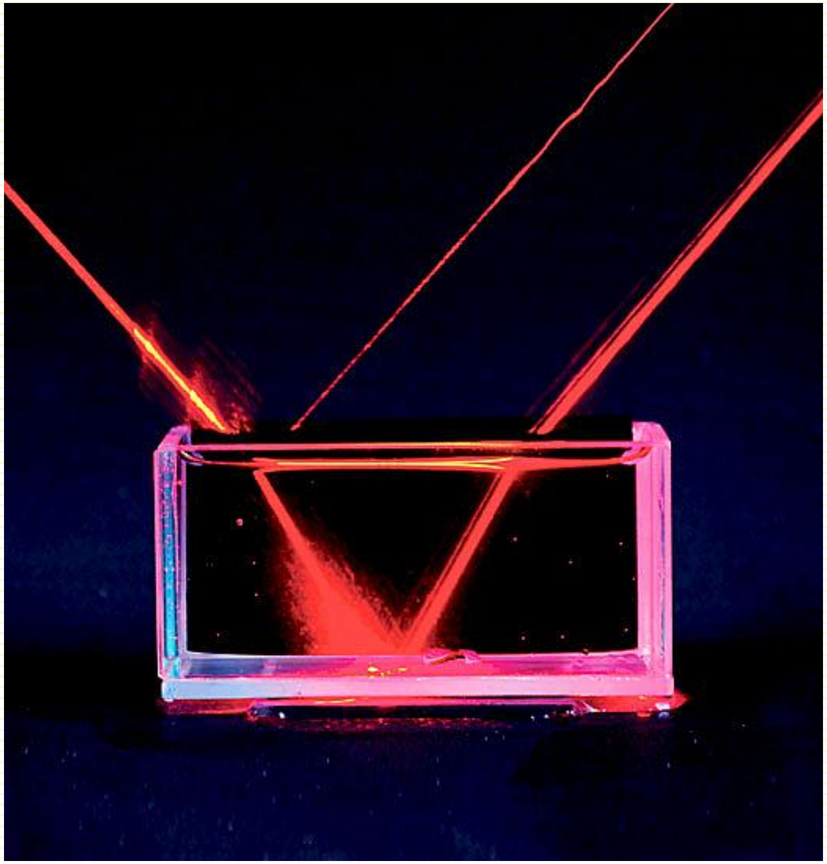


Chapter 43

Reflection and Refraction at plane Surfaces

Units of Chapter 43

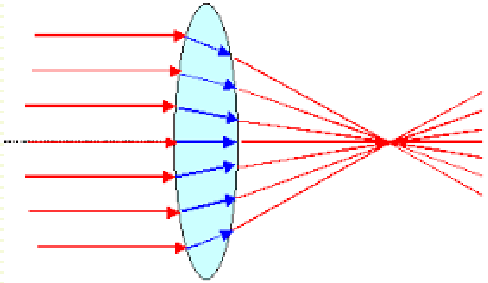
- GEOMETERICLA OPTICS AND WAVE OPTICS
- REFLECTION AND REFRACTION
- IMAGE FORMAITON BY PLANEMIRRORS
- TOTAL INTERNAL REFRLECTION

