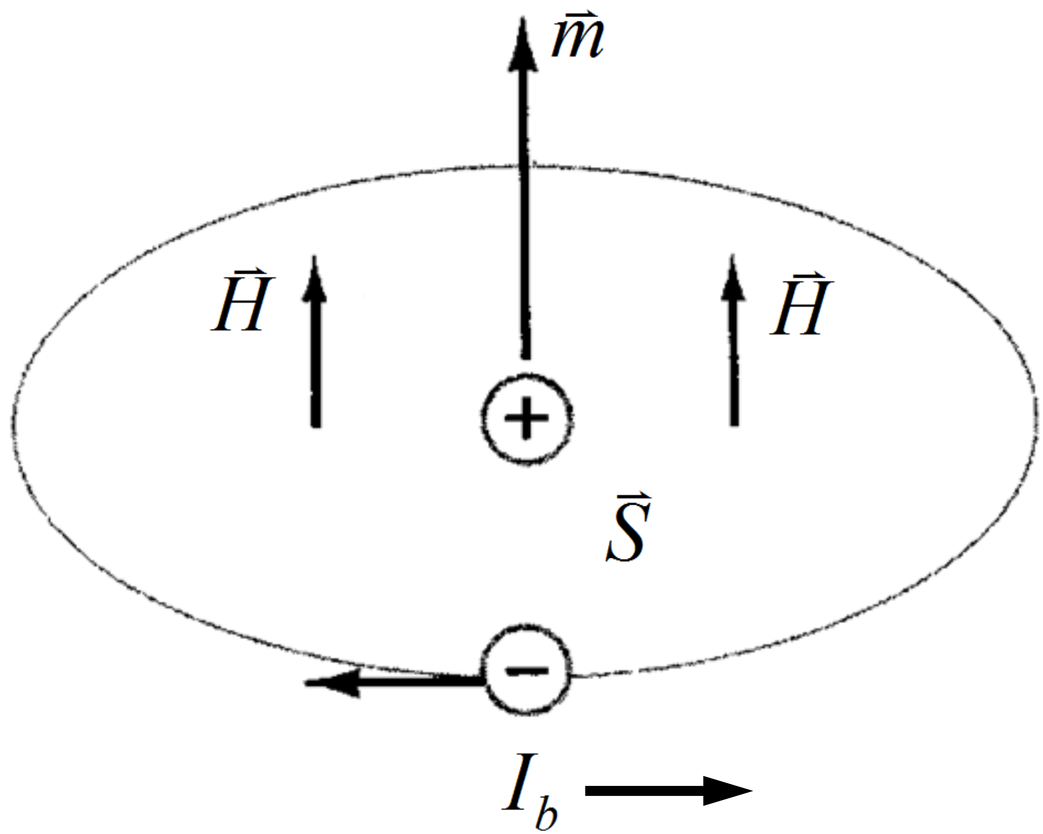
Magnetic Material

Property of Magnetic Material (1)



Property of Magnetic Material (2)

- Magnetic Dipole Moment

$$\vec{m} = I_b \vec{S}$$

$\vec{m}$: Magnetic Dipole Moment $(\mathrm{A} \cdot \mathrm{m}^2)$

I_b : Bound Current (A)

$\vec{S}$: Enclosed Area (m^2)

Property of Magnetic Material (3)

- Total Magnetic Dipole Moment

$$\vec{m}_{total} = \sum_{i=1}^{n} \vec{m}_i$$

n : Number of Magnetic Dipole moment

- Magnetization

$$\vec{M} = \lim_{v \to 0} \frac{1}{v} \vec{m}_{total}$$

$\vec{M}$: Magnetization (A/m)

v : Volume (m^3)

Property of Magnetic Material (6)

