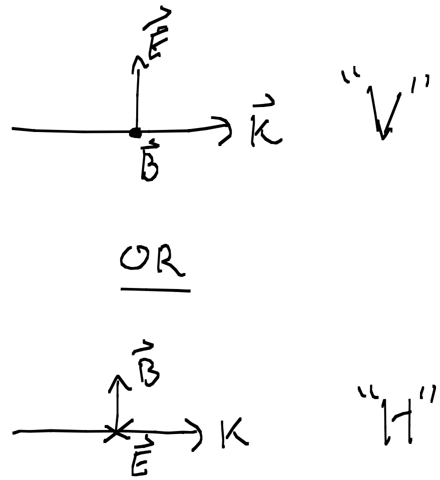
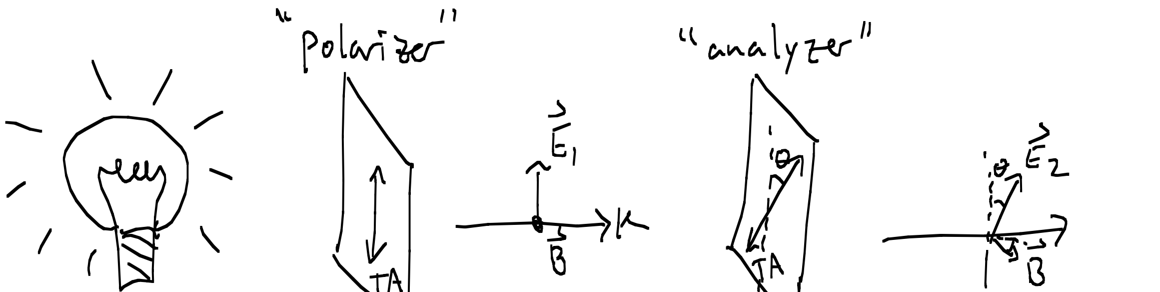
Polarization

Plane waves:
two orthogonal
linearly
polarization
states



polarizing filter:



"unpolarized"
incoherent
superposition of
H + V

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

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

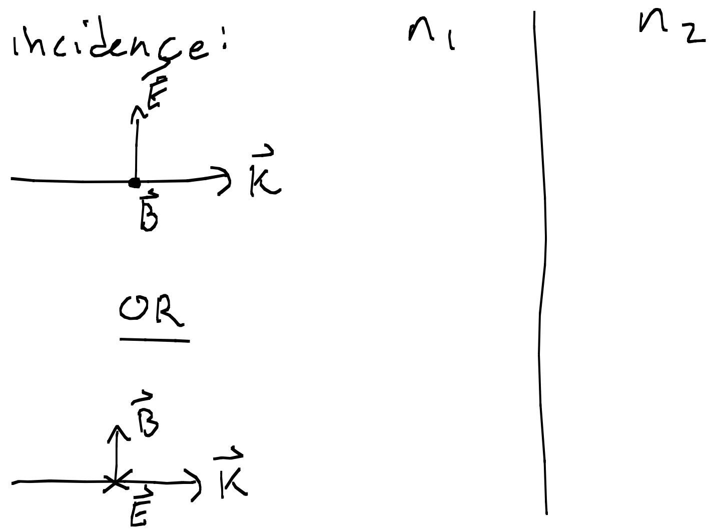
$$|E_2| = |E_1| \cos\theta$$

$$\frac{I_2}{I_1} = \frac{|\vec{E}_1|^2 \cos^2\theta}{|\vec{E}_1|^2} = \cos^2\theta$$

"Malus' Law"

Interfaces: Reflection

normal incidence:

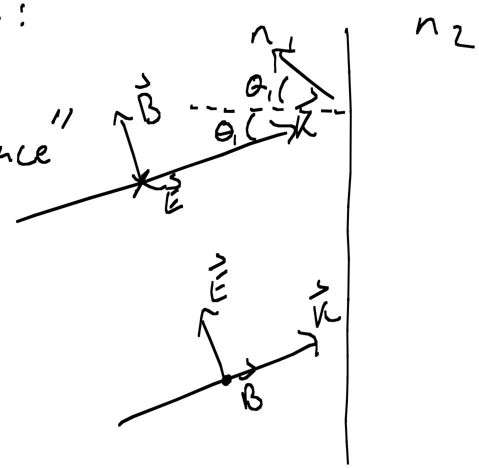


equivalent? ✓

rotational symmetry

Oblique incidence:

"plane of incidence"

