01

Electric Charges and Fields

TREND ANALYSIS 3 YEARS

Average No. of Questions Across all Sets

Topic	Types of Questions	2023	2020	2019
TOPIC 01 Coulomb's Law, Electrostatic Force and Electric Dipole	1 Mark	2	2	3
	2 Marks	1	1	1
	3 Marks	–	–	1
	5 Marks	–	–	1
TOPIC 02 Electric Flux and Gauss' Theorem	1 Mark	1	1	–
	2 Marks	–	–	–
	3 Marks	–	3	2
	5 Marks	2	1	–

TOPIC 1

Coulomb's Law, Electrostatic Force and Electric Dipole

Electric Charge

Charge is an intrinsic property of matter associated with its elementary particles due to which it produces and experiences electric and magnetic effect.

Benjamin Franklin introduced two types of charges namely positive charge and negative charge.

Its **SI unit** is coulomb (C) and

In **CGS system** its units are

- electrostatic unit (esu) or stat-coulomb (stat-C)
- electromagnetic unit (emu) or ab-C (ab-coulomb)

$$1 \text{ ab-C} = 10 \text{ C}, 1 \text{ C} = 3 \times 10^9 \text{ stat-C}$$

Conductors and Insulators

Those substances which readily allow the passage of electricity through them are called **conductors**, e.g. metals, whereas those substances which offer high resistance to the passage of electricity through them are called **insulators,** e.g. plastic rod and nylon.

Basic Properties of Electric Charges

There are some basic properties of electric charges

(i) **Additivity of Electric Charges** Charges are scalars and they add up like real numbers.

(ii) **Conservation of Electric Charges** Total charge of an isolated system always remains conserved.

(iii) **Quantisation of Electric Charges** Charge on a body exists in discrete amount rather than continuous value and hence, it is said to be charge is **quantised**.

Mathematically,

$$\boxed{q = \pm ne}$$

where, n is an integer

and e = electronic charge $= 1.6 \times 10^{-19}$C.

Coulomb's Law : Force between Two Point Charges

It states that the electrostatic force of attraction or repulsion acting between two stationary point charges is given by

$$\boxed{F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}}$$

where, q_1 and q_2 are the stationary point charges and r is the separation between them in air or vacuum.

Also, $\quad \mathrm{dl}/4\pi\varepsilon_0 = 9 \times 10^9$ N-m^{2}C^{-2}

where, $\quad \varepsilon_0$ = permittivity of free space

$= 8.85419 \times 10^{-12}$ C^2/N-m^2

In vector form, $\boxed{\mathbf{F} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{|\mathbf{r}|^2} \hat{\mathbf{r}}}$

Absolute Permittivity of a Medium (Dielectric Constant)

The force between two point charges q_1 and q_2 located at a distance r in a medium other than free space can be expressed as $F_{\text{medium}} = 1/4\pi\varepsilon \cdot q_1 q_2 / r^2$

where, ε is absolute permittivity of the medium.

Relative permittivity (ε_r) or **dielectric constant,**

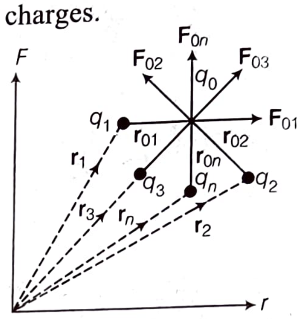
$$\boxed{\frac{\varepsilon}{\varepsilon_0} = \varepsilon_r}$$

Electrostatic Forces

These forces (Coulombian forces) are conservative forces. i.e. the work done by these forces do not depend upon the path followed.

Principle of Superposition of Electrostatic Forces : Forces between Multiple Charges

This principle states that the net electric force experienced by a given charge particle q_0 due to a system of charged particles is equal to the vector sum of all the forces exerted on it individually. Force between two charges is not affected by other charges.



Superposition of electrostatic forces

Net force in terms of position vector,

$$\boxed{\mathbf{F}_0 = \frac{q_0}{4\pi\varepsilon_0}\left[\sum_{i=1}^{n} \frac{q_i}{|\mathbf{r}_0 - \mathbf{r}_i|^3}(\mathbf{r}_0 - \mathbf{r}_i)\right]}$$

Electrostatic Force due to Continuous Charge Distribution

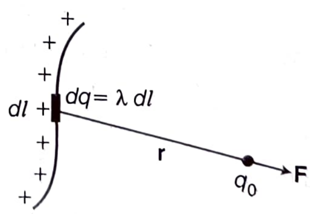
The region in which charges are closely spaced in a continuous manner is said to have continuous distribution of charges.

It is of three types

(i) **Linear Charge Distribution (Charge distributed along a line)** is given by

$$\boxed{dq = \lambda dl \Rightarrow \mathbf{F} = \frac{q_0}{4\pi\varepsilon_0}\int_l \frac{\lambda\, dl}{|\mathbf{r}|^2}\hat{\mathbf{r}}}$$

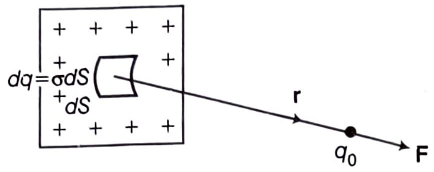
where λ is called **linear charge density** (charge per unit length) and dl is a short length element of linear charge distribution.



(ii) **Surface Charge Distribution (Charge distribution over a plane surface)** is given by

$$\boxed{dq = \sigma\, dS \Rightarrow \mathbf{F} = \frac{q_0}{4\pi\varepsilon_0}\int_S \frac{\sigma\, dS}{|\mathbf{r}|^2}\,\hat{\mathbf{r}}}$$

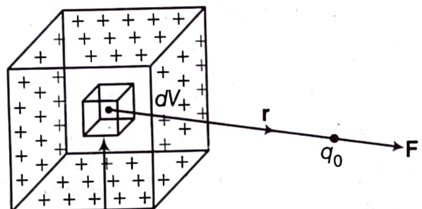
where, σ is called **surface charge density** (charge per unit area) and dS is a small surface element.



(iii) **Volume Charge Distribution (Charge distributed over a volume)** is given by

$$\boxed{dq = \rho\, dV \Rightarrow \mathbf{F} = \frac{q_0}{4\pi\varepsilon_0}\int_V \frac{\rho\, dV}{|\mathbf{r}|^2}\,\hat{\mathbf{r}}}$$

where ρ is called **volume charge density** and dV is a small volume element.



Electric Field

The space around a charge in which its effect can be felt significantly, i.e. the area which produces attractive or repulsive force on another charge placed in that area is called electric field.

Electric Field Intensity

The force experienced per unit positive test charge placed at that point without disturbing the source charge.

It is expressed as

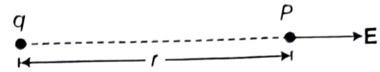
$$\boxed{\mathbf{E} = \lim_{q_0 \to 0} \frac{\mathbf{F}}{q_0}}$$

SI unit of electric field intensity (**E**) is $\mathbf{NC^{-1}}$ and it is a vector quantity.

