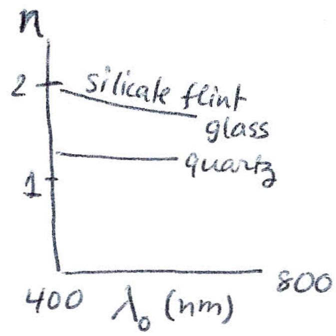
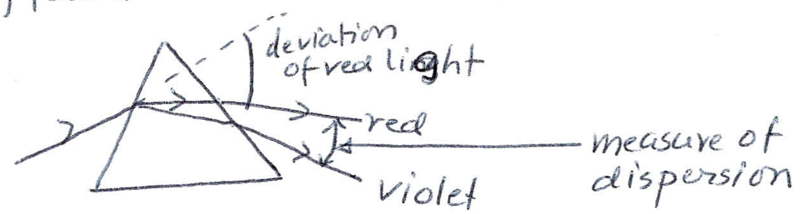
Dispersion

The speed of light in vacuum is the same for all wavelengths. But the speed of light in a material is different for different wavelengths. The index of refraction ($n = \frac{c}{v}$) also depends on the wavelength. This dependence of wave speed and index of refraction on wavelength is called the dispersion.



In most materials the index of refraction decreases with increase of wavelength in vacuum as shown in the figure. Light of lower wavelength (higher frequency) will disperse more than light of larger wavelength (lower frequency).

When white light is sent through a prism of high index of refraction, light of different colors will disperse through different angles and we will get a spectrum of different colors as shown below

