POLARIZATION

Meaning

the act of dividing something, especially something that contains different people or opinions, into two completely separate groups

1669

Erasmus Bartholin noticed that a type of colourless calcite crystal, known as Iceland spar, created a double image when objects were viewed through it . He found that when the crystals were rotated, one image would move around the other in a circular motion, as if splitting the light into two separate beams.

1808

Etienne Louis Malus polarised light was not just relevant to crystals, but could be present in reflections from a wide range of transparent or opaque substances

1812

Sir David Brewster polarising angle depends upon the refractive index

1816

Francois Arago & Fresnel showed that light waves vibrating in mutually perpendicular planes do not interfere

1817

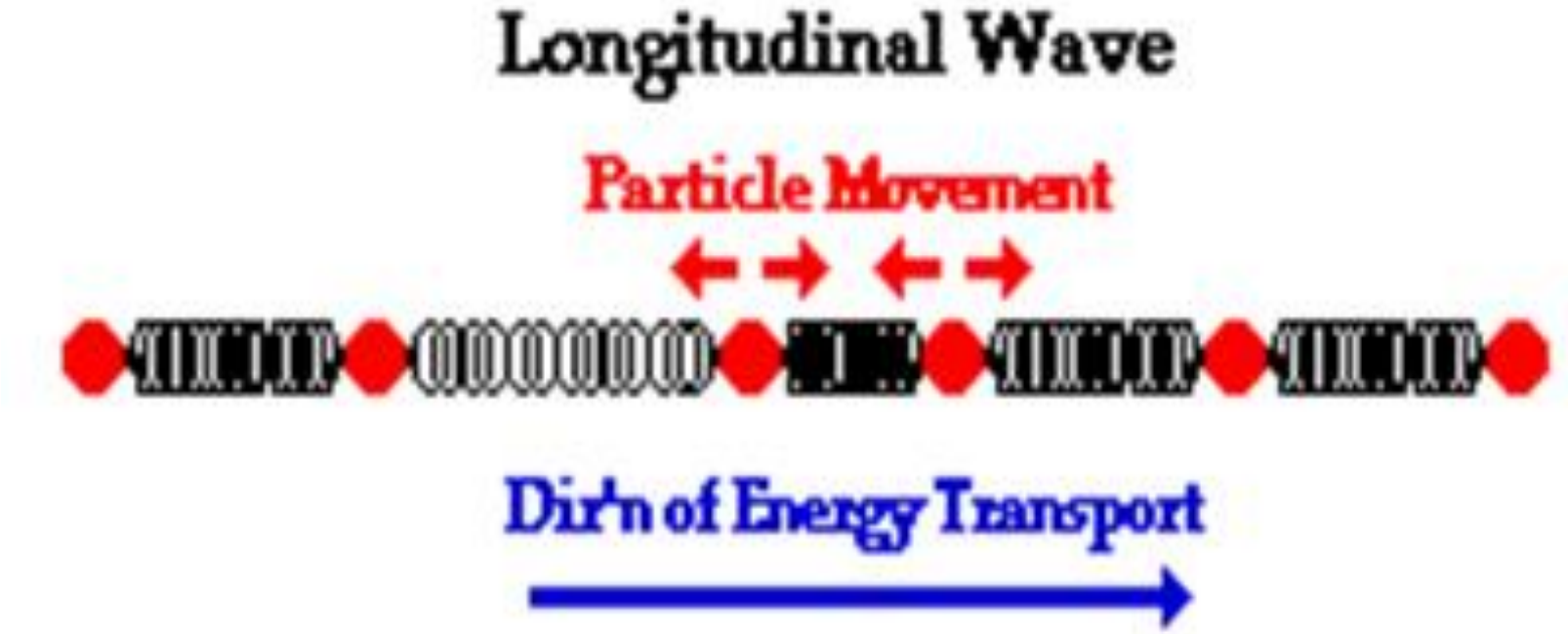
Thomas Young explained the absence of interference by postulating that light waves are transverse

1865(about)

