"Polarisation"

1. Unpolarised, Polarised and Partially Polarised lights.
2. Polarisation by reflection.
3. Double refraction by uniaxial crystals
4. Nical prism
5. Polaroids

6. Huygen's Theory of double refraction
7. Half wave and quarter wave plates.
8. Analysis of plane, elliptical and circularly polarized light.
9. optical activity
10. Fresnel Theory of optical rotation.

11. specific Rotation
12. Biquartz
13. Laurent half shade polarimeters.

Polarization :- The process of removing the Symmetry and bringing in one sidedness in light wave is called polarization

* It tells about the arrangements of electric and magnetic field vectors in the light wave.

$$\boxed{E = BC}$$

Types of polarisation :-

① Polarized light ② Unpolarized light
③ Partially polarized light.

① **Polarized light** :- The electric vectors are confined into one direction

* The electric vectors are distributed asymmetrically

② **Unpolarized light** :- The electric vectors are distributed in all directions.

* The electric vectors are distributed symmetrically.

③ **Partially Polarized light** :- If the state polarisation of given light lying between 0 and 1 called partially polarized light.

Polarized light	Unpolarized light
① Consist waves having their electric vector vibrating in single plane normal to ray direction	① Consist wave with plane of vibration equally distributed in all directions about ray direction
② Asymmetrical about ray direction	② Symmetrical about ray direction.
③ It is obtained with help of polarizers	③ Conventional light sources.
④ may be regarded as resultant of two mutually prependicular Coherent waves having zero phase difference	④ may be regarded as resultant of two incoherent waves of equal intensity but polarized in mutually prependicular planes.

Electric vector -

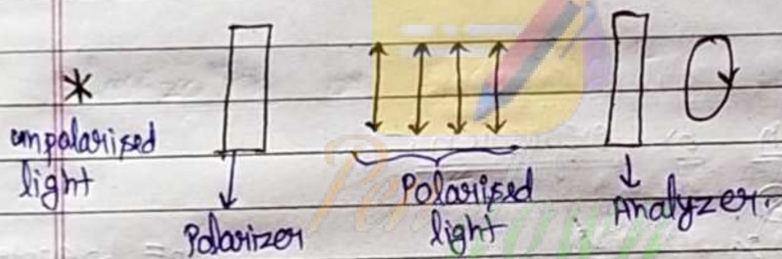
$$E_y = \underbrace{E_0}_{\text{amplitude}} \sin \underbrace{(kz}_{\text{direction of propagation of light}} - \omega t)$$

☆ $\boxed{k = \frac{2\pi}{\lambda}}$ is wave vector.

Plane of vibration :- The plane that Contains the Vibration of electric vectors called plane of vibration.

Plane of Polarization :- The plane prependicular to the plane of vibration is called plane of polarization.

Production of polarized light :-



(Tourmaline crystal)

① Polarization by Reflection
② Polarization by Refraction
③ Polarization by scattering
④ Polarization by double refraction.

Brewster's law :- The Tangent of the angle at which polarization is obtained by reflection is numerically equal to the refractive index of medium.

$$\boxed{\mu = \tan \theta_B}$$

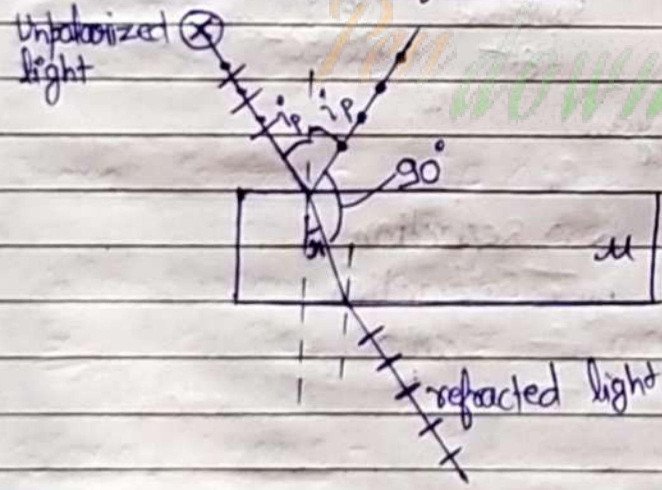
Application of Brewster's law :-

① Brewster's law can be used to determine the refractive index of opaque materials.