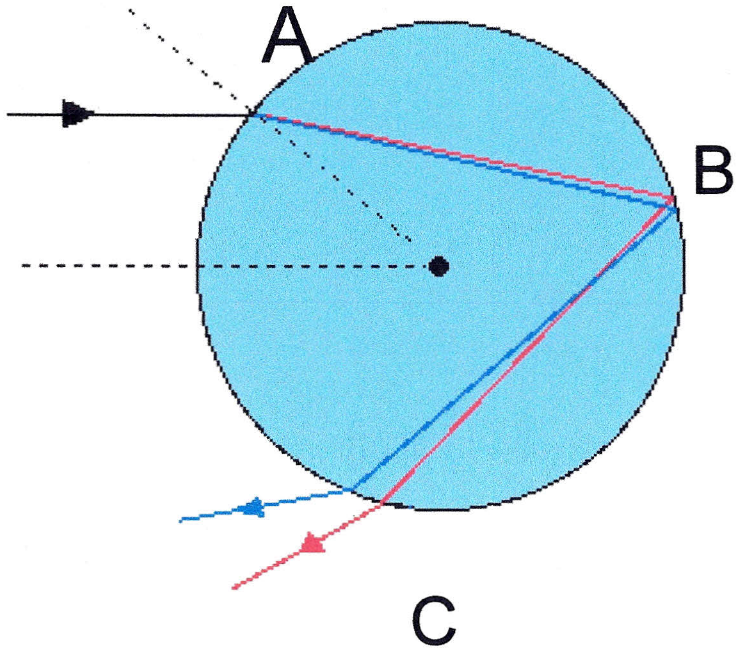


Rainbows

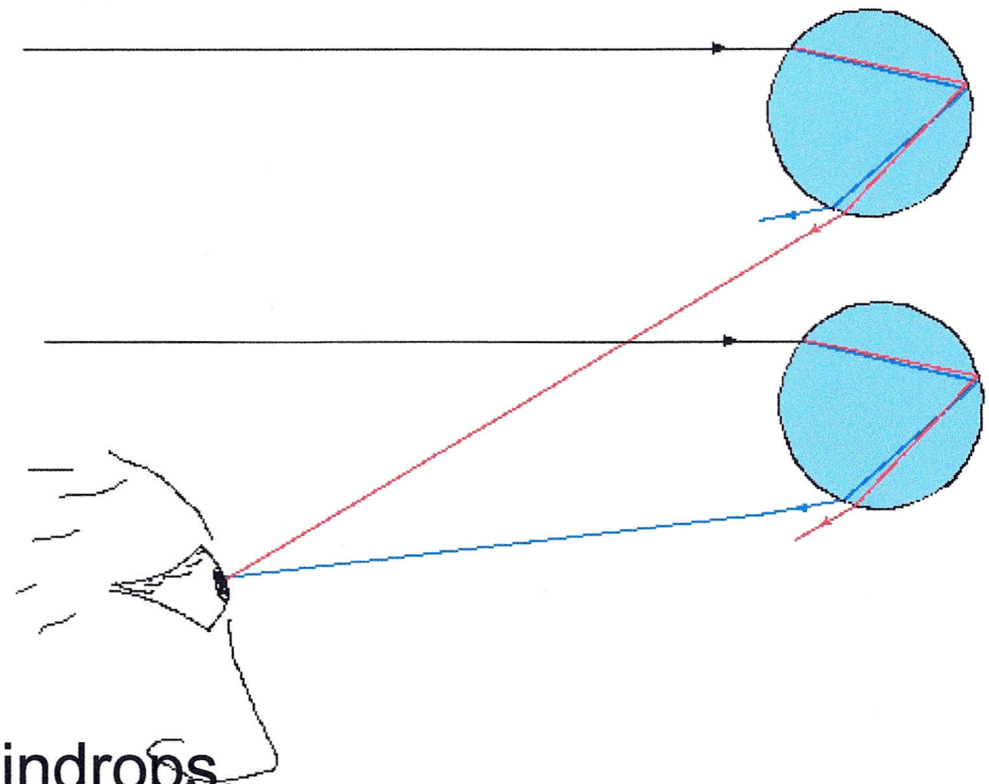
Occurrence of rainbows is the combined effects of dispersion, refraction and reflection. A rainbow is often seen by an observer positioned between the sun and a rain shower. A ray of sunlight (white light) passing overhead strikes a water droplet and is refracted and reflected as shown in the following figure.

The most intense red light returning from a drop high in the sky reaches the observer because it is deviated the most, but the violet passes over the observer because it is deviated the least. A droplet lower in the sky would direct the most intense violet light toward the observer (the most intense red light pass below the observer)

What makes a Rainbow ?



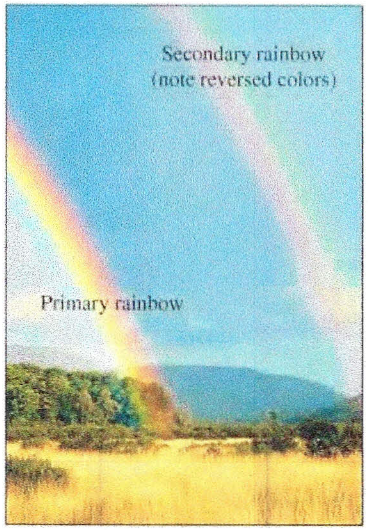
- Blue is refracted more than red (dispersion) at A
- Total internal reflection occurs at B
- Blue is refracted more than red at C



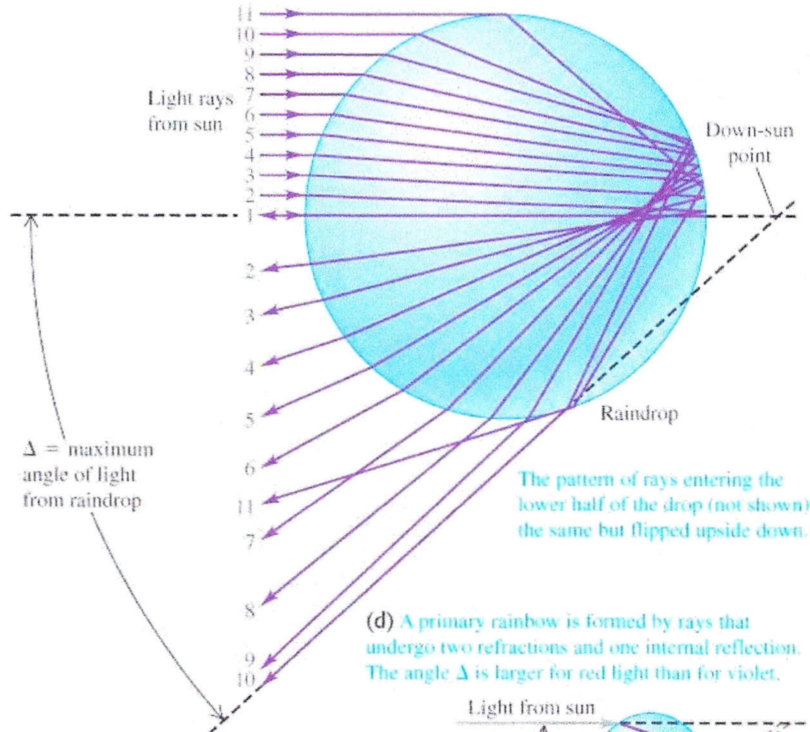
Observer sees red from higher raindrops and blue from lower raindrops.

