**Blue Print (As per PU Board)**

| Topic | 1 mark questions | 2 marks questions | 3 marks questions | 5 marks questions | Total Marks |
|---|---|---|---|---|---|
| Electric Charges, Fields & Potentials (Electrostatics) | 1 | 1 | – | - | 3 |

## One mark questions

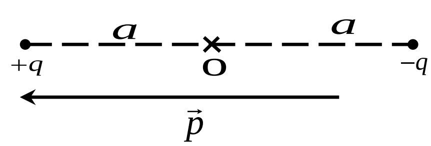
1. **What is meant by quantisation of charges?**
Answer: The charge on any body is equal to an integral multiple of the charge of an electron.
$Q = \pm ne$ where $n$ is an integer and $e$ is the least possible charge on the body which is the charge of an electron.

2. **A cube encloses a charge of $1C$. What is the electric flux emerging from the cube?**
Answer: $\phi = \frac{1}{\varepsilon_o}.Q$
$= \frac{1}{8.85\times10^{-12}}\times1$
$= 0.113\times10^{12} = 1.13\times10^{11}\ Nm^2C^{-1}$

3. **What is electric polarisation?**
Answer: Electric polarisation is defined as dipole moment per unit volume.

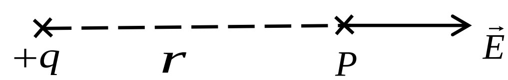
## Two marks questions

4. **Define dipole moment. What is its SI unit?**
Answer: Dipole moment of an electric dipole is defined as the product of magnitude of the charges and the distance between them.




$+q$ and $-q$ are two charges separated by a distance 2a. 'a' is the distance of either charge from the centre. Then
$\text{Dipolemoment} = p = q\times2a$ (1 mark)
The SI unit of dipole moment is Cm. (1 mark)

5. **Define electric field. Write an expression for electric field at any point due to a point charge.**
Answer: The region of space surrounding a charge within which it exerts force on a test charge is called electric field.
Consider a point charge $+q$. Let $P$ be any point at distance $r$ from the charge. The intensity of the electric field at the point $P$ be given by




(1 mark)

$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\cdot \vec{E} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}\cdot\hat{r}$ Where $\hat{r}$ is a unit vector in the direction of $\vec{r}$ (1 mark)

6. **What happens to the electrical force between two charges if the distance between them is doubled?**

Answer: The force between two charges is inversely proportional to the square of the distance between them.
$F \alpha \frac{1}{d^2}$

$\frac{F_1}{F_2} = \frac{d_2^2}{d_1^2}$ (1 mark)

Let $d_1 = x$

$d_2 = 2x$

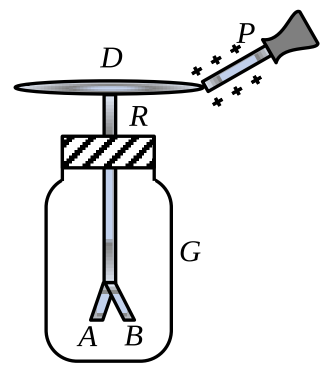
$\therefore \frac{F_1}{F_2} = \frac{(2x)^2}{x^2} = 4$

$\therefore F_2 = \frac{F_1}{4}$ (1 mark)

**7. Explain the construction of a gold leaf electroscope.**

Answer: A thin metallic rod with a metallic disc D is fixed inside a glass bottle as shown in the figure. Two thin gold leaves (or aluminium foils) are fixed at the ends of the rod R. (1 mark)

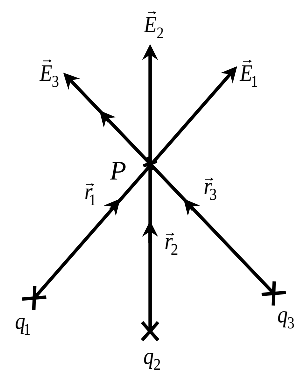
When a positively charged body is brought in contact with the disc D, both the gold leaves acquire the same kind of charge. Hence they repel each other. The extent of divergence of the gold leaves is a measure of the charge. (1 mark)




### Three marks questions

**8. What is the electric field at a point due to a system of charges? Write the expression for it.**

Answer: The electric field due to a system of charges is defined as the force experienced by a unit positive charge placed at that point without disturbing the original positions of charges.




