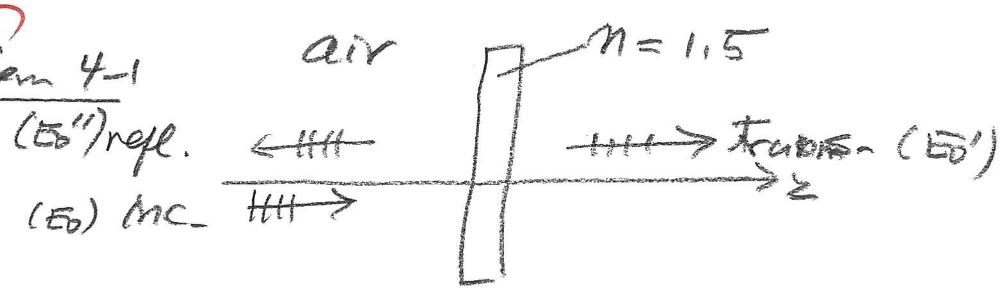
(2 pts)

Problem 4-1



Fresnel's equations for normal incidence,

$$\frac{E_0''}{E_0} = \frac{n_{air} - n_{glass}}{n_{glass} + n_{air}} = \frac{1 - 1.5}{1.5 + 1} = 0.2$$

Intensity = energy flux

$$I_0 = \frac{c}{4\pi} E_0^2 \quad \text{and} \quad I_0'' = \frac{c}{4\pi}(E_0'')^2$$

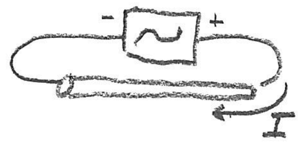
$$\frac{I_0''}{I_0} = 0.04$$ so the answer is $\underbrace{I_0'' = 0.04\, I_0.}_{\text{2 points}}$

(4 points = 2+2)

Problem 4.2

Exercise 9.5.1 $\boxed{\text{Method \#1}}$

(a)



Assume $\vec{E}(t) = \mathrm{Re}\, \vec{\mathcal{E}}(\omega) e^{-i\omega t}$

$= \mathcal{E}(\omega) \cos\omega t \ \hat{e}_z$

↑ real

then $\vec{J}(t) = \mathrm{Re}\left\{ \sigma(\omega)\, \vec{\mathcal{E}}(\omega)\, e^{-i\omega t} \right\}$

$= \mathcal{E}(\omega)\, \hat{e}_z \ \mathrm{Re}\left\{ (\sigma_1(\omega) + i\sigma_2(\omega))(\cos\omega t - i\sin\omega t) \right\}$

$= \mathcal{E}(\omega)\, \hat{e}_z \left\{ \sigma_1(\omega)\cos\omega t + \sigma_2(\omega)\sin\omega t \right\}$

$= \mathcal{E}(\omega)\, \hat{e}_z \sqrt{\sigma_1^2+\sigma_2^2} \left\{ \frac{\sigma_1}{\sqrt{\sigma_1^2+\sigma_2^2}} \cos\omega t + \frac{\sigma_2}{\sqrt{\sigma_1^2+\sigma_2^2}} \sin\omega t \right\}$

$\hookrightarrow = \cos\omega t \cos\delta + \sin\omega t \sin\delta$

$= \cos(\omega t - \delta)$ where $\tan\delta = \frac{\sigma_2}{\sigma_1}$

$= \mathcal{E}(\omega)\, \hat{e}_z \sqrt{\sigma_1^2+\sigma_2^2} \cos(\omega t - \delta)$

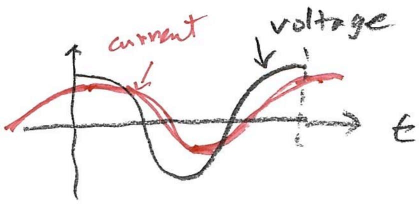
↑ phase difference

Now $\sigma = \frac{ne^2}{m} \frac{1}{\gamma - i\omega} \Rightarrow \begin{cases} \sigma_1 = \frac{n_c e^2}{m} \frac{\gamma}{\gamma^2+\omega^2} \\ \sigma_2 = \frac{n_c e^2}{m} \frac{\omega}{\gamma^2+\omega^2} \end{cases}$

