Engineering PHYSICS

Unit - 1

Wave Optics

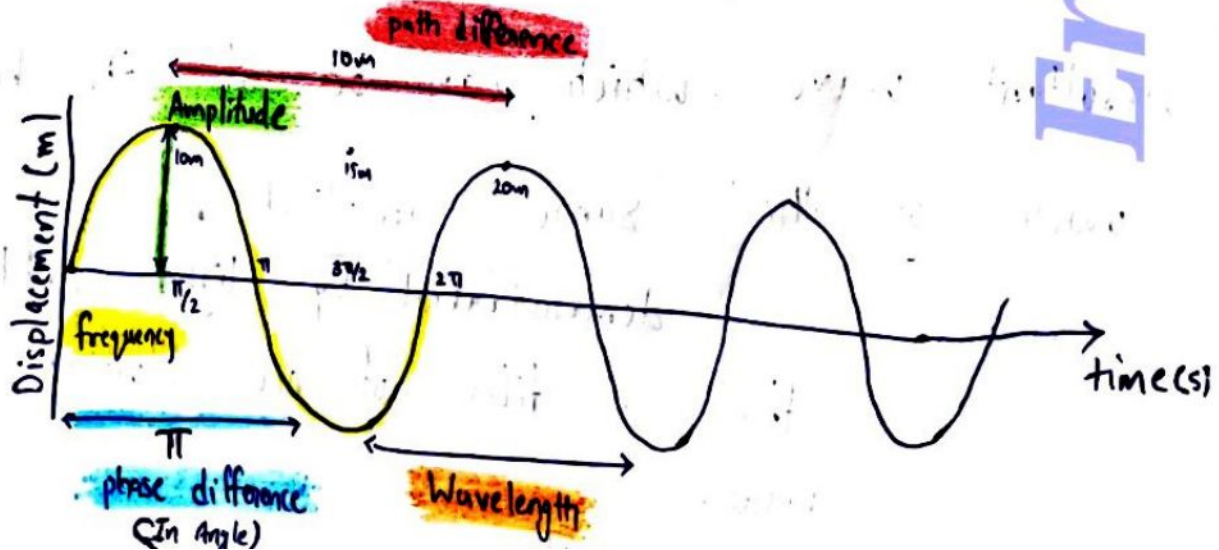
Optics is a branch of physics which deals with the "Theory of light and its propagation in a given medium".

Optics → Ray or Geometrical Optics

Optics → Physical or Wave Optics

Ray optics :- It deals with image formation by optical systems.

Wave optics :- It deals with nature of light. It is the study of how light behaves when it propagates as a wave.



Amplitude :- maximum displacement moved by a point on a vibrating body or wave.

Wavelength :- The distance blw two successive crests or troughs of a wave.

frequency :- No. of waves that pass a fixed point in a given amount of time.

path difference :- The difference in the path traversed by the two waves.

phase difference :- The difference in the phase angle of two waves.

Interference of Light

Interference is the natural phenomenon in which two waves superimpose of waves to form a resultant wave, which can be of the higher, lower or the same amplitude.

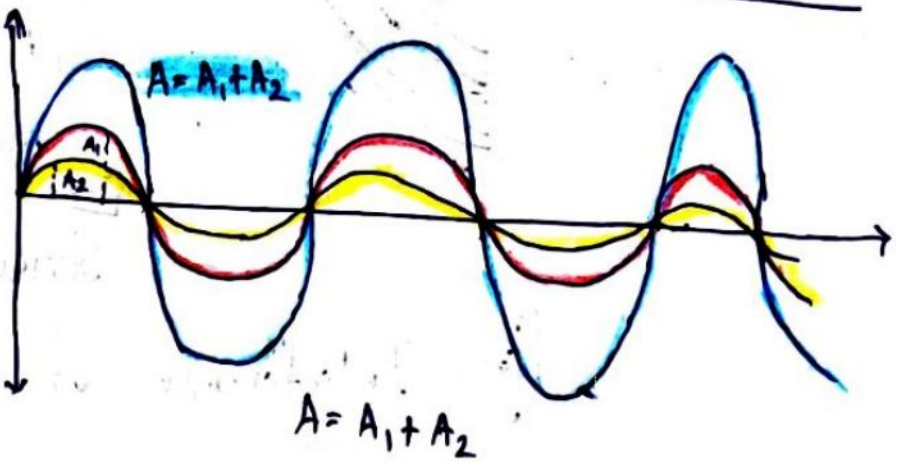
Example - It is demonstrated by light reflected from a film of oil floating on water.
- Soap Bubble.

