DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB101J -Electromagnetic Theory, Quantum Mechanics, Waves and Optics

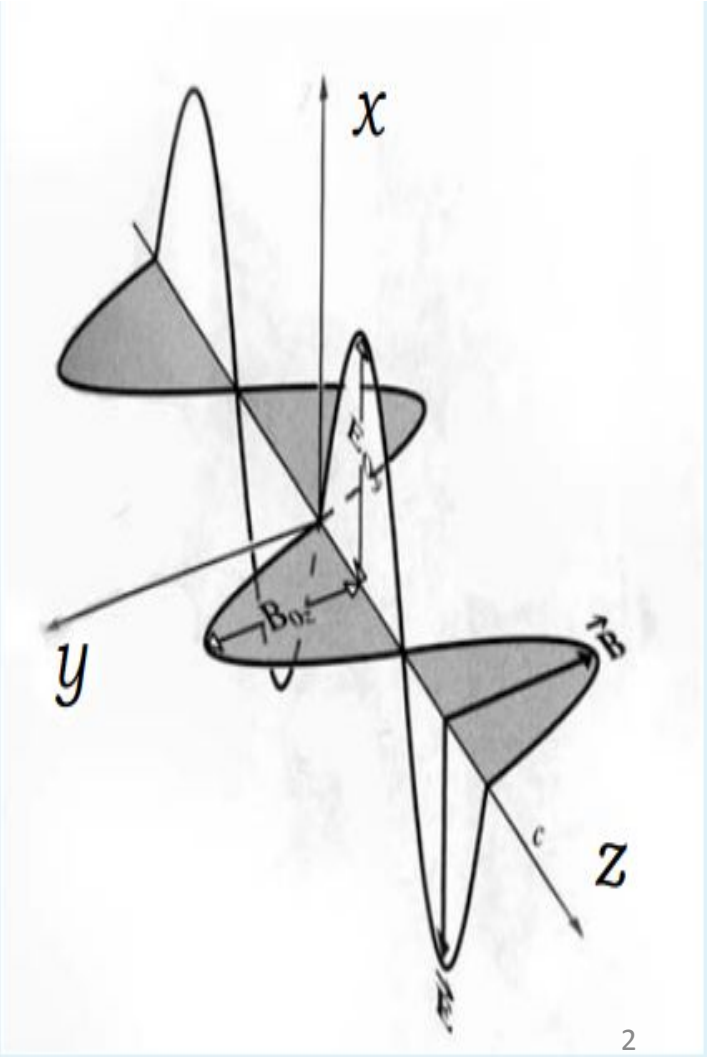
Module-IV (Waves and Optics) Lecture-9

Concepts of Polarization by reflection and Polarization by double refraction-Nicol Prism