② It help in calculating polarizing angle necessary for total polarization of reflected light for any material if refractive index is known.

③ This law is not applicable for metallic surfaces

① Polarisation by reflection :-

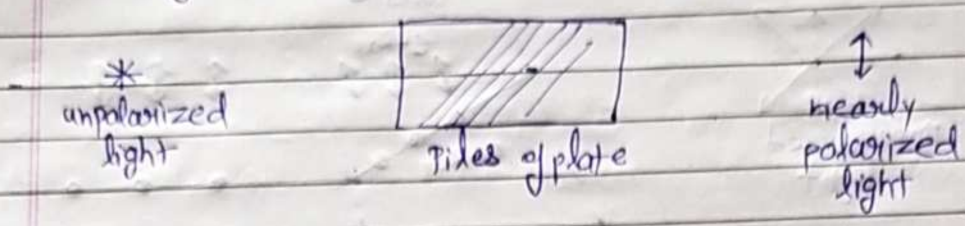


i_p = brewster angle

$$\boxed{\mu = \tan i_p}$$ ⟶ Brewster equation

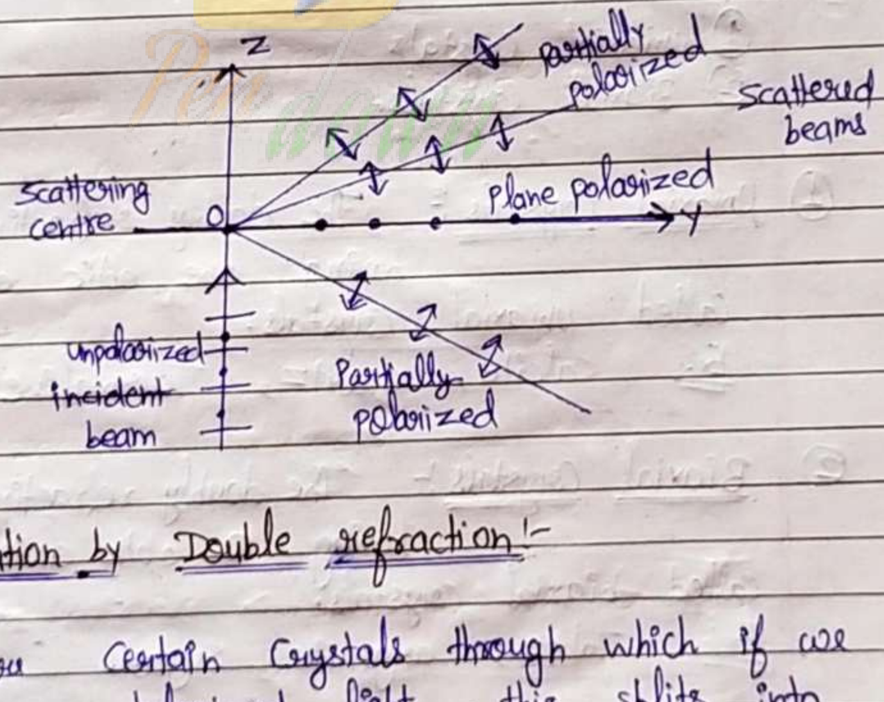
② Polarization by Refraction :-

Arrangement used = piles of plate



Unpolarized light enter the tube and is incident on plates at brewster angle and transmitted light will be totally polarized parallel to plane of incidence.

