VIVEK
GUPTA
20CS61

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* Physics Assignment *

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Reflection and Refraction of em wave :-

When the em wave travelling in one medium reaches at the surface of another medium, some of its energy Returns while the remainder trans mitted same into second medium. the transmitted energy constetute the refracted wave and the energy of the incident wave which returns constitute reflection wave. the reflection and refraction of light at a plane surface between two media of different dialectric properties is a familiar example of refraction and refraction of the em wave.

The various aspect of the Phenomenon an divice themselves into two classes
a Kinematic properties
b. Dynamic properties.

(A) Kinematic properties (universal truth) :-
followings are kinematic properties of reflection and refraction

The frequency of the

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(iii) Law of reflection :- In case of reflection the angle of reflection (θ_R) is equal to the angle of incident (θ_i)

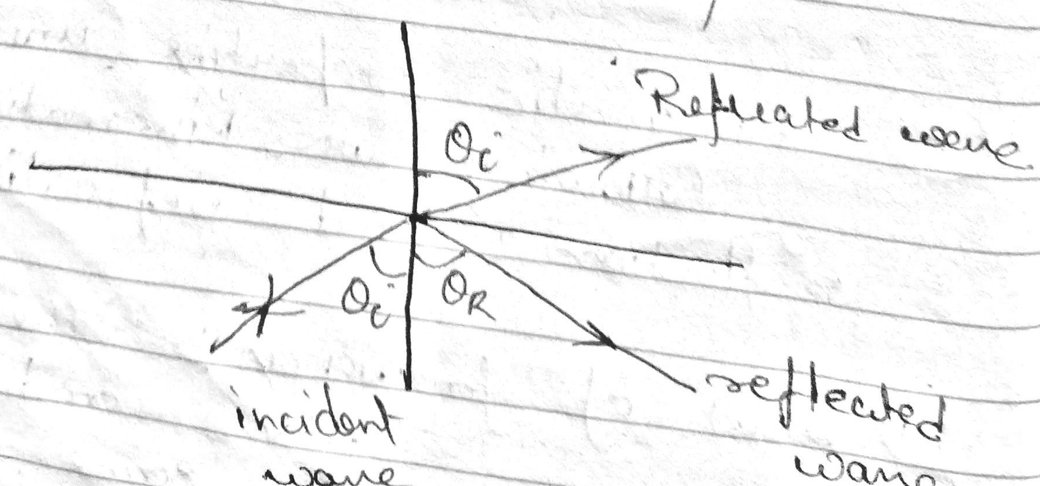
$$\boxed{\theta_R = \theta_i}$$

(iv) Snell's law :-

In case of refraction the ratio of the sum of the angle of refraction to the sine of the angle of incidence is equal to the ratio of refraction incidien of the two media i.e.

$$\frac{\sin\theta_R}{\sin\theta_i} = \frac{n_1}{n_2}$$

where n_1 & n_2 are the refraction incidences of the two media respectively.



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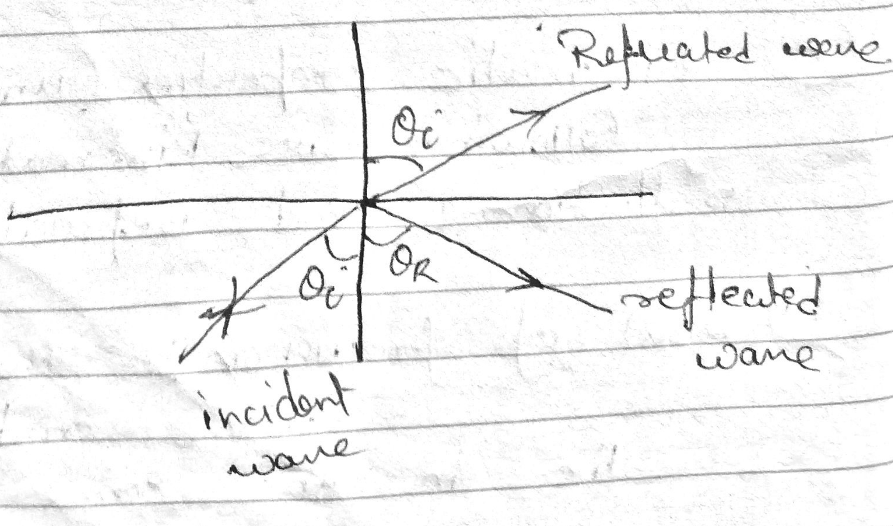

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(8) Dynamic Properties (changeable) :-
These properties are concerned with the
i) Intensities (amplitude) of reflected
ii) Phase change and polarization of wave change.

