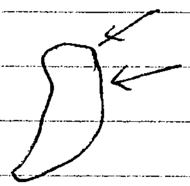
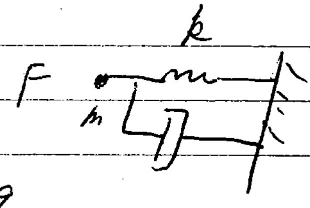




k, b (↑ damping), q (↑ charge) $\qquad F = qE_0 e^{-i\omega t}$

~~$m\ddot{x} + b\dot{x} + kx = F = qE_0 e^{-i\omega t}$~~

$x \sim x_0(\omega) e^{i\omega t}$

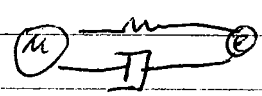
$(-m\omega^2 - ib\omega + k) = qE_0$

$\frac{k}{m} = \omega_0^2 \qquad \frac{b}{m} = \gamma$

$N q X_0(\omega) = \frac{q^2 E \quad N}{m(\omega_0^2 - \omega^2 - i\gamma\omega)}$ polarization

$P = \varepsilon_0 \frac{Nq^2}{\varepsilon_0 m} \frac{1}{\omega_0^2 - \omega^2 - i\omega\gamma}$

$P = \varepsilon_0 X E$



i) $\chi(\omega) \quad \omega \to \infty \quad X_0(\omega) \to 0$

ii) $X(\omega) = X' + iX''$, $X'' \geq 0$ ↑ absorption has to be +

- evanescent
- surface wave

$\gamma \neq 0$

$X_{\text{free electron}} = -\frac{Nq^2}{m\varepsilon_0} \frac{1}{\omega(\omega + i\gamma)}$

$$1 + \left(\frac{\omega_p^2}{\omega_0^2 - \omega^2 - i\omega\gamma}\right)_b - \left(\frac{\omega_p^2}{\omega(\omega + i\gamma)}\right)_f$$

$$\varepsilon(\omega) = 1 - \frac{\omega_p^2}{\omega(\omega + i\gamma)}$$

$\gamma << \omega_p$

$\downarrow$

$\sim 10\,eV$

Neglect γ part

$1 - \frac{\omega_p^2}{\omega^2}$ ① $\omega < \omega_p$ $\quad \varepsilon < 0$ ③

② $\omega > \omega_p$ $\quad \varepsilon > 0$

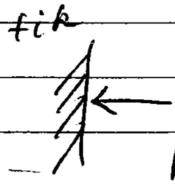
refractive index $n = \varepsilon^{\frac{1}{2}}$

$= \sqrt{1 - \frac{\omega_p^2}{\omega^2}}$ $\quad n > 0$, $k = 0$

$= i \frac{\omega_p}{\omega}$

$\uparrow$ imaginary part

$n + ik$

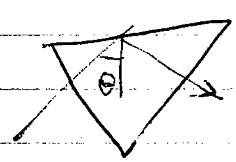


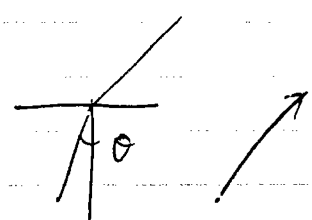
reflectivity $\left|\frac{N-1}{N+1}\right|^2 = \left|\frac{i\frac{\omega_p}{\omega} - 1}{i\frac{\omega_p}{\omega} + 1}\right|^2 = 1$ metal

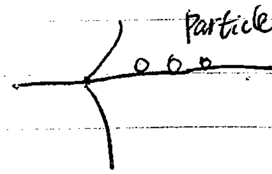
$\omega << \omega_p$

ω inside is weak

no strong polarization inside

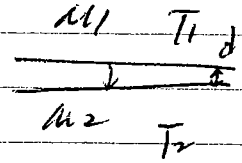




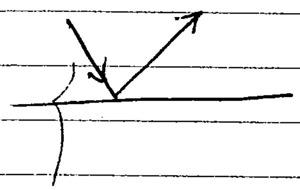


Negative refractive index

surface waves



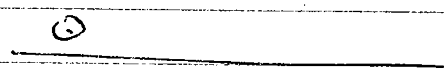
$R_1 =$ Fresnel coefficient



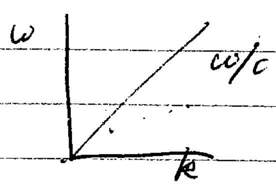
water waves

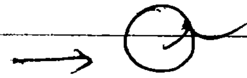
$$R_{TM} = \frac{(\varepsilon_1 k_2 - \varepsilon_2 k_1)}{\varepsilon_1 k_2 + \varepsilon_2 k_1} = 0$$

$$R_{TE} = \frac{k_{z2} - k_{z1}}{k_{z2} + k_{z1}} = 0$$



But sphere can be excited





It can radiate

$\vec{G}$

4/6/2006

$\hbar \omega_p = E_f - E_i$

$\hbar k = \vec{P_f} - \vec{P_i} + \vec{G}$

Atom { translation, electronic

molecules { vibration, ~~R~~otation R