Inductor

Inductance

- Self Inductance

$$L = \frac{N\Phi}{I}$$

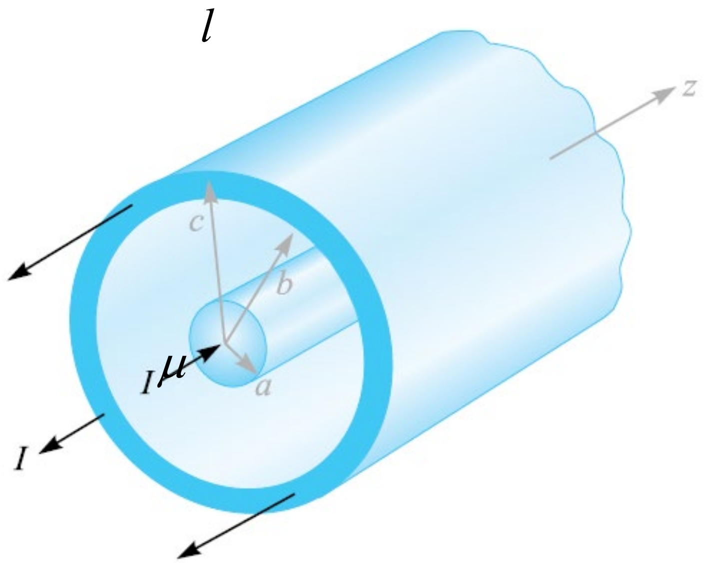
$$L: \ \text{Inductance (H)}$$

- Mutual Inductance

$$M_{12} = \frac{N_2\Phi_{12}}{I_1}$$

$$M_{12}: \ \text{Mutual Inductance (H)}$$

Coaxial Inductor



$$a < \rho < b$$

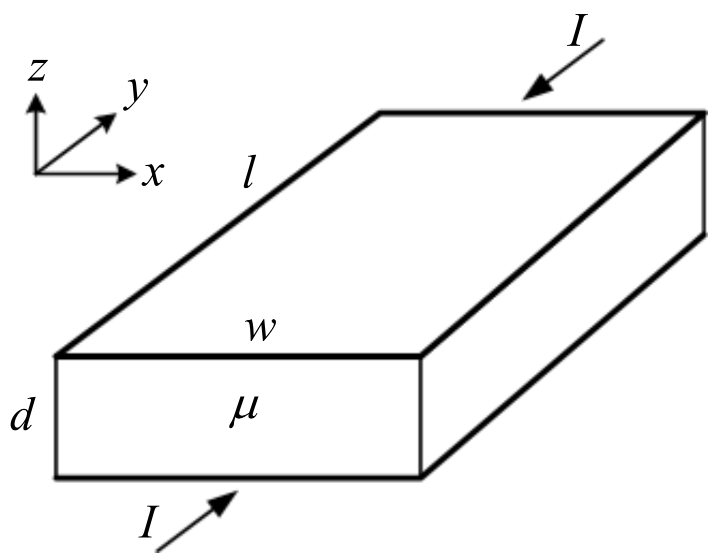
$$\vec{H} = \frac{I}{2\pi\rho}\vec{a}_\phi$$

$$\vec{B} = \mu\vec{H} = \frac{\mu I}{2\pi\rho}\vec{a}_\phi$$

$$\Phi = \int_S \vec{B} \cdot d\vec{S} = \frac{\mu l I}{2\pi}\ln\left(\frac{b}{a}\right)$$

