Optics

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OUTLINES

- Double Refraction
- Polarization by double refraction
- Nicole prism

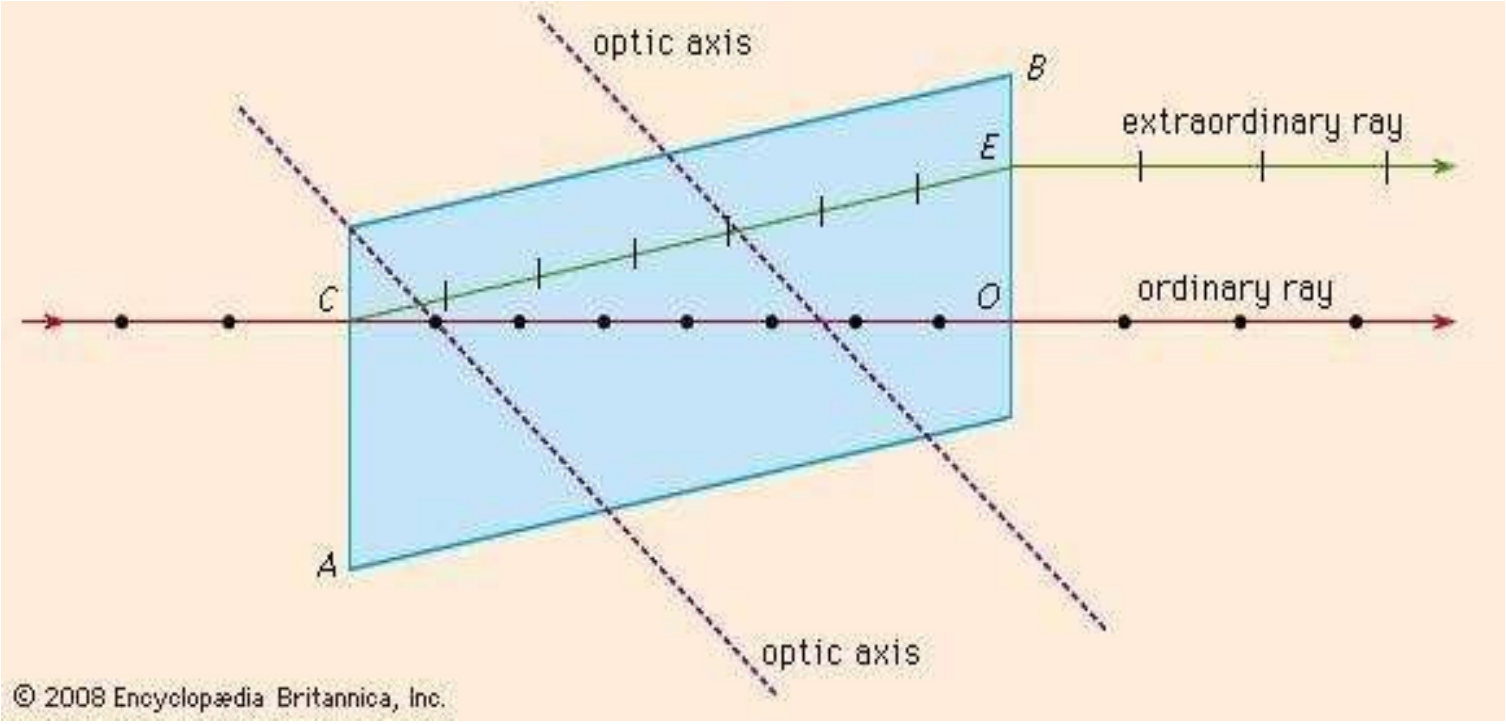
Double Refraction

Double refraction, also called **birefringence**, an optical property in which a single ray of unpolarized light entering an anisotropic medium is split into two rays, each traveling in a different direction. One ray (called the extraordinary ray) is bent, or refracted, at an angle as it travels through the medium; the other ray (called the ordinary ray) passes through the medium unchanged.

Double refraction can be observed by comparing two materials, glass and calcite ($CaC0_3$). If a pencil mark is drawn upon a sheet of paper and then covered with a piece of glass, only one image will be seen; but if the same paper is covered with a piece of calcite, and the crystal is oriented in a specific direction, then two marks will become visible.