$\therefore \tan\delta = \frac{\omega}{\gamma}$

← 2 points

δ is positive so the voltage precedes the current

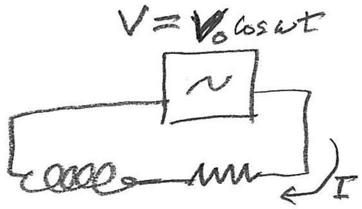


(max voltage $= t = 0$
max current $= t = \phi > 0$)

"ELI the ICE man"

This is an INDUCTIVE phase difference.

(b) Consider an LR circuit.



$$I = I_R = I_L$$

$$V = V_R + V_L = R I_R + L \frac{\partial I_L}{\partial t}$$

$$V_0 \cos\omega t = R I + L \frac{\partial I}{\partial t}$$

$$I = I_0 \cos(\omega t - \delta)$$

$$V_0 \cos\omega t = R I_0 \cos(\omega t - \delta) + L(-\omega) I_0 \sin(\omega t - \delta)$$

$$= I_0 \cos\omega t \{ R \cos\delta + L\omega \sin\delta \}$$

$$+ I_0 \sin\omega t \{ R \sin\delta - \omega L \cos\delta \}$$

Coefficient of $\sin\omega t = 0 \Rightarrow \tan\delta = \frac{\omega L}{R}$

$$V_0 \cos\omega t = I_0 \cos\omega t \left\{ R \frac{R}{\sqrt{R^2 + (\omega L)^2}} + L\omega \frac{\omega L}{\sqrt{R^2 + (\omega L)^2}} \right\}$$

$$V_0 = I_0 \sqrt{R^2 + (\omega L)^2} = I_0 \sqrt{R^2 + X_L^2}$$

$\boxed{\text{From part (a)}}$: $\tan\delta = \frac{\omega}{\gamma} = \frac{\omega L}{R} \Rightarrow L = R/\gamma$

Also, $R = \rho \frac{l}{A} = \frac{1}{\sigma(0)} \frac{l}{A} = \frac{m\gamma}{n_c e^2} \frac{l}{A} = \frac{m\gamma l}{n_c e^2 A}$

Low frequency approximation

Thus

$$\underbrace{L = \frac{m l}{n_c e^2 A}}_{\text{(inductance)}} \quad \text{and} \quad X_L = \omega L = \frac{m l \omega}{n_c e^2 A}$$

(reactance)

← 2 points

~~Low frequency approximation~~

<u>Exercise 9.5.1 continues</u> $\boxed{\text{Method \#2}}$

(a) Consider Equation 8.73. For <u>harmonic fields</u> (e.g., $\vec{E}(\vec{x},t) = \vec{E}(\vec{x})e^{-i\omega t}$ $\leftarrow$ possibly complex)

$$\frac{1}{2} I^* V = \frac{1}{2}\int d^3x \; \vec{J}_f^*(\vec{x})\cdot\vec{E}(\vec{x}) + \underbrace{2i\omega\int d^3x\,(w_e - w_m) + \oint_{S-S_1} \vec{S}\cdot d\vec{A}}_{\text{neglect these terms}}$$

Let $V = IZ$.

$$\frac{1}{2}|I|^2 Z = \frac{1}{2}\int d^3x \; \vec{E}(\vec{x})\cdot\sigma^*(\omega)\,\vec{E}^*(\vec{x}) \qquad \boxed{\sigma(\omega) = \frac{n_c e^2}{m(\gamma - i\omega)}}$$

$$= \frac{1}{2}\int d^3x\,|E|^2 \; \frac{n_c e^2}{m(\gamma + i\omega)}$$

$$Z = \frac{\int d^3x\,|E|^2}{|I|^2}\;\frac{n_c e^2}{m(\gamma^2+\omega^2)}\,(\gamma - i\omega)$$

