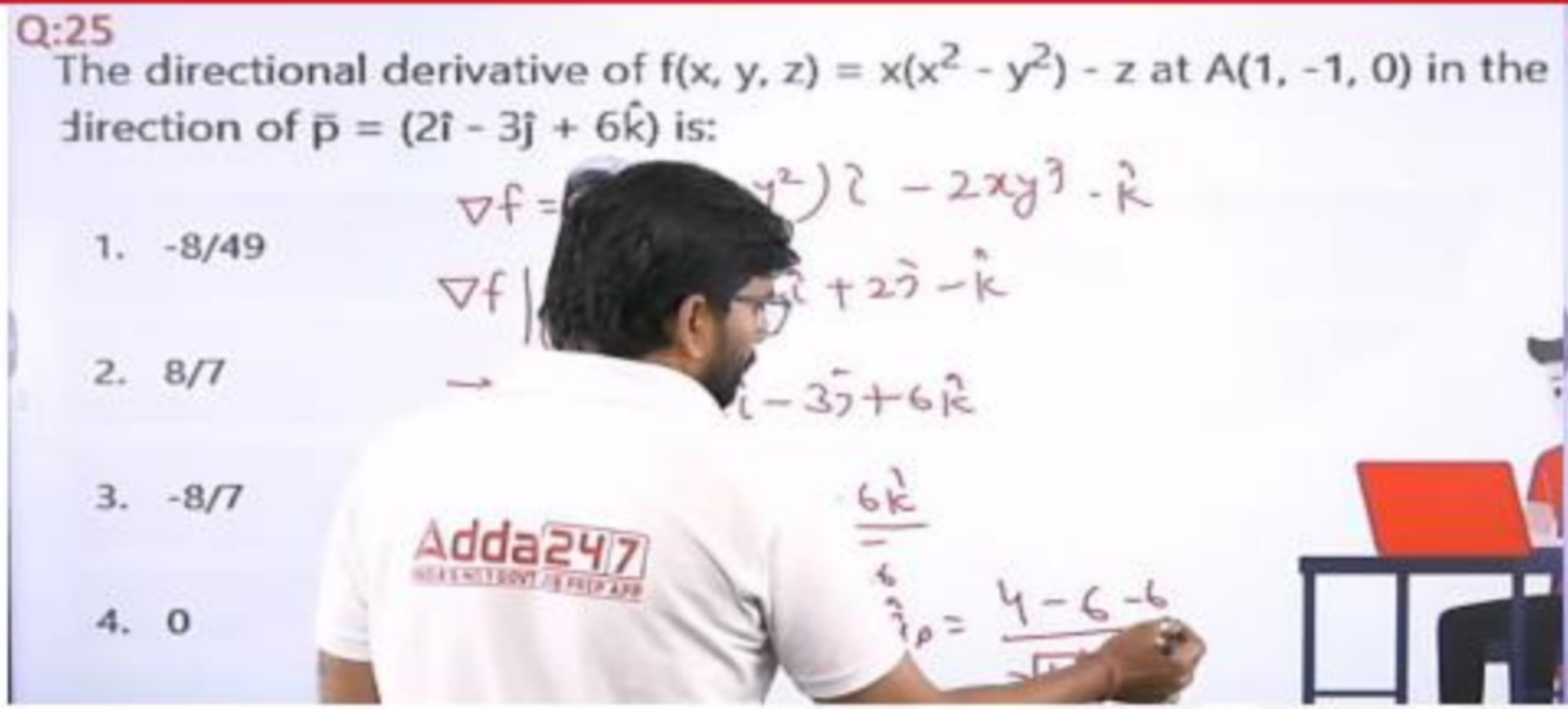
Vector Differentials

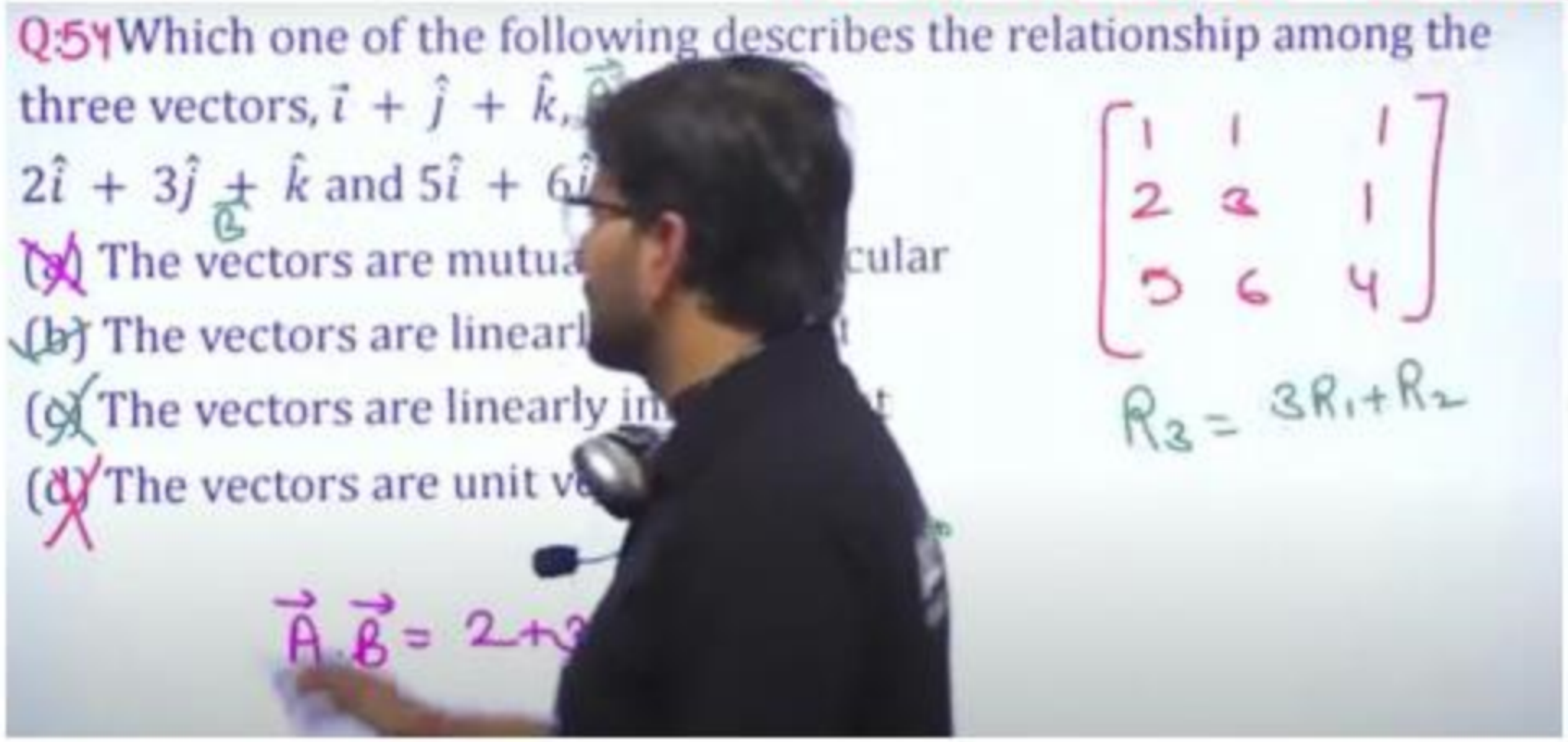
Dipole

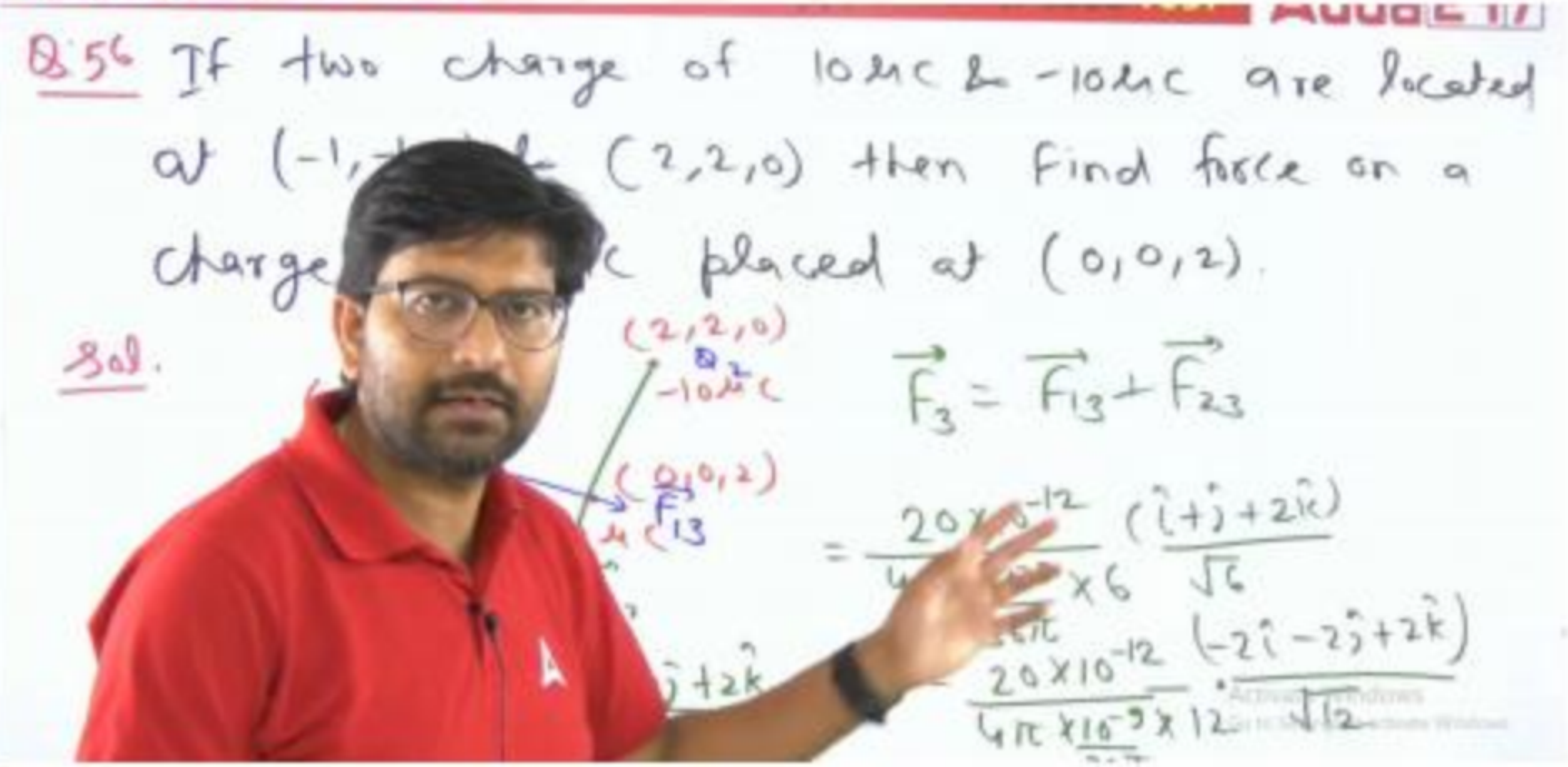
Fields in Material Space

Recap



Number of Questions covered-72





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GATE 2024
GATE
प्रचण्ड Batch
Electromagnetic Field Theory
FIELDS IN MATERIAL SPACE
LEC-14
EE &ECE

1. Basic introduction of Fields
2. Basics of Vectors
3. Coordinate Systems
4. Vector Integrals
5. Vector differentials
6. Coulomb's law and Gauss law
7. Field due to line, Surface and Spherical Volume Charge
8. Electric Potential

