Medium #1:

$$\mu_o\mu_{r1},\ \ \varepsilon_{1c} = \varepsilon_o\varepsilon_{r1} - j(\varepsilon_1'' + \frac{\sigma_1}{\omega})$$

$$\Rightarrow jk_{1c} = \gamma_1 = j\omega\sqrt{\mu_o\mu_{r1}\varepsilon_{1c}} = \alpha_1 + j\beta_1$$

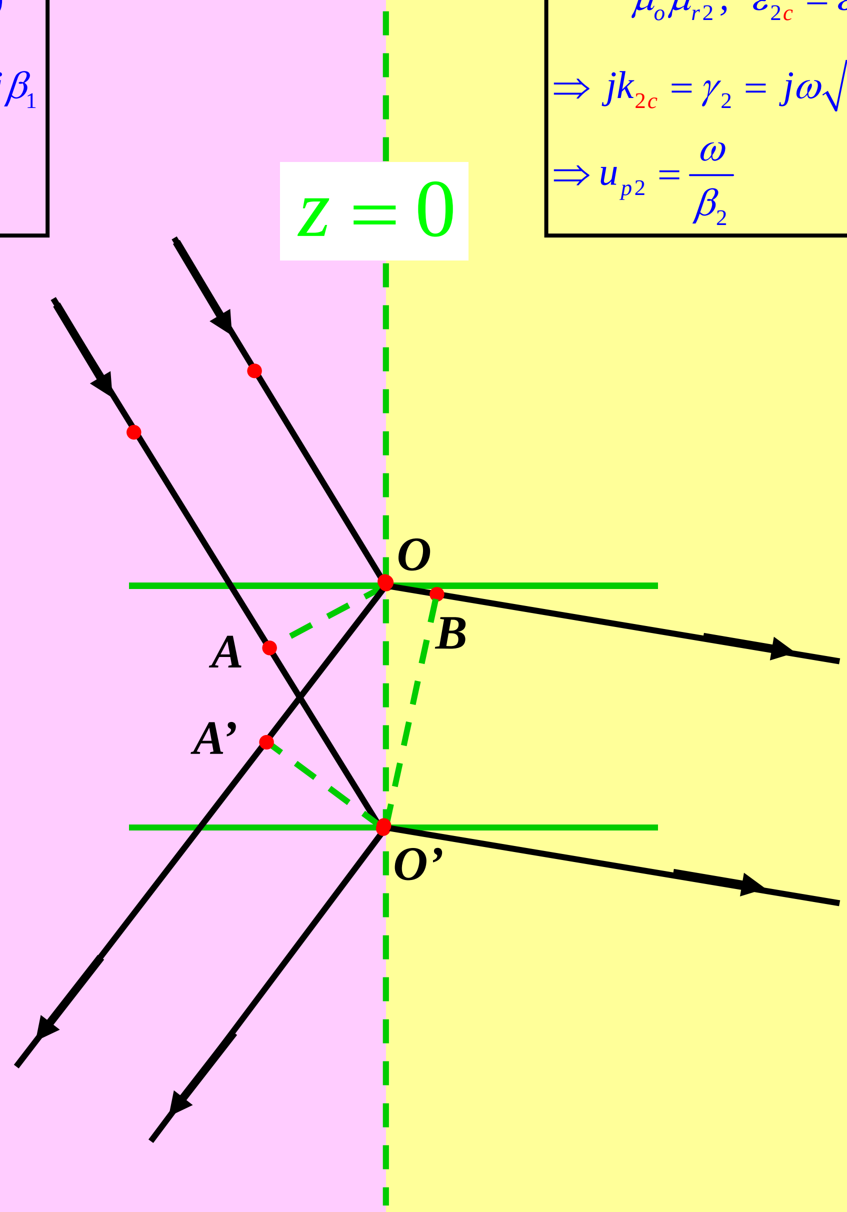
$$\Rightarrow u_{p1} = \frac{\omega}{\beta_1}$$

Medium #2:

$$\mu_o\mu_{r2},\ \ \varepsilon_{2c} = \varepsilon_o\varepsilon_{r2} - j(\varepsilon_2'' + \frac{\sigma_2}{\omega})$$

$$\Rightarrow jk_{2c} = \gamma_2 = j\omega\sqrt{\mu_o\mu_{r2}\varepsilon_{2c}} = \alpha_2 + j\beta_2$$

$$\Rightarrow u_{p2} = \frac{\omega}{\beta_2}$$



Medium #1:

$$\mu_o\mu_{r1},\ \ \varepsilon_{1c} = \varepsilon_o\varepsilon_{r1} - j(\varepsilon_1'' + \frac{\sigma_1}{\omega})$$

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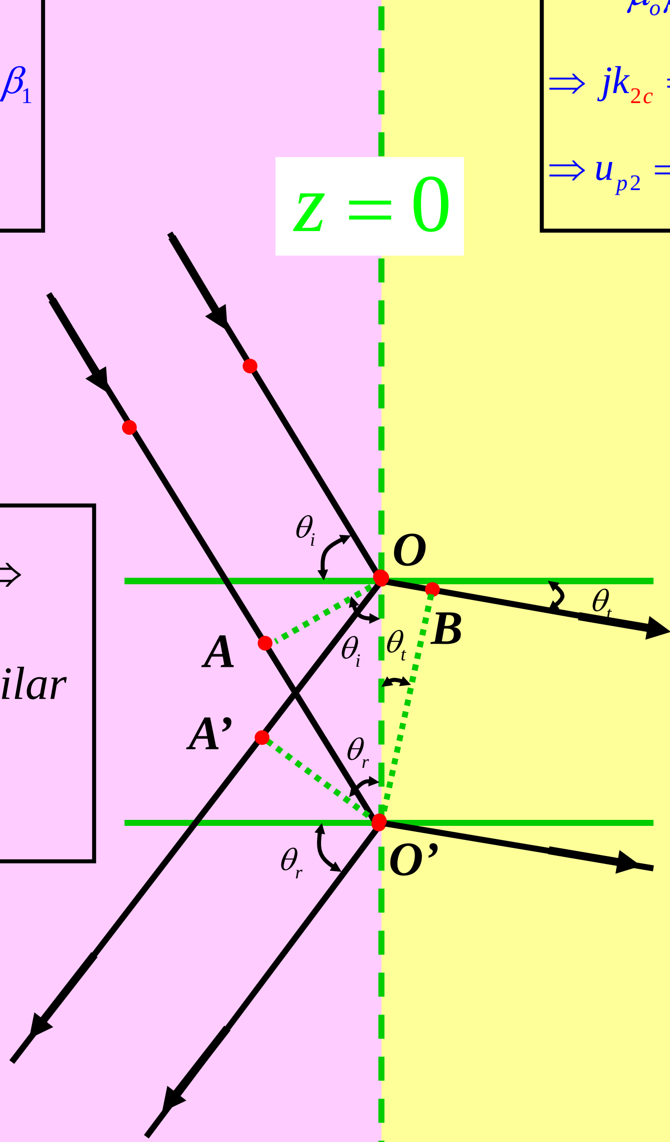
$$\Rightarrow u_{p1} = \frac{\omega}{\beta_1}$$