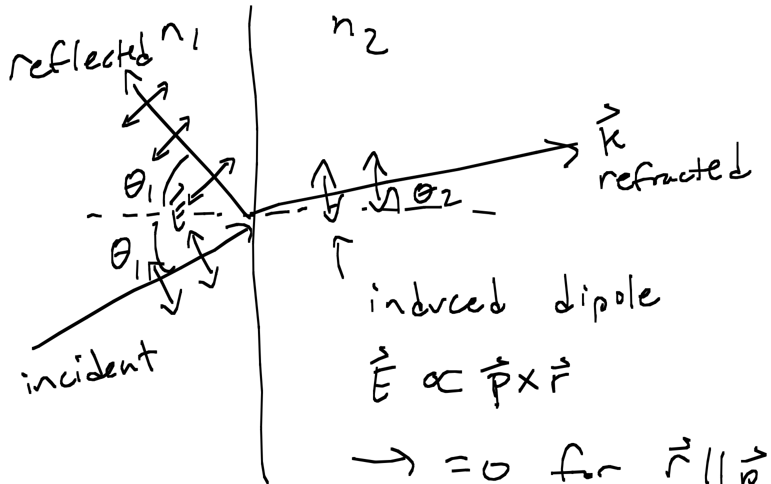


"Transverse Electric" (TE)

"Transverse Magnetic" (TM)

Oblique Incidence (TM)

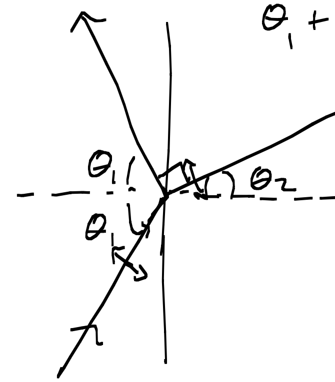
microscopic perspective of reflection:



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

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

no reflection when



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

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

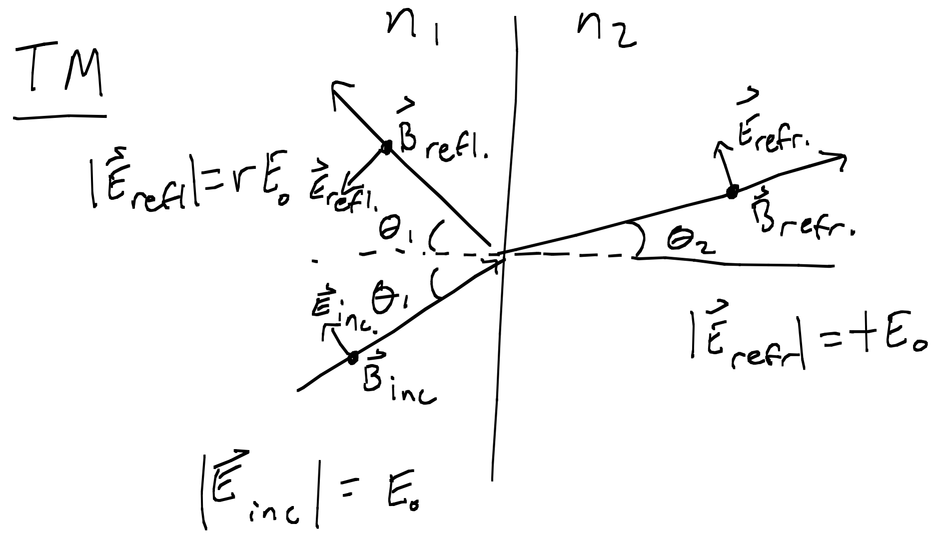
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

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

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

"Brewster's Angle"

Maxwell's Eqns: Boundary Conditions



① $E_1^{\parallel} = E_2^{\parallel}$

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

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

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

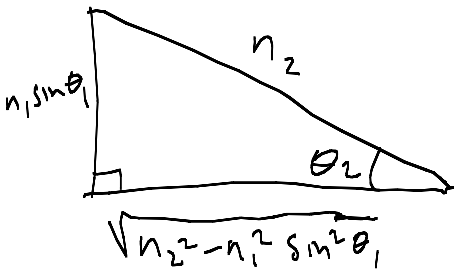
	$E^{\parallel}$	$B^{\parallel}$
refracted:	$tE_0 \cos\theta_2$	$\frac{n_2}{c} tE_0$

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

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

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

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

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

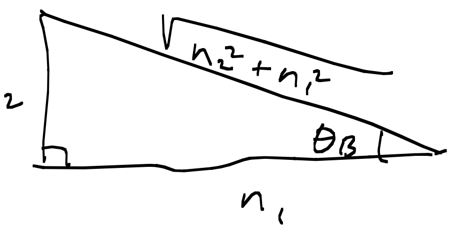
$$t_{TM} = \frac{2 \cos\theta_1}{\left(\frac{\sqrt{n_2^2 - n_1^2 \sin^2\theta_1}}{n_2} + \frac{n_2}{n_1} \cos\theta_1 \right)}$$

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

c.f. "Fresnel Eqns"
23-30, 23-28

What happens when $\theta_1 = \theta_B$?