Types of interference :-

Constructive ⇒ [Bright fringes] where intensity is maximum, interference is called Constructive.

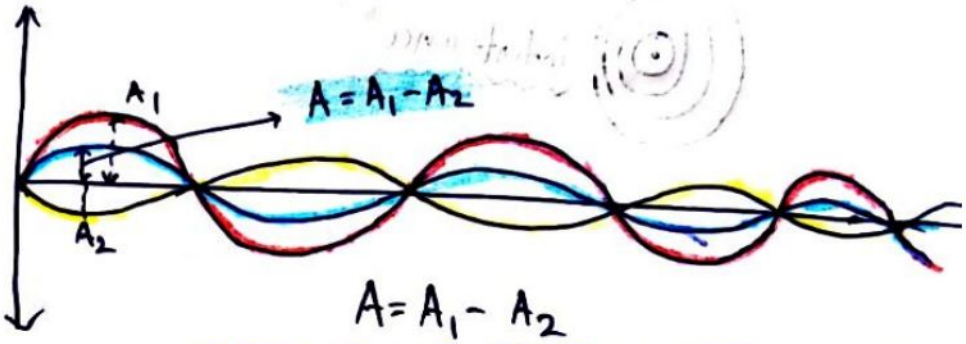
Destructive ⇒ [Dark Fringes] where intensity is minimum, interference is called Destructive.

Constructive Interference ⇒ (Bright)



$A = A_1 + A_2$

Destructive Interference ⇒ (Dark)