Medium #2:

$$\mu_o\mu_{r2},\ \ \varepsilon_{2c} = \varepsilon_o\varepsilon_{r2} - j(\varepsilon_2'' + \frac{\sigma_2}{\omega})$$

$$\Rightarrow jk_{2c} = \gamma_2 = j\omega\sqrt{\mu_o\mu_{r2}\varepsilon_{2c}} = \alpha_2 + j\beta_2$$

$$\Rightarrow u_{p2} = \frac{\omega}{\beta_2}$$



$$\frac{\overline{O}\overline{A}'}{u_{p1}} = \frac{\overline{A}\overline{O}'}{u_{p1}} \Rightarrow \overline{O}\overline{A}' = \overline{A}\overline{O}' \Rightarrow$$

Right-angle triangle OO'A *similar to* Right-angle triangle O'OA'

$$\Rightarrow \quad \theta_r = \theta_i$$

$$\frac{AO'}{u_{p1}} = \frac{OB}{u_{p2}} \Rightarrow$$

$$\frac{OO'sin\theta_i}{u_{p1}} = \frac{OO'sin\theta_t}{u_{p2}} \Rightarrow$$

$$\frac{sin\theta_t}{sin\theta_i} = \frac{u_{p2}}{u_{p1}} (= \frac{\beta_1}{\beta_2})$$

Medium #1: dense medium

$$\mu_o\mu_{r1},\ \ \varepsilon_{1c}=\varepsilon_o\varepsilon_{r1}-j(\varepsilon_1''+\frac{\sigma_1}{\omega})$$

$$\Rightarrow jk_{1c}=\gamma_1=j\omega\sqrt{\mu_o\mu_{r1}\varepsilon_{1c}}=\alpha_1+j\beta_1$$

$$\Rightarrow u_{p1}=\frac{\omega}{\beta_1}$$

$z=0$

$u_{p1}<u_{p2}$

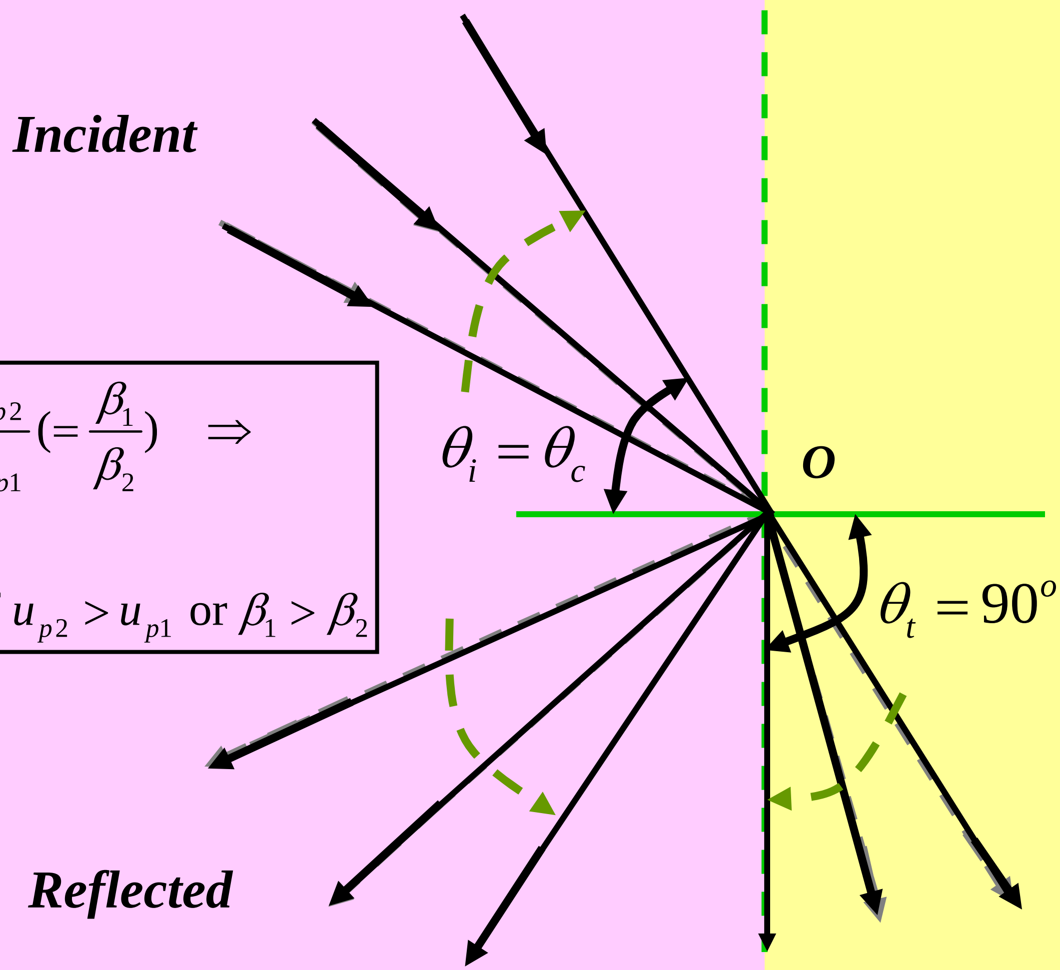
Waves travels slower in medium #1 than in medium #2

Medium #2: less dense medium

$$\mu_o\mu_{r2},\ \ \varepsilon_{2c}=\varepsilon_o\varepsilon_{r2}-j(\varepsilon_2''+\frac{\sigma_2}{\omega})$$

$$\Rightarrow jk_{2c}=\gamma_2=j\omega\sqrt{\mu_o\mu_{r2}\varepsilon_{2c}}=\alpha_2+j\beta_2$$

$$\Rightarrow u_{p2}=\frac{\omega}{\beta_2}$$



$$\frac{\sin\theta_t}{\sin\theta_i}=\frac{u_{p2}}{u_{p1}}(=\frac{\beta_1}{\beta_2})\quad\Rightarrow$$

$\theta_t>\theta_i$ if $u_{p2}>u_{p1}$ or $\beta_1>\beta_2$

$$\frac{\sin 90^o}{\sin\theta_c}=\frac{u_{p2}}{u_{p1}}\quad\Rightarrow$$

No Transmission $(u_{p1}<u_{p2})$:

Critical angle $\theta_c=\sin^{-1}(\frac{u_{p1}}{u_{p2}})$

To have no transmission:

$\theta_i\geq\theta_c$ or $\sin\theta_i\geq\sin\theta_c$

A Special Case:

Medium #1: dense lossless medium

$$\mu_o\mu_{r1},\quad \varepsilon_1 = \varepsilon_o\varepsilon_{r1}$$

$$\Rightarrow jk_1 = j\omega\sqrt{\mu_o\mu_{r1}\varepsilon_o\varepsilon_{r1}} = j\beta_1$$

