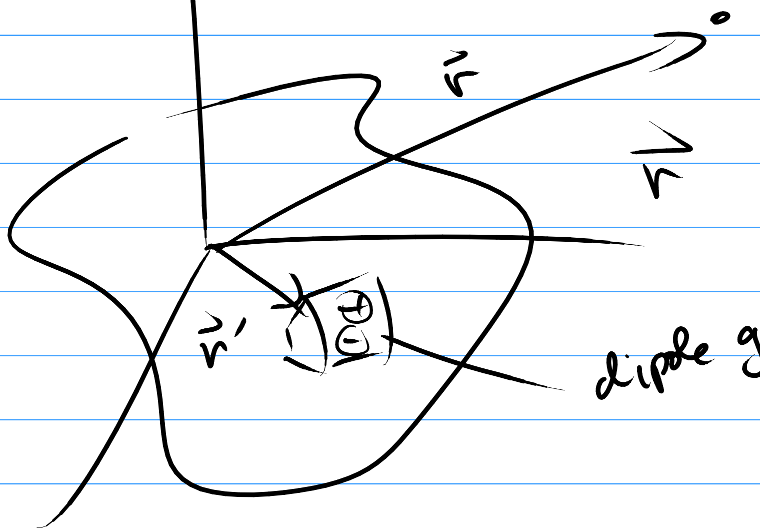
Magnetic materials: start w/ how we treated dielectric materials & draw an analogy



dipole generates dV_{dipole}

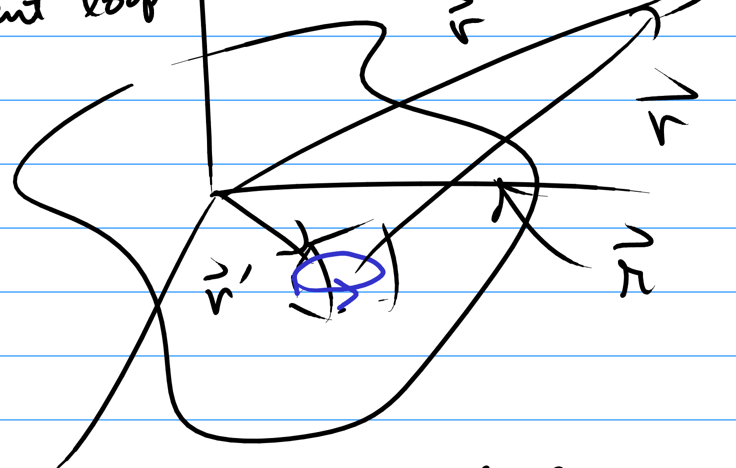
$$d\vec{A} = \frac{\mu_0}{4\pi}\frac{\vec{M}\,d\tau \times \hat{r}}{r^2}$$

atom with magnetic dipole moment consists of a current loop

I_{atom}

$\vec{m} = I\vec{a}$

mag area



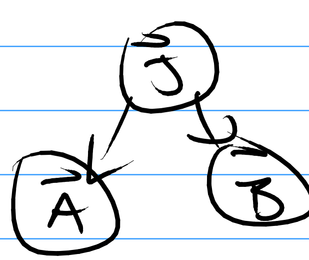
$$\vec{A}_{dipole} = \frac{\mu_0}{4\pi}\frac{\vec{m}\times\hat{r}}{r^2}$$

dipole

$\vec{M}$ $\left(\frac{\text{mag dipole mom}}{\text{vol}}\right)$

$$\vec{A}_{dipole} = \frac{\mu_0}{4\pi}\frac{\vec{m}\times\hat{r}}{r^2}$$

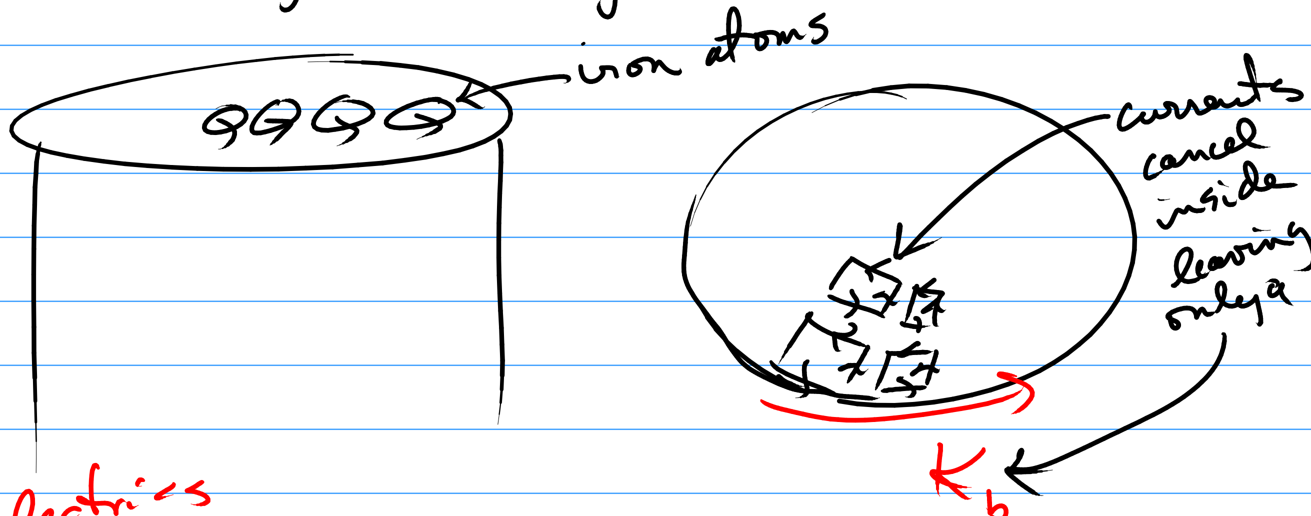
$$\vec{A}_{dipole} = \frac{\mu_0}{4\pi}\int \frac{\vec{M}\times\hat{r}}{r^2}\,d\tau$$



$$\Downarrow$$

$$\vec{A} = \frac{\mu_0}{4\pi}\int \frac{\vec{J}_b(\vec{r}\,')\,d\tau'}{\mathscr{r}} + \frac{\mu_0}{4\pi}\oint \frac{\vec{K}_b(\vec{r}\,')\,da'}{\mathscr{r}}$$

