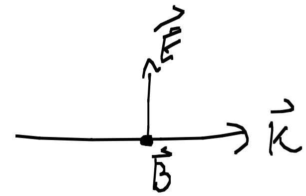
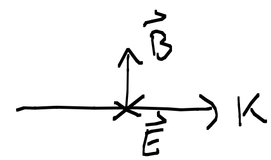
Polarization

Plane waves: two orthogonal polarization states

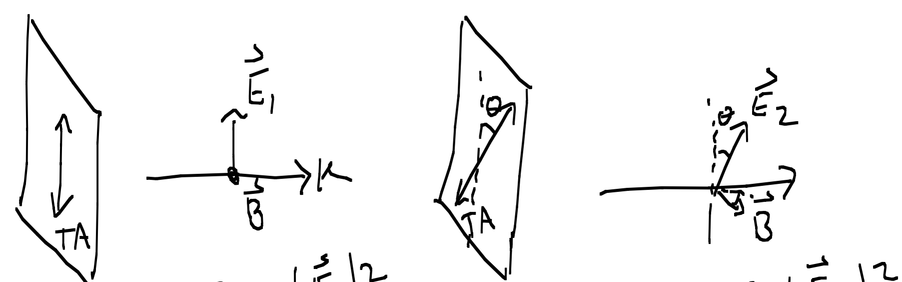


OR



polarizing filter:

unpolarized



$I_1 = |\vec{E}_1|^2$

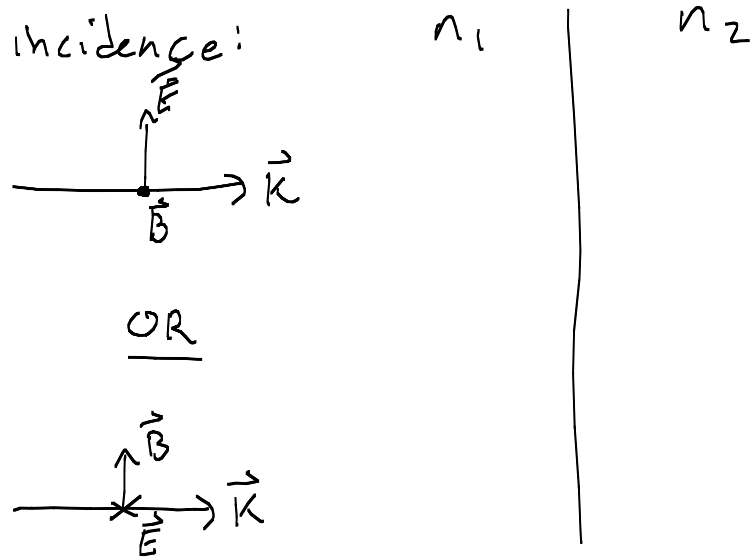
$I_2 = |\vec{E}_2|^2$

$$\frac{I_2}{I_1} = \cos^2\Theta$$

"Malus' Law"

Interfaces: Reflection

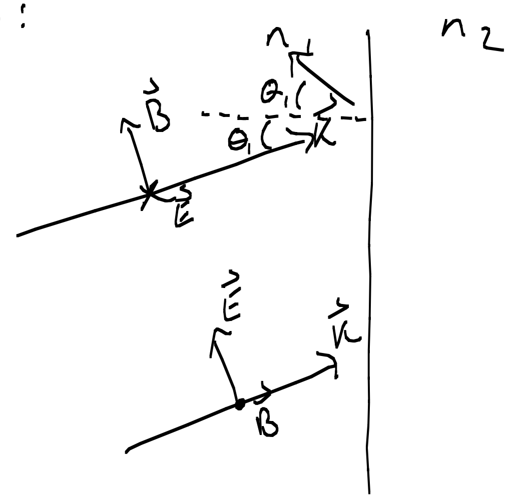
normal incidence:



equivalent!