The Figure shows the phenomenon of double refraction through a calcite crystal. An incident ray is seen to split into the ordinary ray *CO* and the extraordinary ray *CE* upon entering the crystal face at *C*. If the incident ray enters the crystal along the direction of its optic axis, however, the light ray will not become divided.

Double Refraction



Polarization by double refraction

The phenomenon of double refraction can be easily demonstrated by allowing a narrow beam of unpolarized light to be incident normally on calcite crystal. There will be two refracted beams in place of the usual one as in glass. Since the two opposite faces of a calcite crystal are always parallel and since no double refraction occurs at the second face, the two refracted rays emerge parallel to the incident beam and therefore, parallel to each other. But the two rays are relatively displaced by a distance, which is proportional to the thickness of the crystal, *i.e.*, the path traversed within the crystal. If the rays are received on a screen, there will be two images instead of one. One of the images O lies in the direction of the incident ray *i.e.*, passes through the crystal without deviation and, therefore, must have been formed in accordance with the ordinary laws of refraction. The other image E is found to be separated from the O image, despite its perpendicular incidence and therefore, does not in general, obey the ordinary laws of refraction. If the calcite crystal is rotated around the incident beam as an axis, the O image remains stationary while the E image revolves in a circular path with its centre at the O image (Fig. 30.7).

