Lecture 26

Physics II

Chapter 23

Ray Optics

Spherical Mirrors

Course website:

http://faculty.uml.edu/Andriy_Danylov/Teaching/PhysicsII

Lecture Capture:

http://echo360.uml.edu/danylov201415/physics2spring.html

Flat Mirrors

Images in flat mirrors are the same size as the object and are located behind the mirror.

Concave Mirrors

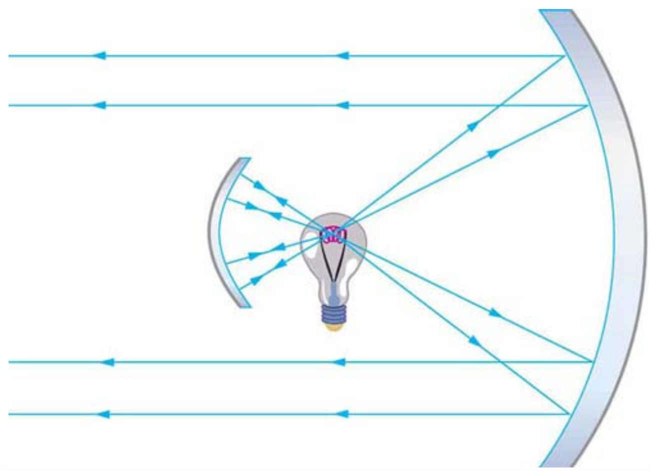
Like lenses, mirrors can form a variety of images. For example, dental mirrors may produce a magnified image, just as makeup mirrors

Convex Mirrors

Security mirrors in shops, on the other hand, form images that are smaller than the object.

We will use the law of reflection to understand how mirrors form images, and we will find that mirror images are analogous to those formed by lenses.

Concave Mirrors



Concave Spherical Mirrors

- The figure shows a **concave mirror**, a mirror in which the edges curve *toward* the light source.

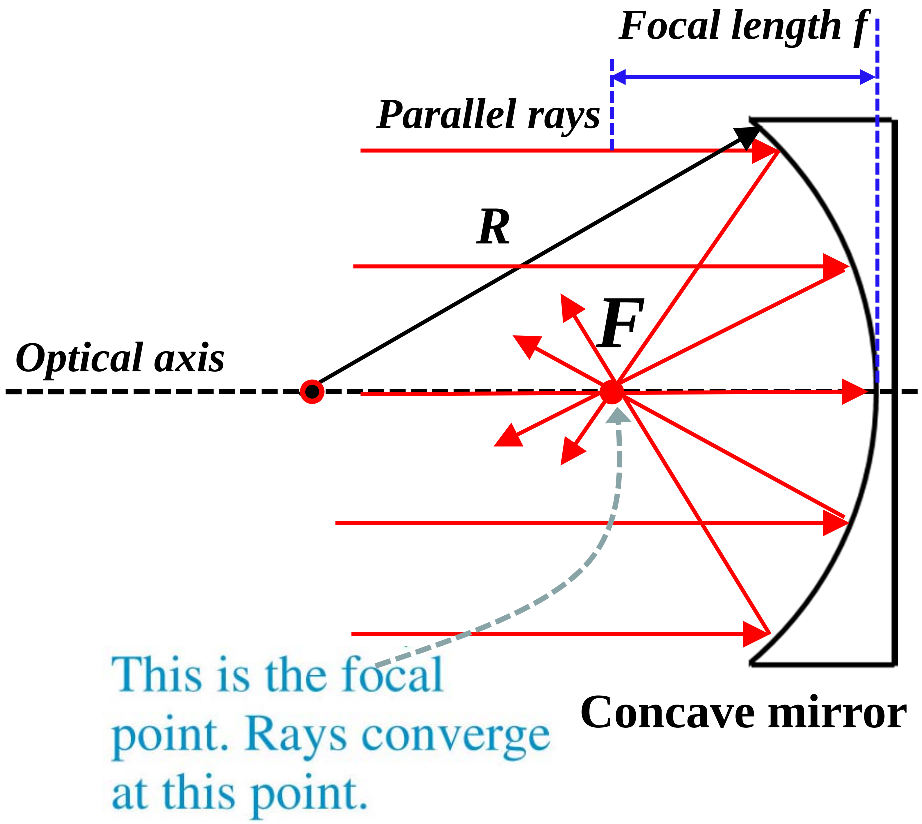
The focal length f is related to the mirror's radius of curvature by:

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

It is very simple.