Electric Field due to a Point Charge

Electric field intensity at point P due to a point charge q is

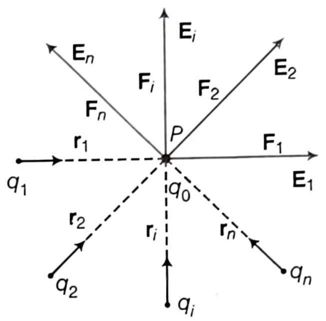
$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{|\mathbf{r}|^2}\,\hat{\mathbf{r}}$$



The magnitude of the electric field at a point P is given by

$$\boxed{|\mathbf{E}| = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}}$$

Electric Field due to a System of Charges



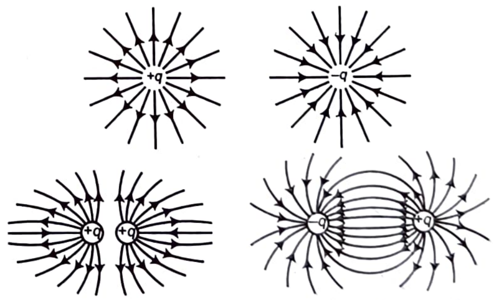
A System of Charges

$$\mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2 + \mathbf{E}_3 + \ldots + \mathbf{E}_n = \sum_{i=1}^{n} \mathbf{E}_i$$

$$\Rightarrow \quad \boxed{\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{|\mathbf{r}_i|^2}\,\hat{\mathbf{r}}_i}$$

Electric Field Lines

Electric field lines are a way of pictorially mapping the electric field intensity around a configuration of charge(s). These lines start from positive charge and end on negative charge. The tangent on these lines at any point gives the direction of electric field at that point. Electric field lines due to positive and negative point charges and their combinations are shown below:



Field lines due to two equal positive charges

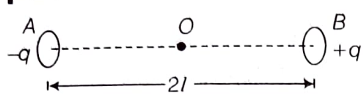
Field lines due to an electric dipole

Different electric field lines

Electric Dipole

Two point charges of equal magnitude and opposite in sign separated by a small distance form an electric dipole. e.g. HCl, H_2O, N_2O, etc. molecules.

Electric Dipole Moment



$$\boxed{\mathbf{p} = 2q\mathbf{l}}$$

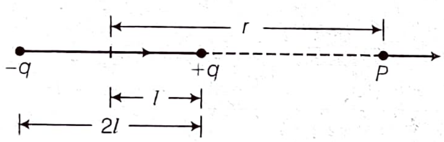
Its SI unit is C-m, it is a vector quantity and its direction is from negative charge $(-q)$ to positive charge $(+q)$.

Electric Field due to Electric Dipole

(i) Electric Field at a Point on the Axial Line due to Electric Dipole (End-on position)

At a point on axial line of the dipole at a distance r from the centre of the dipole is given by

$$\mathbf{E}_{\text{axial}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2\mathbf{p}r}{(r^2 - l^2)^2}$$

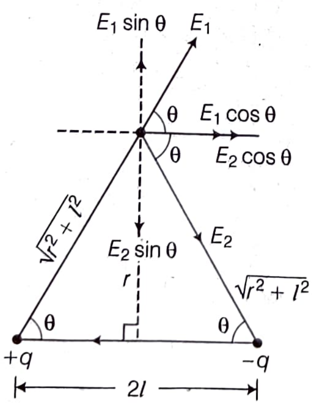


When $l << r$, $\mathbf{E}_{\text{axial}} = \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{2\mathbf{p}}{r^3}$

$$\Rightarrow \quad \boxed{|\mathbf{E}_{\text{axial}}| = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2|\mathbf{p}|}{r^3}}$$

(ii) Electric Field at a Point on the Equatorial Line due to Electric Dipole (Broadside-on position)

At a point on equatorial line of the dipole at a distance r from the centre of the dipole is given by



$$\mathbf{E}_{\text{equatorial}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{-\mathbf{p}}{(r^2 + l^2)^{3/2}}$$

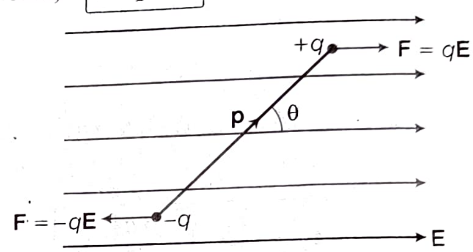
If $l << r$, $\boxed{|\mathbf{E}_{\text{equatorial}}| = \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{|\mathbf{p}|}{r^3}}$

Torque on an Electric Dipole Placed in a Uniform Electric Field

Torque acting on the dipole is given by

$$\tau = pE \sin\theta$$

In vector form, $\boxed{\tau = \mathbf{p} \times \mathbf{E}}$



- **Minimum torque**
  when $\theta = 0°$ or π
  $$\tau = \tau_{\text{min}} = 0$$
- **Maximum torque**
  when $\sin\theta = 1$
  $$\Rightarrow \quad \theta = \pi/2$$
  $$\tau = \tau_{\text{max}} = pE$$
- Dipole is in stable equilibrium in uniform electric field when the angle between $\mathbf{p}$ and $\mathbf{E}$ is $0°$ and in unstable equilibrium when the angle is $180°$.

Work Done and Potential Energy of Electric Dipole

When an electric dipole is placed in an electric field, then work is done in rotating it is given by

$$\boxed{W = pE\,(\cos\theta_1 - \cos\theta_2)}$$

Potential energy when $\theta_1 = 90°$ to $\theta_2 = \theta$

$$W = pE\,(\cos 90° - \cos\theta)$$
$$= -pE\cos\theta = -\mathbf{p}\cdot\mathbf{E}$$

Conditions

(i) Work done in rotating the electric dipole when $\theta_1 = 0°$ and $\theta_2 = \pi$.

$$W = 2pE$$

(ii) Work done in rotating the elecric dipole when $\theta_1 = 0°$ and $\theta_2 = 90°$.

$$W = pE$$

PYQs Previous Years Questions

1 Mark Questions

Multiple Choice Questions

1. The magnitude of the electric field due to a point charge object at a distance of 4.0 m is 9 N/C. From the same charged object the electric field of magnitude, 16 N/C will be at a distance of **CBSE 2023**

(a) 1 m (b) 2 m
(c) 3 m (d) 6 m

2. An electric dipole of dipole moment 2×10^{-8} C-m in a uniform electric field experiences a maximum torque of 6×10^{-1} N-m. The magnitude of electric field is **CBSE 2023**

(a) $2.2 \times 10^{3}\ \text{Vm}^{-1}$ (b) $1.2 \times 10^{4}\ \text{Vm}^{-1}$
(c) $3.0 \times 10^{7}\ \text{Vm}^{-1}$ (d) $4.2 \times 10^{3}\ \text{Vm}^{-1}$

3. An isolated point charge particle produces an electric field **E** at a point 3 m away from it. The distance of the point at which the field is $\frac{\mathbf{E}}{4}$ will be **CBSE 2023**

(a) 2 m (b) 3 m
(c) 4 m (d) 6 m

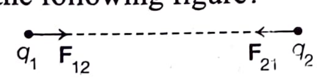
4. An electron experiences a force $(1 \cdot 6 \times 10^{-18}\ \text{N})\ \hat{\mathbf{i}}$ in an electric field **E**. The electric field **E** is **CBSE 2023**