Learning goals of this chapter

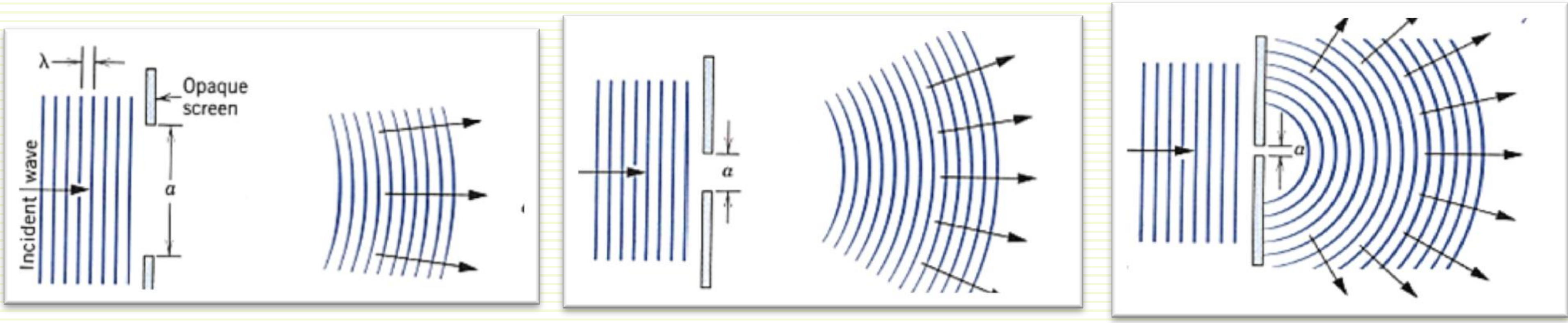
- **On completing this chapter, the student will be able to :**
- Define the following terms:
  - The incident ray.
  - The refracted ray.
  - The reflected ray.
  - The angle of incidence.
  - The refractive index.
  - The law of reflection.
  - The law of refraction (Snell's law).
  - The total internal reflection.

Geometrical Optics and Wave Optics

- A light ray is a line that is perpendicular to the light's wave fronts
- Geometrical optics, describes light propagation in terms of rays to treat reflection and refraction. It does not consider optical effects such as diffraction and interference.

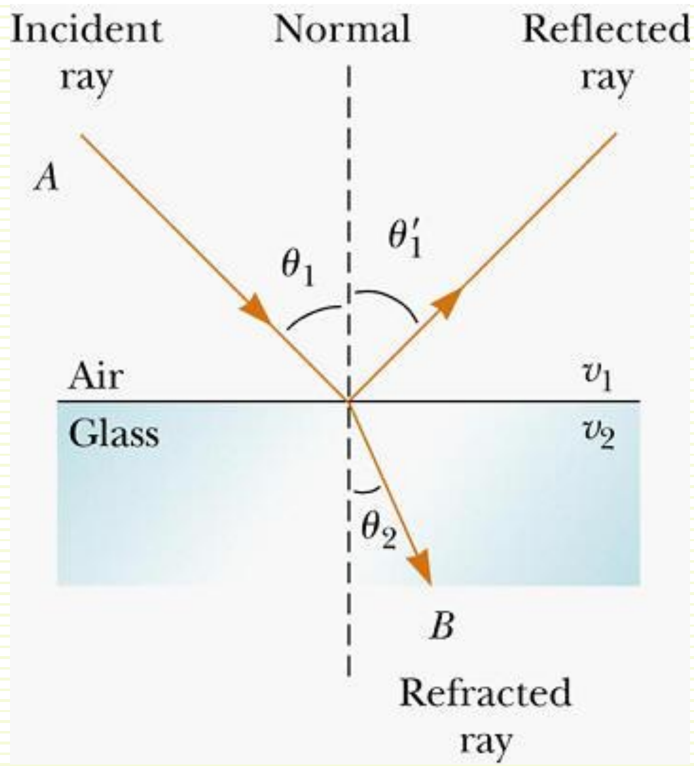


- Wave optics studies interference, diffraction, polarization, and other phenomena for which geometric optics is not valid.
- The figure shows how light is diffracted while passing through narrow slit, and in case of decreasing the width of the slit.



