Light and Concave Mirrors

by

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P4.8 Wave Behavior — Reflection and Refraction

The laws of reflection and refraction describe the relationships between incident and reflected/refracted waves.

P4.8A Draw ray diagrams to indicate how light reflects off objects or refracts into transparent media.

P4.8B Predict the path of reflected light from flat, curved, or rough surfaces (e.g., flat and curved mirrors, painted walls, paper).

P4.9B Explain how various materials reflect, absorb, or transmit light in different ways.

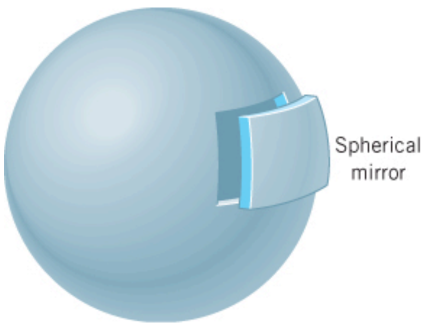
Items;

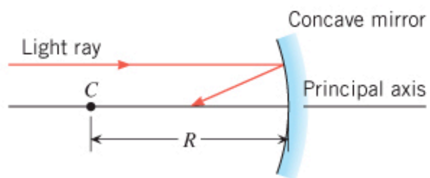
1- Concave Mirror

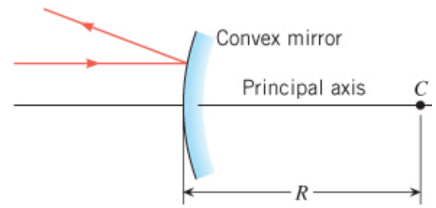
2- Ray Tracing and Images in Concave Mirrors

CURVED REFLECTORS, SPHERICAL MIRRORS

A curved mirror may be thought of as a section of a hollow sphere.



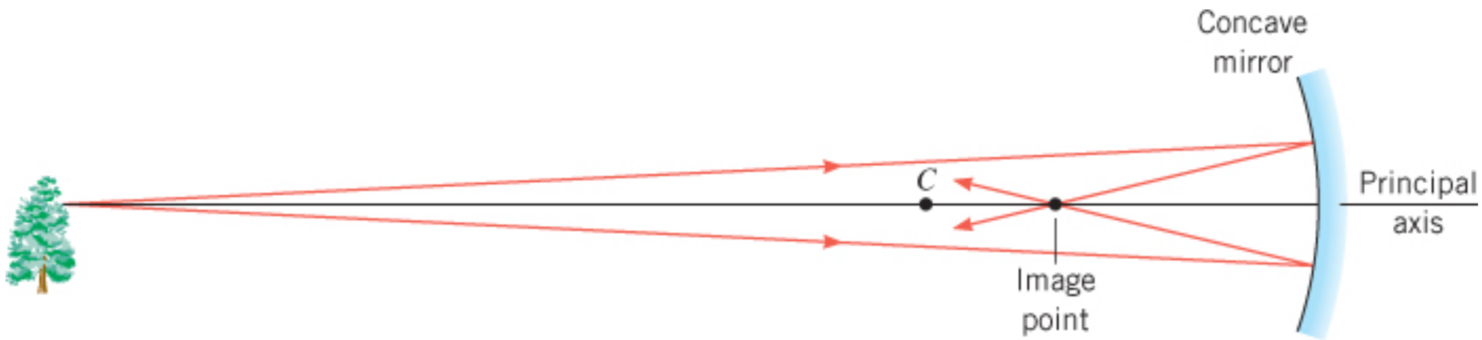




If the inside of the sphere is polished to reflect light, the resulting mirror has a concave shape and makes parallel light rays converge on each other. Hence the term concave (converging) mirror.

Convex (diverging) mirror: If the outside surface of a similar section is polished, the resulting mirror has a convex shape and makes parallel light rays diverge.