Occasionally, a second inverted rainbow is seen along with the primary one. This is the result of dispersion, refraction and two ~~refraction~~ reflections from the back surface of a raindrop as shown in Figure(e). The secondary rainbow is relatively fainter because of loss of intensity by two reflections. The second reflection reverses the sequence of color of the secondary rainbow.

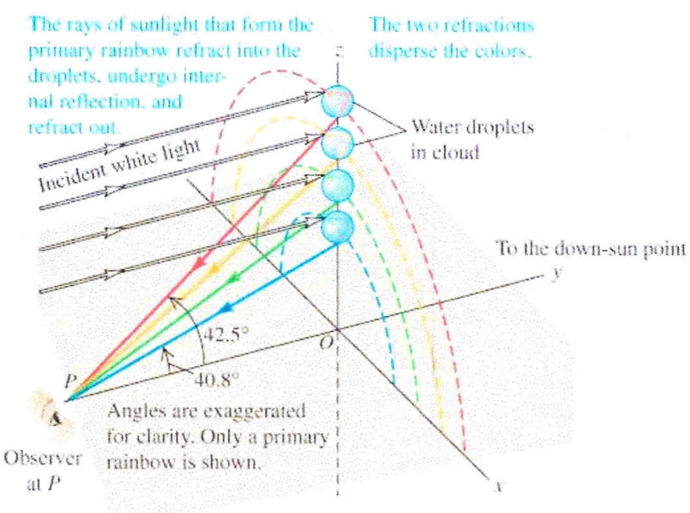
(a) A double rainbow



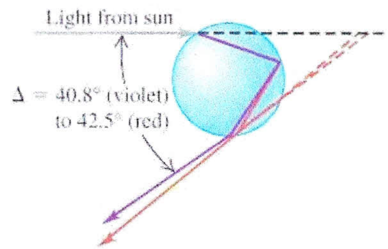
(b) The paths of light rays entering the upper half of a raindrop



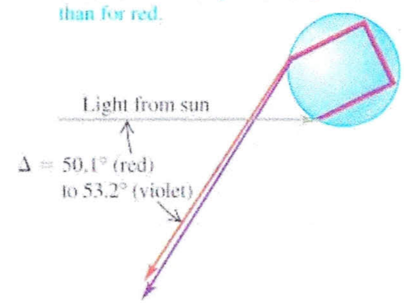
(c) Forming a rainbow. The sun in this illustration is directly behind the observer at *P*.



(d) A primary rainbow is formed by rays that undergo two refractions and one internal reflection. The angle Δ is larger for red light than for violet.



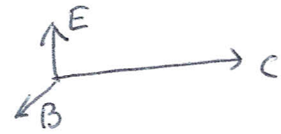
(e) A secondary rainbow is formed by rays that undergo two refractions and *two* internal reflections. The angle Δ is larger for violet light than for red.



DOUBLE RAINBOWS occur because of an additional total internal reflection !!!