Proof :- Assuming that the electric vectors of an electromagnetic wave is given by $E = E_0 e^{-i(\omega t - kr)}$
and is crossing a boundary the tangential component of electric intensity is continuous then prove the various law of reflection and refraction

Sol^n :- Let the medium below the plane $z=0$ (i.e. x-z plane) have permittivity and permeability ε_1 & μ_1 respectively. while above it is ε_2 & μ_2. If the plane wave with wave vector $\vec{k}_0$

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$(E_{0i})_x e^{-i(\omega_i t - K_i r)} + (E_{0R})_x e^{-i(\omega_R t - K_R x)}$
$= E_{0T})_x e^{-i(\omega_x t - K_T \cdot x)}$ — (2)

Equation (2) can only be satisfied if time and space varying components of the phases are equal therefore

$$\omega_i t = \omega_R t = \omega_T t$$
$$\omega_i = \omega_R = \omega_T \quad \text{— (3)}$$

The equation (3) shows that the frequency of the wave remain unchanged by reflection and refraction

Also

$$(K_i r)_{z=0} = (K_r \cdot n)_{z=0} = (K_T x)_{z=0} \quad \text{— (4)}$$

As the incident become in x-z plane. $(K_i \cdot r) = K_i (x \sin\theta_i + z \cos\theta_i)$

$(K_R \cdot r) = K_R (x \sin\theta_R + z \cos\theta_R)$ (b)

$(K_T \cdot r) = K_T (x \sin\theta_T + z \cos\theta_T)$ (c)

from equation (4) s (a) & (b) we get

$K_i x \sin\theta_i = K_R x \cos\theta_R$

$K_i \sin\theta_i = K_R \sin\theta_R$

As $\omega_i = \omega_R$ & $V_i = V_R$ (medium is

$\sin\theta_i = \sin\theta_R$

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Also from equation (4), 5(a) & 5(b)

$$K_i \sin\theta_i = K_T \sin\theta_T$$

$$\frac{\omega_i}{v_i}\sin\theta_i = \frac{\omega_T}{v_T}\sin\theta_T$$

$$= \nu_i \qquad = \nu_4$$

$$\frac{\sin\theta_i}{\sin\theta_T} = \frac{V_i}{V_2} = \frac{cv_1}{cv_2} = \frac{n_2}{n_1}$$

Fresnel's formula (Dynamical properties)

These formula relates the amplitude of the refracted and transmitted wave with that of incident wave. Here we will consider the case of reflection & refraction at the interface of two dielectric media.

Case Ist :- E parallel to the plane of incidence ⊥

In this case the magnetic vectors are all to the bound any surface

$$\left.\begin{aligned}(H_i)_t &= H_i\\ (H_R)_t &= H_R\\ (H_T)_t &= H_T\end{aligned}\right\} \longrightarrow 1(a)$$

&

$$\left.\begin{aligned}(E_i)_t &= E_i\cos\theta_i\\ (E_R)_t &= E_R\cos\theta_R\\ (E_T)_t &= E_T\cos\theta_T\end{aligned}\right\} - 1(b)$$

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Now using boundary Condition

$$(E_1)_t = (E_2)_t$$

& $(H_1)_t = (H_2)_t$, we get

$$E_i \cos\theta_i - E_R \cos\theta_R - E_T \cos\theta_T$$

$$(E_i - E_R)\cos\theta_i = E_T \cos\theta_T \quad \text{— 2(a)}$$

&

$$H_i + H_R = H_T \quad \text{- 2(b)}$$

But we know that

$$H = \sqrt{\frac{\epsilon}{\mu}} \cdot E$$

Now $H_i = \sqrt{\frac{\epsilon_1}{\mu_1}} E_i$, $H_R = \sqrt{\frac{\epsilon_1}{\mu_1}} E_R$

& $H_T = \sqrt{\frac{\epsilon_2}{\mu_2}} E_T$

for non magnatic media is

$$\frac{\mu_2}{\mu_1} = \mu_r = 1 \Rightarrow \mu_2 = \mu_1$$

Relative permeability

Also $\frac{\epsilon_2}{\epsilon_1} = \frac{\epsilon_{r_2}\epsilon_0}{\epsilon_{r_1}\epsilon_0} = \frac{\epsilon_{r_2}}{\epsilon_{r_1}} = \frac{n_2^2}{n_1^2}$

for non-polar midia

Eqn 2 (b) gives

$$\sqrt{\frac{\epsilon_1}{\mu_1}} (E_i + E_R) = \sqrt{\frac{\epsilon_2}{\mu_2}} E_T \quad \text{— (3)}$$

$$E_i + E_R = \frac{n_2}{n_1} E_T$$

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Putting. $E_T = n_1/n_2 (E_i + E_R)$ in 2(a) we get

