20.14 POLARIZER AND ANALYZER

A **polarizer** is an optical device that converts unpolarized light into polarized light. A polarizer is said to be **linear polarizer** if it produces linearly polarized light. A linear polarizer is associated with a specific direction called the **transmission axis** of the polarizer. When an ordinary (natural) light is incident on a linear polarizer, only those vibrations which are *parallel* to the transmission axis are allowed to pass through the polarizer while vibrations perpendicular to this direction are totally blocked.

An **analyzer** is a device used to identify the direction of vibration of linearly polarized light. The method of fabrication of a polarizer and an analyser is the same and they behave identical to the incident light. Dichroic cyrstal are used for fabricating linear polarizer.

20.15 NICOL PRISM

It is an ingenious optical device made from a calcite crystal for producing and detecting plane polarized light; in the former case it is called a *polarizer* and in the latter an *analyzer*. It derives its name from its inventor William Nicol who first designed it in 1828. It is used in many optical instruments.

We have seen above that when a beam of ordinary unpolarized light is passed through a doubly refracting crystal, it is split up into two plane polarized beams– ordinary and extraordinary, whose planes of polarization are mutually perpendicular. It is only necessary to get rid of one of them to obtain a strong beam which shall be plane-polarized.

In the Nicol prism the *O*-ray is eliminated by total internal reflection so that we are left with only *E*-ray, whose vibrations lie in the principal plane.

One of the most common forms of the Nicol prism is made by taking a long, clear rhomb of calcite so that its length *AE* is three times its width *AD* (Fig. 20.14). The end faces *ABCD* and *EFGH* of the rhomb are ground so as to reduce the angles *C* and *E* from 71° to 68°. The resulting crystal is then cut into two parts along the plane A_1G_1 (Fig. 20.15), passing through the blunt corners and perpendicular to both

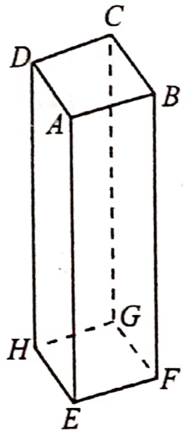

Fig. 20.14. *Calcite rhomb.*

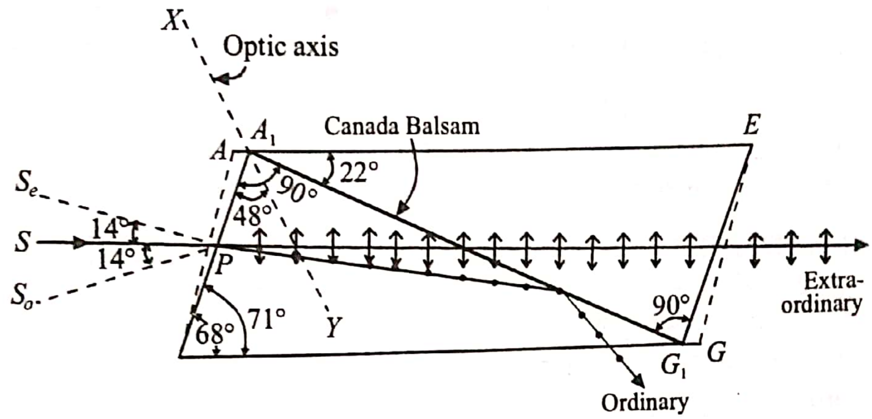

Fig. 20.15. *Nicol prism.*

the principal section and the end faces, so that A_1G_1 makes an angle of 90° with ends G_1E and A_1C. The two cut faces are ground and polished optically flat. They are then cemented by a thin layer of Canada balsam which is a clear transparent substance whose index of refraction* lies midway between the indices of *O*-ray and *E*-ray of calcite. For example, for sodium light, $\lambda = 5893$ Å.

$$\mu_0 = 1.65837,\ \mu_{CB} = 1.550,\ \mu_e = 1.48641.$$

It may be noted that the principal section of the crystal coincides with the principal planes of both the *O* and *E*-rays. The two end faces of the prism are kept open while its sides are coated with lamp black and kept covered by a brass tube. A ray incident along *SP* on one of the end faces of the nicol and moving nearly parallel to its length is divided into *O* and *E* rays whose vibrations are respectively perpendicular and parallel to the principal section of the nicol prism. The ordinary ray is travelling from a denser to an optically rarer medium and will suffer total internal reflection provided the angle of incidence at the balsam layer is greater than the *critical angle* for the two media, calcite and balsam,

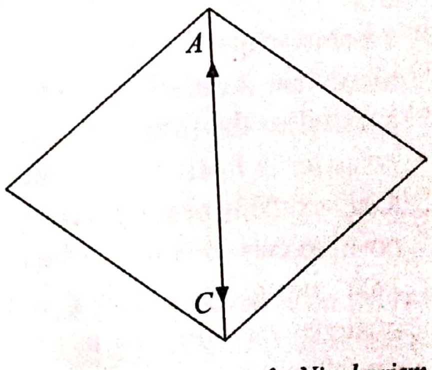

Fig. 20.16. *End-view of a Nicol prism showing direction of displacement in the transmitted rays.*

i.e., greater than $\sin^{-1}\left(\dfrac{1.550}{1.658}\right) = 69°$.