- Permeability

$$\mu = \mu_r \mu_0$$

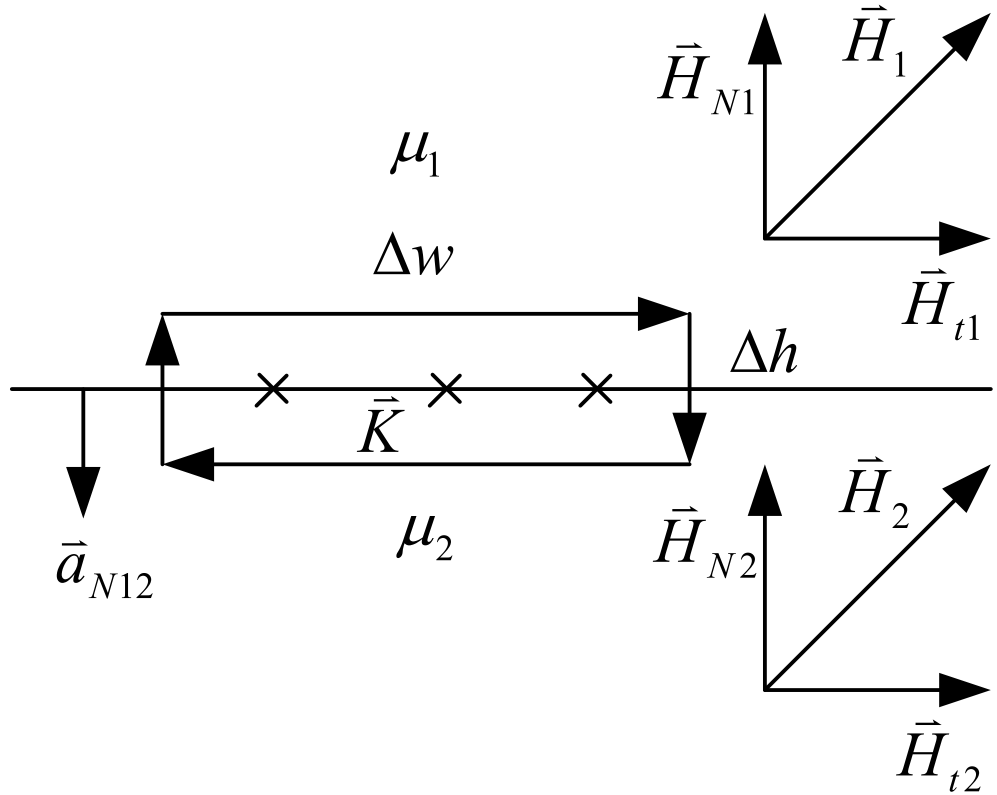
μ_r : Relative Permeability

μ : Permeability (F/m)

$$\boxed{\vec{B} = \mu_r \mu_0 \vec{H} = \mu \vec{H}}$$

Magnetic Boundary Condition (1)

- Tangent



Magnetic Boundary Condition (2)

กำหนดให้ $\Delta h \rightarrow 0$ จะได้

$$\oint \vec{H} \cdot d\vec{L} = I$$

$$H_{t1}\Delta w - H_{t2}\Delta w = I$$

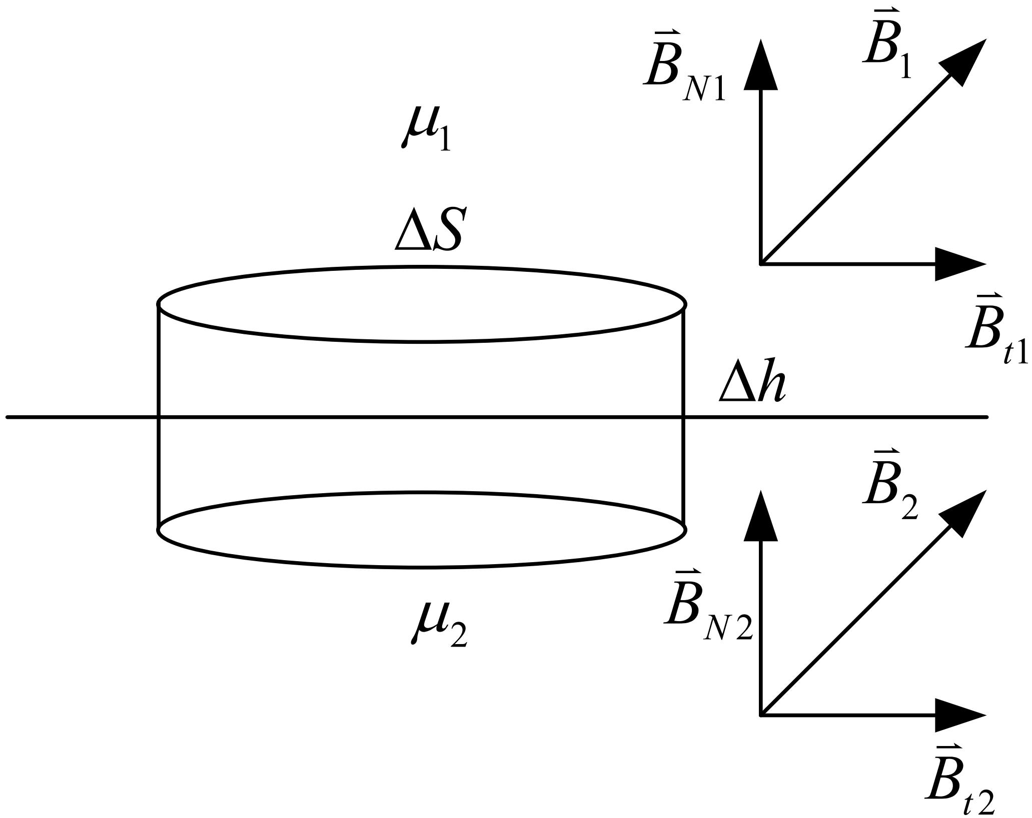
$$H_{t1} - H_{t2} = \frac{I}{\Delta w} = K$$

