$$\vec{\nabla}\cdot\vec{D} = \rho_f$$

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

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

$$\vec{\nabla}\times\vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

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

σ: conductivity

$$\vec{E} = \vec{E}_0 e^{i(\tilde{k}z - \omega t)}$$

$$\vec{B} = \vec{B}_0 e^{i(\tilde{k}z - \omega t)}$$

$$\vec{\tilde{k}} = \tilde{k}\hat{z}$$

$$\tilde{k} = k + i\kappa = K e^{i\phi}$$

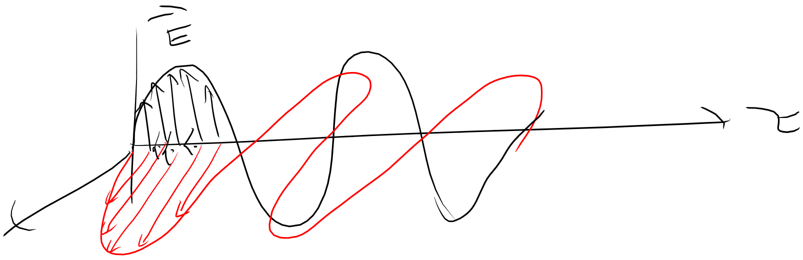
$$\vec{B}_0 = \frac{\vec{\tilde{k}} \times \vec{E}_0}{\omega}$$

$$\vec{E} = \vec{E}_0^R \cos(kz - \omega t + \delta_E) e^{-\kappa z}$$

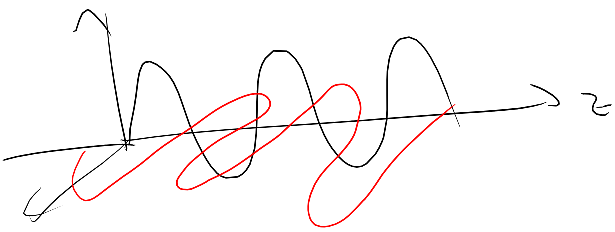
$$\vec{B} = \vec{B}_0^R \cos(kz - \omega t + \delta_B) e^{-\kappa z}$$

$$\delta_B = \phi + \delta_E$$

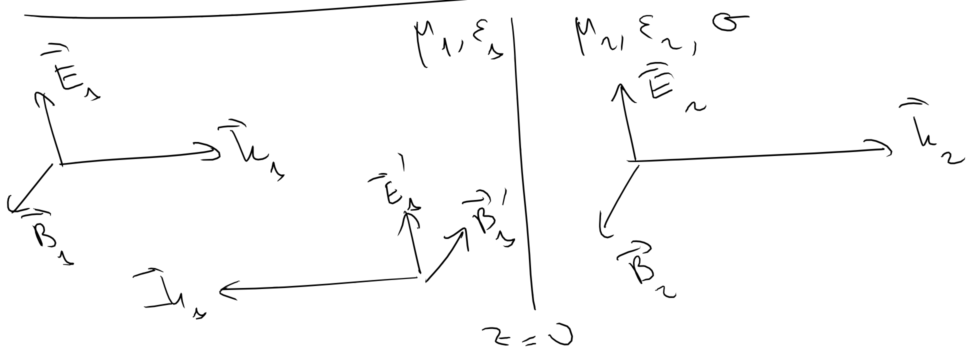
non-conducting medium



conducting medium



Reflection on a Conducting Surface



$\vec{\nabla}\cdot\vec{D} = \rho_f \Rightarrow \varepsilon_2 E_\perp^{(2)} - \varepsilon_1 E_\perp^{(1)} = \sigma_f$ ✓ $(\sigma_f = 0)$