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*Since $\mu = \dfrac{\text{velocity of light in vacuum}}{\text{velocity of light in the medium}}$.

This totally reflected ray is absorbed by the lamp black layer on the side of the prism. The extraordinary ray on the other hand, travels from an optically rarer to an optically denser medium and so emerges out of the crystal, and leaves the faces EG_1 parallel to the direction SP of the incident ray. Thus we obtain a beam of plane polarized light of considerable intensity. Since the vibrations in the extraordinary ray occur in the principal plane, it follows that the vibrations in the emergent beam will be parallel to the plane of the paper. Figure. 20.16 shows the end view of Nicol prism. The direction of vibration in the emergent plane-polarised light is parallel to the shorter diagonal AC of the end face or in the direction of double arrow.

It may be noted that the angle of incidence on the face A_1C is limited to a very narrow range of about 14°. For the angle of incidence greater than this, the O-ray will strike the balsam layer at angles less than the critical and so will be transmitted.

Since only along the optic axis the E-ray travels with the same velocity as the O-ray and in all other directions it has different velocities, it being maximum at right angles to the optic axis ; the value of μ_e for sodium light is 1.486 or 1.658 according as the E-ray travels at right angles to the optic axis or along the optic axis. Along the optic axis $\mu_e = \mu_o = 1.658$. Thus for the intermediate angles the effective value of μ_e lies between 1.486 and 1.658, so that when the angle of incidence at the end faces exce· · a certain limit, the canada balsam becomes optically less dense than calcite and E-ray is totally reflected by the balsam. This limits the angle of incidence for the E-ray also to about 14°. Thus to avoid the transmission of O-ray and the total internal reflection of E-ray the angle between the extreme incident rays is limited to about 28°. Hence a *nicol prism cannot be used in highly convergent or divergent light.*

20.15.1 Nicol as an Analyzer

The function of the nicol as an analyser of plane-polarized light is easily understood from Fig. 20.17. Here two nicols P and A are arranged co-axially and they constitute a **polariscope**; the first prism is the polarizer and the second the *analyzer*. When the nicols are similarly orientated, that is, the principal section of the analyzer A is parallel to the principal section of the polarizer P, the extraordinary ray from the polarizer is freely transmitted by the analyzer. This position and the other position correponding to the angle of 180° between the two principal sections when they are again parallel are referred to as "parallel nicols" and are shown in Fig. 20.17 (a) and (c).

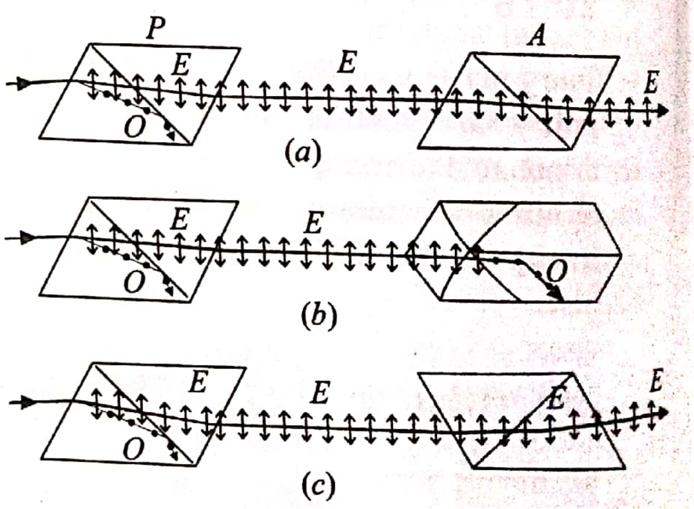

Fig. 20.17. *Nicol as an analyser.*

When the analyser A is turned through 90° from these positions, that is, the principal sections of the two are mutually perpendicular as shown in Fig. 20.17 (b) the nicols are said to be 'crossed' and no light is transmitted by the system. That this should be the case is obvious as the ray on emerging out of the polarizer has vibrations in its principal section and, therefore, perpendicular to the principal section of the analyzer. It will thus have no component in the principal section of the latter and will travel as an ordinary ray in it to be totally reflected at the balsam layer.

For intermediate positions the *E*-ray transmitted by the polarizer on being incident at the analyzer is broken up into two components one having vibrations parallel to the principal section of the analyser and the other perpendicular to it. It is the former component which passes through and the latter is ultimately reflected at the balsam layer. The intensity of the beam emerging from the polariscope obeys cosine square law, viz., $I \propto \cos^2 \theta$, where θ is the angle of rotation from the position of maximum intensity.