(a) $\left(1 \cdot 0 \times 10^{3}\ \frac{\text{N}}{\text{C}}\right)\hat{\mathbf{i}}$ (b) $-\left(1.0 \times 10^{3}\ \frac{\text{N}}{\text{C}}\right)\hat{\mathbf{i}}$
(c) $\left(1.0 \times 10^{-3}\ \frac{\text{N}}{\text{C}}\right)\hat{\mathbf{i}}$ (d) $-\left(1.0 \times 10^{-3}\ \frac{\text{N}}{\text{C}}\right)\hat{\mathbf{i}}$

5. Two parallel large thin metal sheets have equal surface densities $26.4 \times 10^{-12}\ \text{C/m}^2$ of opposite signs. The electric field between these sheets is **CBSE SQP 2022-23**

(a) 1.5 N/C (b) 1.5×10^{-16} N/C
(c) 3×10^{-10} N/C (d) 3 N/C

6. According to Coulomb's law, which is the correct relation for the following figure? **CBSE SQP 2022-23**



(a) $q_1 q_2 > 0$ (b) $q_1 q_2 < 0$
(c) $q_1 q_2 = 0$ (d) $1 > q_1 q_2 > 0$

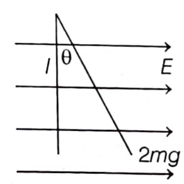
7. Two point charges $+8q$ and $-2q$ are located at $x = 0$ and $x = L$ respectively. The point on X-axis at which net electric field is zero due to these charges is **CBSE SQP 2022-23**

(a) $8L$ (b) $4L$ (c) $2L$ (d) L

8. Two point charges placed in a medium of dielectric constant 5 are at a distance r between them, experience an electrostatic force F. The electrostatic force between them in vacuum at the same distance r will be **CBSE SQP 2021-22**

(a) $5F$ (b) F (c) $F/2$ (d) $F/5$

9. A small object with charge q and weight mg is attached to one end of a string of length L attached to a stationary support. The system is placed in a uniform horizontal electric field E, as shown in the accompanying figure. In the presence of the field, the string makes a constant angle θ with the vertical. The sign and magnitude of q is **CBSE SQP 2021-22**



(a) positive with magnitude mg/E
(b) positive with magnitude $(mg/E)\tan\theta$
(c) negative with magnitude $mg/E \tan\theta$
(d) positive with magnitude $E\tan\theta / mg$

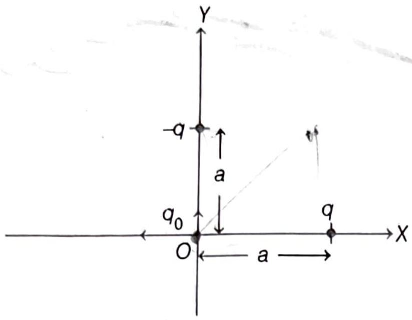
10. A negatively charged object X is repelled by another charged object Y. However, an object Z is attracted to object Y. Which of the following is the most possibility for the object Z? **CBSE 2022 (Term-I)**

(a) Positively charged only
(b) Negatively charged only
(c) Neutral or positively charged
(d) Neutral or negatively charged

11. In an experiment, three microscopic latex spheres are sprayed into a chamber and became charged with charges $+3e$, $+5e$ and $-3e$, respectively. All the three spheres came in contact simultaneously for a moment and got separated. Which one of the following are possible values for the final charge on the spheres? **CBSE 2022 (Term-I)**

(a) $+5e, -4e, +5e$
(b) $+6e, +6e, -7e$
(c) $+4e, +3.5e, +5.5e$
(d) $+5e, -8e, +7e$

12. Three charges q, $-q$ and q_0 are placed as shown in the figure. The magnitude of the net force on the charge q_0 at point O is $\left(\text{Take, } K = \frac{1}{4\pi\varepsilon_0}\right)$ **CBSE 2022 (Term-I)**



(a) 0 (b) $\frac{2Kqq_0}{a^2}$ (c) $\frac{\sqrt{2}Kqq_0}{a^2}$ (d) $\frac{1}{\sqrt{2}}\frac{Kqq_0}{a^2}$

13. An object has charge of 1 C and gains 5.0×10^{18} electrons. The net charge on the object becomes **CBSE 2022 (Term-I)**

(a) -0.80 C (b) $+0.80$ C
(c) $+1.80$ C (d) $+0.20$ C

Assertion-Reason Questions

Directions (Q. Nos. 14-19) *In the following questions, two statements are given- one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below*

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both Assertion and Reason are incorrect.

14. **Assertion** In a non-uniform electric field, a dipole will have translatory as well as rotatory motion.

Reason In a non-uniform electric field, a dipole experiences a force as well as torque. **CBSE SQP 2022-23**

15. **Assertion** A negative charge in an electric field moves along the direction of the electric field.

Reason On a negative charge the force acts in the direction of the electric field. **CBSE 2022 (Term-I)**

16. **Assertion** When charges are shared between any two bodies, then no charge is really lost but some loss of energy does occur.

Reason Some energy disappears in the form of heat, sparking, etc.

17. **Assertion** The coulomb force is the dominating force in the universe.

Reason The coulomb force is weaker than the gravitational force.

18. **Assertion** At the centre of the line joining two equal and opposite charges, $E = 0$.

Reason At the centre of the line joining two equal and similar charge, $E \neq 0$.

19. **Assertion** If a dipole is enclosed by a surface, then according to Gauss's law, electric flux linked with it will be zero.

Reason The charge enclosed by a surface is zero.

Very Short Answer Questions

20. A point charge is placed at the centre of a hollow conducting sphere of inner radius r and outer radius $2r$. The ratio of the surface charge density of the inner surface to that of the outer surface will be .... **Delhi 2020**

21. Torque acting on an electric dipole placed in an uniform electric field is maximum when the angle between the electric field and the dipole moment is .... **All India 2020**

22. Draw the pattern of electric field lines, when a point charge $-Q$ is kept near an uncharged conducting plate. **Delhi 2019**

23. Draw a pattern of electric field lines due to two positive charges placed a distance d apart. **All India 2019**

24. Draw the pattern of electric field lines due to an electric dipole. **All India 2019**

25. Why do the electrostatic field lines not form closed loop? **All India 2014, Delhi 2012**

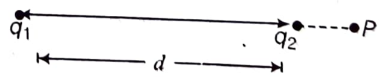
26. Two identical balls having same positive charge q coulomb are suspended by two insulating strings of equal length. What would be the effect on the force when a plastic sheet is inserted between the two? **All India 2014**

27. Why do the electric field lines never cross each other? **All India 2014**

28. Why must electrostatic field at the surface of a charged conductor be perpendicular to every point on it? **Foreign 2014, Delhi 2012**

29. Two point charges q_1 and q_2 are placed at a distance d apart as shown in the figure.

The electric field intensity is zero at the point P on the line joining them as shown. Write two conclusions that you can draw from this. **Delhi 2014C**



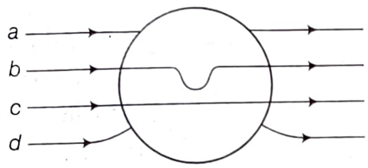
30. Define dipole moment of an electric dipole. Is it a scalar quantity or a vector quantity? **Foreign 2012; All india 2011**

31. Draw a plot showing the variation of electric field E with distance r due to a point charge q. **Delhi 2012**

> **KEY idea**
>
> Electric field is inversely proportional to the square of the distance between two charged particles.

