4.7 BIREFRINGENCE

In an isotropic material such as water and glass, the refractive index is same in all directions in the material. But when you have a crystalline material, it may have different refractive indices in different directions. Uniaxial crystals such as **calcite** (Calcium carbonate), **tourmaline** (Boron silicate) and **quartz** (Silicon oxide) have a special direction called the **optic axis**. The refractive index of light is different depending on the polarization of the wave relative to the optic axis. When an electromagnetic wave is incident along the optic axis, only one wave comes out of the crystal, but when it is incident at an angle to the optic axis, two waves result (Fig. 4.11).

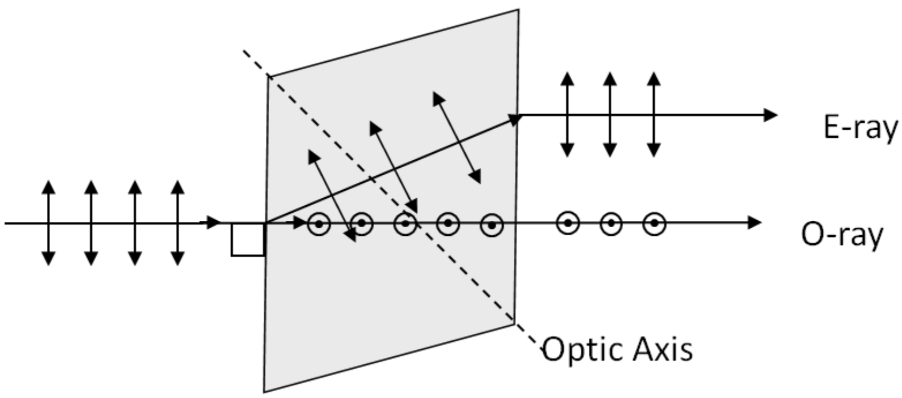

Figure 4.11: Light through a birefringent crystal. A polarized light perpendicular to the optic axis is shown incident on at 90-degrees on a principal section of a calcite single crystal.

One of these waves obeys the law of refraction, and the other does not. The wave in the crystal that obeys Snell's law is called the **ordinary or O-ray**, and the strangely behaving ray is called the **extraordinary or E-ray**. Due to the generation of two rays, the O-ray and the E-ray, you see a **double image** when you look through a **birefringent crystal** as illustrated in Fig. 4.12.

The refractive index of the ordinary ray n_o may be larger or smaller than the refractive index of the extraordinary ray n_e. The difference $n_e - n_o$ is called the **birefringence** of the birefringent crystal. The values of some commonly used birefringent crystals are given in Table 4.1.

Polarizers can be constructed by using birefringence. One such birefringent polarizer is a **Nicol prism** (Fig. 4.13). The Nicol prism

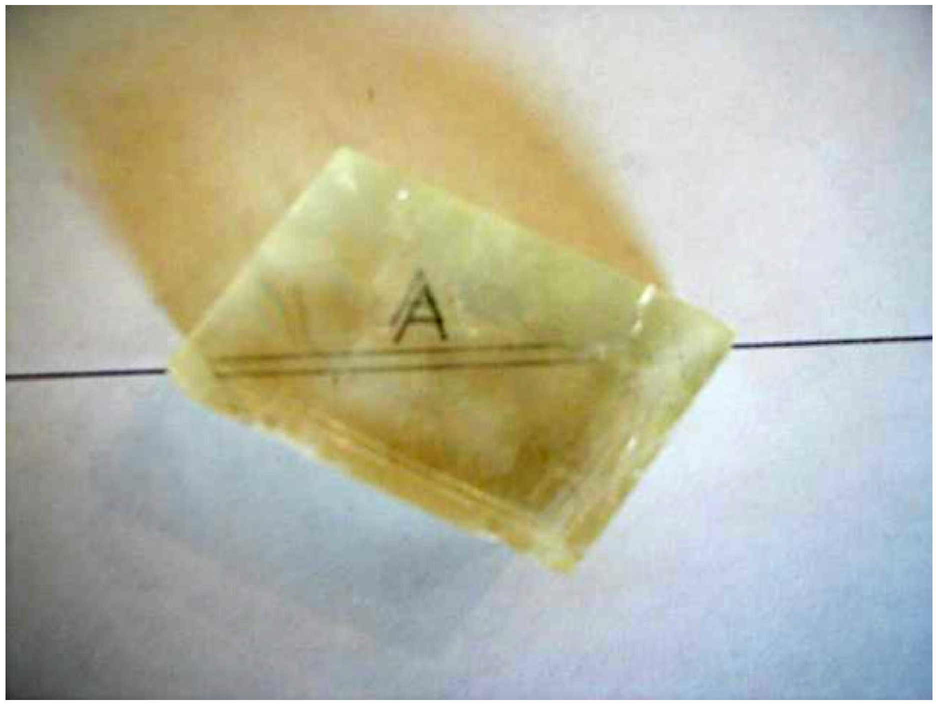

Figure 4.12: Double images from Iceland spar, a calcite crystal.

Table 4.1: Refractive indices for birefringent crystals

Crystal	n_o	n_e	$n_e - n_o$
Calcite	1.6585	1.4864	-0.1721
Quartz	1.5443	1.5534	0.0091
Sodium Nitrate	1.5854	1.3369	-0.2485
Tourmaline	1.669	1.638	-0.031

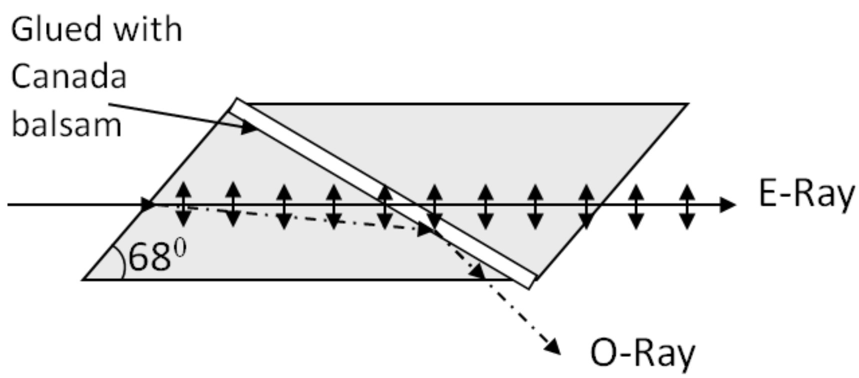

Figure 4.13: Polarization using a Nicol prism.

is made by cementing two prisms of calcite with Canada balsam which is transparent in the visible spectrum and has a refractive index between the ordinary and extraordinary rays. The cemented surface is oriented such that the ordinary ray suffers a total internal reflection at the prism/balsam interface. That leaves the extraordinary ray enter the second prism and emerge from the second prism.