

Chapter 1 · Electric Charges and Fields

CBSE Class 12 Physics (042) · Unit I Electrostatics · Unit I + II = 16 marks · Ultimate Revision Sheet

60-SECOND RECALL

Coulomb's law	$F = kq_1q_2/r^2$, $k = 9 \times 10^9 \text{ N m}^2\text{C}^{-2}$ · in a medium divide by K
Field of a point charge	$E = kq/r^2 \rightarrow$ falls as $1/r^2$
Dipole moment	$p = q \times 2a$, direction $-q \rightarrow +q$
Dipole field	Axial $2kp/r^3$ · Equatorial $kp/r^3 \rightarrow$ axial = 2 × equatorial , both $1/r^3$
Torque on dipole	$\tau = pE \sin\theta$ ($\tau = p \times E$)
Gauss's theorem	$\phi = q_{\text{enclosed}} / \epsilon_0$
The three Gauss results	Wire $\lambda/2\pi\epsilon_0 r$ · Sheet $\sigma/2\epsilon_0$ · Shell kq/r^2 outside, ZERO inside

1. Charge — the three properties

WRITE THIS VERBATIM **Quantisation:** charge exists only as an integral multiple of the elementary charge, $q = ne$, where $e = 1.6 \times 10^{-19} \text{ C}$.

Conservation: the total charge of an isolated system remains constant — charge is neither created nor destroyed, only transferred.

Additivity: total charge is the **algebraic** sum of individual charges (signs included).

2. Coulomb's Law

FORMULAS

$$F = (1/4\pi\epsilon_0) \cdot q_1q_2/r^2 \quad k = 1/4\pi\epsilon_0 = 9 \times 10^9 \text{ N m}^2\text{C}^{-2}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2} \text{ (permittivity of free space)}$$

$$\text{In a medium: } F_{\text{medium}} = F_{\text{vacuum}} / K \quad K = \text{dielectric constant (relative permittivity)}$$

Vector form: $F_{21} = k q_1q_2 \hat{r}_{21} / r^2$ — the force is along the line joining the charges, and $F_{12} = -F_{21}$ (Newton's third law).

SUPERPOSITION PRINCIPLE The force on any one charge due to several charges is the **vector sum** of the forces due to each one taken separately. **The presence of other charges does not change the pairwise force.**

TRAP Coulomb's law as written applies to **point charges at rest**. For an extended body, **r** is the **distance between centres** only when the bodies are uniformly charged spheres.

A dielectric **always weakens** the force, because $K > 1$ for every medium ($K = 1$ for vacuum, ≈ 1.00059 for air).

3. Electric Field

FORMULAS

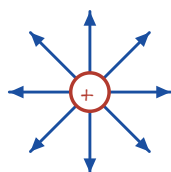
$$\mathbf{E} = \mathbf{F} / q_0 \quad \text{units } \text{N C}^{-1} \text{ or } \text{V m}^{-1}$$

$$\mathbf{E} = kq/r^2 \quad (\text{point charge}) \quad \cdot \quad \mathbf{F} = q\mathbf{E} \quad \text{on a charge placed in the field}$$

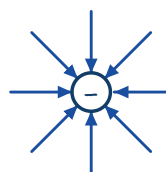
ELECTRIC FIELD LINES — the properties asked

1. Start at **positive**, end at **negative**; for a single charge they end at infinity.
2. They are **continuous curves without breaks** and never form closed loops (electrostatic field is conservative).
3. **Two field lines never cross** — if they did, the field would have two directions at one point, which is impossible.
4. They are **closer together where the field is stronger**.
5. They are always **perpendicular to the surface of a conductor**.

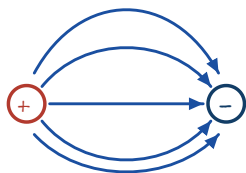
(a) single +q — lines go OUT



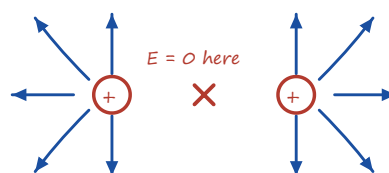
(b) single -q — lines come IN



(c) dipole — + to -, none cross



(d) two +q — note the neutral point



Lines start on +, end on -, never cross, never form closed loops, and meet a conductor surface at 90°. Crowding means a stronger field.

4. Electric Dipole

DEFINITION

Two equal and opposite charges separated by a small distance $2a$. Dipole moment $p = q \times 2a$, a vector directed from $-q$ to $+q$, unit C m .