Consider a system of charges $q_1, q_2, q_3$ ------

Let P be a point such that it is at distances $r_1, r_2, r_3$ ------- from the respective charges.

$\overrightarrow{q_1 p} = \vec{r_1}$

$\overrightarrow{q_2 p} = \vec{r_2}$

$\overrightarrow{q_3 p} = \vec{r_3}$

Let $\vec{E_1}, \vec{E_2}, \vec{E_3}$ ------- be the intensities of the electric fields produced by the respective charges. (1 mark)

$\vec{E_1} = \frac{1}{4\pi\varepsilon_o} \cdot \frac{q_1}{r_1^2} r_1$

$\vec{E_2} = \frac{1}{4\pi\varepsilon_o} \cdot \frac{q_2}{r_2^2} r_2$ (1 mark)

$r_1, r_2, r_3$, ------ are the unit vectors in the directions of $\vec{r_1}, \vec{r_2}, \vec{r_3}$ ----- respectively.

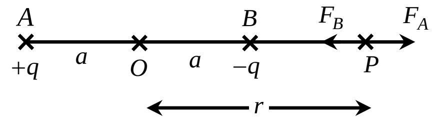
Then the electric field due to the system of charges is given by

$\vec{E} = \vec{E_1} + \vec{E_2} + \vec{E_3} +$ --------

$\vec{E} = \frac{1}{4\pi\varepsilon_o}\left[\frac{q_1}{r_1^2} r_1 + \frac{q_2}{r_2^2} r_2 + \frac{q_3}{r_3^2} r_3 + - - -\right]$ (1 mark)

**Five marks questions**

**9. Derive an expression for the intensity of the electric field produced by an electric dipole at a point on its axial line.**




Answer: Consider a point P on the axial line of a dipole at distance $r$ from its centre. Let us imagine a unit $+ve$ charge to be placed at the point P.

Force due to +q at the point P

(1 mark)

$$F_A = \frac{1}{4\pi\varepsilon_o}\frac{q_A}{AP^2}$$

$$= \frac{1}{4\pi\varepsilon_o}\frac{q}{(r+a)^2}$$ (Repulsion along $\overrightarrow{AP}$

Force due to – q at the point P

$$F_B = \frac{1}{4\pi\varepsilon_o}\frac{q_B}{BP^2}$$

$$= \frac{1}{4\pi\varepsilon o}\frac{q}{(r-a)^2}$$ (Attraction along $\overrightarrow{PB}$

Thus there are two forces $F_A$ and $F_B$ acting along the same line in opposite directions. The resultant force acting on the unit +ve charge at P gives the intensity of the electric field at P.

$$E_{ax} = F_B - F_A \qquad (\because F_B > F_A)$$ (1 mark)

$$E_{ax} = \frac{1}{4\pi\varepsilon_o}\left[\frac{q}{(r-a)^2} - \frac{q}{(r+a)^2}\right]$$

$$= \frac{1}{4\pi\varepsilon_o}\left[\frac{q.4ra}{(r-a)^2(r+a)^2}\right]$$

$$= \frac{1}{4\pi\varepsilon_o}\left[\frac{2(q\times 2a)r}{(r^2-a^2)^2}\right]$$

But $(q\times 2a) = p$ = dipole moment

$$\therefore E_{ax} = \frac{1}{4\pi\varepsilon_o}\frac{2pr}{(r^2-a^2)^2}$$ (1 mark)