R is the radius of curvature of the mirror. C is the center of curvature. The principal axis of the mirror is a straight line drawn through the center of curvature C and the midpoint of the mirror.



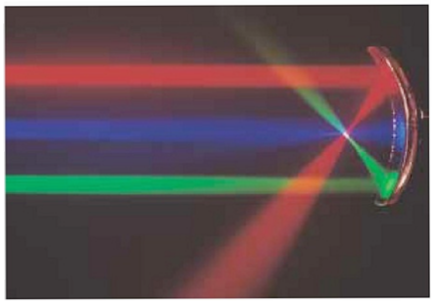
The picture shows a far away tree and a concave mirror. C is the center of curvature.

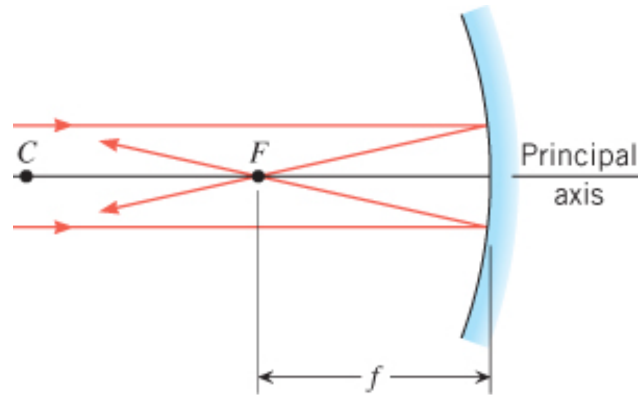
Consider a point located on the tree and also lies on the principal axis of the concave mirror. Consider two rays coming from it toward the mirror (red arrows).

When the rays hit the mirror, they are almost parallel to each other and to the principal axis. All rays are reflected from the mirror and cross the axis at the image point.

The image point is referred to as the focal point F of the mirror.

RULES FOR CONCAVE MIRROR





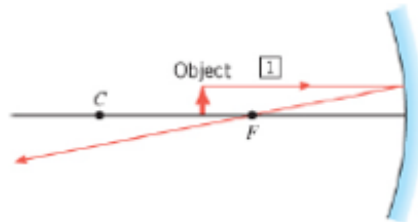
Light rays near and parallel to the principal axis are reflected from the concave mirror and converge at the focal point **F**. The focal point F of a concave mirror is halfway between the center of curvature of the mirror C and the mirror at B.

$$f = \frac{1}{2}R$$

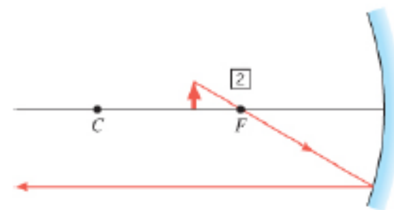
The focal length $\boldsymbol{f}$ is the distance between the focal point and the mirror. $\boldsymbol{R}$ is the radius of curvature of the mirror.

An object emitting rays and placed in front of a concave mirror. From its top point:

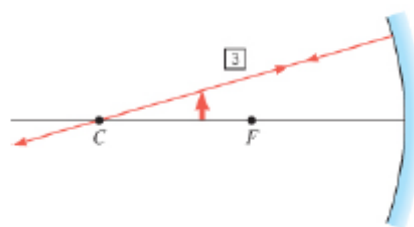
1- A ray emitted parallel to the principal axis is reflected through the principal focus (F).



2- An emitted ray that passes through the principal focus (F) is reflected parallel to the principal axis.