$\vec{\nabla}\cdot\vec{B} = 0 \Rightarrow B_\perp$ is continuous ✓

$\vec{\nabla}\times\vec{E} = -\frac{\partial\vec{B}}{\partial t} \Rightarrow \vec{E}_\parallel$ is continuous

$$\vec{E}_{10} e^{i(k_1 z - \omega t)} + \vec{E}'_{10} e^{i(-k_1 z - \omega t)} = \vec{E}_{20} e^{i(\tilde{k}_2 z - \omega t)}\Big|_{z=0}$$

$$\boxed{\vec{E}_{10} + \vec{E}'_{10} = \vec{E}_{20}}$$

$$\left.\begin{aligned} \vec{E}_{10} &= E_{10}\hat{x} \\ \vec{E}'_{10} &= E'_{10}\hat{x} \\ \vec{E}_{20} &= E_{20}\hat{x} \end{aligned}\right\} \quad \boxed{E_{10} + E'_{10} = E_{20}}$$

$$\left.\begin{aligned} &\vec{J} = \sigma\vec{E} \\ &\vec{J} = \vec{K}\delta(z) + \dots \\ &\vec{E} \text{ is finite on the surface} \end{aligned}\right\} \quad \vec{K} = 0$$

$\vec{\nabla}\times\vec{H} = \sigma\vec{E} + \frac{\partial\vec{D}}{\partial t} \Rightarrow \left(\frac{B_\parallel}{\mu}\right)$ is continuous

$$\frac{B_{10}}{\mu_1}\hat{y} - \frac{B'_{10}}{\mu_1}\hat{y} = \frac{B_{20}}{\mu_2}\hat{y}$$

$$B_{10} = \frac{1}{v_1}E_{10}$$

$$B'_{10} = \frac{1}{v_1}E'_{10}$$

$$\boxed{B_{20} = \frac{\tilde{k}}{\omega}E_{20}}$$

$$\frac{E_{10}}{v_1\mu_1} - \frac{E'_{10}}{v_1\mu_1} = \frac{\tilde{k}}{\omega\mu_2}E_{20}$$

$$\begin{cases} E_{10} - E'_{10} = \tilde{\beta}E_{20} \\ E_{10} + E'_{10} = E_{20} \end{cases} \qquad \tilde{\beta} = \frac{\tilde{k}}{\omega}\frac{v_1\mu_1}{\mu_2}$$

$$\left.\begin{aligned} E_{10} &= \tilde{\beta}E_{20} + E'_{10} \\ E_{10} &= E_{20} - E'_{10} \end{aligned}\right\} \quad E_{20} = \frac{2}{1+\tilde{\beta}}E_{10}$$

$$E'_{10} = E_{20} - E_{10} = \frac{1-\tilde{\beta}}{1+\tilde{\beta}}E_{10}$$

$$\tilde{\beta} = \frac{\tilde{k}}{\omega}\frac{v_1 \mu_1}{\mu_2}, \quad \tilde{k} = k + iK, \quad K \propto \sigma$$

For a perfect conductor: $E_{20} = 0$

$E'_{10} = -E_{10}$

all the wave is reflected.

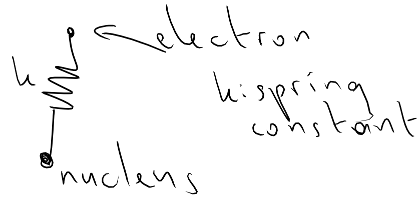
$$\tilde{k}^2 = \frac{\omega^2}{2v^2}\left[1 + \sqrt{1 + A(\omega)}\right]$$

$$\left(\frac{k}{\omega}\right)^2 = \frac{1}{2v^2}\left[1 + \sqrt{1 + A(\omega)}\right]$$

$\varepsilon(\omega)$

electric permitivity.

