Optics
Image Formation by Refracting Surfaces

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Last time

- images formed by spherical mirrors
- refracting surfaces

Overview

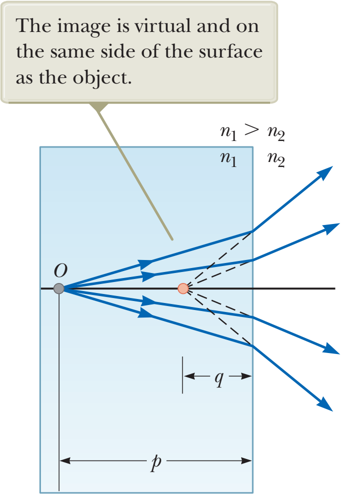
- images formed by refraction
- lenses

Images Formed by Refraction

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

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

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

Flat Refracting Surfaces Example (Problem 30)

A cubical block of ice 50.0 cm on a side is placed over a speck of dust on a level floor. Find the location of the image of the speck as viewed from above. The index of refraction of ice is 1.309.

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

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$$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R} \text{ , } R \to \infty$$

$$\begin{aligned}
\Rightarrow q &= -\frac{n_2}{n_1} p \\
&= -\frac{1}{1.309} (50.0 \text{ cm}) \\
&= -38.2 \text{ cm}
\end{aligned}$$

The image will appear <u>38.2 cm</u> below the surface of the ice.

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

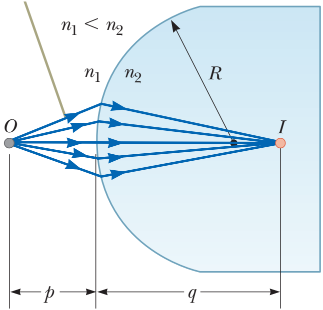
Quick Quiz 36.4 In the figure, what happens to the image point I as the object point O is moved to the right from very far away to very close to the refracting surface?

(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.

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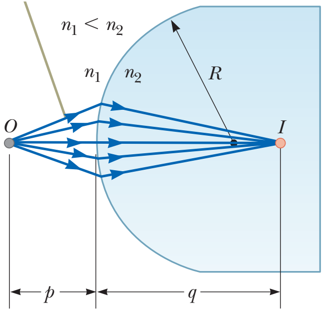

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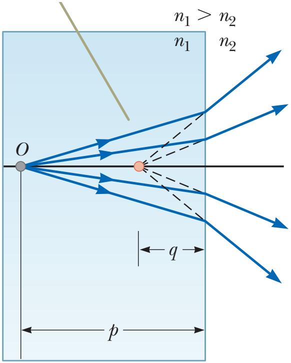
Refracting Surface Question

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.

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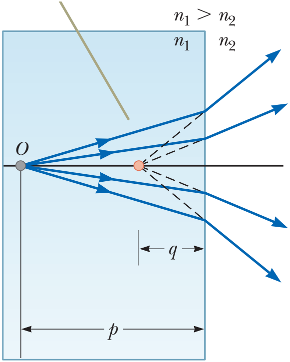

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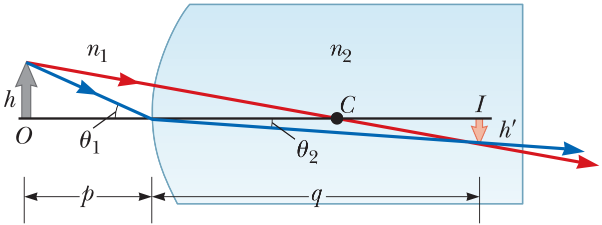
Refracting Surface Example (Problem 34)

A curved refracting surface separates a material with index of refraction n_1 from a material with index n_2. Prove that the magnification is given by $M = -\frac{n_1 q}{n_2 p}$.



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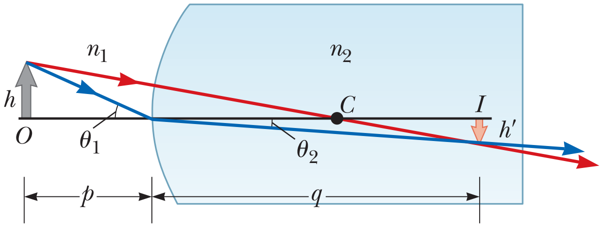

Hint: For paraxial rays, we assume θ_1 and θ_2 are small, so we may write Snell's Law as $n_1 \tan\theta_1 = n_2 \tan\theta_2$.

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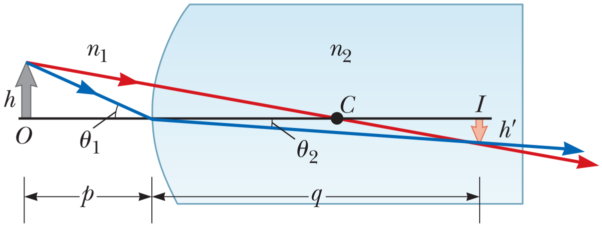

Hint: For paraxial rays, we assume θ_1 and θ_2 are small, so we may write Snell's Law as $n_1 \tan\theta_1 = n_2 \tan\theta_2$.

For small angles:

$$
\begin{aligned}
n_1 \tan\theta_1 &= n_2 \tan\theta_2 \\
n_1 \frac{h}{p} &= n_2 \frac{(-h')}{q} \quad \Rightarrow \quad M = \frac{h'}{h} = -\frac{n_1 q}{n_2 p}
\end{aligned}
$$

Images Formed by Thin Lenses

We will derive the **thin lens equation**

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

(Notice it is the same as the mirror equation!)

And the **lens maker's equation**

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

We do this by considering each side of the lens as a refracting surface.

Summary

- images formed by refraction
- lenses

Collected Homework! due Monday, June 18.

Final Exam 9:15-11:15am, Tuesday, June 26.

Homework Serway & Jewett:

- Carefully read *all* of Chapter 36.
- Ch 36, onward from page 1123. OQs: 1, 3, 5, 11; CQs: 5, 9, 11; Probs: 39, 43, 53, 71