Reflection and Refraction

- If light travel from on medium to another; two phenomenal may happen: Reflection and Refraction



- θ_1 : *angle of incidence*
- θ_1' : *angle of refelction*
- θ_2 : *angle of refraction*

- All angles lie in the same plane

- **Law of Reflection**

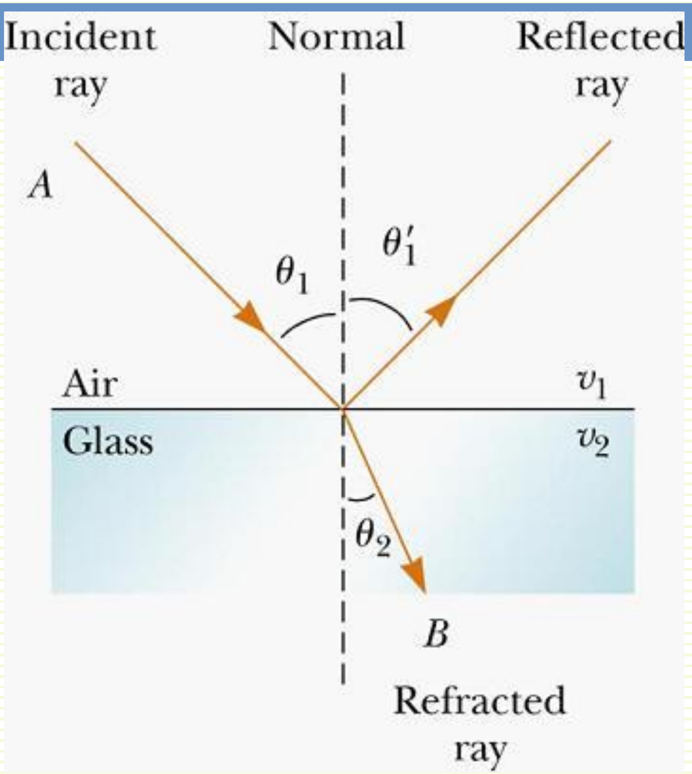
$$\theta_1' = \theta_1$$

Reflection and Refraction

- **Law of Refraction:** Snell's Law

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

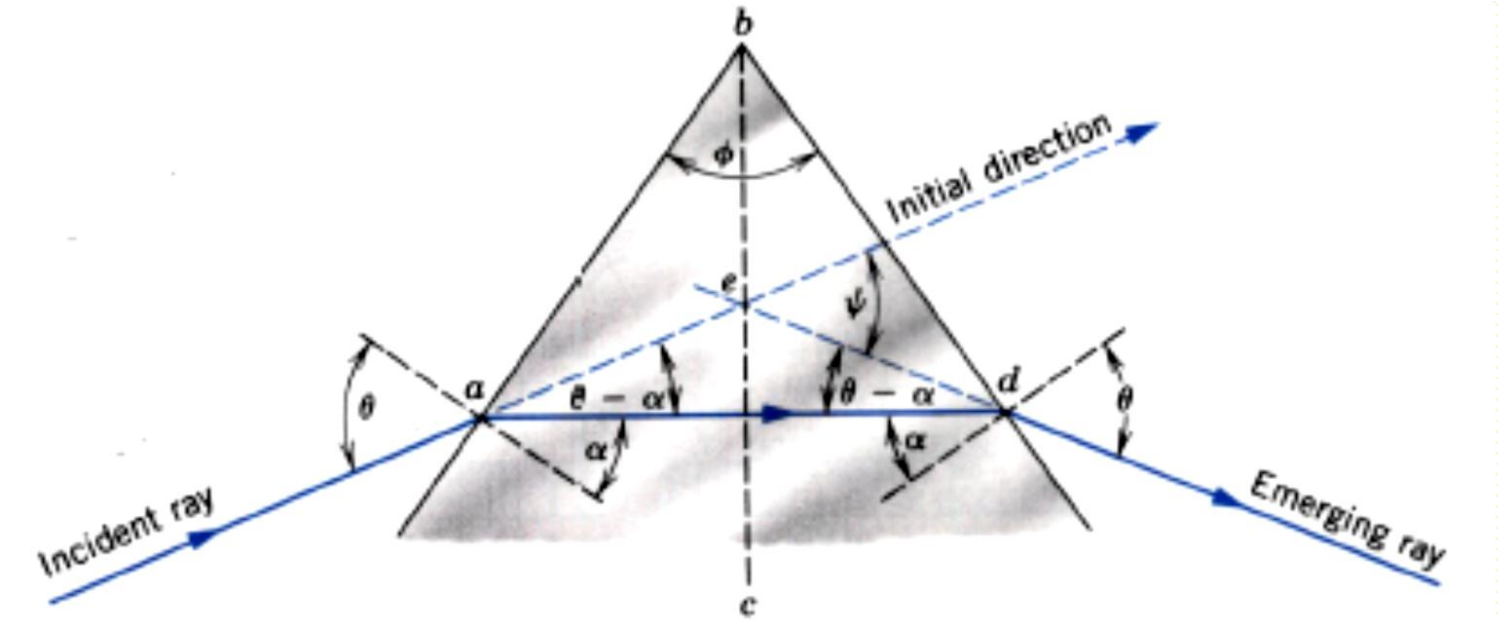
- n_1 *and* n_2 are refractive index of medium 1 and medium 2