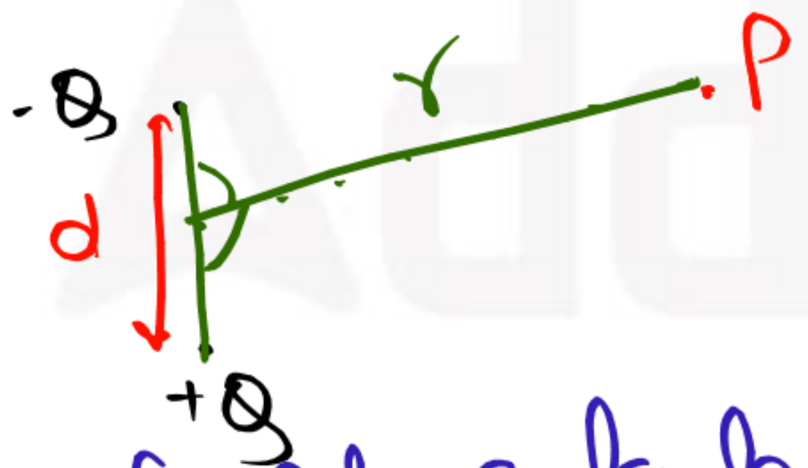
Vector Differentials

Dipole

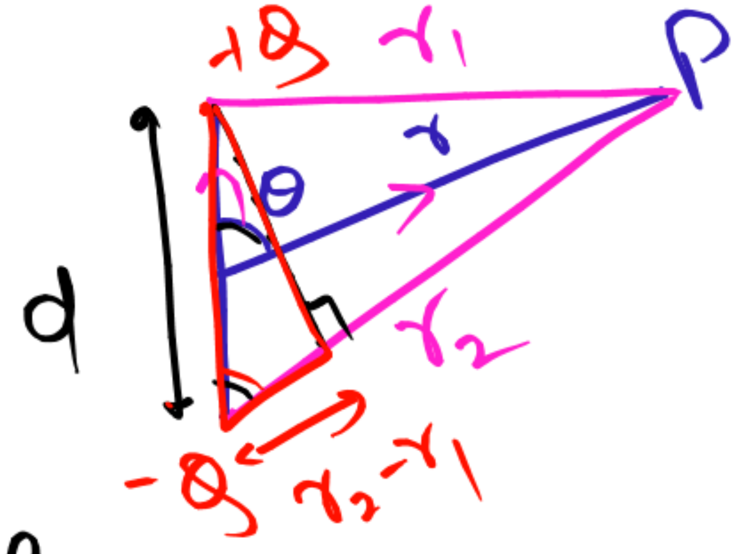
Fields in Material Space

Dipole and Fields due to dipole

Dipole :→ It is combination of same amount of positive and negative charge placed at very small distance with each other.



electric field calculations due to dipole at a point placed at distance r and oriented at an angle 'θ' from dipole axis.



$\lim_{d \to 0}$

$\vec{p}$ i.e. dipole moment is directed from -ve pole to +ve pole.

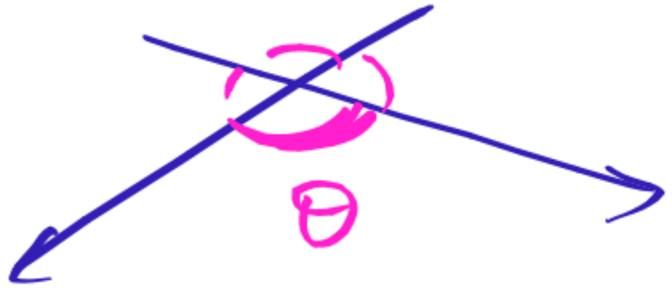
$$V = V_1 + V_2$$

$$V = \frac{Q}{4\pi\varepsilon_0 r_1} - \frac{Q}{4\pi\varepsilon_0 r_2}$$

$$V = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$V = \frac{Q}{4\pi\varepsilon_0}\left(\frac{r_2 - r_1}{r_1 r_2}\right) \simeq \frac{Q}{4\pi\varepsilon_0}\frac{d\cos\theta}{r^2}$$

