\upsilon$ in any intermediate stage.

$$\therefore C = \frac{q}{\upsilon}$$

$$\therefore \upsilon = \frac{q}{C} \quad ....... \quad (1)$$

Suppose a small charge $+dq$ is added to the condenser, the existing charge $q$ will repel this charge $+dq$ and hence work will be done in supplying the charge $dq$ against the repulsive force.

Work done is given by : $d\omega = \upsilon \, . \, dq$

Putting the value of $\upsilon$ from equation (1)

$$\therefore d\omega = \frac{q}{C} dq$$

Let Q and V is the charge and potential when the condenser is fully charged. So to charge the condenser from 0 to Q the total work done will be obtained by integration.

$$\therefore \omega = \int_0^Q d\omega$$

$$\therefore \omega = \int_0^Q \frac{q}{C} dq$$

$$\therefore \omega = \frac{1}{C} \int_0^Q q \, dq$$

$$\therefore \omega = \frac{1}{C} \left[ \frac{q^2}{2} \right]_0^Q$$

$$\therefore \omega = \frac{1}{2C} \left[ Q^2 - 0^2 \right]$$

$$\therefore \omega = \frac{1}{2C} . Q^2 = \frac{Q^2}{2C}$$

This work done is stored in the condenser in form of electric potential energy in the space between the plates of condenser.

$\therefore$ Energy of condenser $= \dfrac{Q^2}{2C}$ ..... (2)

**Different Forms :**

We know that $C = \dfrac{Q}{V}$ $\quad \therefore Q = CV$

Putting the value of Q in equation (2),

$$Energy = \frac{(CV)^2}{2C} = \frac{C^2V^2}{2C} = \frac{1}{2} CV^2$$

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

Also $C = \dfrac{Q}{V}$

Putting this value in equation (3),

$$Energy = \frac{1}{2} . \frac{Q}{V} . V^2 = \frac{1}{2} Q.V \, .$$

$$\therefore Energy \ of \ condenser = \frac{Q^2}{2C}$$

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

**b. Three condensers with capacitance $10\mu F$, $20\mu F$ and $30\mu F$ are connected in series and a potential difference of 220 volt is applied across the combination. Find the resultant capacity, charge on each condenser and P.D. across each condenser.**

**Ans :** **Given** : $C_1 = 10\mu F$, $C_2 = 20\mu F$, $C_3 = 30\mu F$

**To Find**: $C_s = ?, Q_1 = ?, Q_2 = ?, Q_3 = ?, V_1 = ?, V_2 = ?, V_3 = ?$

**Solu$^n$:** $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

$\therefore \frac{1}{C_s} = \frac{1}{10} + \frac{1}{20} + \frac{1}{30}$

$\therefore \frac{1}{C_s} = \frac{6+3+2}{60} \quad \therefore \quad \frac{1}{C_s} = \frac{11}{60}$

$\therefore C_s = \frac{60}{11} \mu F$

$\therefore Q_s = C_s.V = \frac{60}{11} \times 10^{-6} \times 220$

$\therefore Q_s = 1200 \times 10^{-6} C$

Charge $Q_s = Q_1 = Q_2 = Q_3 = 1200 \times 10^{-6} C$

$\therefore C_1 = \frac{Q_1}{V_1}$

$\therefore V_1 = \frac{Q_1}{C_1}$

$\therefore V_1 = \frac{1200 \times 10^{-6}}{10 \times 10^{-6}} = 120$ V

$\therefore V_2 = \frac{Q_2}{C_2}$

$\therefore V_2 = \frac{1200 \times 10^{-6}}{20 \times 10^{-6}} = 60$ V

$\therefore V_3 = \frac{Q_3}{C_3}$

$\therefore V_3 = \frac{1200 \times 10^{-6}}{30 \times 10^{-6}} = 40$ V

**OR**

2) **a. Derive the formula for effective capacity of three condensers connected in parallel.**

**Ans :** Consider the three condensers of capacities

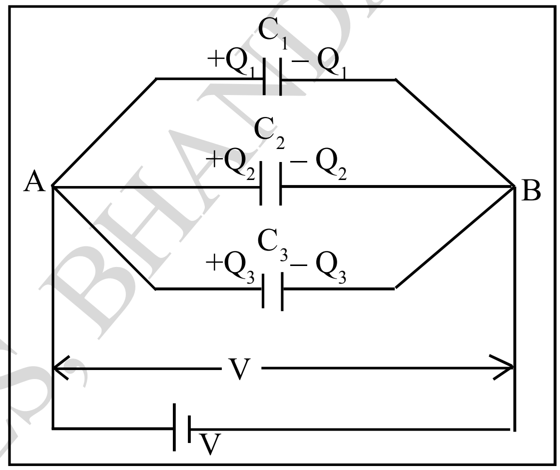
$C_1$, $C_2$ and $C_3$ connected in parallel as shown in the figure.

Let the total charge supplied by the cell be Q. This charge will be distributed among the three capacitors according to their capacities.

Let the charge on capacitors of capacities $C_1, C_2$ and $C_3$ be $Q_1$, $Q_2$ and $Q_3$ respectively.

$\because$ The condensers are connected in parallel, hence the P.D. across each of them will be same and equal to total voltage V.

$Q = Q_1 + Q_2 + Q_3$ ..... (1)




$C_1 = \frac{Q_1}{V}$

$\therefore Q_1 = C_1 V, \; Q_2 = C_2 V, \; Q_3 = C_3 V$

Putting the values of $Q_1$, $Q_2$ and $Q_3$ in equation (1)

$Q = C_1 V + C_2 V + C_3 V$

$Q = V(C_1 + C_2 + C_3)$ .... (2)

Let the effective capacity of combination is $C_P$

$C_p = \frac{Q}{V} \quad \therefore$

$Q = C_p V$

Putting the value of Q in equation (2), we get

$C_p V = V(C_1 + C_2 + C_3)$

$\therefore C_p = C_1 + C_2 + C_3$

When the capacitors are connected in parallel their effective capacity is equal to the sum of individual capacitances.

**b. A positively charged sphere of radius 10cm is surrounded by a medium of dielectric constant 5. If the magnitude of the electric field intensity at a point outside the sphere at a distance r from the centre of sphere is $6.4\times10^{-4}$ V/m and charge on the sphere is $6.4\times10^{-12}$ C, find r.**

**Ans :** Given : R = 10 cm = $10\times10^{-2}$ cm

$k = 5$

$q = 6.4\times10^{-12}$ C

E = $6.4\times10^{-4}$ C

To Find: r = ?

Solution:

Electric Intensity $E = \frac{1}{4\pi \in_0 k} . \frac{q}{r^2}$

$$\therefore \ r^2 = \frac{1}{4\pi \in_0 k} . \frac{q}{E}$$

$$\therefore \ r^2 = \frac{9\times10^9}{5} \times \frac{\cancel{6}\times10^{-12}}{\cancel{6}\times10^{-4}}$$

$$\therefore \ r^2 = \frac{9}{5}\times10^{13}\times10^{-12}$$

$$\therefore \ r^2 = 1.8\times10^1$$

$$\therefore \ r^2 = 180$$

$$\therefore \ \text{r} = \sqrt{180}$$

$$\therefore \ \boxed{r = 13.81m}.$$

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