FIELD OF A DIPOLE — the two standard results

Axial (end-on): $\mathbf{E} = 2kp / r^3$ direction: same as p

Equatorial (broadside-on): $\mathbf{E} = kp / r^3$ direction: opposite to p

Exact expressions (before the $r \gg a$ approximation):

$$\text{Axial } E = 2kpr/(r^2 - a^2)^2 \quad \cdot \quad \text{Equatorial } E = kp/(r^2 + a^2)^{3/2}$$

TORQUE IN A UNIFORM FIELD

$$\tau = pE \sin\theta \quad \tau = p \times E$$

Net force is ZERO in a uniform field (the two forces are equal and opposite), so the dipole only rotates, it does not translate.

$\theta = 0 \rightarrow \tau = 0$, stable equilibrium · $\theta = 90^\circ \rightarrow \tau$ is maximum = pE · $\theta = 180^\circ \rightarrow \tau = 0$, unstable equilibrium.

THE TRAP THAT COSTS MOST MARKS Axial field is TWICE the equatorial field at the same distance, and the two point in opposite directions.

A dipole field falls as $1/r^3$, faster than a point charge's $1/r^2$, because the two opposite charges increasingly cancel as you move away.

In a non-uniform field a dipole experiences both a torque and a net force.

5. Electric Flux and Gauss's Theorem

WRITE THIS VERBATIM Electric flux is the total number of electric field lines crossing a surface normally. $\phi = E \cdot A = EA \cos\theta$, a scalar, unit $N m^2 C^{-1}$.

Gauss's theorem: the total electric flux through a closed surface equals $1/\epsilon_0$ times the net charge enclosed by it.

STATEMENT

$$\phi = \oint \mathbf{E} \cdot d\mathbf{A} = q_{\text{enclosed}} / \epsilon_0$$

Charges outside the closed surface contribute nothing to the net flux — whatever enters also leaves.

THE THREE APPLICATIONS THE SYLLABUS NAMES

Charge distribution	Field	Key point
Infinitely long straight wire linear density λ	$E = \lambda / 2\pi\epsilon_0 r$	Falls as $1/r$. Gaussian surface: a cylinder ; the flat ends contribute no flux.
Uniformly charged infinite plane sheet surface density σ	$E = \sigma / 2\epsilon_0$	Independent of distance — the field is uniform. Gaussian surface: a cylinder through the sheet.
Uniformly charged thin spherical shell	Outside: $E = kq/r^2$ Surface: $E = kq/R^2$ Inside: $E = 0$	From outside the shell behaves as if all charge sat at the centre .

TRAP $E = 0$ inside a shell but the **POTENTIAL** is not zero — it is constant and equal to the surface value kq/R . Zero field means no change in potential, not zero potential.

For the sheet, E does not depend on r at all. Students routinely write $\sigma/2\epsilon_0 r$.

Flux depends only on enclosed charge, never on the shape or size of the Gaussian surface.

6. Question Triggers what the wording is really asking

If the question says...

Use

"force between two charges"	Coulomb's law; divide by K if a medium is named
"net force due to several charges"	Superposition — resolve into components, then add as vectors
"derive the field on the axis of a dipole"	Axial result $2kp/r^3$
"dipole placed in a uniform field"	Net force zero, torque $pE \sin\theta$
"flux through a closed surface / a cube"	Gauss. For a charge at the centre of a cube, each face gets $q/6\epsilon_0$
"field due to a long wire / sheet / shell"	Quote Gauss, then the standard result
"field inside a conductor or a shell"	ZERO

WORKED EXAMPLE — the standard flux question A charge of $8.85 \times 10^{-6} \text{ C}$ is placed at the centre of a cube. Find the flux through **one face**.

$$\text{Total flux} = q/\epsilon_0 = (8.85 \times 10^{-6}) / (8.85 \times 10^{-12}) = 1 \times 10^6 \text{ N m}^2 \text{ C}^{-1}$$

By symmetry the six faces share it equally:

$$\text{Flux through one face} = 1 \times 10^6 / 6 = 1.67 \times 10^5 \text{ N m}^2 \text{ C}^{-1}$$

MOST-ASKED BOARD QUESTIONS

1. [3M] Using Gauss's theorem, derive the field due to a uniformly charged **infinite plane sheet**.
2. [3M] Derive the electric field on the **axial line** of an electric dipole.
3. [3M] Derive the field due to an **infinitely long straight charged wire** using Gauss's theorem.
4. [2M] Show that the field **inside a uniformly charged spherical shell is zero**.
5. [2M] Derive the **torque** acting on a dipole in a uniform electric field.
6. [1M] Why can two electric field lines **never intersect**?
7. [1M] Name the physical quantity whose SI unit is N C^{-1} . → **Electric field intensity**

THE HABIT THAT SCORES — In every derivation, state the **Gaussian surface you chose and why** before writing a single equation. Examiners give a separate mark for the choice of surface, and it is the easiest mark in the chapter to lose by rushing.