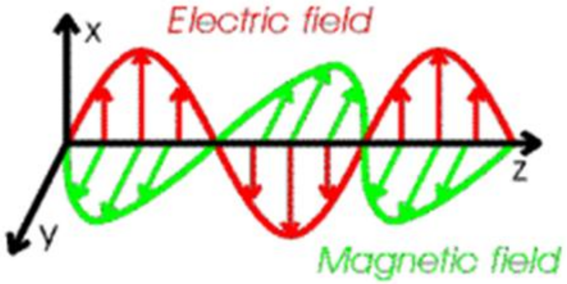
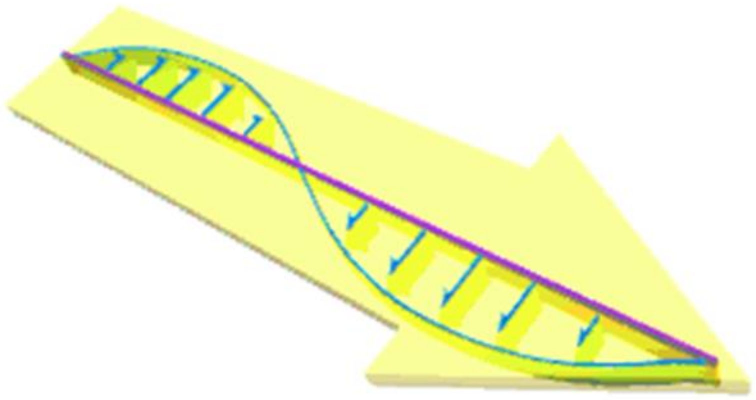
Polarization



UNIT III
Optics

Lecture-7



Content of Lecture

- PHENOMINA POLARIZATION
- POLARIZATION OF LIGHT.
- REPRESENTATION OF POLARIZED AND UNPOLARIZED LIGHT.
- PLANE OF POLARIZATION AND PLANE OF VIBRATION.
- POLARIZATION BY REFLECTION AND THE BREWSTER'S LAW.
- MALUS LAW.
- DOUBLY REFRACTING CRYSTALS.
- PHENOMENA OF POLARIZATION BY DOUBLE REFRACTION.

Polarization

- Optical phenomena such as interference and diffraction could be explained on the basis of Huygens' wave theory. However, these phenomena could not explain the nature of light wave: longitudinal or transverse.

- If we move one end of a string up and down, then a transverse wave is generated.

- Each point of the string executes a sinusoidal oscillation in a straight line and the wave is, therefore, known as a linearly polarised wave.

- It is also known as a plane polarised wave because the string is always confined to the x–z plane

Polarization of Light

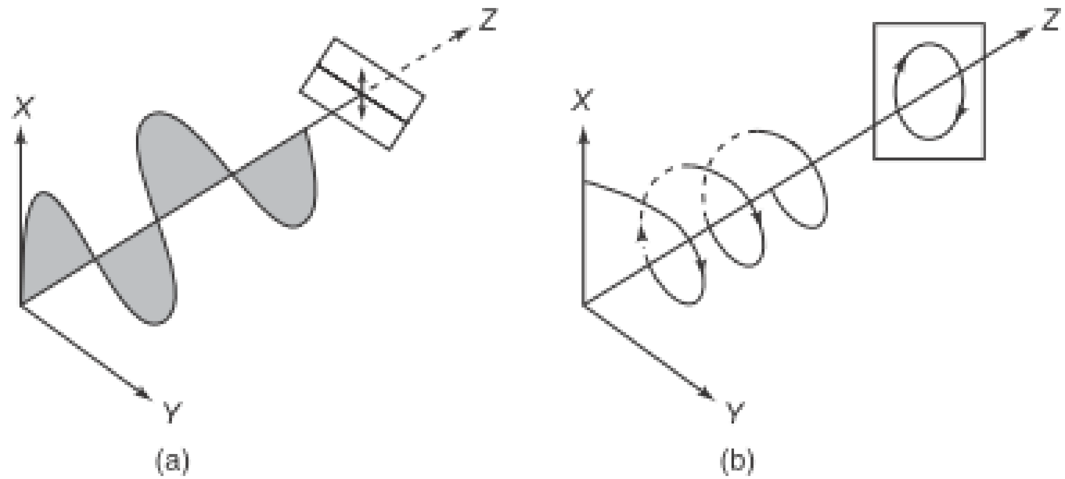
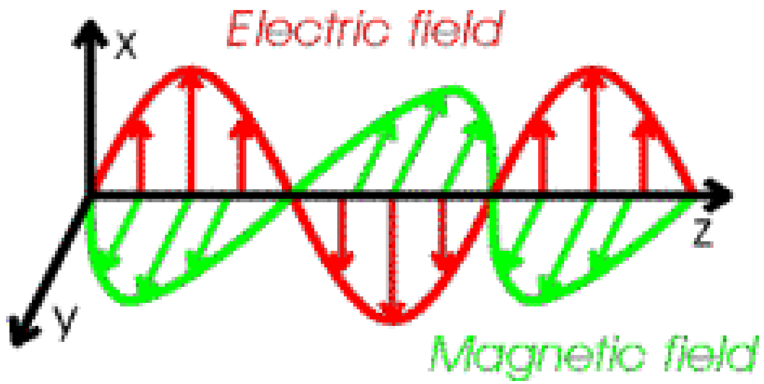