(rotational symmetry)

Oblique incidence:



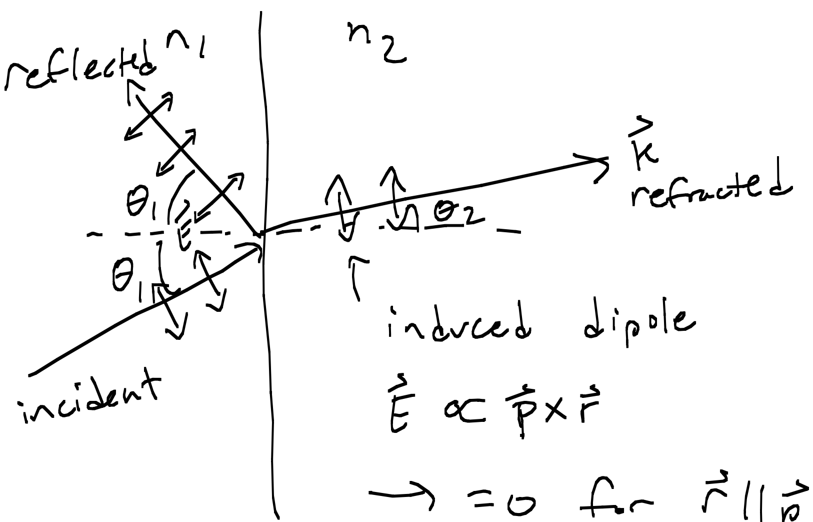
Transverse Electric (TE)

Transverse Magnetic (TM)

Not Equivalent! why?

Oblique Incidence (TM)

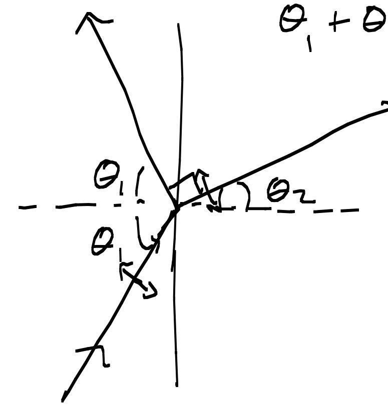
microscopic perspective of reflection:



$\vec{E} \propto \vec{p} \times \vec{r}$

$\rightarrow = 0$ for $\vec{r} \parallel \vec{p}$

no reflection when



$\theta_1 + \theta_2 = \frac{\pi}{2}$

$\theta_2 = \frac{\pi}{2} - \theta_1$

$$n_1 \sin\theta_B = n_2 \sin\theta_2$$

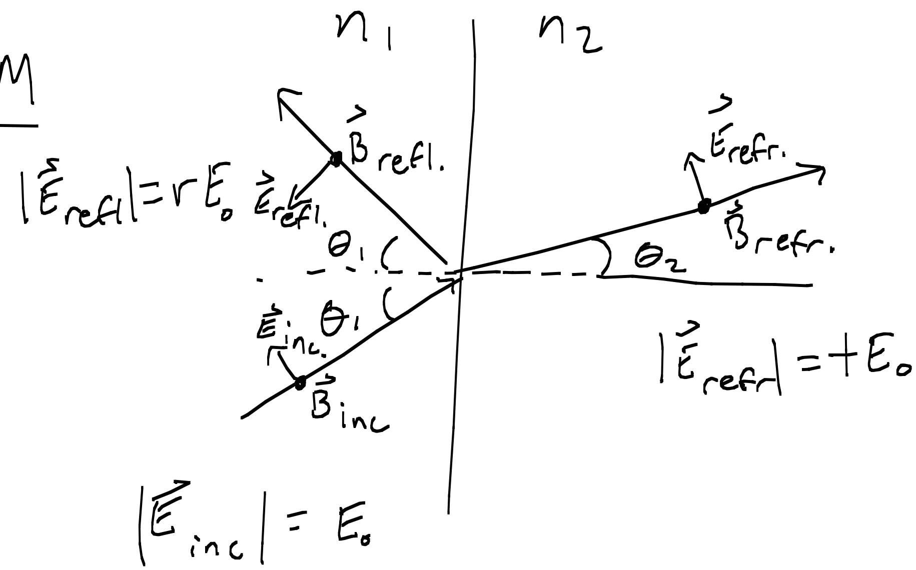
$$n_1 \sin\theta_B = n_2 \sin\left(\frac{\pi}{2} - \theta_B\right) = n_2 \cos\theta_B$$

$$\tan\theta_B = \frac{n_2}{n_1} \qquad \theta_B = \tan^{-1}\frac{n_2}{n_1}$$

"Brewster's Angle"