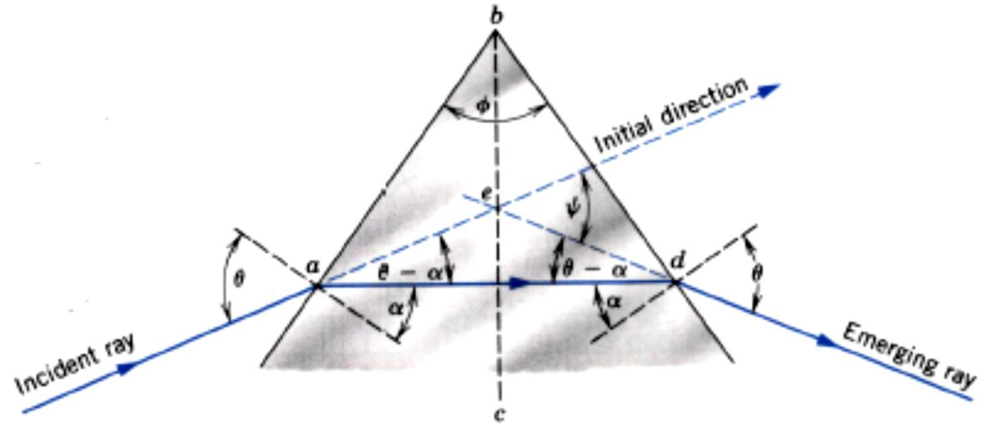
$$n = \frac{c}{v} = \frac{speed\ of\ light\ in\ vacuum}{speed\ of\ light\ in\ medium}$$

Problem 1

- A light beam in air is incident on one face of a glass prism. The angle θ is chosen so that the emerging ray also makes an angle θ with the normal to the other face. Derive an expression for the index of refraction of the prism material, taking n=1 for air.



Solution



Note that $\angle bad + \alpha = \pi/2$ and that $\angle bad + \phi/2 = \pi/2$, where ϕ is the prism angle. Therefore

$$\alpha = \tfrac{1}{2}\phi. \qquad (1)$$

The deviation angle ψ is the sum of the two opposite interior angles in triangle *aed*, or

$$\psi = 2(\theta - \alpha).$$

Substituting $\frac{1}{2}\phi$ for α and solving for θ yield

$$\theta = \tfrac{1}{2}(\psi + \phi). \qquad (2)$$

Solution

At point a, θ is the angle of incidence and α the angle of refraction. The law of refraction (see Eq. 2) is

$$\sin \theta = n \sin \alpha,$$

in which n is the index of refraction of the glass.

$$\sin \frac{\psi + \phi}{2} = n \sin \frac{\phi}{2}$$

$$n = \frac{\sin (\psi + \phi)/2}{\sin (\phi/2)},$$

Image Formation by Plane Mirrors

- If an object ***O*** is placed a distance *o* in front of a plane mirror, rays out of that object fall on the mirror.
- Each ray strikes the mirror and is then reflected back.
- At the points of contact between each ray and the mirror, we construct a normal and draw the reflected ray.
- If we extend the reflected rays backward, they intersect at the point ***I*** which is the image.
- The image is at the same distance behind the mirror that the object ***O*** is in front of it.