$A = A_1 - A_2$

Condition for sustained Interference :-

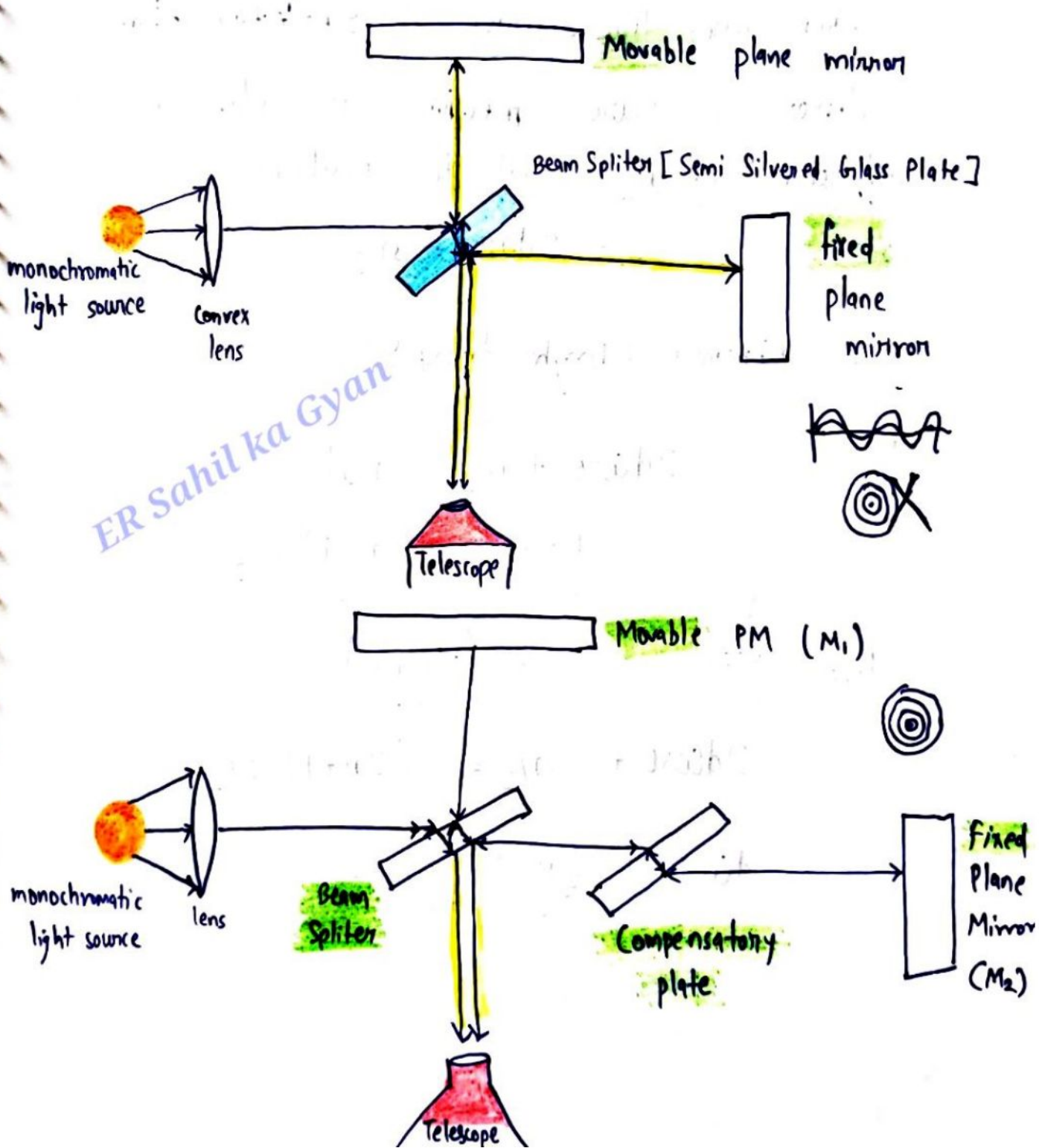
→ Should have same frequency, wavelength, amplitude with zero path & phase difference