Z = impedance ; $R = \mathrm{Re}\{Z\}$ (resistance) and $X = -\,\mathrm{Im}\{Z\}$ (reactance)

$$X = \frac{\int d^3x\,|E|^2}{|I|^2}\;\frac{n_c e^2\omega}{m(\gamma^2+\omega^2)} \approx \frac{\int d^3x\,|E|^2}{|I|^2}\;\frac{n_c e^2\omega}{m\gamma^2} = \omega L$$

(INDUCTIVE)

$$R = \frac{\int d^3x\,|E|^2}{|I|^2}\;\frac{n_c e^2\gamma}{m(\gamma^2+\omega^2)} \approx \frac{\int d^3x\,|E|^2}{|I|^2}\;\frac{n_c e^2}{m\gamma}$$

(b) 

$\therefore R = \rho\,\ell/A = \dfrac{1}{\sigma}\dfrac{\ell}{A} = \dfrac{m\gamma}{n_c e^2}\,\dfrac{\ell}{A} = \dfrac{\int d^3x\,|E|^2}{|I|^2}\;\dfrac{n_c e^2}{m\gamma}$

For inductance L, $X = \omega L$. Thus

$$L = \frac{X}{\omega} = \frac{\int d^3x\,|E|^2}{|I|^2}\;\frac{n_c e^2}{m\gamma^2} = \left(\frac{m\gamma}{n_c e^2}\right)^2\frac{\ell}{A}\;\frac{n_c e^2}{m\gamma^2} = \frac{m\ell}{n_c e^2 A}$$

(Same result as Method #1)

(2 points)

Problem 4.3

Exercise 9.5.4

$$I = \int_{-\infty}^{\infty} \frac{d\omega\ \omega^2\gamma}{(\omega^2-\omega_0^2)^2+\omega^2\gamma^2}$$

This integral is used in (9.139) and (9.194).

In the complex ω plane, there are 4 simple poles.

$$(\omega^2-\omega_0^2)^2+\omega^2\gamma^2 = 0$$

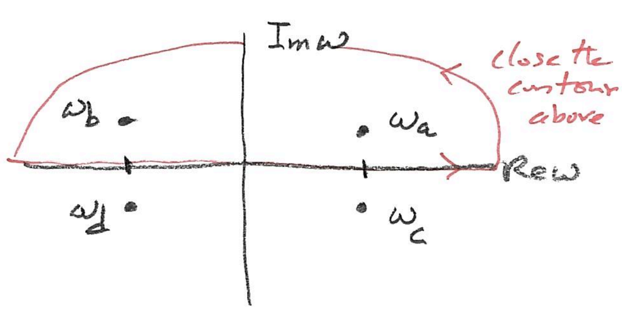
$$\omega^2-\omega_0^2 = \pm i\omega\gamma \quad \Rightarrow \quad \omega^2 \pm i\omega\gamma - \omega_0^2 = 0$$

$$(\omega \pm i\gamma/2)^2 + \left(\frac{\gamma}{2}\right)^2 - \omega_0^2 = 0$$

$$(\omega \pm i\gamma/2)^2 = \pm\sqrt{\omega_0^2-\gamma^2/4}$$

$$\left.\begin{matrix}\omega_a\\ \omega_b\end{matrix}\right\} = \frac{i\gamma}{2} \pm \sqrt{\omega_0^2-\gamma^2/4}$$

$$\left.\begin{matrix}\omega_c\\ \omega_d\end{matrix}\right\} = -\frac{i\gamma}{2} \pm \sqrt{\omega_0^2-\gamma^2/4}$$



$$I = \int_{-\infty}^{\infty} \frac{d\omega\ \omega^2\gamma}{(\omega-\omega_a)(\omega-\omega_b)(\omega-\omega_c)(\omega-\omega_d)}$$

