

## Reflection and refraction of E.M.W.

Since no energy can be added to the wave as it passes through the boundary surface, the only way that a new balance can be achieved is for some of the incident energy reflected. This is what actually happens. The transmitted energy constitutes the refracted wave and the reflected one the reflected waves.

The reflection and refraction of light at a plane surface between two media of different dielectric properties is a familiar example of reflection and refraction of electromagnetic waves. The various aspects of the phenomenon divide themselves into two classes.

### (A) Kinematic Properties:-

Following are the kinematic properties of reflection and refraction.

(i) Law of Frequency:- The frequency of the wave remains unchanged by reflection and refraction.

(ii) The reflected and refracted waves are in the same plane as the incident wave and

and the normal to the boundary surface.

(iii) Laws of Reflection:- In case of reflection the angle of reflection is equal to the angle of incidence i.e

$$\theta_i = \theta_R$$

(iv) Snell's Law:- In case of refraction the ratio of the sin of the angle of refraction of the sine of incidence is equal to the ratio of the refractive indices of the two media i.e.

$$n_1 \sin \theta_i = n_2 \sin \theta_2$$

#### (B) Dynamic Properties:-

These properties are concerned with the

- (i) Intensities of reflected and refracted waves.
- (ii) Phase change and polarisation of waves.

The kinematic properties follow immediately from the wave nature of phenomenon and the fact that there are boundary condition to be satisfied. But they do not depend on the nature of the wave or the boundary conditions. On the other hand the dynamic properties depend entirely on the specific nature of electromagnetic fields and the boundary conditions. Kinematic properties

are proved in given example below while the dynamic properties are discussed in details in forthcoming articles.

Example :— Assuming that the electric vector of an electromagnetic wave is given by

$$E = E_0 e^{-i(\omega t - K \cdot \vec{r})}$$

and is crossing a boundary tangential component of electric intensity is continuous prove the various laws of reflection and refraction.

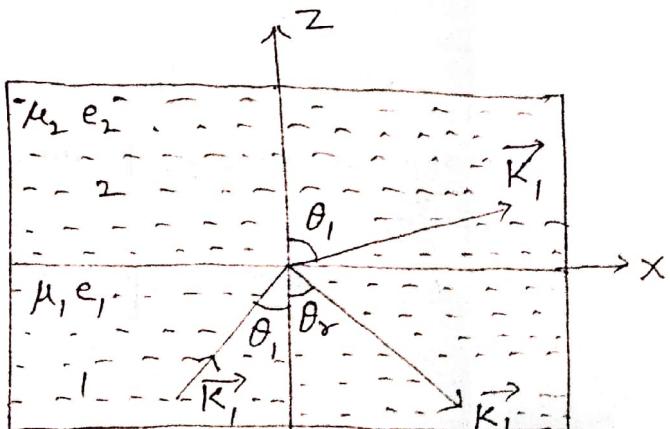
Solution :— Let the medium below the plane  $Z=0$  (ie  $x-y$  plane) have permittivity and permeability  $\epsilon_2$  and  $\mu_2$ , respectively while above it  $\epsilon_1$  and  $\mu_1$ . If the plane wave with vector  $k_1$  in the  $x-z$  plane and  $\omega_1$  is incident from medium - 1 while the waves with wave vector  $k_R$  and  $k_T$  and frequencies  $\omega_R$  and  $\omega_T$  are the reflected and transmitted wave, given boundary condition

$$[E_i]_t + [E_R]_t = [E_T]_t$$

yields

$$(E_i)_x + (E_R)_x = (E_T)_x$$

which is light of



given equation

$$E = E_0 e^{-(\omega t - k_i \cdot \mathbf{r})}$$

reduces to

$$(E_{i0})_x e^{-i(\omega_i t + k_i \cdot \mathbf{r})} \\ + (E_{R0})_x e^{-i(\omega_R t - k_R \cdot \mathbf{r})} \\ \pm (E_{T0})_x e^{-i(\omega_T t - k_T \cdot \mathbf{r})} \quad (1)$$

for all value of  $x, y$  and  $t$  (as  $z$  component is normal to the boundary). The eqn (1) can only be satisfied if the time and space varying components of the phase in eqn (1) we get.

$$\omega_i t = \omega_R t = \omega_T t$$

$$\text{i.e. } \omega_i = \omega_R = \omega_T = \omega \text{ (say)} \quad (2)$$

The eqn (2) shows that the frequency of the wave remains unchanged by reflection and refraction.

And equating the space varying components of the phase in equation (1) we get

$$(k_i \cdot \mathbf{r})_{z=0} = (k_R \cdot \mathbf{r})_{z=0} = (k_T \cdot \mathbf{r})_{z=0} \quad (3)$$

Now as the incident beam is in  $x-z$  plane,  $n_y$  is zero. It then follows that  $y$ -terms in the other expression of eqn (3) are also zero.

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