Optics
Image formation from Mirrors

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Last time

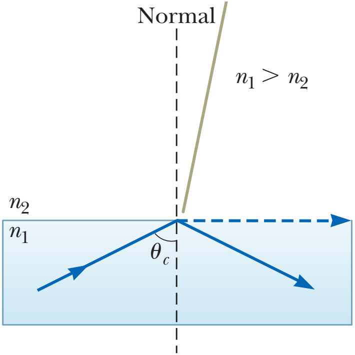
- refraction
- dispersion
- total internal reflection

Overview

- ray diagrams and terminology
- image formation from mirrors

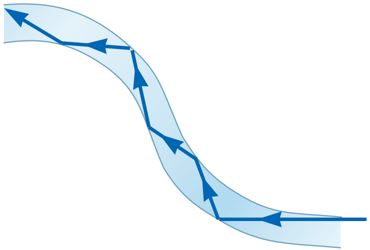
Total Internal Reflection

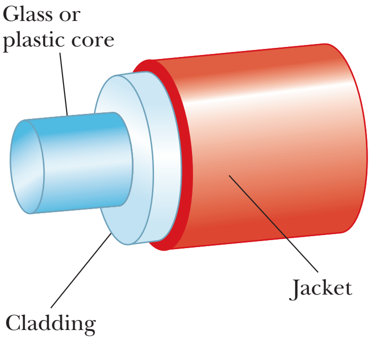
The **critical angle**, θ_c, is the maximum angle of incidence such that there could be a refracted ray. The ray would just skim along the surface between the media.



In this case, the angle of refraction $\theta_2 = 90°$.

Application of TIR: Optical Fibers





Optical fibers are mainly used for telecommunications: much more information can be carried by an optical fiber than an electrical one in a given amount of time.

Optical fibers are also used in medicine.

Ray Optics and Image Formation

Simple geometric ray optics can be used to understand how images are formed by simple optical devices: mirrors and lenses.

[1] Wikipedia user Heptagon.

Images Formed by Flat Mirrors

When we see an object "in the mirror", we are not actually seeing something that is behind the mirror.

We are seeing an **image** of an **object** that is placed in front of the mirror.

The image seems to be the same distance behind the mirror as the object is in front of it.

The image seems to be the same size as the object.

This is not true for all optical devices, but we can work out things about how the image will form for many different optical devices.

Image Formation Terminology

object distance, p

The perpendicular (shortest) distance from the object to the device.

image distance, q

The perpendicular (shortest) distance from where the image appears to be to the device.

(lateral) magnification, M

The factor by which the image size exceeds the object's size

$$M = \frac{\text{image height}}{\text{object height}}$$

For mirrors and lenses

$$M = -\frac{q}{p}$$

Image Formation Terminology

real image

An image that can be displayed on a screen formed when the light rays pass through and diverge from the image point.

virtual image

An image that cannot be displayed on a screen, but can be seen "in the device" because the light rays appear to diverge from the image point.

The image in a flat mirror is virtual.

Image Formation Terminology

upright image

An image that appears to be right-side-up with respect to the object.

inverted image

An image that appears to be upside-down with respect to the object.

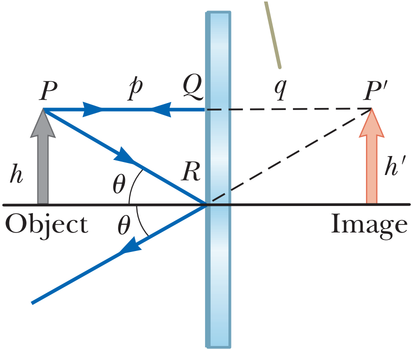
The image in a flat mirror is upright.

focal length, f

The distance from the optical device to where a set parallel rays striking the device head on (perpendicularly) will be focused.

For a flat mirror, the f is infinite.

Ray Diagram for a Flat Mirror



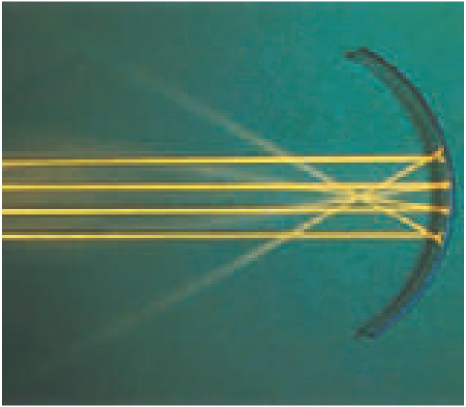
Ray diagrams have the optical device sketched vertically in cross section, the object on the left represented by an arrow pointing up.

The image is also represented by an arrow, but it may be to the left or right, pointing up or down depending on how the image is formed.

We sketch rays with paths we know to find the image.

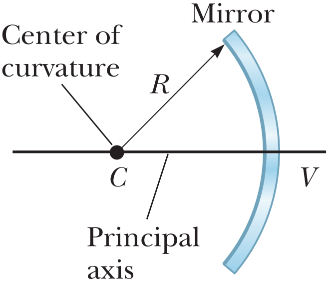
Images formed by Spherical Mirrors: Concave Mirrors

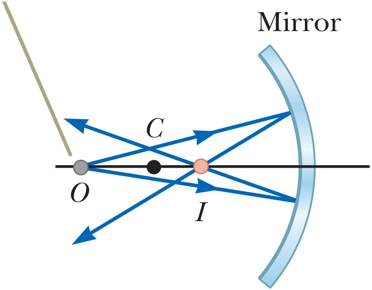
Henry Leap and Jim Lehman



Concave mirrors can focus light.