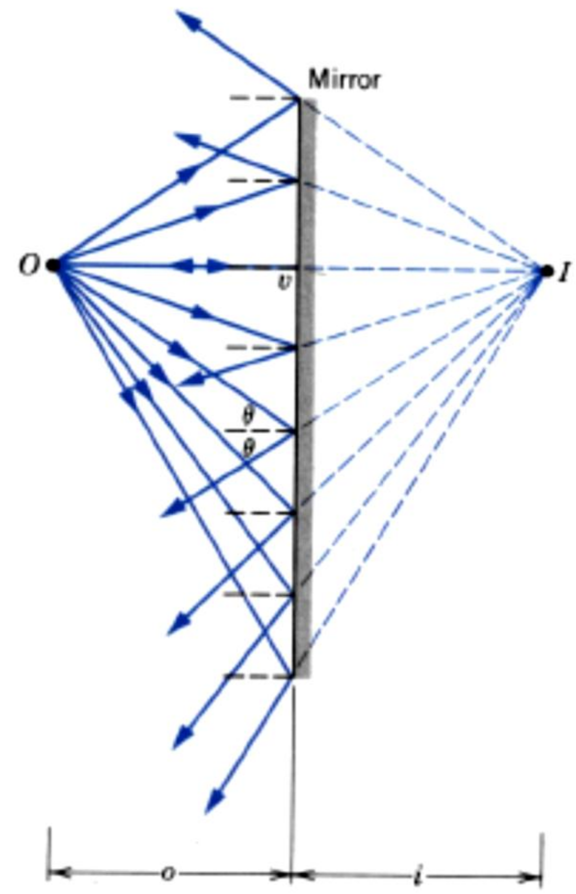
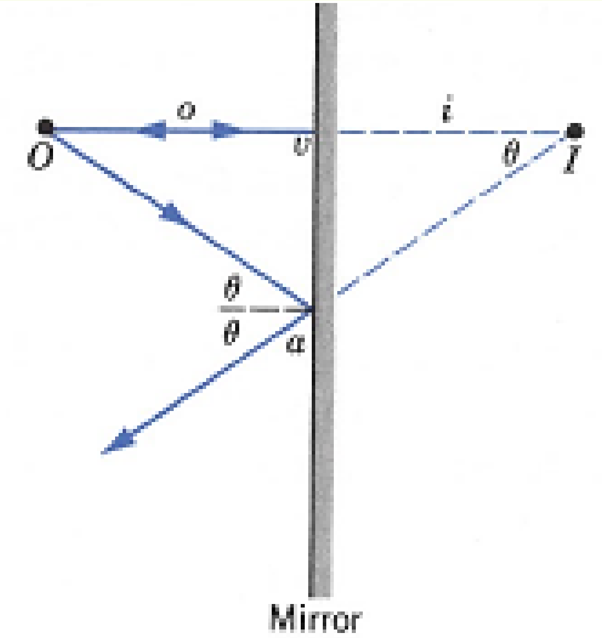


Image Formation by Plane Mirrors

- In the case of plane mirrors, the image is Virtual.
  Virtual images are images that are formed in locations where light does not actually reach.

