Electric Charges and Fields

Class 12 · Physics · Quick Revision · **chapternotes.in**

NEET: 1-2 Qs (~4-8 marks) | Boards: 8-10 marks

Scan: practise free

How charges interact (Coulomb), the field they set up, the dipole, and Gauss's law - the shortcut that cracks symmetric distributions.

1. Charge & Coulomb's Law

Charge is quantized and conserved; force between two charges follows an inverse-square law.

$q = ne,\ e = 1.6\times10^{-19}$ C
quantization (n = integer)

$F = kq_1q_2/r^2$
Coulomb's law

$k = 1/(4\pi\varepsilon_0) = 9\times10^9$
$\varepsilon_0 = 8.85\times10^{-12}\ C^2N^{-1}m^{-2}$

$F_{medium} = F/K$
K = dielectric constant

$q' = (q_1+q_2)/2$
identical spheres touched

- Charge is conserved and additive (add with signs); like charges repel, unlike attract.

MUST KNOW Force is along the line joining the charges and obeys Newton's third law - both feel equal & opposite force, even if one charge is huge.

MUST KNOW For many charges use superposition: add force VECTORS, not magnitudes - resolve into components first.

2. Electric Field & Field Lines

The field is force per unit positive test charge; it belongs to space, not the test charge.

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

$E = kq/r^2$
point charge

$F = qE$
force on charge in a field

MUST KNOW E points away from +q and toward -q; force is along E for +q but OPPOSITE to E for -q.

- Field lines start on +, end on -, never cross, and are denser where E is stronger; tangent gives direction.

MUST KNOW Between two LIKE charges the field cancels at the midpoint; between UNLIKE charges it reinforces (adds).

3. Electric Dipole & Torque

Two equal, opposite charges a small distance apart; aligns with a field like a compass needle.

$p = q\cdot 2a$ (dipole moment)
points from -q to +q, units C m

$E_{axial} = 2kp/r^3$
end-on ($r \gg a$)

$E_{equa} = kp/r^3$
broadside ($r \gg a$)

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

$U = -pE\cos\theta$
potential energy

MUST KNOW Axial field is TWICE the equatorial field at the same distance; both fall as $1/r^3$ (faster than a point charge's $1/r^2$).

MUST KNOW In a UNIFORM field net force = 0, only torque acts; max torque (pE) at θ=90°, zero at θ=0° (stable) and 180° (unstable).

- U is minimum (-pE) at θ=0°, so the dipole turns to align with the field.

4. Electric Flux & Gauss's Law

Flux measures field lines through a surface; net flux out of a closed surface depends only on charge inside.

$\Phi = E\cdot A = EA\cos\theta$
θ from the NORMAL; units $N\ m^2\ C^{-1}$

$\Phi = q_{enc}/\varepsilon_0$ (Gauss)
closed surface

MUST KNOW Flux depends ONLY on enclosed charge - reshaping or enlarging the Gaussian surface, or moving the charge inside, changes nothing.

- Outside charges add zero net flux (lines enter one side, leave the other).

MUST KNOW Charge at the centre of a cube: each face gets $\Phi = q/(6\varepsilon_0)$. At a corner: $\Phi = q/(8\varepsilon_0)$.

5. Applications of Gauss - Line, Sheet, Shell

Pick a surface where E is constant, pull E out of the integral, and read off the field.

$E = \lambda/(2\pi\varepsilon_0 r)$ (line)
infinite line, $E \propto 1/r$

$E = \sigma/(2\varepsilon_0)$ (sheet)
uniform, independent of distance

$E = kQ/r^2$ (shell, outside)
acts like a point charge

$E = 0$ (shell, inside)
no enclosed charge

MUST KNOW Line field dies as 1/r, sheet field is constant, shell field is $1/r^2$ outside and ZERO inside.

- Outside a uniformly charged shell, all the charge behaves as if concentrated at the centre.

6. Conductors in a Field

Free charges rearrange until the interior field vanishes.

$E = 0$ (inside conductor)
electrostatic equilibrium

$E = \sigma/\varepsilon_0$ (conductor surface)
just outside, ⊥ to surface

MUST KNOW Field inside a conductor is zero and net charge resides only on the surface; the field just outside is perpendicular to the surface.

MUST KNOW Conductor-surface field σ/ε_0 is TWICE the isolated-sheet field $\sigma/(2\varepsilon_0)$ - watch the factor of 2.

Field of Symmetric Distributions

Source	Field E	Dependence
Point charge	kq/r^2	$1/r^2$
Infinite line (λ)	$\lambda/(2\pi\varepsilon_0 r)$	$1/r$
Infinite sheet (σ)	$\sigma/(2\varepsilon_0)$	constant
Conductor surface (σ)	σ/ε_0	constant
Shell outside (Q)	kQ/r^2	$1/r^2$
Shell inside	0	-

Conductor vs Insulator

	Conductor	Insulator (dielectric)
Free charges	Many	Almost none
Field inside	Zero (equilibrium)	Can be non-zero
Charge location	On surface only	Spread throughout
In a field	Charges redistribute	Molecules polarize

Mnemonic - Dipole axial field = 2 × equatorial field at the same distance
Axial is Always twice ($2kp/r^3$); equatorial is just kp/r^3.

Common traps

- Gauss's law is always TRUE, but only USEFUL for finding E when there is symmetry (sphere, line, sheet) so E is constant on the surface.
- Field INSIDE a conductor is zero, and inside a charged shell it is zero too - not kQ/R^2.
- Sheet gives $\sigma/(2\varepsilon_0)$; conductor surface gives σ/ε_0. Don't mix the factor of 2.
- Measure θ in flux from the NORMAL to the surface, not from the surface itself; grazing field (θ=90°) gives zero flux.
- A dipole sealed in any surface encloses zero net charge, so total flux = 0 - even though E on the surface is not zero.

Most asked in NEET » Quantization & identical-sphere sharing $(q_1+q_2)/2$ | Coulomb force vs distance / dielectric (F/K) | Net force in symmetric arrangements (triangle, square) | Dipole torque $\tau = pE\sin\theta$ & work to rotate | Flux through a cube face: $q/6\varepsilon_0$ (centre), $q/8\varepsilon_0$ (corner) | Shell field: kQ/r^2 outside, 0 inside | Sheet vs conductor field (factor of 2)