32. In which orientation, a dipole placed in a uniform electric field is in (i) stable equilibrium (ii) unstable equilibrium? **Delhi 2011**

33. A metallic sphere is placed in a uniform electric field as shown in the figure. Which path is followed by electric field lines and why? **Foreign 2010**



34. Point out whether the following statement is right or wrong.

The mutual forces between two charges do not get affected by the presence of other charges. **All India 2010**

2 Marks Questions

35. An electric dipole of dipole moment **p** is kept in a uniform electric field **E**. Show graphically the variation of torque acting on the dipole τ with its orientation θ in the field. Find the orientation in which torque is (i) zero and (ii) maximum. **CBSE 2023**

36. Derive the expression for the torque acting on an electric dipole when it is held in a uniform electric field. Identify the orientation of the dipole in the electric field in which it attains a stable equilibrium. **Delhi 2020**

37. Derive an expression for the electric field due to a dipole of dipole moment **p** at a point on its perpendicular bisector. **Delhi 2019**

38. An electric dipole is placed in a uniform electric field **E** with its dipole moment **p** parallel to the field. Find the orientation of the dipole for which the torque acting on it becomes maximum. **All India 2014C**

39. Point charge $(+Q)$ is kept in the vicinity of an uncharged conducting plate. Sketch electric field lines between the charge and the plate. **Foreign 2014**

40. Two concentric metallic spherical shells of radii R and $2R$ are given charge Q_1 and Q_2, respectively. The surface charge densities on the outer surfaces of the shells are equal. Determine the ratio $Q_1 : Q_2$. **Foreign 2013**

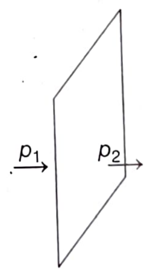
> **KEY idea**
>
> Surface charge density is inversely proportional to the square of the radius of the metallic spherical shell.

41. Two identical metallic spherical shells A and B having charges $+4Q$ and $-10Q$ are kept a certain distance apart. A third identical uncharged sphere C is first placed in contact with sphere A and then with sphere B, then spheres A and B are brought in contact and then separated. Find the charge on the spheres A and B. **All India 2011C**

42. Deduce the expression for the electric field **E** at a point r due to a system of two charges q_1 and q_2 with position vectors $\mathbf{r}_1$ and $\mathbf{r}_2$ with respect to common origin. **Delhi 2010C**

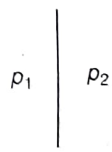
3 Marks Questions

43. (i) An electric dipole is kept first to the left and then to the right of a negatively charged infinite plane sheet having a uniform surface charge density. The arrows p_1 and p_2 show the directions of its electric dipole moment in the two cases. **CBSE SQP 2018-19**



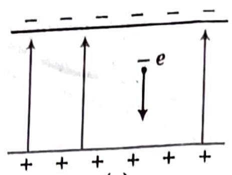
Identify for each case, whether the dipole is in stable or unstable equilibrium. Justify each answer.

(ii) Next, the dipole is kept in a similar way (as shown), near an infinitely long straight wire having uniform negative linear charge density.



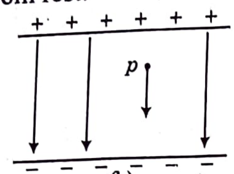
Will the dipole be in equilibrium at these two position? Justify your answer. (NO)

44. An electron falls through a distance of 1.5 cm in a uniform electric field of magnitude 2.0×10^4 N/C (Fig. a)



(a)

(i) Calculate the time it takes to fall through this distance starting from rest.



(b)

(ii) If the direction of the field is reversed (Fig. b) keeping its magnitude unchanged, calculate the time taken by a proton to fall through this distance starting from rest. **CBSE 2018C**

45. (i) Derive the expression for electric field at a point on the equatorial line of an electric dipole.

(ii) Depict the orientation of the dipole in (a) stable, (b) unstable equilibrium in a uniform electric field. **Delhi 2017**

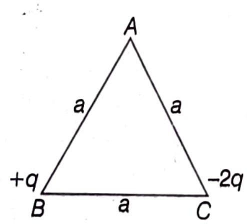
46. (i) Obtain the expression for the torque τ experienced by an electric dipole of dipole moment **p** in a uniform electric field **E**.

(ii) What will happen, if the field were non-uniform? **Delhi 2017**

47. A thin circular ring of radius r is charged uniformly so that its linear charge density becomes λ. Derive an expression for the electric field at a point P at a distance x from its centre along the axis of the ring. Hence, prove that at large distances ($x >> r$), the ring behaves as a point charge. **Delhi 2016**

48. An electric dipole of dipole moment **p** is placed in a uniform electric field **E**. Obtain the expression for the torque τ experienced by the dipole. Identify two pairs of perpendicular vectors in the expression. **Delhi 2015C**

49. Two point charges $+q$ and $-2q$ are placed at the vertices B and C of an equilateral ΔABC of side a 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. **All India 2014C**

50. Define the term electric dipole moment. Is it a scalar or vector? Deduce an expression for the electric field at a point on the equatorial plane of an electric dipole of length $2a$. **All India 2013**

51. An electric dipole is kept in a uniform electric field. Derive an expression for the net torque acting on it and write its direction. State the conditions under which the dipole is in

(i) stable equilibrium

(ii) unstable equilibrium. **Delhi 2012C**

52. Sketch the pattern of electric field lines due to

(i) a conducting sphere having negative charge on it.

(ii) an electric dipole. **All India 2011C**

5 Marks Questions

53. (i) Define an ideal electric dipole. Give an example.

(ii) Derive an expression for the torque experienced by an electric dipole in a uniform electric field. What is net force acting on this dipole.

(iii) An electric dipole of length 2 cm is placed with its axis making an angle of 60° with respect to uniform electric field of 10^5 N/C.
If it experiences a torque of $8\sqrt{3}$ Nm, calculate the magnitude of charge on the dipole, and its potential energy. **CBSE SQP 2020-21**

54. (i) Derive an expression for the electric field at any point on the equatorial line of an electric dipole.

(ii) Two identical point charges q each are kept 2 m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q. **Delhi 2019**

55. (i) Derive an expression for the electric field E due to a dipole of length $2l$ at a point distant r from the centre of the dipole on the axial line.

(ii) Draw a graph of E versus r for $r >> l$.

(iii) If this dipole is kept in a uniform external electric field E_0, diagrammatically represent the position of the dipole in stable and unstable equilibrium and write the expressions for the torque acting on the dipole in both the cases. **All India 2017**

56. (i) Define torque acting on a dipole of dipole moment **p** placed in a uniform electric field **E**. Express it in the vector form and point out the direction along which it acts.

(ii) What happens if the field is non-uniform?

