உலகத்தை மாற்ற நீங்கள் பயன்படுத்தக்கூடிய சக்தி வாய்ந்த ஆயுதம், கல்வி.

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SAIVEERA ACADEMY PHYSICS MINIMUM STUDY MATERIAL

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- **CHAPTERWISE BOOK BACK & BOOK INSIDE 2M,3M,5M IMPORTANT QUESTIONS WITH ANSWERS**
- **CHAPTERWISE BOOK BACK ONE MARKS**

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UNIT – 1 ELECTROSTATICS

Two Marks

1.What are the difference between Coulomb force and gravitational force?

Gravitational force	Coulomb force
Force between two masses is always **attractive**	Force between two charges can be **attractive or repulsive**, depending on the nature of charges
Force between two masses is **independent of the medium**	Force between the two charges **depends on nature of the medium**

2.Define 'Electric Field'

The electric field at the point P at a distance r from the point charge q is the **force experienced by a unit charge**

3.Define electric dipole. Give the expression for the magnitude of its electric dipole moment and its direction

Two equal and opposite charges separated by a small distance constitute an electric dipole. p = 2qa

Direction of dipole moment : from -q to +q

4.What is an equipotential surface ?

An equipotential surface is a surface on which all the **points are at the same potential**

5. What are the Properties of equipotential surfaces

(i) The work done to move a charge q between any two points A and B is zero

(ii) The electric field is normal to an equipotential surface.

6.Define Electric Flux

The number of electric field lines crossing a given area kept normal to the electric field lines is called electric flux **Unit :** $\mathrm{Nm^2C^{-1}}$

7.What is meant by electrostatic energy density?

The energy stored per unit volume of space is defined as energy density

$$U_E = \frac{U}{VOLUME} = \frac{1}{2}\varepsilon_o E^2$$

8.Write a short note on electrostatic shielding

It is the process of shielding a particular region or space from the effect of external field produced by an electric charge

9.What is polarization?

Polarisation is defined as the total dipole moment per unit volume of the dielectric

$$\vec{p} = \chi_e \vec{E}_{ext}$$

10.What is dielectric strength?

The maximum electric field the dielectric can withstand before it breakdowns is called dielectric strength

11. What is corona discharge or action of points ?

Leakage of charges from the sharp pointed conductor is called corona discharge

12. State Coulomb's law

It states that the electrostatic force is directly proportional to the product of the magnitude of the two point charges and is inversely proportional to the square of the distance between the two point charges.

Three Marks

1. Discuss the basic properties of electric charge

(i) Electric charge

- ✓ Electric charge is **intrinsic and fundamental property** of particles..
- ✓ The SI unit of charge is coulomb.

(ii) Conservation of charges

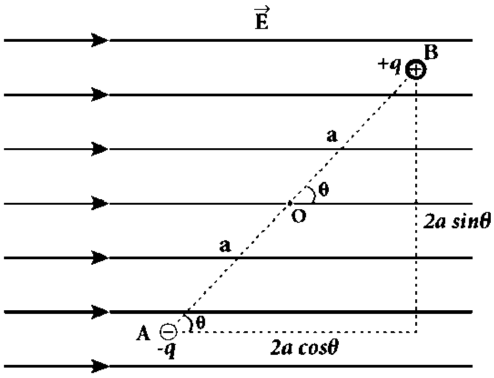
- ✓ The total electric charge in the universe is constant and charge can neither be created nor be destroyed.
- ✓ Net **change in charge will always be zero**

(iii) Quantisation of charges

- ✓ $q = ne$ n is any integer (0, ±1, ...)

2.Derive an expression for Torque experienced by a dipole due to a uniform electric field

- ✓ Consider an electric dipole of dipole moment $\vec{p}$ placed in a uniform electric field.
- ✓ Since the external field is uniform, the total force acting on the dipole is zero. These two forces acting at different points will constitute a couple and the dipole experience a torque.
- ✓ This torque tends to rotate the dipole.



