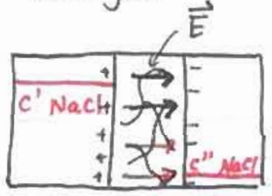
$\boxed{\text{Today}}$: Start Electrical System 10/4

I. Maxwell's Eqn's: Integral + Differential Forms
+ Conservation of charge
+ Lorentz Force Law (E)
⇒ "Complete Description" of Electrodynamics

II. Electroquasistatic (EQS) Subset of Maxwell's Eqns ⇒ (Rest of the term)

Examples: 1. Charged Macromolec. moving thru. charged tissues to charged cell surface

2. 

ion transport across membrane / tissue

$D^{\infty}_{Na^+} \sim 1.3 \times 10^{-9}$ (m^2/s)

$D^{\infty}_{Cl^-} \sim 2.1 \times 10^{-9}$ (m^2/s)

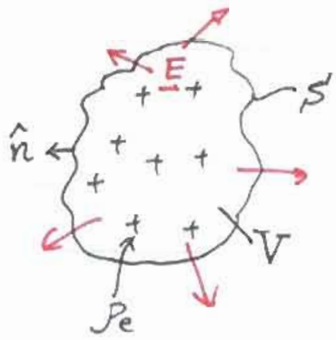
$D_{eff} = \left(\dfrac{2D_+ D_-}{D_+ + D_-}\right)$

Maxwell's Eqns:

1. Gauss' Law

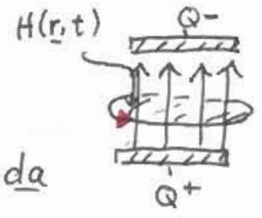
~~$\rho_e(r,t)$~~

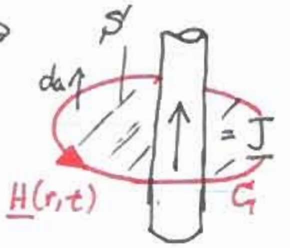
$$\oint_S \underbrace{\varepsilon_0 \underline{E}}_{\text{flux of } \varepsilon_0 E} \cdot \underline{n}\, da = Q_{net} = \int_V \rho_e \, dV$$



2. Ampère's Law

$$\underbrace{\oint_C \underline{H} \cdot \underline{ds}}_{\text{"circulation of H"}} = \underbrace{\int_S \underline{J} \cdot \underline{da}}_{\text{flux of J.}} + \underbrace{\frac{d}{dt}\int_S \varepsilon_0 \underline{E} \cdot \underline{da}}_{\text{Maxwell}}$$





Differential Form of Maxwell's Eqn:

Gauss Thm: $\oint_S \bar{A} \cdot d\bar{s} = \int_V \nabla \cdot A \, dV$

Stokes Thm: $\oint_C \underline{A} \cdot d\underline{s} = \int_S \nabla \times \underline{A} \cdot d\underline{a}$

field $\Leftarrow$ source

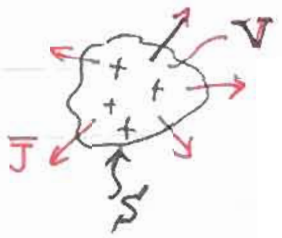
1' $\nabla \cdot \varepsilon \underline{E} = \rho_e \Rightarrow \nabla \cdot \varepsilon \underline{E}(\bar{r}, t) = \rho_e(\vec{r}, t)$

3' $\nabla \times \underline{E}(r,t) \Rightarrow \nabla \times E(\bar{r}, t) = -\frac{\partial}{\partial t} \mu \underline{H}(\underline{r}, t)$

2' $\nabla \cdot \left(\nabla \times \underline{H} = \underline{J} + \frac{\partial}{\partial t} \varepsilon \underline{E}\right) \Rightarrow$ 5'

4' $\nabla \cdot \underbrace{\mu H}_{\underline{B}} = 0$

5 Conservation of charge: $\oint_{S'} \underline{J} \cdot d\underline{a} = -\frac{d}{dt} \int \rho_e \, dv$



5' $\boxed{\nabla \cdot J = -\frac{\partial \rho_e}{\partial t}}$ $\Leftarrow$ from 1 & 2

6 $\underline{f} = q(\underline{E} + \underline{V} \times B)$ Lorentz force Law

7 "$f = ma$" $\Rightarrow f = m \frac{dv}{dt}$

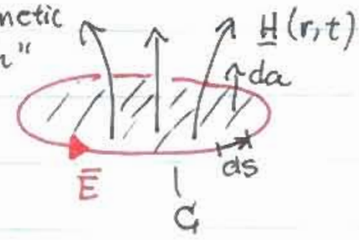
1 ~ 7 $\Rightarrow$ Complete Description of Electrodynamics

Statics & waves

③. Faraday:

"electromagnetic induction"

$$\oint_C \underline{E}\cdot d\underline{s} = -\frac{d}{dt}\int_S \mu_0 \underline{H}\cdot d\underline{a} \quad \mu$$



④ Gauss' Law (for H)

$$\oint_S \mu\underline{H}\cdot d\underline{a} = 0$$ = (no magnetic monopoles except in CA)

List of Parameters in Maxwell Eqns.

$\rho_e(\underline{r},t) \equiv$ charge density $\left(\frac{Coul}{m^3}\right)$

$\varepsilon_0 \equiv$ permittivity of free space (8.85×10^{-12} Farad/m)

μ_0 = mag. permeability of vacuum

$\varepsilon \equiv$ permittivity of medium

$\varepsilon_w \sim 80\,\varepsilon_0$

μ = mag. permeability of medium ($\sim 4\pi\times10^{-7}$ Henries/m)

$J \equiv$ current density $\left(\frac{A = \frac{Coul}{s}}{m^2}\right)$

$\underline{H}(\underline{r},t)$ = magnetic field intensity

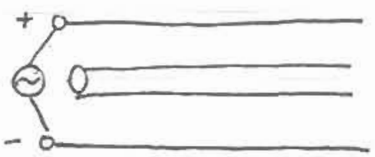
$\varepsilon, \mu \equiv$ isotropic homogeneous linear

$\underline{B} = \mu\underline{H}$

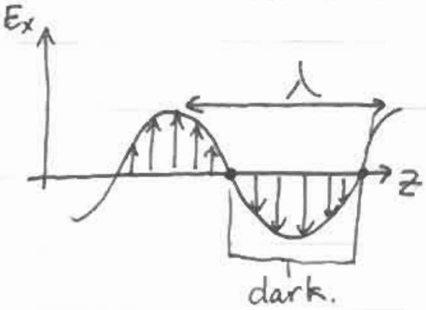
$\underline{D} = \varepsilon\underline{E}$

for $L^{chan} \ll \lambda \Rightarrow$ Q.S.

Demo:



f = 200MHz, standing wave of $\underline{E}, \underline{H}$



(see $|E|^2$)

$f\lambda = c$

$\lambda = \frac{3\times10^8}{2\times10^8} = 1.5m$

use 3' & 2'

$\boxed{\nabla^2 E = \frac{\partial^2 E}{\partial t^2}\cdot\mu\varepsilon}$ wave eqns.