$$\Rightarrow u_{p1} = \frac{\omega}{\beta_1}$$

$z=0$

$u_{p1} < u_{p2}$

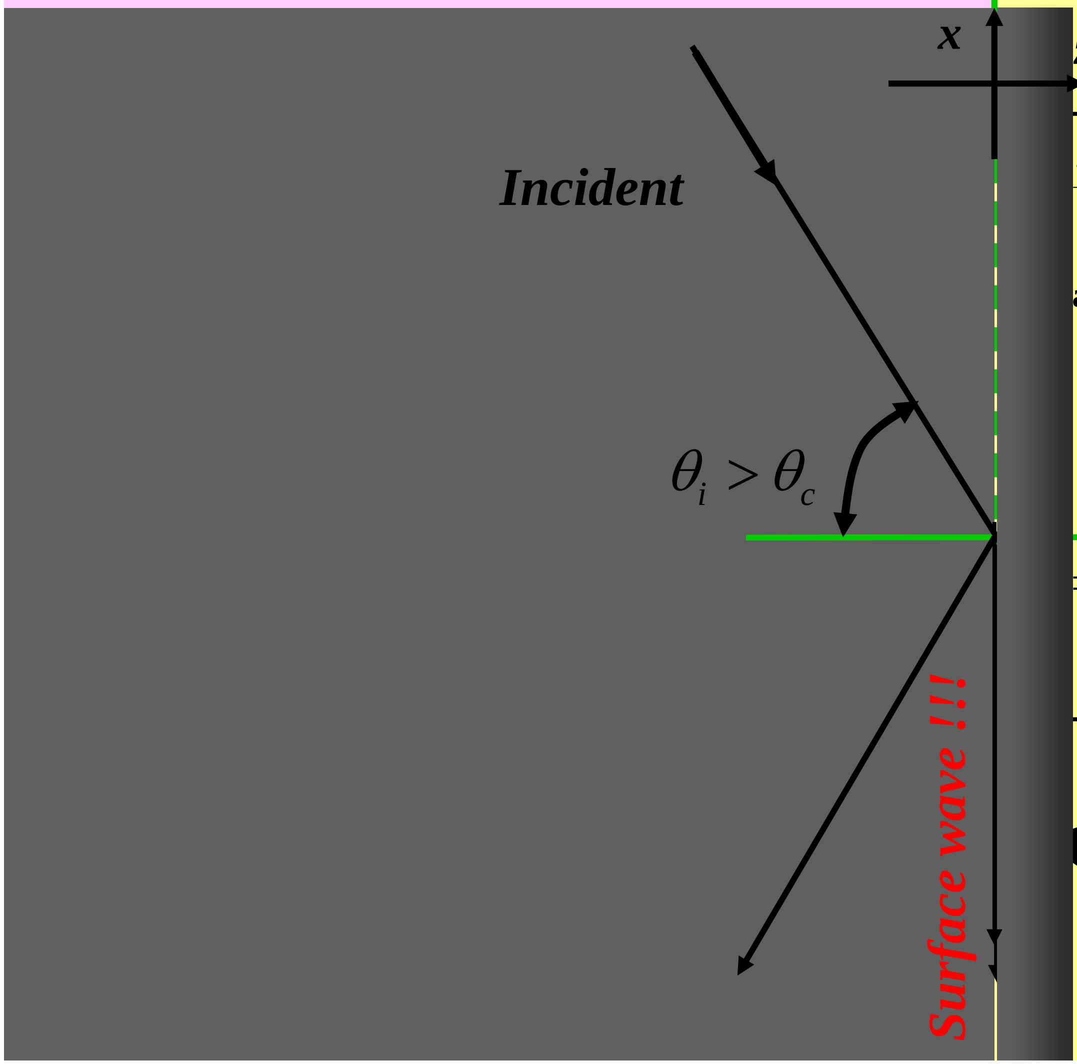
Waves travels slower in medium #1 than in medium #2

Medium #2: less dense lossless medium

$$\mu_o\mu_{r2},\quad \varepsilon_2 = \varepsilon_o\varepsilon_{r2}$$

$$\Rightarrow jk_2 = j\omega\sqrt{\mu_o\mu_{r2}\varepsilon_o\varepsilon_{r2}} = j\beta_2$$

$$\Rightarrow u_{p2} = \frac{\omega}{\beta_2}$$



$$\frac{\sin\theta_t}{\sin\theta_i} = \frac{u_{p2}}{u_{p1}} \quad \Rightarrow \sin\theta_t = \frac{u_{p2}}{u_{p1}}\sin\theta_i > 1$$

$$\mathbf{a}_{nt} = -\mathbf{a}_x\sin\theta_t + \mathbf{a}_z\cos\theta_t$$

$$= -\mathbf{a}_x\sin\theta_t + \mathbf{a}_z\sqrt{1-\sin^2\theta_t}$$

$$= -\mathbf{a}_x\sin\theta_t - \mathbf{a}_z j\sqrt{\sin^2\theta_t - 1}$$

$$\Rightarrow e^{-j\beta_2\mathbf{a}_{nt}\bullet(x\mathbf{a}_x + y\mathbf{a}_y + z\mathbf{a}_z)} = e^{-j\beta_2\mathbf{a}_{nt}\bullet(x\mathbf{a}_x + y\mathbf{a}_y + z\mathbf{a}_z)}$$

$$= e^{j\beta_2\sin\theta_t x}\, e^{-\beta_2\sqrt{\sin^2\theta_t - 1}\, z}$$

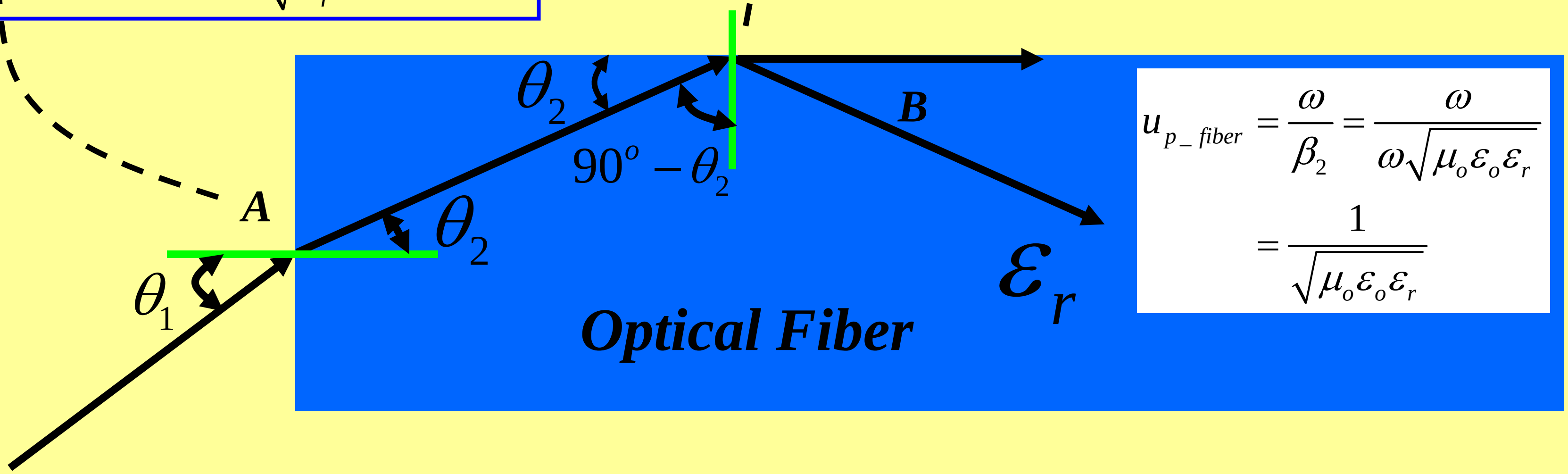
Attenuation in the z-direction

At A: $\dfrac{\sin\theta_2}{\sin\theta_1} = \dfrac{u_{p\_fibre}}{u_{p\_air}} = \dfrac{1}{\sqrt{\varepsilon_r}}$