(iii) What would happen if the external field **E** is increasing (a) parallel to **p** and (b) anti-parallel to **p**? **Foreign 2016**

TOPIC 2

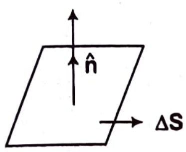
Electric Flux and Gauss' Theorem

Area Vector

It is the vector associated with every area element of a closed surface and taken in the direction of the outward normal.

$$\boxed{\Delta \mathbf{S} = |\Delta \mathbf{S}|\hat{\mathbf{n}} = (\Delta S)\hat{\mathbf{n}}}$$

Here, $\Delta \mathbf{S}$ is the area vector in the direction of the unit vector $\hat{\mathbf{n}}$ normal to the surface area ΔS.



Representation of area vector

Electric Flux

Electric flux linked with any surface is proportional to the total number of electric field lines that normally pass through that surface. It is a scalar quantity.

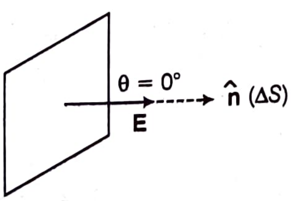
SI unit of electric flux is $\mathbf{N\text{-}m^2C^{-1}}$ or $\mathbf{J\text{-}mC^{-1}}$ or **V-m.**

CGS unit of electric flux is $\mathbf{dyne\text{-}cm^2/C}$.

Different Conditions for the Electric Flux Linked with a Surface

There are following conditions for the electric flux linked with a surface

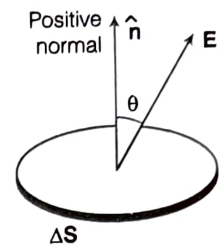
(i) When surface is held normal to the direction of a uniform electric field **E**, then $\Delta\phi_E = E\Delta S$



Electric flux through a normal area

(ii) When area vector of surface makes an angle θ with the direction of a uniform electric field $\mathbf{E}$, then $\Delta\phi_E = E\Delta S \cos\theta$.

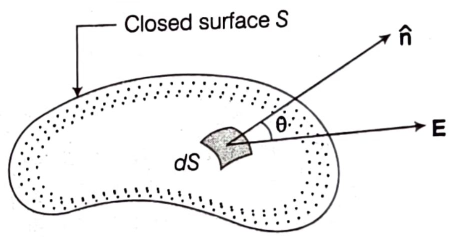
In vector form, $\boxed{\Delta\phi_E = \mathbf{E}\cdot\Delta\mathbf{S}}$



Eelectric Flux through an angle θ

(iii) Closed surface S lying inside the non-uniform electric field **E**, the total electric flux linked

$$\boxed{\phi = \oint_S \mathbf{E}\cdot d\mathbf{S}}$$



Electric flux through a closed surface S

Gauss' Theorem

The total electric flux linked with closed surface S is

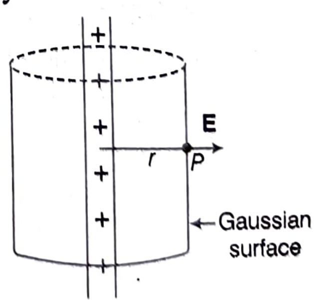
$$\boxed{\phi_E = \oint \mathbf{E}\cdot d\mathbf{S} = \frac{q}{\varepsilon_0}}$$

where, q is the total charge enclosed by the closed Gaussian (imaginary) surface.

Applications of Gauss' Theorem

There are some applications of Gauss' theorem

(i) **Electric field due to infinitely long uniformly charged wire** with linear charged density λ. We have considered cylindrical Gaussian surface.



From Gauss' law,

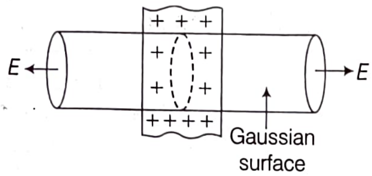
$$\oint \mathbf{E} \cdot d\mathbf{S} = \frac{q}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0}$$

$$\Rightarrow \quad E \times 2\pi r l = \frac{\lambda l}{\varepsilon_0}$$

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

Here, r is the perpendicular distance from the charged wire.

(ii) (a) **Electric field due to a thin infinite plane sheet of charge** with uniform surface charge density σ at any nearby point



$$E = \frac{\sigma}{2\varepsilon_0}$$

[for infinite plane sheet of charge]

and $$E = \frac{\sigma}{\varepsilon_0}$$

[for any charged conducting surface]

(b) Electric field intensity due to two equally and oppositely charged parallel plane sheet of charge at any point

$$E = \frac{\sigma}{\varepsilon_0} \quad \text{[between the two plates]}$$

and $E = 0$ [outside the plates]

(iii) **Electric field due to a thin charged spherical shell of radius R at a distance r from its centre.**

To find the field at a distance r from the centre of the spherical shell.

(a) **For point lying outside the shell** ($r > R$)

$$\oint \mathbf{E} \cdot d\mathbf{S} = \frac{q}{\varepsilon_0}$$ Since, $\mathbf{E}$ and $d\mathbf{S}$ are in the same direction, $\mathbf{E}\oint d\mathbf{S} = \frac{q}{\varepsilon_0}$

$$\Rightarrow \quad \boxed{E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}}$$

Since, $q = \sigma \times 4\pi R^2$

$$\boxed{E = \frac{\sigma R^2}{\varepsilon_0 r^2}}$$

(b) **Field at a point inside the shell** ($r < R$)

Here, the charge inside the Gaussian surface shell

As, $q = 0$

$$\Rightarrow \quad \boxed{\mathbf{E} = 0}$$

(c) **Field at a point on the surface** ($r = R$)

On putting $r = R$,

$$\Rightarrow \quad E = \frac{q}{4\pi\varepsilon_0 R^2} = \frac{\sigma}{\varepsilon_0}$$

where, σ is surface charge density,

$$\boxed{\sigma = \frac{q}{4\pi R^2}}$$

PYQs Previous Years Questions

1 Mark Questions

Multiple Choice Questions

1. A charge Q is placed at the centre of a cube. The electric flux through one if its face is **CBSE 2023**

(a) $\frac{Q}{\varepsilon_0}$ (b) $\frac{Q}{6\varepsilon_0}$ (c) $\frac{Q}{8\varepsilon_0}$ (d) $\frac{Q}{3\varepsilon_0}$

2. A cylinder of radius r and length l is placed in an uniform electric field parallel to the axis of the cylinder. The total flux for the surface of the cylinder is given by **CBSE SQP 2021-22**

(a) zero (b) πr^2
(c) $E\pi r^2$ (d) $2E\pi r^2$

3. Which statement is true for Gauss' law? **CBSE SQP 2021-22**

(a) All the charges whether inside or outside the gaussian surface contribute to the electric flux.
(b) Electric flux depends upon the geometry of the gaussian surface.
(c) Gauss theorem can be applied to non-uniform electric field.
(d) The electric field over the gaussian surface remains continuous and uniform at every point.