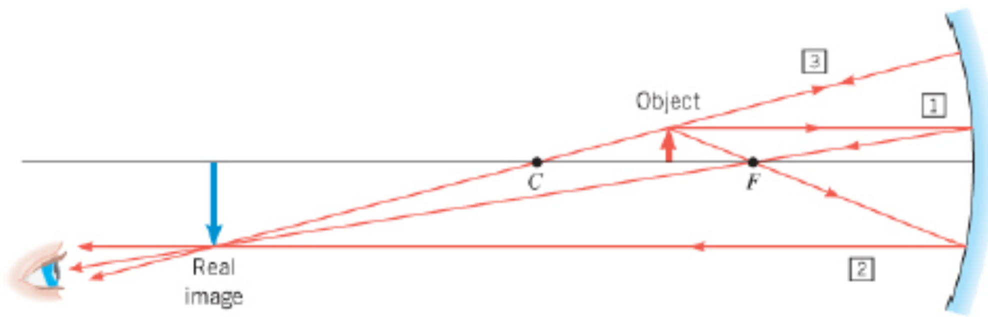


3- An emitted ray that passes through the center of curvature (C) is reflected back along the same path.



RAY TRACING AND IMAGES IN A CONCAVE MIRROR

To locate the image of an in front of a concave mirror, we may use any two of the rays described in the rules listed above.



(a)

1. From the top of an object placed between C and F (up arrow, red) we can draw:

Ray 1: is drawn parallel to the principal axis is reflected through F.

Ray 2: passes through F and is reflected parallel to the principal axis.

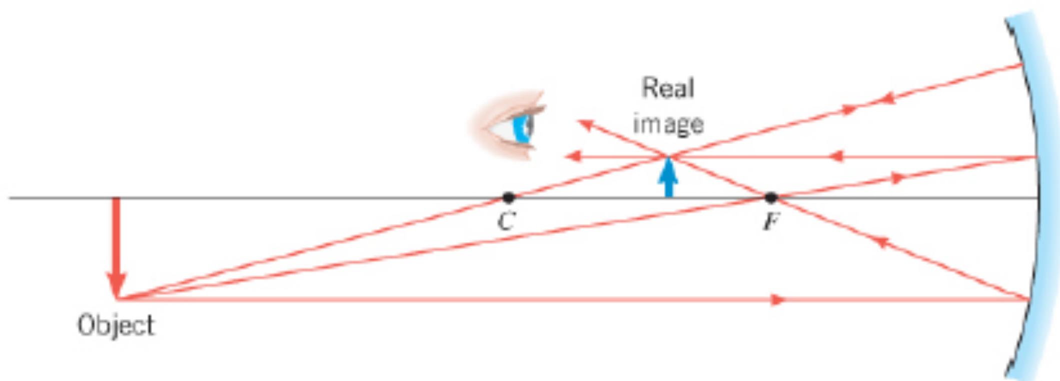
Ray 3: passes through C and is reflected back along the same path.

Actually only two of these rays are required, but the third can act as a check.

All three rays intersect in front of the mirror. The point at which all three rays intersect is the real image location (down arrow, blue). The image is real, inverted

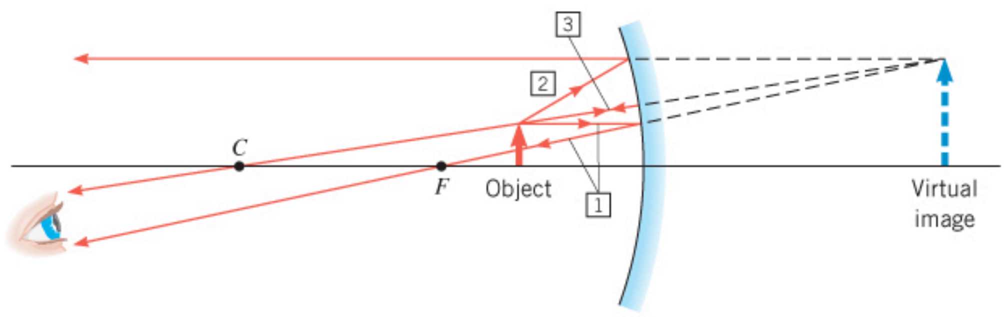
and magnified compared to the object. The image is real because light is actually passing through the image (it can be projected onto a screen).
To be able to see the object, the eye has to be in an appropriate location to catch the rays that form the image.