- Consider only two rays, The first is incident perpendicular and strikes the mirror at v, and the other ray incident with an angle θ and strikes the mirror at *a*. Then:

$$\angle aOv = \angle aIv$$



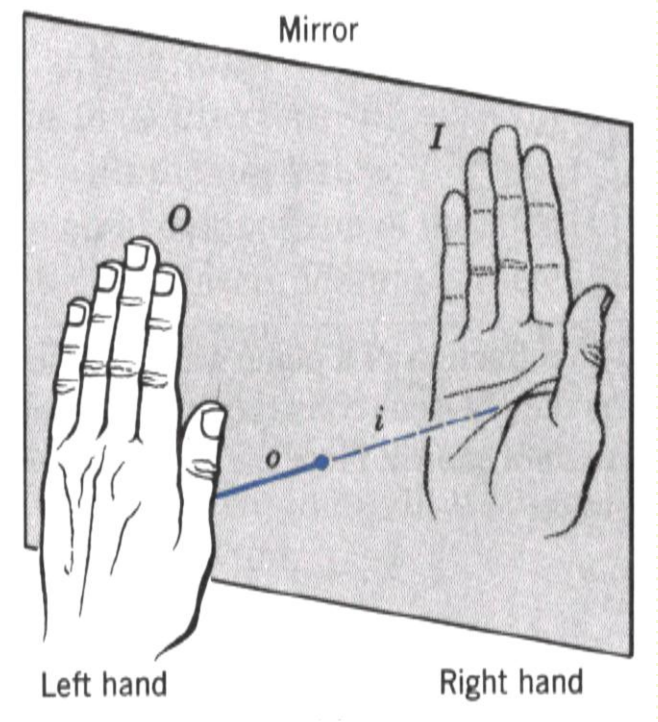
  - From the similarity of the triangles *aOv* and aIv, it follows that

$$o = -I$$

(the –ve sign means the image is in the opposite side on the mirror)

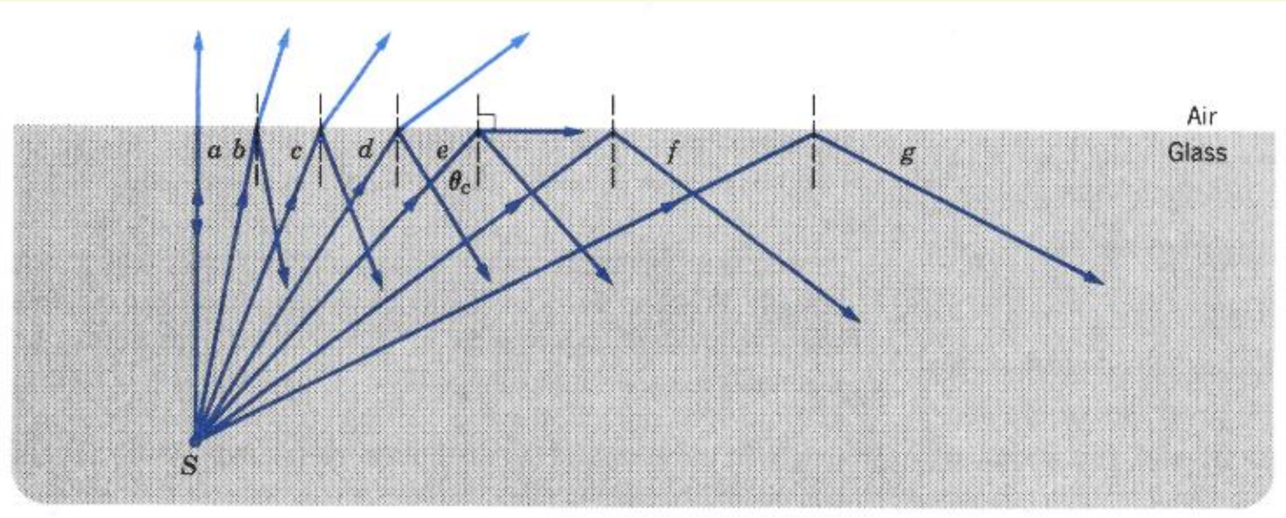
Image Formation by Plane Mirrors

- Images reflected from plane mirrors are reversed i.e. the left hand appears to be a right hand



Total Internal Reflection

- If the light source is set inside the glass as shown; and the angle of incidence θ is increased as shown in rays *a, b, c, d*.
- Rays will be refracted near to the surface, till it becomes parallel to the surface as in ray *e,* at which the angle of refraction is *90°* . This is called the ***"critical angle"***



