Chapter-1

ELECTRIC CHARGES AND FIELDS

1 MARK QUESTIONS

1. What does $q_1 + q_2 = 0$ signify?
2. Define electric field intensity. Give its SI unit.
3. What is relative permittivity or dielectric constant of a medium?
4. What is force experienced by a charge q placed in a uniform electric field E?
5. Write a relation for permittivity of a medium in terms of dielectric constant.
6. Define electric dipole moment. Write its S.I. unit.
7. Is electric dipole moment a scalar or a vector? If it is a vector, then what is its direction?
8. In which orientation, a dipole placed in a uniform electric field is in

   (i) Stable equilibrium (ii) unstable equilibrium?
9. Define electric flux. Write its S.I. unit.
10. Draw the electric field lines of a point charge Q when (i) $Q > 0$ and (ii) $Q < 0$.

2 MARKS QUESTIONS

11. Write any two basic properties of electric charges.
12. Write any two limitations of Coulomb's law
13. Write properties of electric field lines. Why two electric field lines do not intersect to each other?
14. State Gauss's theorem in electrostatics. An electric dipole is inside the Gaussian surface. What is electric flux through the Gaussian surface?

3 MARKS QUESTIONS

15. State and prove Gauss's law.
16. Show that net force on an electric dipole placed in a uniform electric field is zero. Find an expression for torque experienced by the electric dipole.
17. What is an electric dipole? Give an electric field sketch for a dipole.

5 MARKS QUESTIONS

18. Find an expression for the electric field strength at any point on the axial line of an electric dipole.
19. State and Prove Gauss theorem in electrostatics. Using Gauss's theorem

derive the expression for electric field at a point due to an infinitely long, thin, uniformly charged straight wire.

20. State Gauss's theorem in electrostatics. Using Gauss's theorem derive the expression for electric field at a point due to uniformly charged infinite plane sheet.

ANSWERS

1 MARK QUESTIONS

1. $q_1 + q_2 = 0$ Therefore, $q1 = - q_2$ Thus both charges are equal in magnitude but of opposite nature.
2. The electric field intensity due to a static point charge at any point in its electric field is defined as the force experienced by a unit positive test charge placed at that point

$$\vec{E} = \frac{\vec{F}}{q_0}$$

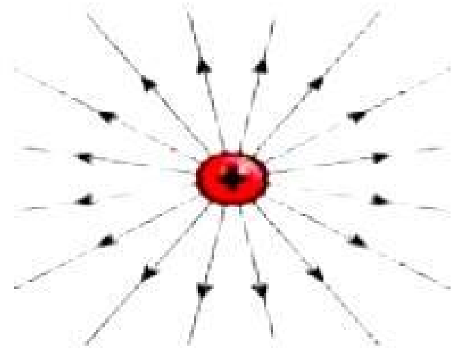
   It is a vector quantity. Its SI unit is NC^{-1}.
3. Relative permittivity of a medium is defined as the ratio of electrostatic force between two point charges separated by a certain distance in air to the electrostatic force between the same two point charges separated by the same distance in a medium.
4. $F = qE$
5. $\in = \in_0 K$
6. Electric dipole moment of an electric dipole is defined as the product of the magnitude of either charge of the electric dipole and the dipole moment.

   Its SI unit is Coulomb metre (Cm).
7. Electric dipole moment is a vector quantity. Its direction is from negative charge to positive charge of the dipole.
8. (i) Stable equilibrium: When the electric dipole moment ($\vec{p}$) is parallel to the electric field ($\vec{E}$).

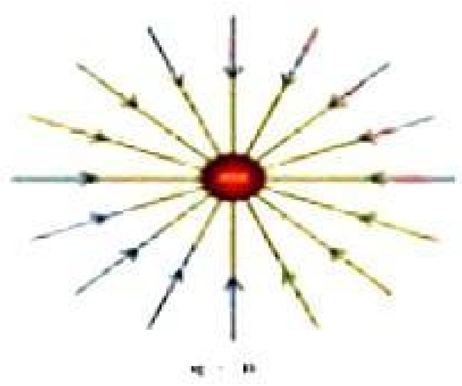
   (ii) Unstable equilibrium: When the electric dipole moment ($\vec{p}$) is antiparallel to the electric field ($\vec{E}$).