4. The magnitude of electric field due to a point charge $2q$ at distance r is E. Then, the magnitude of electric field due to a uniformly charged thin sphere shell of radius R with total charge q at a distance $\frac{r}{2}$ $(r >> R)$ will be **CBSE 2022 (Term-I)**

(a) $\frac{E}{4}$ (b) 0 (c) $2E$ (d) $4E$

5. A square sheet of side a is lying parallel to XY-plane at $z = a$. The electric field in the region is $\mathbf{E} = cz^2\hat{\mathbf{k}}$. The electric flux through the sheet is **CBSE 2022 (Term-I)**

(a) a^4c (b) $\frac{1}{3}a^3c$

(c) $\frac{1}{3}a^4c$ (d) 0

6. A charge q is placed at the point of intersection of body diagonals of a cube. The electric flux passing through any one of its face is **CBSE SQP 2019-20**

(a) $\frac{q}{6\varepsilon_0}$ (b) $\frac{3q}{\varepsilon_0}$ (c) $\frac{6q}{\varepsilon_0}$ (d) $\frac{q}{3\varepsilon_0}$

7. The electric flux through a closed Gaussian surface depends upon **Delhi 2020**

(a) net charge enclosed and permittivity of the medium
(b) net charge enclosed, permittivity of the medium and the size of the Gaussian surface
(c) net charge enclosed only
(d) permittivity of the medium only

Assertion-Reason Questions

Directions (Q. Nos. 8-9) *In the following questions, two statements are given- one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below*

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both Assertion and Reason are incorrect.

8. **Assertion** In a region, where uniform electric field exists, the net charge within volume of any size is zero.
Reason The electric flux within any closed surface in region of uniform electric field is zero.

9. **Assertion** With the help of Gauss's theorem, we can find electric field at any point.
Reason Gauss's theorem cannot be applied for any type of charge distribution.

Very Short Answer Questions

10. How does the electric flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased? **Delhi 2016**

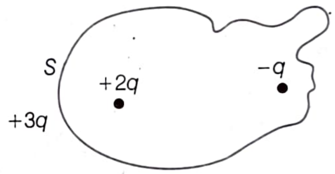
11. What is the electric flux through a cube of side 1 cm which encloses an electric dipole? **All India 2015**

12. What is the flux due to electric field $\mathbf{E} = 3\times10^3\,\hat{\mathbf{i}}\,\text{NC}^{-1}$ through a square of side 10 cm, when it is held normal to $\mathbf{E}$? **All India 2015C**

13. Two charges of magnitudes $-2Q$ and $+Q$ are located at points $(a, 0)$ and $(4a, 0)$, respectively. What is the electric flux due to these charges through a sphere of radius $3a$ with its centre at the origin? **All India 2013**

14. A charge q is placed at the centre of a cube of side l. What is the electric flux passing through each face of the cube? **All India 2010; Foreign 2010**

15. Figure shows three point charges, $+2q$, $-q$ and $+3q$. Two charges $+2q$ and $-q$ are enclosed within a surface S. What is the electric flux due to this configuration through the surface S? **Delhi 2010**



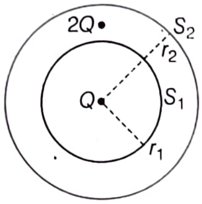
2 Marks Questions

16. Given a uniform electric field $\mathbf{E}=5\times10^3\,\hat{\mathbf{i}}\,\text{NC}^{-1}$. Find the flux of this field through a square of side 10 cm whose plane is parallel to the YZ-plane. What would be the flux through the same square if the plane makes an angle of 30° with the X-axis? **Delhi 2014**

17. Given a uniform electric field $\mathbf{E}=2\times10^3\,\hat{\mathbf{i}}\,\text{NC}^{-1}$. Find the flux of this field through a square of side 20 cm whose plane is parallel to the YZ-plane. What would be the flux through the same square if the plane makes an angle of 30° with the X-axis? **Foreign 2014**

18. Given a uniform electric field $\mathbf{E} = 4\times10^3\,\hat{\mathbf{i}}\,\text{NC}^{-1}$. Find the flux of this field through a square of side 5 cm whose plane is parallel to the YZ-plane. What would be the flux through the same square if the plane makes an angle of 30° with the X-axis? **Delhi 2014C**

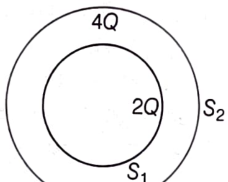
19. A sphere S_1 of radius r_1 encloses a net charge Q. If there is another concentric sphere S_2 of radius $r_2 (r_2 > r_1)$ enclosing charge $2Q$. Find the ratio of the electric flux through S_1 and S_2. How will the electric flux through sphere S_1 change if a medium of dielectric constant K is introduced in the space inside S_2 in place of air? **All India 2014**



20. A thin straight infinitely long conducting wire having linear charge density λ is enclosed by a cylindrical surface of radius r and length l, its axis coinciding with the length of the wire. Find the expression for the electric flux through the surface of the cylinder. **All India 2011**

21. Show that the electric field at the surface of a charged spherical conducting shell is given by $E = \frac{\sigma}{\varepsilon_0}\hat{\mathbf{n}}$, where σ is the surface charge density and $\hat{\mathbf{n}}$ is a unit vector normal to the surface in the outward direction. **All India 2010**

22. Consider two hollow concentric spheres S_1 and S_2 enclosing charges $2Q$ and $4Q$ respectively as shown in the figure. (i) Find out the ratio of the electric flux through them. (ii) How will the electric flux through the spheres S_1 change if a medium of dielectric constant ε_r is introduced in the space inside S_1 in place of air? Deduce the necessary expression. **Foreign 2010**



3 Marks Questions

23. State Gauss's law on electrostatics and derive an expression for the electric field due to a long straight thin uniformly charged wire (linear charge density λ) at a point lying at a distance r from the wire. **Delhi 2020**

24. A hollow conducting sphere of inner radius r_1 and outer radius r_2 has a charge Q on its surface. A point charge $-q$ is also placed at the centre of the sphere.

(i) What is the surface charge density on the (a) inner and (b) outer surface of the sphere?

(ii) Use Gauss's law of electrostatics to obtain the expression for the electric field at a point lying outside the sphere. **All India 2020**

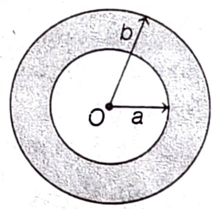
25. (i) An infinitely long thin straight wire has a uniform linear charge density λ. Obtain the expression for the electric field E at a point lying at a distance x from the wire by using Gauss' law.

(ii) Show graphically the variation of this electric field E as a function of distance x from the wire. **All India 2020**

26. A point charge $+Q$ is placed at the centre O of an uncharged hollow spherical conductor of inner radius a and outer radius b. Find the following

(i) The magnitude and sign of the charge induced on the inner and outer surface of the conducting shell.

(ii) The magnitude of electric field vector at a distance (a) $r = \frac{a}{2}$ and (b) $r = 2b$, from the centre of the shell. **CBSE SQP 2018-19**



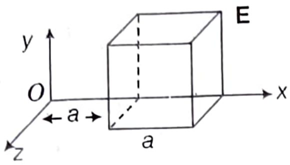
27. Two large charged plane sheets of charge densities σ and $-2\sigma\ \mathrm{C/m^2}$ are arranged vertically with a separation of d between them. Deduce expressions for the electric field at points (i) to the left of the first sheet (ii) to the right of the second sheet and (iii) between the two sheets. **All India 2019**

28. A spherical conducting shell of inner radius r_1 and outer radius r_2 has a charge Q.

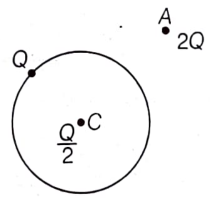
(i) A charge q is placed at the centre of the shell. Find out the surface charge density on the inner and outer surfaces of the shell.

