Total Internal Reflection :- We consider a situation in which radiation is incident from a medium of higher refractive index on the surface of a medium of lower refractive index, i.e. $n_1 > n_2$.

We have from Snell's law

$$\sin\theta_T = \frac{n_1}{n_2}\sin\theta_I \quad ---(1)$$

If θ_I gradually increased starting from zero. θ_T will also increase until it attains the value $\pi/2$. Let us represent the value of θ_I, when this happens, by symbol of θ_c.

From eq^n (1)

$$\sin\theta_c = \frac{n_2}{n_1} \quad --(2)$$

The angle θ_c is called the "critical angle".

Since $\theta_I = \theta_c$ there is only reflected wave, no transmitted wave.

What will happen if θ_c is increased further, i.e. when $\theta_I > \theta_c$?

Let us express θ_T in terms of θ_I and θ_c

$$\cos\theta_T = \sqrt{1-\sin^2\theta_T}$$

But $\sin\theta_T = \frac{n_1}{n_2}\sin\theta_I = \frac{\sin\theta_I}{\sin\theta_c}$ [from eq (2)]

$$\Rightarrow \cos\theta_T = \sqrt{1-\frac{\sin^2\theta_I}{\sin^2\theta_c}} \quad -(3)$$

Value of $\cos\theta_T$ decreases as θ_I is increased! it becomes zero at $\theta_I = \theta_c$ and for values of $\theta_I > \theta_c$, $\cos\theta_T$ becomes an imaginary number.

We calculate the amplitude of the reflected electric vector when $\theta_I > \theta_C$

for $\theta_I > \theta_C$ we write

$$\cos\theta_T = \sqrt{1 - \frac{\sin^2\theta_I}{\sin^2\theta_C}} = iQ$$

i.e. $$Q = \sqrt{\frac{\sin^2\theta_I}{\sin^2\theta_C} - 1} \quad \text{--- (4)}$$

In the case when E is polarized perpendicular to the plane of incidence

$$\frac{E_{OR}}{E_{OI}} = \frac{\cos\theta_I - \frac{n_2}{n_1}\cos\theta_T}{\cos\theta_I + \frac{n_2}{n_1}\cos\theta_T} = \frac{\cos\theta_I - \frac{n_2}{n_1} iQ}{\cos\theta_I + \frac{n_2}{n_1} iQ}$$

Therefore

$$\left|\frac{E_{OR}}{E_{OI}}\right|^2 = 1 \quad \text{i.e.} \quad |E_{OR}| = |E_{OI}|$$

Similarly when E is polarized parallel to the plane of incidence

$$\left|\frac{E_{OR}}{E_{OI}}\right|^2 = 1$$

i.e. $$|E_{OR}| = |E_{OI}|$$

Thus the wave is totally reflected. This phenomenon is known as <u>total internal reflection</u>.

There is a change of phase on reflection; if the incident wave is polarized in a plane intermediate between the plane of incidence and the plane normal to it, the two components will not be in phase after reflection and the wave will be elliptically polarized.

Radiation from Accelerated Charges

Modification of Coulomb's law → include velocity and acceleration dependent terms

Radiation → Unguided transport of waves and energy through empty space. Any distribution of changing charge and current acts as a source of electromagnetic radiation.

Knowledge of retarded potential is required.

Retarded Potentials :- The relation of radiation fields to their sources can be easily found if the fields are expressed in terms of electromagnetic potentials A and ϕ

$$\left.\begin{aligned} E &= -\nabla\phi - \frac{\partial A}{\partial t} \\ \text{and} \quad B &= \nabla \times A \end{aligned}\right\} \quad \text{---(1)}$$

Introduction of Lorentz condition in the Maxwell's eq^ns yields the following two inhomogeneous eq^ns for A and ϕ

$$\nabla^2\phi - \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} = -\frac{\rho}{\varepsilon_0} \quad \text{--(2)}$$

$$\nabla^2 A - \frac{1}{c^2}\frac{\partial^2 A}{\partial t^2} = -\mu_0 j \quad \text{--(3)}$$

Source terms ρ and j appear on the R.H.S.

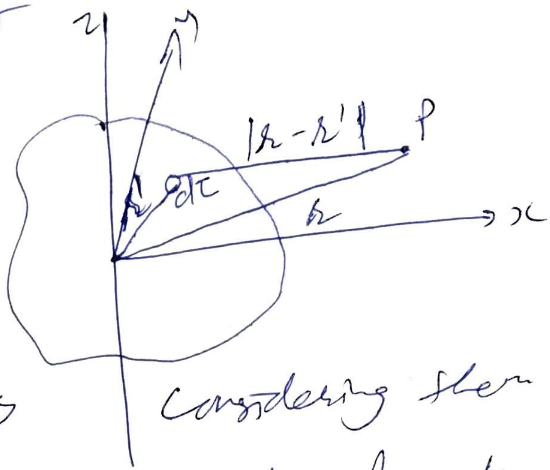
Solutions of the eq^ns in analogy of steady state problems in electrostatics and magnetostatics $\nabla^2\phi = -\rho/\varepsilon_0$ and $\nabla^2 A = -\mu_0 j$ are

$$\phi(r) = \frac{1}{4\pi\varepsilon_0}\int_V \frac{\rho(r)}{|r-r'|}\,d\tau$$

$$A(r) = \frac{\mu_0}{4\pi}\int \frac{j(r)}{|r-r'|}\,d\tau \quad \text{--(4)}$$

$d\tau \rightarrow$ small volume element

The potentials are to be computed at a point P whose position vector is 'r'. This is done by integrating ρ and j throughout V by considering them as



function of r', the position of vector of volume element $d\tau$. eq^n (4) are valid If the charges are at rest and the currents are steady.

Consider now → If ρ changes with time.
What is potential at point P at time t?
If the charge distribution within the volume element $d\tau$ changes with time, the field observed at P at time 't' must have been "launched" by the element $d\tau$ at a time 't'' earlier than 't'. This is because the electric fields associated with these changes propagate with the finite velocity 'c' and hence, the time taken to travel the distance $d\tau$ to P is $\frac{|r - r'|}{c}$.

Contribution to the potential at the point P at time 't', due to the charge in $d\tau$, does not depend on what is the charge at time "t" but on what it was at the time $t - \frac{|r - r'|}{c}$. This is the time at which the electric fields must have been propagated from the charges in $d\tau$ at r' in order to arrive at P at the time 't'.