Optics
Image Formation by Refracting Surfaces

Lana Sheridan

De Anza College

June 15, 2020

Last time

- images formed by spherical mirrors

Overview

- spherical mirror example
- images formed by refraction
- lenses

Example 36.4: Convex Mirror Image

An automobile rearview mirror shows an image of a truck located 10.0 m from the mirror. The focal length of the mirror is −0.60 m.

Find the position of the image of the truck and the magnification of the image.

Example 36.4: Convex Mirror Image

An automobile rearview mirror shows an image of a truck located 10.0 m from the mirror. The focal length of the mirror is -0.60 m.

Find the position of the image of the truck. (where does it appear to be?)

Example 36.4: Convex Mirror Image

An automobile rearview mirror shows an image of a truck located 10.0 m from the mirror. The focal length of the mirror is −0.60 m.

Find the position of the image of the truck. (where does it appear to be?)

$$q = \underline{-0.57 \text{ m}}$$

Find the magnification of the image.

Example 36.4: Convex Mirror Image

An automobile rearview mirror shows an image of a truck located 10.0 m from the mirror. The focal length of the mirror is −0.60 m.

Find the position of the image of the truck. (where does it appear to be?)

$$q = \underline{-0.57 \text{ m}}$$

Find the magnification of the image.

$$M = -\frac{q}{p} = \underline{+0.057}$$

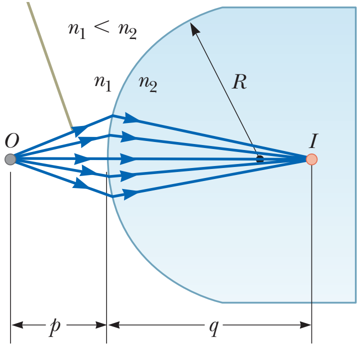
Images Formed by Refraction

When light rays change media they are bent.

This also can form images.

Images Formed by Refraction

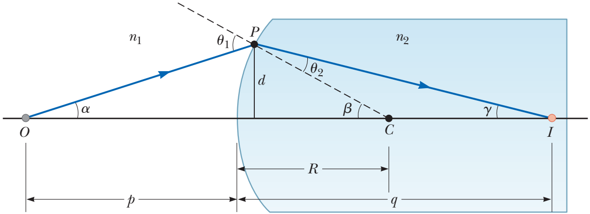
We can find the location and size of the image formed by considering paraxial rays.



For paraxial rays, Snell's law becomes:

$$n_1\theta_1 = n_2\theta_2 \quad (1)$$

Images Formed by Refraction



Looking at the diagram:

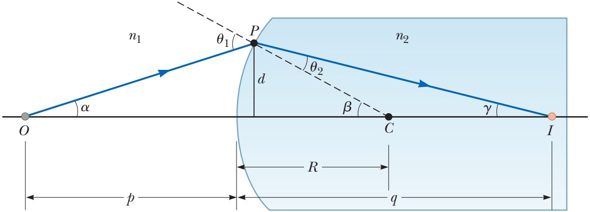
$$180^\circ - \theta_1 = 180^\circ - \alpha - \beta \quad \Rightarrow \quad \theta_1 = \alpha + \beta \qquad (2)$$

likewise:

$$\beta = \gamma + \theta_2 \qquad (3)$$

Multiply (2) by n_1 and (3) by n_2, add them and subtract (1):

Images Formed by Refraction



Looking at the diagram:

$$180^\circ - \theta_1 = 180^\circ - \alpha - \beta \quad \Rightarrow \quad \theta_1 = \alpha + \beta \qquad (2)$$

likewise:

$$\beta = \gamma + \theta_2 \qquad (3)$$

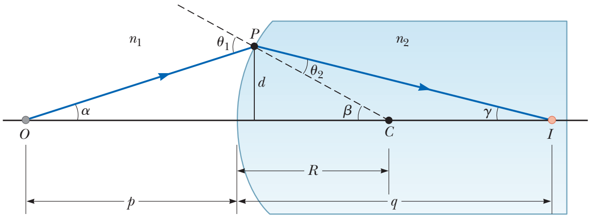
Multiply (2) by n_1 and (3) by n_2, add them and subtract (1):

$$n_2\beta = n_1\alpha + n_1\beta + n_2\gamma$$

Rearranging:

$$n_1\alpha + n_2\gamma = (n_2 - n_1)\beta$$

Images Formed by Refraction



For small angles (paraxial approx):

$$\alpha \approx \tan \alpha = \frac{d}{p}$$

Similarly,

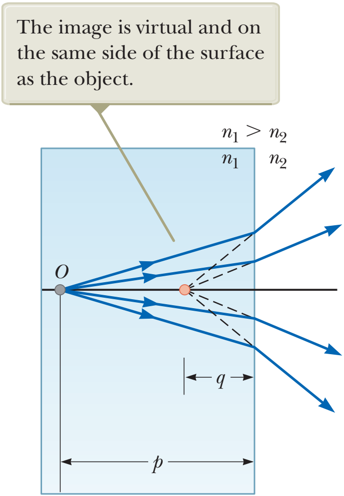
$$\beta \approx \frac{d}{R} \text{ and } \gamma \approx \frac{d}{q}$$

So,

$$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R}$$

Flat Refracting Surfaces

(Like a rectangular fish tank.)



