

CHAPTER 1:

Electric charge is a fundamental property of matter.

ELECTRIC CHARGES AND FIELD

CLASS XII PHYSICS – CONCEPT MAP

CHAPTER AT A GLANCE

- Electric charge
- Coulomb's law
- Electric field
- Electric field lines
- Electric flux & Gauss's law
- Conductors
- Applications

1 NATURE OF ELECTRIC CHARGE

TWO TYPES OF CHARGE

Positive (+) Negative (-)

Like charges repel, unlike charges attract.



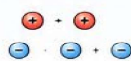
CHARGE IS CONSERVED

In an isolated system, total charge remains constant.



ADDITIVITY OF CHARGE

Net charge of a system is the algebraic sum of all individual charges.



CHARGE IS QUANTISED

Charge occurs in integral multiples of e .

$$q = ne$$

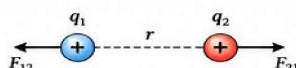
$$e = 1.6 \times 10^{-19} \text{ C}$$

INVARIANCE OF CHARGE

Charge is invariant under change of frame of reference.



2 COULOMB'S LAW



- The electrostatic force between two point charges is directly proportional to the product of charges and inversely proportional to the square of the distance between them.
- Force acts along the line joining the charges.

$$F_{12} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$$

Where,
 $\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$ (Permittivity of free space)
 $\hat{r}_{12}$ = unit vector from q_1 to q_2

KEY POINTS

- ✓ $F \propto q_1 q_2$
- ✓ $F \propto \frac{1}{r^2}$
- ✓ Force is equal and opposite on both charges.

3 ELECTRIC FIELD

ELECTRIC FIELD INTENSITY ($\vec{E}$)

Electric field at a point is the force experienced per unit positive test charge placed at that point.

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

SI unit : N/C

FIELD DUE TO A POINT CHARGE

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \hat{r}$$

(radially outward for +q and inward for -q)

FIELD DUE TO A SYSTEM OF CHARGES

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \dots$$

(Principle of superposition)

ELECTRIC FIELD LINES

- Originate from + charge and terminate at - charge (or at infinity).
- Tangent at any point gives direction of $\vec{E}$.
- Do not intersect.
- Closer lines $\Rightarrow$ stronger field.



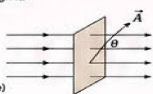
4 ELECTRIC FLUX

Electric flux through a surface is the measure of the number of electric field lines passing through it.

$$\Phi_E = \vec{E} \cdot \vec{A} = EA \cos \theta$$

Where,

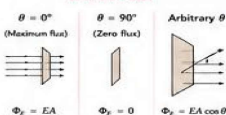
- $\vec{A}$ = Area vector (perpendicular to surface)
- θ = Angle between $\vec{E}$ and $\vec{A}$



FLUX DEPENDS ON

- ✓ Magnitude of $\vec{E}$
- ✓ Area of surface (A)
- ✓ Orientation (θ)

SPECIAL CASES



5 GAUSS'S LAW

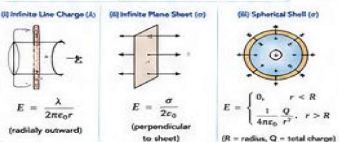
The total electric flux through any closed surface is equal to $\frac{1}{\epsilon_0}$ times the total charge enclosed.

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\epsilon_0}$$

MEANING

- Electric flux through a closed surface depends only on the charge enclosed, not on the shape or size of the surface.

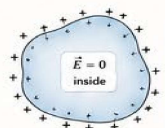
APPLICATIONS (for symmetric charge distributions)



6 CONDUCTORS

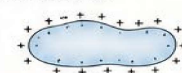
IN ELECTROSTATIC EQUILIBRIUM

- ✓ $\vec{E} = 0$ inside the conductor
- ✓ Potential is constant throughout the conductor
- ✓ Excess charge resides on the outer surface
- ✓ Surface of a conductor is an equipotential
- ✓ Electric field just outside surface is perpendicular to the surface



CHARGE RESIDES ON SURFACE

Charge resides on the surface in such a way that there is no electric field inside.



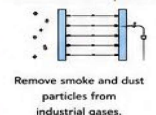
CHARGE DENSITY (σ)

Charge per unit area on the surface.
 Higher at sharp points.



7 APPLICATIONS OF ELECTRIC FIELD

Electrostatic Precipitators



Remove smoke and dust particles from industrial gases.

Photocopiers



Uses electric field to attract toner particles to paper.

Lightning



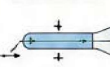
Due to large charge separation between clouds and ground.

Van de Graaff Generator



Builds up very high charge to produce strong electric fields.

Deflection in CRT



Electric field deflects electron beam in TV/monitor screens.

KEY TAKEAWAYS

- ✓ Charge is conserved and quantised.
- ✓ Coulomb's law governs the force between charges.
- ✓ Electric field represents the influence of charge.
- ✓ Field lines visualize the electric field.
- ✓ Gauss's law is a powerful tool for symmetric cases.
- ✓ In conductors, charge resides on the surface and field inside is zero.

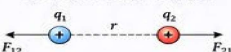
ELECTRIC CHARGES AND FIELD

CLASS XII PHYSICS – FORMULA SHEET

Formulae to remember, concepts to conquer!

1. COULOMB'S LAW

Force between two point charges.



$$F_{12} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$$

VECTOR FORM

$$\vec{F}_{12} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

KEY POINTS

- $F \propto q_1 q_2$
- $F \propto \frac{1}{r^2}$
- Force is along the line joining charges.
- Equal and opposite on both charges.

2. ELECTRIC FIELD

Electric field intensity.