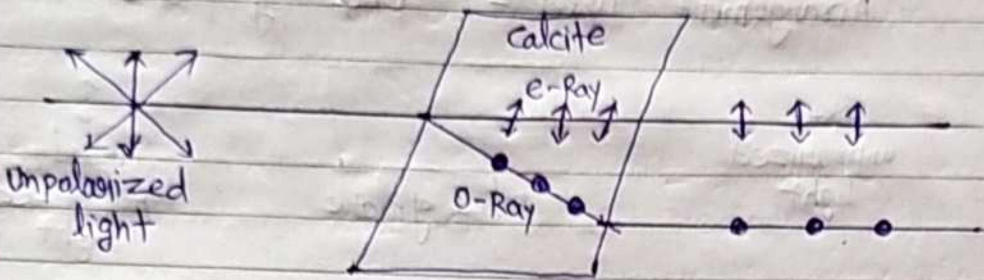
③ Polarization by Scattering :-



④ Polarization by Double refraction :-

There are certain crystals through which if we pass any unpolarized light, this splits into two polarized light. this phenomena is called Double refraction. and that crystal is called Double refracting crystal.

Crystal :- Anisotropic crystal like calcite or quartz.



o-ray = ordinary Ray
e-ray = extra ordinary Ray.

Double Refracting Crystals

1. uniaxial crystals
2. Biaxial crystals

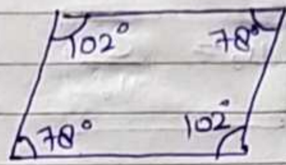
1. **Uniaxial Crystals :-** The doubly refracting crystals having one optic axis are called uniaxial crystals.
   Ex:- Calcite, quartz, Tourmaline.

2. **Biaxial Crystals :-** The doubly refracting crystal having 2 optic axis are called biaxial crystals.
   Ex: Topaz, argenite, sugar.

optic axis :- Direction in crystal along which both rays move with same velocity.

Calcite Crystal :- ($CaCO_3$) [Rhombohedron]

The opposite corners must meet at ~~obtuse~~ obtuse angle ($>90°$) are called blunt corners.



optic axis - direction along which a line passing through any one of the blunt corner and making equal angles with each of 3 ~~an~~ edges.

Principal section :- Plane containing the optic axis of crystal and prependicular to its two opposite refracting faces is called principal section.

Properties of e-ray and o-ray :-

① O-ray obeys law of refraction but e-ray doesnot follow law of refraction.

② e-ray has electric vectors parallel to plane of crystal while o-ray has electric vectors prependicular to plane of crystal

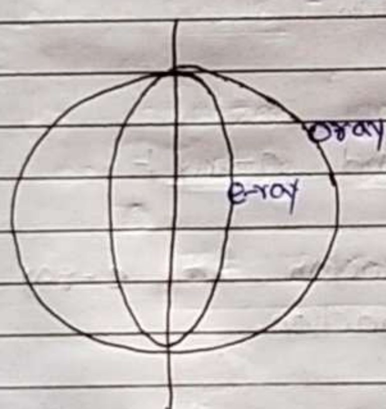
③ e-ray travels faster than O-ray in -ve crystal

(4) refractive index of e-ray varies per direction but of o-ray = same because o-ray have same velocity in all directions.

$$\boxed{\mu_o = \frac{c}{v_o}}$$ (for o-ray).

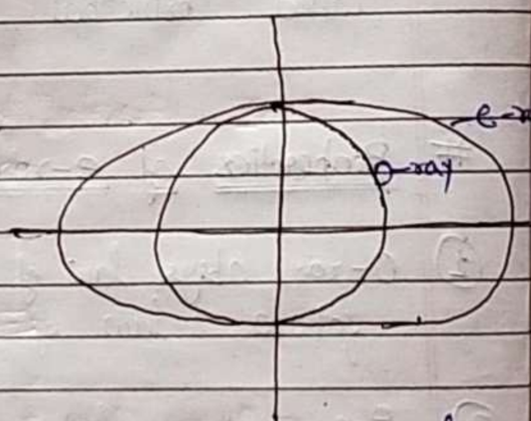
Positive crystal:- Crystal in which e-wave front lies with in o-wave front.

Negative Crystal:- Spherical wavefront of o-ray is enclosed by ellipsoidal wavefront of e-ray.



