

PHYSICS • CLASS 12

CHAPTER 2

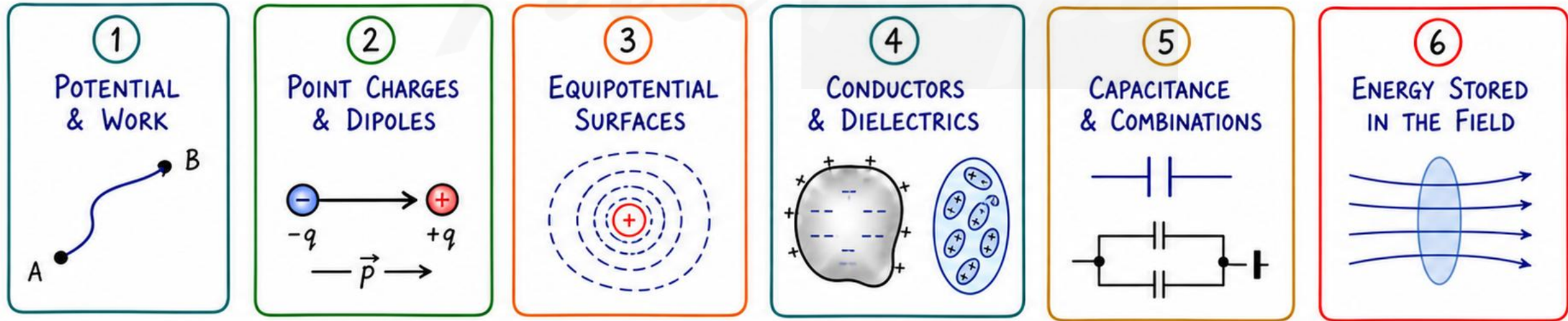
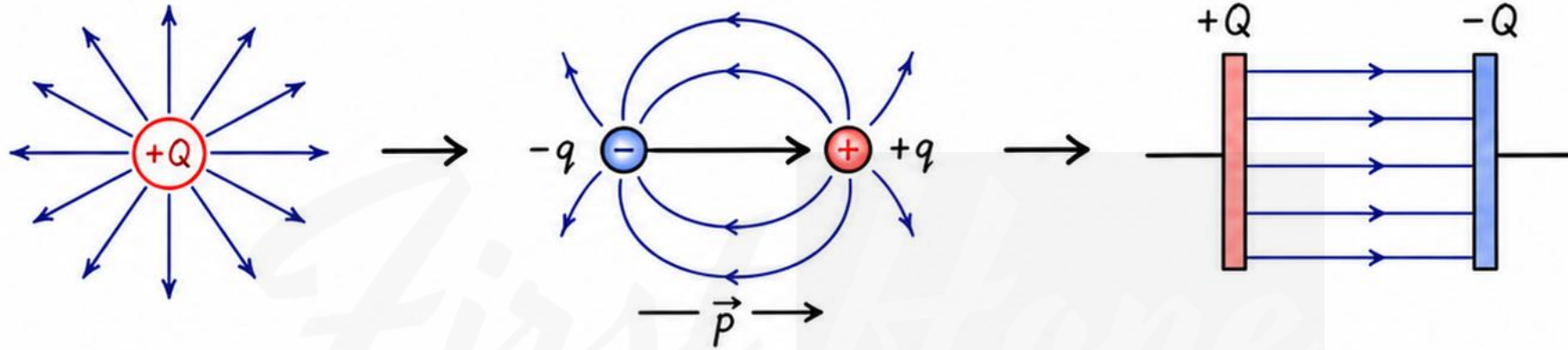
Electrostatic Potential and Capacitance

CHAPTER NOTES



ELECTROSTATIC POTENTIAL & CAPACITANCE

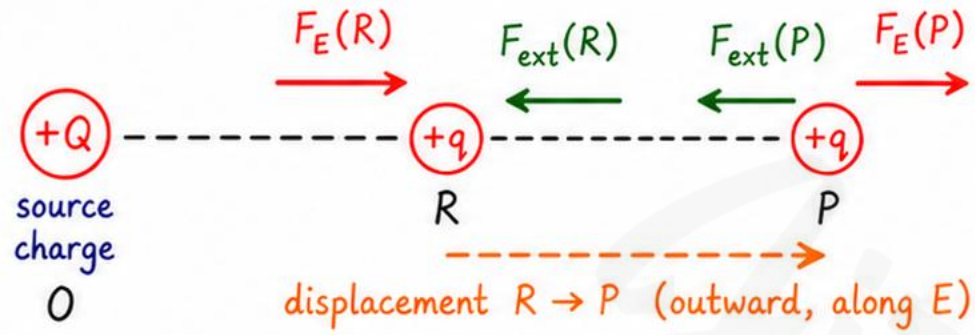
From conservative electric forces to capacitors that store energy.



