Chapter 12

ELECTROSTATICS

Gauss's Theorem: For a close surface of any shape, total normal electric induction over this surface is equal to the algebraic sum of the electric charges enclosed by that surface.

Explanation: Total normal electric induction over a close surface is given by –

T. N. E. I. = $\int \varepsilon \, E \cos\theta \, ds$

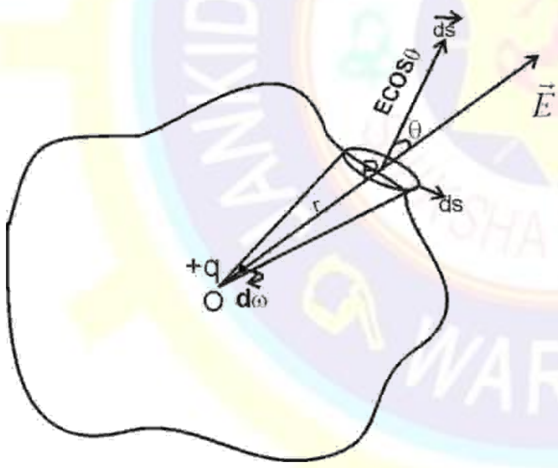
Let, the surface is enclosing q_1, q_2, q_3, …q_n no. of electric charges, then according to Gauss's theorem.

$$\int \in E \cos\theta \, ds = q_1 + q_2 + q_3 + - - - + q_n$$

OR

T. N. E. I. = $\sum_{i=1}^{n} q_i$

Proof:



Consider, a charge +q is situated at point O inside a closed surface. Let, 'ds' be small area of surface around a point P at a distance r from charge + q.

Therefore electric intensity at point P is given by –

$$E = \frac{1}{4\pi\varepsilon} \frac{q}{r^2} \text{ -------------- (1)}$$

Let, the normal drawn to the area ds makes an angle θ with the direction of electric intensity then,

N. E. I. through area ds = $\in$E cos θ ds.

Using equation (1),

N. E. I. over area 'ds' = $\varepsilon \frac{1}{4\pi\varepsilon} \frac{q}{r^2}$ cos θ ds

$$= \frac{q}{4\pi} \left(\frac{\cos\theta \, ds}{\mathbf{r}^2} \right) \text{ -------(2)}$$

But, $\left(\frac{\cos\theta \, ds}{\mathbf{r}^2} \right)$ = dω

= Solid angle subtended by area ds at point O.

$\therefore$ N. E. I. = $\frac{q}{4\pi}$ dω ------------ (3)

Therefore, T.N. E. I. over the whole surface is given by integrating above equation,

T.N. E. I. over whole surface = $\int \frac{q}{4\pi}$. dω

$$= \frac{q}{4\pi} \int d\omega \text{ ---- (4)}$$

But, $\int d\omega$ = 4π = total solid angle subtended by whole surface at point O.

$\therefore$ T. N. E. I. = $\frac{q}{4\pi}$. 4π

$\therefore$ T. N. E. I. = q ----------- (5)

i.e. T. N. E. I. = charge enclosed by the surface.

Thus, same result can be obtained if surface encloses q_1, q_2, q_3, ------, q_n charges.

$\therefore$ T. N. E. I. = $q_1 + q_2 + q_3 +$ ------$+q_n$

OR T. N. E. I. = $\sum_{i=1}^{n} q_i$

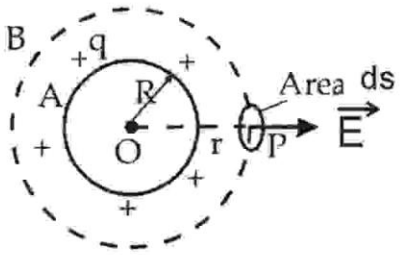
OR

$\int \in E \cos\theta \, ds =$ T. N. E. I. = $\sum_{i=1}^{n} q_i$

Hence, proved.

Applications of Gauss's theorem:

1) Expression for Electric Intensity at a point out side a charged sphere:



Consider a charge conducting sphere 'A' of radius R, having charge +q on its surface. Because of the spherical symmetry, the charge is distributed uniformly over the sphere.

Let, point P is out side the change sphere at a distance 'r' from its centre, where electric intensity is to be determined.