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

SI unit : N/C

FIELD DUE TO A POINT CHARGE

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \hat{r}$$

FIELD DUE TO SYSTEM OF CHARGES

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \dots$$

PROPERTIES

- Radially outward for + charge
- Radially inward for - charge
- Direction of $\vec{E}$ is the direction of force on +ve test charge.

3. ELECTRIC FLUX

Electric flux through a surface.

$$\Phi_E = \vec{E} \cdot \vec{A} = EA \cos \theta$$

SPECIAL CASES

Condition	Flux (Φ_E)
$\theta = 0^\circ$ ($\vec{E}$ parallel to $\vec{A}$)	EA
$\theta = 90^\circ$ ($\vec{E}$ perpendicular to $\vec{A}$)	0
Arbitrary θ	$EA \cos \theta$

WHERE

- $\vec{A}$ = Area vector (perpendicular to surface)
- θ = Angle between $\vec{E}$ and $\vec{A}$

4. GAUSS'S LAW

Total electric flux through any closed surface.

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\epsilon_0}$$

SYMMETRIC CASES (RESULTS)

(i) Infinite Line Charge (λ)	$E = \frac{\lambda}{2\pi\epsilon_0 r}$
(ii) Infinite Plane Sheet (σ)	$E = \frac{\sigma}{2\epsilon_0}$
(iii) Spherical Shell (Radius R, Charge Q)	$E = \begin{cases} 0, & r < R \\ \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}, & r > R \end{cases}$

IMPORTANT CONSTANT

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$

(Permittivity of free space)

5. CONDUCTORS (IN ELECTROSTATIC EQUILIBRIUM)

- ✓ $\vec{E} = 0$ inside the conductor
- ✓ Potential is constant throughout
- ✓ Charge resides on the outer surface
- ✓ Surface is an equipotential
- ✓ Electric field just outside the surface is perpendicular to it

JUST OUTSIDE SURFACE

$$E = \frac{\sigma}{\epsilon_0}$$

WHERE σ = Surface charge density

DIRECTION REMINDER

- ✓ $\vec{E}$ direction = direction of force on positive test charge.



FIELD LINES SUMMARY

- Originate from + and terminate at - (or infinity).
- Closer lines $\Rightarrow$ stronger field.
- Do not intersect.

REMEMBER

- ✓ Field is a vector quantity.
- ✓ Gauss's law depends only on charge enclosed.
- ✓ Use symmetry to apply Gauss's law easily.



MULTIPLE CHOICE QUESTIONS

For Aspiring DOCTORS

Q1. Two identical charged conducting spheres A and B have their centres separated by a certain distance. Charge on each sphere is q and the force of repulsion between them is F . A third identical uncharged conducting sphere is brought in contact with sphere A first and then with B and finally removed from both. New force of repulsion between spheres A and B (Radii of A and B are negligible compared to the distance of separation so that for calculating force between them they can be considered as point charges) is best given as:

NEET 2025

- (a) $3F/5$ (b) $2F/3$ (c) $2F$ (d) $3F/8$

Q2. A thin spherical shell of radius R has charge Q spread uniformly over its surface. Which of the following graphs most appropriately represents the electric field $E(r)$ produced by the shell in the range $0 \leq r < \infty$, where r is the distance from the centre of the shell?

- (a) A graph showing E constant inside the shell.
(b) A graph showing $E = 0$ for $r < R$ and E decreasing as $1/r^2$ for $r > R$.
(c) A graph showing E increasing linearly inside.
(d) A graph showing E decreasing linearly outside.

NEET 2024

Q3. An electric dipole is placed at an angle of 30° with an electric field of intensity $2 \times 10^5 \text{ N C}^{-1}$. It experiences a torque equal to 4 N m . Calculate the magnitude of charge on the dipole, if the dipole length is 2 cm .

NEET 2023

- (a) 8 mC (b) 2 mC (c) 5 mC (d) 7 mC

Q4. A spherical conductor of radius 10 cm has a charge of $3.2 \times 10^{-7} \text{ C}$ distributed uniformly. What is the magnitude of electric field at a point 15 cm from the centre of the sphere-?

- (a) $1.28 \times 10^4 \text{ N/C}$ (b) $1.28 \times 10^5 \text{ N/C}$ (c) $1.28 \times 10^6 \text{ N/C}$ (d) $1.28 \times 10^7 \text{ N/C}$ NEET 2020

Q5. Polar molecules are the molecules:

NEET 2021

- (a) having a permanent electric dipole moment.
(b) having zero dipole moment.
(c) acquire a dipole moment only in the presence of electric field due to displacement of charges.
(d) acquire a dipole moment only when magnetic field is absent.

For Aspiring Engineers

Q6. Given below are two statements:

Statement I: If the net positive charge of a closed surface is zero, then the net electric flux through the surface is zero.

Statement II: If the electric flux through a closed surface is zero, then the net charge inside the surface must be zero.

Choose the correct answer:

JEE Main 2023

- (a) Both Statement I and Statement II are true.
(b) Both Statement I and Statement II are false.
(c) Statement I is true but Statement II is false.

(d) Statement I is false but Statement II is true.