In this case $R \to \infty$.

$$\frac{n_1}{p} + \frac{n_2}{q} = 0$$

And so

$$q = -\frac{n_2}{n_1} p$$

Sign Conventions for Refracting Surfaces!

$$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R}$$

Variable	is Positive	is Negative
p	object in front of surface	[virtual object][1]
q	image behind surface (real)	image in front of surface (virtual)
h' (and M)	image upright	image inverted
R	object faces convex surf. (C behind surface)	object faces concave surf. (C in front of surface)

C is the center of curvature.
$M = \frac{h'}{h} = -\frac{n_1 q}{n_2 p}$

[1]Will be useful in derivations.

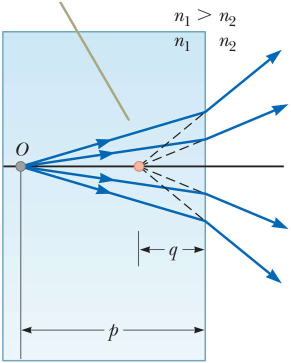
Refracting Surface Question

Quick Quiz 36.5 In the figure, what happens to the image point I as the object point O moves toward the right-hand surface of the material of index of refraction n_1?

(A) It always remains between O and the surface, arriving at the surface just as O does.

(B) It moves toward the surface more slowly than O so that eventually O passes I.

(C) It approaches the surface and then moves to the right of the surface.



[1]Serway & Jewett, page 1102.

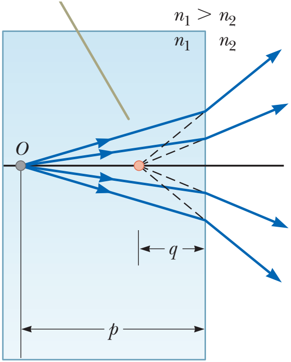
Refracting Surface Question

Quick Quiz 36.5 In the figure, what happens to the image point I as the object point O moves toward the right-hand surface of the material of index of refraction n_1?[1]

(A) It always remains between O and the surface, arriving at the surface just as O does. ←

(B) It moves toward the surface more slowly than O so that eventually O passes I.

(C) It approaches the surface and then moves to the right of the surface.



[1] Serway & Jewett, page 1102.

Refracting Surface Question

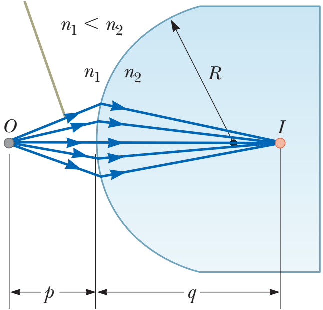
Quick Quiz 36.4 In the figure, what happens to the image point I as the object point O is moved to the right from very far away to very close to the refracting surface?

(A) It is always to the right of the surface.

(B) It is always to the left of the surface.

(C) It starts off to the left, and at some position of O, I moves to the right of the surface.

(D) It starts off to the right, and at some position of O, I moves to the left of the surface.



[1]Serway & Jewett, page 1102.

Refracting Surface Question

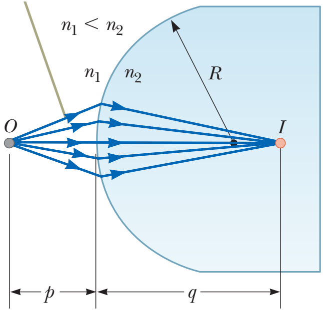
Quick Quiz 36.4 In the figure, what happens to the image point I as the object point O is moved to the right from very far away to very close to the refracting surface?

(A) It is always to the right of the surface.

(B) It is always to the left of the surface.

(C) It starts off to the left, and at some position of O, I moves to the right of the surface.

(D) It starts off to the right, and at some position of O, I moves to the left of the surface. ←



[1] Serway & Jewett, page 1102.

Summary

- images formed by refraction
- lenses

Test 6 Tomorrow, in class.

Final Exam 9:15-11:15am, Tuesday, June 23.

Homework Serway & Jewett:

- Carefully read *all* of Chapter 36.