$$\Rightarrow \sin\theta_2 = \frac{1}{\sqrt{\varepsilon_r}}\sin\theta_1$$

At B: $90^o - \theta_2 \geq \theta_c$

$$\Rightarrow \sin(90^o - \theta_2) \geq \sin\theta_c = \frac{u_{p\_fibre}}{u_{p\_air}} = \frac{1}{\sqrt{\varepsilon_r}}$$



$$u_{p\_fiber} = \frac{\omega}{\beta_2} = \frac{\omega}{\omega\sqrt{\mu_o\varepsilon_o\varepsilon_r}} = \frac{1}{\sqrt{\mu_o\varepsilon_o\varepsilon_r}}$$

$$u_{p\_air} = \frac{\omega}{\beta_1} = \frac{\omega}{\omega\sqrt{\mu_o\varepsilon_o}} = \frac{1}{\sqrt{\mu_o\varepsilon_o}}$$

$$\cos\theta_2 = \sqrt{1-\sin^2\theta_2} = \sqrt{1-\left(\frac{1}{\sqrt{\varepsilon_r}}\sin\theta_1\right)^2} > \frac{1}{\sqrt{\varepsilon_r}}$$

$$\Rightarrow \varepsilon_r \geq 1+\sin^2\theta_1 \Rightarrow \varepsilon_r \geq 2$$

Medium #1:

$$\mu_o\mu_{r1},\quad \varepsilon_{1c}=\varepsilon_o\varepsilon_{r1}-j(\varepsilon_1''+\frac{\sigma_1}{\omega})$$

$$\Rightarrow jk_{1c}=\gamma_1=j\omega\sqrt{\mu_o\mu_{r1}\varepsilon_{1c}}=\alpha_1+j\beta_1$$

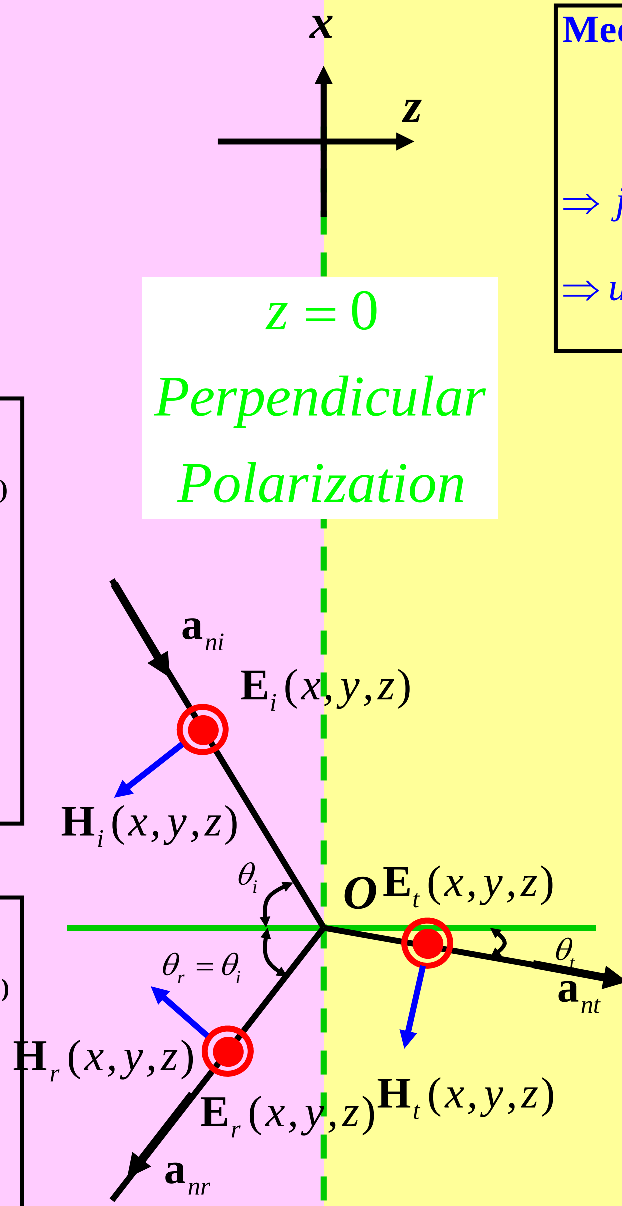
$$\Rightarrow u_{p1}=\frac{\omega}{\beta_1}$$

Medium #2:

$$\mu_o\mu_{r2},\quad \varepsilon_{2c}=\varepsilon_o\varepsilon_{r2}-j(\varepsilon_2''+\frac{\sigma_2}{\omega})$$

$$\Rightarrow jk_{2c}=\gamma_2=j\omega\sqrt{\mu_o\mu_{r2}\varepsilon_{2c}}=\alpha_2+j\beta_2$$

$$\Rightarrow u_{p2}=\frac{\omega}{\beta_2}$$



$$\mathbf{a}_{ni}=\mathbf{a}_z\cos\theta_i-\mathbf{a}_x\sin\theta_i$$

$$\mathbf{E}_i(x,y,z)=\mathbf{a}_yE_{io}e^{-jk_{1c}\mathbf{a}_{ni}\bullet(x\mathbf{a}_x+y\mathbf{a}_y+z\mathbf{a}_z)}$$

$$\mathbf{H}_i(x,y,z)=\frac{1}{\eta_{1c}}\mathbf{a}_{ni}\times\mathbf{E}_i(x,y,z)$$

$$k_{1c}=\omega\sqrt{\mu_o\mu_{r1}\varepsilon_{1c}},\quad \eta_{1c}=\sqrt{\frac{\mu_o\mu_{r1}}{\varepsilon_{1c}}}$$

$$\mathbf{a}_{nr}=-\mathbf{a}_z\cos\theta_i-\mathbf{a}_x\sin\theta_i$$

$$\mathbf{E}_r(x,y,z)=\mathbf{a}_yE_{ro}e^{-jk_{1c}\mathbf{a}_{nr}\bullet(x\mathbf{a}_x+y\mathbf{a}_y+z\mathbf{a}_z)}$$

$$\mathbf{H}_r(x,y,z)=\frac{1}{\eta_{1c}}\mathbf{a}_{nr}\times\mathbf{E}_r(x,y,z)$$

$$k_{1c}=\omega\sqrt{\mu_o\mu_{r1}\varepsilon_{1c}},\quad \eta_{1c}=\sqrt{\frac{\mu_o\mu_{r1}}{\varepsilon_{1c}}}$$

$$\mathbf{a}_{nt}=\mathbf{a}_z\cos\theta_t-\mathbf{a}_x\sin\theta_t$$

$$\mathbf{E}_t(x,y,z)=\mathbf{a}_yE_{to}e^{-jk_{2c}\mathbf{a}_{nt}\bullet(x\mathbf{a}_x+y\mathbf{a}_y+z\mathbf{a}_z)}$$

$$\mathbf{H}_t(x,y,z)=\frac{1}{\eta_{2c}}\mathbf{a}_{nt}\times\mathbf{E}_t(x,y,z)$$

$$k_{2c}=\omega\sqrt{\mu_o\mu_{r2}\varepsilon_{2c}},\quad \eta_{1c}=\sqrt{\frac{\mu_o\mu_{r2}}{\varepsilon_{2c}}}$$

Medium #1:

$$\mu_o\mu_{r1},\ \ \varepsilon_{1c} = \varepsilon_o\varepsilon_{r1} - j(\varepsilon_1^{''} + \frac{\sigma_1}{\omega})$$

$$\Rightarrow jk_{1c} = \gamma_1 = \omega\sqrt{\mu_o\mu_{r1}\varepsilon_{1c}} = \alpha_1 + j\beta_1$$