Q7. A point charge of $2\ \mu\text{C}$ is placed at the center of a cubic Gaussian surface of side 10 cm. The net electric flux through the surface is: ($\epsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2\ \text{N}^{-1}\ \text{m}^{-2}$)

(a) $2.26 \times 10^5\ \text{N m}^2/\text{C}$

(b) $1.13 \times 10^5\ \text{N m}^2/\text{C}$

(c) $4.52 \times 10^5\ \text{N m}^2/\text{C}$

(d) $0.56 \times 10^5\ \text{N m}^2/\text{C}$

JEE Main 2022

Q8. Three charges $+Q$, q , $+Q$ are placed respectively at distance 0, $d/2$ and d from the origin on the x-axis. If the net force on $+Q$ placed at $x = 0$ is zero, then the value of q is:

JEE Main 2020

(a) $+Q/4$

(b) $-Q/2$

(c) $-Q/4$

(d) $+Q/2$

Q9. An electric dipole is formed by two charges $+q$ and $-q$ located at $(0,0,d)$ and $(0,0,-d)$ respectively. A third charge $+Q$ is kept at $(L,0,0)$ where $L \gg d$. The force on the charge $+Q$ is proportional to: **JEE Adv 2023**

(a) $1/L^2$

(b) $1/L^3$

(c) $1/L^4$

(d) L

Q10. (Multi-correct): A disk of radius R with uniform positive surface charge density σ is placed on the xy-plane with center at origin. The Electric potential V and electric field E at point $(0,0,z)$ are given. If $R \rightarrow \infty$, then **JEE Adv 2022**

(a) $E = \sigma / 2\epsilon_0$

(b) $E = \sigma / \epsilon_0$

(c) V is proportional to z

(d) V is independent of z

For Practice

Q11. Two identical point charges are placed in a laboratory vacuum at a distance r . If a technician moves them closer such that the new distance is exactly half of the original, how does the electrostatic force of interaction change?

(a) It reduces to one-fourth.

(b) It reduces to half.

(c) It increases to double.

(d) It increases to four times.

Q12. Two charged metallic spheres are suspended in air and experience a force F . If the entire setup is lowered into a tank filled with a special insulating oil having a dielectric constant $K = 4$, the new force between the spheres will be:

(a) $2F$

(b) $4F$

(c) $F/2$

(d) $F/4$

Q13. A hollow spherical shell used in a Van de Graaff generator is given a positive charge of $10\ \mu\text{C}$. A student measures the electric field at the exact geometric center of this 2-meter radius sphere. The reading on the meter will be:

(a) Zero

(b) $5 \times 10^3\ \text{N/C}$

(c) $20 \times 10^3\ \text{N/C}$

(d) $10\ \text{N/C}$

Q14. An electric dipole (like a water molecule model) with charges $\pm 2 \times 10^{-6}\ \text{C}$ separated by 2 cm is placed in a uniform atmospheric electric field of $5 \times 10^5\ \text{N/C}$. The maximum torque experienced by this molecule to align itself with the field is:

(a) $0.01\ \text{N}\cdot\text{m}$

(b) $0.02\ \text{N}\cdot\text{m}$

(c) $1 \times 10^{-4}\ \text{N}\cdot\text{m}$

(d) $2 \times 10^{-2}\ \text{N}\cdot\text{m}$

Q15. For a short electric dipole, the electric field strength at a distant point P on its longitudinal axis varies with the distance r from the center as:

(a) $E \propto r^2$

(b) $E \propto 1/r^2$

(c) $E \propto r^3$

(d) $E \propto 1/r^3$

Q16. If E_{axial} represents the electric field of a short dipole at a distance d on its axis, and $E_{\text{equatorial}}$ represents the field at the same distance on its broadside-on position, the correct relationship is:

- (a) $E_{\text{axial}} = E_{\text{equatorial}}$ (b) $E_{\text{axial}} = 2 E_{\text{equatorial}}$
 (c) $E_{\text{equatorial}} = 2 E_{\text{axial}}$ (d) $E_{\text{axial}} = 1/2 E_{\text{equatorial}}$

Q17. A tiny dust particle carries a charge q and is trapped exactly at the center of a cubical box. According to Gauss's Theorem, the electric flux passing through only one of the six faces of the cube is:

- (a) q/ϵ_0 (b) $q/6\epsilon_0$ (c) $6q/\epsilon_0$ (d) Zero

Q18. Two small identical metallic balls having charges q and $-2q$ are kept far at a separation r . They are brought in contact and then separated at distance $r/2$. Compared to the initial force F , they will now : **CBSE 2026**

- (a) attract with a force $F/2$ (b) repel with a force $F/2$
 (c) repel with a force F (d) attract with a force F

Q19. In a region of space, electric field lines are observed to be curved and their density varies from point to point. This indicates that the electric field in that region is:

- (a) Uniform in magnitude but varying in direction.
 (b) Uniform in both magnitude and direction.
 (c) Non-uniform in both magnitude and direction.
 (d) Zero throughout the region.

Q20. Which of the following is a fundamental property of electrostatic field lines that helps distinguish them from magnetic field lines?

- (a) They always form closed continuous loops.
 (b) They can cross each other in a strong field.
 (c) They start from positive charges and end on negative charges without forming closed loops.
 (d) They are always parallel to the surface of a conductor.

Q1. New force = $3F/8$. Ans: (d). Q2. Inside shell $E = 0$; outside $E \propto 1/r^2$. Ans: (b). Q3. $q = 2$ mC. Ans: (b). Q4. $E = 1.28 \times 10^5$ N/C. Ans: (b). Q5. Polar molecules have permanent dipole moment. Ans: (a). Q6. Both Gauss's Law statements are true. Ans: (a). Q7. Flux = 2.26×10^5 N•m²/C. Ans: (a). Q8. $q = -Q/4$. Ans: (c). Q9. Force $\propto 1/L^3$. Ans: (b). Q10. E constant, V varies linearly with z . Ans: (a) & (c). Q11. Force becomes $4F$. Ans: (d). Q12. New force = $F/4$. Ans: (d). Q13. Field inside shell = 0. Ans: (a). Q14. Maximum torque = 0.02 N•m. Ans: (d). Q15. $E \propto 1/r^3$. Ans: (d). Q16. $E_{\text{axial}} = 2E_{\text{equatorial}}$. Ans: (b). Q17. Flux per face = $q/6\epsilon_0$. Ans: (b). Q18. Final force = $F/2$ and repulsive. Ans: (b). Q19. Non-uniform field in both magnitude and direction. Ans: (c). Q20. Field lines start on positive and end on negative. Ans: (c).

