

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
- □ θ₁ : angle of incidence
 □ θ'₁ : angle of refelction
 □ θ₂ : angle of refraction

All angles lie in the same plane





Reflection and Refraction



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

$$\alpha = \frac{1}{2}\phi. \tag{1}$$

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

$$\theta = \frac{1}{2}(\psi + \phi). \tag{2}$$

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

Π

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

 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:

$$\theta_{\rm c} = \sin^{-1} \frac{n_2}{n_1} = \sin^{-1} \frac{1}{n} ,$$
$$n = \frac{1}{\sin \theta_{\rm c}} ,$$

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

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