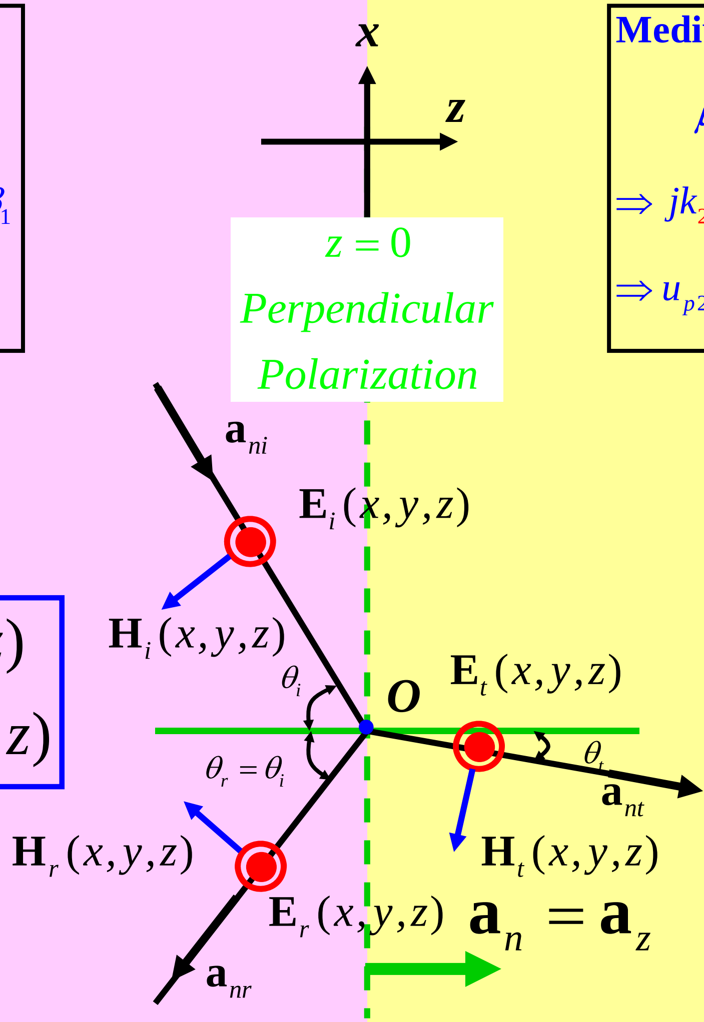
$$\Rightarrow u_{p1} = \frac{\omega}{\beta_1}$$

Medium #2:

$$\mu_o\mu_{r2},\ \ \varepsilon_{2c} = \varepsilon_o\varepsilon_{r2} - j(\varepsilon_2^{''} + \frac{\sigma_2}{\omega})$$

$$\Rightarrow jk_{2c} = \gamma_2 = \omega\sqrt{\mu_o\mu_{r2}\varepsilon_{2c}} = \alpha_2 + j\beta_2$$

$$\Rightarrow u_{p2} = \frac{\omega}{\beta_2}$$



$$\mathbf{E}_1 = \mathbf{E}_i(x,y,z) + \mathbf{E}_r(x,y,z)$$

$$\mathbf{H}_1 = \mathbf{H}_i(x,y,z) + \mathbf{H}_r(x,y,z)$$

$$\mathbf{E}_2 = \mathbf{E}_t(x,y,z)$$

$$\mathbf{H}_2 = \mathbf{H}_t(x,y,z)$$

$$z = 0: \quad \mathbf{E}_{1t}(x,y,z=0) = \mathbf{E}_{2t}(x,y,z) = 0$$

$$z = 0: \quad \mathbf{a}_n \times [\mathbf{H}_1(x,y,z=0) - \mathbf{H}_2(x,y,z=0)] = 0$$

Medium #1:

$$\mu_o \mu_{r1}, \quad \varepsilon_{1c} = \varepsilon_o \varepsilon_{r1} - j(\varepsilon_1^{''} + \frac{\sigma_1}{\omega})$$

$$\Rightarrow jk_{1c} = \gamma_1 = j\omega\sqrt{\mu_o \mu_{r1} \varepsilon_{1c}} = \alpha_1 + j\beta_1$$

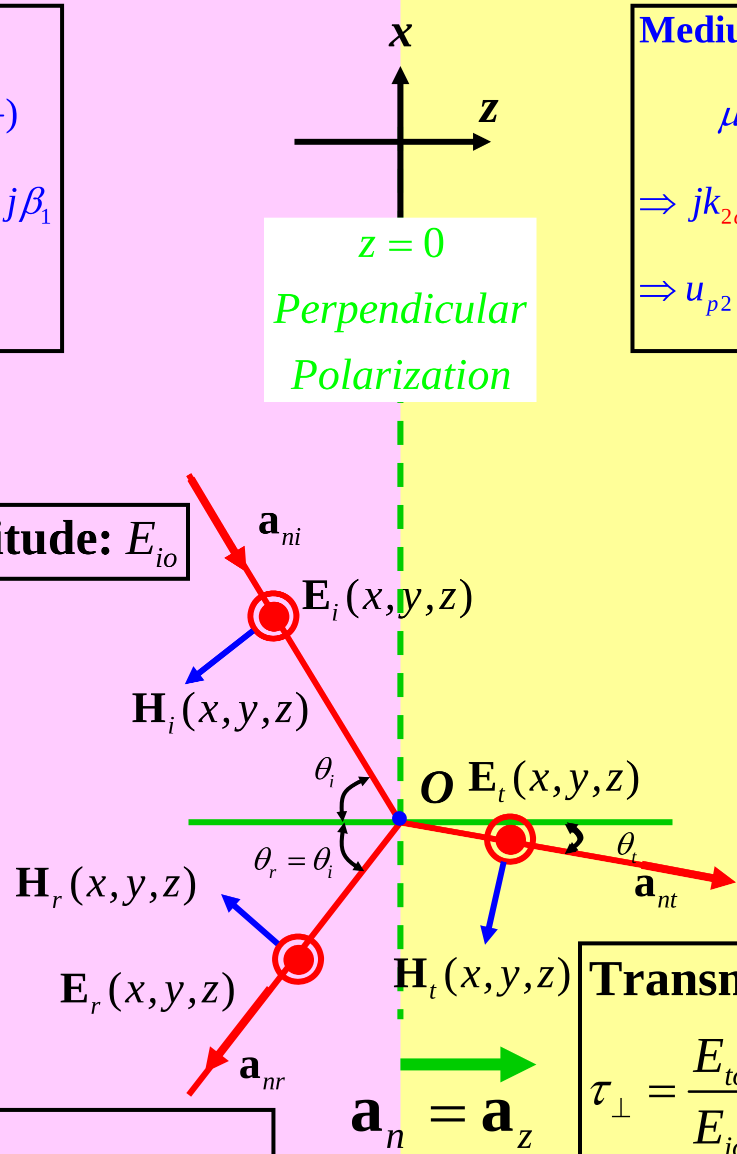
$$\Rightarrow u_{p1} = \frac{\omega}{\beta_1}$$