ASSERTION AND REASON QUESTIONS

In the following questions, two statements are given –one labelled Assertion (A) and other labeled Reason (R).

Select the correct answer to these questions from the options as given below.

- (a). If both Assertion and Reason are true and Reason is the correct explanation of Assertion.
 (b). If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
 (c). If Assertion is true but Reason is false.

(d). If both Assertion and Reason are false.

Q1. Assertion: If a point charge is rotated in a circle around a central charge, the work done by the electrostatic force is zero.

Reason: The electrostatic force is a conservative force, and the displacement is always perpendicular to the force in a circular path.

Q2. Assertion: The electric flux through a closed surface depends only on the net charge enclosed, regardless of the shape or size of the surface.

Reason: Gauss's Law is based on the inverse square dependence on distance contained in Coulomb's Law.

Q3. Assertion: It is safer to be inside a car than under a tree during a lightning storm.

Reason: The metallic body of the car acts as a "Faraday Cage," ensuring the electric potential inside remains zero.

Q4. Assertion: An electric dipole placed in a non-uniform electric field always experiences a net force and a net torque.

Reason: In a non-uniform field, the forces on the two charges of the dipole are unequal in magnitude.

Q5. Assertion: The surface charge density at the sharp pointed ends of a conductor is higher than at its flatter portions.

Reason: For a conductor of any shape, the surface charge density is inversely proportional to the radius of curvature at that point.

Q6. ASSERTION: In a non-uniform electric field, a dipole may have translatory motion as well as rotational motion.

REASON: In a non-uniform electric field, a dipole experiences a force as well as torque.

Q6. ASSERTION: Gauss law is applicable only for symmetric charge distribution.

REASON: In gauss law, electric field is due to only those charges which are present inside the closed surface.

Q8. ASSERTION: A point charge q_0 is kept outside a solid metallic sphere, the electric field inside the sphere is zero.

REASON: Induced charge does not contribute to electric field or potential at a given point.

Q9. ASSERTION (A): No torque acts on an electric dipole when its dipole moment is in a direction opposite to the electric field.

REASON (R): An electric dipole is in stable equilibrium when placed in a uniform electric field with its dipole moment opposite to the field.

Q10. ASSERTION (A) : If a point charge q is placed in front of an infinite grounded conducting plane surface, the point charge will experience a force.

REASON (R): This force is due to the induced charge on the conducting surface which is at zero potential.

Answers of Assertion and Reason Questions

1.	2.	3.	4.	5.	6.	7.	8.	9.	10
a	a	c	b	a	a	d	c	c	a

Exercise Assertion and Reason Questions

Q1. Assertion (A): The total amount of charge on a body equal to 4×10^{-19} C is not possible.

Reason (R): Experimentally it is established that all free charges are integral multiples of a basic unit of charge denoted by e . Thus, charge q on a body is always given by $q = ne$.

Q2. Assertion (A): The Coulomb force between two points charges depends upon the dielectric

constant of the intervening medium.

Reason(R): Coulomb's force varies inversely with the dielectric constant of medium.

Q3. Assertion (A): An electron with velocity 'v' enters a uniform electric field, it tends to move along the direction of electric field.

Reason (R): An electron at rest in a uniform electric field never experiences a force.

Q4. Assertion (A): When a charged comb run through dry hair and taken near a paper, molecules in the paper gets polarized resulting in net force of attraction.

Reason(R): A comb run through one's dry hair attracts small bits of paper.

Q5. Assertion (A): Electrostatic force is conservative in nature.

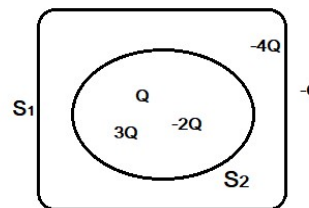
Reason (R): Electric field lines do not form closed loops

Answers of Exercise Assertion and Reason									
1.	A	2.	A	3.	D	4.	B	5.	B

VERY SHORT ANSWER TYPE QUESTIONS

Q1. A spherical balloon carries a charge that is uniformly distributed over its surface. As the balloon is blown up and increases in size, how does the electric flux come out of the surface change? Give reason.

Q2. Find ratio of electric flux through the surface S_1 and S_2 as shown in figure



Q3. Two small balls, each with a charge Q , hang from the same point by insulating strings of length L from a fixed support. Consider the setup in a region of zero gravity and in equilibrium.

- What will be the angle between the two strings?
- What will be the tension in each of the strings?

Q4. A thundercloud carries a charge of $+50\text{ C}$ at a height of 4000 m and a charge of -50 C at a height of 2000 m from the ground. An airplane crosses through the charged thundercloud at a height of 3000 m from the ground. Find the magnitude and the direction of the electric field acting on the airplane as it crosses through the charged-up thundercloud.

Q5. Two charged conducting spheres of radii a and b are connected to each other by a wire. Find the ratio of the electric fields at their surfaces.

Q6. Why can two electric field lines never cross each other?

Q7. What is the net flux through a closed surface containing an electric dipole?