James Clerk Maxwell developed electromagnetic theory and suggested that light waves are electromagnetic waves

Electromagnetic waves are transverse waves ….hence light waves…. Leads to the concept of polarisation

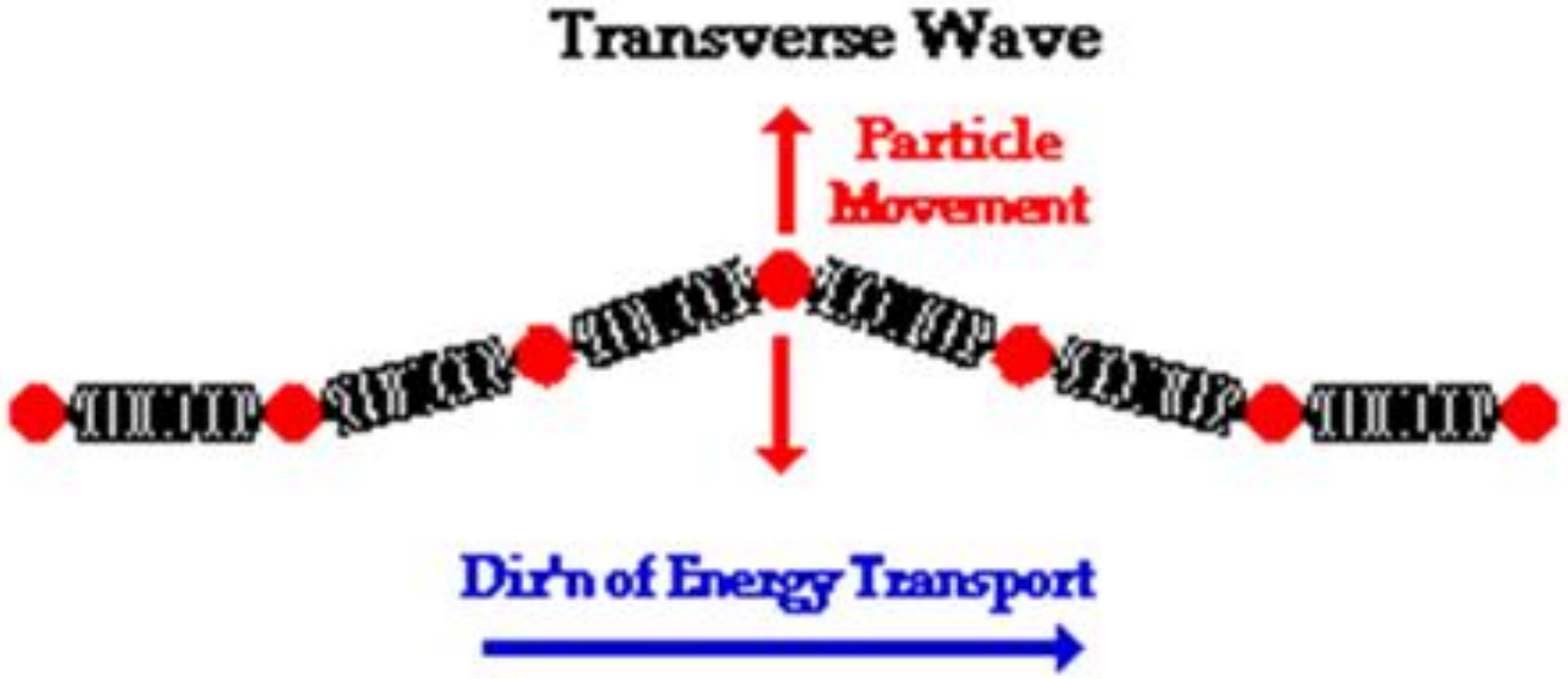
Longitudinal waves particles of the medium oscillate to and fro along the direction of wave propagation….



Examples?

Transverse waves every particle of the medium oscillates up and down at right angles to the direction of wave propagation

...direction of particle displacement occurs perpendicular (direction normal) to the wave propagation – preferential direction



Examples?

