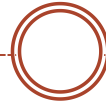


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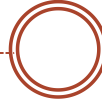
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Huygens' Theory of Double Refraction

Phenomenon of double refraction was explained by Huygens' for which he extended his principle of secondary wavelets and made the following assumptions.

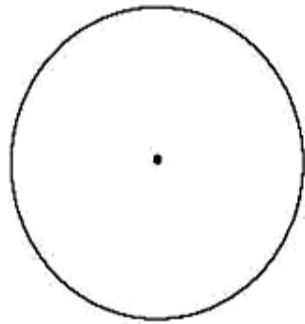
- When a light wave strikes the surface of a doubly refracting crystal, each point of the crystal becomes the origin of two secondary wavelets, named as ordinary ray and extraordinary ray. These two wavelets spread out into the crystal.
- The wavefront corresponding to ordinary ray is spherical as the velocity of ordinary ray remains the same in all the directions.

POLARISATION

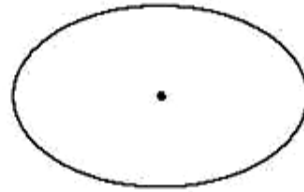


- The wave front corresponding to extraordinary ray is an ellipsoid of revolution with the optic axis as its axis of revolution. This is due to the fact that the velocity of E-ray is different in different directions in the crystal.
- The two wave fronts corresponding to O-ray and E-ray touch each other along the optic axis since both the rays travel with the same velocity along the direction of optic axis.
- For negative uniaxial crystals (like calcite) in which the velocity of O-ray is less than the velocity of E-ray, sphere lies inside the ellipsoid. However, for positive uniaxial crystals (like quartz) the ellipsoid lies inside the sphere since in this case the velocity of O-ray is greater than the velocity of E-ray.

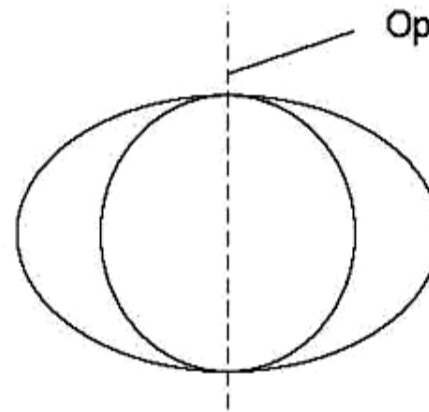
POLARISATION



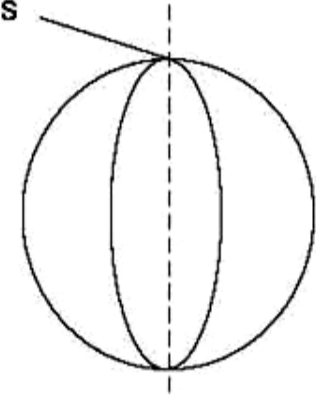
(a) Spherical Wavefront



(b) Ellipsoid of Revolution




(c) Negative Crystal



(d) Positive Crystal

Nicol Prism

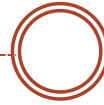


Nicol prism is an optical device which is used for producing and analyzing plane polarized light in practice.