Images formed by Spherical Mirrors: Concave Mirrors





Assumption: paraxial rays

In studying curved mirrors and thin lenses we assume that all rays are **paraxial rays**.

Paraxial rays are rays close to the principle optical axis of our optical device. (Rays that strike close to the middle.)

For a spherical lens, rays that strike further from the axis are not focused to the same point (spherical aberration).

Mirror Equation and Thin Lens Equation

The same equation can help us to find the location and magnification of the image that will be formed by curved mirrors and thin lenses.

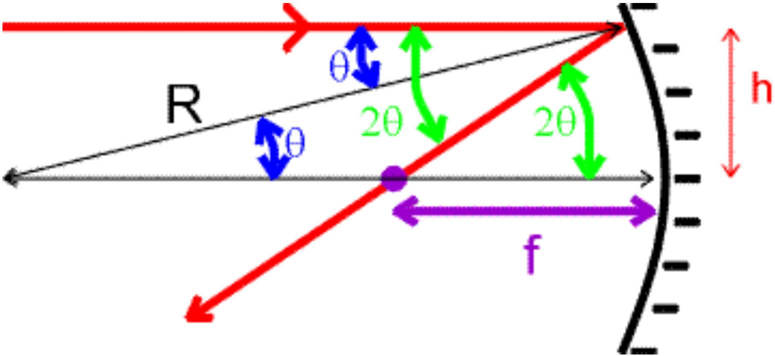
$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Spherical Concave Mirrors

The focal point is where the detectors are place on satellite dishes and radio telescopes.

[1]Parkes telescope in Australia.

Spherical Concave Mirrors Focal Length

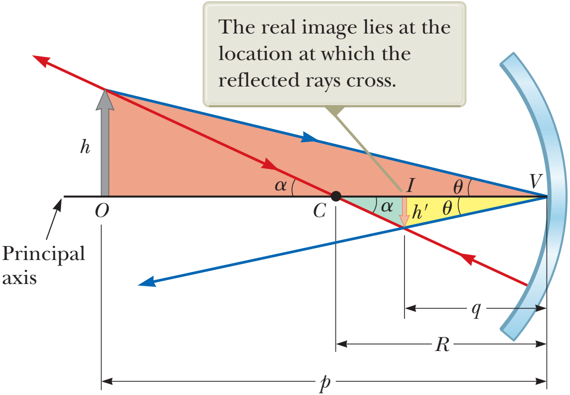


For a spherical concave mirror of radius R

$$f = \frac{R}{2}$$

Concave Mirrors and the Mirror Equation

Simple geometry shows why the mirror equation is true for a concave mirror.



We will use this ray diagram.

Ray Diagrams for Spherical Mirrors

For a ray diagram: draw at least two rays that you know the path of accurately.

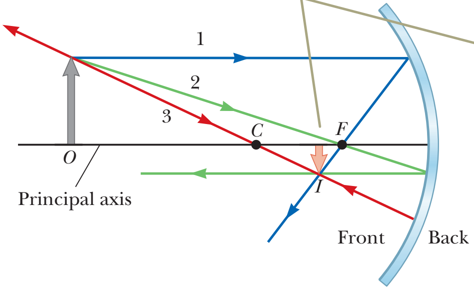
For Spherical mirrors:

1. Draw a ray from the top of the object parallel to the principle axis reflected through the focal point F.
2. Draw a ray from the top of the object through the focal point and reflected parallel to the principal axis.
3. Draw a ray from the top of the object through the center of curvature C and reflected back on itself.

Where the lines meet, an image is formed.

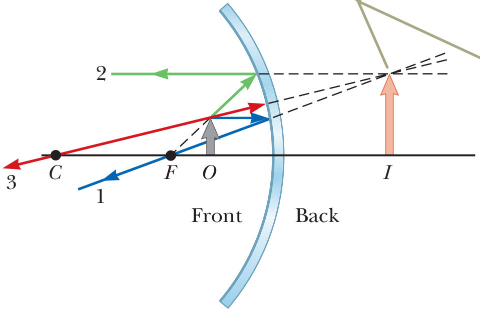
Examples of Ray Diagrams

When the object is located so that the center of curvature lies between the object and a concave mirror surface, the image is real, inverted, and reduced in size.

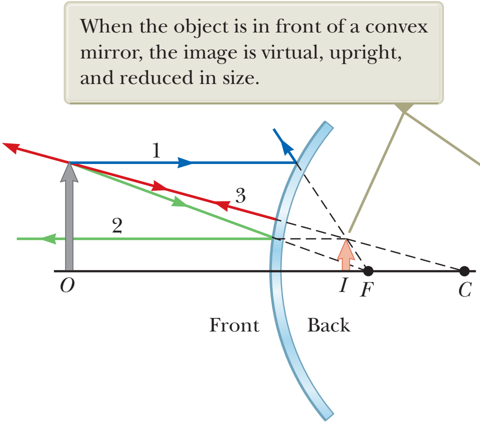


Examples of Ray Diagrams

When the object is located between the focal point and a concave mirror surface, the image is virtual, upright, and enlarged.



Examples of Ray Diagrams (Convex Mirror)



Summary

- image terminology
- images formed by spherical mirrors

4th Collected Homework due Monday June 18.

Quiz Monday.

Homework Serway & Jewett:

- Carefully read *all* of Chapter 36. (over the next few days)
- Ch 36, onward from page 1123. OQs: 13; Probs: 1, 7, 9, 19, 21, (93)