$$V = \frac{Q\,\vec{d}\cdot\hat{r}}{4\pi\varepsilon_0 r^2}$$

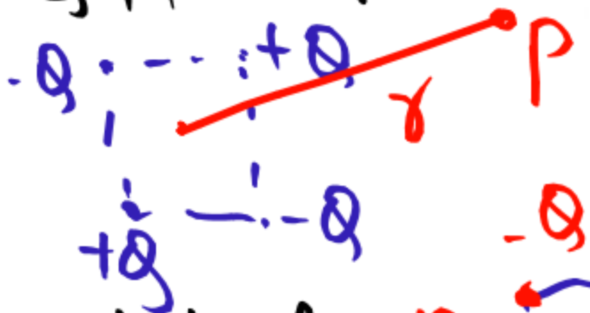


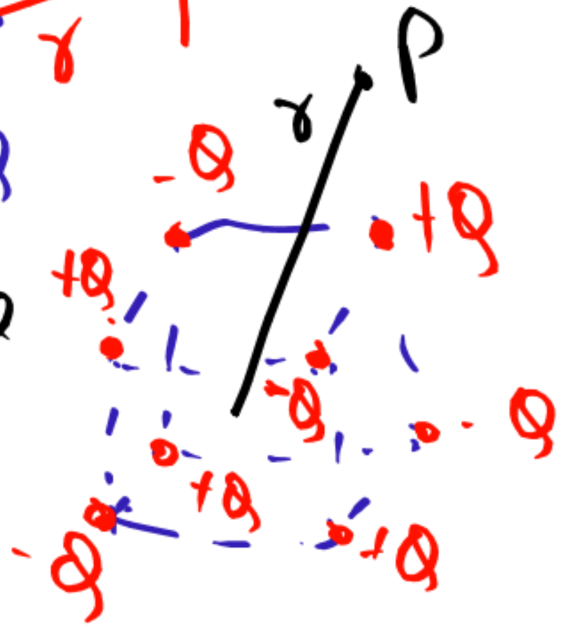
$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

$Q\vec{d} = \vec{p}$

dipole moment of dipole

	V	E
① Monopole	$\propto \frac{1}{r}$	$\propto \frac{1}{r^2}$
② Dipole	$\propto \frac{1}{r^2}$	$\propto \frac{1}{r^3}$