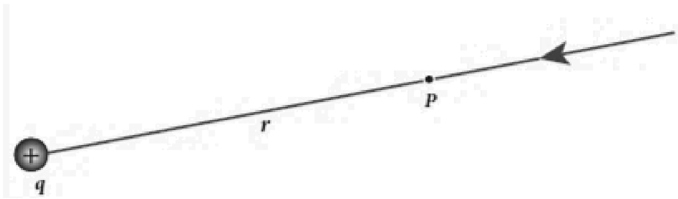
$$\vec{\tau} = |\vec{OA}||-q\vec{E}|\sin\theta + |\vec{OB}||q\vec{E}|\sin\theta$$

$$= qE\,2a\sin\theta$$

$$\vec{\tau} = \vec{p} \times \vec{E} \quad (\text{since } p = 2qa)$$

3.Derive an expression for electrostatic potential due to point charge

- ✓ Consider a positive charge q kept fixed at the origin.
- ✓ Let P be a point at distance r from the charge q.



$$V = -\int_{\infty}^{r} (\vec{E}).d\vec{r}$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

$$V = -\int_{\infty}^{r} \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}.d\vec{r}$$

$$d\vec{r} = dr\hat{r} \qquad \hat{r}.\hat{r} = 1$$

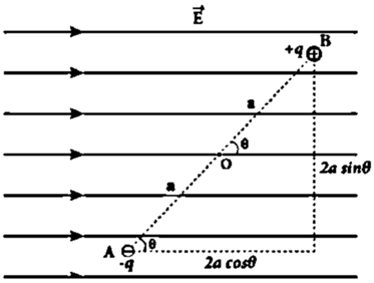
$$V = -\frac{1}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{q}{r^2}.dr$$

After the integration

$$\mathbf{V} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

4.Derive an expression for electrostatic potential energy of the dipole in a uniform electric field

✓ Consider a dipole placed in the uniform electric field $\vec{E}$.



$W = \int_{\theta'}^{\theta} \tau_{ext}\, d\theta$ **.........(1)**

$\tau = pE\sin\theta$ **.........(2)**

substituting (2) in (1) in above equation

$W = \int_{\theta'}^{\theta} pE\sin\theta\, d\theta$

$W = -pE[\cos\theta]_{\theta'}^{\theta}$

$W = pE(\cos\theta' - \cos\theta)$

$U(\theta) - U(\theta') = -pE\cos\theta + -pE\cos\theta'$

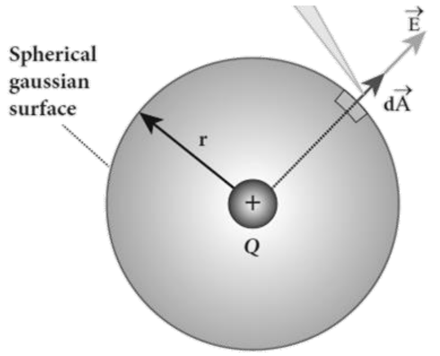
$$\mathbf{U = -pE\cos\theta}$$

4.Obtain Gauss law from Coulomb's law

Gauss's law

Gauss's law states that if a charge Q is enclosed by an arbitrary closed surface, then the total electric flux Φ_E through the closed surface is

$$\Phi_E = \frac{Q_{encl}}{\varepsilon_0}$$



$\emptyset_E = \oint \vec{E}.d\vec{A}\cos\theta$ **........(1)**

$\emptyset_E = \oint E.dA$ **........(2)** since $\cos 0° = 1$

E is uniform on the surface of the sphere

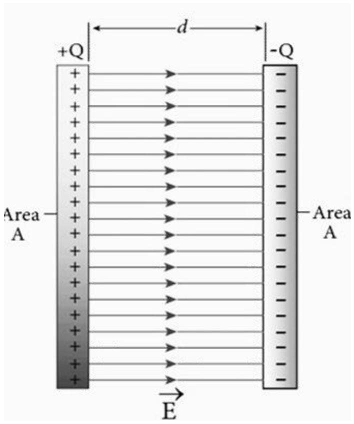
$\emptyset_E = E\oint .dA$ ....(3)