Polarization

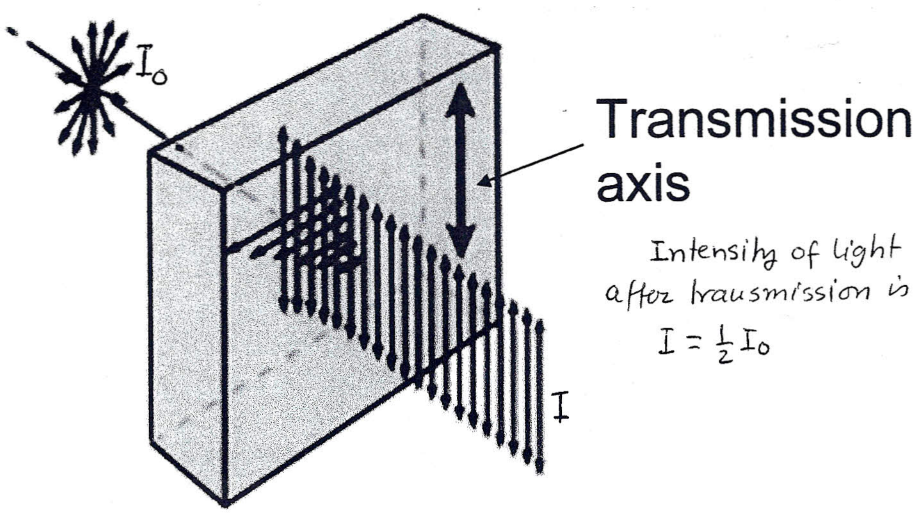
We have seen that em-wave is a transverse wave i.e. oscillations of the electric and magnetic fields are mutually orthogonal and normal to the direction of propagation as shown.



The direction of polarization of an em-wave is taken to be direction of oscillation of the E-field, not the B-field because many em-wave detectors more readily detect the E-field.

When light is produced by a group of atoms like in an incandescent bulb, all directions of oscillations are possible. This means that the resultant em-waves will have polarization as shown in the figure. We say that the light beam is unpolarized.

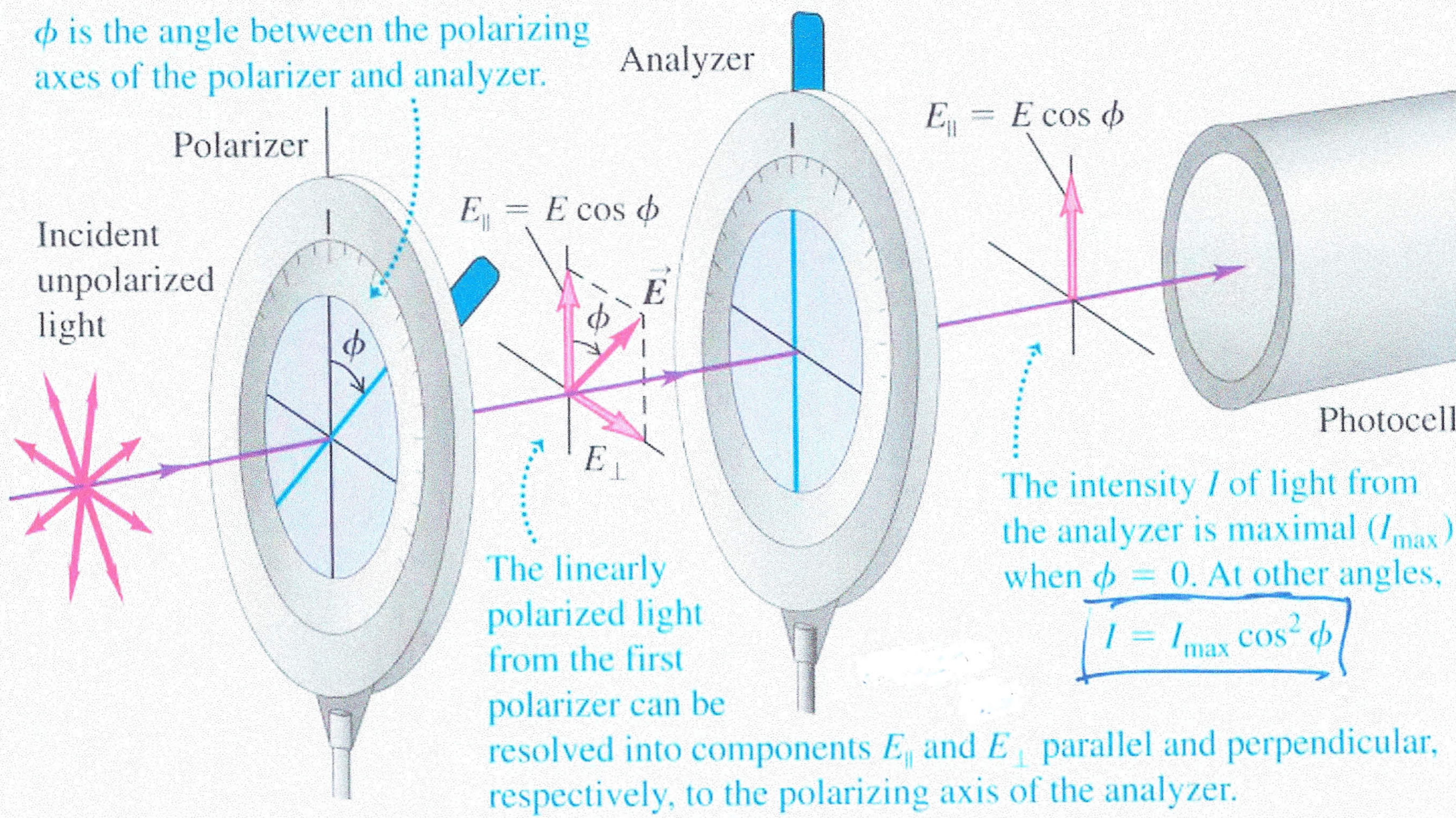
An em-wave can be made to be linearly polarized (plane polarized) by sending it through a special material called polaroid matter first developed by E. H. Land. This material has substances that have dichroism which selectively absorbs light polarized along one plane. This is usually a hydrocarbon impregnated with ~~hydrogen~~ iodine. Thus each polarizer has an axis of transmission i.e. it can transmit light polarized in a certain direction as shown.



