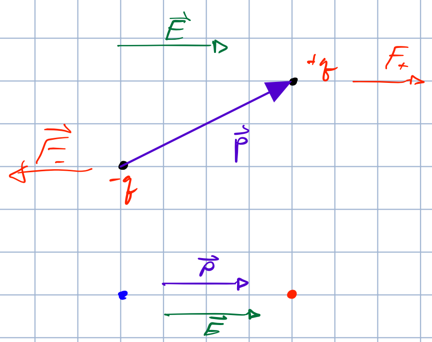
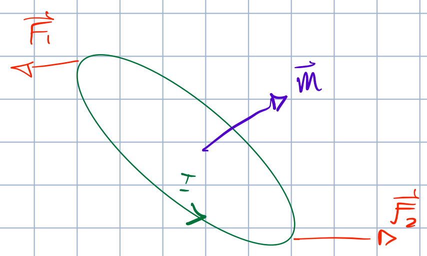
Magnetization



net force: $\vec{F}_+ + \vec{F}_- = 0$

net torque: $\vec{N} = \vec{p} \times \vec{E}$

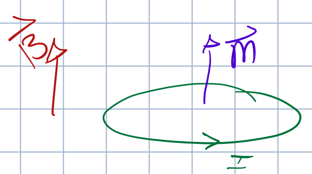
$\vec{p} \parallel \vec{E}$



$\vec{F}_1 = I \cdot d\vec{l}_1 \times \vec{B}$
$\vec{F}_2 = I \cdot d\vec{l}_2 \times \vec{B}$ $\quad d\vec{l}_1 = -d\vec{l}_2$

$\rightarrow \vec{F}_1 + \vec{F}_2 = 0$

net force: $\vec{F} = 0$

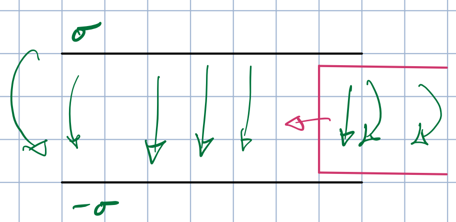


net torque: $\vec{N} = \vec{m} \times \vec{B}$

$\vec{m} \parallel \vec{B}$

Nonuniform $\vec{E}$

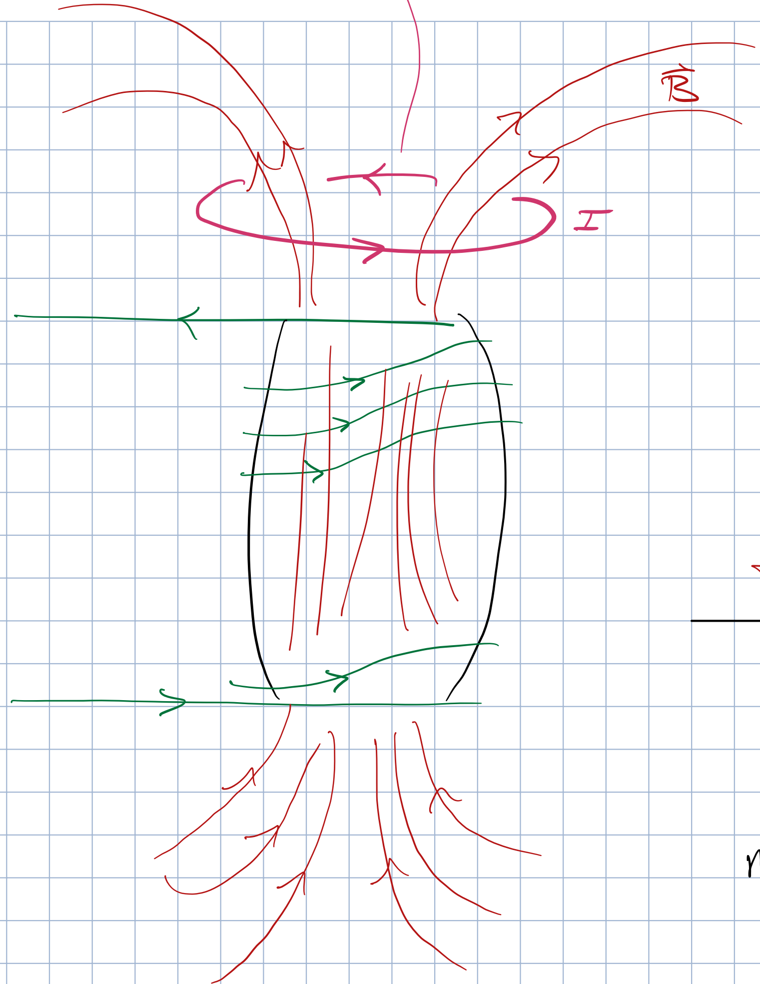
bring dialectric $\rightarrow$ pulled into capacitor