In the case of a short dipole $a << r$

$a^2$ may be neglected compared to $r^2$

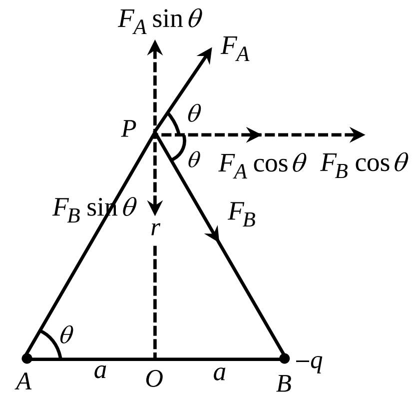
$$\therefore E_{ax} = \frac{1}{4\pi\varepsilon_o}\cdot\frac{2pr}{(r^2)^2}$$

$$\therefore E_{ax} = \frac{1}{4\pi\varepsilon_o}\frac{2p}{r^3}$$ (1 mark)

The electric field acts along the direction of the dipole moment vector. (1 mark)

**10. Derive an expression for the electric field produced by an electric pole at a point on the equatorial line of a dipole**

Answer: Consider a dipole AB having two charges +q and –q separated by a distance. P is a point on the equatorial line (perpendicular bisector of the axis of the dipole) at distance $r$ from the centre. $OP = r$




Let a unit +ve charge be placed at P.

Force exerted by A on the unit +ve charge

$F_A = \frac{1}{4\pi\varepsilon_o}\frac{q}{AP^2}$ (1 mark)

But $AP^2 = \left(r^2 + a^2\right)$

$\therefore F_A = \frac{1}{4\pi\varepsilon_o}\frac{q}{\left(r^2+a^2\right)}$ along $\overrightarrow{AP}$ (1 mark)

Force exerted by B on the unit +ve charge

$F_B = \frac{1}{4\pi\varepsilon_o}\frac{q}{BP^2}$

But $BP^2 = \left(r^2 + a^2\right)$

$\therefore F_B = \frac{1}{4\pi\varepsilon_o}\frac{q}{\left(r^2+a^2\right)}$ along $\overrightarrow{PB}$ (1 mark)

To find the resultant of $F_A$ and $F_B$ we resolve them into two components:

(i) Parallel to the axis of the dipole

(ii) Perpendicular to the axis of the dipole

After resolution, we get $F_A \sin\theta$ and $F_B \sin\theta$ acting in the same line. Since they are equal in magnitude and act in opposite directions, they cancel each other. But $F_A \cos\theta$ and $F_B \sin\theta$ acting in the same line, in the same direction get added up. So the resultant force gives the electric field $E_B$ acting at the point P.

$E_B = F_A\cos\theta + F_B\cos\theta = 2F_A\cos\theta$

$(\because F_A = F_B)$

$= 2\left[\frac{1}{4\pi\varepsilon_o}\frac{q}{\left(r^2+a^2\right)}\right]\cos\theta$

In ΔAOP, $\cos\theta = \frac{OA}{AP}$

$= \frac{a}{\sqrt{r^2+a^2}}$

$\therefore E_B = 2\left[\frac{1}{4\pi\varepsilon_o}\frac{q}{\left(r^2+a^2\right)}\right]\frac{a}{\sqrt{r^2+a^2}}$

$E_B = \frac{1}{4\pi\varepsilon_o}\left[\frac{(q\times 2a)}{\left(r^2+a^2\right)^{3/2}}\right]$

But $q \times 2a = p$ = dipole moment

$\therefore E_B = \frac{1}{4\pi\varepsilon_o}\frac{p}{\left(r^2+a^2\right)^{3/2}}$ (1 mark)

The electric field acts in the direction opposite to that of the dipole moment vector.
In the case of a short dipole $a << r$

$\therefore E_B = \frac{1}{4\pi\varepsilon_o}\frac{p}{r^3}$ (1 mark)

The electric field acts along the direction opposite to that of the dipole moment vector.

**11. Derive an expression for the torque acting on a dipole placed in a uniform electric field. When is the couple (i) maximum and (ii) minimum**

Answer: Consider a uniform electric field of intensity E, A uniform electric field is defined as that field in which both the magnitude and direction are the same at all points in the field. AB is a dipole having two charges +q and –q separated by a distance 2a. The dipole is placed with its axis inclined to the field direction at an angle $\theta$.
The charge +q experiences force qE newtons in the direction of the field. The charge –q experiences the same force qE newtons in the opposite direction of the field.

