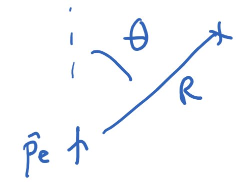
ELECTRIC DIPOLE



$$V = \frac{p_e \cos\theta}{4\pi\varepsilon_0 R^2}$$

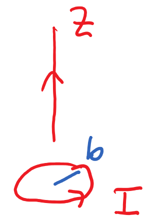
$$\bar{E} = -\nabla V = -\bar{a}_R \frac{\partial}{\partial R} V - \frac{1}{R}\bar{a}_\theta \frac{\partial}{\partial \theta} V$$

$$= \frac{p_e}{4\pi\varepsilon_0 R^3}\left(2\cos\theta\, \bar{a}_R + \sin\theta\, \bar{a}_\theta\right)$$

+z-axis

$$\frac{p_e}{4\pi\varepsilon_0 z^3} 2\bar{a}_z$$

MAGNETIC DIPOLE (+z-axis)



$$\bar{H} = \frac{\mu_0 I \pi b^2}{4\pi \mu_0 z^3} 2\bar{a}_z$$

$$p_m = \mu_0 \overbrace{I\pi b^2}^{m}$$

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

$$\bar{B} = \mu_0 \bar{H}$$

$\mu_0 = 4\pi \cdot 10^{-7} \frac{Vs}{Am}$

OHM'S LAW

$$\bar{J} = \sigma \bar{E}$$

σ: CONDUCTIVITY

$S/m = \frac{A}{Vm}$

$$\varepsilon = \varepsilon_r \varepsilon_0$$

$\varepsilon_0 = 8.854 \cdot 10^{-12} \frac{As}{Vm}$

MAGNETIC MATERIALS

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

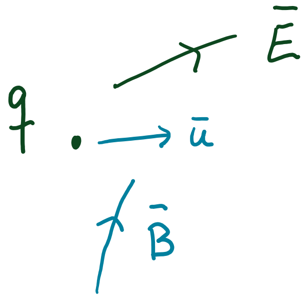
$\mu = \mu_r \mu_0$

RELATIVE PERMEABILITY $\mu_r = 1 + \chi_m$

$$\bar{D} = \varepsilon_0 \bar{E}$$

$$\bar{J} = \sigma \bar{E}$$

$$w_e = \frac{1}{2} \bar{E} \cdot \bar{D} = \frac{1}{2} \varepsilon_0 E^2$$



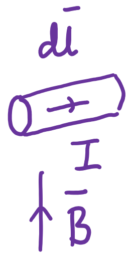
$$\bar{F}_e = q\bar{E}$$

$$\bar{F}_m = q\,\bar{u}\times\bar{B}$$

$$As\,\frac{V}{m} = \frac{Ws}{m} = \frac{J}{m} = N$$

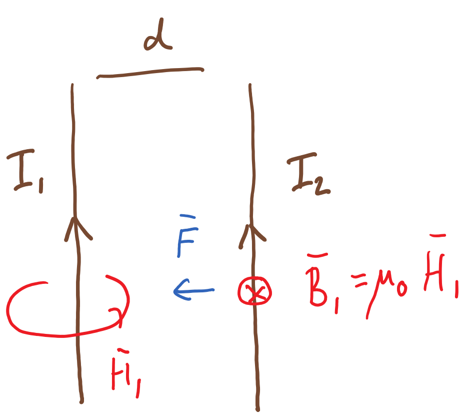
$$A\cancel{s}\,\frac{\cancel{m}}{\cancel{s}}\,\frac{Vs}{m^{\cancel{2}}} = N$$