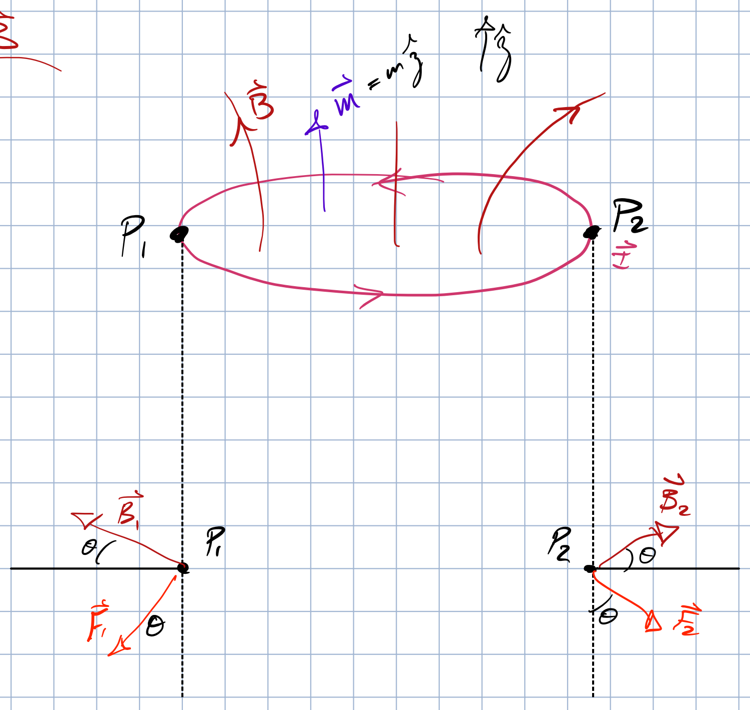


get fringe fields

Nonuniform $\vec{B}$

bring wire loop (w/current I) $\rightarrow$ pulled into solenoid





net force ↓ $\qquad F = q(\vec{v} \times \vec{B})$

$$|F_1^z| = |F_2^z| = F\cos\theta = qvB_s = (2\pi s)I \cdot B\cos\theta$$

$$= 2\pi s I \; \hat{z} \cdot \vec{B}$$

$$= \frac{d\vec{m}}{ds} \cdot \vec{B} = \frac{\partial}{\partial s}(\vec{m} \cdot \vec{B}) \qquad \vec{m} = \pi s^2 I \hat{z}$$

$$\vec{F} = \vec{\nabla}(\vec{m} \cdot \vec{B})$$

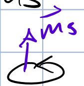
Non-conducting Materials

each atom has tiny magentic dipole (spin, orbitals, ...)

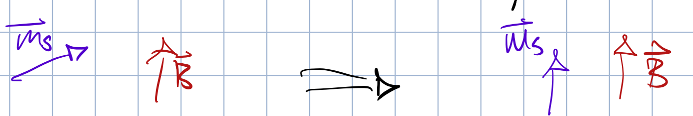
$\vec{E}$ fields polarize materials

$\vec{B}$ fields magnetize materials

① atoms w/ unpaired e^-



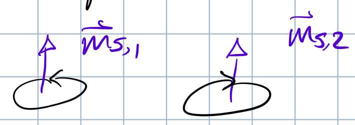
contributions by spin is much greater than those by orbital motion