Compare with a complicated lens maker's eq-n

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



- Rays parallel to the optical axis reflect and pass through the focal point of the mirror.

Images with Concave Spherical Mirrors

There are three rays to find the image:

1. *A ray parallel to the axis reflects through the focal point.*
2. *A ray through the focal point reflects parallel to the axis.*
3. *A ray striking the center of the mirror reflects at an equal angle on the opposite side of the axis.*

Consider $s > f$

For a spherical mirror with negligible thickness, the object and image distances are related by:

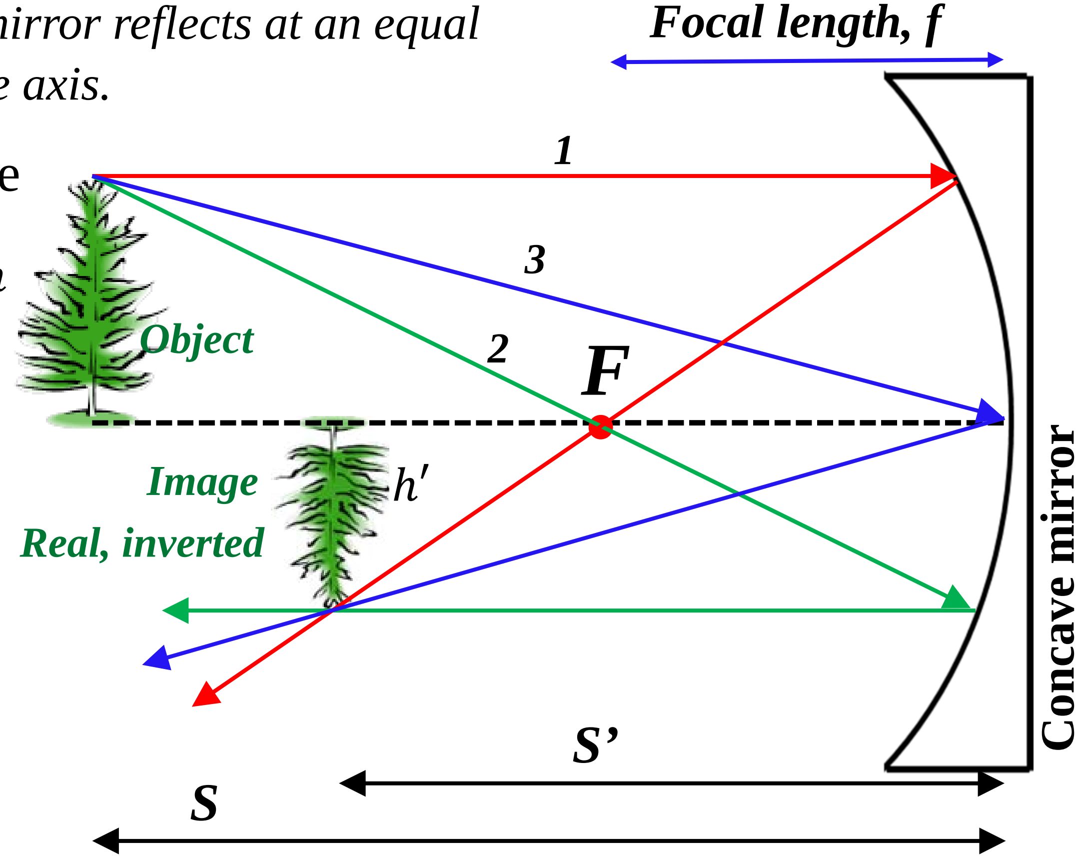
Mirror equation $$\frac{1}{f} = \frac{1}{S} + \frac{1}{S'}$$