$$= 2\pi i \frac{\omega_a^2\gamma}{(\omega_a-\omega_b)(\omega_a-\omega_c)(\omega_a-\omega_d)} + 2\pi i \frac{\omega_b^2\gamma}{(\omega_b-\omega_a)(\omega_b-\omega_c)(\omega_b-\omega_d)}$$

$$\omega_a-\omega_b = 2\sqrt{\omega_0^2-\gamma^2/4}$$

$$(\omega-\omega_c)(\omega-\omega_d) = \left(\omega+\frac{i\gamma}{2}-\sqrt{\omega_0^2-\gamma^2/4}\right)\left(\omega+\frac{i\gamma}{2}+\sqrt{\omega_0^2-\gamma^2/4}\right) = \left(\omega+\frac{i\gamma}{2}\right)^2-\omega_0^2+\gamma^2/4$$

$$= \omega^2 + i\omega\gamma - \omega_0^3$$

$$(\omega_a-\omega_c)(\omega_a-\omega_d) = 2i\omega_a\gamma \quad \text{and} \quad (\omega_b-\omega_c)(\omega_b-\omega_d) = 2i\omega_b\gamma$$

$$I = 2\pi i \frac{\omega_a^2 \gamma}{(\omega_a - \omega_b)\, 2i\omega_a \gamma} + 2\pi i \frac{\omega_b^2 \gamma}{(\omega_b - \omega_a)\, 2i\omega_b \gamma}$$

$$I = \frac{2\pi i \gamma}{2i\gamma} \frac{\omega_a - \omega_b}{\omega_a - \omega_b}$$

$$I = \pi$$ ← 2 points

Problem 4-4 (8 points total; 2+2+2+2)

Exercise 9.5.5

(a) $k^2 = \frac{\mu\omega^2}{c^2}\left(\epsilon + i\frac{4\pi\sigma}{\omega}\right)$

Write $k = \alpha + i\beta$ and solve for α and β

$$k^2 = \alpha^2 - \beta^2 + 2i\alpha\beta = \frac{\mu\epsilon\omega^2}{c^2} + i\frac{4\pi\sigma\mu\omega}{c^2}$$

Real part $\alpha^2 - \beta^2 = \frac{\mu\epsilon\omega^2}{c^2}$

Im. part $2\alpha\beta = \frac{4\pi\sigma\mu\omega}{c^2}$

Solution $\beta = \sqrt{\alpha^2 - \frac{\mu\epsilon\omega^2}{c^2}}$

$$\Rightarrow \quad \alpha\sqrt{\alpha^2 - \frac{\mu\epsilon\omega^2}{c^2}} = \frac{2\pi\sigma\mu\omega}{c^2}$$

$$\alpha^2\left(\alpha^2 - \frac{\mu\epsilon\omega^2}{c^2}\right) = \left(\frac{2\pi\sigma\mu\omega}{c^2}\right)^2$$

$$\alpha^4 - \alpha^2\frac{\mu\epsilon\omega^2}{c^2} - \left(\frac{2\pi\sigma\mu\omega}{c^2}\right)^2 = 0$$

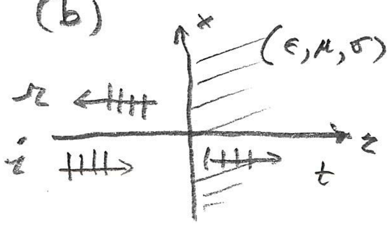
$$\alpha^2 = \frac{\mu\epsilon\omega^2}{2c^2} + \sqrt{\left(\frac{\mu\epsilon\omega^2}{2c^2}\right)^2 + \left(\frac{2\pi\sigma\mu\omega}{c^2}\right)^2}$$

$$\alpha = \sqrt{\frac{\mu\epsilon\omega^2}{2c^2}}\left\{1 + \sqrt{1 + \left(\frac{4\pi\sigma}{\epsilon\omega}\right)^2}\right\}^{1/2}$$