$\vec{m}_{s,after} - \vec{m}_{s,before} > 0$

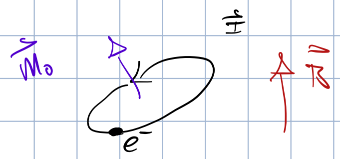
→ "paramagnetism"

② atoms w/ paired e^-



spin contributions cancel

$\vec{m}$ is due to orbital motion of e^-'s



harder to tilt entire orbit

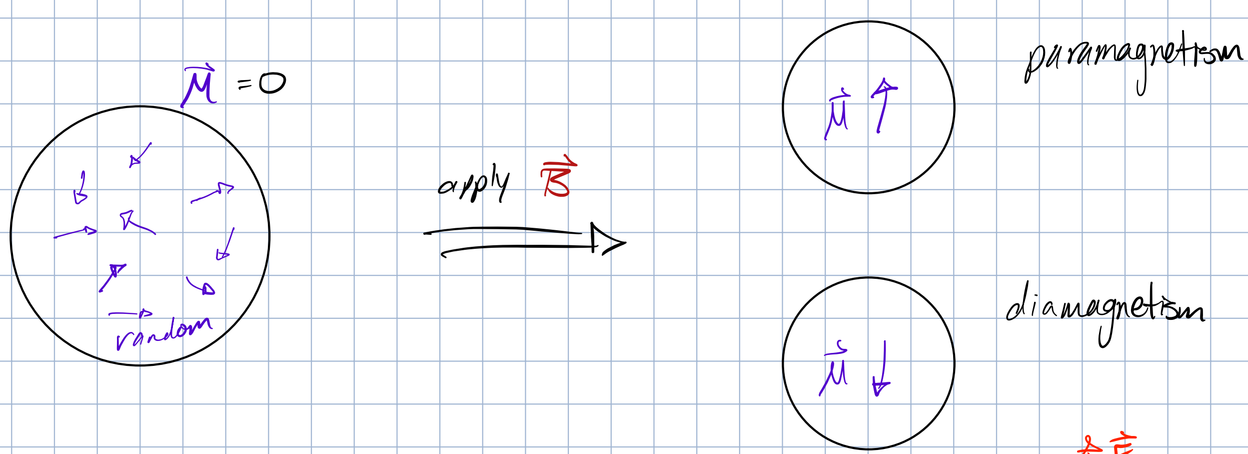
$\vec{B}$ affects orbital motion → speed up/slow down

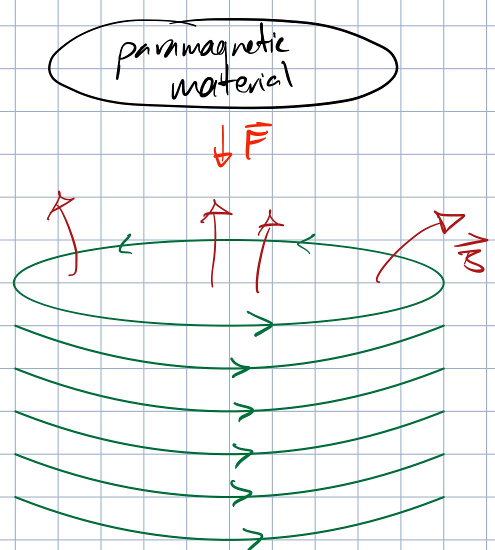
↑ $\vec{B}$ e^- speed reduced, $\vec{m}$ reduced

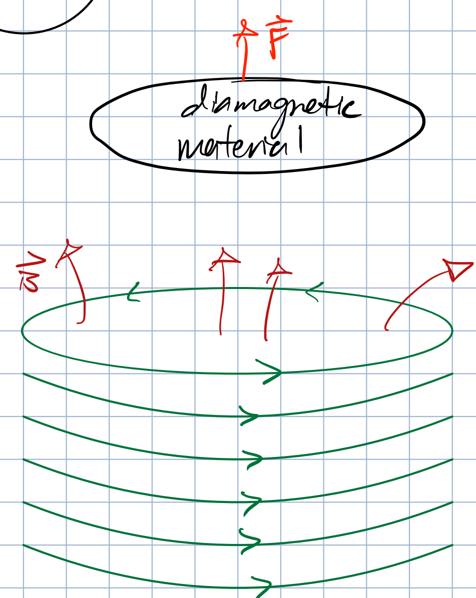
$\vec{m}$ in $\vec{B}$ direction is reduced opposite to paramagnetism