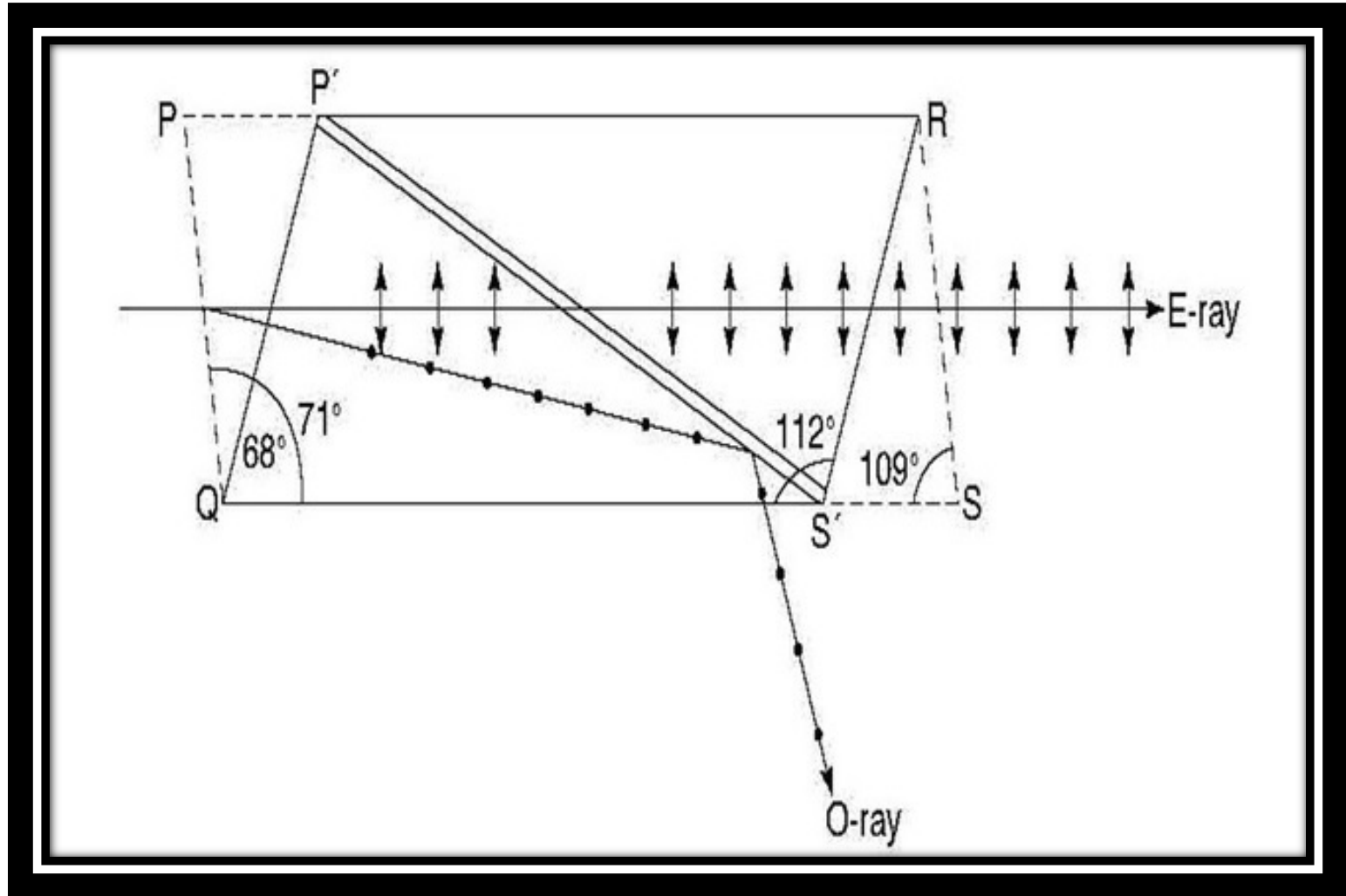
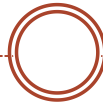
Principal

Nicol Prism is based upon phenomenon of Double refraction.

Construction



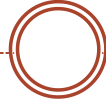
- It is constructed from the calcite crystal PQRS having length three times of its width.
- Its end faces PQ and RS are cut such that the angles in the principal section become 68° and 112° in place of 71° and 109°
- The crystal is then cut diagonally into two parts. The surfaces of these parts are grinded to make optically flat and then these are polished.
- Thus polished surfaces are connected together with a special cement known as Canada Balsam.



Working

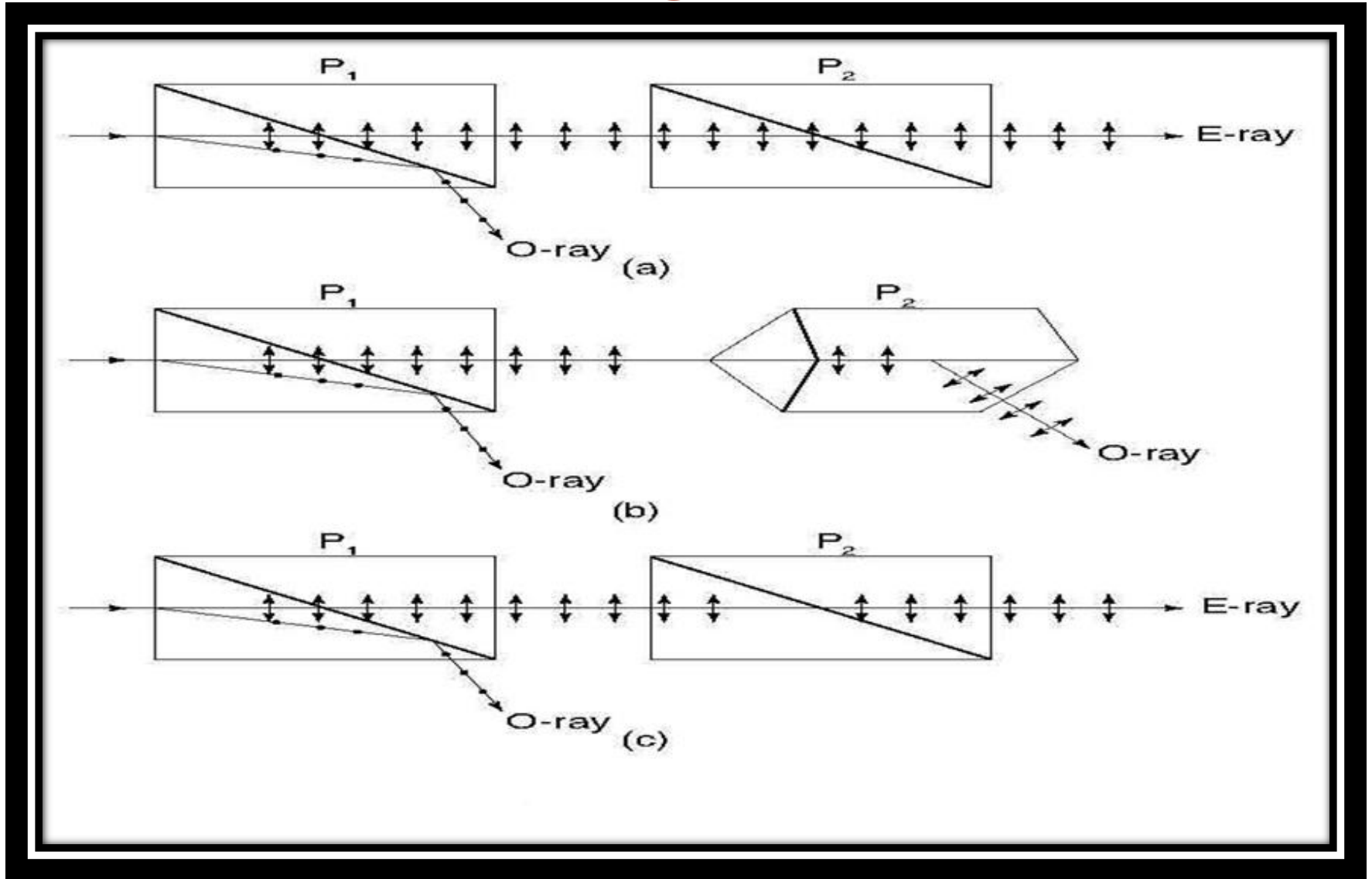
- When a beam of unpolarised light is incident on the face P'Q, it gets split into two refracted rays, named O-ray and E-ray.
- These two rays are plane polarised rays, whose vibrations are at right angles to each other. The refractive index of Canada balsam cement being 1.55 lies between those of ordinary and extraordinary and 1.4864, respectively.
- It is clear from the above discussion that Canada Balsam layer acts as an optically rarer medium for the ordinary ray and it acts as an optically denser medium for the extraordinary ray.
- When ordinary ray of light travels in the calcite crystal and enters the Canada balsam cement layer, it passes from denser to rarer medium. Moreover, the angle of incidence is greater than the critical angle, the incident ray is totally internally reflected from the crystal and only extraordinary ray is transmitted through the prism.
- Therefore, fully plane polarised wave is generated with the help of Nicol prism.