Sub $\oint .dA = 4\pi r^2$ **&** $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ **in (3)**

$\emptyset_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} \times 4\pi r^2$

$\emptyset_E = \frac{Q}{\varepsilon_0}$

5.Obtain the expression for capacitance for a parallel plate capacitor



Consider a capacitor with two parallel plates each of cross-sectional area A and separated by a distance d

$E = \frac{\sigma}{\varepsilon_0}$ **.........(1)** $\sigma = \frac{Q}{A}$

The electric field between the plates is

$E = \frac{Q}{A\varepsilon_0}$ **..........(2)**

$V = Ed = \frac{Qd}{A\varepsilon_0}$ **..........(3)**

Capacitance of the capacitor is given by

$C = \frac{Q}{V} = \frac{Q}{\frac{Qd}{A\varepsilon_0}} = \frac{\varepsilon_0 A}{d}$

6.Obtain the expression for energy stored in the parallel plate capacitor

- ✓ To transfer the charge, work is done by the battery.
- ✓ This work done is stored as electrostatic potential energy in the capacitor.
- ✓ To transfer an infinitesimal charge dQ for a potential difference V, the work done is given by

$dW = V\,dQ$

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

$W = \int_0^Q \frac{Q}{C}\,dQ = \frac{Q^2}{2C}$

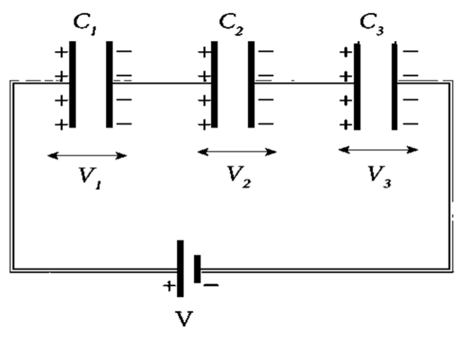
This work done is stored as electrostatic potential energy (U_E) in the capacitor

$$U_E = \frac{Q^2}{2C} = \frac{CV^2}{2}$$

7.Derive the expression for resultant capacitance when capacitors are connected in series and in parallel

Capacitance in series

- ✓ C_1, C_2 and C_3 connected in series .
- ✓ C_S is effective capacitance
- ✓ Charge in each capacitor is same
- ✓ Voltage across each capacitor is different



$V = V_1 + V_2 + V_3$

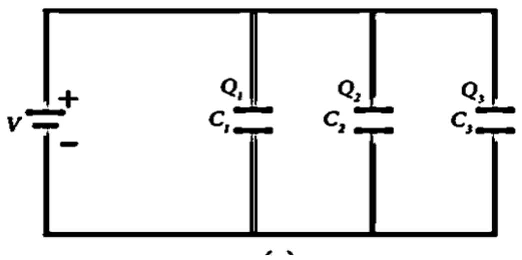
$V = \frac{q}{C_s}$ $V_1 = \frac{q}{C_1}$, $V_2 = \frac{q}{C_2}$, $V_3 = \frac{q}{C_3}$

$$\frac{q}{C_s} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

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

Capacitance in parallel

- ✓ C_1, C_2 and C_3 connected in Parallel.
- ✓ C_P is effective capacitance
- ✓ Potential in each capacitor is same
- ✓ Charge in each capacitor is different