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

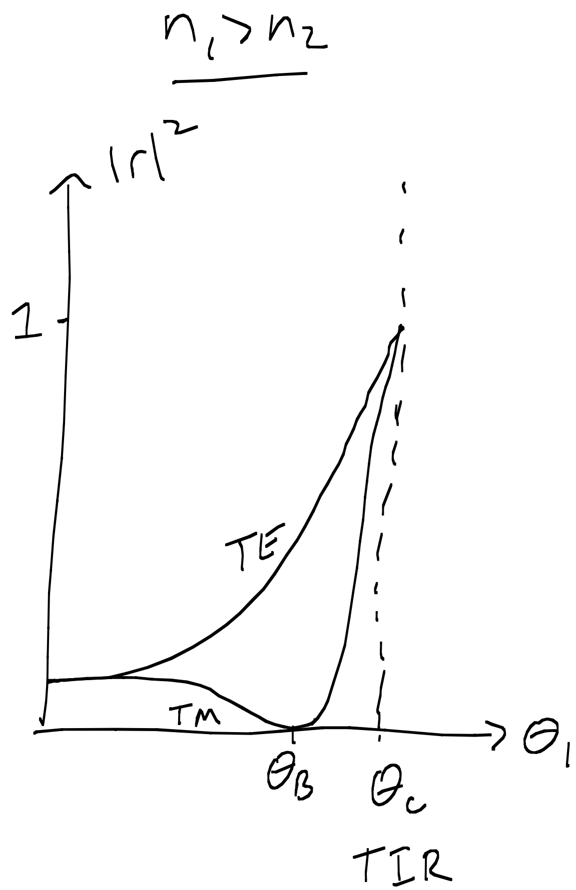


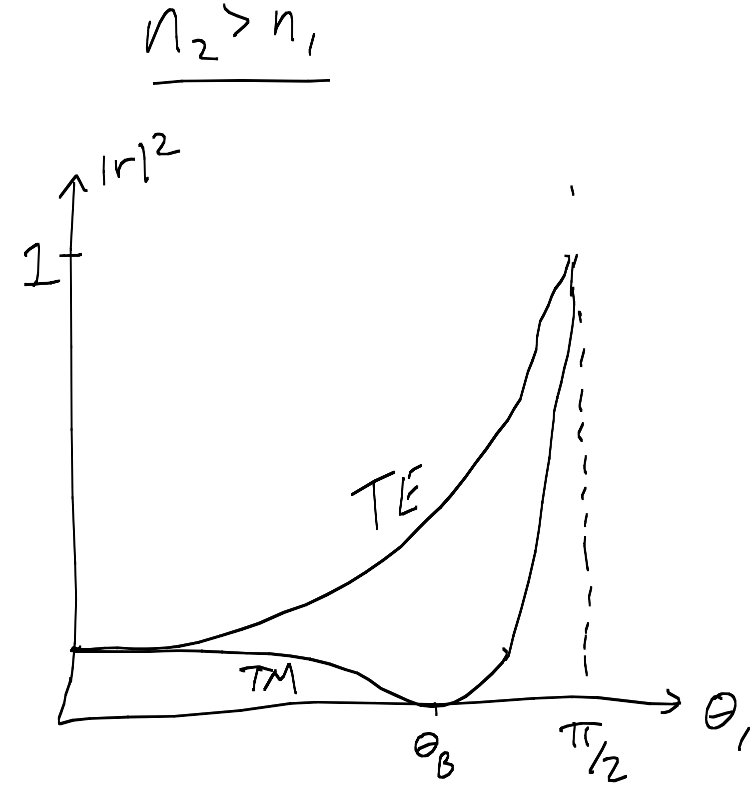
so $\cos\theta_B = \dfrac{n_1}{\sqrt{n_2^2+n_1^2}}$ and $\sin\theta_B = \dfrac{n_2}{\sqrt{n_2^2+n_1^2}}$

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

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

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





So specularly reflected light is predominately TE - polarized !

$\longrightarrow$ hence polarized sunglasses to reduce glare