# Vector Potential

$$\boldsymbol{B} = \boldsymbol{\nabla} \times \boldsymbol{A}$$

From current density $\boldsymbol{J}_{tot}(\boldsymbol{r}')$:

$$\boldsymbol{A}(\boldsymbol{r}) = \frac{\mu_0}{4\pi} \int \frac{\boldsymbol{J}_{tot}(\boldsymbol{r}')}{R}\, dv'$$

From current line:

$$\boldsymbol{A}(\boldsymbol{r}) = \frac{\mu_0}{4\pi} \int \frac{I\, d\boldsymbol{l}'}{R}$$

From long straight current path:

$$\boldsymbol{A} = \frac{\mu_0 I}{2\pi} \ln\left(\frac{1}{r}\right) \boldsymbol{e}_z$$

From point dipole :

$$\boldsymbol{A} = \frac{\mu_0}{4\pi} \frac{\boldsymbol{m} \times \boldsymbol{r}}{r^3}$$

### Magnetic Flow

$$\Phi = \int \boldsymbol{B} \cdot \boldsymbol{e}_n\, dS = \oint \boldsymbol{A} \cdot dl$$

### Linked Flow

$$\Lambda = N\Phi$$

### Self-Inductance and Mutual Inductance

$$\Lambda_1 = L_1 I_1 + M I_2$$
$$\Lambda_2 = L_2 I_2 + M I_1$$

### Magnetic Field Strength

Amperes Law:

$$\oint \boldsymbol{H} \cdot d\ell = \int \boldsymbol{J} \cdot \boldsymbol{e}_n\, dS = I_{\text{inside}}$$

Connection between magnetization $\boldsymbol{M}, \boldsymbol{B}$ and $\boldsymbol{H}$:

$$\begin{cases} \boldsymbol{B} = \mu_0(\boldsymbol{H} + \boldsymbol{M}) & \text{(holds generally)} \\ \boldsymbol{B} = \mu_r \mu_0 \boldsymbol{H} \end{cases}$$

### Equivalent Current Density

$$\boldsymbol{J}_m = \boldsymbol{\nabla} \times \boldsymbol{M} \qquad \text{volume current density}$$

$$\boldsymbol{J}_m = \boldsymbol{\nabla} \times \boldsymbol{M} \qquad \text{surface current density}$$

### Boundary Conditions

$$\begin{cases} \boldsymbol{e}_{n2} \times (\boldsymbol{H}_1 - H_2) = \boldsymbol{J}_s \\ \boldsymbol{B}_n \text{ Continuous} \end{cases}$$

### Scalar Potential

From magnetic dipole $\boldsymbol{m}$:

$$V_m = \frac{1}{4\pi} \frac{\boldsymbol{m} \cdot \boldsymbol{e}_R}{R^2}$$

### Magnetic Pole Density

$$\begin{cases} \rho_m = -\boldsymbol{\nabla} \cdot \boldsymbol{M} & \text{volume pole density} \\ \rho_{m,s} = e_{n1} \cdot (\boldsymbol{M}_1 - \boldsymbol{M}_2) & \text{surface pole density} \end{cases}$$

### Magnetic Force Law

$$d\boldsymbol{F}_m = I d\boldsymbol{l} \times \boldsymbol{B}$$

### Magetic moment for current loop

$$\boldsymbol{m} = \int I \boldsymbol{e}_n\, dS$$

### Torque on Magnetic Moment

$$\boldsymbol{T}_m = \boldsymbol{m} \times \boldsymbol{B}$$

### Maxwell's Voltage

$$|\boldsymbol{T}| = \frac{1}{2} \boldsymbol{B} \cdot \boldsymbol{H} \qquad \boldsymbol{B} \text{ is a bisector to } \boldsymbol{e}_n \text{ and } \boldsymbol{T}$$

### Magnetic Energy

$$W_m = \frac{1}{2} \int \boldsymbol{J} \cdot \boldsymbol{A} dv = \frac{1}{2} \int \boldsymbol{B} \cdot \boldsymbol{H} dv = \frac{1}{2} \sum_i \sum_j L_{ij} I_i I_j$$

Two coils:

$$W_m = \frac{1}{2} L_1 I_1^2 + \frac{1}{2} L_2 I_2^2 + M I_1 I_2$$

**Reluctance**

$$R = \frac{1}{\mu_r \mu_0 S}$$