Medium #2:

$$\mu_o \mu_{r2}, \quad \varepsilon_{2c} = \varepsilon_o \varepsilon_{r2} - j(\varepsilon_2^{''} + \frac{\sigma_2}{\omega})$$

$$\Rightarrow jk_{2c} = \gamma_2 = j\omega\sqrt{\mu_o \mu_{r2} \varepsilon_{2c}} = \alpha_2 + j\beta_2$$

$$\Rightarrow u_{p2} = \frac{\omega}{\beta_2}$$



Incident Amplitude: E_{io}

Transmitted Amplitude: E_{to}

$$\tau_\perp = \frac{E_{to}}{E_{io}} = \frac{2(\eta_{2c} / \cos\theta_t)}{(\eta_{2c} / \cos\theta_t) + (\eta_{1c} / \cos\theta_i)}$$

Reflected Amplitude: E_{ro}

$$\Gamma_\perp = \frac{E_{ro}}{E_{io}} = \frac{(\eta_{2c} / \cos\theta_t) - (\eta_{1c} / \cos\theta_i)}{(\eta_{2c} / \cos\theta_t) + (\eta_{1c} / \cos\theta_i)}$$

Medium #1:

$$\mu_o\mu_{r1},\ \ \varepsilon_{1c} = \varepsilon_o\varepsilon_{r1} - j(\varepsilon_1'' + \frac{\sigma_1}{\omega})$$

$$\Rightarrow jk_{1c} = \gamma_1 = \omega\sqrt{\mu_o\mu_{r1}\varepsilon_{1c}} = \alpha_1 + j\beta_1$$

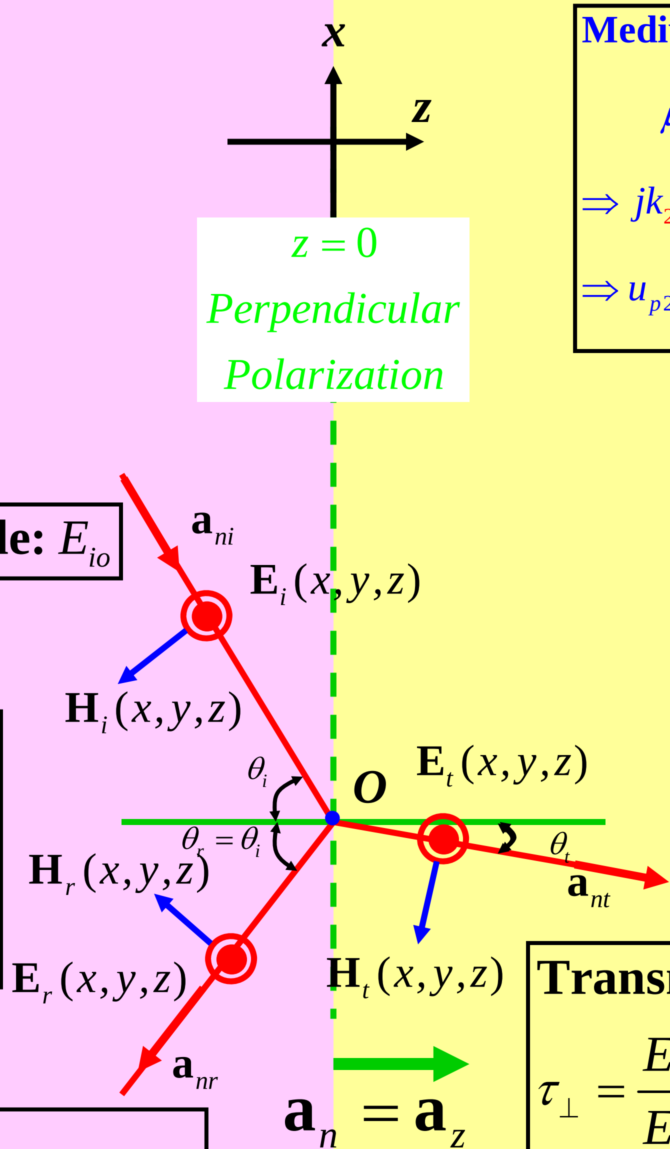
$$\Rightarrow u_{p1} = \frac{\omega}{\beta_1}$$

Medium #2:

$$\mu_o\mu_{r2},\ \ \varepsilon_{2c} = \varepsilon_o\varepsilon_{r2} - j(\varepsilon_2'' + \frac{\sigma_2}{\omega})$$

$$\Rightarrow jk_{2c} = \gamma_2 = \omega\sqrt{\mu_o\mu_{r2}\varepsilon_{2c}} = \alpha_2 + j\beta_2$$

$$\Rightarrow u_{p2} = \frac{\omega}{\beta_2}$$



Incident Amplitude: E_{io}

Zero reflection:

$(\eta_{2c} / \cos\theta_t) - (\eta_{1c} / \cos\theta_i) = 0$

At this moment, the incident angle θ_i is defined as Brewster angle $\theta_i = \theta_B$

Reflected Amplitude: E_{ro}

$$\Gamma_\perp = \frac{E_{ro}}{E_{io}} = \frac{(\eta_{2c} / \cos\theta_t) - (\eta_{1c} / \cos\theta_i)}{(\eta_{2c} / \cos\theta_t) + (\eta_{1c} / \cos\theta_i)}$$

Transmitted Amplitude: E_{to}

$$\tau_\perp = \frac{E_{to}}{E_{io}} = \frac{2(\eta_{2c} / \cos\theta_t)}{(\eta_{2c} / \cos\theta_t) + (\eta_{1c} / \cos_i)}$$

Medium #1:

$$\mu_o\mu_{r1},\ \ \varepsilon_{1c} = \varepsilon_o\varepsilon_{r1} - j(\varepsilon_1'' + \frac{\sigma_1}{\omega})$$

$$\Rightarrow jk_{1c} = \gamma_1 = j\omega\sqrt{\mu_o\mu_{r1}\varepsilon_{1c}} = \alpha_1 + j\beta_1$$

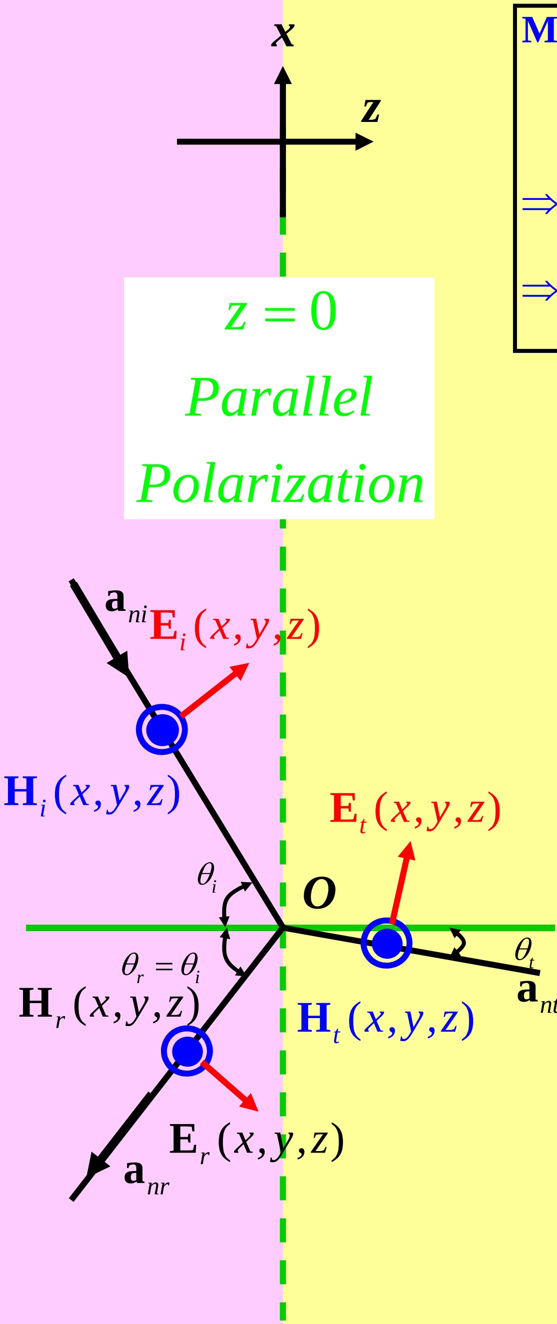
$$\Rightarrow u_{p1} = \frac{\omega}{\beta_1}$$