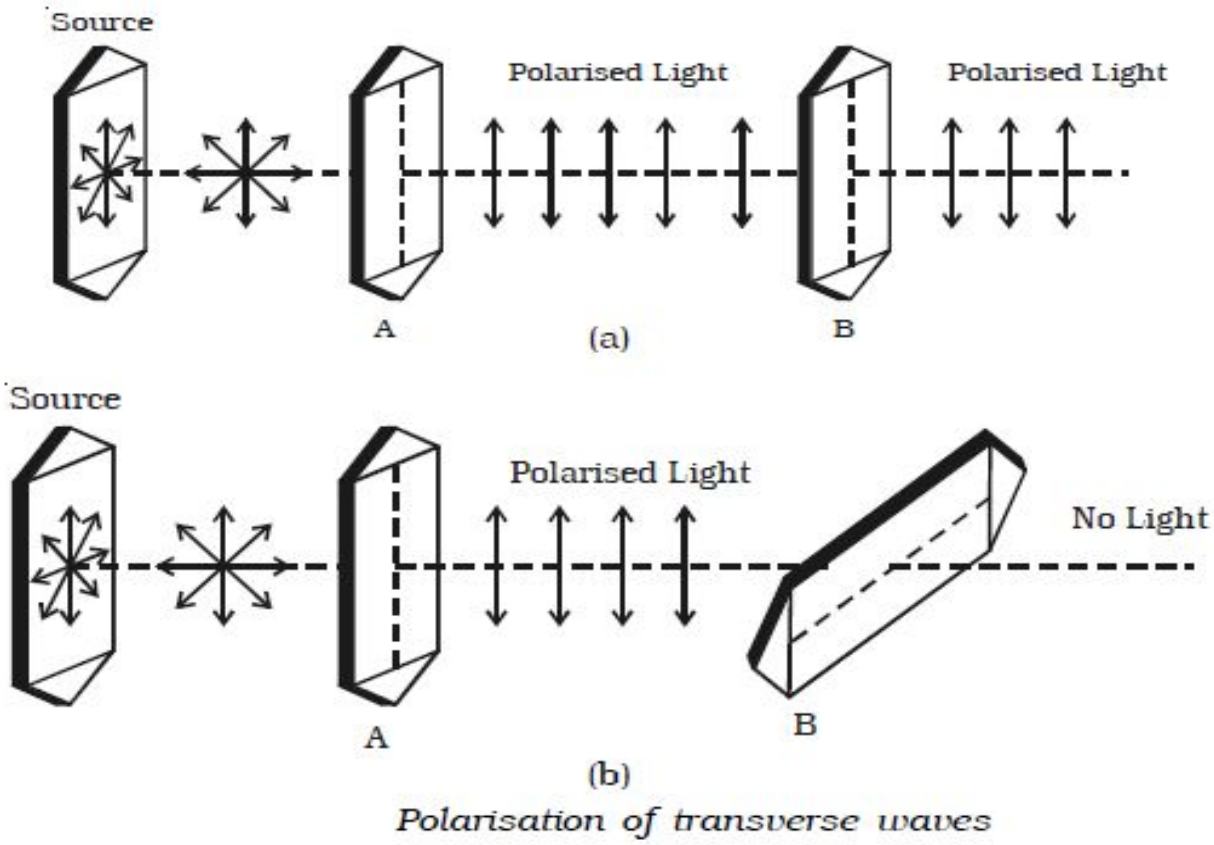
Polarization of Light

Ordinary Light:

- Electromagnetic Wave
- Electric field E & Magnetic field B
- Both E & B Perpendicular to each other, also perpendicular to direction of propagation
- Both E & B in Phase
- Unpolarized in nature



Polarization of Light



Polarisation of transverse waves

- Light from source is allowed to fall on a tourmaline crystal which is cut parallel to its optic axis

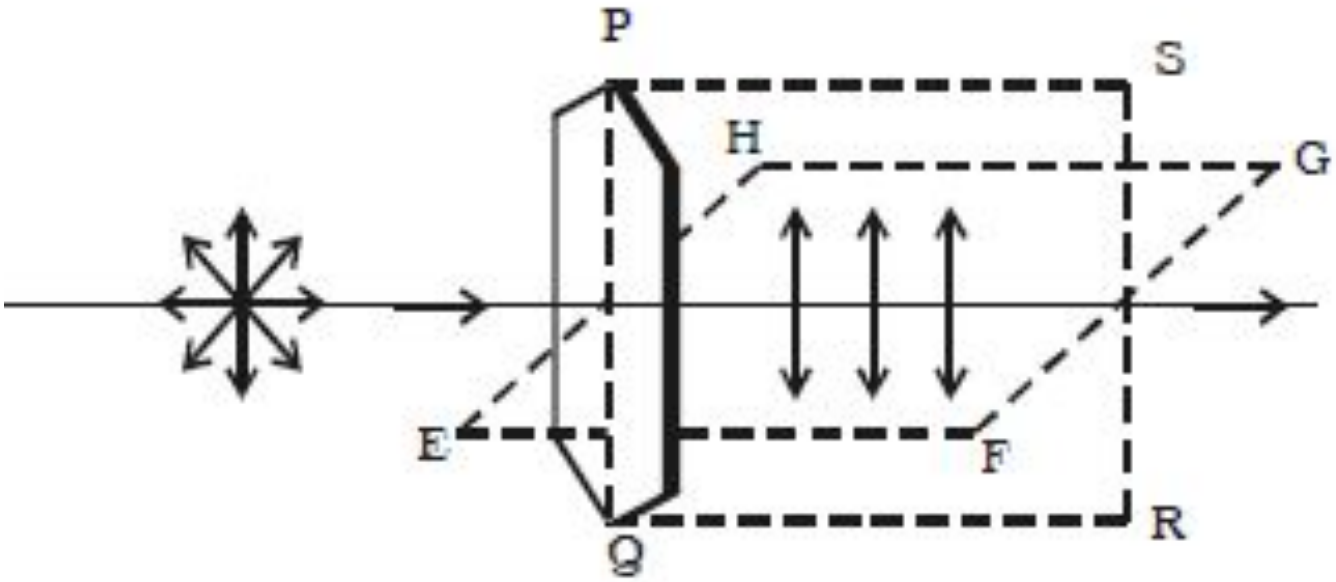
- When the crystal A is rotated, there is no change in the intensity of the emergent light.