Q8. How does the force between two point charges change if the dielectric constant of the medium between them increases?

Q9. Define 'quantization of charge'.

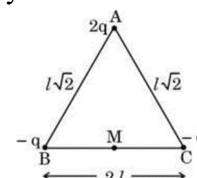
Q10. Draw the electric field lines for a system of two equal negative charges.

Very Short Answer Type Questions – Hints and Solutions

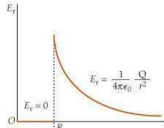
- Q1. The electric flux remains unchanged. According to Gauss's Law, flux depends only on the net enclosed charge ($\Phi = q/\epsilon_0$), not the size or radius of the surface.
- Q2. The ratio is -1:1 (or -1). Net charge in $S_1 = (Q + 3Q - 2Q - 4Q) = -2Q$. Net charge in $S_2 = (Q + 3Q - 2Q) = 2Q$.
- Q3. (a) Angle: 180° . In zero gravity, the only force is electrostatic repulsion, pushing the balls as far apart as possible. (b) Tension: $T = (1 / 4\pi\epsilon_0) \times Q^2 / (2L)^2$. The tension balances the repulsive force at a distance of $2L$.
- Q4. The field magnitude is $E = \sigma/\epsilon_0$ (if treated as plates) or by calculating E_{net} from both layers. The direction is downward (from the $+50 \text{ C}$ layer at 4000 m toward the -50 C layer at 2000 m).
- Q5. The ratio is b: a. When connected, their potentials are equal ($V_a = V_b \Rightarrow kq_a/a = kq_b/b$). Since $E = V/r$, the surface fields are inversely proportional to the radii ($E_a/E_b = b/a$).
- Q6. If they crossed, at the point of intersection, the field would have two different directions, which is physically impossible.
- Q7. Zero. According to Gauss's Law, flux depends on the net charge; a dipole's net charge ($+q - q$) is zero.
- Q8. The force decreases. $F_{\text{medium}} = F_{\text{vacuum}} / K$.
- Q9. It is the property by which all free charges are integral multiples of a basic unit of charge (e), expressed as $q = ne$.
- Q10. Suitable diagram

2 Marks Questions

- Q1. An electric dipole of length 10 cm having charges $\pm 6 \times 10^{-3}$, placed at 30° with respect to a uniform electric field, experiences a torque of $6\sqrt{3} \text{ Nm}$. Calculate the magnitude of the electric field
- Q2. Two point charges $+4Q$ and $-Q$ are fixed on the x-axis at a distance 'a' apart. Find the distance of point on the line joining them where the net electric field intensity zero?
- Q3. The figure shows three point charges kept at the vertices of triangle ABC. Find the net electric field, due to this system of charges, at the midpoint M of base BC. **CBSE 2026**
- Q4. A thin rod of length L of the uniform mass density of $\mu \text{ kg/m}$ and linear charge density $\lambda \text{ C/m}$ is initially at rest. A uniform electric field E is applied in the direction perpendicular to the length of the rod. The rod begins to move in the direction of the applied electric field. Determine the speed of the rod after it travels through 1 m of distance. Ignore all external forces except the electrostatic forces.
- Q5. 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).
- Q6. A point charge $+q$ is placed at a distance $d/2$ directly above the center of a square of side d . Find the magnitude of the electric flux through the square.
- Q7. Five identical charges $+Q$ are placed at five corners of a regular hexagon of side L . Find the magnitude of the electric field at the center of the hexagon.
- Q8. Distinguish between a polar and a non-polar molecule with one example each.
- Q9. An electrostatic field line is a continuous curve. That is, a field line cannot have sudden breaks. Why not?
- Q10. Why must the electric field be normal to the surface of every point of a charged conductor?



2 Marks Questions -Hints and Solutions

- Q1** Formula: $\tau = pE \sin\theta$. $p = q \times 2l = (6 \times 10^{-3} \text{ C}) \times (0.1 \text{ m}) = 6 \times 10^{-4} \text{ C}\cdot\text{m}$. $E = \tau / (p \sin 30^\circ) = 6\sqrt{3} / (6 \times 10^{-4} \times 0.5) = 2\sqrt{3} \times 10^4 \text{ V/m}$.
- Q2** For two opposite charges $+4Q$ and $-Q$, the null point (where $E_{\text{net}} = 0$) lies outside the charges, closer to the smaller magnitude charge ($-Q$). $k(4Q)/(a+x)^2 = kQ/x^2$. $2/(a+x) = 1/x \Rightarrow 2x = a+x \Rightarrow x = a$. The point is at distance a to the right of $-Q$.
- Q3** The fields from charges at B and C (both $-q$) at the midpoint M are equal and opposite, so they cancel out. Result: The net field at M is due only to the charge $+2q$ at vertex A. $E_{\text{net}} = k(2q)/r^2$, where r is the altitude of the triangle AM.
- Q4** Force: $F = qE = (\lambda L)E$. Acceleration: $a = F/m = (\lambda LE)/(\mu L) = \lambda E/\mu$. Equation of Motion: $v^2 = u^2 + 2as \Rightarrow v = \sqrt{(2 \times (\lambda E/\mu) \times 1)} = \sqrt{(2\lambda E/\mu)} \text{ m/s}$.
- Q5** Inside ($r < R$): $E = 0$. Outside ($r > R$): $E \propto 1/r^2$. Graph: The graph shows a jump from zero to maximum at the surface ($r = R$) and then a hyperbolic decay.
- 
- Q6** Imagine the square as one face of a cube with side d . By symmetry and Gauss's Law, total flux $\Phi = q/\epsilon_0$, so flux through one face is $q/6\epsilon_0$
- Q7** A full hexagon with six charges would have zero field at the center. With one missing, the field is equal and opposite to the field that the sixth charge would have produced: $E = kQ/L^2$. for a regular hexagon, the radius of the outer circle (the circumradius) is exactly equal to the length of its side.
- Q8** Polar molecules have a permanent dipole moment (e.g., H_2O), while non-polar molecules acquire one only in an external field (e.g., O_2)
- Q9** Field lines represent the path of a test charge; since force acts continuously in a field, the acceleration and path must be continuous. A break would imply the field suddenly became zero and then reappeared.
- Q10** If it weren't normal, there would be a tangential component of the field which would cause surface charges to move (creating a current), contradicting the state of electrostatic equilibrium.