Maxwell's Eqns: Boundary Conditions

TM



① $E_1^{\parallel} = E_2^{\parallel}$

② $\dfrac{B_1^{\parallel}}{\mu_1} = \dfrac{B_2^{\parallel}}{\mu_2}$

$(H_1^{\parallel} = H_2^{\parallel})$

$|B^{\parallel}| = \frac{n}{c}|E^{\parallel}|$

	$E^{\parallel}$	$B^{\parallel}$
incident:	$E_0 \cos\theta_1$	$\frac{n_1}{c} E_0$
reflected:	$-rE_0 \cos\theta_1$	$\frac{n_1}{c} rE_0$

	$E^{\parallel}$	$B^{\parallel}$
refracted:	$+E_0 \cos\theta_2$	$\frac{n_2}{c} + E_0$

1. $E_1^{\parallel} = E_2^{\parallel}$:

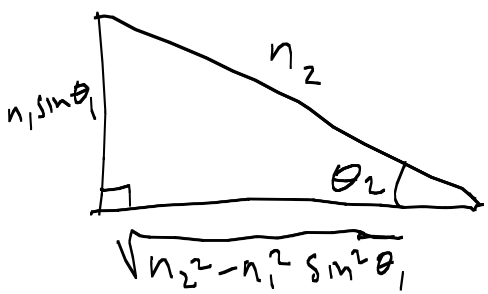
$$E_0 \cos\theta_1 - r E_0 \cos\theta_1 = t E_0 \cos\theta_2$$

$$(1-r)\cos\theta_1 = t\cos\theta_2$$

Snell's Law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$$\sin\theta_2 = \frac{n_1}{n_2}\sin\theta_1$$

$$\theta_2 = \sin^{-1}\left[\frac{n_1}{n_2}\sin\theta_1\right]$$



so, $\cos\theta_2 = \dfrac{\sqrt{n_2^2 - n_1^2\sin^2\theta_1}}{n_2}$

$$(1-r)\cos\theta_1 = t\,\frac{\sqrt{n_2^2 - n_1^2\sin^2\theta_1}}{n_2}$$

2. $\dfrac{B_1^{\parallel}}{\mu_1} = \dfrac{B_2^{\parallel}}{\mu_2}$ (Assume $\mu_1 = \mu_2$)

$$\frac{n_1}{c}E_0 + \frac{n_1}{c} r E_0 = \frac{n_2}{c} t E_0$$

$$(1+r)n_1 = n_2 t$$

$$r = \frac{n_2}{n_1}t - 1$$

Subst. 2 into 1

$$\left(2 - \frac{n_2}{n_1} t\right) \cos\theta_1 = t \frac{\sqrt{n_2^2 - n_1^2 \sin^2\theta_1}}{n_2}$$

$$2\cos\theta_1 = t\left(\frac{n_2}{n_1}\cos\theta_1 + \frac{\sqrt{n_2^2 - n_1^2 \sin^2\theta_1}}{n_2}\right)$$

$$t_{TM} = \frac{2 n_2 \cos\theta_1}{\frac{n_2^2}{n_1}\cos\theta_1 + \sqrt{n_2^2 - n_1^2 \sin^2\theta_1}}$$

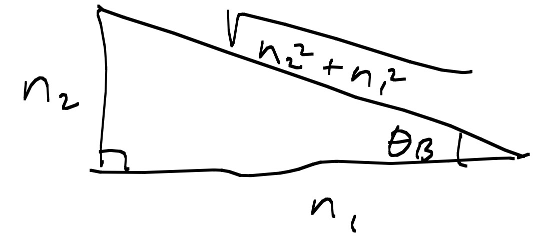
$$r_{TM} = 1 - \frac{n_2}{n_1} t$$

C.f. Eqn 23-30 and 23-28

"Fresnel equations"

What happens when $\theta_1 = \theta_B$?