2. If the object is placed at a distance greater than C from the mirror, we use two or three rays as described in the previous page.



The formed image is real, inverted and reduced in size. The image is real because light is actually passing through the image (it can be projected onto a screen).

3. When an object is placed between the focal point F and a concave mirror, The image is virtual, upright, and magnified (as in the case of images from flat mirrors).



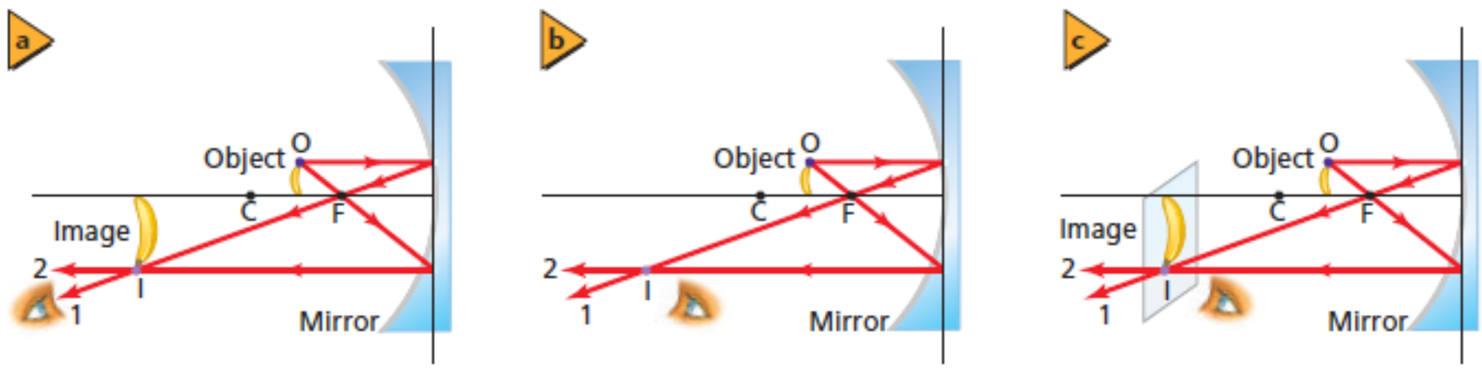
(a)

(b)

The reflected rays that enter the eye do not intersect in front of the mirror, but appear to originate at a point behind the mirror. The image can be located behind the mirror by extending the reflected ray backward as dotted lines. The extended rays intersect at the image. Therefore, the image formed is virtual. This virtual image can not be projected onto a screen.

Example 1: Image of a Banana in a Concave Mirror;

A concave mirror is reflecting the image of a banana placed between C and F as shown.



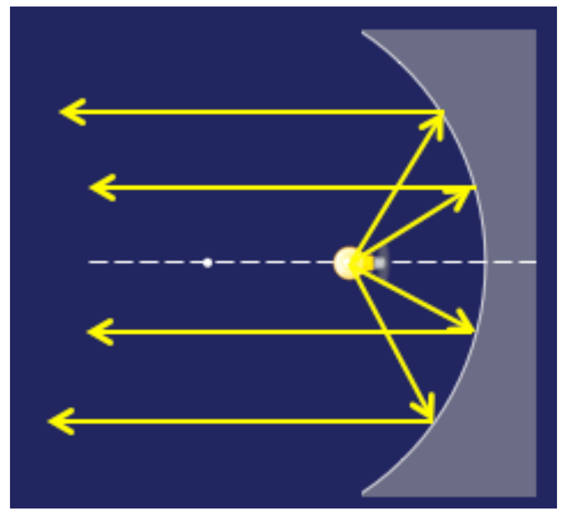
a) For the eye, it appears that there is an object on I blocking the view of the mirror.

b) The eye can see the object disappear because there is not light reflected to the eye.

c) A board is placed the eye is able to see the image.