$$\boxed{\vec{H}_{t1} - \vec{H}_{t2} = \vec{a}_{N12} \times \vec{K}}$$

$\vec{K}$: Surface Current (A/m)

Magnetic Boundary Condition (3)

- Normal



Magnetic Boundary Condition (4)

กำหนดให้ $\Delta h \to 0$ จะได้

$$\oint_S \vec{B} \cdot d\vec{S} = 0$$

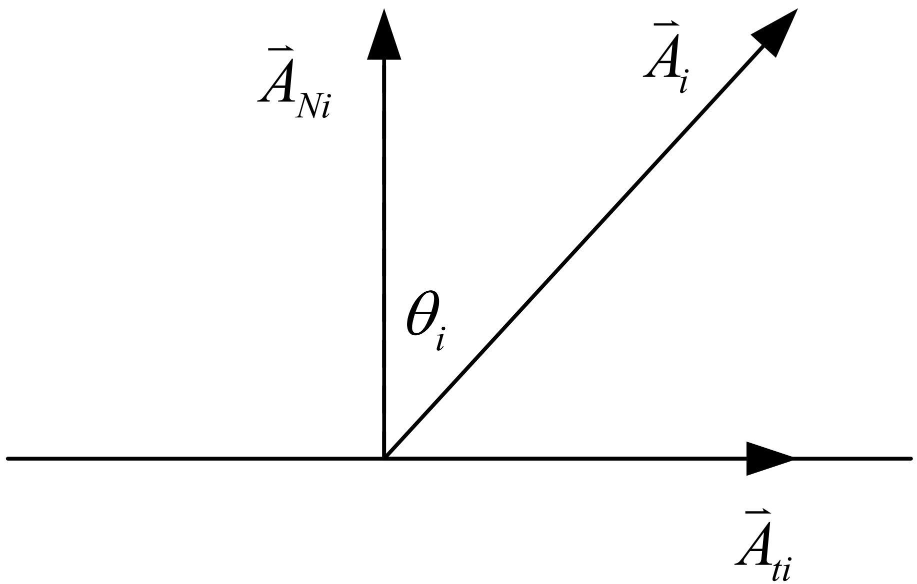
$$B_{N1}\Delta S - B_{N2}\Delta S = 0$$

$$B_{N1} = B_{N2}$$

$$\boxed{\vec{B}_{N1} = \vec{B}_{N2}}$$

Magnetic Boundary Condition (5)

- Angle

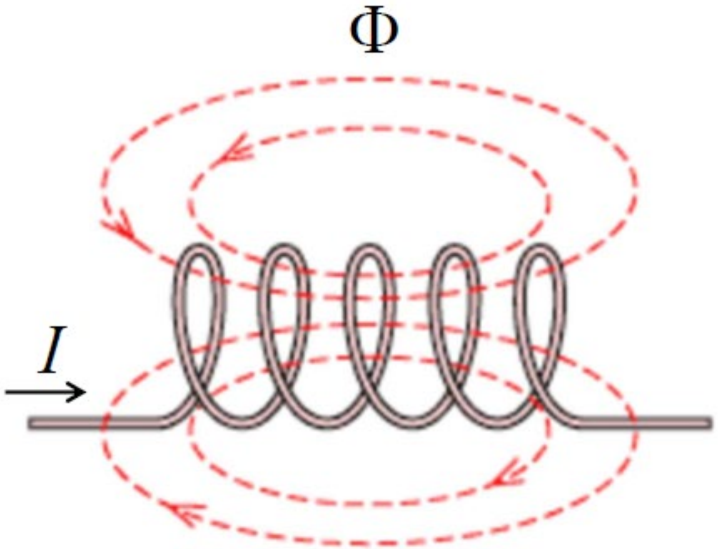


$$\boxed{\theta_i = \tan^{-1}\left(\frac{A_{ti}}{A_{Ni}}\right)}$$

A is H or B

i is 1 or 2

Inductance



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

L : Inductance (H)