(ii) Is the electric field inside a cavity (with no charge) zero independent of the fact whether the shell is spherical or not? Explain. **All India 2019**

29. Define electric flux and write its SI unit. The electric field components in the figure shown are $E_x = \alpha x$, $E_y = 0$, $E_z = 0$, where $\alpha = \frac{100\text{N}}{\text{Cm}}$. Calculate the charge within the cube, assuming $a = 0.1$ m. **CBSE 2018C**

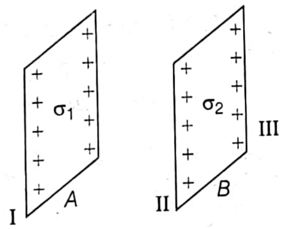


30. A thin metallic spherical shell of radius R carries a charge Q on its surface. A point charge $Q/2$ is placed at its centre C and an other charge $+2Q$ is placed outside the shell at a distance x from the centre as shown in the figure.



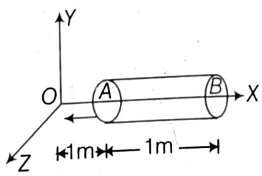
Find
(i) the force on the charge at the centre of shell and at the point A.
(ii) the electric flux through the shell. **All India 2015**

31. Two infinitely large plane thin parallel sheets having surface charge densities σ_1 and $\sigma_2 (\sigma_1 > \sigma_2)$ are shown in the figure. Write the magnitudes and directions of the net fields in the regions marked II and III. **Foreign 2014**



KEY idea
In case of two thin parallel plane sheets with different surface charge densities, flux will be multiplied by area of each faces of Gaussian cylinder with electric field.

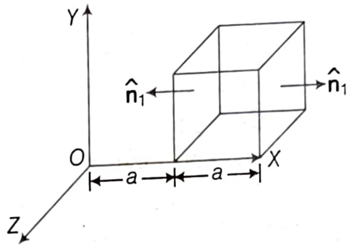
32. A hollow cylindrical box of length 1 m and area of cross-section 25 cm^2 is placed in a three-dimensional coordinate system as shown in the figure. The electric field in the region is given by $\mathbf{E} = 50\,x\hat{\mathbf{i}}$, where E is in NC^{-1} and x is in metre.



Find
(i) net flux through the cylinder.
(ii) charge enclosed by the cylinder. **Delhi 2013**

33. (i) State Gauss' law.
(ii) A thin straight inifintely long conducting wire of linear charge density λ is enclosed by a cylindrical surface of radius r and length l. Its axis coinciding with the length of the wire. Obtain the expression for the electric field indicating its direction at a point on the surface of the cylinder. **Delhi 2012**

34. State Gauss' law in electrostatics. A cube with each side a is kept in an electric field given by $\mathbf{E} = Cx\hat{\mathbf{i}}$ as shown in the figure, where C is a positive dimensional constant. Find out



(i) the net electric flux through the cube.
(ii) the net charge inside the cube. **Foreign 2012**

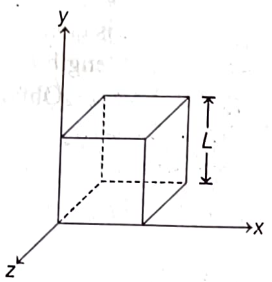
35. Using Gauss' law obtain the expression for the electric field due to uniformly charged spherical shell of radius R at a point outside the shell. Draw a graph showing the variation of electric field with r, for $r > R$ and $r < R$. **All India 2011**

5 Marks Questions

36. (i) Use Gauss' law to obtain an expression for the electric field due to an infinitely long thin straight wire with uniform linear charge density λ.
(ii) An infinitely long positively charged straight wire has a linear charge density λ. An electron is revolving in a circle with a constant speed v such that the wire passes through the centre, and is perpendicular to the plane, of the circle. Find the kinetic energy of the electron in terms of magnitudes of its charge and linear charge density λ on the wire.
(iii) Draw a graph of kinetic energy as a function of linear charge density λ. **CBSE 2023**

37. (i) Define electric flux and write its SI Unit.
(ii) Use Gauss' law to obtain the expression for the electric field due to a uniformly charged infinite plane sheet.

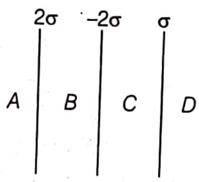
(iii) A cube of side L is kept in space as shown in the figure. An electric field $\mathbf{E} = (Ax + B)\,\hat{\mathbf{i}}\,\frac{\text{N}}{\text{C}}$ exists is the region. Find the net charge enclosed by the cube.



CBSE 2023

38. (i) State Gauss' law in electrostatics. Show that with help of suitable figure that outward flux due to a point charge Q, in vacuum within gaussian surface, is independent of its size and shape.

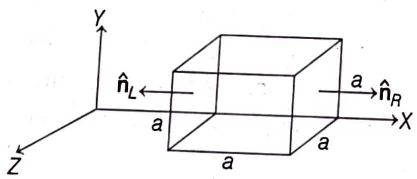
(ii) In the figure there are three infinite long thin sheets having surface charge density $+2\sigma$, -2σ and $+\sigma$ respectively. Give the magnitude and direction of electric field at a point to the left of sheet of charge density $+2\sigma$ and to the right of sheet of charge density $+\sigma$.



CBSE SQP 2020-21

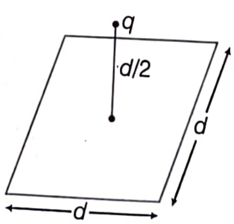
39. (i) Using Gauss' law derive expression for intensity of electric field at any point near the infinitely long straight uniformly charged wire.

(ii) The electric field components in the following figure are $E_x = \alpha x$, $E_y = 0$, $E_z = 0$; in which $\alpha = 400$ N/C m. Calculate (a) the electric flux through the cube, and (b) the charge within the cube assume that $a = 0.1$ m. **CBSE SQP 2019-2020**



40. (i) Define electric flux. Is it a scalar or a vector quantity?

A point charge q is at a distance of $d/2$ directly above the centre of a square of side d as shown in the figure. Use Gauss' law to obtain the expression for the electric flux through the square.



(ii) If the point charge is now moved to a distance d from the centre of the square and the side of the square is doubled, explain how the electric flux will be affected. **CBSE 2018**

41. (i) Use Gauss' law to derive the expression for the electric field (**E**) due to a straight uniformly charged infinite line of charge density λ C/m.

(ii) Draw a graph to show the variation of E with perpendicular distance r from the line of charge.

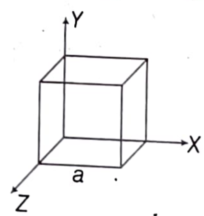
(iii) Find the work done in bringing a charge q from perpendicular distance r_1 to r_2 $(r_2 > r_1)$. **CBSE 2018**

42. (i) Use Gauss' theorem to find the electric field due to a uniformly charged infinitely large plane thin sheet with surface charge density σ.