$$L = \frac{N\Phi}{I} = \frac{\mu l}{2\pi}\ln\left(\frac{b}{a}\right)$$

Parallel Plate Inductor



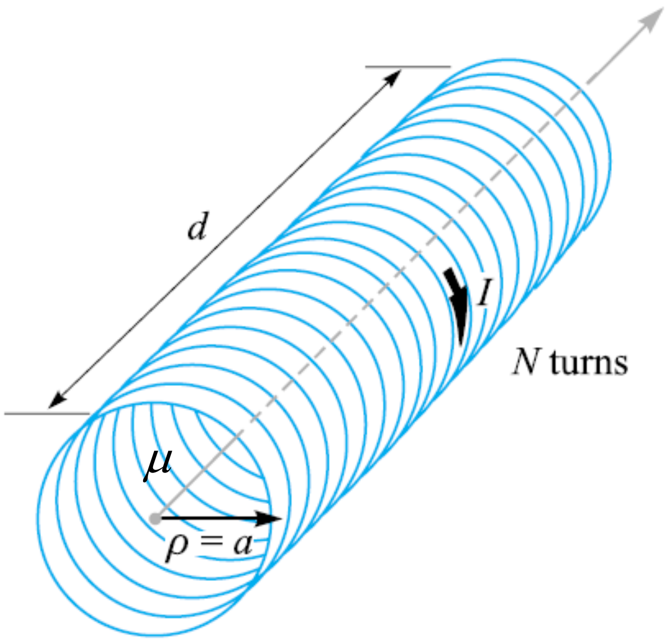
$$\vec{H} = \frac{I}{w}\vec{a}_x$$

$$\vec{B} = \mu\vec{H} = \frac{\mu I}{w}\vec{a}_x$$

$$\Phi = \int_S \vec{B}\cdot d\vec{S} = \frac{\mu d l I}{w}$$

$$L = \frac{N\Phi}{I} = \frac{\mu d l}{w}$$

Solenoid Inductor



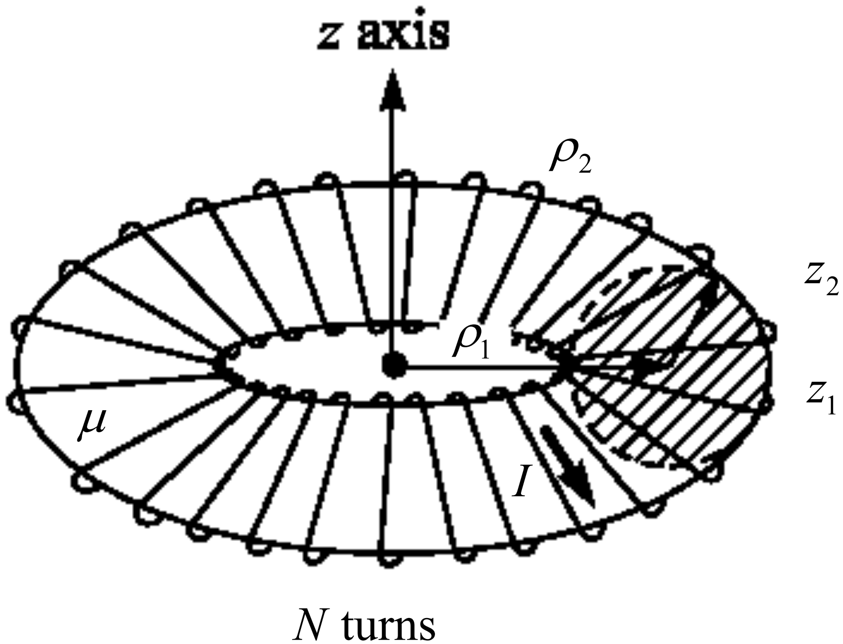
$$\vec{H} = \frac{NI}{d}\vec{a}_z$$

$$\vec{B} = \mu\vec{H} = \frac{\mu NI}{d}\vec{a}_z$$

$$\Phi = \int_S \vec{B}\cdot d\vec{S} = \frac{\pi\mu a^2 NI}{d}$$

$$L = \frac{N\Phi}{I} = \frac{\pi\mu a^2 N^2}{d}$$

Toroid Inductor



$$\vec{H} = \frac{NI}{2\pi\rho}\vec{a}_\phi$$

$$\vec{B} = \mu\vec{H} = \frac{\mu NI}{2\pi\rho}\vec{a}_\phi$$

$$\Phi = \int_S \vec{B}\cdot d\vec{S} = \frac{\mu NI}{2\pi}(z_2 - z_1)\ln\left(\frac{\rho_2}{\rho_1}\right)$$

$$L = \frac{N\Phi}{I} = \frac{\mu N^2}{2\pi}(z_2 - z_1)\ln\left(\frac{\rho_2}{\rho_1}\right)$$