+ve crystal

$\boxed{\mu_e > \mu_o}$



-ve crystal

$\boxed{\mu_e < \mu_o}$

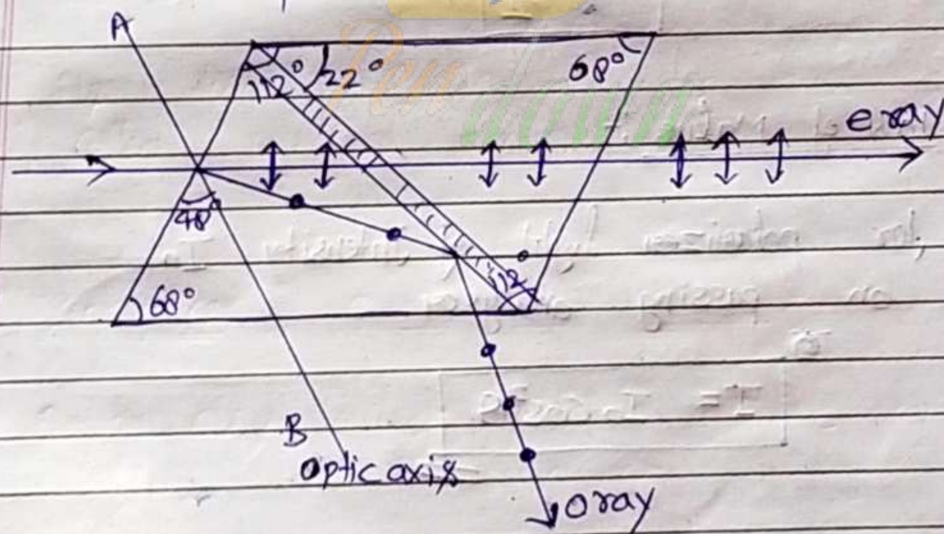
#

** # ~~Bi~~ Birefringence OR Amount of Double Refraction of Crystal –

$$\boxed{\Delta\mu = \mu_e - \mu_o}$$

① $\Delta\mu$ = +ve for positive crystal
② $\Delta\mu$ = −ve for −ve crystal

Nical Prism :- It is a polarizing device made of calcite crystal fabricated from a double refracting crystal similar to polaroid sheet in action.



$\mu_o = 1.66$
$\mu_e = 1.486$
$\mu_{canada\ balsam} = 1.55$

from Canada balsam layer, e ray transmitted and o-ray internally reflected and absorbed hence
we get only e-ray (plane polarized) by Nicol prism.

☆ Nicol prism is used as polarizer and Analyser.

Some Important points :-

① unpolarized light of Intensity I_0 transmitted by polarizer then polarized light will have Intensity

$$\boxed{I = \frac{I_0}{2}}$$

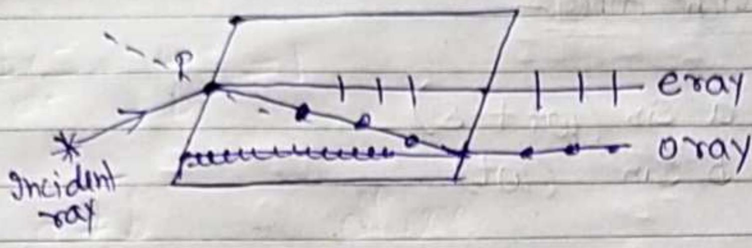
② **Law of Malus :-**

for polarizer light of Intensity I_0 on passing analyser

$$\boxed{I = I_0 \cos^2\theta}$$

☆ $I = 0$ at $\theta = 90°$ and $270°$
(axes are ⊥ar)

Huygen's Theory of Double refraction :-



for -ve crystal

$\boxed{\mu_e > \mu_o}$

P will send 2 wavefronts — ① associated with e-ray

② associated with o-ray.

optical path travelled by e-ray = $\mu_e t$

optical path travelled by o-ray = $\mu_o t$

☆ optical path difference = $t(\mu_o - \mu_e)$

If t is such that

① $t(\mu_o - \mu_e) = \frac{\lambda}{2}$ (Half wave plate)
(phase difference = π)

② $t(\mu_o - \mu_e) = \frac{\lambda}{4}$ (quarter wave plate)
(phase difference = $\frac{\pi}{2}$)