$q_1 = C_1V$, $q_2 = C_2V$, $q_3 = C_3V$ $q = C_PV$

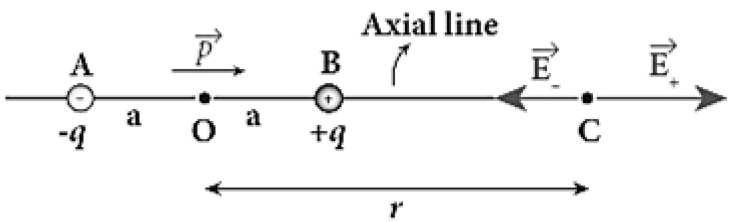
$C_PV = C_1V + C_2V + C_3V$

$$\mathbf{C_P = C_1 + C_2 + C_3}$$

Five Marks

1. Calculate the electric field due to a dipole on axial line

- ✓ Consider an electric dipole placed on x axis.
- ✓ A point C is located at a distance of r from the midpoint O of the dipole along the axial line.



The electric field at a point C due to +q

$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p}$**...........(1)**

The electric field at a point C due to -q

$\vec{E}_- = -\frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$ **...........(2)**

Total electric field at C calculated using super position principle

$\vec{E}_{tot} = \vec{E}_+ + \vec{E}_-$

$= \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$

$= \frac{q}{4\pi\varepsilon_0}\left(\frac{4ra}{(r^2-a^2)^2}\right)\hat{p}$

$\mathbf{r >> a}$ $(r^2 - a^2)^2 = r^4$

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_o}\left(\frac{4aq}{r^3}\right)\hat{p}$$

$$= \frac{1}{4\pi\varepsilon_o}\left(\frac{2\vec{p}}{r^3}\right) \textbf{ since } 2aq\hat{p} = \vec{p}$$

The direction of electric field is along the direction of the dipole moment

2.Electric field due to an electric dipole on the equatorial plane

✓ Consider point C is located at a distance of r from the midpoint O of the dipole on the equatorial plane.

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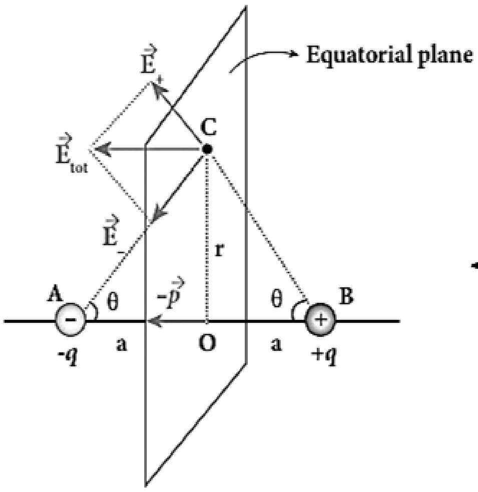
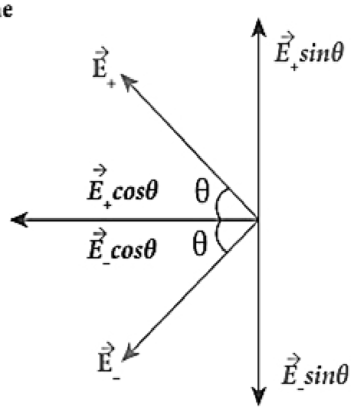




$$\vec{E}_{tot} = -|\vec{E}_+|\cos\theta\hat{p} - |\vec{E}_-|\cos\theta\hat{p}$$

$$|\vec{E}_+| = |\vec{E}_-| = \frac{1}{4\pi\varepsilon_o}\frac{q}{(r^2+a^2)}$$

$$\vec{E}_{tot} = -\frac{1}{4\pi\varepsilon_o}\frac{q}{(r^2+a^2)}\cos\theta - \frac{1}{4\pi\varepsilon_o}\frac{q}{(r^2+a^2)}\cos\theta$$

$$\vec{E}_{tot} = -\frac{1}{4\pi\varepsilon_o}\frac{2q\cos\theta}{(r^2+a^2)}\hat{p}$$