Magnification $$m = -\frac{S'}{S} = -\frac{h'}{h}$$

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

Sign convention for a concave mirror:

$$f > 0;\ S > 0$$

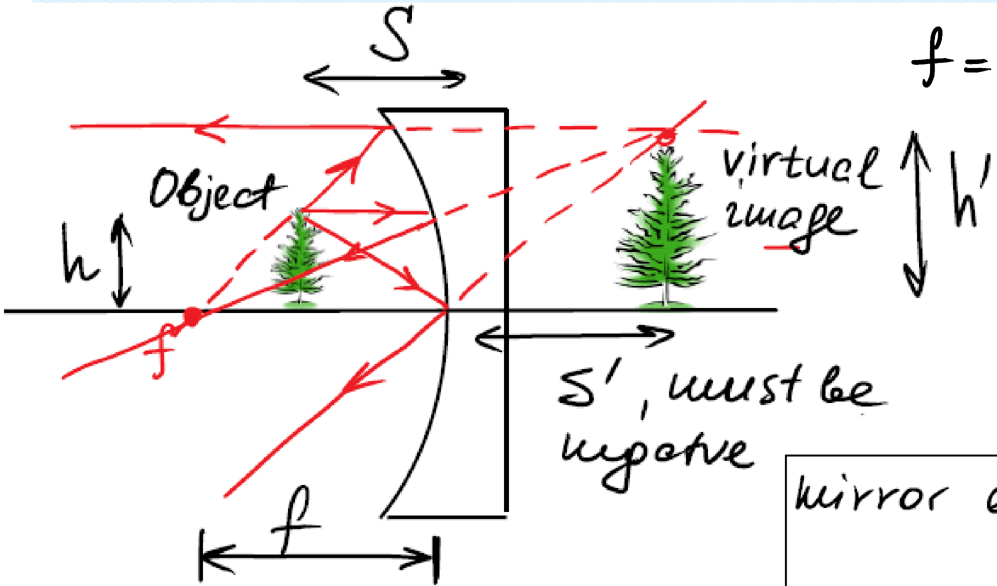


The mirror sign conventions

Focal length, f	**f > 0** **for a concave mirror**	**f < 0** **for a convex mirror**
Image distance, s'	**s' > 0,** **for a real image**	**s' < 0,** **for a virtual image**
Magnification, m	**m > 0,** **for an upright image**	**m < 0,** **for an inverted image**
Object distance, s	**s > 0**	**s > 0**

EXAMPLE 23.17 Analyzing a concave mirror

A 3.0-cm-high object is located 20 cm from a concave mirror. The mirror's radius of curvature is 80 cm. Determine the position, orientation, and height of the image.



$f = \frac{R}{2} = \frac{80\,cm}{2} = 40\,cm;\ S = 20\,cm;\ h = 3\,cm$

so $S < f$

mirror eq-n: $\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$; $f > 0$ (concave mirror)

$$s' = \frac{s \cdot f}{s - f} = \frac{20\,cm \cdot 40\,cm}{20\,cm - 40\,cm} = -40\,cm$$

"−" means a virtual image

Magnification:

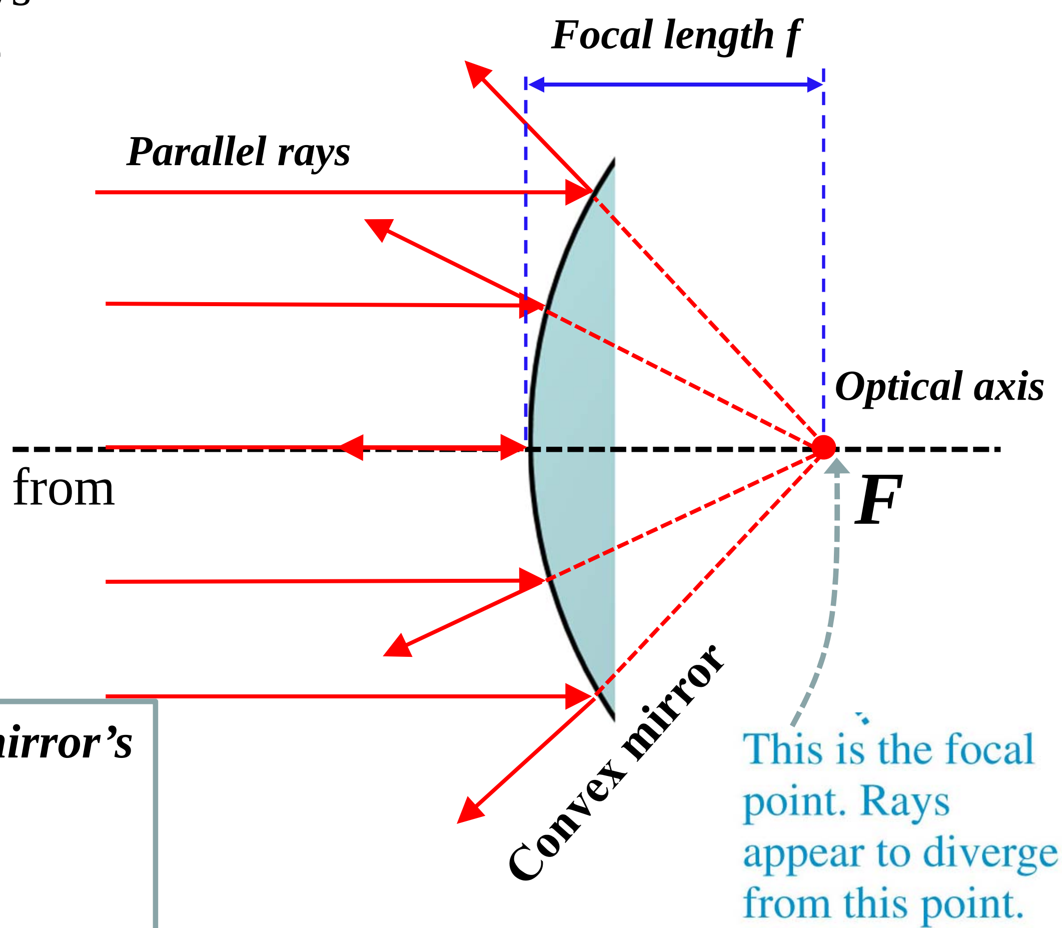
$$m = -\frac{s'}{s} = -\frac{(-40\,cm)}{20\,cm} = 2$$