9. The total number of electric field lines passing normally through a surface is defined as the electric flux. Its SI unit is N m^2 C^{-1}.

10. (i) Q>0



(ii)Q < 0



2 MARKS QUESTIONS

11. The basic properties of electric charges are

    (i) Additivity of electric charges.

    (ii) Conservation of electric charges.

    (iii) Quantization of electric charges.

    (iv) Invariance of electric charges.

    (Any two)

12. Two limitations of Coulomb's law

    (i) It holds good for point charges at rest.

    (ii) It is medium dependent law.

13. Properties of electric field lines

    (i) Electric field lines begin from a positive charge and terminate at a negative charge.

    (ii) Electric field lines are imaginary lines.

(iii) The tangent at any point on an electric field line gives the direction of the electric field at that point.

(iv) Two electric field lines do not cross each other.

14. **Gauss's law**: The electric flux linked to a closed surface is equal to the charge enclosed divided by the permittivity. The total electric flux through a closed surface is given as

$$\oint \boldsymbol{E.ds} = q/\epsilon_0$$

Where q = total charge enclosed by the closed surface.

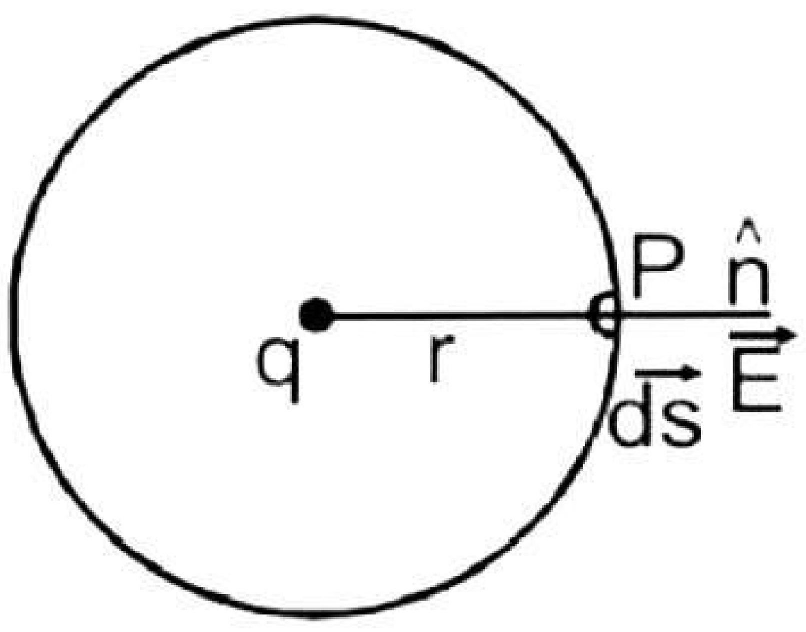
Net charge of electric dipole is zero. So flux through the surface is zero.

3 MARKS QUESTIONS

15. Gauss's law: See answer of Q.No.14

Proof of Gauss's Law:

Let the charge be q.