We draw a Gaussian sphere i.e. imaginary sphere of radius (r) concentric with sphere 'A'. Electric Intensity $\overline{E}$ at every point on Gaussian sphere is same & perpendicular to the surface directed radially outwards. Therefore,

$$\theta = 0^0 \Rightarrow \cos\theta = 1.$$

The T. N. E. I. over the sphere 'B' is given by –

T. N. E. I. = $\int \varepsilon \, E \cos\theta \, ds$

Since, Cos θ = 1,

$\therefore$ T. N. E. I. = $\int \in E ds = \in E \int ds$

Over Gaussian sphere B,

But, $\int ds = 4\pi r^2$

= Total surface area of Gaussian sphere 'B'

$\therefore$ T.N.E. I. over B = $\in E \times 4\pi r^2$ -------- (1)

But, according to Gauss's theorem,

$\therefore$ T. N. E. I. Over 'B' = q ---------- (2)

From (1) & (2)

$$E = \frac{q}{4\pi \in r^2}$$

$$E = \frac{1}{4\pi \in} \frac{q}{r^2}$$

Let, K be the dielectric constant of media.

Then, $E = \dfrac{1}{4\pi \in_0 K} \dfrac{q}{r^2}$ --------- (3)

This is expression for electric, intensity at a point outside a charged sphere.

Special Cases:

Case I: Expression for Electric intensity in term of surface charge density.

Let, σ be the surface charge density over the sphere A.

$\therefore$ σ = $\dfrac{\textbf{Charge}}{\textbf{Area}}$

$\therefore$ σ = $\dfrac{q}{4\pi R^2}$ (since, A = 4π R^2)

Rearranging, we get,

$$\frac{q}{4\pi} = \sigma R^2 \text{ ---------- (4)}$$

From equation (3),

$$E = \frac{1}{4\pi \in_0 K} \frac{q}{r^2}$$

OR E = $\left(\dfrac{q}{4\pi}\right) \dfrac{1}{\in_0 Kr^2}$

Using (4), we get,

$\therefore$ E = $\dfrac{\sigma R^2}{\in_0 Kr^2}$ --------- (5)

Case II: When point 'P; lie on the surface of sphere 'A':-

R = r

$\therefore$ From equation (3),

$$E = \frac{1}{4\pi \in_0 K} \frac{q}{R^2} \text{ --------- (6)}$$

& From (5),

$$E = \frac{\sigma R^2}{\in_0 Kr^2}$$

$\therefore$ E = $\dfrac{\sigma}{\in_0 K}$ ----------- (7)

Case III: When Point 'P; lie in side charged sphere.

In such case-

r < R

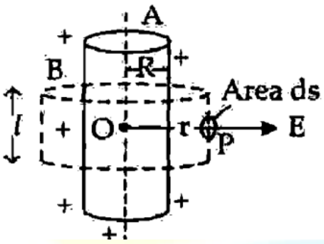
Thus, the Gaussian sphere 'B' can be drawn inside the charged sphere. Therefore, sphere 'B' will not enclosed any charge.

$\therefore$ T. N. E. I. = 0

$\therefore$ E = 0
i.e. electric intensity inside a charge conductor is always zero.

2) Expression for Electric Intensity out side a charged cylinder:-

Consider a charged cylinder 'A' of radius R. Let λ charge per unit length is distributed uniformly over the surface of cylinder A.



i.e.
λ = Charge per unit length
= linear charge density of cylinder 'A'.

To determine electric intensity at a distance 'r' from axis of cylinder at point P, we consider a Gaussian cylinder 'B' of length (l) such that point 'P' lie on the curved surface of cylinder 'B'.

The electric field intensity is directed radially outward & perpendicular to each & every point on the curved surface of cylinder 'B'.

Thus, angle between $\overline{E}$ & $\overline{ds}$, θ equal to 0^0.

The T. N. E. I. over curved surface of gaussions cylinder 'B' is given by –

T. N. E. I. over cylinder B = $\int \in E \cos\theta \, ds$

Since, $\theta = 0^0$,
$\therefore$ cos θ = 1.

$\therefore$ T. N. E. I. over cylinder 'B' = $\int \in E ds$

$$= \in E \int ds$$

But, $\int ds = 2\pi r l$,

since, ds = Curved surface area of cylinder 'B'.

$\therefore$ T. N. E. I. over cylinder 'B' =

$$\in E \times 2\pi r l \text{ ---(1)}$$

Now, according to Gauss's theorem,

T. N. E. I. over cylinder 'B' = $\lambda \, l$ -------- (2)

From (1) and (2)

$$\in E \times 2\pi r l = \lambda l$$

$$\therefore \text{ E} = \frac{\lambda}{2\pi \in r}$$

If K = dielectric constant of medium, then,

$$\text{E} = \frac{1}{2\pi \in_0 K} \frac{\lambda}{r} \text{ -------- (3)}$$

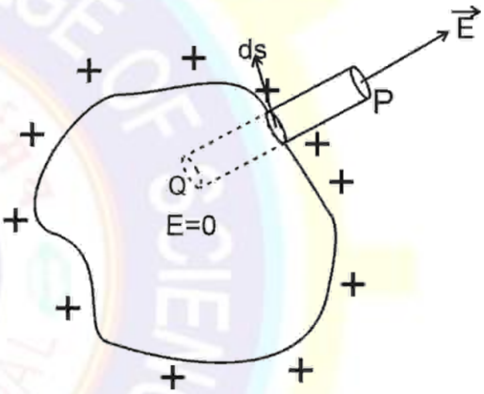
This is expression for electric intensity at a point a charged cylinder.