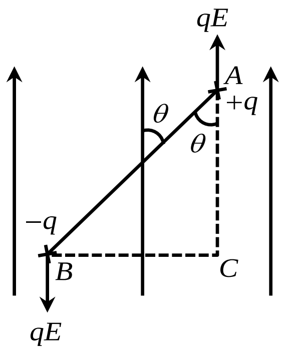



Fig (1 mark)

So the dipole is subjected to the action of two equal unlike parallel forces which constitute a couple. The moment of the couple (or torque) is given by

$\tau$ = one of the forces $\times$ perpendicular distance between them

$\tau = qE \times BC$ (1 mark)

In $\Delta ABC, \quad \sin\theta = \frac{BC}{AB}$

$BC = AB \sin\theta$

$BC = 2a\sin\theta$

$\therefore \tau = qE \times 2a\sin\theta$

$= (q \times 2a)E\sin\theta$

But $q \times 2a = p =$ dipole moment

$\therefore \tau = pE\sin\theta$ (1 mark)

(i) When $\theta = 90°$, $\tau_{max} = pE$

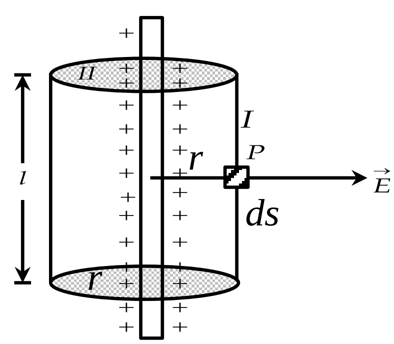
$\tau$ is maximum when the axis of the dipole is placed perpendicular to the electric field. (1 mark)

(ii) When $\theta = 0°$, $\tau = 0$

$\tau$ is minimum when the axis of the dipole is placed parallel to the electric field. (1 mark)

**12. State Gauss's law in electrostatics. Derive an expression for the electric field produced by infinitely long straight charged wire.**

Answer: Consider a straight wire which is infinitely long. Let $\lambda$ be the linear charge density.




$\lambda = \frac{\text{Charge}}{\text{length}}$ Fig. (1 mark)

Let $P$ be a point at distance $r$ from the wire. We can construct a cylinder round the wire having length $\ell$ and cross-sectional radius $r$. This is the Gaussian surface and the electric field lines (or lines of force) pass perpendicular to the axis of the cylinder. Lines of force do not pass through the end faces of the cylinder. The field lines are perpendicular to the end faces.

This is because the flux passing through the end faces is zero. So the field lines are passing out of the curved surface of the cylindrical surface only. Let ds be a small elementary area of this surface. The total electric flux passing out of the curved surface is given by

$\phi = \int E ds \cos\theta$ (1 mark)

$\theta = 0°$ since the electric field is along the normal to the elementary area d $S$

$\therefore \phi = \int E ds$

But $\int ds$ = Surface area of the curved surface

$= 2\pi r \ell$

$\therefore \phi = E\left(2\pi r \ell\right)$ (1 mark)

According to Gauss' theorem, the flux passing through the closed surface is $\frac{1}{\varepsilon_0}$ times the total charge enclosed by it. (1 mark)

$$\phi = \frac{1}{\varepsilon_0} q$$

$$E\left(2\pi r \ell\right) = \frac{q}{\varepsilon_0}$$

$$E = \frac{\left(\frac{q}{\varepsilon_0}\right)}{2\pi r \ell}$$

$$E = \frac{1}{2\pi \varepsilon_0 r}\left(\frac{q}{\ell}\right)$$

But $\frac{q}{\ell} = \lambda =$ Linear density of charge

$$\therefore E = \frac{1}{2\pi \varepsilon_0 r} \cdot \lambda$$

$$\vec{E} = \frac{\lambda}{2\pi \varepsilon_o r} \cdot \hat{r}$$

$\hat{r}$ is a unit vector in the direction of $\vec{r}$ (1 mark)