🌟 ELECTROSTATIC POTENTIAL & CAPACITANCE – FULL STUDY GUIDE (CLASS 12)

🎯 *Perfect for Board Exams • Easy to Understand • Fun to Learn*

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1. THEORY IN SIMPLE WORDS (WITH VISUALS)

🌈 1.1 What is Electrostatic Potential?

Electrostatic potential at a point =
"Amount of work you need to bring a +1 C charge from infinity to that point."

Visual Meaning:

```
∞  →  point P
(work done to bring charge)
```

Formula:

$$V = \frac{W}{q}$$

Analogy:

Think of potential like height in gravity.
Higher height = more potential.
Higher electric potential = more "electric height."

🌈 1.2 Potential Due to a Point Charge

$$V = k\frac{q}{r}$$

Visual:

```
      +q
      |
V decreases as r increases
```

🌈 1.3 Potential Difference ($V_1 - V_2$)

Difference in electric potential between two points.

Everyday example:

Battery terminals:

```
+ ---- higher potential
- ---- lower potential
```

🌈 1.4 Electric Potential Energy

Energy stored due to position of charges.

$$U = k\frac{q_1 q_2}{r}$$

🌈 1.5 Relation Between Electric Field and Potential

$$E = -\frac{dV}{dr}$$

Visual:

```
Steep slope → strong field
Gentle slope → weak field
```

🌈 1.6 Equipotential Surfaces

Surfaces having **same potential everywhere**.

Properties

- No work done in moving charge along it.
- Always perpendicular to electric field.

Visual:

```
E ⊥ equipotential lines
```

🌈 1.7 Conductors & Dielectrics in Electrostatics

Inside a conductor:

- Electric field = 0
- Potential = constant
- Excess charge resides on surface

Dielectric:

Insulating material used between capacitor plates.

Analogy:
Like inserting cardboard between books — increases spacing and safety.

🌈 1.8 Capacitors

A device used to **store electric charge and energy**.

Common diagram:

```
| |   = parallel plate capacitor
```

Capacitance:

$$C = \frac{Q}{V}$$

🌈 1.9 Capacitance of Parallel Plate Capacitor

$$C = \epsilon_0 \epsilon_r \frac{A}{d}$$

Where:
A = plate area
d = separation
ε_r = dielectric constant

Visual:

```
| | closer → larger C
|       | farther → smaller C
```

🌈 1.10 Energy Stored in a Capacitor

$$U = \frac{1}{2}CV^2$$

or

$$U = \frac{Q^2}{2C}$$

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2. KEY CONCEPTS & FORMULAS TABLE

Concept	Formula	Memory Trick
Potential	$V = kq/r$	"Potential falls as r rises"
Potential diff.	$V = W/q$	V = Work per charge
Energy	$U = kq_1q_2/r$	Like masses but with charge
E–V relation	$E = -dV/dr$	E = Negative slope
Capacitance	$C = Q/V$	C = Charge Vault
Parallel plate	$C = \varepsilon A/d$	**A↑ → C↑ ; d↑ → C↓**
Energy stored	$U = ½CV^2$	"Half CV square"
Series combo	$1/C = 1/C_1 + 1/C_2$	Resistances style
Parallel combo	$C = C_1 + C_2$	Reverse of resistors

🌟 Mnemonics

For Capacitance: "CAP = A/d"

C ∝ A
C ∝ 1/d

For series & parallel:

"RES-SER, CAP-PAR"

- Resistances add in series
- Capacitors add in parallel

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3. SOLVED NUMERICAL PROBLEMS (STEPWISE)

⭐ *Type 1: Potential due to point charge*

Example 1

Find potential at 20 cm from a 5 μC charge.

Solution:

$$V = k\frac{q}{r}$$

$$= 9 \times 10^9 \cdot \frac{5 \times 10^{-6}}{0.2}$$

$$= 2.25 \times 10^5 \text{ V}$$

✔ Tip: Always convert cm → m.