$$\vec{E}_{tot} = -\frac{1}{4\pi\varepsilon_o}\frac{2qa}{(r^2+a^2)^{\frac{3}{2}}}\hat{p} \quad \textbf{since } \cos\theta = \frac{a}{\sqrt{r^2+a^2}}$$

$$\vec{E}_{tot} = -\frac{1}{4\pi\varepsilon_o}\frac{\vec{p}}{(r^2+a^2)^{\frac{3}{2}}} \quad \textbf{since } 2aq\hat{p} = \vec{p}$$

$$\mathbf{r >> a} \quad (r^2 + a^2)^{\frac{3}{2}} = r^3$$

$$\vec{E}_{tot} = -\frac{1}{4\pi\varepsilon_o}\left(\frac{\vec{p}}{r^3}\right)$$

The direction of electric field acts opposite to the direction of the dipole moment

3. Derive an expression for electrostatic potential due to an electric dipole

✓ Consider two equal and opposite charges separated by a small distance 2a.

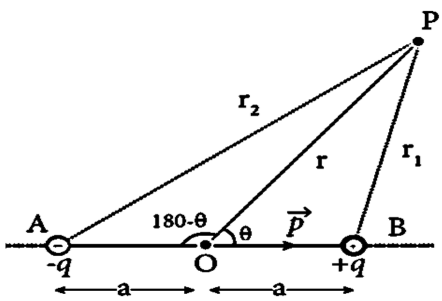
✓ The point P is located at a distance r from the midpoint of the dipole.

Potential at P due to charge +q $V_1 = \frac{1}{4\pi\varepsilon_o}\frac{q}{r_1}$

Potential at P due to charge -q $V_2 = -\frac{1}{4\pi\varepsilon_o}\frac{q}{r_2}$

Total potential: $V = V_1 + V_2$

$V = \frac{1}{4\pi\varepsilon_o}q\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$**............(1)**



By the cosine law for triangle BOP

$$r_1^2 = r^2 + a^2 - 2ra\cos\theta$$

$$= r^2\left(1 + \frac{a^2}{r^2} - \frac{2a}{r}\cos\theta\right)$$

$r >> a$; $\frac{a^2}{r^2}$ can be neglected

$r_1^2 = r^2\left(1 - \frac{2a}{r}\cos\theta\right)$

$r_1 = r\left(1 - \frac{2a}{r}\cos\theta\right)^{\frac{1}{2}}$

$\frac{1}{r_1} = \frac{1}{r}\left(1 - \frac{2a}{r}\cos\theta\right)^{-\frac{1}{2}}$

Using binomial theorem

$\frac{1}{r_1} = \frac{1}{r}\left(1 + \frac{a}{r}\cos\theta\right)$**............(2)**

Similarly applying the cosine law for triangle AOP,

$r_2^2 = r^2 + a^2 - 2ra\cos(180 - \theta)$

$\frac{1}{r_1} = \frac{1}{r}\left(1 - \frac{a}{r}\cos\theta\right)$**..........(3)**

Sub (3) & (2) in (1)

$V = \frac{1}{4\pi\varepsilon_0}q\left[\frac{1}{r}\left(1 + \frac{a}{r}\cos\theta\right) - \frac{1}{r}\left(1 - \frac{a}{r}\cos\theta\right)\right]$

$V = \frac{1}{4\pi\varepsilon_0}\frac{2aq}{r^2}\cos\theta$

$\mathbf{V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}\cos\theta}$ **(since $p = 2qa$)**

Special cases

Case (i) If the point P lies on the axial line of the dipole on the side of +q,then

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$$

Case (ii) If the point P lies on the axial line of the dipole on the side of –q,then

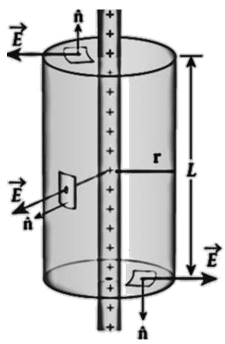
$$V = -\frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$$

Case (iii) If the point P lies on the equatorial line of the dipole,

Hence $V = 0$

4. Obtain expression for electric field due to an infinitely long charged wire

- ✓ Consider an infinitely long straight wire having uniform linear charge density λ.
- ✓ Let P be a point located at a perpendicular distance r from the wire.
- ✓ Charged wire possesses a cylindrical symmetry of radius r and length L.