Maxwell Equations (1)

- Time Invariant

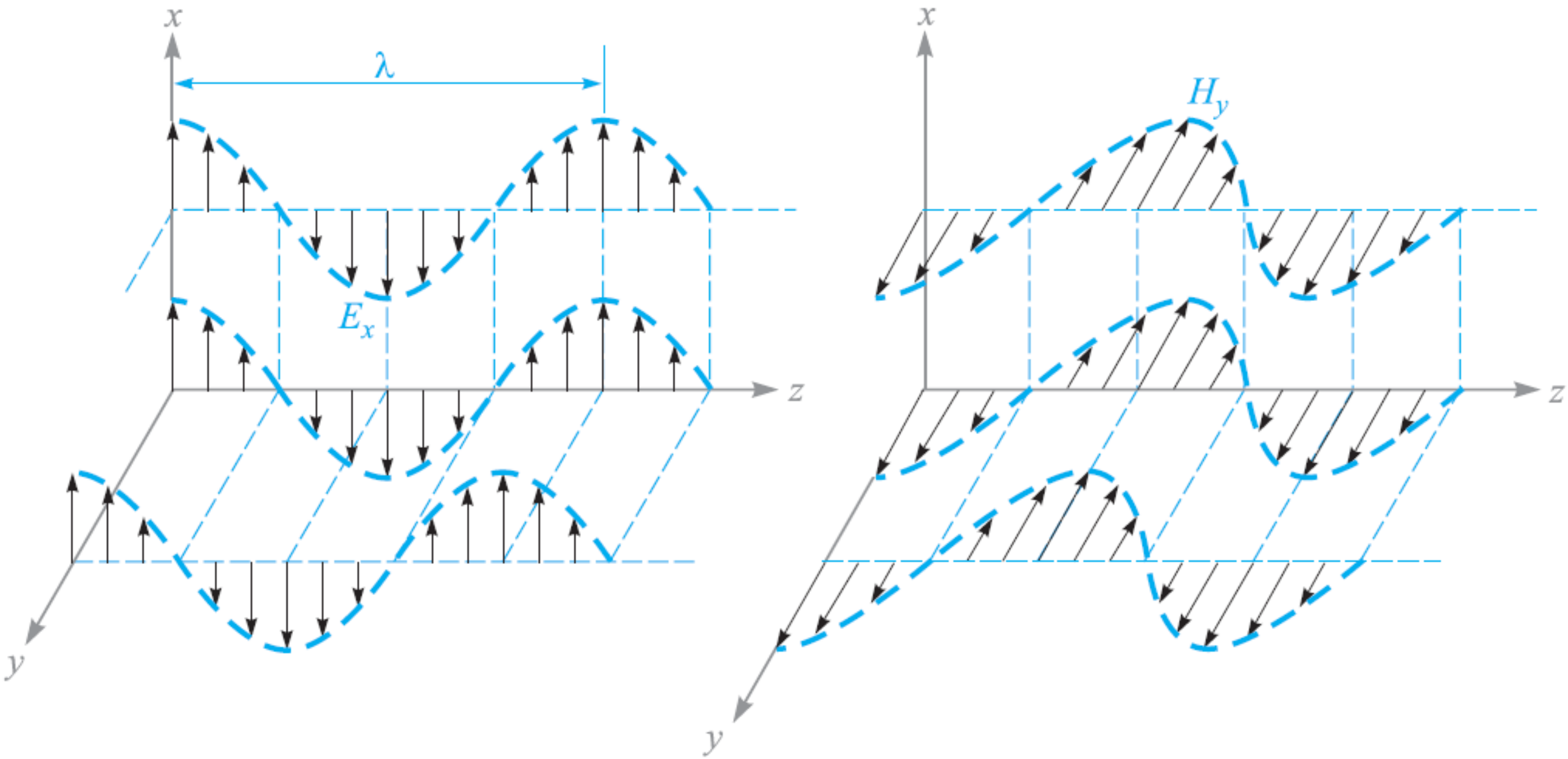
Differential Form	Integral Form
$\nabla \cdot \vec{D} = \rho_v$	$\oint_S \vec{D} \cdot d\vec{S} = Q$
$\nabla \times \vec{E} = 0$	$\oint \vec{E} \cdot d\vec{L} = 0$
$\nabla \times \vec{H} = \vec{J}$	$\oint \vec{H} \cdot d\vec{L} = I$
$\nabla \cdot \vec{B} = 0$	$\oint_S \vec{B} \cdot d\vec{S} = 0$