- Place another crystal B parallel to A and both the crystals are rotated together, so that their axis are parallel, the intensity of light coming out of B does not change.

- When B is alone rotated, the intensity of the emergent light from B gradually decreases. When the axis of B is at right angles to the axis of A, no light emerges from B.

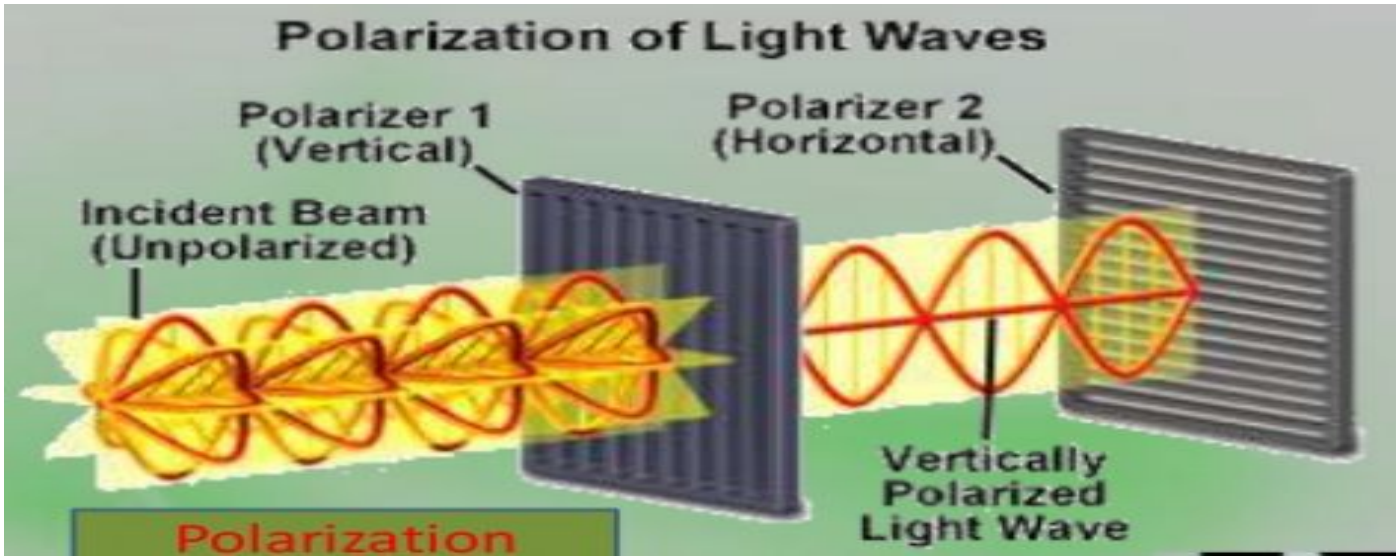
- Light waves coming out of tourmaline crystal A have their vibrations in only one direction, perpendicular to the direction of propagation.

- These waves are said to be polarized. **Since the vibrations are restricted to only one plane parallel to the axis of the crystal, the light is said to be plane polarized.**



Planes of vibration and polarisation

- PQRS represents the plane of vibration and EFGH represents the plane of polarization.