Expression for Electric Intensity at a point near a charged conductor of any shape:-

Consider, a closed conducting surface of any shape on which positive charge is deposited. The charge will spread over the entire outer surface of the conductor.

Let, σ be the surface charge density over the surface of conductor.

Let us consider two points P & Q outside and inside the conductor very closed to its



surface. On these points we have to find expression for electric intensity.

For this, we draw a Gaussian's surface in the shape of a small cylinder such that, it is enclosing small area element 'ds' of the surface of conductor. Thus, the ends of the cylinder will also have area 'ds'. One end of this cylinder is inside the conductor enclosing Point Q & the other end is outside the conductor enclosing point P.

At pt. Q-
E = 0, Since, no charge enclosed inside the conductor.

But, the electric intensity just outside the conductor is perpendicular to its surface. The total Normal Electric Induction over the closed cylinder passes through its end face outside the conductor. Therefore,

T. N. E. I. through area ds = $\in E \cos\theta \, ds$

But, $\theta = 0^0$.
$\therefore$ cos θ = 1.
$\therefore$ T. N. E. I. = $\in E.ds$ ---------- (1)

Since, σ is the charge per unit area or surface charge density on the surface, then, the total charge inside the cylinder is equal to σ ds.

∴ According to Gauss's theorem,

T. N. E. I. over ds = σ . ds --------- (2)

∴ From (1) & (2)

$\in E.ds$ = σ . ds

∴ $E = \frac{\sigma}{\in}$

If K is the dielectric constant of median Then,

$$E = \frac{\sigma}{\in_0 K}$$

This is the expression for electric intensity at a point near the charged conductor of any shape.

Expression for Mechanical Force per unit area on a charged conductor:

Consider a charged conductor of any shape situated in a medium of dielectric constant (K).

Let σ be the surface charge density over the charged surface, then electric intensity at a point near a charged conductor is given by

$$E = \frac{\sigma}{\in_0 K} \text{ ------------- (1)}$$

We consider E is made up of two parts.

i) E_1: Due to the charge on small area element ds directed towards both the sides of ds.

ii) E_2 – Due to the charges on rest of the conductor. It is directed only in outward direction.

∴ At point 'A', outside the charged conductor resultant intensity is given by-

$E = E_1 + E_2$ --------- (2)

At point 'B', just inside the conductor resultant intensity is given by –

$E = E_2 - E_1$ (Considering $E_2 > E_1$)

But, at point 'B',

$E = 0$

Since intensity is always zero at any point inside the charged conductor.

∴ $0 = E_2 - E_1$

∴ $E_1 = E_2$

Substituting in equation (2), we get,

$$2E_2 = \frac{\sigma}{\in_0 K}$$

$$\therefore \quad E_2 = \frac{\sigma}{2\in_0 K} = E_1 \text{ ---------- (3)}$$

We imagine that, area ds is separated from the conductor & kept in the electric field of intensity E_2.

∴ Force on area ds (F) = Charge on ds × E_2

$$\therefore \quad F = \sigma.ds \times \frac{\sigma}{2\in_0 K}$$

$$\therefore \quad F = \frac{\sigma^2}{2\in_0 K}.ds$$

This is mechanical force on area ds.

∴ Mechanical force = $\frac{\sigma^2}{2\in_0 K}.ds$

$$\therefore \quad \frac{\textbf{Mechanical force}}{\textbf{ds}} = \frac{\sigma^2}{2\in_0 K}$$

∴ Mechanical force per unit area = $\frac{\sigma^2}{2\in_0 K}$ -----(4)

This is expression for mechanical force per unit area in terms of surface charge density.

From equation (1),

$\sigma = \in_0 KE$

Substituting in equation (4), we get,

$$= \frac{(\in_0 KE)^2}{2\in_0 K}$$

$$= \frac{\in_0^2 K^2 E^2}{2\in_0 K}$$

∴ Mechanical force per unit area =

$$\frac{1}{2}\in_0 KE^2$$

This is expression for mechanical force per unit area in terms of electric intensity.