Medium #2:

$$\mu_o\mu_{r2},\ \ \varepsilon_{2c} = \varepsilon_o\varepsilon_{r2} - j(\varepsilon_2'' + \frac{\sigma_2}{\omega})$$

$$\Rightarrow jk_{2c} = \gamma_2 = j\omega\sqrt{\mu_o\mu_{r2}\varepsilon_{2c}} = \alpha_2 + j\beta_2$$

$$\Rightarrow u_{p2} = \frac{\omega}{\beta_2}$$



$$\mathbf{a}_{ni} = \mathbf{a}_z \cos\theta_i - \mathbf{a}_x \sin\theta_i$$

$$\mathbf{H}_i(x,y,z) = \mathbf{a}_y \frac{E_{io}}{\eta_{1c}} e^{-jk_{1c}\mathbf{a}_{ni}\bullet(x\mathbf{a}_x + y\mathbf{a}_y + z\mathbf{a}_z)}$$

$$\mathbf{E}_i(x,y,z) = -\eta_{1c}\mathbf{a}_{ni} \times \mathbf{H}_i(x,y,z)$$

$$k_{1c} = \omega\sqrt{\mu_o\mu_{r1}\varepsilon_{1c}},\ \ \eta_{1c} = \sqrt{\frac{\mu_o\mu_{r1}}{\varepsilon_{1c}}}$$

$$\mathbf{a}_{nt} = \mathbf{a}_z \cos\theta_t - \mathbf{a}_x \sin\theta_t$$

$$\mathbf{H}_t(x,y,z) = \mathbf{a}_y \frac{E_{to}}{\eta_{2c}} e^{-jk_{2c}\mathbf{a}_{nt}\bullet(x\mathbf{a}_x + y\mathbf{a}_y + z\mathbf{a}_z)}$$

$$\mathbf{E}_t(x,y,z) = -\eta_{2c}\mathbf{a}_{nt} \times \mathbf{H}_t(x,y,z)$$

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$$\mathbf{H}_r(x,y,z) = \mathbf{a}_y \frac{-E_{ro}}{\eta_{1c}} e^{-jk_{1c}\mathbf{a}_{nr}\bullet(x\mathbf{a}_x + y\mathbf{a}_y + z\mathbf{a}_z)}$$

$$\mathbf{E}_r(x,y,z) = -\eta_{1c}\mathbf{a}_{nr} \times \mathbf{H}_r(x,y,z)$$

$$k_{1c} = \omega\sqrt{\mu_o\mu_{r1}\varepsilon_{1c}},\ \ \eta_{1c} = \sqrt{\frac{\mu_o\mu_{r1}}{\varepsilon_{1c}}}$$

Medium #1:

$$\mu_o \mu_{r1}, \quad \varepsilon_{1c} = \varepsilon_o \varepsilon_{r1} - j(\varepsilon_1'' + \frac{\sigma_1}{\omega})$$

$$\Rightarrow jk_{1c} = \gamma_1 = \omega\sqrt{\mu_o \mu_{r1} \varepsilon_{1c}} = \alpha_1 + j\beta_1$$

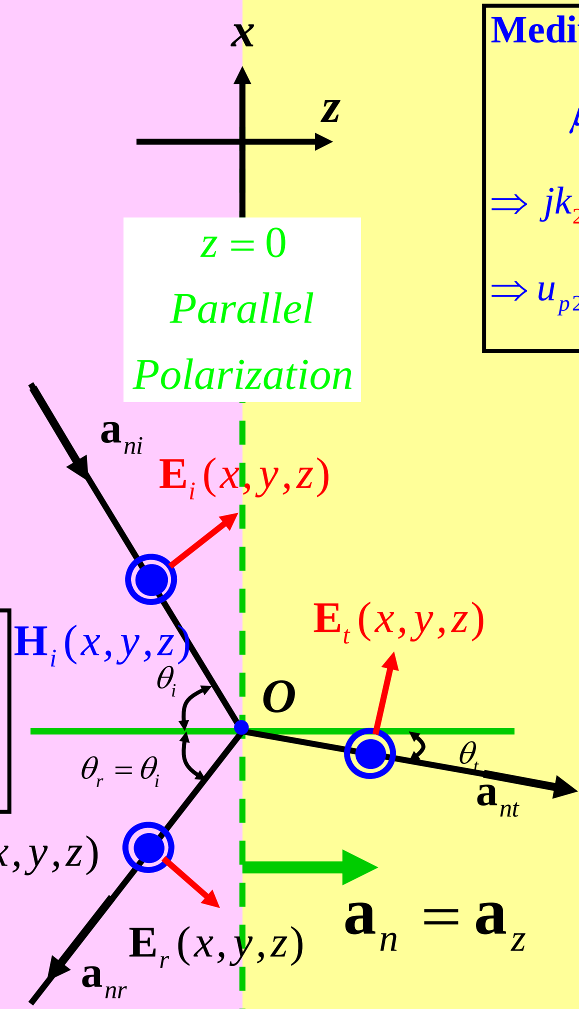
$$\Rightarrow u_{p1} = \frac{\omega}{\beta_1}$$

Medium #2:

$$\mu_o \mu_{r2}, \quad \varepsilon_{2c} = \varepsilon_o \varepsilon_{r2} - j(\varepsilon_2'' + \frac{\sigma_2}{\omega})$$

$$\Rightarrow jk_{2c} = \gamma_2 = \omega\sqrt{\mu_o \mu_{r2} \varepsilon_{2c}} = \alpha_2 + j\beta_2$$

$$\Rightarrow u_{p2} = \frac{\omega}{\beta_2}$$



$$\mathbf{E}_1 = \mathbf{E}_i(x,y,z) + \mathbf{E}_r(x,y,z)$$
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$$\mathbf{E}_2 = \mathbf{E}_t(x,y,z)$$
$$\mathbf{H}_2 = \mathbf{H}_t(x,y,z)$$

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$$z = 0: \qquad \mathbf{a}_n \times [\mathbf{H}_1(x,y,z=0) - \mathbf{H}_2(x,y,z=0)] = 0$$

Medium #1:

$$\mu_o\mu_{r1},\ \ \varepsilon_{1c}=\varepsilon_o\varepsilon_{r1}-j(\varepsilon_1''+\frac{\sigma_1}{\omega})$$

$$\Rightarrow jk_{1c}=\gamma_1=j\omega\sqrt{\mu_o\mu_{r1}\varepsilon_{1c}}=\alpha_1+j\beta_1$$