Now $\beta^2 = \alpha^2 - \frac{\mu\epsilon\omega^2}{c^2} = \frac{\mu\epsilon\omega^2}{2c^2}\left\{-1 + \sqrt{1 + \left(\frac{4\pi\sigma}{\epsilon\omega}\right)^2}\right\}$ — 2 points

$$\beta = \sqrt{\frac{\mu\epsilon\omega^2}{2c^2}}\left\{-1 + \sqrt{1 + \left(\frac{4\pi\sigma}{\epsilon\omega}\right)^2}\right\}^{1/2}$$

(b) NORMAL INCIDENCE



(i) $\begin{cases} \vec{E} = E_0\,\hat{e}_x\,e^{i(kz-\omega t)} & \text{where } \omega = ck \\ \vec{B} = E_0\,\hat{e}_y\,e^{i(kz-\omega t)} \end{cases}$

(r) $\begin{cases} \vec{E}'' = E_0''\,\hat{e}_x\,e^{i(-kz-\omega t)} \\ \vec{B}'' = -E_0''\,\hat{e}_y\,e^{i(-kz-\omega t)} \end{cases}$

(f) $\begin{cases} \vec{E}' = E_0' \hat{e}_x e^{i[(\alpha+i\beta)z-\omega t]} \\ \vec{B}' = \frac{ck'}{\omega} E_0' \hat{e}_y e^{i[(\alpha+i\beta)z-\omega t]} \end{cases}$

$$\nabla\times E' = -\frac{1}{c}\frac{\partial \vec{B}'}{\partial t}$$

$$\begin{vmatrix} e_x & e_y & e_z \\ 0 & 0 & \partial_z \\ E_x' & 0 & 0 \end{vmatrix} = \hat{e}_y \frac{\partial E_x'}{\partial z} = \frac{i\omega}{c}\vec{B}'$$

$$\vec{B}' = \frac{-ic}{\omega}\hat{e}_y\, i(\alpha+i\beta) E_x'$$

$$= \frac{c(\alpha+i\beta)}{\omega} E_y' = \frac{ck'}{\omega} E_y'$$

$$k' = \alpha + i\beta$$

Boundary Conditions at $z=0$

E_{tang}: $E_0 + E_0'' = E_0'$

D_{normal}: $0+0=0$

B_{normal}: $0+0=0$

H_{tang}: $E_0 - E_0'' = \frac{ck'}{\omega\mu} E_0'$

Solve for E_0''/E_0

$$E_0 - E_0'' = \frac{ck'}{\omega\mu}(E_0 + E_0'')$$

$$E_0\left[1 - \frac{ck'}{\omega\mu}\right] = E_0''\left[1 + \frac{ck'}{\omega\mu}\right] \Rightarrow \frac{E_0''}{E_0} = \frac{1 - ck'/\omega\mu}{1 + ck'/\omega\mu}$$

The relative phase, comparing E_0'' and E_0

$$\frac{E_0''}{E_0} = \frac{\mu\omega - c(\alpha+i\beta)}{\mu\omega + c(\alpha+i\beta)} = \frac{\mu\omega - c\alpha - ic\beta}{\mu\omega + c\alpha + ic\beta}$$

$$\boxed{\tan\phi = \frac{Im(E_0''/E_0)}{Re(E_0''/E_0)}}$$

$$\frac{E_0''}{E_0} = \frac{(\mu\omega - c\alpha - ic\beta)(\mu\omega + c\alpha - ic\beta)}{(\mu\omega + c\alpha)^2 + (c\beta)^2}$$

Numerator $= (\mu\omega - ic\beta)^2 - (c\alpha)^2$

$$Im\left(\frac{E_0''}{E_0}\right) = \frac{-2\mu\omega c\beta}{(\mu\omega + c\alpha)^2 + (c\beta)^2}$$

$$Re\left(\frac{E_0''}{E_0}\right) = \frac{\mu^2\omega^2 - c^2\beta^2 - c^2\alpha^2}{(\mu\omega + c\alpha)^2 + (c\beta)^2}$$