(ii) An infinitely large thin plane sheet has a uniform surface charge density $+\sigma$. Obtain the expression for the amount of work done in bringing a point charge q from infinity to a point of distant r in front of the charged plane sheet. **All India 2017**

43. (i) An electric dipole of dipole moment $\mathbf{p}$ consists of point charges $+q$ and $-q$ separated by a distance $2a$ apart. Deduce the expression for the electric field $\mathbf{E}$ due to the dipole at a distance x from the centre of the dipole on its axial line in terms of the dipole moment $\mathbf{p}$. Hence, show that in the limit $x >> a$, $\mathbf{E} \longrightarrow 2\mathbf{p}/(4\pi\varepsilon_0 x^3)$.

(ii) Given the electric field in the region $\mathbf{E} = 2x\hat{\mathbf{i}}$, find the net electric flux through the cube and the charge enclosed by it. **All India 2015; Delhi 2015**

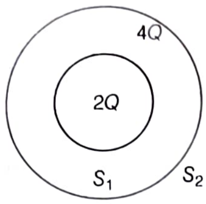


44. (i) Define electric flux. Write its SI unit. Gauss' law in electrostatics is true for any closed surface, no matter what its shape or size is. Justify this statement with the help of a suitable example.

(ii) Use Gauss' law to prove that the electric field inside a uniformly charged spherical shell is zero. **Delhi 2015**

45. (i) Deduce the expression for the torque acting on a dipole of dipole moment p in the presence of uniform electric field E.

(ii) Consider two hollow concentric spheres S_1 and S_2 enclosing charges $2Q$ and $4Q$ respectively as shown in the figure (a) find out the ratio of the electric flux through them. (b) How will the electric flux through the sphere S_1 changes if a medium of dielectric L is introduced in the space inside S_1 in place of air? Deduce the necessary expression? **All India 2014**



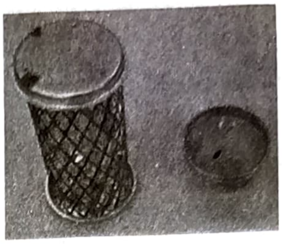
46. Using Gauss' law, deduce the expression for the electric field due to a uniformly charged spherical conducting shell of radius R at a point
    (i) outside the shell (ii) inside the shell.
    Plot a graph showing variation of electric field as a function of $r > R$ and $r < R$.
    (r being the distance from the centre of the shell) **All India 2013**

47. (i) Define electric flux. Write its SI unit.
    (ii) Using Gauss' law prove that the electric field at a point due to a uniformly charged infinite plane sheet is independent of distance from it.
    How is the field directed if the sheet is
    (a) positively charged?
    (b) negatively charged? **Delhi 2012**

Case Based Question (4 Marks) (For Complete Chapter)

Directions (Q.No. 48) *This question is case study based question. Attempt any 4 sub parts. Each question carries 1 mark*

48. **Faraday Cage**
    A Faraday cage or Faraday shield is an enclosure made of a conducting material. The fields within a conductor cancel out with any external fields, so the electric field within the enclosure is zero. These Faraday cages act as big hollow conductors you can put things in to shield them from electrical fields. Any electrical shocks the cage receives, pass harmlessly around the outside of the cage. **CBSE SQP 2020-21**



(i) Which of the following material can be used to make a Faraday cage? **(1)**
(a) Plastic (b) Glass
(c) Copper (d) Wood

(ii) Example of a real-word Faraday cage is **(1)**
(a) car (b) Plastic box
(c) lightning rod (d) metal rod

(iii) What is the electrical force inside a Faraday cage when it is struck by lightning? **(1)**
(a) The same as the lightning
(b) Half that of the lightning
(c) Zero
(d) A quarter of the lightning

(iv) An isolated point charge $+q$ is placed inside the Faraday cage. Its surface must have charge equal to **(1)**
(a) Zero (b) $+q$
(c) $-q$ (d) $+2q$

(v) A point charge of $2\,\mu C$ is placed at centre of Faraday cage in the shape of cube with surface of 9 cm edge. The number of electric field lines passing through the cube normally will be **(1)**
(a) $1.91\times 10^5\, Nm^2\, C$ entering the surface
(b) $1.91\times 10^5\, Nm^2/C$ leaving the surface
(c) $2.25\times 10^5\, Nm^2/C$ leaving the surface
(d) $2.25\times 10^5\, Nm^2/C$ entering the surface

CHAPTER TEST

01 Mark Questions

1 Two charges +1 μC and +4 μC are situated at a distance in air. The ratio of the faces acting on them is

(a) 1:4 (b) 4:1 (c) 1:1 (d) 1:16

2 A force of 2.25 N acts on a charge of 15×10^{-4} C. The intensity of electric field at that point is

(a) 150 NC^{-1} (b) 15 NC^{-1}
(c) 1500 NC^{-1} (d) 1.5 NC^{-1}

3 If two charges having equal and opposite charge of 2C each are placed at a distance of 0.04 m. Dipole moment of the system is

(a) 6×10^{-8} C-m (b) 8×10^{-6} C-m
(c) 8×10^{-2} C-m (d) 1.5×10^{2} C-m

4 An electric dipole of moment 2×10^{-8} C-m is aligned in a uniform electric field 2×10^{4} N/C. The work done in rotating the dipole from 80° to 60°.

(a) 1.464×10^{-4} J (b) 1.62×10^{-2} J
(c) 1.40×10^{-3} J (d) zero

5 When the intensity of electric field at the surface of conducting hollow surface is 10 NC^{-1} and its radius is 10 cm. The value of electric field at the centre of sphere.

(a) zero (b) 10 NC^{-1}
(c) 1 NC^{-1} (d) 100 NC^{-1}

02 Marks Questions

6 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 charge?

7 An infinite line charge produces a field of 9×10^{4} N/C at distance of 2 m. Calculate the linear charge density.

03 Marks Questions

8 Plot a graph showing the variation of coulomb's force (F) *versus* $\frac{1}{r^2}$, where r is the distance between two charges of each pair of charge (1 μC, 2 μC) and (1 μC, –3 μC), interpret the graphs obtained.

9 Derive an expression for Coulomb's law in vector form. 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 air?

10 An electric dipole is held at any angle θ in a uniform electric field E. Will there be any (i) net translating force (ii) torque. Explain.

05 Marks Questions

11 (i) State Gauss' theorem.

(ii) Using Gauss' law, prove that the electric field at a point due to uniformly charge infinite plane sheet is independent of the distance from it.

(iii) Find the electric dipole moment electron and a proton which distance is 4.3 nm apart.

12 (i) Deduce the expression for the torque acting on a dipole moment p in the presence of a uniform electric field E.

(ii) An electric dipole with dipole moment 4×10^{-9} C-m is aligned at 30° with the direction of a uniform electric field of magnitude 5×10^{4} N/C. Calculate the magnitude of the torque acting on the dipole.

(iii) What do yu mean by an "ideal electric dipole".

Answers

1. (b) **2.** (c) **3.** (b) **4.** (d) **5.** (d)
7. 10 μC/m **9.** 6×10^{-3} N
11. (iii) 6.8×10^{-28} C-m **12.** (ii) 10^{-4} N-m