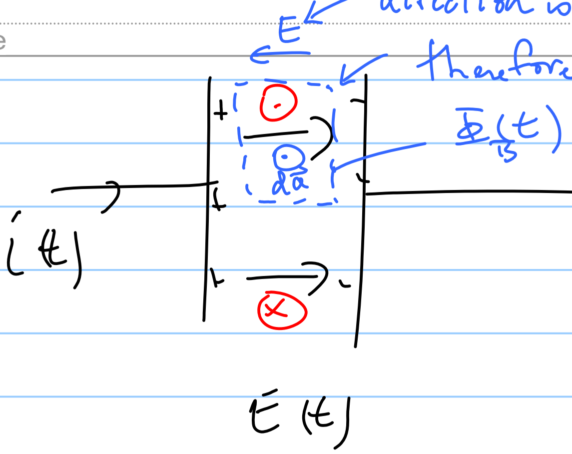
$E = E_0 \cos\omega t$

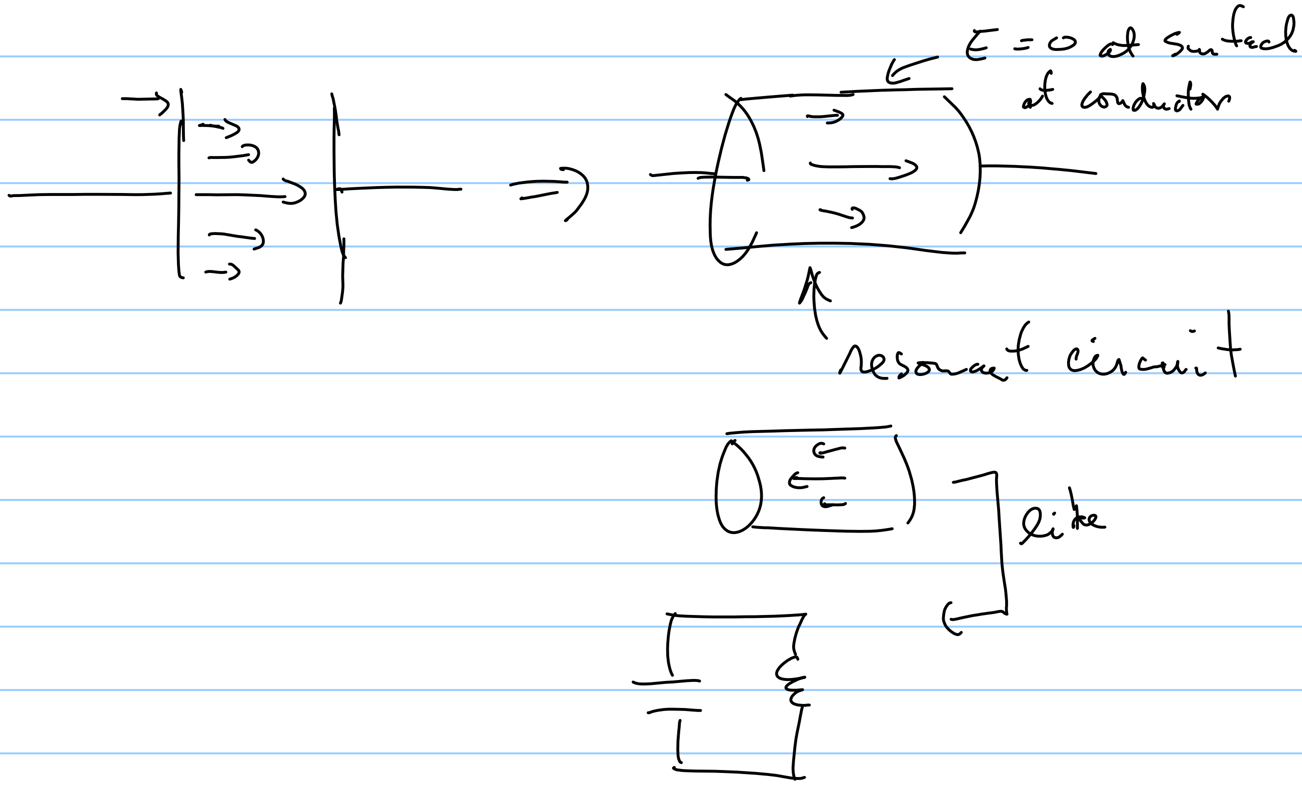
direction is complicated. $I_d = \epsilon_0 \frac{\partial E}{\partial t} = \epsilon_0(-E_0\omega)\sin\omega t$ & $B \propto I_d$