Longitudinal waves – Sound waves, waves in spring etc

Transverse waves – ripples on water surface, waves on ropes etc

Transverse waves – preferential direction

Preferential direction leads to polarisation of transverse waves…

Polarisation – not found in longitudinal waves (no directional property)

Electromagnetic wave – a transverse wave consisting of electric and magnetic fields vibrating perpendicular to each other and the direction of propagation.

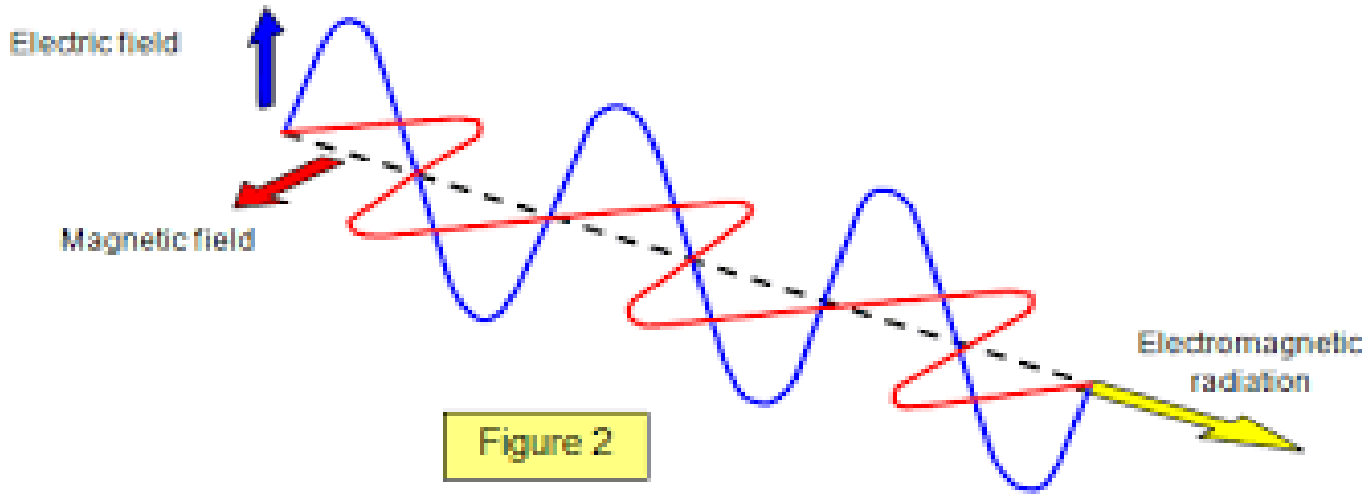
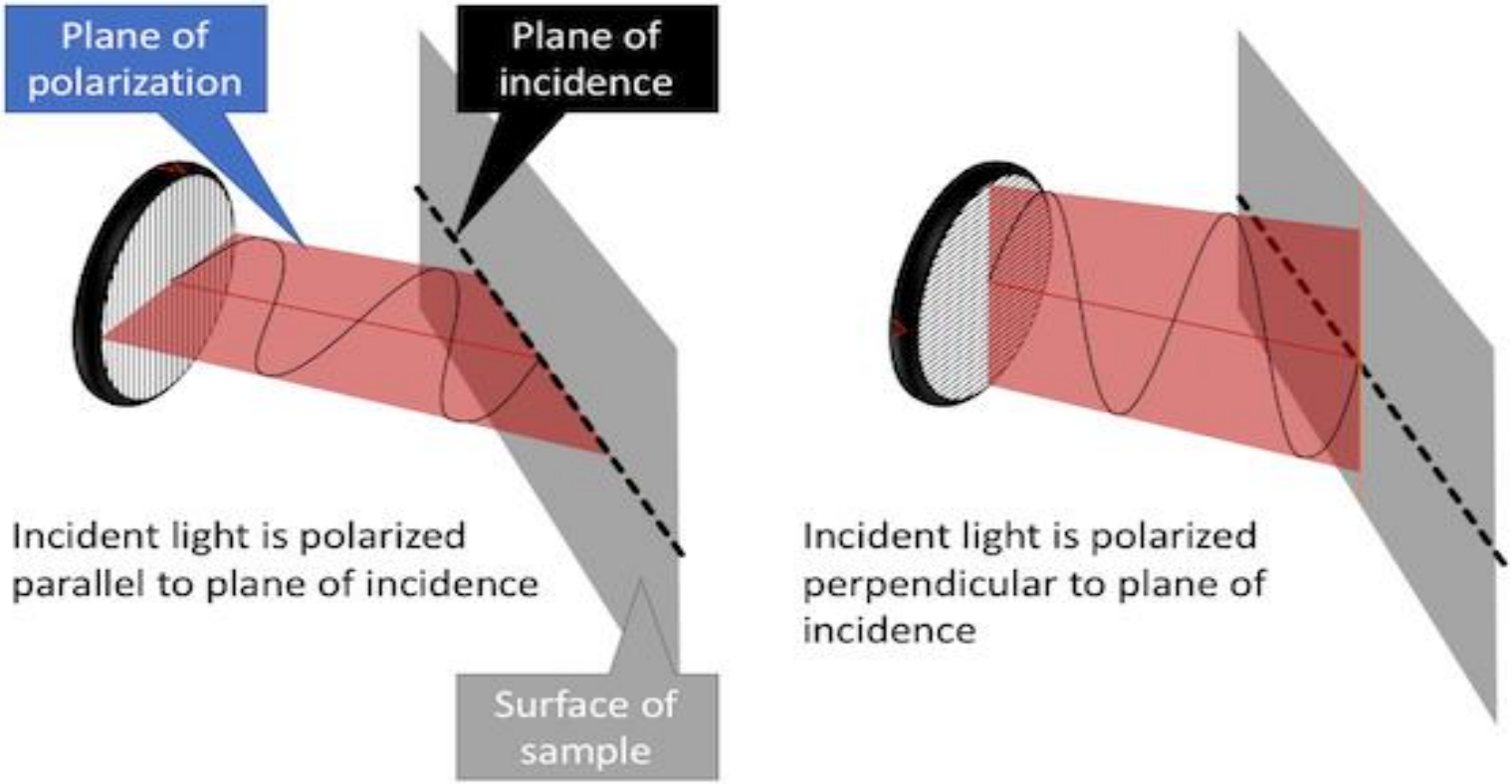
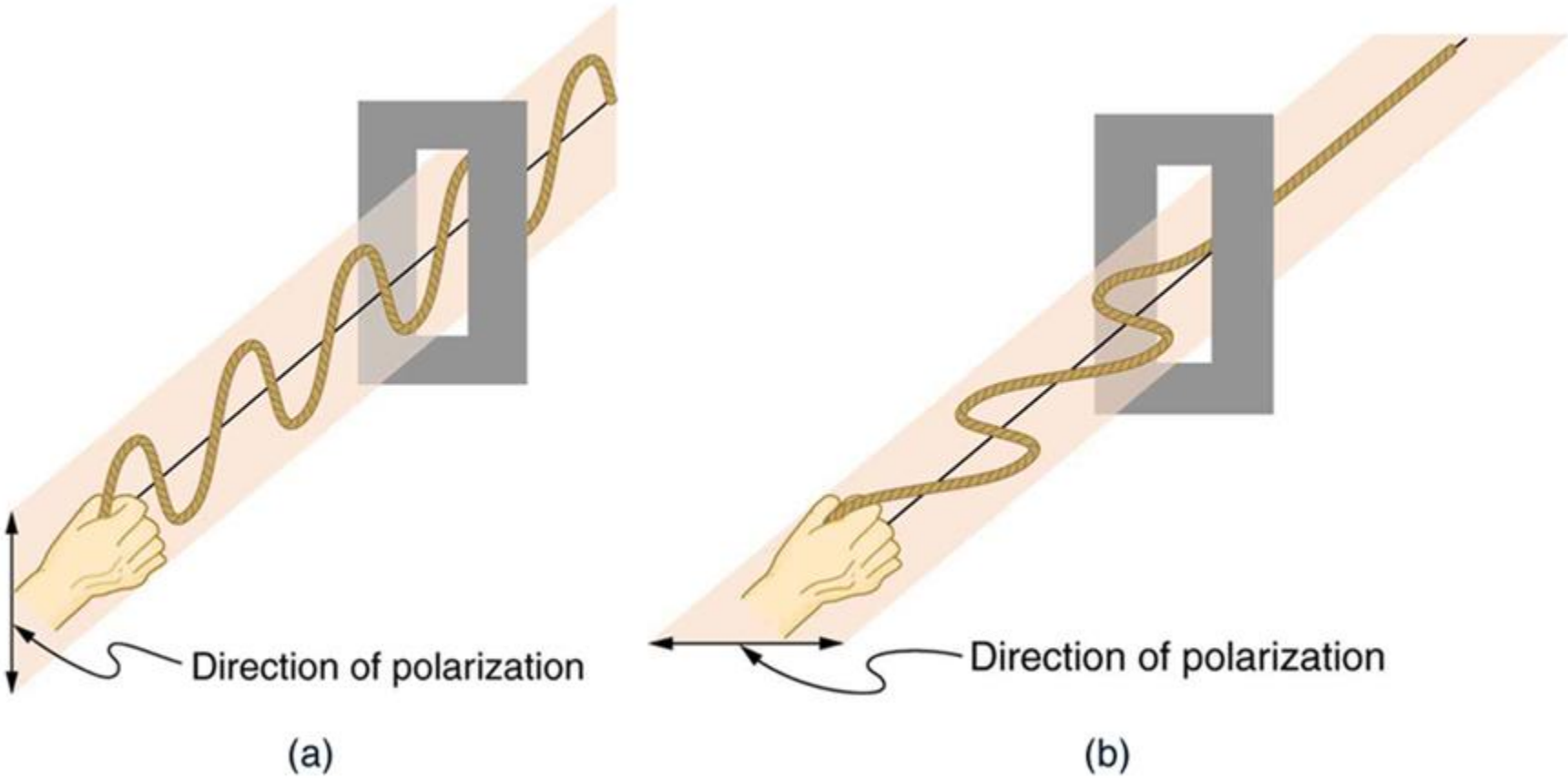
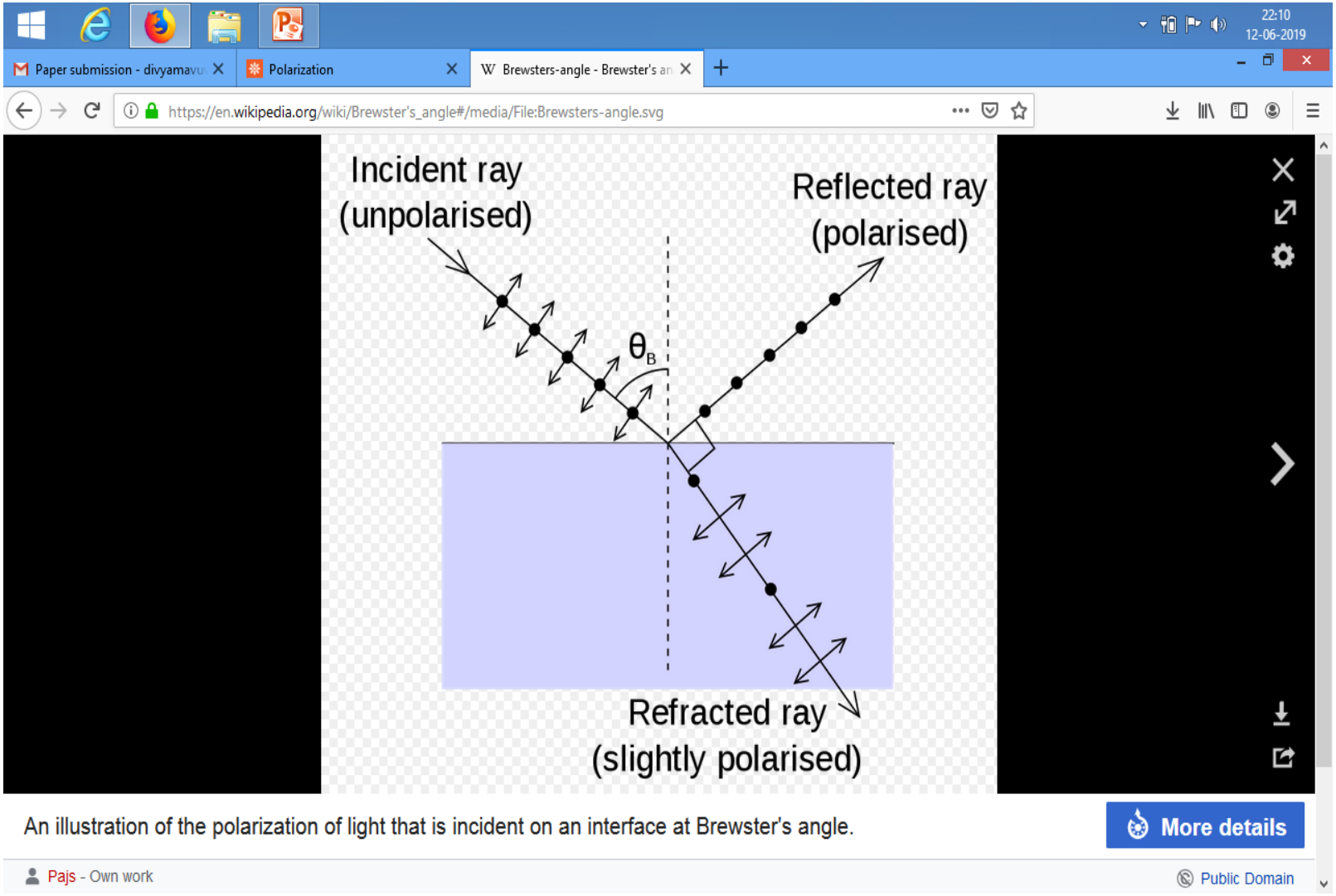