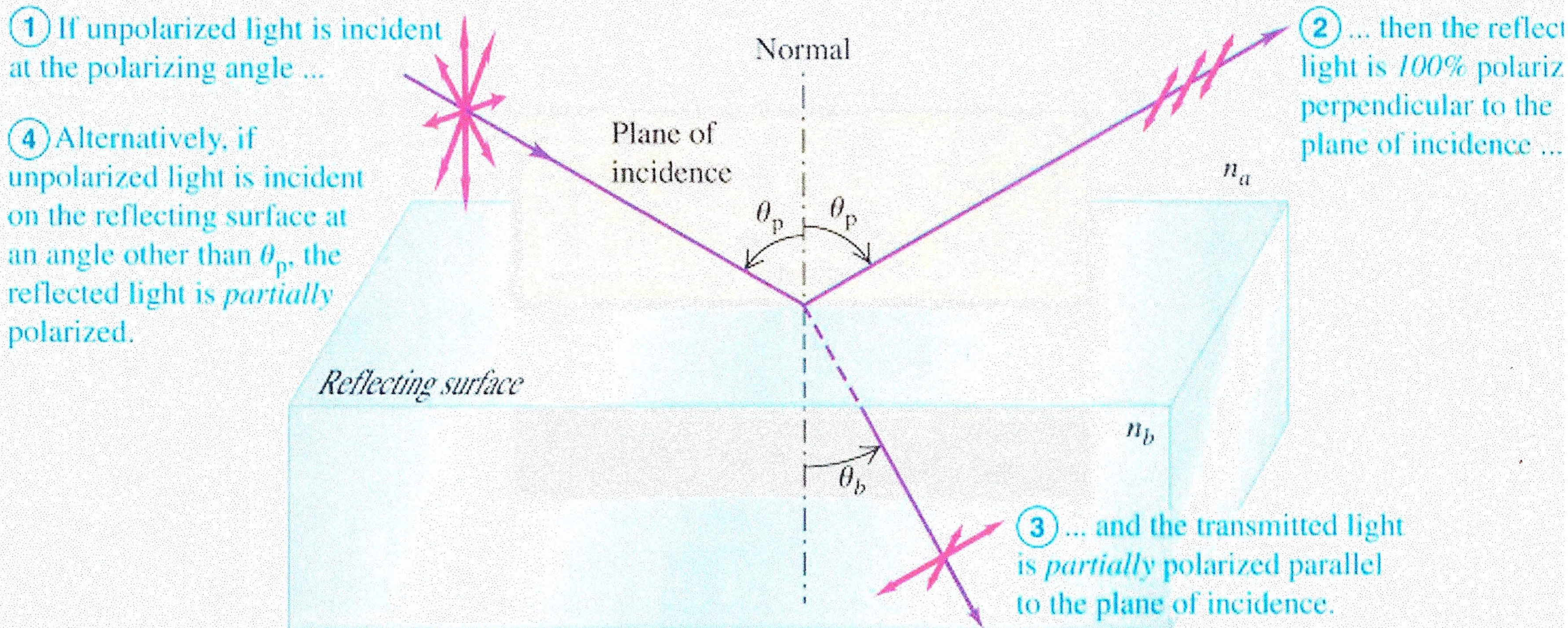
Intensity of light after transmission is