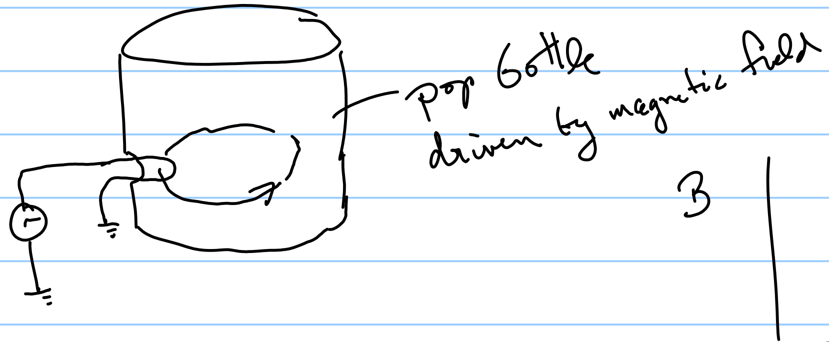
therefore $\Phi_B \propto I_d$ and increases into page so E must act in the direction shown

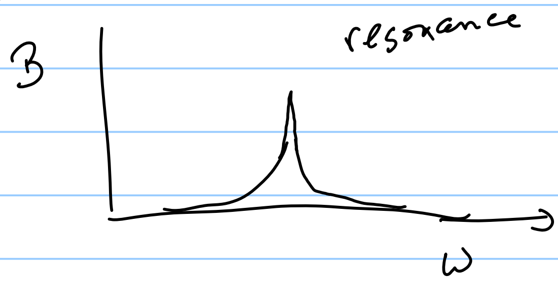
$\mathcal{E}_{mf} = -\frac{d\Phi_m}{dt}$



$i(t) = i_{max}\cos(\Omega t)$







Perturbation analysis

or Solve Maxwell's eqn.

free space

$\vec\nabla\cdot\vec B = 0$ $\qquad$ $\vec\nabla\times\vec B = \mu_0\vec J = \mu_0\epsilon_0\frac{\partial\vec E}{\partial t}$

$\vec\nabla\cdot\vec E = 0$ $\qquad$ $\vec\nabla\times\vec E = -\frac{\partial\vec B}{\partial t}$

$$\vec\nabla\times\vec\nabla\times\vec E = \vec\nabla(\underbrace{\vec\nabla\cdot\vec E}_{0}) - \nabla^2\overset{E_{tot}}{\vec E} = -\frac{\partial}{\partial t}\underbrace{\vec\nabla\times\overset{B_{tot}}{\vec B}}_{\mu_0\epsilon_0\frac{\partial\vec E}{\partial t}}$$

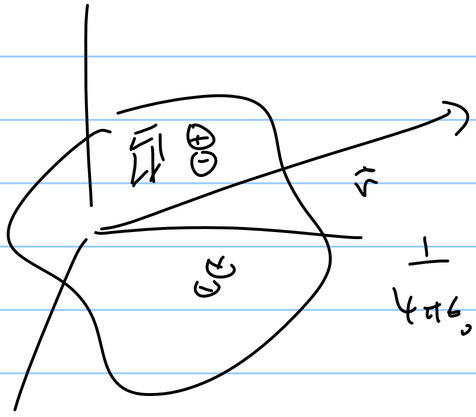
$$\nabla^2\vec E = \mu_0\epsilon_0\frac{\partial^2\vec E}{\partial t} \qquad \text{1-D} \quad \frac{\partial^2}{\partial x^2}\vec E = \mu_0\epsilon_0\frac{\partial^2\vec E}{\partial t^2}$$

Wave eqn

Magnetic materials

$$\frac{1}{4\pi\epsilon_0}\int\frac{k\,dq}{r} \qquad \sigma\,da \quad \rho\,d\tau \qquad \boxed{\rho} \to \boxed{V} \quad \boxed{E}$$

Dielectrics

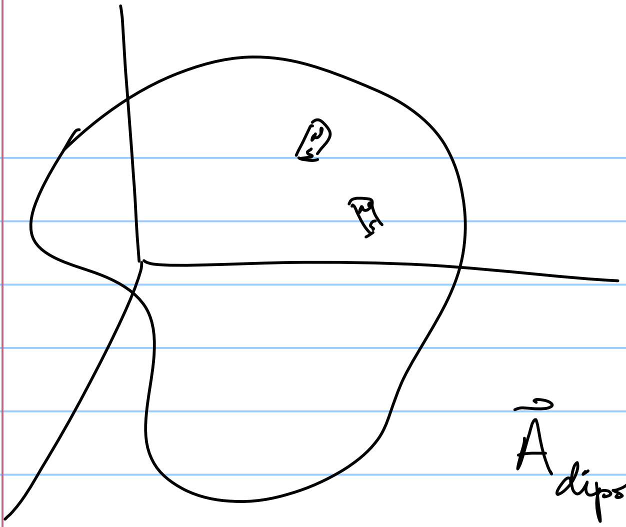


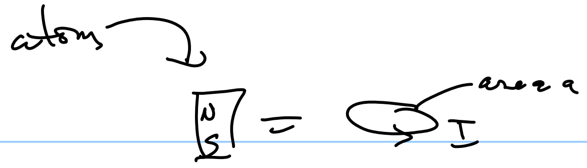
$$V_{dipole} = \frac{1}{4\pi\epsilon_0}\frac{\vec p\cdot\hat{r}}{r^2} \qquad \vec E_{dipole} = -\vec\nabla V_{dipole}$$