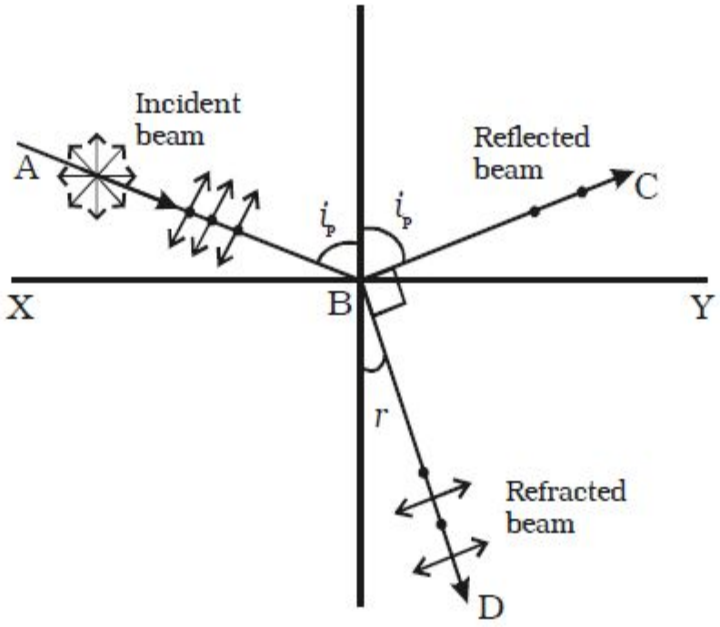


POLARIZATION

- Transforming unpolarized light into polarized light
- Restriction of electric field vector E in a particular plane so that vibration occurs in a single plane
- Characteristic of transverse wave
- Longitudinal waves can't be polarized; direction of their oscillation is along the direction of propagation

Polarization by reflection

- The simplest method of producing plane polarized light is by reflection.
- Malus, discovered that when a beam of ordinary light is reflected from the surface of transparent medium like glass or water, it gets polarized.
- The degree of polarization varies with angle of incidence.



- When the light is allowed to be incident at a particular angle, (for glass it is 57.5°) the reflected beam is completely plane polarized.

- The angle of incidence at which the reflected beam is completely plane polarized is called the **polarizing angle** (i_p). This is called **Brewster's Law**

From Fig $i_p + 90^0 + r = 180^0$

$r = 90^0 - i_p$

From Snell's law, $\frac{\sin i_p}{\sin r} = \mu$

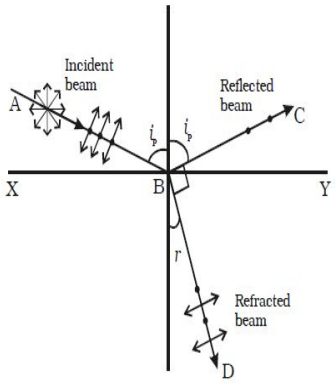
where μ is the refractive index of the medium (glass)

Substituting for r, we get

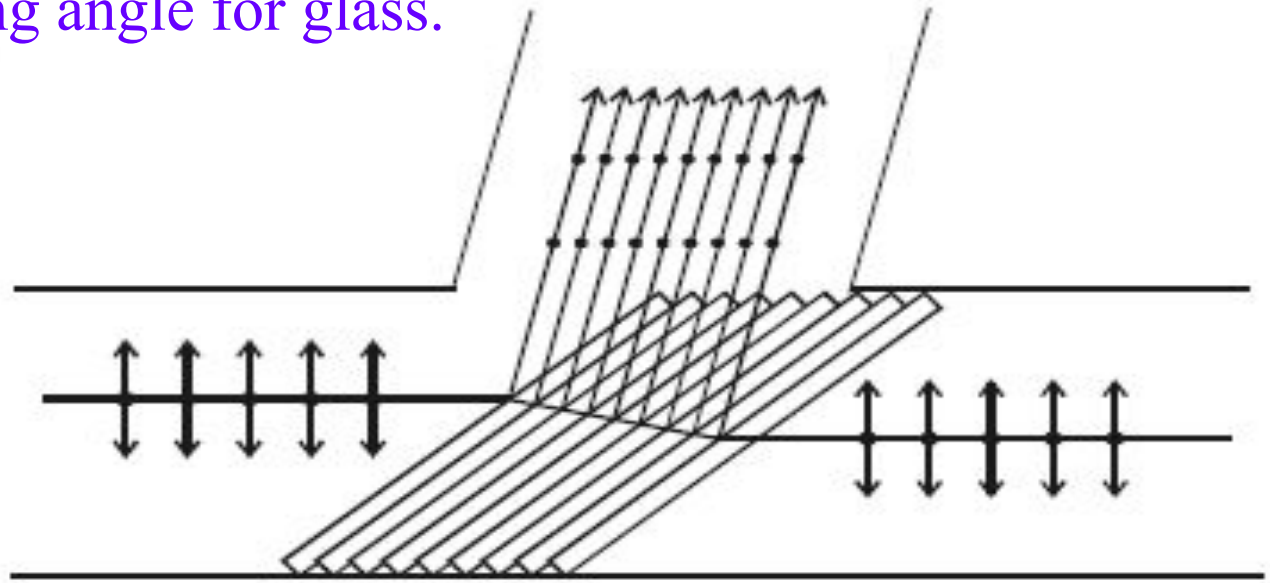
$\frac{\sin i_p}{\sin(90 - i_p)} = \mu$; $\frac{\sin i_p}{\cos i_p} = \mu$

$\therefore \quad \tan i_p = \mu$

The tangent of the polarising angle is numerically equal to the refractive index of the medium.