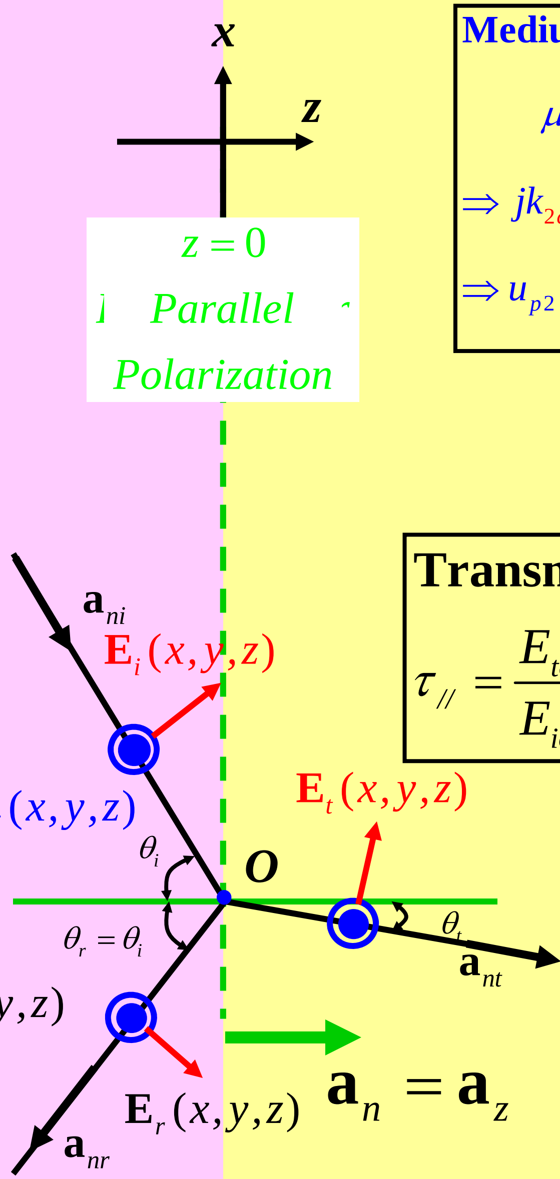
$$\Rightarrow u_{p1}=\frac{\omega}{\beta_1}$$

Medium #2:

$$\mu_o\mu_{r2},\ \ \varepsilon_{2c}=\varepsilon_o\varepsilon_{r2}-j(\varepsilon_2''+\frac{\sigma_2}{\omega})$$

$$\Rightarrow jk_{2c}=\gamma_2=j\omega\sqrt{\mu_o\mu_{r2}\varepsilon_{2c}}=\alpha_2+j\beta_2$$

$$\Rightarrow u_{p2}=\frac{\omega}{\beta_2}$$



Incident Amplitude: E_{io}

Transmitted Amplitude: E_{to}

$$\tau_{//}=\frac{E_{to}}{E_{io}}=\frac{2(\eta_{2c}\cos\theta_i)}{(\eta_{2c}\cos\theta_t)+(\eta_{1c}\cos_i\theta)}$$

Reflected Amplitude: E_{ro}

$$\Gamma_{//}=\frac{E_{ro}}{E_{io}}=\frac{(\eta_{2c}\cos\theta_t)-(\eta_{1c}\cos\theta_i)}{(\eta_{2c}\cos\theta_t)+(\eta_{1c}\cos\theta_i)}$$

Medium #1:

$$\mu_o\mu_{r1},\ \ \varepsilon_{1c}=\varepsilon_o\varepsilon_{r1}-j(\varepsilon_1^{''}+\frac{\sigma_1}{\omega})$$

$$\Rightarrow jk_{1c}=\gamma_1=\omega\sqrt{\mu_o\mu_{r1}\varepsilon_{1c}}=\alpha_1+j\beta_1$$

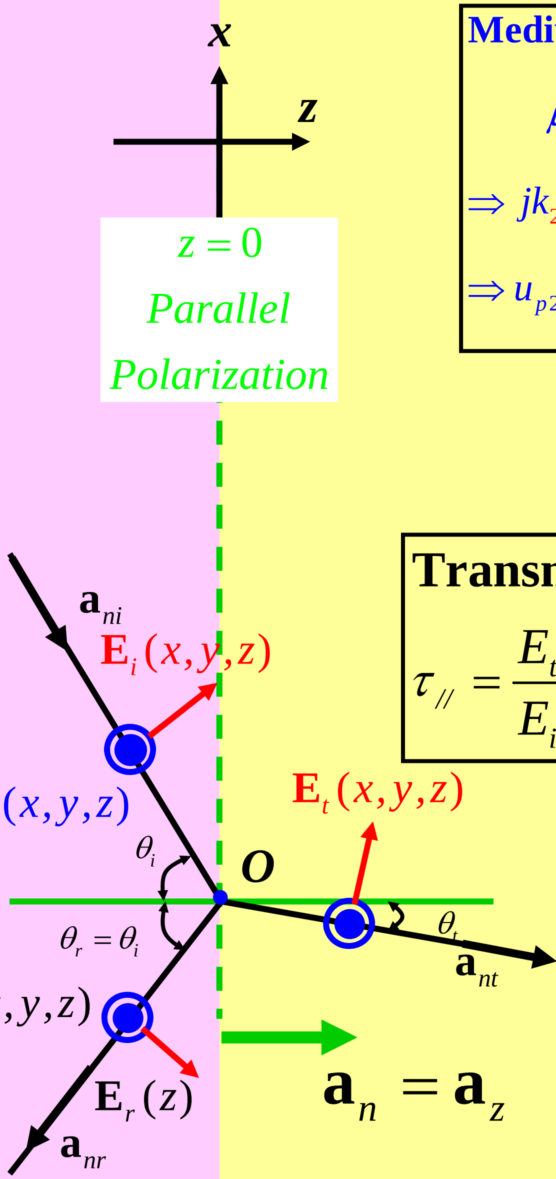
$$\Rightarrow u_{p1}=\frac{\omega}{\beta_1}$$

Medium #2:

$$\mu_o\mu_{r2},\ \ \varepsilon_{2c}=\varepsilon_o\varepsilon_{r2}-j(\varepsilon_2^{''}+\frac{\sigma_2}{\omega})$$

$$\Rightarrow jk_{2c}=\gamma_2=\omega\sqrt{\mu_o\mu_{r2}\varepsilon_{2c}}=\alpha_2+j\beta_2$$

$$\Rightarrow u_{p2}=\frac{\omega}{\beta_2}$$



Incident Amplitude: E_{io}

Transmitted Amplitude: E_{to}

$$\tau_{//}=\frac{E_{to}}{E_{io}}=\frac{2(\eta_{2c}\cos\theta_i)}{(\eta_{2c}\cos\theta_t)+(\eta_{1c}\cos\theta_i)}$$

Zero reflection:

$(\eta_{2c}\cdot\cos\theta_t)-(\eta_{1c}\cdot\cos\theta_i)=0$

At this moment, the incident angle θ_i is defined as Brewster angle $\theta_i=\theta_{B//}$

Reflected Amplitude: E_{ro}

$$\Gamma_{//}=\frac{E_{ro}}{E_{io}}=\frac{(\eta_{2c}\cos\theta_t)-(\eta_{1c}\cos\theta_i)}{(\eta_{2c}\cos\theta_t)+(\eta_{1c}\cos\theta_i)}$$