③ Quadrupole	$\propto \frac{1}{r^3}$	$\propto \frac{1}{r^4}$
④ Octopole	$\propto \frac{1}{r^4}$	$\propto \frac{1}{r^5}$





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Types of Materials

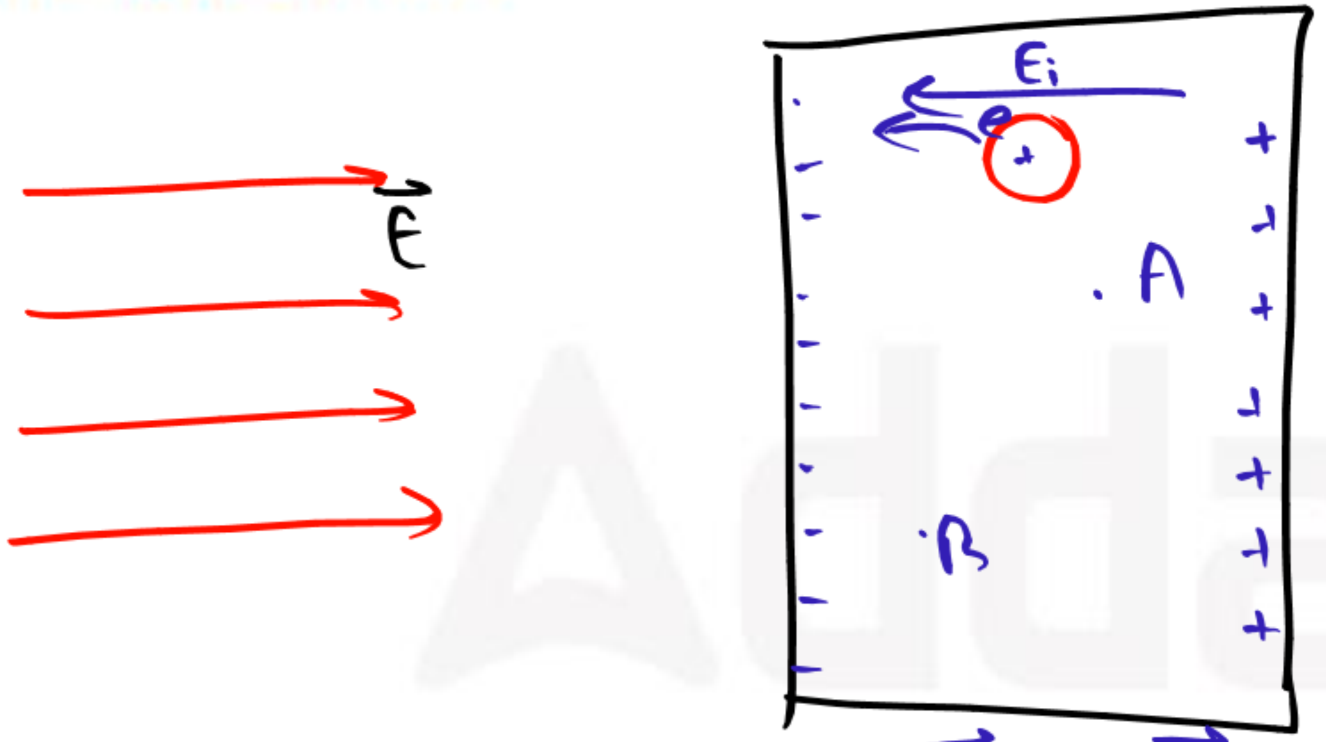
1. Conductors :→ $\sigma >> 1$
2. Insulators / dielectric → $\sigma << 1$
3. Semiconductors :→ Semiconductor physics → E.D.C.