Figure 2


Plane of polarization
Plane of incidence
Incident light is polarized parallel to plane of incidence
Surface of sample
Incident light is polarized perpendicular to plane of incidence


Direction of polarization
(a)
Direction of polarization
(b)

Polarization by reflection



Brewster's law(1812)

Tangent of angle at which polarisation is obtained by reflection is numerically equal to the refractive index of the medium

$$\mu = \tan \theta_p$$

Maximum polarisation of reflected ray occurs when it is at right angles to the refracted ray

θ_p + r = 90^0 or $r = 90^0 - \theta_p$

By Snell's law

$$\frac{\sin \theta_p}{\sin r} = \frac{\mu_2}{\mu_1} \longrightarrow \frac{\sin \theta_p}{\sin(90^0 - \theta_p)} = \frac{\mu_2}{\mu_1} \longrightarrow \frac{\sin \theta_p}{\cos(\theta_p)} = \frac{\mu_2}{\mu_1}$$

Thus $\tan \theta_p = \frac{\mu_2}{\mu_1}$

$\theta_p = \theta_B$

Applications of Brewster’s law

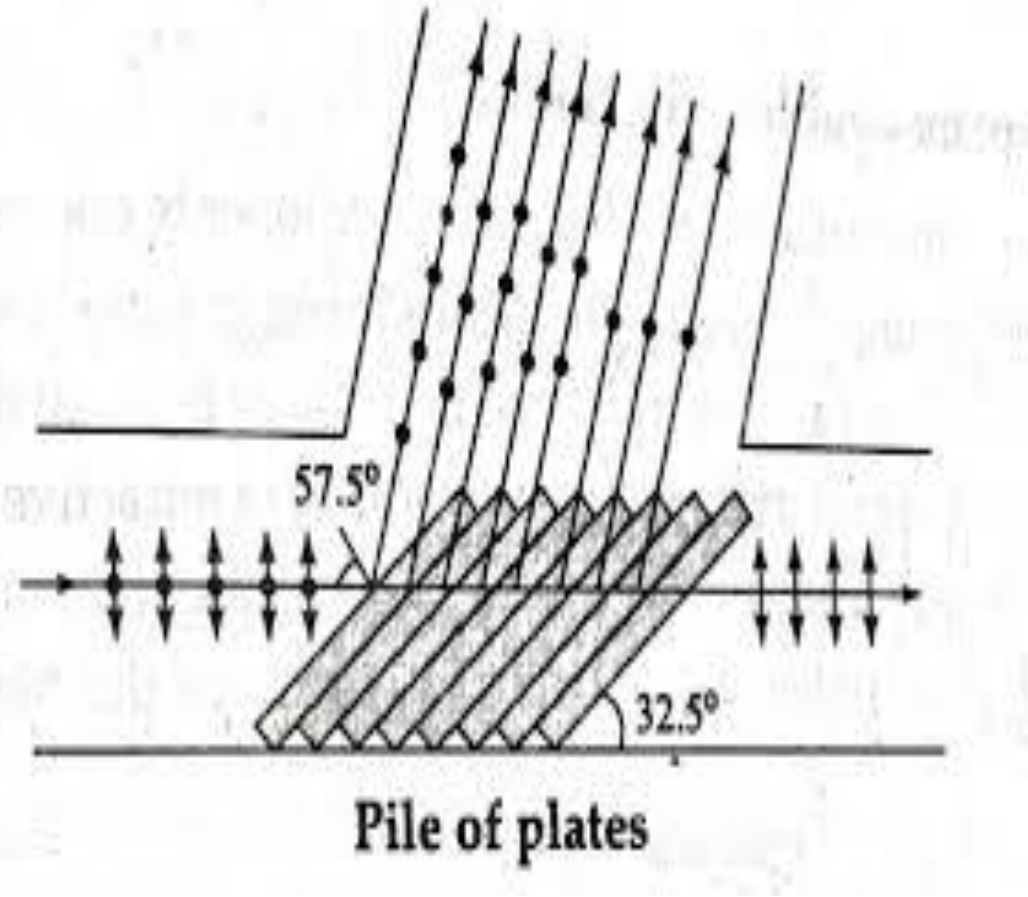
Used to find the refractive index of the material

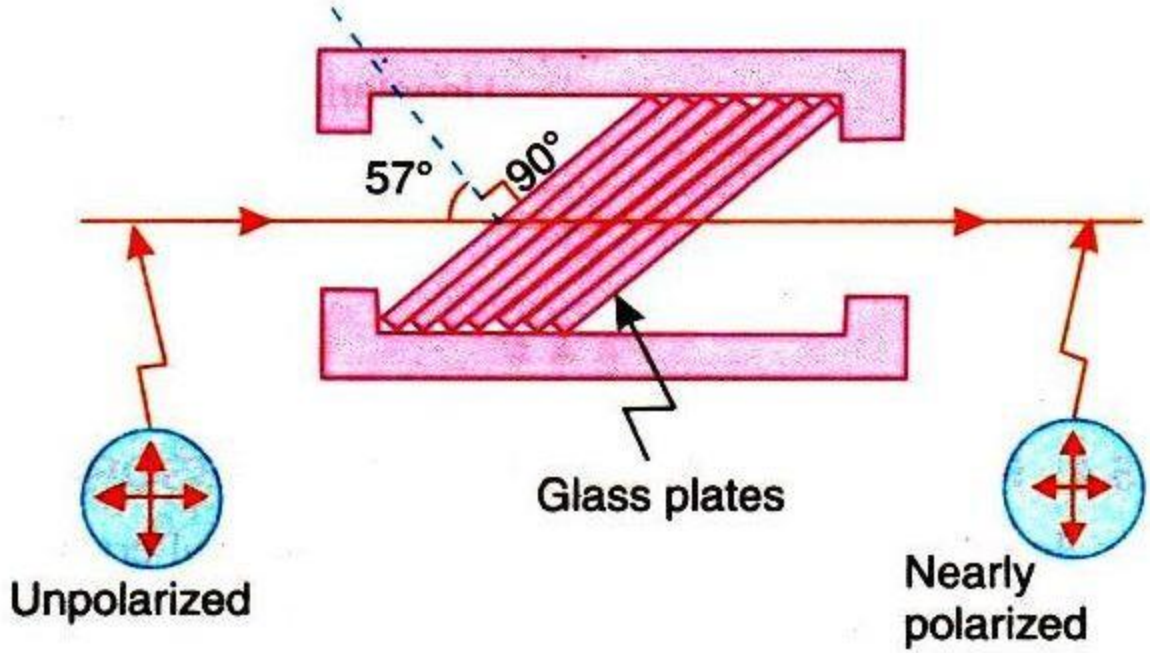
Polarized sunglasses use the principle of Brewster's angle - reduce glare from the sun reflecting off horizontal surfaces such as water or road