Let us construct the Gaussian sphere of radius = r

Now, consider, a small surface area element ds at point P

Electric flux through ds

$d\varnothing = E\ d\ s\ \mathrm{Cos}\ \theta$

But, $\theta = 0$, $d\varnothing = E\ d\ s\ \mathrm{Cos}\ 0 = E\ ds$

Total flux through the spherical Gaussian surface

$\Phi = \int d\varnothing = \int E ds$

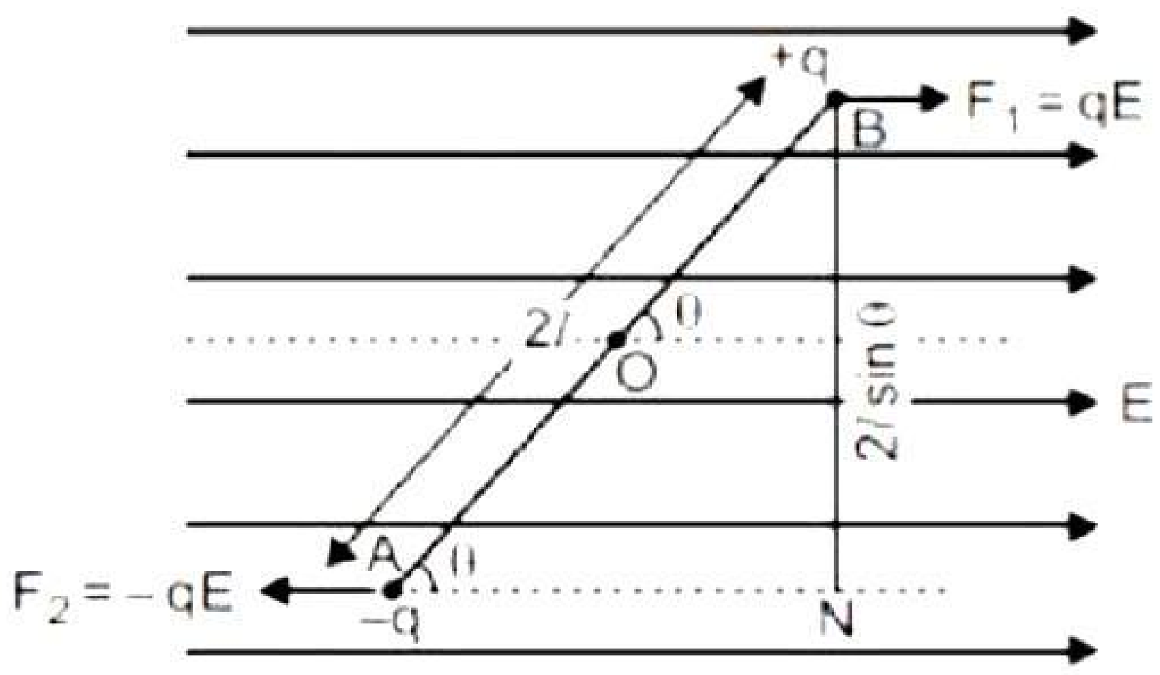
$= E\, 4\pi r^2$

$\Phi = (1 / 4\pi\varepsilon_o\, q / r^2)\, 4\pi r^2$

$\Phi =$ q / ε_o

This is Gauss's law.

16.



Net force on dipole

Let AB be an electric dipole of charges +q and −q. Dipole length is 2l.Dipole moment makes angle θ with the electric field E.

Force on + q charge, $F_1 = q E$ (in the direction of E)

Force on - q charge, $F_2 = - q E$ (in opposite direction of E)

These forces are equal in magnitude and opposite to each other. Therefore net force on dipole is zero.

Torque on dipole

Torque = Magnitude of either force × Perpendicular distance between the two forces