Potential describes energy per unit charge; capacitance describes charge stored per unit potential difference.

CONSERVATIVE FORCE, WORK & POTENTIAL ENERGY

Electrostatic force between stationary charges is conservative: work depends only on the initial and final points.



q moves slowly from R to P away from $+Q$.
quasi-static: $F_{\text{ext}} = -F_E$, so no acceleration.

$$\Delta U = U_P - U_R = W_{\text{ext}}(R \rightarrow P)$$

$$W_{\text{field}}(R \rightarrow P) = -\Delta U$$

$$\oint \vec{E} \cdot d\vec{l} = 0$$

work is path independent.

ZERO REFERENCE

Choose $U(\infty) = 0$.

Then $U(P) = W_{\text{ext}}(\infty \rightarrow P)$.

Only differences in potential energy are physically measurable.

For a positive test charge ($+q$):	$\rightarrow$ (red)	Move against E (toward higher potential)	$\Rightarrow$	External work positive	$\Rightarrow$	U increases
	$\rightarrow$ (green)	Move along E (toward lower potential)	$\Rightarrow$	External work negative	$\Rightarrow$	U decreases
For a negative test charge ($-q$):	$\rightarrow$ (red)	Move against E (toward higher potential)	$\Rightarrow$	External work negative	$\Rightarrow$	U decreases
	$\rightarrow$ (green)	Move along E (toward lower potential)	$\Rightarrow$	External work positive	$\Rightarrow$	U increases

ELECTRIC POTENTIAL & POTENTIAL DIFFERENCE

1. DEFINITION

Electric potential is electrostatic potential energy per unit test charge.

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

2. POTENTIAL DIFFERENCE

The potential difference between points P and R is the change in potential energy per unit charge.

$$V_P - V_R = \frac{U_P - U_R}{q}$$

$$\Delta V = \frac{W_{\text{ext}}}{q} = - \frac{W_{\text{field}}}{q}$$

V is a scalar property of the source configuration; it does not depend on the chosen infinitesimal test charge.

3. CHOICE OF REFERENCE

The potential is defined up to an additive constant. By convention, take potential at infinity to be zero.

$$V(\infty) = 0 \\ \Rightarrow V(P) = \frac{W_{\text{ext}}(\infty \rightarrow P)}{q}$$

4. UNITS

The SI unit of electric potential is volt (V).

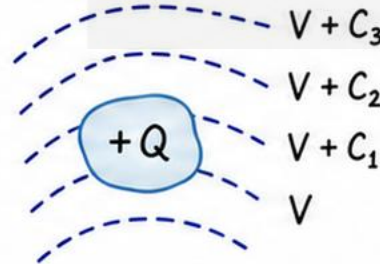
$$1 \text{ volt} = 1 \text{ joule per coulomb}$$

$$1 \text{ V} = 1 \text{ J C}^{-1}$$

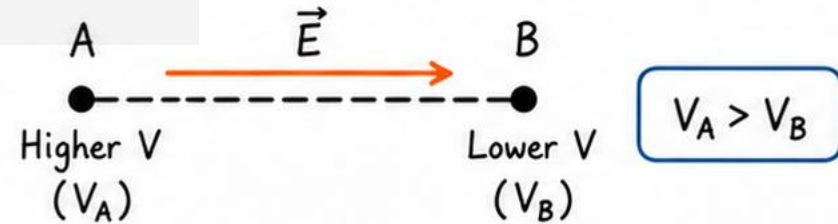
5. ADDITIVE CONSTANT

V and $V + C$ describe the same electric field; only potential differences matter.

(Adding a constant shifts all potentials equally.)



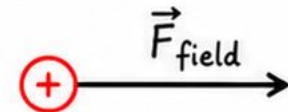
6. SIGN CONVENTION & DIRECTION



$\vec{E}$ points toward decreasing potential.