Maxwell Equations (2)

- Time Varying

Differential Form	Integral Form
$\nabla \cdot \vec{D} = \rho_v$	$\oint_S \vec{D} \cdot d\vec{S} = Q$
$\nabla \times \vec{E} = -\dfrac{\partial \vec{B}}{\partial t}$	$\oint \vec{E} \cdot d\vec{L} = -\int_S \dfrac{\partial \vec{B}}{\partial t} \cdot d\vec{S}$
$\nabla \times \vec{H} = \vec{J} + \dfrac{\partial \vec{D}}{\partial t}$	$\oint \vec{H} \cdot d\vec{L} = I + \int_S \dfrac{\partial \vec{D}}{\partial t} \cdot d\vec{S}$
$\nabla \cdot \vec{B} = 0$	$\oint_S \vec{B} \cdot d\vec{S} = 0$

Plane Wave (1)



$$\text{Direction of } \vec{E} \perp \text{Direction of } \vec{H}$$

$$\text{Direction of } \vec{v} = \text{Direction of } \vec{E} \times \vec{H}$$

Plane Wave (2)

$$E = \eta H \qquad \eta = \sqrt{\frac{\mu}{\varepsilon}} \qquad v = \frac{1}{\sqrt{\varepsilon\mu}}$$

E : Electric Field Intensity (V/m)

H : Magnetic Field Intensity (A/m)

ε : Permittivity, $\varepsilon_0 = \dfrac{1}{36\pi} \times 10^{-9}$ H/m for Free Space

μ : Permeability, $\mu_0 = 4\pi \times 10^{-7}$ H/m for Free Space

η : Intrinsic Impedance, $\eta_0 \approx 120\pi\ \Omega$ for Free Space

v : Velocity, $c \approx 3 \times 10^8$ m/s for Free space

Example

Solenoid Inductor 2 ชุด อยู่ใกล้กันโดยมีแกนกลางเดียวกันอยู่ในแกน z กำหนดให้ $I_1 = 2$ mA ไหลในทิศทาง $\vec{a}_\phi$, $d = 5$ cm, $a = 2$ cm $N_1 = 50$ รอบ, $N_2 = 100$ รอบ $\mu_r = 10$ และฟลักซ์แม่เหล็กไปยัง Solenoid Inductor ชุดที่ 2 ได้ 80% จงหา $\vec{H}_1$, $\vec{B}_1$, Φ_1, L_1, Φ_{12}, M_{12}

Solution (1)

หา $\vec{H}_1$ ได้

$$\vec{H}_1 = \frac{N_1 I_1}{d}\vec{a}_z = \frac{50\times 2\times 10^{-3}}{5\times 10^{-2}}\vec{a}_z = 2.00\vec{a}_z \ \ \text{A/m}$$

หา $\vec{B}_1$ ได้

$$\vec{B}_1 = \mu\vec{H}_1 = 10\times 4\pi\times 10^{-7}\times 2\vec{a}_z = 25.13\vec{a}_z \ \ \mu\text{T}$$

หา Φ_1 ได้

$$\Phi_1 = \int_S \vec{B}_1\cdot d\vec{S} = \pi a^2 B_1 = \pi\times\left(2\times 10^{-2}\right)^2\times 25.13\times 10^{-6} = 31.58 \ \ \text{nWb}$$

Solution (2)