Expression for energy stored per unit volume of a charged conductor:-

When charge is given to a conductor and electric field is produced in the surrounding medium of the conductor hence, work has to be done to deposit the charge on the conductor. This work done is stored in the form of energy.

Mechanical force acting on the area 'ds' of the charge conductor is given by-

$$F = \frac{\sigma^2 .ds}{2 \in_0 K} \text{ --------- (1)}$$

Let, area ds has moved to a distance dx against this force, then –

Work done = force × displacement.

$\therefore$ dw = F × dx

Using equation (1), we get,

$$dw = \frac{\sigma^2 .ds}{2. \in_0 K} .dx$$

But, ds × dx = dv = Volume covered by an element ds.

$$\therefore \quad dw = \frac{\sigma^2}{2 \in_0 K} .dv$$

This work done is stored in the form of energy in volume dv.

$\therefore$ Energy stored = $\frac{\sigma^2}{2 \in_0 K} .dv$

$$\therefore \quad \frac{\text{Energy stored}}{dv} = \frac{\sigma^2}{2 \in_0 K}$$

$\therefore$ Energy stored per unit volume = $\frac{\sigma^2}{2 \in_0 K}$

This is the expression in terms of surface charge density.

But, $E = \frac{\sigma}{\in_0 K}$

$\therefore \quad \sigma = \in_0 KE$

$\therefore$ Energy stored per unit volume

$$= \frac{(\in_0 KE)^2}{2 \in_0 K}$$

$\therefore$ Energy stored per unit volume

$$= \frac{\in_0^2 K^2 E^2}{2 \in_0 K}$$

$\therefore$ Energy stored per unit volume

$$= \frac{1}{2} \in_0 KE^2$$

Capacity of a Conductor:

Definition: The ability of a conductor to hold the charges on its surface is called as its capacity.

Capacity of a conductor depends upon –

1) Shape and size of the conductor.

2) the nature of the surrounding medium in which the conductor is kept.

3) The presence of other conductor near a charged conductor.

When some charge is deposited on a conductor, its potential increases. The charge on the conductor is found to be proportional to the potential of the conductor i.e.

Q α V.

OR Q = CV.

The proportionality constant 'C' is called the capacity of a conductor.

Thus,

Capacity (C) = $\frac{\textbf{Charge (Q)}}{\textbf{Potential(V)}}$

If V = 1, then

C = Q

Thus, the capacity of a conductor is defined as the quantity of charge required to raise its potential by unity.

S.I. unit of Capacity:

The S.I. unit of capacity is called farad (F)

We have,

$$C = \frac{Q}{V}$$

$\therefore$ 1 Farad = $\frac{1 \, Columb}{1 Volt}$

Thus, the capacity of conductor is said to be 1 farad, if 1 coulomb of charge raises its potential by 1 Volt.

Smaller units of Capacity:

1 mf = 10^{-3} F

1 μf = 10^{-6} F

1 pf = 10^{-12} F

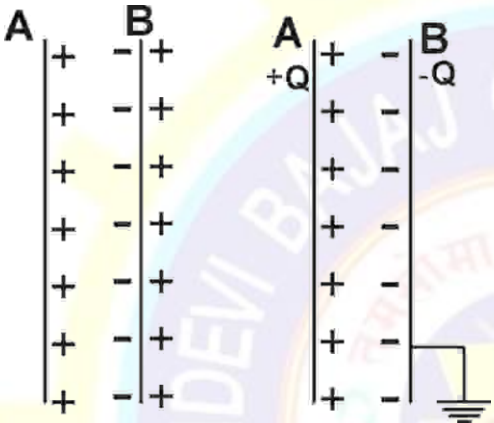
Concept of condenser:

Definition of Condenser: An arrangement of conductors used to increase the capacity of the conductor without much increases in its potential is called a condenser.

Principle of condenser: The capacity of a conductor can be increased if another conductor connected to the earth is kept near it.

Let, +Q be the charge given to the plate A and its potential is raises by V, then the capacity of conductor A is given by-

$$C = \frac{Q}{V} \text{ ------------- (1)}$$



Now, the plate B is brought near the conductor A. Due to induction – Q charge induced on the inner side of the conductor B and +Q charge on outer side of it. If the conductor B is earthed, then +Q charge on the outer side of the conductor B becomes zero & hence, only –Q charge remains on its inner side.