↓ $\vec{B}$ e^- speed increased, $\vec{m}$ increased

"dia magnetism"



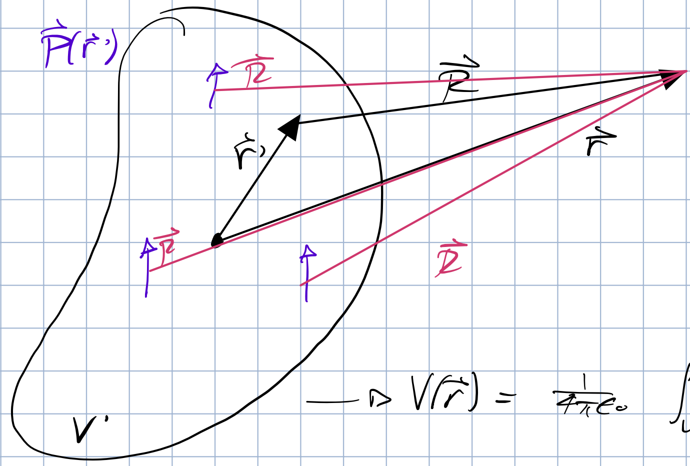




$\vec{P}$ = polarization
= electric dipole per unit volume

$\vec{M}$ = Magnetization
= magnetic dipole per unit volume

Polarized Material

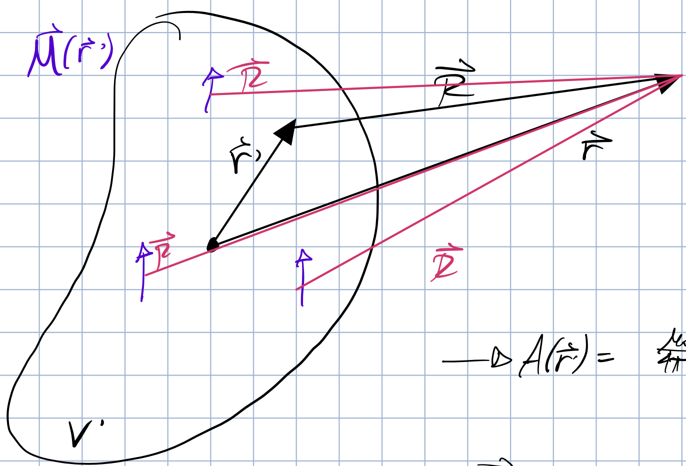


$$V(\vec{r}) = \frac{1}{4\pi\epsilon_0}\int_{V'} \frac{\vec{P}(\vec{r}')\cdot\hat{R}}{R^2}\, d\tau'$$

$$\longrightarrow V(\vec{r}) = \frac{1}{4\pi\epsilon_0}\int_{V'} \frac{\rho_{bound}(\vec{r}')}{R}\, d\tau' + \frac{1}{4\pi\epsilon_0}\int_{S'} \frac{\sigma_{bound}(\vec{r}')}{R}\, d\vec{a}'$$

$$\rho_{bound}(\vec{r}') = -\vec{\nabla}'\cdot P(\vec{r}')$$

$$\sigma_{bound}(\vec{r}') = \vec{P}(\vec{r}')\,\hat{n}$$



$$A(\vec{r}) = \frac{\mu_0}{4\pi}\int_{V'} \frac{M(\vec{r}')\times\hat{R}}{R^2}\, d\tau'$$

$$\longrightarrow A(\vec{r}) = \frac{\mu_0}{4\pi}\int_{V'} \frac{\vec{J}_{bound}(\vec{r}')}{R}\, d\tau' + \frac{\mu_0}{4\pi}\oint_{S'} \frac{\vec{K}_{bound}(\vec{r}')}{R}\, d\tau'$$

$$\vec{J}_{bound}(\vec{r}) = \vec{\nabla}'\times M(\vec{r}')$$

$$\vec{K}_{bound}(\vec{r}) = M(\vec{r}')\times\hat{n}'$$