$= q E \times 2l \sin\theta$

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

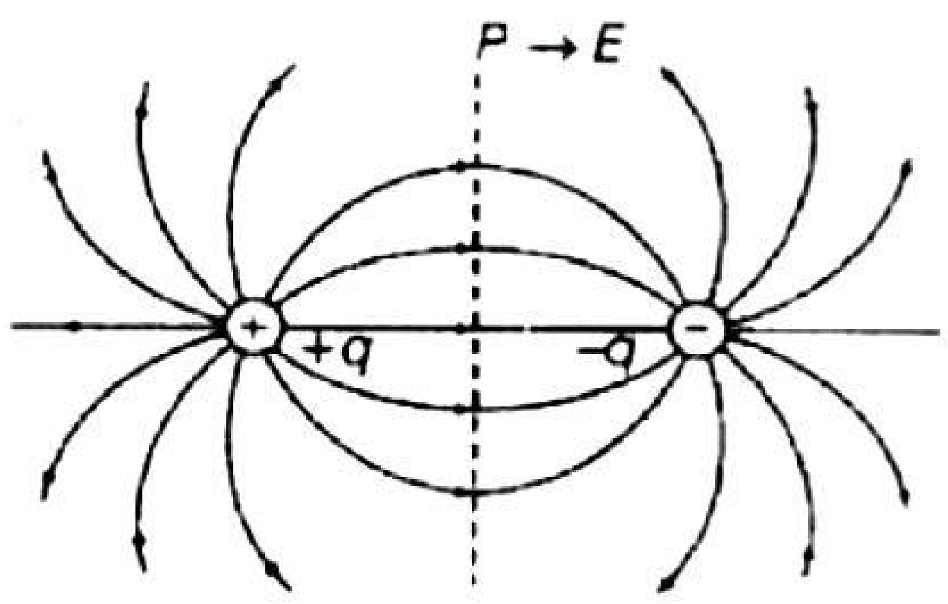
$= p E \sin\theta$

In vector terms

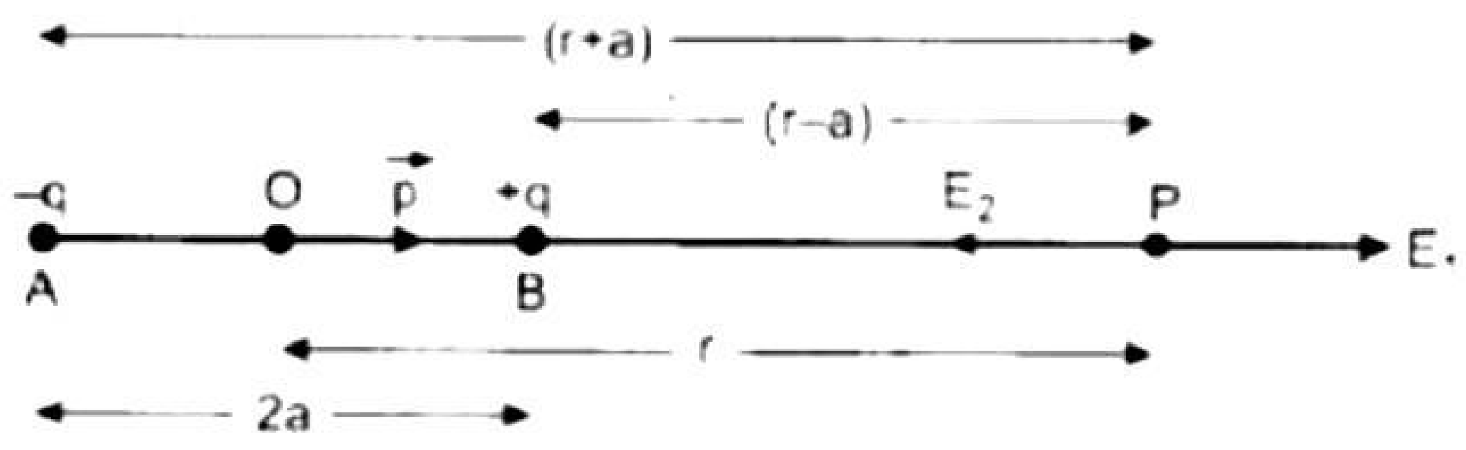
$\vec{\tau} = \vec{p} \times \vec{E}$

17. Electric dipole is a system of two equal and opposite charges separated by a small distance.

Electric field lines of an electric dipole



18. Electric field strength at any point on the axial line of an electric dipole.



AB is an electric dipole. Its charges are +q and −q. Dipole length is 2a. P is a point on its axis at a distance r where electric field is to be determined.