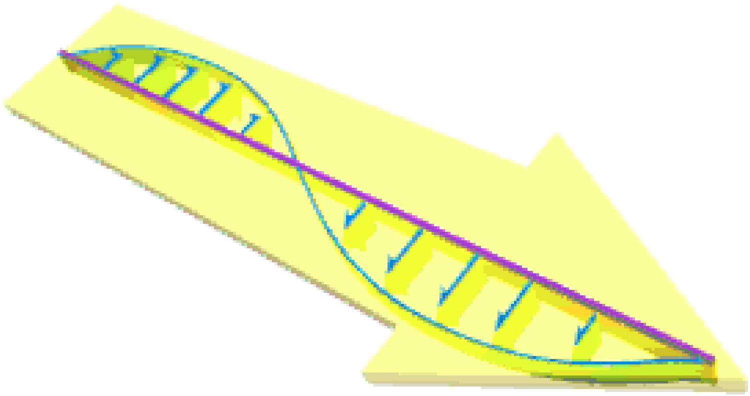
Fig. 14.1 **(a)** A linearly polarised wave on a string with the displacement confined in *x–z* plane and **(b)** the displacement corresponding to a circularly polarised wave

Graphical representation of Electromagnetic waves

Light is a transverse wave, in which electric and magnetic component are just as shown in figure



Pictorial Representation of Unpolarized light (natural light)



Pictorial Representation of Polarized Light

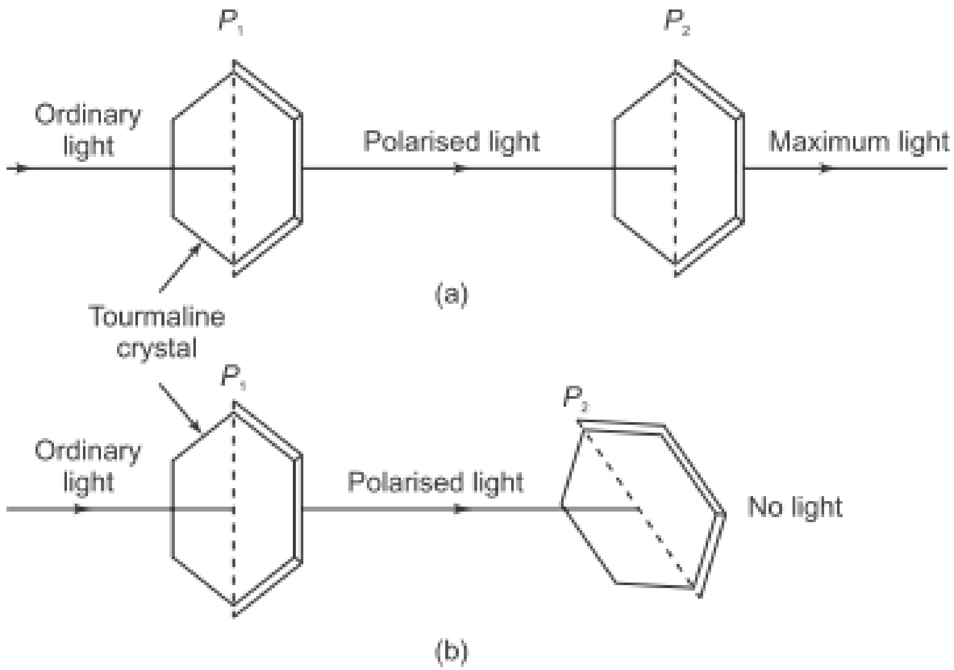


Fig. 14.4 Polarisation of light

POLARISATION OF LIGHT

- When unpolarised light is incident normally on a pair of parallel tourmaline crystal plates P_1 and P_2 (Fig. 14.4) cut parallel to their crystallographic axes, the emergent light shows a variation in the intensity as P_2 is rotated.