Optical fibres - Utilises the Brewster’s law for transmitting a light beam without reflection losses

In lasers- Brewster window is an uncoated substrate that is positioned at Brewster’s angle within a laser, instead of external mirrors. This substrate acts as a polarizer, such that the p-polarized light enters and exits the window without reflection losses, while the s-polarized light is reflected.

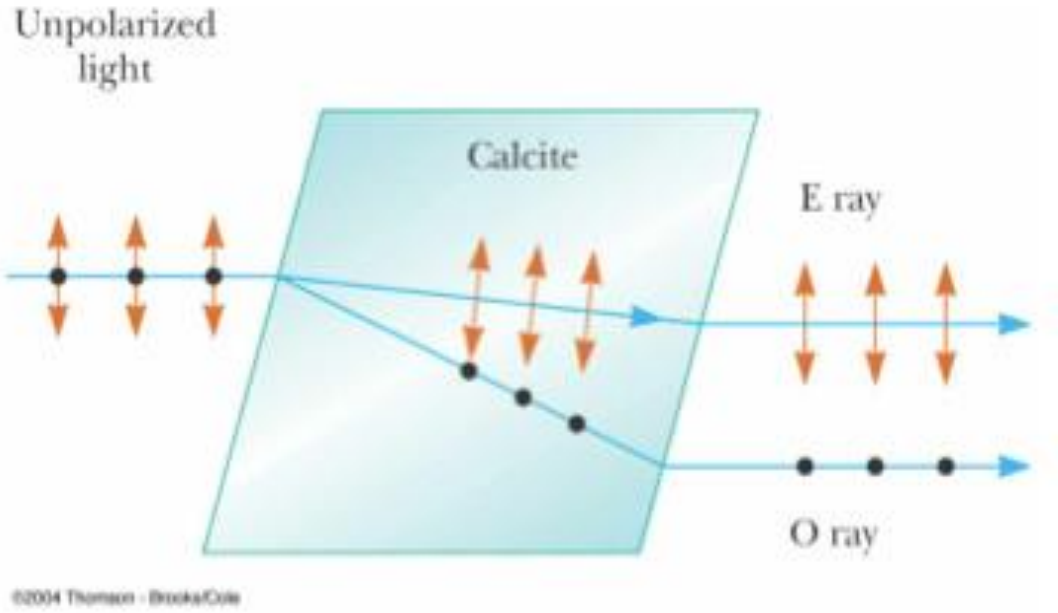
Polarization by refraction – pile of plates




57°
90°
Glass plates
Unpolarized
Nearly
polarized

Polarisation by double refraction(birefringence)

1669 by Erasmus Bartholinus in calcite crystals



O ray – obeys Snell's law
E ray – does not Snell's law

Anisotropic Crystals

Variation in

- refractive index
- velocity of light
- thermal conductivity
- electrical conductivity
- force of interaction between electron cloud and lattice

……with direction

Geometry of Calcite crystals