Let, -V' be the potential developed on the conductor B, then due to potential of conductor B potential of conductor A gets affected. The resultant potential of A becomes.

$$V_R = V - V'$$

$\therefore$ New capacity of conductor 'A' is given by-

$$C' = \frac{Q}{V_R}$$

OR

$$C' = \frac{Q}{V - V'} \text{ ---------- (2)}$$

Thus, from comparing (1) & (2), it is observed that-

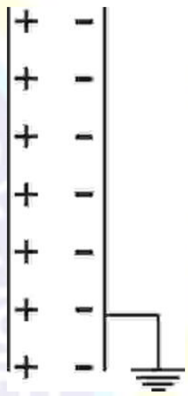
$$C' > C$$

Thus, capacity of conductor 'A' increases without depositing any charge on it by decreasing its potential with the help of above arrangement. This is called condenser.

Type of condenser: Condenser can be classified according to their shape in the following three types.

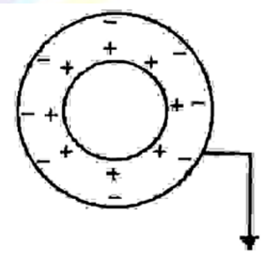
1) Parallel plate condenser:

Parallel plate condenser consists of two plates parallel to each other and a dielectric material is kept between the two parallel plates. One of the plates is earthed.



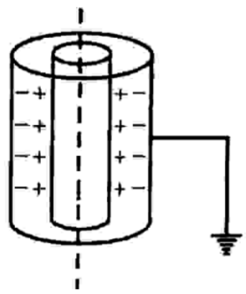
2) Spherical Condenser:

This condenser consists of two concentric hollow spheres. Between the spaces of these hollow spheres, a dielectric material is kept. We can earthed either inner or outer sphere.

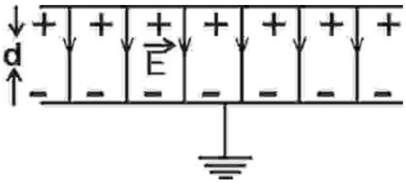


3) Cylindrical Condenser:

This condenser consists of two hollow co-axial cylinders. Between the spaces of hollow cylinders, a dielectric material is kept. The outer cylinder is earthed.



Expression for capacity of parallel plate Condenser:



Let us consider a parallel plate condenser which consists of two parallel plates P_1 and P_2 separated by a distance (d).

Let 'A' is area of each plate and 'K' is dielectric constant of the medium between the two plates.

To the plate P_1, +Q charge is given and plate P_2 is earthed. The charge +Q on P_1, induces charge –Q on the inner surface of P_2.

According to Gauss's theorem, the intensity at any point between the plates of condenser is given by-

$$E = \frac{\sigma}{\in_0 K} \text{ ------------ (1)}$$

Where, σ = Surface charge density.

But, $$\sigma = \frac{Charge}{Area}$$

$$\therefore \quad \sigma = \frac{Q}{A},$$

Substituting this value in (1), we get,

$$E = \frac{Q}{\in_0 KA} \text{ ----------- (2)}$$

But, $$E = \frac{V}{d}$$

Where, V = Potential difference between two plates.

$\therefore$ V = E . d

Using equation (2), we get,

$$V = \frac{Q.d}{\in_0 KA} \text{ ------------- (3)}$$

Let, C be the capacity of parallel plate condenser, then –

$$C = \frac{Q}{V}$$

Using equation (3),

$$C = \frac{Q}{Q.d / \in_0 KA}$$

$$\therefore \quad C = \frac{\in_0 KA}{d}$$

This is expression for capacity of a parallel plate condenser.

Effect of dielectric on Capacity:

The expression for capacity of a parallel plate condenser, when the space between the plates is filled by a dielectric is given by-

$$C = \frac{\in_0 KA}{d} \text{ --------- (1)}$$

If the air is filled between the space of the plates K = 1

$$\therefore C_a = \frac{\in_0 A}{d} \text{ --------- (2)}$$

By (1) ÷ (2)

$$\frac{C}{C_A} = K$$

For any dielectric material K > 1

$$\therefore C > C_a$$

Thus the capacity of a condenser having the space between its plates filled by a dielectric is grater than its capacity when there is air or vacuum between the plates. In other words ,the presence of a dielectric material helps to increase the capacity of a parallel plate condenser. This is true for all types of condensers.