Nicol Prism as a Polariser and an Analyser

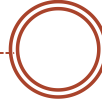


- In order to produce and analyse the plane polarised light, we arrange two nicol prisms.
- When a beam of unpolarised light is incident on the nicol prism, emergent beam from the prism is obtained as plane polarised, and which has vibrations parallel to the principal section.
- This prism is therefore known as polariser. If this polarised beam falls on another parallel nicol prism P2, whose principal section is parallel to that of P1, then the incident beam will behave as E-ray inside the nicol prism P2 and gets completely transmitted through it.
- This way the intensity of emergent light will be maximum.

POLARISATION



POLARISATION



- Now the nicol prism P2 is rotated about its axis, then we note that the intensity of emerging light decreases and becomes zero at 90° rotation of the second prism (Fig. b).
- In this position, the vibrations of E-ray become perpendicular to the principal section of the analyser (nicol prism P2).
- Hence, this ray behaves as O-ray for prism P2 and it is totally internally reflected by Canada balsam layer. This fact can be used for detecting the plane polarised light and the nicol prism P2 acts as an analyser.
- If the nicol prism P2 is further rotated about its axis, the intensity of the light emerging from it increases and becomes maximum for the position when principal section of P2 is again parallel to that of P1 (Fig. c).
- Hence, the nicol prisms P1 and P2 acts as polariser and analyser, respectively.

Quarter Wave Plate

It is a plate of doubly refracting uniaxial crystal like quartz or calcite, whose refracting faces are cut parallel to the optic axis and its thickness is such that it introduces a phase change of $\pi/2$, i.e. a path change of $\lambda/4$ between the ordinary and extraordinary light waves. Let μ_o and μ_e be the refractive indices for the ordinary

and extraordinary light waves, respectively, and t the thickness of the plate. The path difference between the ordinary and extraordinary waves is given by

$$(\mu_o - \mu_e)t = \frac{\lambda}{4} \text{ for negative crystal}$$

$$(\mu_e - \mu_o)t = \frac{\lambda}{4} \text{ for positive crystal}$$

$$t = \frac{\lambda}{4(\mu_o - \mu_e)} \text{ for negative crystal}$$

Quarter wave plate is used to produce circularly and elliptically polarised light.

Half Wave Plate

It is a plate of doubly refracting uniaxial crystal like quartz or calcite, whose refracting faces are cut parallel to the optic axis and its thickness is such that it introduces a phase change of π , i.e, a path change of $\lambda/2$, between the ordinary and extraordinary light waves. For the refractive indices μ_o and μ_e for ordinary and extraordinary light waves, the path difference is written as.

For Half Wave Plate

$$(\mu_o - \mu_e)t = \frac{\lambda}{2} \text{ for negative crystal}$$

$$(\mu_e - \mu_o)t = \frac{\lambda}{2} \text{ for positive crystal}$$

$$t = \frac{\lambda}{2(\mu_o - \mu_e)} \text{ for negative crystal}$$