The distance of point p from + q charge = (r - a)

The distance of point p from - q charge = (r + a)

The electric field at the point P due to +q placed at B is,

$$E_1 = 1/4\pi\varepsilon_0 \times q / (r-a)^2 \qquad \text{(along BP)}$$

The electric field at the point P due to - q placed at A is,

$$E_2 = 1/4\pi\varepsilon_0 \times \frac{q}{(r+a)2} \qquad \text{(along PA)}$$

Net electric field at point P due to the dipole

$$E = E_1 - E_2$$

$$= 1/4\pi\varepsilon_0 \times q/(r-a)^2 - 1/4\pi\varepsilon 0 \times \frac{q}{(r+a)2}$$

$$= q / 4\pi\varepsilon_0 \, [1/(r-a)^2 - 1/(r-a)2\,]$$

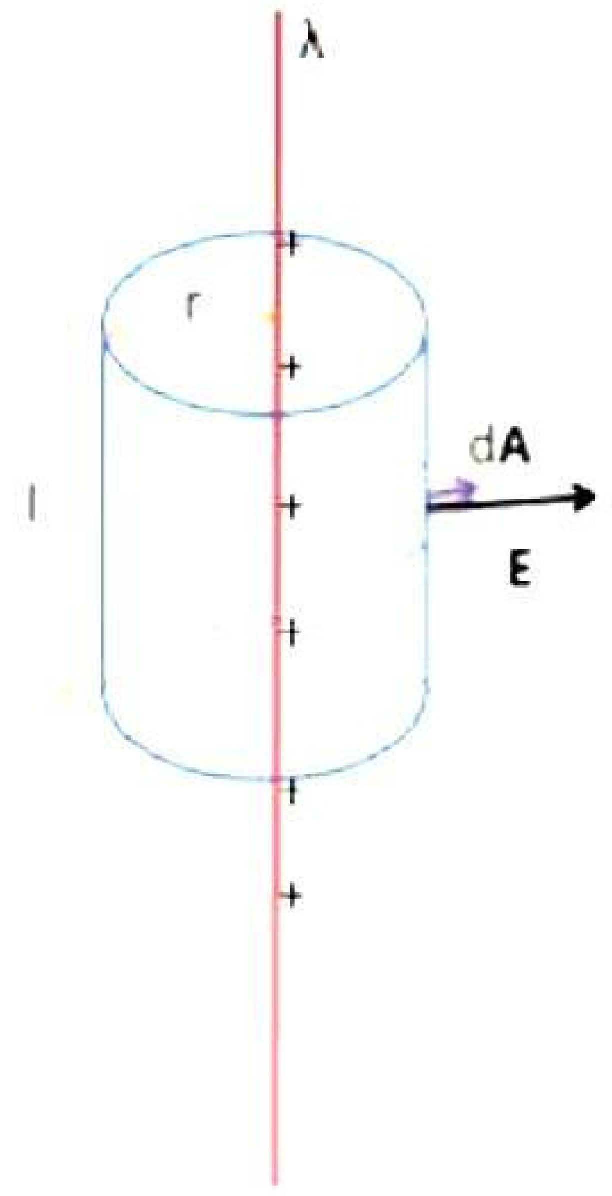
$$= 1/4\pi\varepsilon_0 \, (2pr/[(r^2 - a^2)^2]$$

For short dipole a<< r, a^2 can be neglected compare to r^2.

Therefore, the net electric field, $E = 2p/4\pi\varepsilon_0 r^3$

19. Electric field at a point due to an infinitely long, thin, uniformly charged straight wire

Consider a uniformly charged infinitely long thin wire of surface charge densityλ. We wish to find its electric field at a distance of r from it. Let a cylinder of radius r and height l be the Gaussian surface.