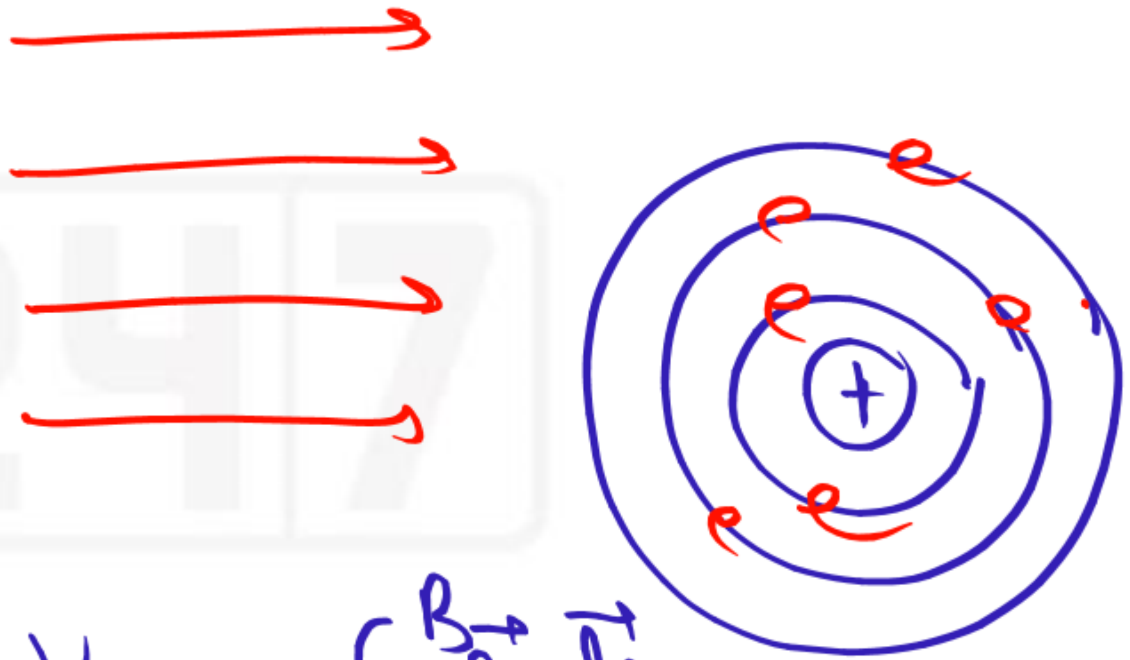
Dielectric constant → ε

Electric Fields in Conductor Space

$\vec{F} = q\vec{E}$

Isolated Conductors





At equilibrium $\vec{E_i} = -\vec{E}$

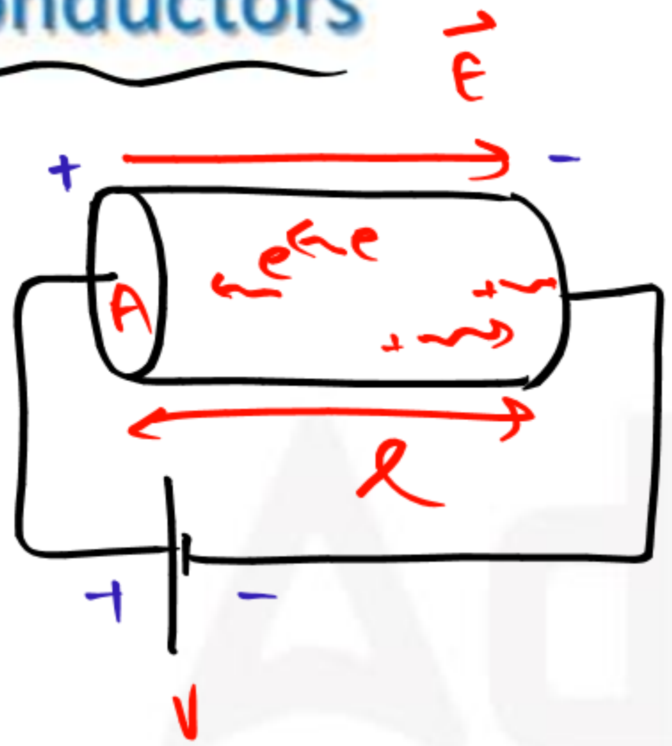
so $E_{total} = 0$

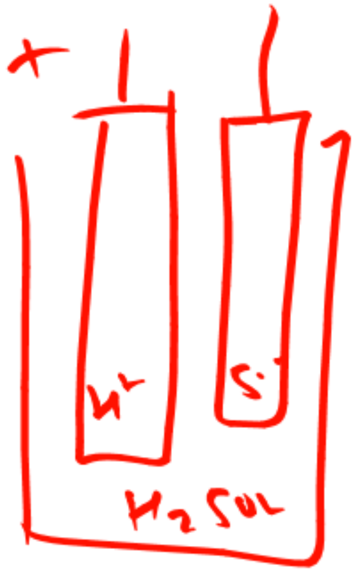
$V_{BA} = -\int_A^B \vec{E} \cdot \vec{dl} = 0$

* electric field inside conductor = 0
* All inside points are equipotential.

