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MSC PHY 06 (4th sem)

Potential formulation:- We have two types of potential
(a) scalar potential $V(r,t)$
(b) vector potential $\vec{A}(r,t)$

Both of these potentials are function of time in electrodynamics. In electrostatics & magnetostatics these two potentials are independent of time.

From Maxwell's eqn in electrodynamics we have

$$\vec{\nabla}\cdot\vec{B} = 0 \Rightarrow \boxed{\vec{B} = \vec{\nabla}\times\vec{A}} \quad --(1)$$

$$\vec{\nabla}\times\vec{E} = -\frac{\partial B}{\partial t} = -\vec{\nabla}\times\frac{\partial \vec{A}}{\partial t} \qquad \bar{B} = \bar{\nabla}\times\bar{A}$$

$$\vec{\nabla}\times\left[\bar{E} + \frac{\partial\bar{A}}{\partial t}\right) = 0$$

$$\Rightarrow \bar{E} + \frac{\partial\bar{A}}{\partial t} = -\vec{\nabla}V$$

$$\Rightarrow \boxed{\bar{E} = -\bar{\nabla}V - \frac{\partial\bar{A}}{\partial t}} \quad --- (2)$$

For the same value of $\bar{E}$ & $\bar{B}$ we might have different value of V & $\vec{A}$ because $\bar{E}$ & $\bar{B}$ depends on each-other.

Example $\boxed{\vec{A}' = \vec{A} + \vec{\nabla}\lambda}$ $\vec{A}$ vector potential for $\vec{B}$
$\vec{A}'$,, ,, $\vec{B}'$

we have to show different $\vec{A}, \vec{A}'$ we will get same $\vec{B}$

simultaneously $\boxed{V' = V - \frac{\partial\lambda}{\partial t}}$

Here λ = Guage function

for $A \longrightarrow V, \vec{E}$ & for $A' \longrightarrow V', \bar{E}'$

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$\vec{B}' = \bar{\nabla} \times A' = \nabla \times (A + \nabla\lambda) = \nabla \times A + \nabla \times \nabla\lambda \Rightarrow \bar{B}' = \nabla \times A$ as we know that $\nabla \times \nabla\lambda = 0$

$\Rightarrow \vec{B}' = \vec{B}$

$\Rightarrow$ on changing $\vec{A}$ by $\vec{A}'$, $\vec{B}$ (magnetic field) remains same

Similarly

$$\bar{E}' = -\bar{\nabla} V' - \frac{\partial A'}{\partial t} = -\bar{\nabla} V + \nabla\left(\cancel{\frac{\partial \lambda}{\partial t}}\right) - \frac{\partial \bar{A}}{\partial t} - \vec{\nabla}\left(\cancel{\frac{\partial \lambda}{\partial t}}\right) -$$

$$\bar{E}' = -\nabla V - \frac{\partial \bar{A}}{\partial t} = \bar{E}$$

Hence it is proved that for the same value of E & B we get different set of $\bar{A}$ & $\hat{V}$.