☆ optical phase difference = $\frac{2\pi}{\lambda}\left(t(\mu_o - \mu_e)\right)$

superposition of two linearly polarised wave with their optical vectors prependicular to each other—

$$E_x = a\sin(\omega t + \delta)$$
$$E_y = b\sin(\omega t)$$

$$\frac{E_x}{a} = \sin(\omega t+\delta) \quad , \quad \frac{E_y}{b} = \sin(\omega t)$$

on simplify

$$\boxed{\frac{E_x^2}{a^2} + \frac{E_y^2}{b^2} - \frac{2E_xE_y}{ab}\cos\delta = \sin^2\delta}$$

State of polarization of resultant wave and is oblique ellipse.

① $\delta = 0$:-

$$\frac{E_x}{a} = \frac{E_y}{b}$$

$$\boxed{E_y = \left(\frac{b}{a}\right)E_x}$$ plane polarised light

② $\delta = \pi$:-

$$\left(\frac{E_x}{a} + \frac{E_y}{b}\right)^2 = 0$$

$$\boxed{E_y = -\frac{b}{a}E_x}$$ plane polarized light.

③ $\delta = \frac{\pi}{2}$ or $\frac{3\pi}{2}$

$$\frac{E_x^2}{a^2} + \frac{E_y^2}{b^2} = 1$$

ⓐ $a \neq b$ ellipse

ⓑ $a = b$ circle

~~④ δ = 3π/2~~

\# To determine clockwise or anticlockwise polarized:-

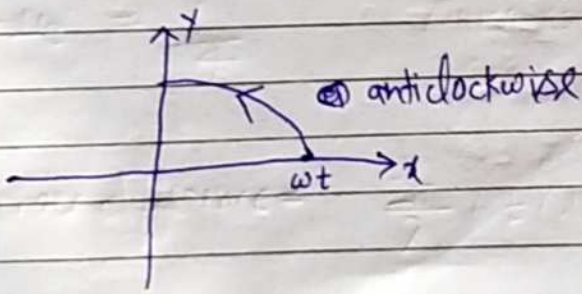
$$\boxed{\begin{aligned} E_x &= E_0(\sin \omega t + \delta) \\ E_y &= E_0 \sin \omega t \end{aligned}}$$

① for circularly polarized, $\delta = \pi/2$

$E_x = E_0 \cos \omega t$

$E_y = E_0 \sin \omega t$

	$\omega t = 0$	$\omega t = \pi/2$
E_x	E_0	0
E_y	0	E_0

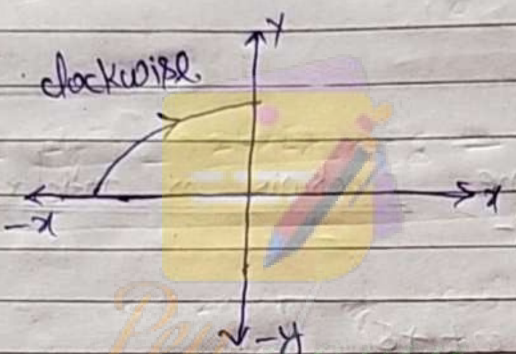


② $\delta = \frac{3\pi}{2}$

$E_x = -E_0 \cos\omega t$

$E_y = E_0 \sin\omega t$

	$\omega t = 0$	$\omega t = \pi/2$
E_x	$-E_0$	0
E_y	0	E_0



similarly can proceed for given cases.

\# ① CPL $\longrightarrow$ $\pi/2$ (quarter plate) $\longrightarrow$ LP

② EPL $\longrightarrow$ $\pi/2$ (quarter plate) $\longrightarrow$ LP

Special Cases:-

① when optical path diff $= 0 \Rightarrow$ linearly polarized

② when optical path diff $= \frac{\lambda}{4}$

$\Rightarrow$ elliptical polarized.

③ when optical path diff $= \frac{\lambda}{4}$, $a = b$,

$\Rightarrow$ circularly polarized

Hence

A quarter wave plate is used to produce elliptical or circularly polarized light