$$\theta_B = \tan^{-1}\frac{n_2}{n_1}$$



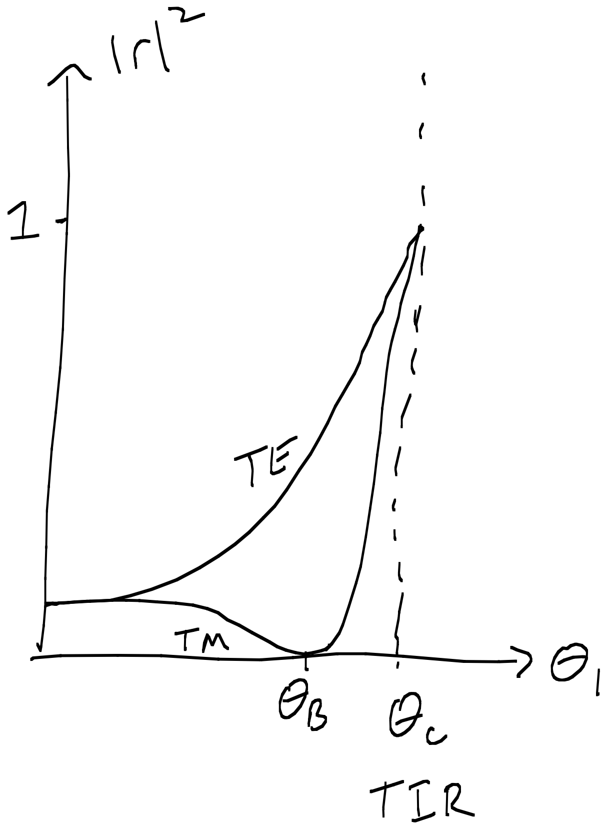
so $\cos\theta_B = \dfrac{n_1}{\sqrt{n_2^2+n_1^2}}$ and $\sin\theta_B = \dfrac{n_2}{\sqrt{n_2^2+n_1^2}}$

$$t_{TM}(\theta_1=\theta_B) = \frac{2n_2\frac{n_1}{\sqrt{n_2^2+n_1^2}}}{\frac{n_2^2}{n_1}\frac{n_1}{\sqrt{n_2^2+n_1^2}} + \sqrt{n_2^2 - n_1^2\frac{n_2^2}{n_2^2+n_1^2}}}$$

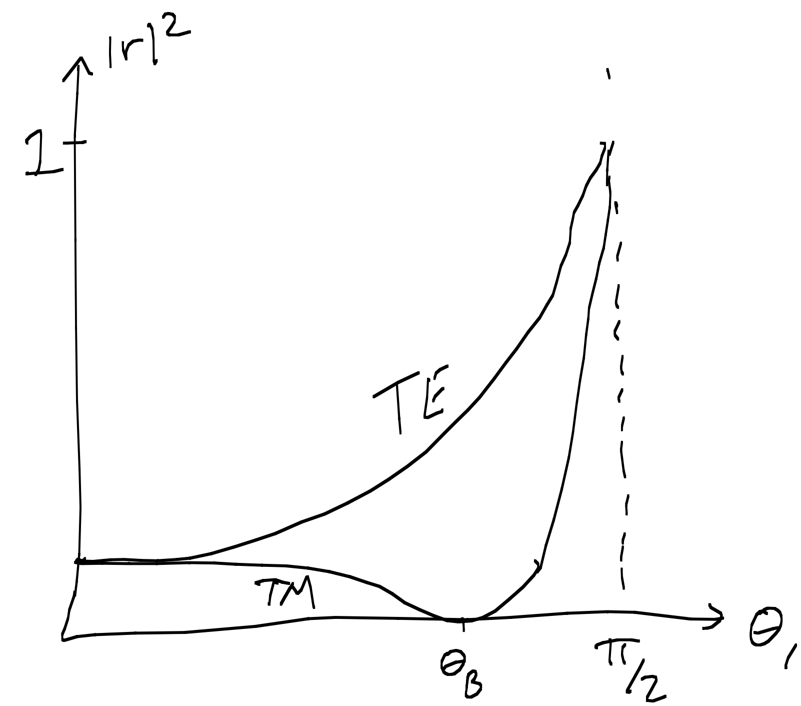
$$= \frac{\frac{2n_1n_2}{\sqrt{\ }}}{\frac{n_2^2}{\sqrt{\ }} + \frac{\sqrt{n_2^4+n_1^2n_2^2-n_1^2n_2^2}}{\sqrt{\ }}} = \frac{n_1}{n_2}$$

$$r_{TM}(\theta_1=\theta_B) = 1 - \frac{n_2}{n_1}t_{TM}(\theta_1=\theta_B) = 0!$$ as expected

$\underline{n_1 > n_2}$



$\underline{n_2 > n_1}$



So specularly reflected light is predominately TE - polarized!

$\rightarrow$ hence polarized sunglasses to reduce glare