According to Gauss's law

$$EA = q/ \varepsilon_0$$

Now at the top and bottom phases of cylinder i.e. its base and top electric field (E) and area vectors (d A) are perpendicular to each other hence it does not contributes to electric flux. Only the curved surface contributes electric flux. Therefore taking

$A = 2\pi rl$

So, $E \times 2\pi rl = q/ \varepsilon_0$

Taking $\lambda = q / l$

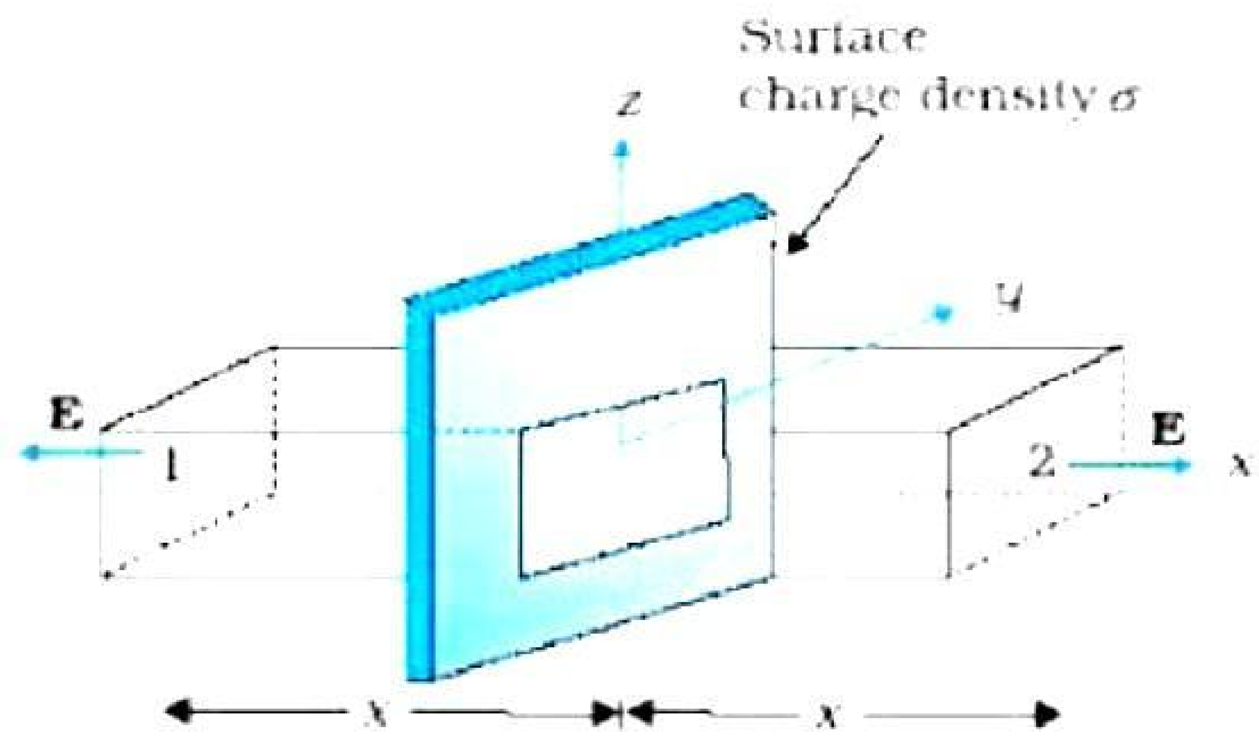
Simplifying we get

$E = \lambda / 2\pi \varepsilon_0 r$.

20. Electric field at a point due to uniformly charged infinite plane sheet.

The direction of the electric field due to an infinite charge sheet is perpendicular to the plane of the sheet. Let us consider a rectangular parallelepiped of cross sectional area A as Gaussian surface, whose axis is normal to the plane of the sheet. The surface charge density is σ. Electric field **E** from Gauss's Law law

$$\Phi = q/ \varepsilon_0$$



The unit vector normal to surface 1 is in −x direction and unit vector normal to surface 2 is in direction +x direction. Therefore the total flux through the Gaussian surface will be 2EA. The charge enclosed is σ A.

Therefore by Gauss's law

$2EA = q/ \varepsilon_0$

$2EA = \sigma A / \varepsilon_0$

Or, $E = \sigma / 2\varepsilon_0$