Expression for Energy stored in a parallel plate condenser:

Let, q is the charge and V is the potential at some stage out of charging at a condenser, then the capacity of condenser is given by

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

$$\therefore \quad V = \frac{q}{C} \text{ ------------- (1)}$$

Let, further dq charge is added on the condenser; Hence, small work done in this process is given by –

dw = V. dq

$\therefore$ Using (1),

$$dw = \frac{q}{C}.dq$$

Let us consider that we have to charge the condenser up to charge Q. Thus, total work done to charge the condenser from 0 to Q can be obtained by integrating above equation within limits 0 to Q.

$$\therefore \quad \int dw = \int_0^Q \frac{q}{C}.dq$$

$$\therefore \quad W = \frac{1}{C}\int_0^Q q.dq$$

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

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

$$\therefore \quad W = \frac{1}{2C} \times Q^2$$

$$\therefore \quad W = \frac{1}{2}\ \frac{Q^2}{C}$$

This work done is stored in the form of Energy in the condenser.

∴ Energy stored,

$$E = \frac{1}{2}\ \frac{Q^2}{C} \text{ ----------- (2)}$$

But, $C = \frac{Q}{V}$

$$\therefore \quad E = \frac{1}{2}\ \frac{Q^2}{Q} \times V$$

$$\therefore \quad E = \frac{1}{2}\ \mathbf{QV} \text{ ------------ (3)}$$

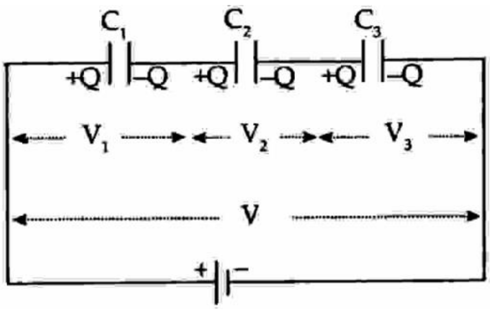
But, Q = CV

$$\therefore \quad E = \frac{1}{2}\ \mathbf{CV^2} \text{ -------------(4)}$$

Series and Parallel Combination of Condensers:

1) Condensers in Series:

Let, 3 condensers of capacity C_1, C_2 & C_3 are connected as shown in following figure.



It is observed that, charge on each condenser is same i.e. Q while potential difference across these condensers is different i.e V_1, V_2 & V_3 respectively.

In such a case, condensers are said to be connected in series.

The charge +Q on the 1st plate of C_1 induces the charge –Q on the inner side of the second plate & +Q charge induces on the outer side of second plate. This causes the charge +Q on the first plate of C_2 & so on.

We know that,

But, $V = V_1 + V_2 + V_3$ --------- (1)

$$C = \frac{Q}{V}$$

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

$$\therefore \quad V_1 = \frac{Q}{C_1}$$

$$V_2 = \frac{Q}{C_2}$$

$$V_3 = \frac{Q}{C_3}$$

Let, C_S be the equivalent capacity of the combination, then

$$V = \frac{Q}{C_S}$$

Substituting these values in equation (1), we get,

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

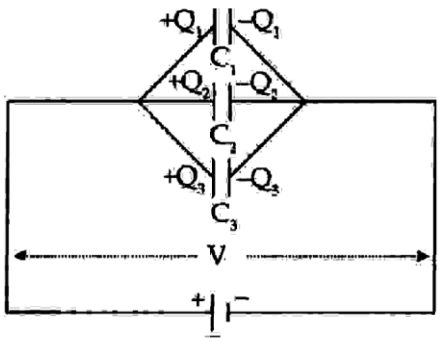
$$\therefore \quad \frac{Q}{C_S} = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$$

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

In general, if ‘n’ condensers are connected in series, then the resultant capacity of the combination is given by-

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + ------- + \frac{1}{C_n}$$

2) Condensers in Parallel:



Let, 3 condensers of capacity C_1, C_2, C_3 are connected as shown in above figure. In such a case, it is observed that charge on these condenser is different i.e. Q_1, Q_2 and Q_3 respectively while potential difference across each condenser is same i.e. V. Such a combination of condensers is called parallel combination.

Let, the total charge be Q.

Then,

$$Q = Q_1 + Q_2 + Q_3 \text{ ---------- } (1)$$

We know that,

$$C = \frac{Q}{V}$$

$$\therefore \quad Q = CV$$

$$\therefore \quad Q_1 = C_1V,\ Q_2 = C_2V \text{ and } Q_3 = C_3V$$

Let, Cp be the equivalent capacity of the parallel combination of condensers.

