DYNAMIC PROPERTIES

Transverse electric (TE) radiation

Also called s-polarization

The orientations of what will be considered "the positive axis orientations of the reflected and transmitted fields" have been arbitrarily chosen.

Condition at the interface $z=0$:

From Fig.6, this condition implies,

Using $B = \frac{E}{|E|} = \frac{E}{n}$, we obtain an expression for the two unknown quantities $E_{or}$ and $E_{ot}$. 

\[
E_{i} = E_{or} \cos(k_{x}x + k_{y}y + k_{z}z - \omega t) \\
E_{r} = E_{or} \cos(k_{x}x + k_{2}y + k_{z}z - \omega t) \\
E_{t} = E_{or} \cos(k_{x}x + k_{y}y + k_{z}z - \omega t) \\
\] 

\[
\frac{E_{o,i}}{E_{o,r}} + \frac{E_{o,r}}{E_{o,t}} = E_{o,t} \\
- \frac{B_{o,i} \cos \theta_{i}}{\mu_{i}} + \frac{B_{o,r} \cos \theta_{r}}{\mu_{r}} = - \frac{B_{o,t} \cos \theta_{t}}{\mu_{t}} \\
\]
The result, assuming $\mu_\text{t} = \mu_\text{i}$, is

\[ r = \left( \frac{E_\text{or}}{E_0} \right) = \frac{\eta_\text{t} \cos \theta_\text{t} - \eta_\text{i} \cos \theta_\text{i}}{\eta_\text{t} \cos \theta_\text{t} + \eta_\text{i} \cos \theta_\text{i}} 
\]

\[ t = \left( \frac{E_0 + E_\text{r}}{E_0} \right) = \frac{2 \eta_\text{t} \cos \theta_\text{t}}{\eta_\text{t} \cos \theta_\text{t} + \eta_\text{i} \cos \theta_\text{i}} \]

Using Snell's Law

\[ \frac{\eta_\text{t}}{\sin \theta_\text{t}} \frac{\sin \theta_\text{t}}{\sin \theta_\text{i}} = \frac{\eta_\text{i}}{\sin \theta_\text{i}} \frac{\sin \theta_\text{i}}{\sin \theta_\text{t}} 
\]

\[ \frac{\sin \theta_\text{t}}{\sin \theta_\text{i}} = \frac{\eta_\text{t}}{\eta_\text{i}} 
\]

\[ \theta_\text{r} = \theta_\text{i} \pm \arcsin \left( \frac{\eta_\text{t}}{\eta_\text{i}} \sin \theta_\text{i} \right) 
\]

\[ \theta_\text{t} = \theta_\text{i} \pm \arcsin \left( \frac{\eta_\text{i}}{\eta_\text{t}} \sin \theta_\text{i} \right) 
\]

\[ \frac{\sin \theta_\text{t}}{\sin \theta_\text{i}} = \frac{\eta_\text{t}}{\eta_\text{i}} 
\]

\[ \frac{\sin \theta_\text{i}}{\sin \theta_\text{t}} = \frac{\eta_\text{i}}{\eta_\text{t}} 
\]

\[ \eta_\text{t} > \eta_\text{i} \]

\[ \theta_\text{r} \]

\[ \theta_\text{t} \]

\[ \eta_\text{t} = 1, \eta_\text{i} = 3.5 \]

\[ \theta_\text{i} = \frac{\pi}{3} \]

\[ \theta_\text{r} = \theta_\text{i} + \frac{\pi}{2} \]

\[ r_\perp < 0 \text{ indicates a phase change equal to } \pi \text{ in the reflected wave} \]
\[ n_t < n_i \]

\[ \sin \theta_e = 3.5 \sin \theta_i \]

\[ \theta_i \quad \theta_e \]

\begin{array}{ll}
0 & 0 \\
2.5 & 8.8 \\
5 & 17.7 \\
7.5 & 27 \\
10 & 37.4 \\
12.5 & 49.2 \\
15 & 64.9 \\
16 & 74.7 \\
16.5 & 83.7 \\
16.6 & 89.2 \\
\end{array}

\[ r_\perp > 0 \quad \text{indicates a zero phase change in the reflected wave} \]

\[ t_\perp > 0 \quad \text{indicates a zero phase change in the transmitted wave} \]

Notice in both cases \( n_t < n_i \) and \( n_t > n_i \), depicted in Fig. 7 and Fig. 8 respectively, that

\[ t_\perp - r_\perp = 1 \]

In fact, the first equation in (12) states

\[ E_{0i} + E_{or} = E_{ot} \]

which implies

\[ E_{0i} = E_{ot} - E_{or} \]

\[
 I = \frac{E_{ot} - E_{or}}{E_{0i}} = t_\perp - r_\perp
\]
Reflection (R) and Transmission (T) coefficients

INTENSITY: Time-average energy per unit area

\[ I = \frac{\gamma \varepsilon}{2} E^2 \]

\[ \left( \sqrt{\varepsilon / \mu} = \frac{1}{\nu} \right) \]

\[ \frac{\mu}{2} \frac{1}{\nu} E^2 \]

\[ \frac{1}{2} \nu \frac{E^2}{\mu} \]

\[ I = \frac{n_t}{2 \mu c} E^2 \]

Incident energy \[ = I_i A \cos \theta_i \]

Reflected energy \[ = I_r A \cos \theta_r \]

Transmitted energy \[ = I_t A \cos \theta_t \]

\[ I_i A \cos \theta_i = I_r A \cos \theta_r + I_t A \cos \theta_t \]

\[ \frac{I_r}{I_i} + \frac{I_t}{I_i} \frac{\cos \theta_t}{\cos \theta_i} \]

\[ = \frac{E_{or}^2}{E_{oi}^2} + \frac{n_e}{n_i} \frac{\mu_i}{\mu_e} \frac{\cos \theta_t}{\cos \theta_i} E_{oi}^2 \]

\[ \left( \mu_e = \mu_i = \mu_0 \right) \]

\[ 1 = r^2 + \left( \frac{\eta_i \cos \theta_i}{\eta_t \cos \theta_t} \right) t^2 \]

\[ \equiv R + T \]

Reflection (R) and Transmission (T) coefficients
\( n_i < n_t \)

**Fig. 10. EXTERNAL REFLECTION**

\( \theta_i \) vs. \( R_\perp \)

\( \theta_i \) vs. \( T_\perp \)

**Fig. 11. INTERNAL REFLECTION**

\( n_i < n_t \)

\( \theta_i \) vs. \( R_\perp \)

\( \theta_i \) vs. \( T_\perp \)
In Fig. 6 we defined, arbitrarily, the positive orientation of the spatial reference axis for each of the three waves. The phase shifts of the transmitted and reflected waves will be evaluated with respect to these axis.

**Phase change in the s-polarization case**
When we consider fields perpendicular to the plane of incidence (s-polarization) there is no confusion for discerning whether or not two fields at the interface (the incident and reflected, or the incident and transmitted) are in phase or π-radiant out of phase. We just look at whether not or not they are parallel or anti-parallel.

Fig. 7 and Fig. 8 indicate that for s-polarization the following phase shift occurs,

\[
\Delta \phi = 90^\circ.
\]

Fig. 12 Phase shift of TE-polarized radiation upon incident at a dielectric-\(n_i\)/dielectric-\(n_r\) interface.
Phase change in the p-polarization case
The meaning of phase change is less obvious when the fields are contained in the incident plane.
Arbitrarily, we give the following definition:
  Two fields in the incident plane are in phase if their y-components (i.e. the component along the direction perpendicular to the plane of interface) are parallel. If those components are anti-parallel, we will state that the fields are out of phase.