- The intensity is found to be maximum when the axis of P_2 is parallel to that of $P_{1,}$ and minimum when at right angles.

- This shows that the nature of light emerging from P_1 is not symmetrical about the direction of propagation of light, but its vibrations are confined only to a single line in a plane perpendicular to the direction of propagation . Such light is called plane polarised or linearly polarised light.

REPRESENTATION

- In an unpolarised beam of light all directions of vibrations at right angles to that of the propagation of light are possible; hence, it is represented by a star [Fig. 14.5(a)].

- In a plane polarised beam of light, the vibrations are along a straight line. If the vibrations are parallel to the plane of the paper, they are represented by arrows [Fig. 14.5(b)].

- If they are along a straight line perpendicular to the plane of the paper, they are represented by dots [Fig. 14.5(c)].

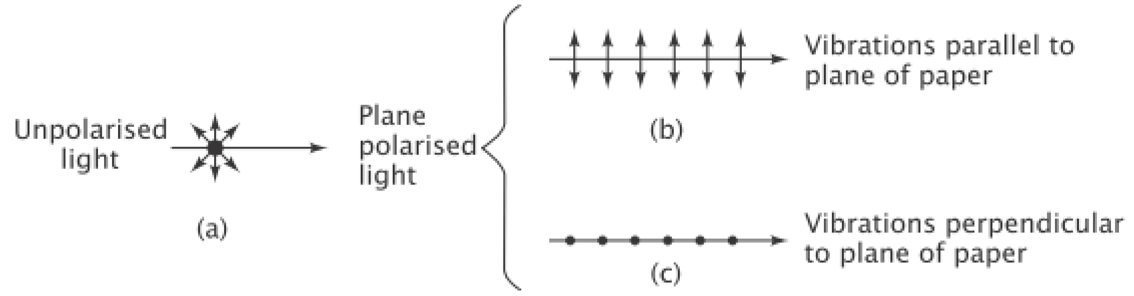


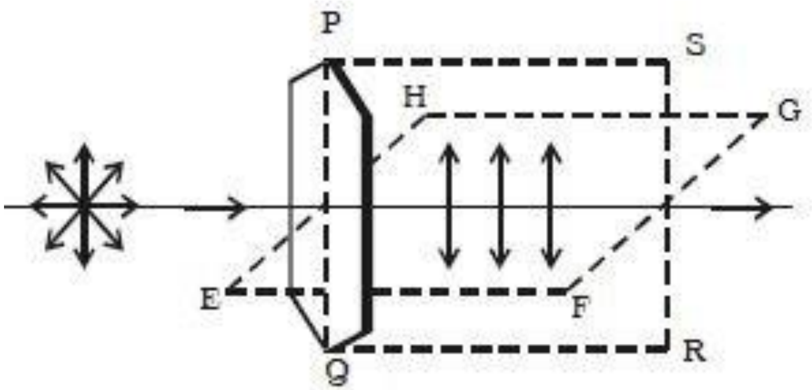
Fig. 14.5 **(a)** Unpolarised light and **(b, c)** linearly polarised light

PLANE OF VIBRATION

The plane containing the direction of vibration and the direction of propagation of light is called the plane of vibration. PQRS represents the plane of vibration.

PLANE OF POLARISATION

The plane passing through the direction of propagation and containing no vibration is called plane of polarisation. EFGH represents the plane of polarization.

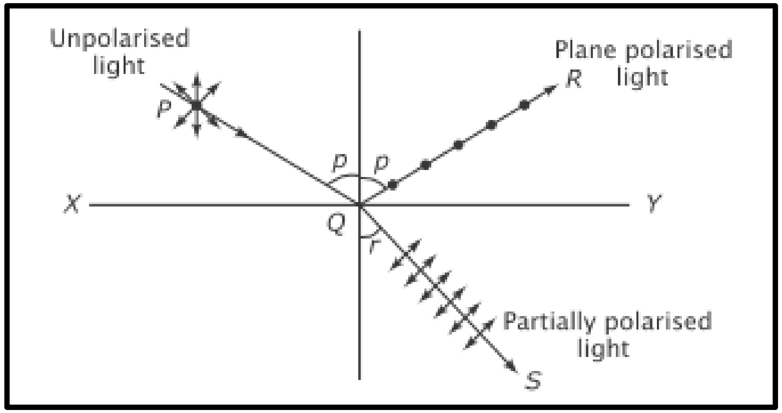


Polarisation by Reflection: Brewster's Law

- Brewster discovered that there is a simple relation between the polarising angle (p) and refractive index (μ) of the material relative to the medium. This is called Brewster's law and is given by