$$\therefore \quad Q = C_pV$$

Substituting these values in equation (1), we get,

$$C_pV = C_1V + C_2V + C_3V$$

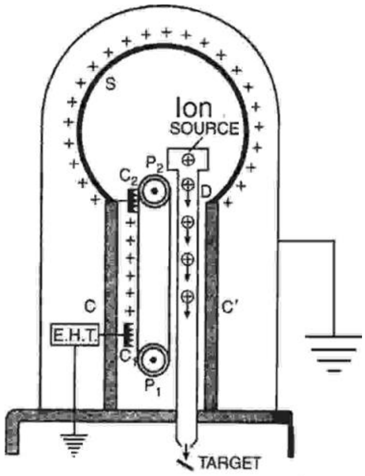
$$\therefore \quad C_pV = V\,[C_1 + C_2 + C_3]$$

$$\therefore \quad C_p = C_1 + C_2 + C_3$$

If 'n' condensers each of capacity C_1, C_2 & C_3 ------- C_n are connected in parallel, then in general their equivalent capacity is given by –

$$C_p = C_1 + C_2 + C_3 + \text{------ } C_n.$$

Van de Graff Generator:



CC' $\rightarrow$ Insulating Columns.
C_1 $\rightarrow$ Spreading Comb
C_2 $\rightarrow$ Collecting Comb
S $\rightarrow$ Metallic sphere
E. H. T. $\rightarrow$ Earthed High Tension source of Potential.
P_1 P_2 $\rightarrow$ Pulleys.
D $\rightarrow$ Discharge tube

R .J. Van de Graff design an electrostatic generator capable of generating very high potential of the order of 5×10^6 V which is used in accelerating charged particles so that the nuclear reaction can be carried out.

Principle:

It is based on the following two phenomenon of electrostatics:

1) Electric discharge takes place in air or gases at pointed conductors

2) If a hollow conductor is in contact with another conductor, then as charge is supplied to the conductor, the hollow conductor continuous accepting charge, irrespective of the fact that how large its potential may grow. The charge immediately shifts to outer surface of the hollow conductor.

Construction & Working:

Van de Graff generator consist of a large hollow metallic sphere 'S' mounted on two insulating column 'CC' as shown in above figure. An endless belt of an insulating material is made to run on two pulleys P_1 & P_2 with the help of an electric motor. The metal comb 'C_1' called spray comb is held near the lower end of the belt. When the spray comb is maintained at high +ve potential with the help of E. H. T. source nearly 10^4 V, it produces ions on it. The +ve ions get spread on the belt due to the repulsive action of comb 'C_1' & are carried upward by the moving belt.

A comb 'C_2' called connecting comb is placed near the upper end of the belt such that pointed ends touch the belt and the other end is in contact with the inner surface of metallic sphere 'S'. The comb 'C_2' collects the + ve ions & transfers them to the metallic sphere.

The charge transferred by comb ‘C_2’ immediately moves on to outer surface of the hollow sphere. As the belt goes on moving, continuous deposition of + ve charge takes place on the sphere & its potential rises considerably. With the increase of charge on the sphere, its leakage due to ionization of surrounding air also increases. When the rate of loss of charge duet o leakage reaches to equal the rate at which the charge is transferred to the sphere, the sphere reaches to the maximum potential up to which it can be raised. In order to prevent the leakage of charge from the sphere, the generator is completely enclosed inside an earthed steel tank which is field with air under pressure.

If the projectiles such as protons, deuterons, etc. are now generated in a discharge tube with its lower end earthed & upper end inside the hollow sphere. Due to high potential generated these projectiles gets accelerate in downward direction along the length of the tube. At the other end they come to hit the target with large kinetic energy and some nuclear reactions takes place, like nuclear disintegration.

NUMERICALS

1. A condenser of capacity 8μf is charged through potential of 1000 V. Calculate amount of energy stored in condenser.

2. How much work must be done to charge 12μf capacitor until P.D. between plates is 250 V.

3. A condenser is charged to potential 300 V has energy 1 J. Find capacity of condenser.

4. 2 condensers of capacities C_1 & C_2 are joined in parallel & this combination is joined in series with condenser of capacity C_3. Show that capacity of combination is $c_s = \dfrac{c_3[c_1 + c_2]}{c_1 + c_2 + c_3}$

5. Capacity of parallel plate condenser with dielectric constant 10 is 12 μF. What will be its capacity if dielectric is removed?

6. Calculate outward pull on a metal plate of area 0.01 m^2 having charge density 40 μ C/m^2. $\varepsilon_0 = 8.85 \times 10^{-12}$ S. I unit.

7. Metal surface of area $3m^2$ charged with $\sqrt{8.85}$ μC in air. Calculate mechanical force acting on it.

8. Energy density in parallel plate condenser is 2×10^{-8} J/m^3. Find electric field intensity in the region between plates when medium is air.

9. A condenser having capacity 30μF is charged to potential 200 V, if area of each plate of condenser is 10 cm^2 & distance between plate is 0.1 mm. Find energy stored per unit volume between plates.