Maxwell Equations

- Time Invariant

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

Example

กำหนดให้บริเวณที่ 1 $(z > 0)$ มี $\mu_1 = 5$ μH/m และบริเวณที่ 2 $(z < 0)$ มี $\mu_2 = 4$ μH/m มี $\vec{B}_1 = 4\vec{a}_x - \vec{a}_y + \vec{a}_z$ mT และ $\vec{K} = -200\vec{a}_x + 200\vec{a}_y$ A/m บนพื้นผิว $z = 0$ จงหา $\vec{H}_1, \vec{H}_2, \vec{B}_2, \theta_1$ และ θ_2

Solution (1)

หา $\vec{H}_1$ ได้

$$\vec{H}_1 = \frac{1}{\mu_1}\vec{B}_1$$

$$= \frac{1}{5\times10^{-6}}\left(4\vec{a}_x - \vec{a}_y + \vec{a}_z\right)\times10^{-3}$$

$$= 800\vec{a}_x - 200\vec{a}_y + 200\vec{a}_z \text{ A/m} \qquad \#$$

พิจารณาในแนวสัมผัส

$$\vec{H}_{t1} = 800\vec{a}_x - 200\vec{a}_y \text{ A/m}$$

$$\vec{a}_{N12} = -\vec{a}_z$$

Solution (2)

$$\vec{H}_{t1} - \vec{H}_{t2} = \vec{a}_{N12} \times \vec{K}$$

$$800\vec{a}_x - 200\vec{a}_y - \vec{H}_{t2} = -\vec{a}_z \times \left(-200\vec{a}_x + 200\vec{a}_y\right)$$

$$800\vec{a}_x - 200\vec{a}_y - \vec{H}_{t2} = 200\vec{a}_x + 200\vec{a}_y$$

$$\vec{H}_{t2} = 600\vec{a}_x - 400\vec{a}_y \text{ A/m}$$

$$\begin{aligned}\vec{B}_{t2} &= \mu_2 \vec{H}_{t2} \\ &= 4\times10^{-6} \times \left(600\vec{a}_x - 400\vec{a}_y\right) \\ &= 2.4\vec{a}_x - 1.6\vec{a}_y \text{ mT}\end{aligned}$$

Solution (3)

พิจารณาในแนวตั้งฉาก

$$\vec{B}_{N1} = \vec{a}_z \text{ mT}$$

$$\begin{aligned} \vec{B}_{N2} &= \vec{B}_{N1} \\ &= \vec{a}_z \text{ mT} \end{aligned}$$

$$\begin{aligned} \vec{H}_{N2} &= \frac{1}{\mu_2} \vec{B}_{N_2} \\ &= \frac{1}{4 \times 10^{-6}} \vec{a}_z \times 10^{-3} \\ &= 250 \vec{a}_z \text{ A/m} \end{aligned}$$

Solution (4)

หา $\vec{H}_2$ และ $\vec{B}_2$ ได้

$$\vec{H}_2 = \vec{H}_{t2} + \vec{H}_{N2}$$
$$= 600\vec{a}_x - 400\vec{a}_y + 250\vec{a}_z \text{ A/m} \quad \#$$

$$\vec{B}_2 = \vec{B}_{t2} + \vec{B}_{N2}$$
$$= 2.4\vec{a}_x - 1.6\vec{a}_y + \vec{a}_z \text{ mT} \quad \#$$

Solution (5)

หา θ_1 และ θ_2 ได้

$$\theta_1 = \tan^{-1}\left(\frac{B_{t1}}{B_{N1}}\right) = \tan^{-1}\left(\frac{\sqrt{4^2+(-1)^2}}{1}\right) = 76.37^\circ \qquad \#$$

$$\theta_2 = \tan^{-1}\left(\frac{B_{t2}}{B_{N2}}\right) = \tan^{-1}\left(\frac{\sqrt{2.4^2+(-1.6)^2}}{1}\right) = 70.88^\circ \qquad \#$$

Quiz 9

กำหนดให้บริเวณที่ 1 $(x<0)$ มี $\mu_1 = 10$ μH/m และบริเวณที่ 2 $(x>0)$ มี $\mu_2 = 5$ μH/m มี $\vec{B}_2 = -2\vec{a}_x + 4\vec{a}_y - \vec{a}_z$ mT และ $\vec{K} = -200\vec{a}_y + 200\vec{a}_z$ A/m บนพื้นผิว $x = 0$ จงหา $\vec{H}_1$, $\vec{H}_2$, $\vec{B}_1$, θ_1 และ θ_2