Pile of plates consist of number of glass plates placed one over the other at an angle 32.5° to the axis of the tube. The light beam allowed to fall on the pile of plates at an angle 57.5° which is the polarizing angle for glass.



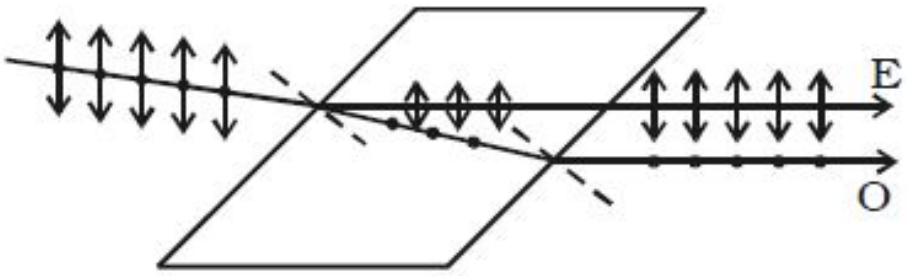
Pile of plates

- The reflected light is plane polarized. It is used as polarizer and Analyzer

Polarization by double refraction

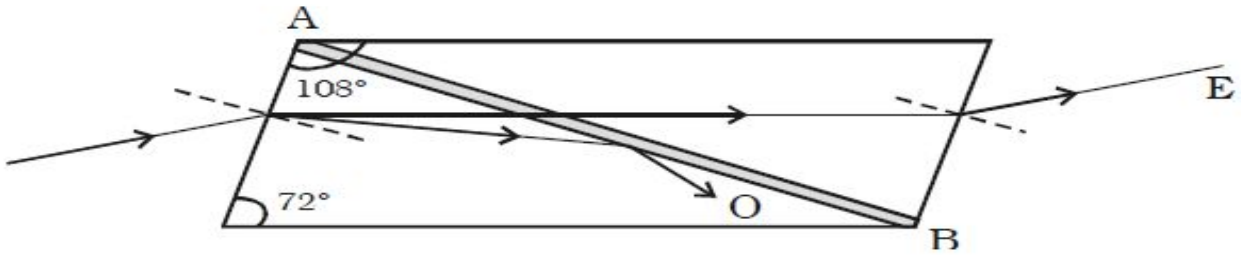
Double Refraction:

- When a ray of unpolarised light is incident on a calcite crystal, two refracted rays are produced, this phenomenon is called **double refraction**.
- Two images of a single object are formed. This phenomenon is exhibited by several other crystals like quartz, mica etc.
- **Ordinary ray** (O) and **Extraordinary ray** (E)



- **Ordinary Ray** (O), obey the laws of reflection & refraction.
- **Extraordinary Ray** (E), do not obey the laws of reflection and refraction.
- Inside a double refracting crystal the ordinary ray travels with same velocity in all directions and the extra ordinary ray travels with different velocities along different directions.
- Inside the crystal there is a particular direction in which both the rays travel with same velocity is called **optic axis**.
- The refractive index is same for both rays and there is no double refraction along optic axis.

Nicol prism



- Nicol prism was designed by William Nicol.
- It is cut into two halves along the diagonal so that their face angles are 72° and 108°.
- The two halves are joined together by a layer of Canada balsam, a transparent cement.
- For sodium light, the refractive index for ordinary light is 1.658 and for extraordinary light is 1.486. The refractive index for Canada balsam is 1.550 for both rays.

- A monochromatic beam of unpolarised light is incident on the face of the nicol prism. It splits up into two rays as ordinary ray (O) and extraordinary ray (E) inside the nicol prism.

- The ordinary ray is totally internally reflected at the layer of Canada balsam and is prevented from emerging from the other face.

- The extraordinary ray alone is transmitted through the crystal which is plane polarized. The nicol prism serves as a polarizer and also an analyser.