$$(E_i - E_R)\cos\theta_i = n_1/n_2 (E_i + E_R)\cos\theta_T$$

$$\frac{E_R}{E_i}\Big|_{H} = \frac{\cos\theta_i - n_1/n_2 \cos\theta_T}{\frac{n_1}{n_2}\cos\theta_T + \cos\theta_R}$$

$$= \frac{\cos\theta_i - \frac{\sin\theta_T}{\sin\theta_i}\cos\theta_T}{\cos\theta_T \cdot \frac{\sin\theta_T}{\sin\theta_i} + \cos\theta_i}$$

$$\frac{E_R}{E_i}\Big|_{H} = \frac{\sin\theta_i\cos\theta_i - \sin\theta_T\cos\theta_T}{\sin\theta_i\cdot\cos\theta_i + \sin\theta_T\cos\theta_T}$$

$$\frac{E_R}{E_i}\Big|_{\parallel} = \frac{\sin 2\theta_i - \sin 2\theta_T}{\sin 2\theta_i + \sin 2\theta_T}$$

$$\frac{E_R}{E_i}\Big|_{\parallel} = \frac{\tan(\theta_i - \theta_T)}{\tan(\theta_i + \theta_T)} \quad \text{——} \ (A)$$

similarly eliminating. E_R from Eq^n 2(a) using, we get.

$$E_T\,| \ = \ 2\cos\theta_i\sin\theta_T \quad \text{——} \ (B)$$

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$$\left.\begin{aligned}(E_i)_t &= E_i \\ (E_R)_t &= E_R \\ (E_T)_t &= E_T\end{aligned}\right\} \text{— } 1(a)$$

$$\left.\begin{aligned}(H_i)_t &= H_i \cos\theta_i \\ (H_R)_t &= H_R \cos\theta_R \\ (H_T)_t &= H_T \cos\theta_T\end{aligned}\right\} \text{— } 1(b)$$

$$(E_1)_t = (E_2)_t$$

&

$$(H_1)_t = (H_2)_t$$

we have

$$E_i + E_R = E_T \text{ — } 2(a)$$

$$H_i \cos\theta_i - H_R \cos\theta_R = H_T \cos\theta_T \text{ — } 2(b)$$

using H & E relations we have 2(b) as

$$(E_i - E_R)\cos\theta_i = n_2/n_1 \cdot E_T \cos\theta_T \text{ — } (3)$$

similarly putting $E_R = E_T - E_i$ from 2(a) in (3) we get

$$\frac{E_T}{E_i}\Big/_t = \frac{2\cos\theta_i \sin\theta_T}{\sin(\theta_i + \theta_T)} \longleftarrow (2)$$

Relations A, B, C and are known as fresnel formula.

Reflection and transmission coficient

$$\frac{E_R}{E_i}\Big|_{\parallel} = \frac{n_2/n_1 \cos\theta_i - \cos\theta_T}{n_2/n_1 \cos\theta_i + \cos\theta_T}$$

$$= \frac{n_2/n_1 \cos\theta_i - \sqrt{1-\sin^2\theta_T}}{n_2/n_1 \cos\theta_i + \sqrt{1-\sin^2\theta_T}}$$

$$= \frac{n_2/n_1 \cos\theta_i - \sqrt{1-(n_1/n_2)^2\sin^2\theta_i}}{n_2/n_1 \cos\theta_i + \sqrt{1-(n_1/n_2)^2\sin^2\theta_i}}$$

for normal incidence. $\theta_i = 0$

$$E_R/E_i\Big|_{\parallel} = \frac{n_2/n_1 - 1}{n_2/n_1 + 1} = \frac{n_2 - n_1}{n_2 + n_1}$$

The reflection cofficient (R) = $\frac{\text{Reflected flux}}{\text{incident flux}}$

$= \frac{\text{Intensity of reflected}}{\text{Intensity of incident beam}}$

$$R = \frac{(E_R)^2 \times v}{(E_i)^2 \times v} = \left(\frac{n_2 - n_1}{n_2 + n_1}\right)^2$$

Transmission cofficient $T = 1 - R$

$$\boxed{T = \frac{4 n_1 n_2}{(n_1 + n_2)^2}}$$

Proven Prove that the glass air interface $n_1 = 1$ $n_2 = 1$ for normal incidence the reflection & transmission coefficient

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Here

$n_1 = 1.5$ & $n_2 = 1$

glass Air

$$R = \left(\frac{n_2 - n_1}{n_2 + n_1}\right)^2 = 0.04$$

$T \Rightarrow 1 - R$

$\Rightarrow 1 - 0.04$

$\Rightarrow 0.96$