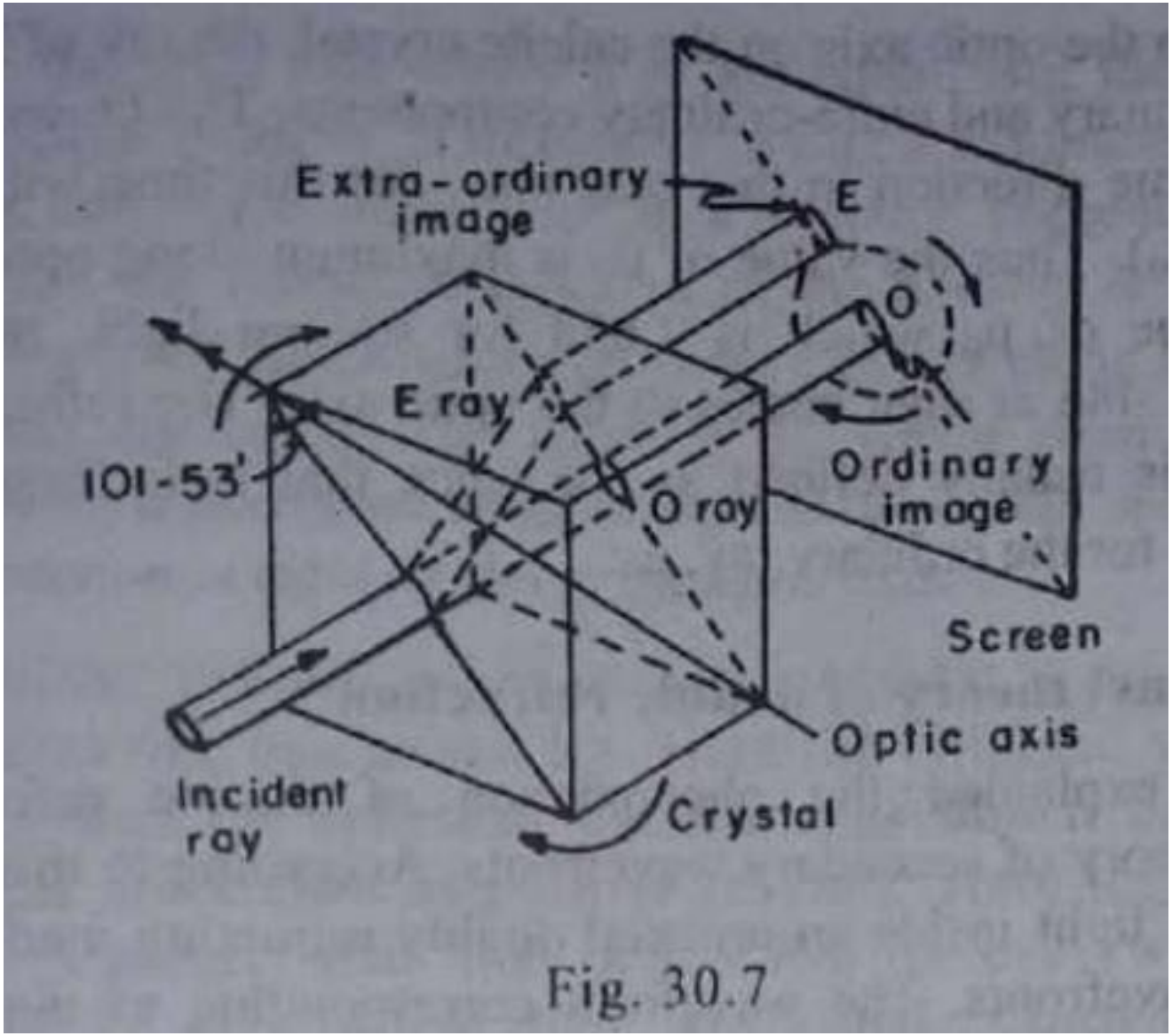

Extra-ordinary image
E
O
E ray
101-53'
O ray
Ordinary image
Screen
Optic axis
Incident ray
Crystal

Fig. 30.7

Of the two refracted rays, the one which always obeys ordinary laws of refraction is called the *ordinary ray* or the *O-ray* while the other which does not obey the ordinary laws of refraction and behaves in quite extra-ordinary manner, is called the *extra-ordinary ray* or the *E-ray*. The ratio *sin i/sin r* physically represents the velocity of light in vacuum to that in the refracting medium. It is, therefore, obvious that the velocity of the *E-ray* is different in different directions whereas the *O-ray* travels with the same velocity in all directions. The *O-ray* consists of dot components *i.e.*, its vibrations are perpendicular to the optic axis *i.e.*, to the principal plane. The *E-ray* on the other hand consists of the arrow components *i.e.*, its vibrations take place in the principal plane.

The refractive index of the crystal with respect to the ordinary light is known as ordinary refractive index, μ_o. The refractive index with respect to extra-ordinary light is known as extra-ordinary refractive index, μ_e. In the case of calcite crystal $\mu_o > \mu_e$. Therefore, the velocity of the light for the ordinary ray inside the crystal will be less compared to the velocity of light for the extra-ordinary ray. Now it has been found that the speed of *E-ray* varies with its direction of travel through the crystal, *i.e.*, the value of μ_e varies with the direction of *E-ray* inside the crystal. When the ordinary beam of light is incident on the calcite crystal in a direction parallel to the optic axis of the crystal, the incident light is not split up into ordinary and extra-ordinary rays. In this case, both the *O-ray* and the *E-ray* travel along the same direction with the same velocity. When the ray of light is incident

perpendicular to the optic axis on the calcite crystal, the ray of light is not split up into ordinary and extra-ordinary components. The *O-ray* and *E-ray* travel in the same direction in this case also, but this time with different velocities ($v_e > v_o$). Thus the value of μ_e is maximum along optic axis and equals the value of μ_0 which is 1.658 for sodium light. Its value is minimum *i.e.*, 1.486 at right angles to the optic axis. The refractive index for *E-ray*, μ_e, is usually defined as the value that is farthest from the refractive index for the ordinary ray, μ_0.

Nicole prism:

Nicol prism is an ingenious optical device for producing and analyzing plane polarized light and is based on the phenomenon of double refraction. It may be recalled that when a beam of ordinary light is allowed to pass through a calcite crystal, two completely plane polarized beams, the *O-wave* and the *E-wave*, with vibrations in mutually perpendicular planes are obtained. If by some means one beam can be eliminated, calcite may be used to obtain plane polarized light from natural light. William Nicol, a Scottish physicist and an expert in cutting and polishing gems and crystals, succeeded in around 1828 in eliminating the *O-wave* by using the phenomenon of total internal reflection at a thin film of canada balsam separating two pieces of calcite. His device has come to be known as *Nicol prism*, although in reality it is a *parallelopipedon* – not a prism.

Uses:

A Nicole prism can be used both for the production (polarizer) and detection (analyzer) of plane polarized light.