

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

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ψ : Magnetic Flux

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

Lenz's Law:

The current in the loop is always in a direction that opposes the change of the magnetic flux that produced it

V_{emf} Cases:

1- Stationary Loop & Time Varying B

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

2-Moving loop & static B

$$V_{emf} = \int (\mathbf{u} \times \mathbf{B}) d\mathbf{l}$$

\mathbf{u} : velocity

3- Moving loop & Time varying B

$$V_{emf} = - \frac{\partial \psi}{\partial t} + \int (\mathbf{u} \times \mathbf{B}) d\mathbf{l}$$

Maxwell's Equations:

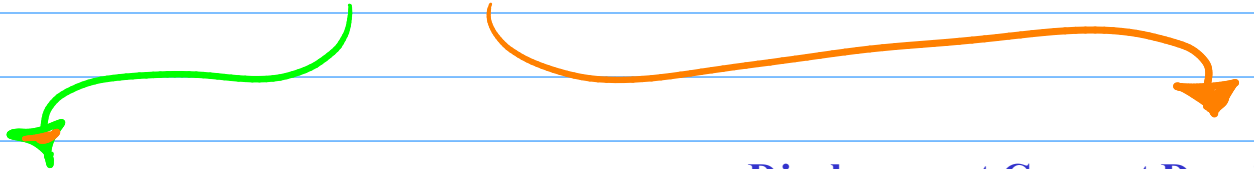
Remark: in EE204 Maxwell's equations are different than EE203 equations because now we account for Time

1- Ampere's circuit law

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

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Conduction Current Density

$$\vec{J}_c = \sigma \vec{E}$$

Displacement Current Density

$$\vec{J}_D = \frac{\partial \vec{D}}{\partial t} = \epsilon \frac{\partial \vec{E}}{\partial t}$$

2- Faraday's Law

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

3- Gauss's Law for Electric field

$$\nabla \cdot \mathbf{D} = \rho_v$$

4- Gauss's Law for Magnetic field

$$\nabla \cdot \mathbf{B} = 0$$

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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:

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

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

Continuity equation

$$\nabla \cdot \mathbf{J} = -\frac{\partial \rho_v}{\partial t} \quad \text{, where } \mathbf{J} = \mathbf{J}_c + \mathbf{J}_d$$

Phase Form & Time domain

$$\vec{A} = A_0 \cos(\omega t \pm \beta z) \hat{a}_x$$

$$\vec{A} = A_0 e^{j(\pm \beta z)} \hat{a}_x$$

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

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

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

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

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

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

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

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

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

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

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