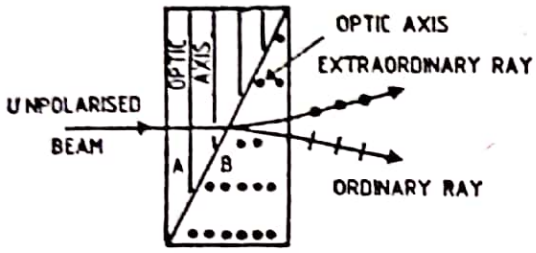
9.12. Double Image Prisms

They are optical devices which produce two separate images (*O*- and *E*-image) in the field of view. There are two such prisms :

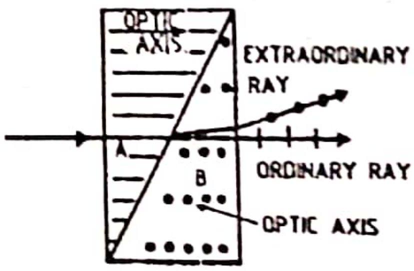


(a) WOLLASTON POLARISER

(i) *Wollaston Prism* : It consists of two right-angled quartz prisms *A* and *B* with their hypotenuse faces in contact (see fig.). In prism *A*, the direction of the optic axis is perpendicular to the direction of the normally incident light. In prism *B*, the optic axis is perpendicular both to the incident light and to the optic axis in *A*.

The incident unpolarised light is divided into two components which diverge in prism *B*. In prism *B*, the extraordinary ray in *A* becomes the ordinary ray, and vice-versa. Divergence occurs in such a way that two plane-polarised beams emerge in different directions from the exit side of *B*. These two beams have equal intensities, and this is a convenience in comparing images of the two beams which are side by side with vibrations perpendicular to one another.

(ii) *Rochon Prism* : It consists of two right-angled prisms *A* and *B* with their hypotenuse faces in contact. The prism *A* has its optic axis parallel to the normally incident light. In prism *B*, the optic axis is perpendicular both to the incident light and to the optic axis in *A*.



(b) WOLLASTON POLARISER

The unpolarised incident beam of light is split into two plane-polarised components, but both travel with the same speed in the direction of the optic axis in *A*. The division of the two rays takes place at the boundary. The divergence is only about half that produced by a Wollaston prism of the same size.

This advantage of the Rochon prism is that the ordinary ray is transmitted without deviation for all wavelengths.

The double-image prisms are useful in the ultra-violet region when a Nicol prism cannot be used because Canada balsam absorbs ultra-violet radiation.

9.14. Retardation Plate

A retardation plate is a plate cut from a doubly refracting crystal by sections parallel to the optic axis and is employed to introduce a given phase difference between the *O*-ray and the *E*-ray on transmission normally through it.

Let t = thickness of plate in the direction of propagation,

μ_o = the refractive index for the *O*-ray,

μ_e = the refractive index for the *E*-ray,

$\therefore$ $\mu_o t$ = Optical path for *O*-ray and

$\mu_e t$ = Optical path for *E*-ray.

$\therefore$ The path difference between the *O*-ray and *E*-ray is

$$\triangle = (\mu_o - \mu_e).t \qquad (\because \mu_o > \mu_e \text{ for Calcite}).$$

The phase difference between the two rays is

$$\delta = \frac{2\pi}{\lambda}(\mu_o - \mu_e).t.$$

There are two retardation plates in common use :

(i) a half-wave plate and

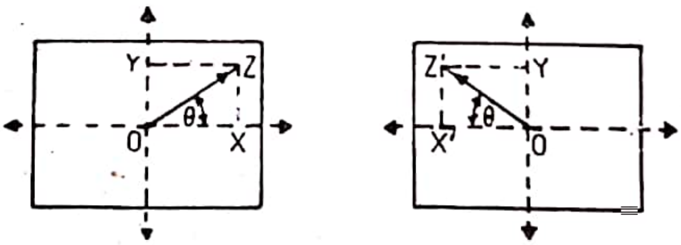
(ii) a quarter-wave plate.

9.15. Half-Wave Plate

A half-wave plate is a retardation plate which produces a phase difference of 180° or a path difference of $\frac{\lambda}{2}$ between the emergent *O*-ray and *E*-ray from it.

For negative crystal, $(\mu_o - \mu_e)t = \frac{\lambda}{2}$ or $t = \frac{\lambda}{2(\mu_o - \mu_e)}$.

For positive crystal, $(\mu_e - \mu_o)t = \frac{\lambda}{2}$ or $t = \frac{\lambda}{2(\mu_e - \mu_o)}$.



(a) (b)

The electric vector *OZ* in the incident plane-polarised light may be resolved into two perpendicular components *OY* and *OX* where $\angle ZOX = \theta$. On traversing a half-wave plate, the *OX* component gains a half wave length on the *OY* component, corresponding to a phase change of 180°. The direction of *OX* is therefore reversed to become *OX'*. The resultant emergent light is now represented by

OZ'. The half-wave plate simply rotates the plane of polarisation through $(180° - 2\theta)$. The emergent light is still plane polarised.

It is used as a half-shade device in a polarimeter.

9.16. Quarter-Wave Plate

A quarter-wave plate is a retardation plate which produces a phase difference of 90° or a path difference of $\frac{\lambda}{4}$ between the O-ray and the E-ray from it.

If t = thickness of quarter-wave plate,

μ_o = refractive index for the O-ray, and

μ_e = refractive index for the E-ray, then

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

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

It is used to produce circularly and elliptically polarised light.