→ Seperation blw 2 slits should be very small

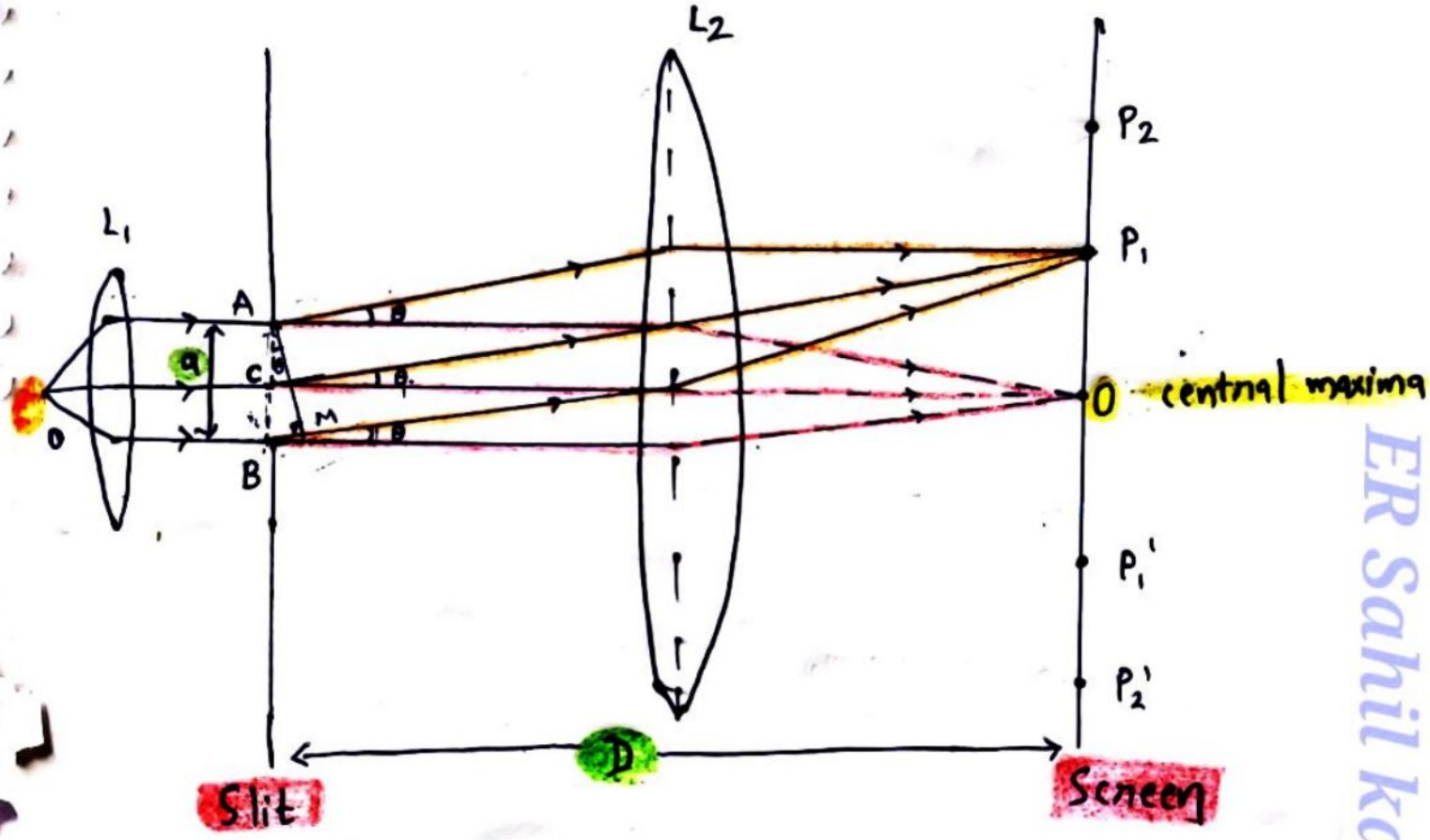
→ Seperation blw screen & slits should be large.

Michelson Interferometer

The Michelson interferometer produces interference fringes by splitting a beam of light so that one beam strikes a fixed mirror and the other a movable mirror. When the reflected beams are brought back together, an interference pattern results.