$$I = \frac{1}{2} I_0$$

177. Figure 33.25 A polarizer and an analyzer

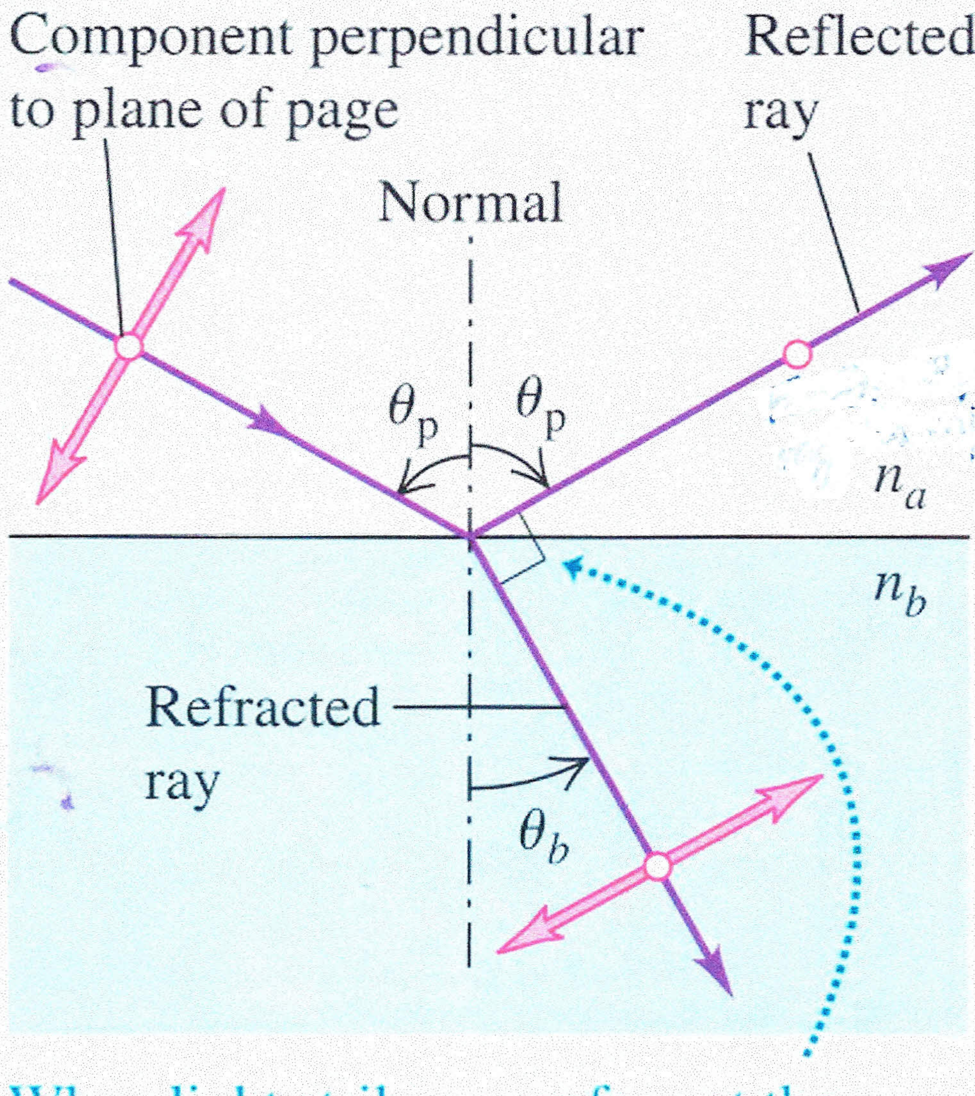


178. Figure 33.27 Polarization of light incident on a reflecting surface



179. Figure 33.28 The significance of the polarizing angle

Note: This is a side view of the situation shown in Fig. 33.27.



When light strikes a surface at the polarizing angle, the reflected and refracted rays are perpendicular to each other and

$$\tan \theta_p = \frac{n_b}{n_a}$$