THE VILLAGE
INTERNATIONAL SCHOOL
"We Nurture Dreams"

AIM HIGH, TOGETHER WE FLY

GRADE XII – PHYSICS

CHAPTER 2 – ELECTROSTATIC POTENTIAL AND CAPACITANCE

Question Bank 1

1) Which orientation of an electric dipole in a uniform electric field would correspond to stable equilibrium ?

Ans - When dipole moment vector is parallel to electric field vector

2) If the radius of the Gaussian surface enclosing a charge is halved, how does the electric flux through the Gaussian surface change ?

Ans - Electic flux φ_E is given by

$\varphi_E = \oint \vec{E} \cdot \vec{ds} = \frac{Q}{\varepsilon_0}$

where [Q is total charge inside the closed surface

∴ On changing the radius of sphere, the electric flux through the Gaussian surface remains same.

3) Define the term electric dipole moment of a dipole. State its S.I. unit

Ans

τ = OE sin θ

If E = 1 unit, θ = 90°, then τ = P

Dipole moment may be defined as the torque acting on an electric dipole, placed perpendicular to a uniform electric dipole, placed perpendicular to a uniform electric field of unit strength.

or Strength of electric dipole is called dipole moment.

$|\vec{P}| = q|2a|$

∴ SI unit is Cm.

4) In which orientation, a dipole placed in a uniform electric field is in

stable,unstable equilibrium ?

Ans-:

For stable equilibrium, a dipole is placed parallel to the electric field.

For unstable equilibrium, a dipole is placed antiparallel to the electric field.

5) Name the physical quantity whose S.I. unit is JC^{-1}. Is it a scalar or a vector quantity? Ans

Physical quantity whose S.I. unit is JC^{-1} is Electric potential.

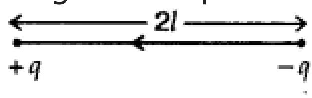
It is a Scalar quantity.

6) Define electric dipole moment. Write its S.I. unit.

Ans

Electric dipole moment of an electric dipole is defined as the product of the magnitude of either charge and dipole length.

$\vec{p} = q(2\vec{l})$



S.I. unit of dipole ($\vec{p}$) is coulomb metre (Cm).

7) Why should electrostatic field be zero inside a conductor?

Ans

Electrostatic field inside a conductor should be zero because of the absence of charge. As in a static condition, charge remains only on the surface.

8) Why must electrostatic field be normal to the surface at every point of a charged conductor?

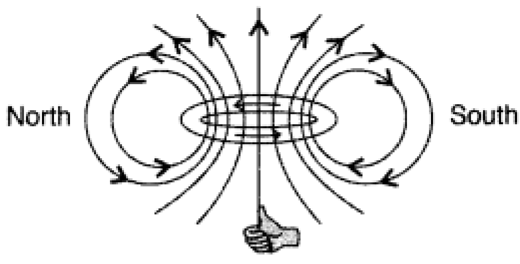
Ans-

So that tangent on charged conductor gives the direction of the electric field at that point

9) Depict the direction of the magnetic field lines due to a circular current carrying loop.

Ans:

Direction of the magnetic field lines is given by right hand thumb rule.



Magnetic field lines

10) What is the direction of the electric field at the surface of a charged conductor having charge density σ < 0?

Ans

The direction of electric field is normal and inward to the surface.

11) Why do the electric field lines not form closed loops?

Ans-

Electric field lines do not form closed loops because the direction of an electric field is from positive to negative charge. So one can regard a line of force starting from a positive charge and ending on a negative charge. This indicates that electric field lines do not form closed loops.

12) Write the expression for the work done on an electric dipole of dipole moment p in turning it from its position of stable equilibrium to a position of unstable equilibrium in a uniform electric
field E.
Ans-
Torque, acting on the dipole is, $\tau = p\,E \sin\theta$

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$$\omega = \int_{\theta_1}^{\theta_2} pE\sin\theta\, d\theta \Rightarrow \omega = pE\,[\cos\theta_1 - \cos\theta_2]$$

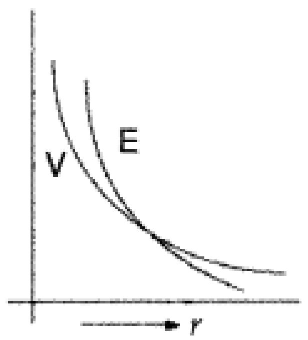
$$\therefore \quad \omega = pE\,[\cos 0^\circ - \cos 180^\circ]$$
$$= pE\,[1 - (-1)] = 2pE \quad \therefore \boxed{\boldsymbol{\omega = 2pE}}$$

13) Why do the electric field lines never cross each other?
Ans-
The electric lines of force give the direction of the electric field. In case, two lines of force intersect, there will be two directions of the electric field at the point of intersection, which is not possible.