FRAUNHOFFER's Diffraction at a Single Slit



→ Intensity & Position of Central maxima

→ Position of minima

→ Intensity and Position of Secondary maxima

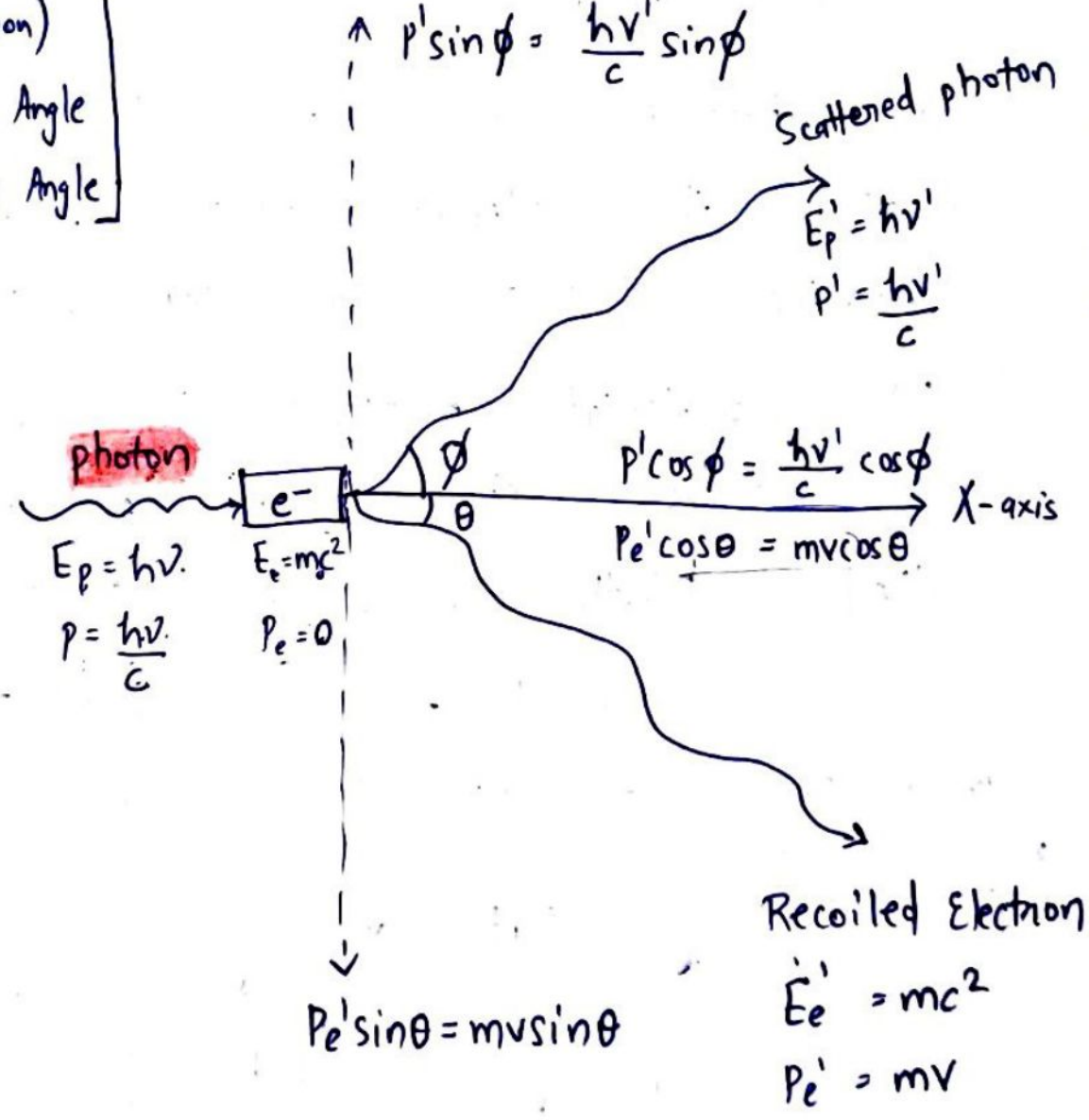
→ Width of Principle maxima

However, the wave nature of light fails to explain the phenomena of compton effect, photoelectric effect, continuous X-ray spectrum & blackbody radiation.

COMPTON Effect

(When a beam of monochromatic X-ray is incident on graphite block, it gets scattered)

[(1 photon interact with 1 electron)
ϕ = Scattering Angle
θ = Recoiling Angle]



→ A photon which is incident on Graphite block emits two types of photon wavelength (λ and λ')

compton shift $\boxed{\Delta\lambda = \lambda' - \lambda}$, $\lambda' > \lambda$

Coherence & Optical Fibers

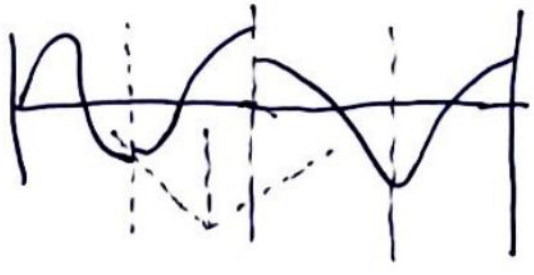
Coherence :- 

When two or more light waves reach to a point in space with phase difference is about to zero & minimum path difference from source & having same wavelength, frequency & amplitude then these lights wave will be coherent to each other & this nature of light waves is known as Coherence.