Freq. Dependent permitivity



x: displacement (in the $\hat{x}$ direction) of the electron from eq. point.

$$\vec{E} = E_0 \hat{x} e^{i\omega t}$$

$$m\frac{d^2x}{dt} = -kx + qE_0 e^{i\omega t} - m\gamma\frac{dx}{dt}$$

$$m\frac{d^2x}{dt^2} + m\gamma\frac{dx}{dt} + kx = qE_0 e^{i\omega t}$$

$$x = A e^{i\omega t}$$

$$A = \frac{qE_0}{-m\omega^2 + im\omega\gamma + k}$$

$$p = qx = \frac{q^2}{-m\omega^2 + im\omega\gamma + k} E_0 e^{i\omega t}$$

$$\vec{p} = \frac{q^2}{-m\omega^2 + im\omega\gamma + k}\vec{E} \Longleftarrow$$

$$\vec{P} = \frac{1}{V}\sum_j q_j^2 \frac{1}{i m_j w \gamma_j + k_j - m_j w_j^2} \qquad \vec{P} = \varepsilon_0 \chi_e \vec{E}$$

$$\varepsilon = \varepsilon_0 (1 + \chi_e) = \boxed{\varepsilon_0 \left[1 + \frac{n q^2}{k - m w^2 + i m w \gamma}\right] = \varepsilon}$$

$$\frac{k}{m} = w_0^2$$

$$\varepsilon = \varepsilon_0 \left[1 + \frac{n q^2/m}{w_0^2 - w^2 + i w \gamma}\right]$$

$$\vec{E} = \vec{E}_0 e^{i(\tilde{k}z - wt)}$$

$$\frac{1}{v} = \frac{\tilde{k}}{w} = \sqrt{\varepsilon \mu} \Rightarrow \tilde{k} = k + iK$$

$$\vec{E} \propto e^{-Kz} \qquad I \propto e^{-2Kz}$$

$\alpha = 2K$: atenuation coefficient
absorption coefficient

phase velocity $\frac{w}{k} = ?$

group velocity $\frac{\partial w}{\partial k} = ?$

$$\frac{\tilde{k}}{w} = \sqrt{\varepsilon \mu_0} = \sqrt{\varepsilon_0 \mu_0}\left[1 + \frac{n q^2/m}{w_0^2 - w^2 + i w \gamma}\right]^{+1/2}$$

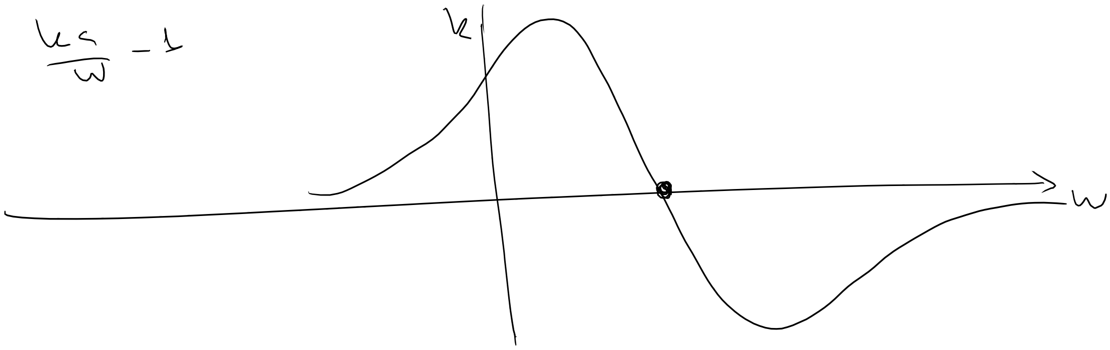
$$\frac{\tilde{k}}{w} = \frac{1}{c}\left[1 + \frac{1}{2}\frac{n q^2/m}{w_0^2 - w^2 + i w \gamma}\right]$$

$$k = \mathrm{Re}\,\tilde{k} = \mathrm{Re}\, \frac{w}{c}\left[1 + \frac{n q^2/2m}{w_0^2 - w^2 + i w \gamma}\right]$$

$$k = \frac{w}{c}\left[1 + \frac{(n q^2/2m)(w_0^2 - w^2)}{(w_0^2 - w^2)^2 + w^2 \gamma^2}\right]$$

$$K = \mathrm{Im}\,\tilde{k} = -\frac{w}{c} \frac{w \gamma \; n q^2/2m}{(w_0^2 - w^2) + w^2 \gamma^2}$$

$\frac{kc}{\omega} - 1$



$\frac{kc}{\omega} - 1 = \frac{c}{v_p} - 1$