LORENTZ FORCE $\bar{F} = q\left(\bar{E} + \bar{u}\times\bar{B}\right)$



$$\bar{F}_m = Q\,\underbrace{\bar{u}}_{\frac{d\bar{l}}{dt}}\times\bar{B} = I\,d\bar{l}\times\bar{B}$$

$$\frac{Q}{dt} = I$$



$$\frac{F}{L} = \mu_0\,\frac{I_1}{2\pi d}\,I_2$$

$$I_1 = I_2 = 1A$$

$$d = 1m$$

$$4\pi\cdot10^{-7}\,\frac{Vs}{Am}\,\frac{1A\cdot1A}{2\pi\,1m} = 2\cdot10^{-7}\,\frac{N}{m}$$

$$\nabla \times \bar{E} = 0 \quad \Rightarrow \quad \bar{E} = -\nabla V$$

$$\nabla \times (\nabla V) = 0$$

$$\nabla \cdot (\nabla \times \bar{A}) = 0$$

$$\left.\begin{aligned} \nabla \times \bar{H} &= \bar{J} \\ \nabla \cdot \bar{B} &= 0 \end{aligned}\right\}$$

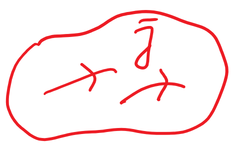
$$\bar{B} = \nabla \times \bar{A}$$

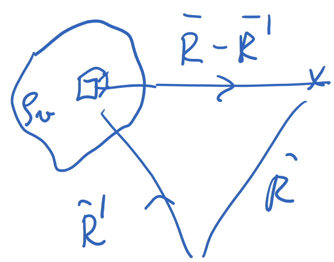
$\bar{A}$ vector potential

$$\nabla \times (\underbrace{\mu_0 \bar{H}}_{\bar{B}}) = \mu_0 \bar{J} \quad = \quad \underbrace{\nabla \times (\nabla \times \bar{A})}_{\nabla \nabla \cdot \bar{A} - \nabla^2 \bar{A}} = \mu_0 \bar{J}$$

$$\underbrace{\nabla \cdot \bar{A}}_{=0} \quad \text{COULOMB'S GAUGE}$$

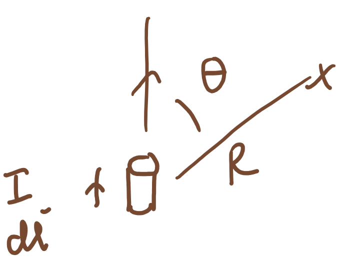
$$\nabla^2 \bar{A} = -\mu_0 \bar{J} \qquad \nabla^2 V = -\frac{\rho_v}{\varepsilon_0}$$





$$V(\bar{R}) = \int \frac{\rho_v \, dv'}{4\pi\varepsilon_0 |\bar{R} - \bar{R}'|}$$

$$\bar{A}(\bar{R}) = \int \frac{\mu_0 \bar{J}(\bar{R}') \, dv'}{4\pi |\bar{R} - \bar{R}'|}$$



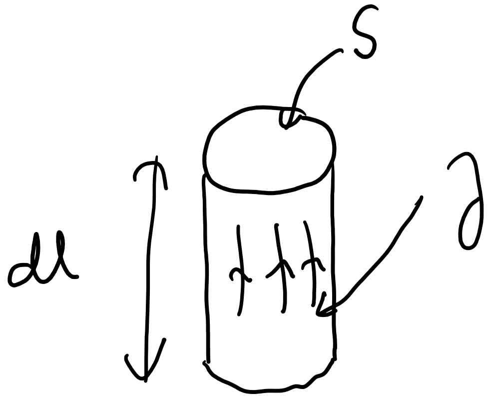
$$\bar{A}(\bar{R}) = \frac{\mu_0}{4\pi R} \int \underbrace{\bar{J} \, dv'}_{\underbrace{J \, dS}_{I} \, d\bar{l}} = \frac{\mu_0 I \, d\bar{l}}{4\pi R}$$

$$-\bar{a}_R \frac{1}{R^2}$$

$$\bar{B} = \nabla \times \bar{A} = \frac{\mu_0 I}{4\pi} \nabla \times \left(\frac{d\bar{l}}{R}\right) = \frac{\mu_0 I}{4\pi} \left(\nabla \frac{1}{R}\right) \times d\bar{l}$$

$$= \frac{\mu_0 I}{4\pi R^2} \, d\bar{l} \times \bar{a}_R$$

(BIOT - SAVART !)



$$\int j \underbrace{dV}_{S\,dl} = I\,dl$$

$$jS = I$$