10. 3 condenser with capacity 2 μF, 4 μF, 8 μF are connected (i) in series & (ii) in parallel. Find equivalent capacity.

11. 2 condenser each of capacity 2 μF connected in parallel. 3 such a combination are connected in series. Find equivalent Capacity of combination.

12. 2 condenser each of capacity 10 μF, battery of 240 V. What arrangement (series/ parallel) using condenser would give maximum energy. What is its value?

13. When 2 capacitors are in series equivalent capacity is 2 μF. When in parallel equivalent capacity is 9 μF. Find capacity of capacitor.

14. 2 condensers of capacities 2 μF & 3μF are connected in series with battery of emf 120 V. Find charge on each condenser & P.D. across each condenser.

15. 3 condensers having capacities 10 μF, 20μF, 30 μF respectively connected in series & pot. difference of 220 V is applied across combination. Find respective capacity. Charge on each plate & pot. difference across each condenser.

16. Electric intensity at a point at a dt. of 1m from centre of sphere of radius 25 cm is 10^4 N/C. Find surface density of charge on sphere. Sphere situated in air.

17. Charge density on surface of conducting sphere is128 x 10^{-7} columb/m^2 & electric intensity at a distance of 4m from centre of sphere is 8π x 10^4 N/C. What is radius of sphere?

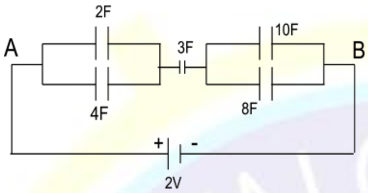
18. An isolated conducting sphere of radius 0.1 m placed in vacuum carries charges of 0.1μC. Find electric intensity at a density 0.2 m from centre

19. Uniformly charged sphere produces intensity of 200 V/m in a medium of dielectric constant 5. Calculate surface charge density.

20. Conducting cylinder having charge density 0.12 μC/m & radius 25 mm surrounded by medium of dielectric constant 4. Find intensity at distance 1m from axis of cylinder.

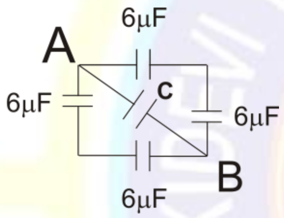
21. Conducting cylinder of length 2m has charge of 100 μC surrounded by medium of dielectric constant 3. Find electric intensity at a distance 3m from axis of cylinder.

22. Condenser of different capacities connected as shown below.



Find equivalent capacity between A & B.

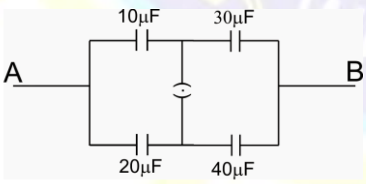
23. Obtain capacity of condenser C in fig. If equivalent capacity between A & B is 12 μF.



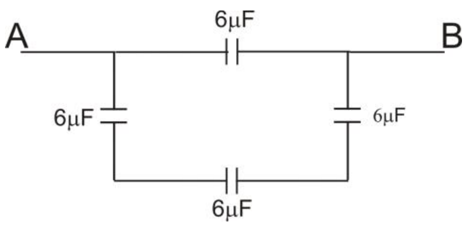
24. Assuming expression for equivalent capacity of no. of condenser in series (C_S) & parallel (Cp) show $Cp = n^2C_S$.

25. 4 capacitor each of 4 μFconnected to produce (i) 1 μF(ii) 16 μF (iii) 3 μF capacitance. Explain how it can be done.

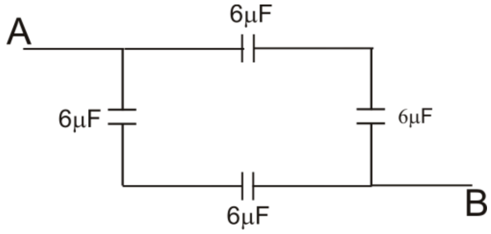
26. Find capacity between A & B when key is open & key is closed.



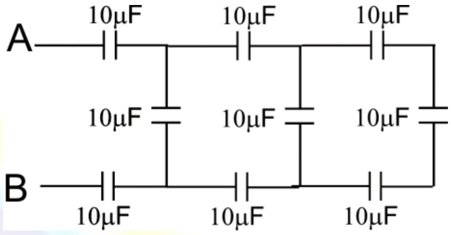
27. Find capacity between A & B



28. Find capacity between A & B



29. In figure alongside all capacitors are equal each of 10 μF Find capacity between A & B



30. Find C such that effective capacity between A & B is 1 μF .

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<u>SPACE FOR EXTRA POINTS</u>