⭐ *Type 2: Capacitance*

Example 2

A parallel plate capacitor has:
A = 1 m^2, d = 0.01 m
Find C.

$$C = \epsilon_0 \frac{A}{d}$$

$$= 8.85 \times 10^{-12} \cdot \frac{1}{0.01}$$

$$= 8.85 \times 10^{-10} \text{F}$$

⭐ *Type 3: Energy stored*

Example 3

A capacitor of 5 μF is charged to 200 V. Find stored energy.

$$U = \frac{1}{2}CV^2$$

$$= \frac{1}{2}(5 \times 10^{-6})(200)^2$$

$$= 0.1 \text{ J}$$

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4. PREVIOUS YEARS' BOARD QUESTIONS (SOLVED)

(Common questions asked repeatedly in CBSE boards)

✔ Q1 (2023)

Define equipotential surface and state two properties.

Answer (short + scoring):
Equipotential surface: surface with same electric potential everywhere.
Properties:

- No work done in moving charge along it.
- Always perpendicular to electric field.

✔ Q2 (2022)

Why is electric field zero inside a conductor?

Answer:
Charges rearrange on surface until internal field cancels → net E = 0.

✔ Q3 (2021)

Derive capacitance of a parallel plate capacitor.

Important steps:

- Assume uniform E
- $E = \sigma/\varepsilon_0$
- $V = Ed$
- $C = Q/V = \varepsilon_0 A/d$

✔ Q4 (2020 – Numerical)

A 10 μF capacitor is charged by a 50 V battery. Find charge stored.

$$Q = CV = 10 \times 10^{-6} \times 50 = 5 \times 10^{-4} C$$

✔ Q5 (2019)

Draw equipotential surfaces for:
(a) point charge
(b) dipole

(Draw concentric circles & double-lobed shape.)

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5. QUICK REVISION NOTES / IMPORTANT POINTS (1–2 PAGES STYLE)

⭐ Electric Potential

- Scalar
- Decreases with distance
- Infinity chosen as reference

⭐ Equipotential Surfaces

- No work done
- Perpendicular to E
- Closer surfaces → stronger field

⭐ Capacitors

- Store charge & energy
- Dielectric increases capacitance
- $C \propto$ area
- $C \propto 1/d$

⭐ Dielectric Effects

- Insertion decreases electric field
- Increases capacitance
- Energy decreases if disconnected from battery
- Energy increases if connected to battery

⭐ Series/Parallel

- Series → C decreases
- Parallel → C increases

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6. PREDICTED / LIKELY BOARD QUESTIONS

Short Questions

- Define electric potential.
- What are equipotential surfaces?
- Why is no work done on equipotential surface?
- State the effect of dielectric on capacitance.
- Give SI unit of capacitance.

Long Questions

- Derive capacitance of parallel plate capacitor.
- Explain how capacitors combine in series and parallel.
- Derive relation between E and V.

Likely Numericals

- Potential due to point charge
- Energy stored in capacitor
- Charge on capacitor plates
- Final energy when dielectric inserted

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7. EXAM TIPS & TRICKS

✔️ Tip 1:

When in doubt, draw diagram! CBSE checks diagrams heavily.

✔️ Tip 2:

For capacitor questions:
Think: A↑? C↑ | d↑? C↓ | ε_r↑? C↑

✔️ Tip 3:

Always check: battery connected or disconnected?
This changes Q & V.

✔️ Tip 4:

Series vs parallel?
Use **CAP-PAR mnemonic.**

✔️ Tip 5:

State units clearly → most students lose ½–1 mark here.

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8. VISUAL & KID-FRIENDLY MEMORY TOOLS

🎨 Visual 1: Potential as Height

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High hill = high V
Low valley = low V
```

🎨 Visual 2: Capacitor as Charge Jar

```
| | ← two plates = two walls of a jar
More area = bigger jar
Less distance = easier to fill
```

🎨 Visual 3: Equipotential Surfaces

```
Concentric circles around a point charge
(like ripples in water)
```