Example 2: *Projectors: Concave Mirror application.*

Below are the pictures of a projector which is a concave mirror and the representation of the light reflection. The light bulb is place at the focal point (F).



Example 3: *Satellites: Concave mirror application:*

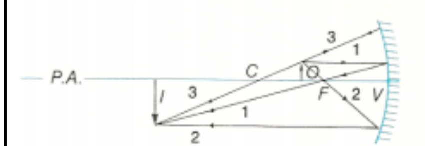
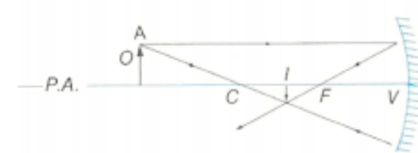
A receiver in a satellite dish is usually placed at the focal point (F). Rays from a very distant source come in parallel.

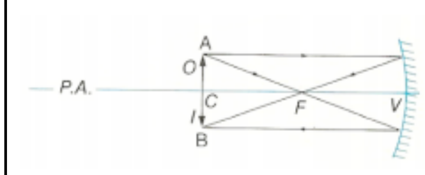
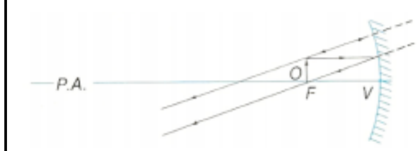
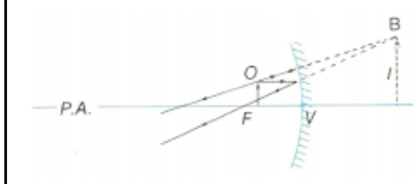
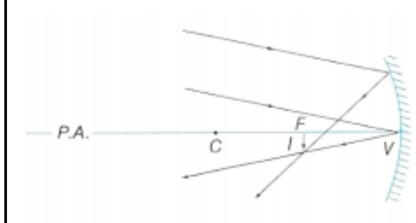
Example 4: *Solar Furnace: Concave mirror application:*

The largest solar furnace is located in the Pyrenees, in southern France. It produces an extremely high temperature.

Example 5: *Summary Table;*

Direction of emitted light from an object placed in front of a concave mirror	Direction of Reflection
Parallel to the principal axis	Reflected through the principal focus
Passes through the principal focus (F)	Reflected parallel to the principal axis
Passes through the center of curvature (C)	Reflected back along the same path

Location of Object (O)	Image (I) Type (real or virtual)	Image (I) Location compared to the mirror	Image (I) Direction (upward or inverted)	Image Size Compared to that of the Object	Ray Tracing
Object is between F and C	Real	beyond C	Inverted	Larger than the object	
Object is beyond C	Real	between C and F	Inverted	Smaller than the object	

Location of Object (O)	Image (I) Type (real or virtual)	Image (I) Location compared to the mirror	Image (I) Direction (upward or inverted)	Image Size Compared to that of the Object	Ray Tracing
Object is at C	Real	at C	Inverted	The same size as the object	
Object is at F	No image is formed				
Object is between F and the mirror	Virtual	beyond the mirror	Upward	Larger than the object	
Object is at a far distance from the mirror.	Real	at F	Inverted	Smaller than the object	

P.A.: Principal Axis

V: the geometric center of the mirror or vertex

O: object

I: Image

References:

1) Humanic. (2013). www.physics.ohio-state.edu/~humanic/. In Thomas Humanic Brochure Page.

Physics 1200 Lecture Slides: Dr. Thomas Humanic, Professor of Physics, Ohio State University, *2013-2014 and Current.* *www.physics.ohio-state.edu/~humanic/*

2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

3) Martindale, D. G. & Heath, R. W. & Konrad, W. W. & Macnaughton, R. R. & Carle, M. A. (1992). *Heath Physics.* Lexington: D.C. Heath and Company

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6) Nada H. Saab (Saab-Ismail), (2009- 2014) Wayne RESA, Bilingual Department, Detroit, Michigan, U.S.A.