Electrostatic Potential and Capacitance

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

NEET: 2-3 Qs (~8-12 marks) | Boards: 8-10 marks

Scan: practise free

Energy view of electrostatics: potential is a scalar that adds easily, the field is its slope, and capacitors store charge and energy in that field.

1. Electric Potential & Potential Energy

Work per unit charge to bring it from infinity; a scalar, so it just adds.

$V = W/q$
SI: volt (1 V = 1 J/C); scalar

$U = qV$
energy of a charge at potential V

$U = kq_1q_2/r$
pair of charges; $k = 1/(4\pi\varepsilon_0)$

$W = q(V_A - V_B)$
work to move B → A

$1\ eV = 1.6 \times 10^{-19}\ J$
electron across 1 V

MUST KNOW Potential is a SCALAR - add contributions with signs, never as vectors.

MUST KNOW A +q charge moves on its own from high to low potential; −q does the opposite.

- Pair energy U and single-charge V go as 1/r, but the force goes as $1/r^2$.

2. Potential Due to Charges & Dipole

Point charge falls as 1/r; dipole falls faster as $1/r^2$.

$V = kq/r$
point charge; +ve for +q, −ve for −q

$V = \Sigma\, kq_i/r_i$
superposition (algebraic sum)

$V = kp\cos\theta/r^2$
dipole, $r \gg a$; θ from axis

MUST KNOW Potential ∝ 1/r while field ∝ $1/r^2$ - don't mix the two.

MUST KNOW Dipole: V is max on the axis (θ = 0) and ZERO on the equatorial line (θ = 90°).

- Inside a charged shell V is NOT zero - it stays constant at the surface value kQ/R.

3. Equipotentials & E–V Relation

Field is the negative slope of potential; always perpendicular to equipotentials.

$E = -dV/dr$
field points high → low V

$E = V/d$
uniform field between plates

$W = q\Delta V = 0$
along an equipotential

MUST KNOW E is ALWAYS perpendicular to an equipotential; no work is done moving along one.

MUST KNOW Closely spaced equipotentials mean a STRONG field (not weak).

- Equipotentials never intersect; a conductor's whole body and surface is one equipotential.

4. Capacitance & Parallel-Plate Capacitor

Charge stored per volt; depends only on geometry and medium.

$C = Q/V$
SI: farad (1 F = 1 C/V)

$C = \varepsilon_0 A/d$
parallel plates, vacuum

$C = 4\pi\varepsilon_0 R$
isolated sphere of radius R

MUST KNOW C depends ONLY on geometry and medium - never on Q or V (they move together).

MUST KNOW Battery connected ⇒ V fixed; battery disconnected ⇒ Q fixed. Decide this FIRST.

- Pull plates of an isolated capacitor apart: Q fixed, C falls, so V rises.

5. Dielectrics & Energy Stored

A dielectric ($K > 1$) raises C; energy lives in the field.

$C = K\varepsilon_0 A/d$
dielectric of constant K

$E_{in} = E_0/K$
field reduced by polarisation

$U = \frac{1}{2}QV = \frac{1}{2}CV^2 = Q^2/2C$
use the form with the fixed quantity

$u = \frac{1}{2}\varepsilon_0 E^2$
energy density in the field

MUST KNOW Battery disconnected (Q fixed): insert dielectric ⇒ energy DECREASES (use $Q^2/2C$).

MUST KNOW Battery connected (V fixed): insert dielectric ⇒ Q and energy INCREASE (use $\frac{1}{2}CV^2$).

- Two capacitors sharing charge always LOSE energy as heat - charge conserved, energy not.

6. Combination of Capacitors

Parallel adds C (same V); series adds reciprocals (same Q).

Parallel: $C_p = C_1 + C_2 + \ldots$
same V; charges add

Series: $1/C_s = 1/C_1 + 1/C_2 + \ldots$
same Q; voltages add

Two in series: $C_s = C_1C_2/(C_1 + C_2)$
product over sum

n identical: parallel nC, series C/n
ratio = n^2

MUST KNOW Series: charge is the SAME on each; parallel: voltage is the same. Identify this first.

MUST KNOW In series the SMALLEST capacitor takes the LARGEST voltage ($V = Q/C$).

- C_p is larger than the biggest member; C_s is smaller than the smallest.

Series vs Parallel Capacitors

	Series	Parallel
Charge Q	Same on each	Divides
Voltage V	Divides	Same across all
Net C	< smallest	Sum (> largest)
Combine	$1/C_s = \Sigma 1/C_i$	$C_p = \Sigma C_i$

Dielectric Inserted ($K > 1$)

Quantity	Battery connected (V fixed)	Disconnected (Q fixed)
C	↑ to KC	↑ to KC
Q	↑ to KQ	Same
V	Same	↓ to V/K
Energy U	↑ (KU)	↓ (U/K)

Mnemonic - In series the charge Q is common; in parallel the voltage V is common.
Series Shares Charge, Parallel Provides Potential

Common traps

- Potential is a scalar - add with signs, never as vectors. V can be zero where the field is not (e.g. midpoint of $+q$ and $-q$).
- Field zero does NOT mean potential zero: inside a charged shell $E = 0$ but $V = kQ/R$ (constant).
- Dielectric does not always raise energy - it lowers it when the battery is disconnected (Q fixed). Always ask 'connected or disconnected?' first.
- In series you add the RECIPROCALS then invert - don't add capacitances directly, and don't forget the final inversion.

Most asked in NEET » Dipole potential (axial vs equatorial) · Potential inside a charged conducting sphere · $E = -dV/dr$ (gradient of V) · Dielectric slab / partial fill ratio · Energy stored & dielectric (connected vs disconnected) · Series-parallel equivalent capacitance & charge