2 points

$$\tan\phi = \frac{-2\mu\omega c\beta}{\mu^2\omega^2 - c^2(\alpha^2+\beta^2)} = \frac{-2c\beta}{\mu\omega - \frac{c^2}{\mu\omega}(\alpha^2+\beta^2)}$$

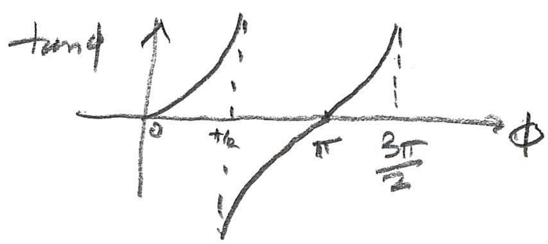
(c) <u>Low frequencies</u> : $\frac{\sigma}{\omega} \gg 1$

$$\alpha \approx \sqrt{\frac{\mu\epsilon\omega^2}{2c^2}}\sqrt{\frac{4\pi\sigma}{\epsilon\omega}} = \sqrt{\frac{2\pi\sigma\mu\omega}{c^2}}$$

$$\beta \approx \sqrt{\frac{2\pi\sigma\mu\omega}{c^2}}$$

$$\tan\phi = \frac{-2\sqrt{2\pi\sigma\mu\omega}}{\mu\omega - \frac{c^2}{\mu\omega}\,2\,\frac{2\pi\sigma\mu\omega}{c^2}} = \frac{-2\sqrt{2\pi\sigma\mu\omega}}{\mu\omega\left[1 - \underset{\uparrow\text{large}}{\frac{4\pi\sigma}{\mu\omega}}\right]}$$

$$\tan\phi \approx \frac{-2\sqrt{2\pi\sigma\mu\omega}}{\mu\omega\,(-)\,\frac{4\pi\sigma}{\mu\omega}} = \sqrt{\frac{\mu\omega}{2\pi\sigma}}$$



$\tan\phi \to 0$ as $\omega \to 0$

$\therefore\ \phi = 0$ or π

$\frac{E_0''}{E_0}$ is negative $\Rightarrow$ $\phi = \pi$ in the limit

<u>High frequencies</u> : $\frac{\sigma}{\omega} \ll 1$

$$\alpha \approx \sqrt{\frac{\mu\epsilon\omega^2}{2c^2}}\sqrt{2} = \sqrt{\frac{\mu\epsilon\omega^2}{c^2}} \quad \text{(large)}$$

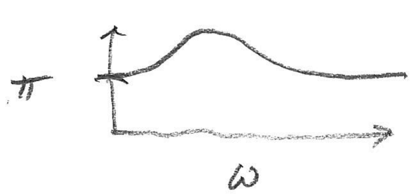
$$\beta \approx \sqrt{\frac{\mu\epsilon\omega^2}{2c^2}}\left\{\frac{1}{2}\left(\frac{4\pi\sigma}{\epsilon\omega}\right)^2\right\}^{1/2} = \sqrt{\frac{\mu\epsilon\omega^2}{4c^2}}\,\frac{4\pi\sigma}{\epsilon\omega} = 2\pi\sigma\sqrt{\frac{\mu}{\epsilon}} \quad \text{(small)}$$

$$\tan\phi = \frac{-2c\;2\pi\sigma\sqrt{\mu/\epsilon}}{\mu\omega - \frac{c^2}{\mu\omega}\left(\frac{\mu\epsilon\omega^2}{c^2}\right)} = \frac{-4\pi\sigma c\sqrt{\mu/\epsilon}}{\mu\omega\left[1 - \frac{\epsilon}{\mu}\right]}$$

$\tan\phi \to 0$ as $\omega \to \infty$, so $\phi = 0$ or π.

$\frac{E_0''}{E_0}$ is negative $\Rightarrow$ $\phi = \pi$ in the limit

<u>Use Mathematica</u> to plot ϕ versus ω



<u>2 points</u> for part C

Exercise 9.5.5 continues ...

