Magnetostatic Fields & Currents

EMPossible
https://empossible.net/

Governing Eqs.

Conditions

1. $\omega = 0$
2. Size $\ll \lambda$

$\nabla \times \vec{H} = \vec{J}$

$\nabla \bullet \vec{B} = 0$

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

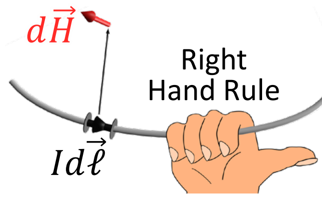
Lorentz Force Law

$\vec{F} = Q\vec{E} + Q\left(\vec{u} \times \vec{B}\right)$

Magnetic Fields Around Current Elements

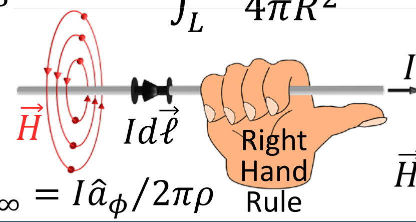
Biot-Savart Law

$$d\vec{H} = \frac{I d\vec{\ell} \times \hat{a}_R}{4\pi R^2} = \frac{I d\vec{\ell} \times \vec{R}}{4\pi \left|\vec{R}\right|^3}$$



Line Current

$$\vec{H} = \int_L \frac{I d\vec{\ell} \times \hat{a}_R}{4\pi R^2}$$

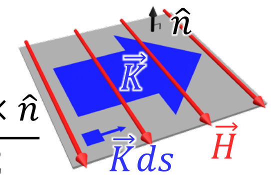


$$\vec{H}_\infty = I\hat{a}_\phi / 2\pi\rho$$

Surrface Current

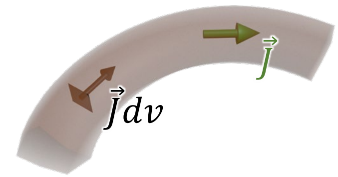
$$\vec{H} = \iint_S \frac{\vec{K} ds \times \hat{a}_R}{4\pi R^2}$$

$$\vec{H}_\infty = \frac{\vec{K} \times \hat{n}}{2}$$

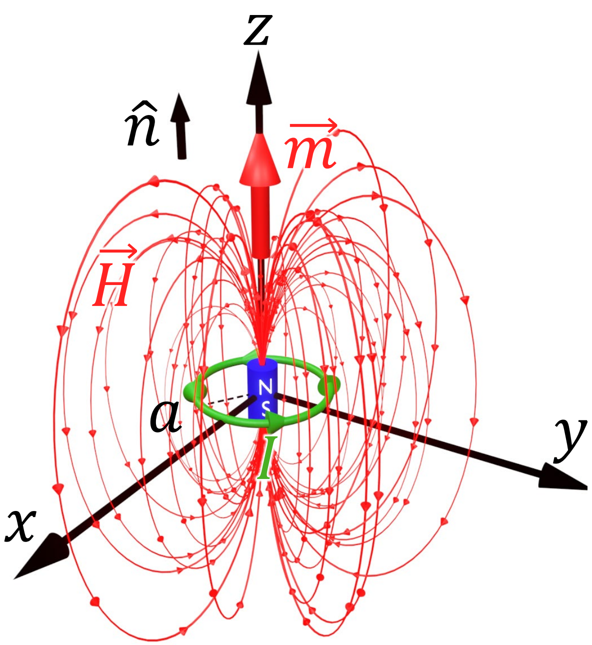


Volume Current

$$\vec{H} = \iiint_V \frac{\vec{J} dv \times \hat{a}_R}{4\pi R^2}$$



Magnetic Dipole



Magnetic Field

$$\vec{H} = \frac{|\vec{m}|}{4\pi r^3}\left(2\cos\theta\,\hat{a}_r + \sin\theta\,\hat{a}_\theta\right)$$

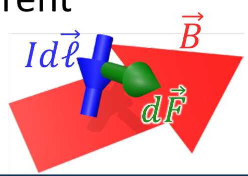
Magnetic Dipole Moment

$$\vec{m} = \pi a^2 I \hat{a}_n$$

Force Magnetic Fields Put on Current Elements

Differential Current

$$d\vec{F} = I d\vec{\ell} \times \vec{B}$$



Line Current

$$\vec{F} = \int_L I d\vec{\ell} \times \vec{B}$$

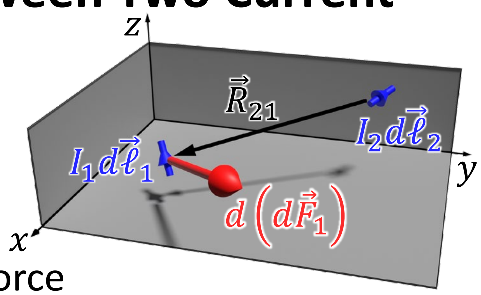
Surrface Current

$$\vec{H} = \iint_S \vec{K} ds \times \vec{B}$$

Volume Current

$$\vec{H} = \iiint_V \vec{J} dv \times \vec{B}$$

Force Between Two Current Elements



Differential Force

$$d\left(d\vec{F}_1\right) = \frac{\mu}{4\pi}\frac{\left(I_1 d\vec{\ell}_1\right) \times \left(I_2 d\vec{\ell}_2\right) \times \hat{a}_{21}}{R_{21}^2}$$

Total Force

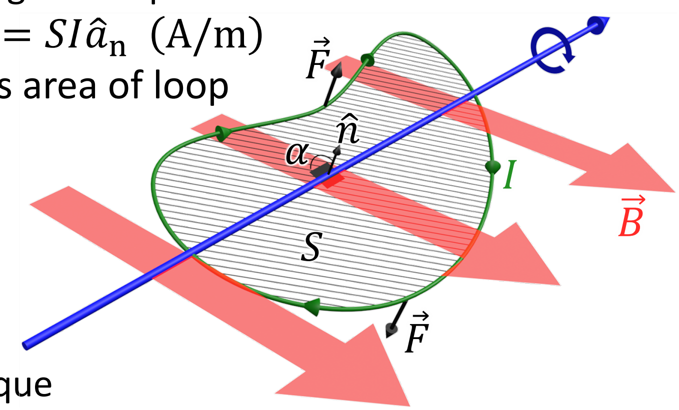
$$\vec{F}_1 = \frac{\mu I_1 I_2}{4\pi}\int_{L_1}\int_{L_2}\frac{d\vec{\ell}_1 \times d\vec{\ell}_2 \times \hat{a}_{21}}{R_{21}^2}$$

Magnetic Torque & Moment

Magnetic Dipole Moment

$\vec{m} = SI\hat{a}_n$ (A/m)

S is area of loop



Torque

$$\vec{T} = \vec{m} \times \vec{B}$$

Acts to reduce α and put $\vec{m}$ and $\vec{B}$ in same direction.

Angle Dependence

$$\left|\vec{T}\right| = BIS \sin\alpha$$