3 MARKS QUESTIONS

- Q1.** Two point charges $q_1 = 2.5 \times 10^{-7} \text{ C}$ and $q_2 = -2.5 \times 10^{-7} \text{ C}$ are located at points $(0, 0, -15 \text{ cm})$ and $(0, 0, 15 \text{ cm})$ respectively. Find : CBSE 2026
 (a) The electric dipole moment of the system, and
 (b) The magnitude and direction of electric field at the origin $(0, 0, 0)$.
- Q2.** Two infinitely long straight wires having linear charge densities $-\lambda$ and 3λ are held vertically parallel to each other, distance r apart in free space. Find the nature and magnitude of the force/length exerted by one wire on the other. CBSE 2026
- Q3.** A small hollow conducting sphere of radius r_1 is given a charge Q . It is surrounded by a concentric conducting spherical shell of inner radius r_2 and outer radius r_3 , having charge $-3q$. If a point charge $2q$ were kept at the centre, find: CBSE 2026
 (I) the electric flux through a concentric spherical Gaussian surface of radius x for (1) $x < r_1$, and (2) $r_1 < x < r_2$.
 (II) Electric field at a point distant x from the centre for (1) $x > r_3$, and (2) $r_1 < x < r_2$.
 (III) Surface charge density on the inner surface of (1) sphere, and (2) shell.
- Q4.** (a) State Coulomb's Law and express it in vector form.

- (b) Consider three charges q_1, q_2, q_3 at the vertices of an equilateral triangle of side L . Derive the expression for the net electrostatic force acting on a charge Q placed at the centroid.
- Q5. A point charge q is placed at: (i) the center of a cube, (ii) one corner of the cube, and (iii) the center of one face. Calculate the electric flux through the entire cube and through each face for each case using Gauss's Law and symmetry.
- Q6. A uniform electric field $\vec{E} = E_0 \hat{i}$ exists in a region. Calculate the flux through a cylinder of radius R and length L whose axis is parallel to the field. Show that the net flux is zero.
- Q7. Derive the expression for the work done in rotating an electric dipole from an angle θ_1 to θ_2 in a uniform electric field E
- Q8. Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs and magnitude $17.7 \times 10^{-12} \text{ C/m}^2$. Calculate the electric field (a) in the outer region of the first plate, and (b) between the plates.
- Q9. Using Gauss's Law, show that the electric field due to a uniformly charged infinite plane sheet is independent of the distance from it.
- Q10. Two identical small pith balls, each of mass m and charge q , are suspended from a common point by two insulating strings of length l . If the system is in equilibrium and the strings make an angle θ with the vertical, derive the expression for the charge q in terms of m, l, g , and θ .

3 Marks Questions -Hints and Solutions

- Q1** a) Dipole Moment: $p = q \times 2a$. Since distance is from -15 cm to $+15 \text{ cm}$, $2a = 30 \text{ cm} = 0.3 \text{ m}$. $p = (2.5 \times 10^{-7}) \times 0.3 = 7.5 \times 10^{-8} \text{ C}\cdot\text{m}$. The direction is from negative to positive (along the $-z$ axis). (b) Field at Origin: Both charges are equidistant from the origin and have opposite signs. Their fields at the origin point in the same direction. $E_{\text{net}} = 2 \times (kq/a^2)$.
- Q2** Formula: $F = qE$ where $q = \lambda_1 l$, Use the field of one wire acting on the other:
 $F = \lambda_1 l E_2 \Rightarrow F/l = \lambda_1 (2k\lambda_2/r)$. Magnitude $= (1 / 2\pi\epsilon_0) \times (3\lambda^2/r)$. Since the charges have opposite signs ($-\lambda$ and 3λ), the force is attractive.
- Q3** (I) Flux: For $x < r_1$: $\Phi = q_{\text{enclosed}}/\epsilon_0 = 2q/\epsilon_0$. For $r_1 < x < r_2$: $\Phi = (2q + Q)/\epsilon_0$.
 (III) Surface Density (σ): The inner surface of shell (r_2) will have an induced charge of $-(2q + Q)$ to cancel the internal field. $\sigma = \text{Charge} / \text{Area} = -(2q + Q) / 4\pi r_2^2$.
- Q4** Vector form: $\vec{F}_{21} = (1 / 4\pi\epsilon_0) \times (q_1 q_2 / r^2) \hat{r}_{12}$. Distance from each vertex to centroid: $R = L/\sqrt{3}$. Due to symmetry, the net force at centroid is zero.
- Q5** Charge at center: Total flux $= q/\epsilon_0$. Flux through each face $= q/6\epsilon_0$.
 Charge at corner: Flux through one cube $= q/8\epsilon_0$. Flux through each of 3 outer faces $= q/24\epsilon_0$. Charge at face center: Flux through one cube $= q/2\epsilon_0$.
- Q6** Left End Cap (Φ_1): The area vector $\vec{A}$ points left ($-x$), and vector $\vec{E}$ points right ($+x$). The angle is 180° . $\Rightarrow (\Phi_1) = E_0 A \cos(180^\circ) = -E_0(\pi R^2)$. Right End Cap (Φ_2): Both the area vector $\vec{A}$ and $\vec{E}$ point right ($+x$). The angle is 0° . $\Rightarrow (\Phi_2) = E_0 A \cos(0^\circ) = +E_0(\pi R^2)$. Curved Surface (Φ_3): The area vector is always perpendicular to the cylinder's axis (and the field). The angle is 90° . $(\Phi_3) = E_0 A \cos(90^\circ) = 0$. The total flux is the sum of these parts: $\Phi_{\text{net}} = \Phi_1 + \Phi_2 + \Phi_3$