7. TEST CHARGE CAVEAT

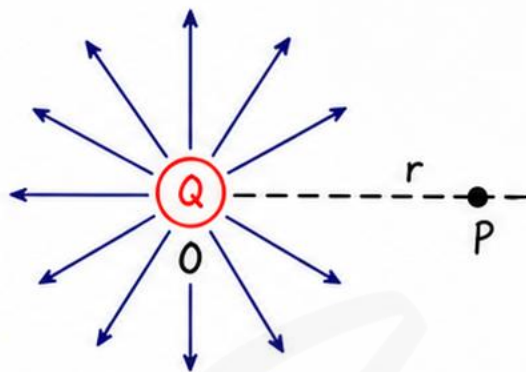
- Use an infinitesimal positive test charge so the original source charges are not disturbed.



POTENTIAL DUE TO A POINT CHARGE

CONCEPT & DIAGRAM:

- A point charge Q is placed at O .
- Potential and electric field are observed at a point P at distance $r > 0$ from O .



RESULT:

Let $k = \frac{1}{4\pi\epsilon_0}$ ($C \cdot m^2 / N$).

Then,

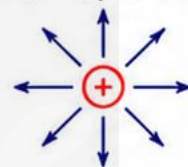
$$V(r) = \frac{kQ}{r} \quad (\text{potential})$$

$$E(r) = \frac{k|Q|}{r^2} \quad (\text{magnitude of electric field})$$

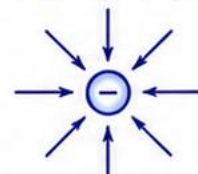
SIGN & DIRECTION:

- If $Q > 0 \Rightarrow V(r) > 0$.
- If $Q < 0 \Rightarrow V(r) < 0$.
- As $r \rightarrow \infty$, $V(r) \rightarrow 0$ and $E(r) \rightarrow 0$.
- Potential V is a scalar (no direction).
- Electric field is radial:

For $Q > 0$:

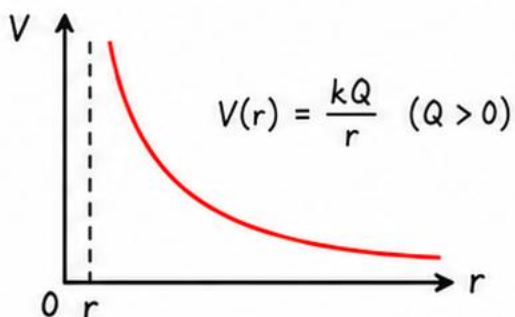


For $Q < 0$:



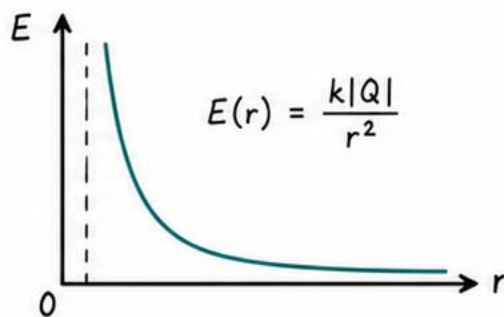
VARIATION WITH DISTANCE $r > 0$ (IDEAL POINT CHARGE)

(a) Potential $V(r)$ for $Q > 0$



At $r = 0$, V is singular ($\rightarrow \infty$).

(b) Electric Field Magnitude $E(r)$



At $r = 0$, E is singular ($\rightarrow \infty$) and falls faster than V .

RELATION BETWEEN E AND V

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

The electric field points in the direction of steepest decrease of potential.

Along the radial line:

- For $Q > 0$, $E_r > 0$ (outward).
- For $Q < 0$, $E_r < 0$ (inward).

EFFECT OF CHANGING DISTANCE

If the distance is doubled: $r \rightarrow 2r$

- Potential:

$$V(2r) = \frac{kQ}{2r} = \frac{1}{2} V(r) \quad |V| \text{ becomes half.}$$

- Electric field magnitude:

$$E(2r) = \frac{k|Q|}{(2r)^2} = \frac{1}{4} \frac{k|Q|}{r^2} = \frac{1}{4} E(r)$$

$|E|$ becomes one quarter.

Both V and E decrease with distance, but E ($\propto 1/r^2$) decreases much more rapidly than V ($\propto 1/r$).

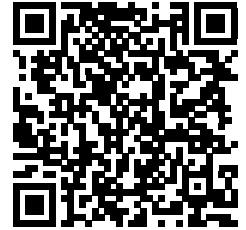


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