$\phi_E = \oint \vec{E}\cdot d\vec{A}$

$= \oint \vec{E}\cdot d\vec{A} + \oint \vec{E}\cdot d\vec{A} + \oint \vec{E}\cdot d\vec{A}$

Curved Surface **Top surface** **Bottom surface**

electric flux through the top and bottom surface is zero

$\phi_E = \oint E.dA\cos\theta$

$\phi_E = \oint E.dA$ [since $\theta = 0$ $\cos 0 = 1$]

= E(2πrl) **......(1)** [since $\oint dA = 2\pi rl$]

By Gauss law $\phi_E = \frac{Q}{\varepsilon_0}$**...........(2)**

Equating (1) & (2)

E((2πrl) = $\frac{Q}{\varepsilon_0}$

Q = λl

$E(2\pi rl) = \frac{\lambda l}{\varepsilon_0}$

$E = \frac{\lambda}{2\pi\varepsilon_0 r}$

5.Explain in detail the construction and working of a van de Graff generator

It is a machine which produces a large amount of electrostatic potential difference, up to several million volts (10^7 V).

Principle

Electrostatic induction and action at points

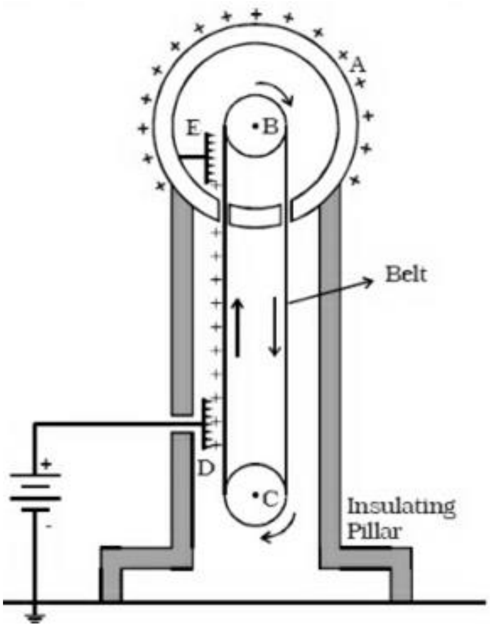
Construction

1) A large hollow spherical conductor is fixed on the insulating stand .
2) Pulley B is mounted at the center of the hollow sphere
3) Pulley C is fixed at the bottom.
4) A belt made up of insulating materials like silk or rubber runs over both pulleys.
5) The pulley C is driven continuously by the electric motor.
6) Two comb shaped metallic conductors E and D are fixed near the pulleys.
7) The comb D is maintained at a positive potential of 10^4 V by a power supply.
8) The upper comb E is connected to the inner side of the hollow metal sphere.

Working

(i) Action of points

1) Due to the high electric field near comb D, air between the belt and comb D gets ionized. The positive charges are pushed towards the belt and negative charges are attracted towards the comb D.
2) The positive charges stick to the belt and move up.



(ii) Electrostatic induction

1) When the positive charges reach the comb E, a large amount of negative and positive charges are induced on either side of comb E due to electrostatic induction.
2) As a result, the positive charges are pushed away from the comb E and they reach the outer surface of the sphere.
3) At the same time, the negative charges nullify the positive charges in the belt due to corona discharge before it passes over the pulley.
4) When the belt descends, it has almost no net charge.
5) This process continues until the outer surface produces the potential difference of the order of 10^7 which is the limiting value.