Chapter 9

Faraday's Law:

The induced voltage in a circuit is directly proportional to the rate of change of magnetic flux

$$V_{emf} = -N \frac{\partial \psi}{\partial t}$$

N : **Number of turns**

ψ : **Magnetic Flux**

Remember: $\psi_{mag} = \int \vec{B} \cdot ds$

Lenz's Law:

The current in the loop is always in a direction that oppos the change of the magnetic flux that produced I

Vemf Cases:

1- Stationary Loop & Time Varying B

$$V_{emf} = -N \frac{\partial \psi}{\partial t}$$

2- Moving loop & static B

$$V_{emf} = \int (u \times B)\, dl$$

u: velocity

3- Moving loop & Time varying B

$$V_{emf} = -\frac{\partial \psi}{\partial t} + \int (u \times B)\, dl$$

Maxwell's Equations:

Remark: in EE204 Maxwell's equations are different than EE203 equations because now we account for Time

1- Ampere's circuit law

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$$\nabla \times \vec{H} = \vec{J}_c + \vec{J}_D$$

Conduction Current Density

$$J_c = \sigma \vec{E}$$

Displacement Current Density

$$J_D = \frac{\partial \vec{D}}{\partial t} = \varepsilon \frac{\partial \vec{E}}{\partial t}$$

2- Faraday's Law

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

3- Gauss's Law for Electric field

$$\nabla \cdot D = \rho_v$$

4- Gauss's Law for Magentic field

$$\nabla \cdot B = 0$$

TABLE 9.1 Generalized Forms of Maxwell's Equations

Differential Form	Integral Form	Remarks
$\nabla \cdot \mathbf{D} = \rho_v$	$\oint_S \mathbf{D} \cdot d\mathbf{S} = \int_v \rho_v \, dv$	Gauss's law
$\nabla \cdot \mathbf{B} = 0$	$\oint_S \mathbf{B} \cdot d\mathbf{S} = 0$	Nonexistence of isolated magnetic charge*
$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$	$\oint_L \mathbf{E} \cdot d\mathbf{l} = -\frac{\partial}{\partial t} \int_S \mathbf{B} \cdot d\mathbf{S}$	Faraday's law
$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$	$\oint_L \mathbf{H} \cdot d\mathbf{l} = \int_S \left(\mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}\right) \cdot d\mathbf{S}$	Ampère's circuit law

*This is also referred to as Gauss's law for magnetic fields.

Remember:

$$\vec{D} = \varepsilon \vec{E} \qquad \vec{B} = \mu \vec{H}$$

Continuity equation

$$\nabla \cdot J = -\frac{\partial \rho_v}{\partial t}, \text{ where } J = J_c + J_D$$

Phase Form & Time domain

$$\vec{A} = A_o \cos(\omega t \pm \beta z)\, \hat{a}_x$$

$$\vec{A} = A_o\, e^{j(\pm \beta z)}\, \hat{a}_x$$

$$\sin\theta = \cos(\theta - 90)$$

$$-\sin\theta = \cos(\theta + 90)$$

$$-\cos\theta = \cos(\theta \pm 180)$$

$$j = e^{j\frac{\pi}{2}}$$

$$\frac{1}{j} = e^{-j\frac{\pi}{2}}$$

Example:- $\vec{A} = 8 \sin(1000t - 4y)\, \hat{a}_x$

$$\vec{A} = 8 \cos(1000t - 4y - 90)\, \hat{a}_x$$

$$\vec{A} = 8\, e^{j(-4y - 90)}\, \hat{a}_x$$

Example:- $\vec{B} = \frac{18}{j}\, e^{j(5x)}\, \hat{a}_y$

$$\vec{B} = \frac{1}{j} \cdot 18\, e^{j(5x)}\, \hat{a}_y = e^{-j\frac{\pi}{2}} \cdot 18\, e^{j(5x)}\, \hat{a}_y$$

$$= 18\, e^{j(5x - \frac{\pi}{2})}\, \hat{a}_y = 18 \cos(\omega t + 5x - \tfrac{\pi}{2})\, \hat{a}_y$$