(d) Summary: $\tan\phi = \dfrac{-2c\beta}{\mu\omega - \frac{c^2}{\mu\omega}(\alpha^2+\beta^2)}$ ← call this x; $x = \tan\phi$

where

$$\alpha = \sqrt{\frac{\mu\epsilon\omega^2}{2c^2}}\left\{1+\sqrt{1+\left(\frac{4\pi\sigma}{\epsilon\omega}\right)^2}\right\}^{1/2}$$

$$\beta = \sqrt{\frac{\mu\epsilon\omega^2}{2c^2}}\left\{-1+\sqrt{1+\left(\frac{4\pi\sigma}{\epsilon\omega}\right)^2}\right\}^{1/2}$$

call this u; $u = \sigma/\omega$

Note that x depends only on the ratio σ/ω

$$x = \frac{-2\sqrt{\frac{\mu\epsilon\omega^2}{2}}\left\{-1+\sqrt{1+\left(\frac{4\pi}{\epsilon}u\right)^2}\right\}^{1/2}}{\mu\omega - \frac{c^2}{\mu\omega}\,\frac{\mu\epsilon\omega^2}{2c^2}\,2\sqrt{1+\left(\frac{4\pi}{\epsilon}u\right)^2}}$$

$$= -\sqrt{\frac{2\epsilon}{\mu}}\;\frac{\left\{-1+\sqrt{1+\left(\frac{4\pi}{\epsilon}u\right)^2}\right\}^{1/2}}{\left\{1-\frac{\epsilon}{\mu}\sqrt{1+\left(\frac{4\pi}{\epsilon}u\right)^2}\right\}}$$

$S = \sqrt{1+\left(\frac{4\pi u}{\epsilon}\right)^2}$

$a = \epsilon/\mu$

$b = 4\pi/\epsilon$

THE MAX. PHASE

Solve for u the equation $\frac{dx}{du} = 0$

$$\Rightarrow \quad u_{cr} = \frac{\epsilon}{4\pi}\sqrt{\left(\frac{2a-1}{a}\right)^2-1} = \frac{\epsilon}{4\pi}\sqrt{3-4\frac{\mu}{\epsilon}+\left(\frac{\mu}{\epsilon}\right)^2}$$

$$\omega_{cr} = \frac{\sigma}{u_{cr}} = \frac{4\pi\sigma}{\epsilon}\left(3-4\frac{\mu}{\epsilon}+\left(\frac{\mu}{\epsilon}\right)^2\right)^{-1/2}$$

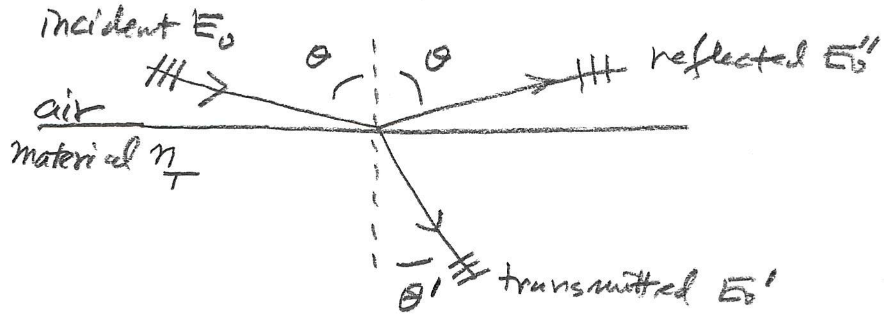
The phase at $\omega = \omega_{cr}$ is ϕ_{cr} where

$$\tan\phi_{cr} = -\sqrt{2a}\;\frac{(-1)}{2\sqrt{a-1}\sqrt{a}} = \frac{1}{\sqrt{2(\epsilon/\mu-1)}}$$

$$\phi_{cr} = \pi + \arctan\left[\frac{1}{\sqrt{2(\epsilon/\mu-1)}}\right].$$

2 points

Problem 4-6 : Polarization by Reflection (4 points = 2+2)



At $\theta = \theta_B$ (Brewster's angle) $E_0'' = 0$ for transverse magnetic (TM) polarization. So, at $\theta = \theta_B$, the reflected light is 100% transverse electric (TE) polarized.