หา L_1 ได้

$$L_1 = \frac{N_1\Phi_1}{I_1} = \frac{50\times 31.58\times 10^{-9}}{2\times 10^{-3}} = 789.50\ \mu\text{H}$$

หา Φ_{12} ได้

$$\Phi_{12} = \Phi_1 \times \frac{80}{100} = 31.58\times 10^{-9} \times \frac{80}{100} = 25.26\ \text{nWb}$$

หา M_{12} ได้

$$M_{12} = \frac{N_2\Phi_{12}}{I_1} = \frac{100\times 25.26\times 10^{-9}}{2\times 10^{-3}} = 1.26\ \text{mH}$$

Quiz 10

Solenoid Inductor 2 ชุด อยู่ใกล้กันโดยมีแกนกลางเดียวกันอยู่ในแกน z กำหนดให้ $I_1 = 5$ mA ไหลในทิศทาง $\vec{a}_\phi$, $d = 2$ cm, $a = 1$ cm $N_1 = 80$ รอบ, $N_2 = 120$ รอบ $\mu_r = 4$ และฟลักซ์แม่เหล็กไปยัง Solenoid Inductor ชุดที่ 2 ได้ 90% จงหา $\vec{H}_1$, $\vec{B}_1$, Φ_1, L_1, Φ_{12}, M_{12}

$\vec{H}_1 = 20.00\vec{a}_z$ A/m, $\vec{B}_1 = 100.53\vec{a}_z$ μT, $\Phi_1 = 31.58$ nWb, $L_1 = 505.28$ μH, $\Phi_{12} = 28.42$ nWb, $M_{12} = 682.08$ μH

Assignment 10

Solenoid Inductor 2 ชุด อยู่ใกล้กันโดยมีแกนกลางเดียวกันอยู่ในแกน z กำหนดให้ $I_1 = 3$ mA ไหลในทิศทาง $\vec{a}_\phi$, $d = 4$ cm, $a = 3$ cm $N_1 = 60$ รอบ, $N_2 = 80$ รอบ $\mu_r = 5$ และฟลักซ์แม่เหล็กไปยัง Solenoid Inductor ชุดที่ 2 ได้ 85% จงหา $\vec{H}_1$, $\vec{B}_1$, Φ_1, L_1, Φ_{12}, M_{12}

$\vec{H}_1 = 4.50\vec{a}_z$ A/m, $\vec{B}_1 = 28.27\vec{a}_z$ μT, $\Phi_1 = 79.93$ nWb, $L_1 = 1.60$ mH, $\Phi_{12} = 67.94$ nWb, $M_{12} = 1.81$ mH

$$\vec{H}_1 = \frac{N_1 I_1}{d}\vec{a}_z$$

$$= \frac{60 \times 3\times10^{-3}}{4\times10^{-2}}\vec{a}_z$$

$$\vec{H}_1 = 4.50\,\vec{a}_z \text{ A/m}$$

$$\vec{B}_1 = \mu \vec{H}_1$$

$$= 5\times 4\pi\times10^{-7}\times 4.50\,\vec{a}_z$$

$$\vec{B}_1 = 28.27\,\vec{a}_z\ \mu T$$

$$\phi_1 = \int_S \vec{B}_1\cdot d\vec{S} = \pi a^2 \vec{B}_1$$

$$= \pi\times(3\times10^{-2})^2\times 28.27\,\vec{a}_z\ \mu$$

$$\phi_1 = 79.93 \text{ n Wb}$$

$$L_1 = \frac{N_1\phi_1}{I_1}$$

$$= \frac{60\times 79.93n}{3\times10^{-3}}$$

$$L_1 = 1.60 \text{ mH}$$

$$\phi_{12} = \phi_1 \times eff\%$$

$$= 79.93n\times\frac{85}{100}$$

$$\phi_{12} = 67.94 \text{ n Wb}$$

$$M_{12} = \frac{N_2\phi_{12}}{I_1}$$

$$= \frac{80\times 67.94n}{3\times10^{-3}}$$

$$M_{12} = 1.81 \text{ mH}$$

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