dipole mom/vol

$$\frac{1}{4\pi\epsilon_0}\int\frac{\vec P\cdot\hat r}{r^2}d\tau \to \underbrace{\oint\frac{\sigma_b\,da}{r} + \int\frac{\rho_b\,d\tau}{r}}$$

$$\sigma_b = \vec P\cdot\hat n \qquad \rho_b = -\vec\nabla\cdot\vec P$$





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

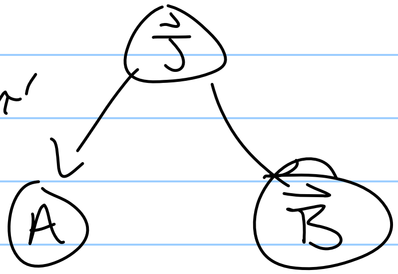
$$\vec{A}_{dipole} = \frac{\mu_0}{4\pi}\,\frac{\vec{m}\times\hat{\mathscr{r}}}{\mathscr{r}^2}$$

$$\vec{B}_{dipole} = \vec{\nabla}\times\vec{A}_{dipole}$$

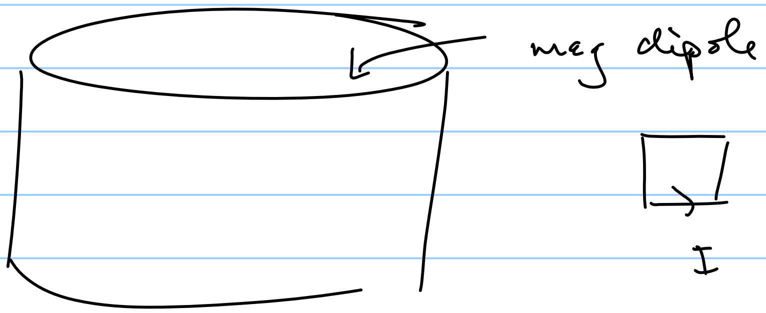
$$\vec{A}_{tot} = \frac{\mu_0}{4\pi}\int\frac{\vec{J}_b\,d\tau'}{\mathscr{r}} + \frac{\mu_0}{4\pi}\oint\frac{\vec{K}_b\,da'}{\mathscr{r}}$$

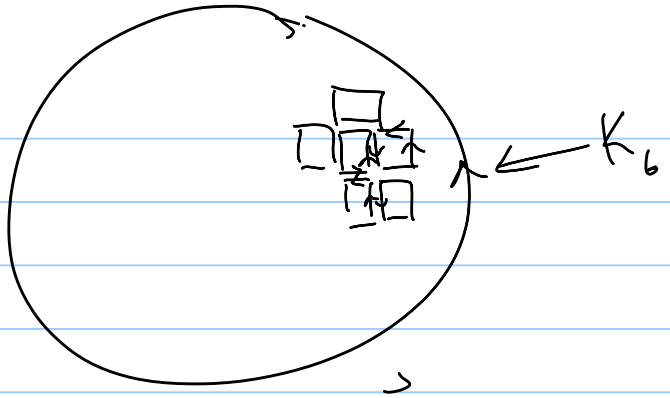
$$\vec{K}_b = \underset{\uparrow\ \frac{\text{mag dipole}}{\text{vol}}}{\underline{\vec{M}}}\times\overset{\swarrow\ \text{at surface}}{\hat{n}} \qquad \vec{J}_b = \vec{\nabla}\times\underline{\vec{M}}$$

$$\vec{A} = \frac{\mu_0}{4\pi}\int\frac{\vec{J}\,d\tau'}{\mathscr{r}}$$



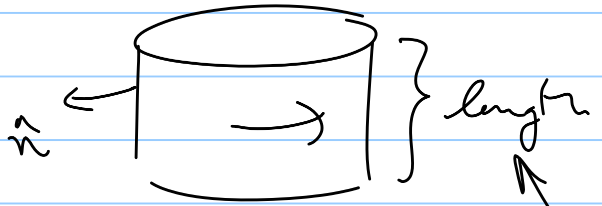
tablet quest





inside currents cancel $\vec{J}_b = 0$

$K_b \neq 0$



$$\vec{K}_b = \vec{M} \times \hat{n}$$

$$\uparrow$$

$$\frac{I\,\text{area}}{\text{vol}} \to \frac{I}{\text{length}}$$