Consider a cylindrical magnet



dielectrics

$$\sigma_b = \vec{P}\cdot\hat{n} \qquad \underline{\rho_b = \vec{\nabla}\cdot\vec{P}}$$

$$\vec{J}_b = \vec{\nabla}\times\vec{M} \qquad K_b = \vec{M}\times\hat{n}$$

found $\vec{P}$ by assuming linear material

$$\underline{\vec{\nabla}\cdot\vec{E}} = \frac{\rho}{\epsilon_0} = \frac{\rho_b}{\epsilon_0} + \frac{\rho_f}{\epsilon_0} = \frac{\vec{\nabla}\cdot\vec{P}}{\epsilon_0} + \frac{\rho}{\epsilon_0}$$

$$\vec{\nabla}\times\vec{B}=\mu_0\vec{J}=\mu_0(\underbrace{\vec{J}_{bnd}}_{=\,\vec{\nabla}\times\vec{M}}+J_{free})$$

$$\vec{\nabla}\times\underbrace{\left(\frac{\vec{B}}{\mu_0}-\vec{M}\right)}_{\vec{H}}=\vec{J}_f$$

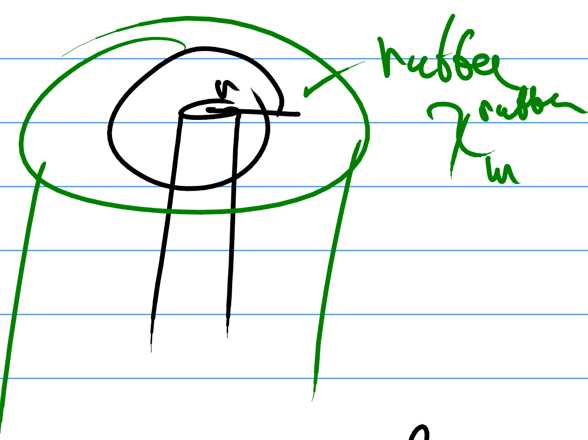
Linear material $\quad \vec{M}=\chi_m\vec{H}$

$$\vec{B}=\mu_0(\vec{H}+\vec{M})=\underbrace{\mu_0(1+\chi_m)}_{\mu}\vec{H}$$

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

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

$\Big\downarrow$ stokes

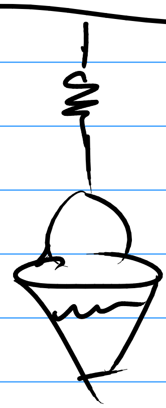


$$\oint\vec{H}\cdot d\vec{l}=\int\vec{J}_f\cdot d\vec{a}=I_{free}$$ Amps law

$$H\,2\pi r = I_{free} \qquad H = \frac{I_{free}}{2\pi r}$$

$$\frac{B}{\mu} = \frac{I_{free}}{2\pi r}$$

$$\boxed{B = \mu \frac{I_{free}}{2\pi r}}$$

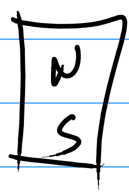


- weak attraction

paramagnetic (permanent dipoles)

- weak repulsion

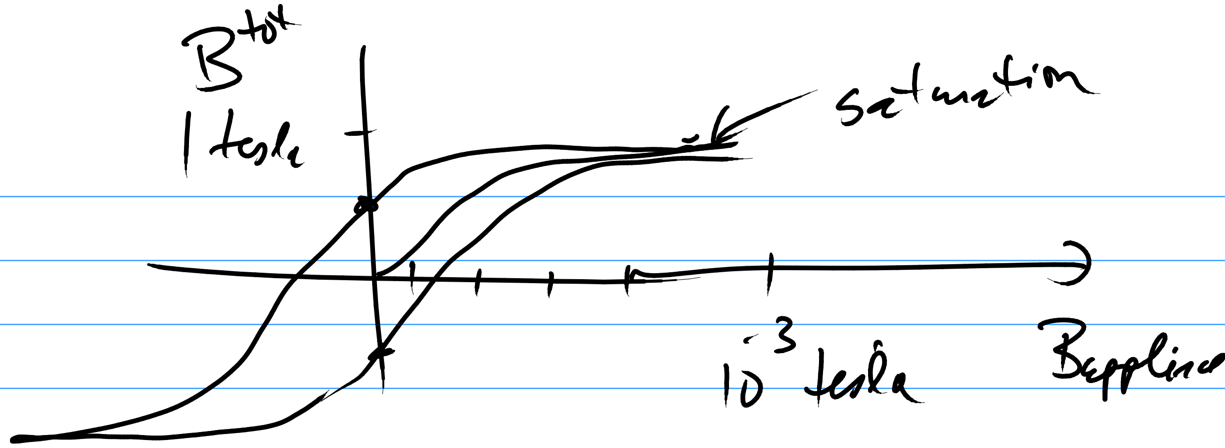
diamagnetism



move wire loop near bar magnet ⇒ Faraday's law generates opposing magnetic dipole

- strong attraction (ferromagnet)

domains where all iron atoms dipoles are aligned



$$B^{tot} = B^{atoms} + B_{applied}$$