Types of Coherence → Temporal
→ Spatial

1. Temporal Coherence :-

It is a measure of the correlation blw the phase of the light wave at different points blw the direction of propagation. It is the correlation blw the waves at one place at different times along the path of a beam called 'temporal Coherence'

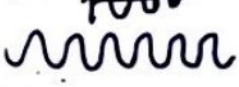


2. Spatial Coherence :-

It refers to the consistency of the phase b/w waves at different points in space, often observed in interference & diffraction patterns.

Coherence Length and Coherence Time →

The average ~~time~~ length of the wavetrains for which the field remains sinusoidal is called 'Coherence Length'.



It is denoted by l_c.

$$l_c = c \times \tau_c$$

where c = speed of light
τ_c = Coherence time

And the average time interval during which the field remains sinusoidal and the phase of the wavetrain can be predicted reliably. It is denoted by τ_c.

$$\tau_c = \frac{l_c}{c}$$

where l_c = Coherence length
c = speed of light

LASER

[Light Amplification by Stimulated Emission of Radiation]

→ Laser, a device that stimulates atoms or molecules to emit light at particular wavelengths & amplifies that light, typically producing a very narrow beam of radiation.

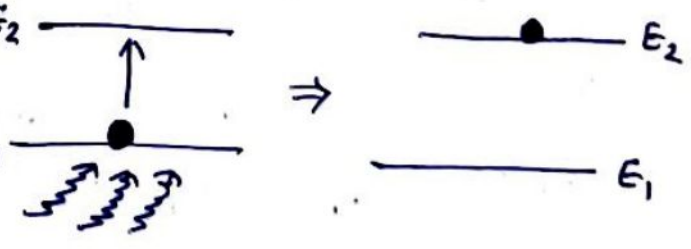
→ The theoretical basis for the development of laser was provided by Albert Einstein in 1917.

Definitions :— Production of LASER is a particular consequence of interaction of radiation with matter.

1. Stimulated absorption (Absorption) ⇒

Let us consider 3 energy levels in an atom. The lower energy level is E_1 & higher energy level is E_2. As the atom or particle initially in E_1 & can be raised to E_2 by absorbing some energy incident on it in form of light.

The probability of this transition depends on the two energy levels under consideration. It also depends on no of photons incident on system.

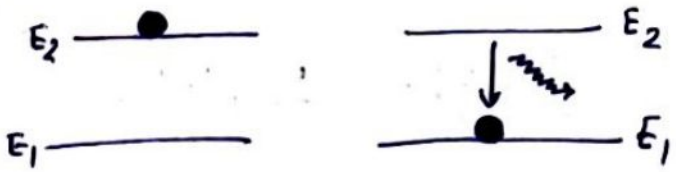


$P_{12} \propto U(\nu)$, $P_{12} = B_{12} U(\nu)$

So the rate of absorption will be

$$R_{12} = N_1 B_{12} U(\nu)$$

2. Spontaneous Emission



When atom is excited to higher energy level, has small life time (10^{-8} sec).

So it can jump from higher energy level to its ground stand by emitting a photon of frequency. This is called as spontaneous emission.

$$P_{21} = A_{21}$$

$$R_{21} = N_2 A_{21} \quad \text{—— (2)}$$

where N_2 = No. of atoms in E_2

R_{21} = Rate of no. of atom going from 2nd energy to 1st energy level

A_{21} = Einstein co-efficient of spontaneous emission.

3. Stimulated Emission :-

As per Einstein when energy incident on system it is not essential that it may always be absorbed by ground state atom. It can also interact with atom in excited state & induce that atom to emit a new photon. This process of emission is known as included or stimulated emission.

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