- $$\mu = \tan p$$

- A direct deduction that can be made with the help of this law is that when light is incident at the polarising angle, the reflected beam is at right angles to the refracted beam.



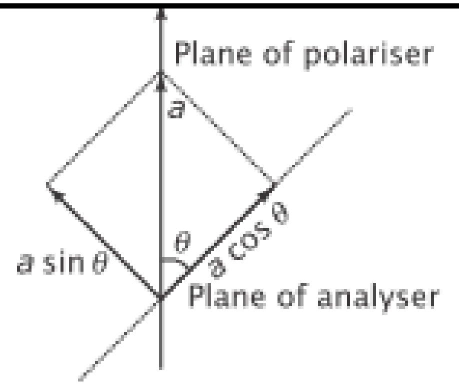
Malus Law

- When a completely plane polarised light beam is incident on an analyser, the intensity of the emergent light varies as the square of the cosine of the angle between the planes of transmission of the analyser and the polariser.

- This is known as Malus law and holds for a combination of reflecting planes, Nicol prisms, and polaroids, but not for the pile of plates, because in this case, the light emerging from the polariser is not completely plane polarised.

$$I_\theta = a^2 \cos^2\theta = I \cos^2\theta$$

When I_θ is varying Intensity and I is the Initial value



Variation of intensity according to θ between analyser and polariser

DOUBLY REFRACTING CRYSTALS

- There are certain crystals which split a ray of light incident upon them into two refracted rays.
- Such crystals are called doubly refracting crystals.
- These are of two types—uniaxial and biaxial.
- In uniaxial crystals, there is one direction called the optic axis along which the two refracted rays travel with the same velocity.
- The examples of such crystals are calcite, tourmaline, and quartz. In biaxial crystals, there are two optic axes. Topaz and aragonite are example of such crystals.

CALCITE CRYSTAL

- The calcite crystal, also known as Iceland spar ($CaCO_3$), is a colourless crystal, transparent to visible as well as ultraviolet light.
- Each face of the crystal is a parallelogram having angles 102° and 78°.
- At the two diagonally opposite corners A and A', three obtuse angles meet.
- These are called blunt corners of the crystal. At the rest of the six corners, one angle is obtuse and two are acute.

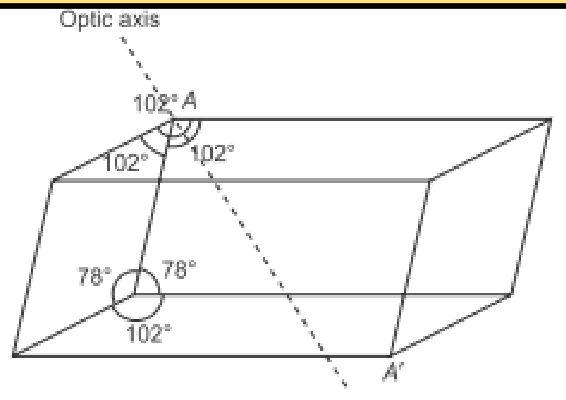


Fig. 14.11 Calcite crystal

Optic Axis of the Crystal

- A line passing through any one of the blunt corners and making equal angles with the three faces which meet there is the direction of the optic axis of the crystal.
- Optic axis is a direction and not a line.
- Any line parallel to the optic axis may be considered as optic axis.

Principal Section of the Crystal

- A plane containing the optic axis and perpendicular to a pair of opposite faces of the crystal is called the principal section of the crystal for that pair of faces.

- Thus, there may be several principal sections passing through any point inside the crystal, one corresponding to each pair of opposite faces.