$\Phi_{net} = -E_0(\pi R^2) + +E_0(\pi R^2) + 0 \Rightarrow \Phi_{net} = 0$. Conclusion: The net flux is zero because the number of field lines entering the cylinder equals the number of field lines leaving it, meaning no net charge is enclosed $q_{inside}=0$

Q7 $dW = \tau d\theta = pE \sin\theta d\theta$. Integrating from θ_1 to θ_2 : $W = pE(\cos\theta_1 - \cos\theta_2)$.

Q8 Outer region: $E = 0$. Between plates: $E = \sigma/\epsilon_0 = 2 \text{ N/C}$.

Q9 Using a cylindrical Gaussian surface: $2EA = \sigma A / \epsilon_0 \Rightarrow E = \sigma/2\epsilon_0$. The field is independent of distance.

Q10 Force Analysis: At equilibrium: Balancing Components:

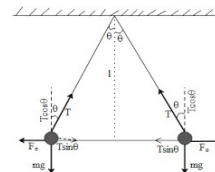
Vertical: $T \cos \theta = mg$. Horizontal: $T \sin \theta = F_e$. Combining

Equations: Dividing the two equations gives: $\tan \theta = F_e / mg$.

Electrostatic Force: $F_e = (1 / 4\pi\epsilon_0) \times (q^2 / r^2)$, where the

separation between the balls is: $r = 2l \sin \theta$. Result: Substituting

F_e and r into the tangent equation and solving for q : $q = \sqrt{(16\pi\epsilon_0 l^2 mg \sin^2\theta \tan \theta)}$



CASE STUDY BASED QUESTION

Q1. When an electric dipole of charges $\pm q$ and dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$ making an angle θ with the $\vec{E}$, then two charges experience equal and opposite forces $+q \vec{E}$ and $-q \vec{E}$. These equal and opposite forces cancel each other. As the two forces are not collinear so a torque acts on the dipole. Since the net force acting on the dipole is zero, no work is done in moving the electric dipole in a uniform electric field, but some work will be done in rotating the dipole against the torque acting on it.

i. Two charges $+q$ and $-q$ are located at points $(a, 0)$ and $(3a, 0)$ on x -axis. The dipole moment of the system has magnitude

(A) $2qa$ and is along $+x$ -axis.

(B) $2qa$ and is along $-x$ -axis.

(C) qa and is along $+x$ -axis.

(D) qa and is along $-x$ -axis.

ii. The magnitude of electric field at a certain distance from a dipole on its axis is E_1 and at the same distance on the equatorial plane of the dipole is E_2 . (E_1/E_2) is

(A) $1/2$

(B) 2

(C) $1/4$

(D) 4

iii. The dimensional formula of dipole moment is –

(A) $[L^2 T^2 A^{-2}]$

(B) $[M^2 L^2 T^1 A^2]$

(C) $[L^1 T^1 A^2]$

(D) $[L^1 T^1 A^1]$

iv. An electric dipole of dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$. The torque exerted by the field on the dipole at that instant is –

(A) Parallel to both the $\vec{E}$ and $\vec{p}$.

(B) Perpendicular to both $\vec{E}$ and $\vec{p}$.

(C) Parallel to $\vec{E}$ and perpendicular to $\vec{p}$.

(D) Perpendicular to $\vec{E}$ and parallel to $\vec{p}$.

Q2. The Millikan's Concept

In 1909, American physicist Robert A. Millikan performed the famous oil drop experiment to determine the nature of electric charge. In the experiment, tiny oil droplets were sprayed between two charged metal plates. By carefully adjusting the electric field, Millikan observed that the charges on the oil drops were always whole-number multiples of a smallest value called the elementary charge.

This proved that electric charge is not continuous but exists in discrete packets. This property is known as **quantization of charge**.

The elementary charge is: $e = 1.6 \times 10^{-19} \text{ C}$

Any charge can therefore be written as: $q = ne$; where n is an integer (positive or negative).

Millikan's experiment also supported the law of conservation of charge, according to which the total charge of an isolated system always remains constant.

i. Which of the following charges is NOT possible?

- A) $1.6 \times 10^{-20} C$ B) $3.2 \times 10^{-16} C$ C) $2.4 \times 10^{-18} C$ D) $4.8 \times 10^{-17} C$

ii. If an object has a net charge of +1 C, it has:

- A) Gained 6.25×10^{18} electrons B) Lost 6.25×10^{18} electrons
C) Gained 1 electron D) Lost 1 electron

iii. The total charge of an isolated system remains:

- A) Zero B) Variable C) Conserved D) Quantized only during friction

iv. Quantization of charge can be ignored at the macroscopic level because:

- A) Charge becomes continuous B) Elementary charge e is extremely small
C) Newton's laws take over D) Gravity cancels the charge

Q3. Dielectric Breakdown and Sharp Points

The electric field near a conductor is given by $E = \sigma/\epsilon_0$. For a given potential, the surface charge density σ is much higher at sharp points (small radius of curvature) than on flat surfaces. This can lead to "Corona Discharge."

i. Why do lightning conductors have sharp pointed ends?