14) Show on a plot the nature of variation of the

- Electric field (E) and
- Potential (V), of a (small) electric dipole with the distance (r) of the field point from the centre of the dipole.

Ans



15) Define electric flux. Write its S.I. unit.
A charge q is enclosed by a spherical surface of radius R. If the radius is reduced to half, how would the electric flux through the surface change?
Ans
Electric flux over an area in an electric field is the total number of lines of force passing through the area. It is represented by φ . It is a scalar quantity. Its S.I

unit is $Nm^2\ C^{-1}$ or Vm.

$$i.e.,\ \phi = \int_S \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$$

Electric flux φ by $q_{enclosed}$

Hence the electric flux through the surface of sphere remains same.

16. Given a uniform electric field $\vec{E} = 2 \times 10^3\ \hat{i}$ N/ C, find the flux of this field through a square of side 20 cm, whose plane is parallel to the y-z plane. What would be the flux through the same square, if the plane makes an angle of 30° with the x-axis?

Ans-(i) 80 Nm^2C^{-1}

(ii) 40 Nm^2C^3

17. Define the term 'electric flux'. Write its S.I. units. What is the flux due to electric field $\vec{E}=3\times10^3\hat{i}$ N/C through a square of side 10 cm, when it is held normal to if?

Ans - Electric flux over an area in an electric field is the total number of lines of force passing through the area. It is represented by φ . It is a scalar quantity. Its S.I unit is $Nm^2\ C^{-1}$ or Vm.

$$i.e.,\ \phi = \int_S \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$$

Electric flux φ by $q_{enclosed}$

Hence the electric flux through the surface of sphere remains same.

Given : $E = 3\times10^3\,\hat{i}$ N/C

$$A = 10 \times 10\ cm^2 = \frac{10}{100}\times\frac{10}{100}\ m^2$$

$$\phi = \vec{E}\times\vec{A} = EA\cos\theta$$

$$\because \theta = 0 \text{ and } \cos\theta = 1$$

$$= EA$$

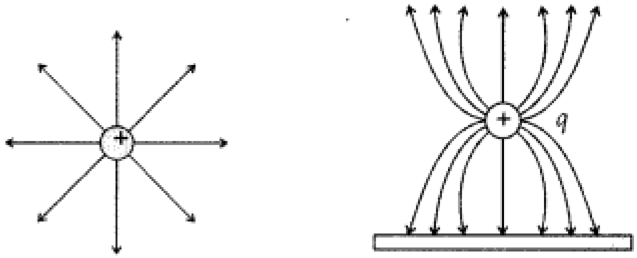
$$= (3\times10^3)\times\left(\frac{10}{100}\times\frac{10}{100}\right)$$

$$= \mathbf{30\ Nm^2\ C^{-1}}$$

18) A positive point charge (+ q) is kept in the vicinity of an uncharged conducting plate. Sketch electric field lines originating from the point on to the surface of the plate.

Derive the expression for the electric field at the surface of a charged conductor.

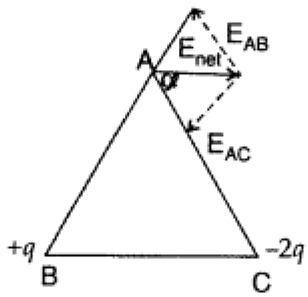
Ans- Representation of electric field. (due to a positive charge)



19) Two point charges + q and -2q are placed at the vertices 'B' and 'C' of an equilateral triangle ABC of side as given in the figure. Obtain the expression for (i) the magnitude and (ii) the direction of the resultant electric field at the vertex A due to these two charges.

Ans-

(*i*) **Magnitude,**



$$|\vec{E}_{AB}| = \frac{1}{4\pi\epsilon_0}\frac{q}{a^2} = E$$

$$|\vec{E}_{AC}| = \frac{1}{4\pi\epsilon_0}\frac{2q}{a^2} = 2E$$

$$E_{net} = \sqrt{(2E)^2 + E^2 + 2\times 2E\times E\times\left(-\frac{1}{2}\right)}$$