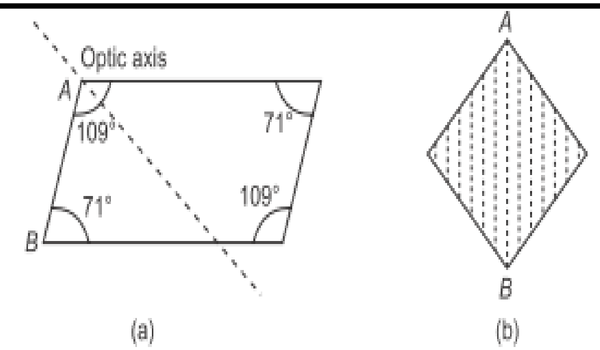


Fig. 14.12 **(a)** Principal section of calcite crystal and **(b)** face of the crystal

POLARISATION BY DOUBLE REFRACTION

- When a ray of unpalorised light is incident on a calcite or quartz crystal, it splits up into two refracted rays. This phenomenon is called double refraction.
- One of these two refracted rays is found to obey the laws of refraction, i.e., it always lies in the plane of incidence and its velocity in the crystal is the same in all directions. This ray is called the ordinary ray (O-ray).
- The other refracted ray does not obey the laws of refraction. It travels in the crystal with different speeds in different directions. Hence, it is called the extraordinary ray (E-ray).
- However, along the optic axis, both the rays have the same velocity and hence same refractive index.

POLARISATION BY DOUBLE REFRACTION

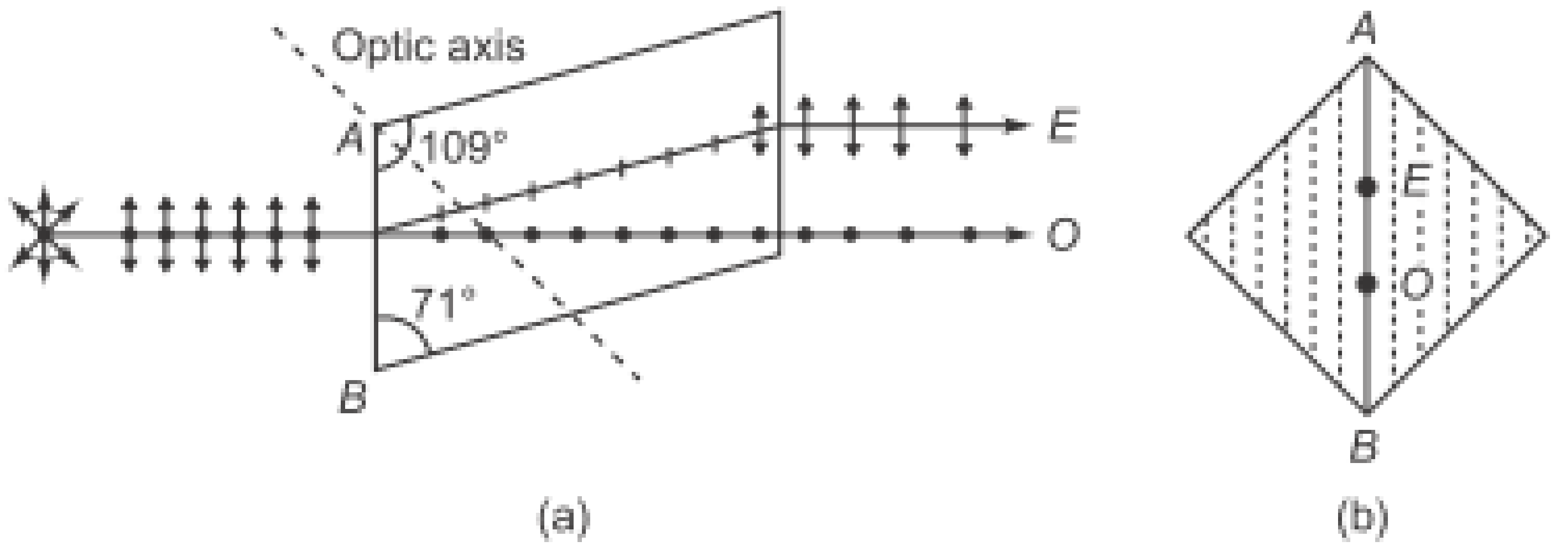


Fig. 14.13 **(a)** Double refraction of unpolarised light and **(b)** dots showing the images corresponding to *E*-and *O*-rays

Assignment Based on this Lecture

- What do you mean by the phenomena of polarization.
- Explain the polarization of light
- How we can represent the polarized and unpolarized light.
- Define plane of polarization and plane of vibration.
- Explain the polarization by reflection and define the Brewster's Law
- What is Malus Law explain.
- What are doubly refracting crystals. Explain the phenomena of polarization by double refraction.