Electric Fields in Conductor Space

Connected Conductors



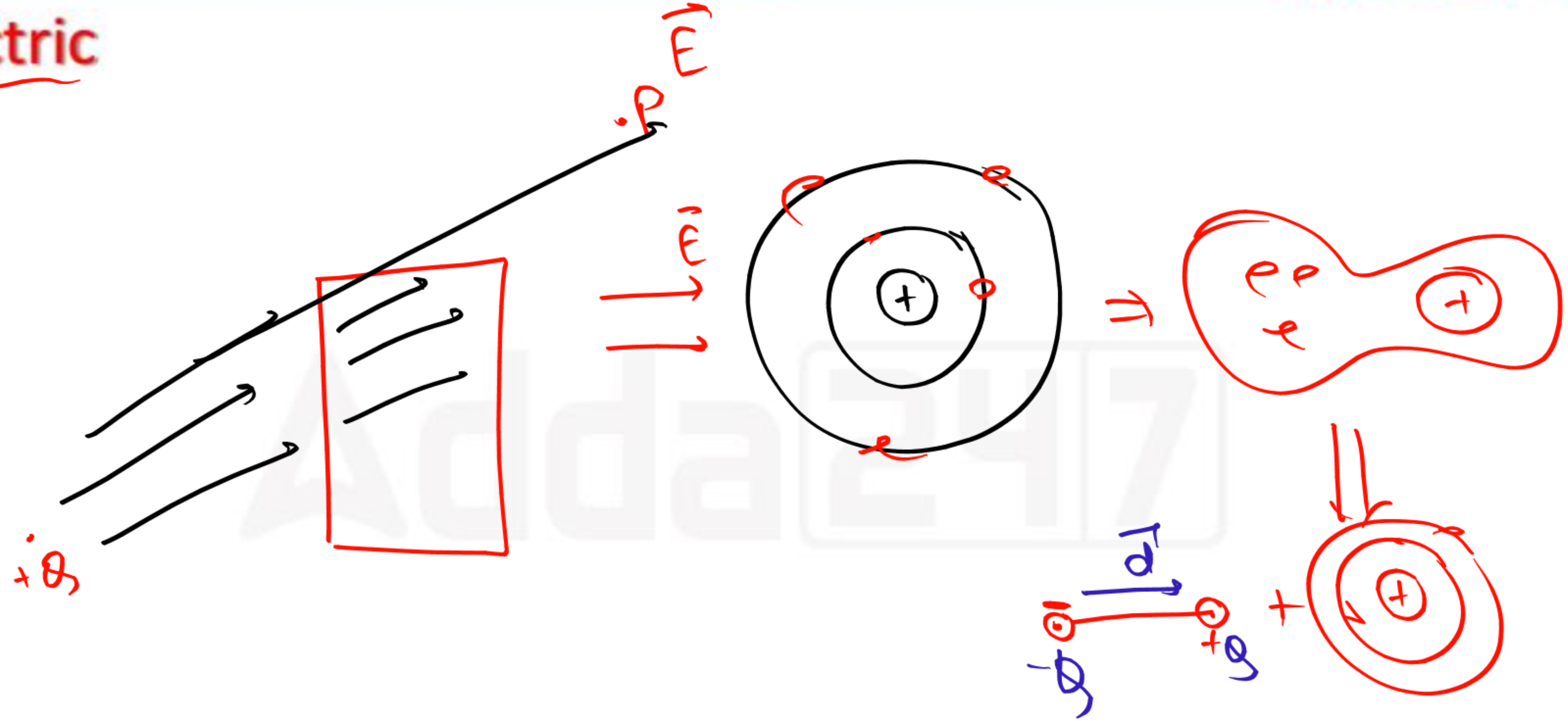


$$I \propto V$$

$$I = \frac{V}{R}$$

$$R = \frac{\rho l}{A}$$

Dielectric



$$\vec{P} = \frac{Q\vec{d_1} + Q\vec{d_2} + Q\vec{d_3} + \dots Q\vec{d_n}}{\Delta V}$$

$$\vec{P} = \frac{\sum_{i=1}^{n} Q\vec{d_i}}{\Delta V}$$ ← Polarization Vector

$$\vec{P} \propto \vec{E}$$

$$\vec{P} = \chi_e \vec{E}$$

χ_e is called electric susceptibility.

It is the measure of how much a material gets polarized when placed in electric field.

$$\vec{E}_{total} = \vec{E} + \vec{P}$$

$$\vec{D} = \varepsilon_0 \vec{E}_{total}$$

$$= \varepsilon_0 [\vec{E} + \chi_e \vec{E})$$

$$\vec{D} = \varepsilon_0 (1 + \chi_e) \vec{E}$$

$$\vec{D} = \varepsilon_0 \varepsilon_r \vec{E}$$

$$\vec{D} = \varepsilon \vec{E}$$

$$\vec{D} = \varepsilon_0 \vec{E}$$

$\varepsilon = \varepsilon_0 \varepsilon_r$

$\varepsilon_0 = 8.854 \times 10^{-12}$ F/m

$\varepsilon_r \rightarrow$ relative permitivity of material. (unit less)

$\varepsilon \rightarrow$ permitivity of material. (F/m)

$\varepsilon_r = 1 + \chi_e$ ← unit less.

$$\vec{D} = \varepsilon \vec{E}$$

THANKS FOR

Watching

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