$\vec{H}_2 = -400\vec{a}_x + 800\vec{a}_y - 200\vec{a}_z$ A/m,

$\vec{H}_1 = -200\vec{a}_x + 600\vec{a}_y - 400\vec{a}_z$ A/m,

$\vec{B}_1 = -2\vec{a}_x + 6\vec{a}_y - 4\vec{a}_z$ mT,

$\theta_1 = 74.50^\circ$,

$\theta_2 = 64.12^\circ$

Assignment 9

กำหนดให้บริเวณที่ 1 ($y<0$) มี $\mu_1 = 2\ \mu$H/m และบริเวณที่ 2 ($y>0$) มี $\mu_2 = 3\ \mu$H/m มีความเข้มสนามแม่เหล็ก $\vec{H}_2 = -300\vec{a}_x + 200\vec{a}_y + 200\vec{a}_z$ A/m และกระแสเชิงพื้นผิว $\vec{K} = 300\vec{a}_x - 100\vec{a}_z$ A/m บนพื้นผิว $y=0$ จงหา $\vec{H}_1$, $\vec{B}_1$, $\vec{B}_2$, θ_1 และ θ_2

$$\vec{B}_2 = -900\vec{a}_x + 600\vec{a}_y + 600\vec{a}_z\ \mu\text{T},$$
$$\vec{H}_1 = -400\vec{a}_x + 300\vec{a}_y - 100\vec{a}_z\ \text{A/m},$$
$$\vec{B}_1 = -800\vec{a}_x + 600\vec{a}_y - 200\vec{a}_z\ \mu\text{T},$$
$$\theta_1 = 53.96^\circ,$$
$$\theta_2 = 60.98^\circ$$

$$\vec{B}_2 = \mu_2 \vec{H}_2$$
$$= 3\times10^{-6}(-300\vec{a}_x + 200\vec{a}_y + 200\vec{a}_z)$$
$$\vec{B}_2 = -900\vec{a}_x + 600\vec{a}_y + 600\vec{a}_z \ \mu T$$

$$H_{t2} = -300\vec{a}_x + 200\vec{a}_z \ A/m$$
$$\vec{a}_{N12} = -\vec{a}_y$$
$$\vec{H}_{t1} - \vec{H}_{t2} = \vec{a}_{n12} \times \vec{K}$$
$$\vec{H}_{t1} + 300\vec{a}_x - 200\vec{a}_z = -\vec{a}_y(300\vec{a}_x - 100\vec{a}_z)$$
$$\vec{H}_{t1} + 300\vec{a}_x - 200\vec{a}_z = -100\vec{a}_x - 300\vec{a}_z$$
$$\vec{H}_{t1} = -400\vec{a}_x - 100\vec{a}_z \ A/m$$
$$B_{t1} = \mu_1 H_{t1}$$
$$B_{t1} = 2\times10^{-6}(-400\vec{a}_x - 100\vec{a}_z)$$
$$B_{t1} = -800\vec{a}_x - 200\vec{a}_z \ \mu T$$
$$B_{N_2} = 600\vec{a}_y \ \mu T$$
$$B_{N2} = B_{N1} = 600\vec{a}_y \ \mu T$$

$$\vec{H}_{N1} = \frac{1}{\mu_1} B_{N1}$$
$$= \frac{1}{2\times10^{-6}}(600\vec{a}_y \times 10^{-6})$$
$$\vec{H}_{N1} = 300\vec{a}_y \ A/m$$

$$\vec{H}_1 = \vec{H}_{t1} + \vec{H}_{N1}$$
$$\vec{H}_1 = -400\vec{a}_x + 300\vec{a}_y - 100\vec{a}_z \ A/m$$

$$\vec{B}_1 = \vec{B}_{t_1} + \vec{B}_{N_1}$$
$$\vec{B}_1 = -800\vec{a}_x + 600\vec{a}_y - 200\vec{a}_z$$

$$\theta_1 = \tan^{-1}\left(\frac{B_{t_1}}{B_{N1}}\right)$$
$$= \tan^{-1}\left(\frac{\sqrt{(-800)^2+(-200)^2}}{600}\right)$$
$$\theta_1 = 53.96^\circ$$

$$\theta_2 = \tan^{-1}\left(\frac{B_{t_2}}{B_{N2}}\right)$$
$$= \tan^{-1}\left(\frac{\sqrt{(-900)^2+(600)^2}}{600}\right)$$
$$\theta_2 = 60.98^\circ$$

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