$$\left[\because \cos 120° = -\frac{1}{2}\right.$$

$$= \sqrt{4E^2 + E^2 - 2E^2}$$

$$= \sqrt{3E^2} = E\sqrt{3} = \frac{1}{4\pi\epsilon_0}\frac{q\sqrt{3}}{a^2}$$

(*ii*) **Direction** of resultant electric field at vertex A,

$$\tan\alpha = \frac{E_{AB}\sin 120°}{E_{AC} + E_{AB}\cos 120°}$$

$$= \frac{E\times\frac{\sqrt{3}}{2}}{2E + E\times\left(\frac{-1}{2}\right)} = \frac{\frac{E\times\sqrt{3}}{2}}{\frac{3E}{2}} = \frac{\sqrt{3}}{3}$$

$$= \frac{1}{\sqrt{3}} = \tan 30°$$

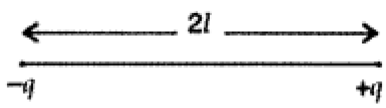
$$\therefore \quad \alpha = 30° \textbf{ (with side AC)}$$

20) Define electric dipole moment. Is it a scalar or a vector? Derive the expression for the electric field of a dipole at a point on the equatorial
plane of the dipole.

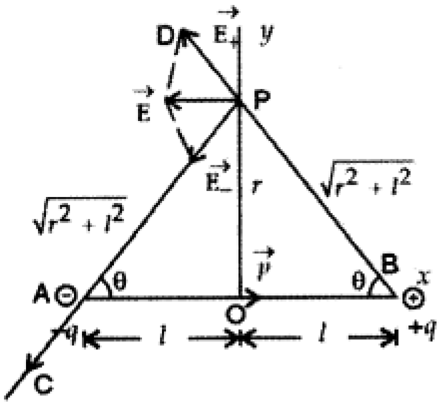
Ans-

Electric dipole moment: It is the product of the magnitude of either charge and distance between them.

$$\vec{q} = q \times 2l$$



It is a vector quantity whose direction is from negative to positive charge.



Expression :

Electric field intensity at P due to +q charge is

$$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{BP^2} \text{ along PD}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+l^2)} \qquad \text{along PD} \ldots(i)$$

Electric field intensity at P due to -q charge is,

$$E = \frac{p}{4\pi\varepsilon_0(r^2+l^2)^{3/2}} \text{ along }(-)x\text{-axis}$$

If $l << r$ *i.e.* dipole is short, then l^2 can be neglected as compared to r^2

Hence $\boxed{E = \frac{p}{4\pi\varepsilon_0 r^3}}$ along (–)x-axis

$$\vec{E}_- = \frac{1}{4\pi\varepsilon_0}\frac{q}{AP^2} \text{ along PC}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+l^2)} \qquad \text{along PC} \ldots(ii)$$

From (*i*) and (*ii*), $|\vec{E}_+| = |\vec{E}_-| = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+l^2)}$ ...(*iii*)

Net electric field intensity due to the electric dipole at point P

$$\therefore \quad E = \sqrt{E_+^2 + E_-^2 + 2E_+E_-\cos 2\theta}$$

$$\Rightarrow \quad E = \sqrt{E_+^2 + E_-^2 + 2E_+^2\cos 2\theta} \qquad (\because E_- = E_+)$$

$$\Rightarrow \quad E = \sqrt{2E_+^2 + 2E_+^2\cos 2\theta}$$

$$\Rightarrow \quad E = \sqrt{2E_+^2(1 + \cos 2\theta)}$$

$$\Rightarrow \quad E = \sqrt{2E_+^2\, 2\cos^2\theta} \qquad (\because 1 + \cos 2\theta = 2\cos^2\theta)$$

$$\therefore \quad E = 2E_+ \cos\theta = 2 \times \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2 + l^2)} \cos\theta$$

[Using equation (*iii*)]

Now from ΔOAP, $\cos\theta = \frac{l}{\sqrt{r^2 + l^2}}$

$$E = 2 \times \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2 + l^2)} \times \frac{l}{(r^2 + l^2)^{1/2}}$$

$$\Rightarrow \quad E = \frac{q \times 2l}{4\pi\varepsilon_0 (r^2 + l^2)^{3/2}}$$

Since $q \times 2l = p$ ...(p is dipole moment)

21) What is the force between two small charged spheres having charges of 2×10^{-7} C and 3×10^{-7} C placed 30 cm apart in the air?

Ans-

Using $F = 9 \times 10^9 \frac{q_1 q_2}{r^2}$, we get

$$F = \frac{9 \times 10^9 \times 0{\cdot}2 \times 10^{-6} \times (0{\cdot}3 \times 10^{-6})}{0{\cdot}3 \times 0{\cdot}3}$$

$$= 6 \times 10^{-3} \text{ N (repulsive).}$$