Brewster's angle $\frac{E_0''}{E_0} = 0$ for TM polarization $\Rightarrow n_T \cos\theta_B = n_I \cos\theta'$ (by Fresnel's equations); also, by Snell's law $\rightarrow n_I \sin\theta_B = n_T \sin\theta'$

Set $n_I = 1$ (index of refraction of air).

ⓐ Solve for θ_B

$$n_T \cos\theta_B = \cos\theta' = \sqrt{1-\sin^2\theta'} = \sqrt{1 - \frac{\sin^2\theta_B}{n_T^2}}$$

$$= n_T\sqrt{1-\sin^2\theta_B}$$

$$n_T^2(1-\sin^2\theta_B) = 1 - \frac{\sin^2\theta_B}{n_T^2} \Rightarrow \sin^2\theta_B = \frac{n_T^2-1}{n_T^2 - \frac{1}{n_T^2}} = \frac{n_T^2}{n_T^2+1}$$

$$\sin\theta_B = \frac{n_T}{\sqrt{n_T^2+1}} \Rightarrow \tan\theta_B = n_T \quad (\text{or } n_T/n_I) \quad (2\text{ pt})$$

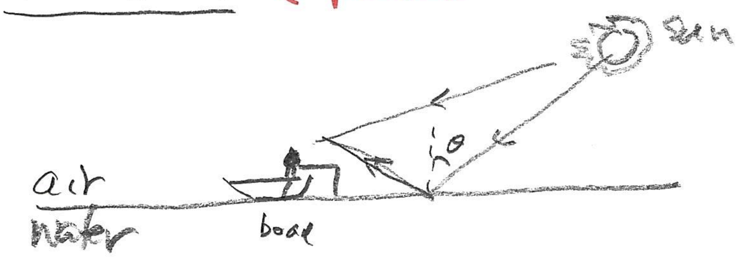
ⓑ Theorem $\theta + \theta' = 90$ degrees

Proof

$$\frac{n_I \sin\theta_B}{n_T \cos\theta_B} = \frac{n_T \sin\theta'}{n_I \cos\theta'} \Rightarrow \tan\theta' = \left(\frac{n_I}{n_T}\right)^2 \tan\theta_B = \frac{n_I}{n_T} = \frac{1}{\tan\theta_B}$$

implies $\theta' = 90° - \theta_B$ (2 pt)

Problem 4.7 (2 points)

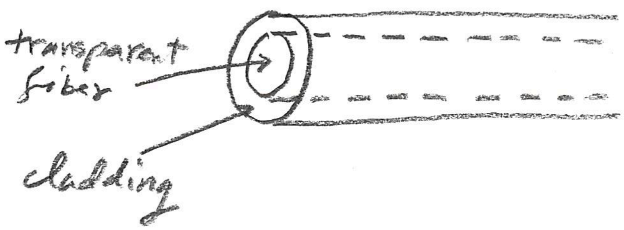


For TM polarization, the reflection is 0 for $\theta = \theta_B = \arctan 1.33 = 53$ degrees.

For $\theta = \theta_B$, the reflected light is 100% TE polarized; and for angles near 53° the reflected light is predominantly TE polarized. If the fisherman is wearing horizontally polarized sunglasses, then the TE polarized light will not pass through the polaroid film, and so the intensity of reflected light will low.

Problem 4-8 (optical Fibers) (2 points)

This is what an optical fiber looks like



fiber index of refraction = n_f

cladding index of refraction = n_c ← 1 point

Make $n_f > n_c$; so that total internal reflection will occur at the interface between fiber and cladding, if the angle of incidence θ is greater than $\theta_c = \sin^{-1}\left(\frac{n_c}{n_f}\right)$. ← 1 point