Total Internal Reflection

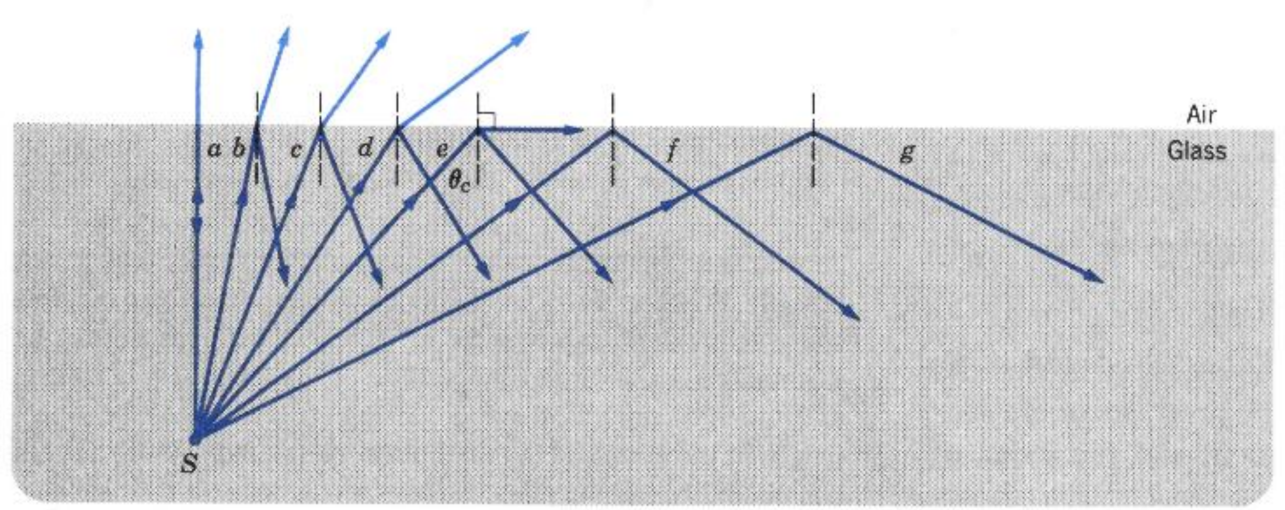
- We find the critical angle by putting $\theta_C = 90^o$ in Snell's law

$$n_1 \sin\theta_C = n_2 \sin 90$$

- Or

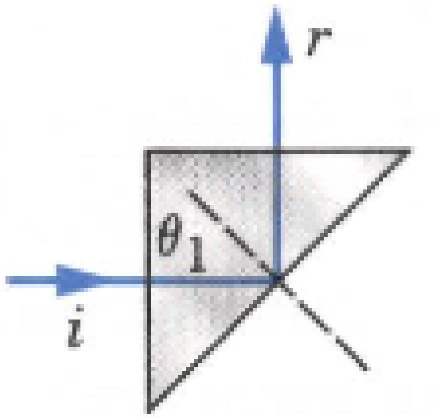
$$\theta_C = \sin^{-1}\frac{n_2}{n_1}$$

- If we increase the angle of incident further, as in ray f, then the ray is reflected back internally in the glass, which is called "**total internal reflection**"



Problem 2

A triangular prism of glass is shown. If a ray incident normal to one face and is totally reflected. If θ_1 is 45°, what can you conclude about the index of refraction *n* of the glass?.



Solution

The angle θ_1 must be equal to or greater than the critical angle θ_c, where θ_c is given by Eq. 16:

$$\theta_c = \sin^{-1}\frac{n_2}{n_1} = \sin^{-1}\frac{1}{n},$$

$$n = \frac{1}{\sin\theta_c},$$

in which the index of refraction of air ($=n_2$) is set equal to unity. Since total internal reflection occurs, θ_c must be less than 45°, and so

$$n > \frac{1}{\sin 45^\circ} = 1.41.$$