- A) To attract lightning more slowly
B) To create a high electric field that ionizes air and provides a path for discharge
C) To increase the resistance of the building
D) To look aesthetically pleasing

ii. The maximum electric field air can withstand before becoming a conductor is called:

- A) Dielectric Constant B) Dielectric Strength C) Permittivity D) Polarization

iii. At a sharp point, the radius of curvature $r \rightarrow 0$. This implies the field E becomes:

- A) Zero B) Negligible C) Very high D) Constant

iv. A spark is seen when a person touches a doorknob after walking on a carpet. This is an example of:

- A) Magnetic induction B) Electrostatic discharge due to potential difference
C) Current electricity D) Thermionic emission

Case Study – Answer key											
1. i	1. ii	1. iii	1. iv	2. i	2. ii	2. iii	2. iv	3. i	3. ii	3. iii	3. iv
b	b	d	b	a	b	c	b	b	b	c	b

5 MARKS QUESTIONS

Q1. (a) Define electric dipole moment. Is it a scalar or a vector?

(b) Derive an expression for the torque acting on an electric dipole placed in a uniform electric field.

(c) At what angle is the torque maximum and minimum? Draw the diagram of orientation of dipole in electric field.

Q2. (a) Derive an expression for the electric field intensity at any point on the axial line of an electric dipole.

(b) How does the field vary with distance r for a short dipole ($r \gg a$)?

(c) Derive the expression for the electric field intensity at a point on the equatorial plane of an electric dipole.

(d) Show that for a short dipole, the field at an axial point is twice the field at an equatorial point at the same distance.

Q3. (a) State Gauss's Law in electrostatics.

(b) Using this law, derive an expression for the electric field due to an infinitely long straight

uniformly charged wire.

(c) Plot a graph showing the variation of E with distance r.

Q4. (a) Define electric flux. Write its SI unit.

(b) Use Gauss's Law to find the electric field intensity due to a uniformly charged infinite plane sheet.

(c) Does this field depend on the distance from the sheet? Explain.

Q5. Using Gauss's Law, derive expressions for the electric field due to a uniformly charged thin spherical shell at a point:

(i) Outside the shell ($r > R$) (ii) On the surface of the shell ($r = R$) (iii) Inside the shell ($r < R$) Include the E vs r graph.

5 Marks Question Derivation Hints	
Q1	Dipole moment ($\vec{p}$) is a vector pointing from $-q$ to $+q$ with magnitude: $p = q \times 2a$. Diagram: Draw two parallel lines for the uniform field $\vec{E}$, an inclined dipole at angle θ , and show forces $+qE$ and $-qE$ acting in opposite directions. Derivation Hint: 1. Explain that net force is zero: $+qE - qE = 0$. 2. Calculate Torque (τ) = Force $\times$ perpendicular distance between forces. 3. $\tau = (qE) \times (2a \sin\theta) = pE \sin\theta$. Max. and Min. Torque: $\tau = 0$ at 0° and 180° (equilibrium). $\Rightarrow \tau = pE$ at 90° .
Q2	Axial Line Hint ($E \propto 1/r^3$): Find the fields due to $+q$ and $-q$ at point P on the axis. Subtract the smaller field from the larger one. Result: $E_{\text{axial}} = 2kp/r^3$ for a short dipole. Equatorial Line Hint: Use vector resolution. The vertical components of the fields ($E \sin\theta$) cancel out, while the horizontal components ($E \cos\theta$) add up. Result: $E_{\text{equatorial}} = kp/r^3$. Diagram: For the equatorial line, show the vector addition forming a resultant parallel but opposite to $\vec{p}$.
Q3	Statement: Total flux through a closed surface is $1/\epsilon_0$ times the net charge enclosed. Diagram: Draw an infinitely long wire with linear charge density λ . Draw a cylindrical Gaussian surface around it of radius r and length l . Flux only passes through the curved surface because flux through flat ends is zero ($\vec{E} \perp d\vec{A}$). Total Flux: $\Phi = E \times (2\pi rl)$. Enclosed charge: $q = \lambda l$. Apply Gauss's Law: $E(2\pi rl) = \lambda l / \epsilon_0 \Rightarrow E = \lambda / (2\pi\epsilon_0 r)$.
Q4.	Definition: Electric Flux (Φ) is the total number of electric field lines passing through a surface. SI Unit: $\text{N} \cdot \text{m}^2/\text{C}$. Gaussian Surface: A cylinder (pillbox) piercing through the sheet, with cross-sectional area A at both ends. The electric field $\vec{E}$ is perpendicular to the sheet. Flux only passes through the two flat ends of the cylinder: $\Phi = 2EA$. 3. Enclosed charge: $q = \sigma A$, where σ is the surface charge density. According to Gauss's Law: $2EA = \sigma A / \epsilon_0 \Rightarrow E = \sigma / 2\epsilon_0$. Distance Factor: The electric field is independent of distance r from the sheet because the field is uniform.
Q5.	Case 1: Outside ($r > R$): Treat the entire charge as concentrated at the center. $E = (1 / 4\pi\epsilon_0) \times (q / r^2)$. Case 2: Inside ($r < R$): A Gaussian surface inside the shell encloses zero charge. Therefore, by Gauss's Law: $E = 0$. Graph: Include the graph showing $E = 0$ until $r = R$ and then a $1/r^2$ decrease.