$$|m| = \frac{h'}{h} \Rightarrow h' = |m| \cdot h = 2 \cdot 3\,cm = 6\,cm$$

Convex Mirrors

Convex Spherical Mirror

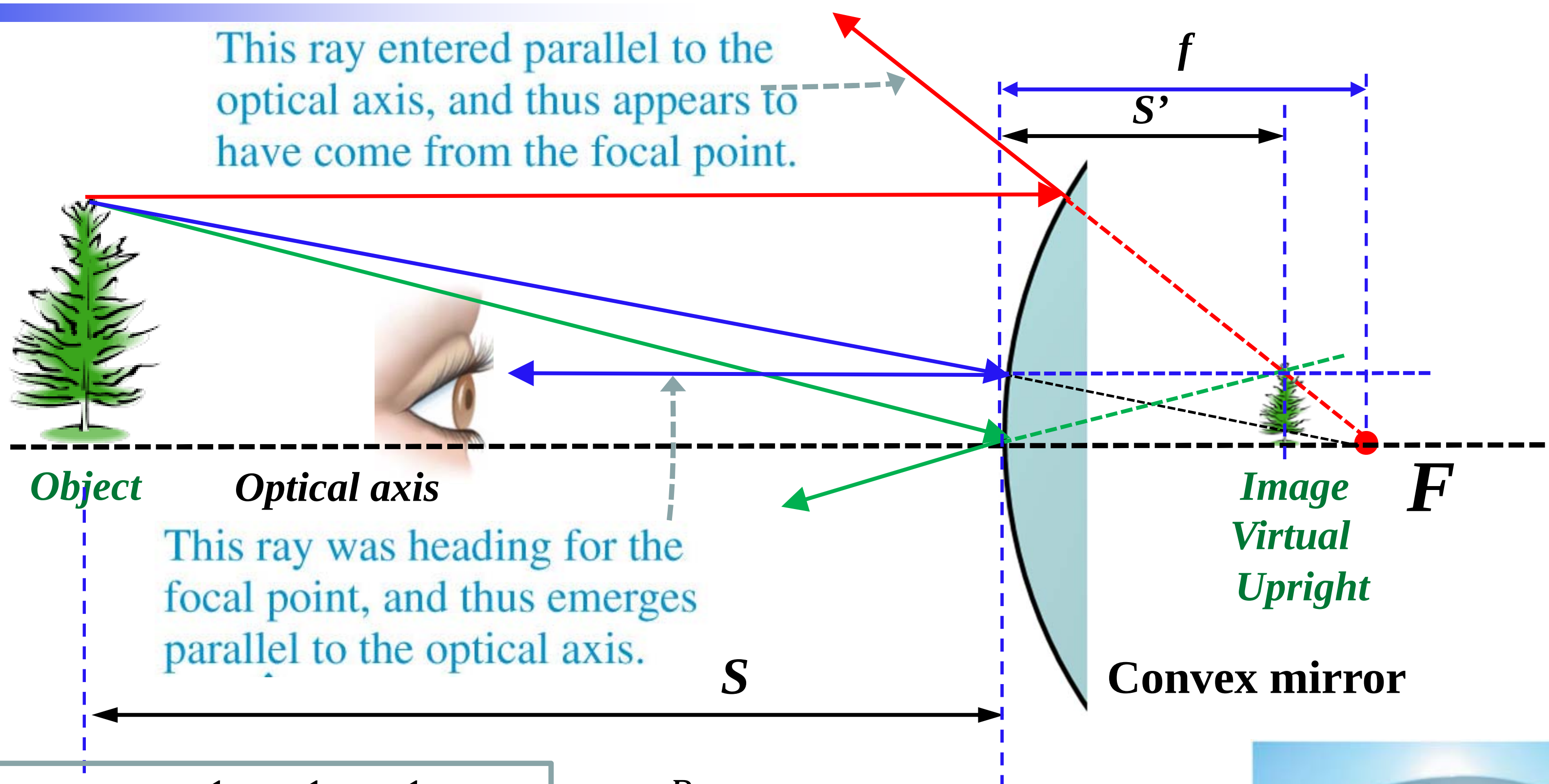
- The figure shows parallel light rays approaching a mirror in which the edges curve *away from* the light source.
- This is called a **convex mirror.**
- The reflected rays appear to come from a point behind the mirror.



The focal length f is related to the mirror's radius of curvature by:

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

Images Formed by a Convex Mirror



Mirror equation $$\frac{1}{f} = \frac{1}{S} + \frac{1}{S'}$$

Magnification $$m = -\frac{S'}{S} = -\frac{h'}{h}$$

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

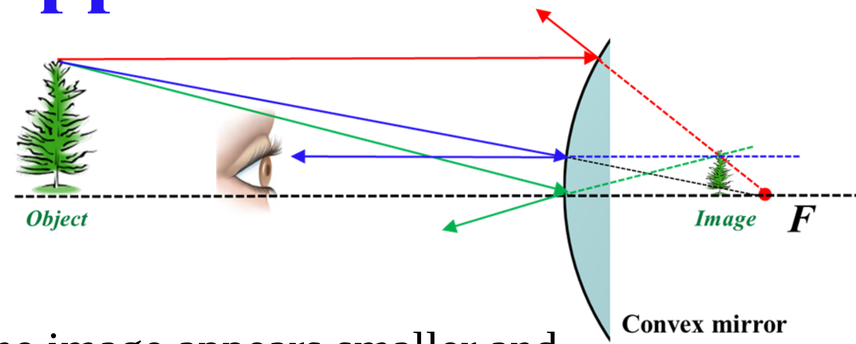
Sign convention for a convex mirror:

$$f < 0; \quad S > 0$$

Note! The image is always upright and smaller than the object

Convex Mirror Applications

Convex mirror are used for a variety of safety and monitoring applications, such as:



1) rearview mirrors

When an object is reflected in a convex mirror, the image appears smaller and you may think that it is farther away from you.

That is why there is a warning sign:

2) The round mirrors used in stores to keep an eye on the customers

ConcepTest Type of a Mirror

- What type of mirror is shown in the photo where a guy stands right next to the mirror?

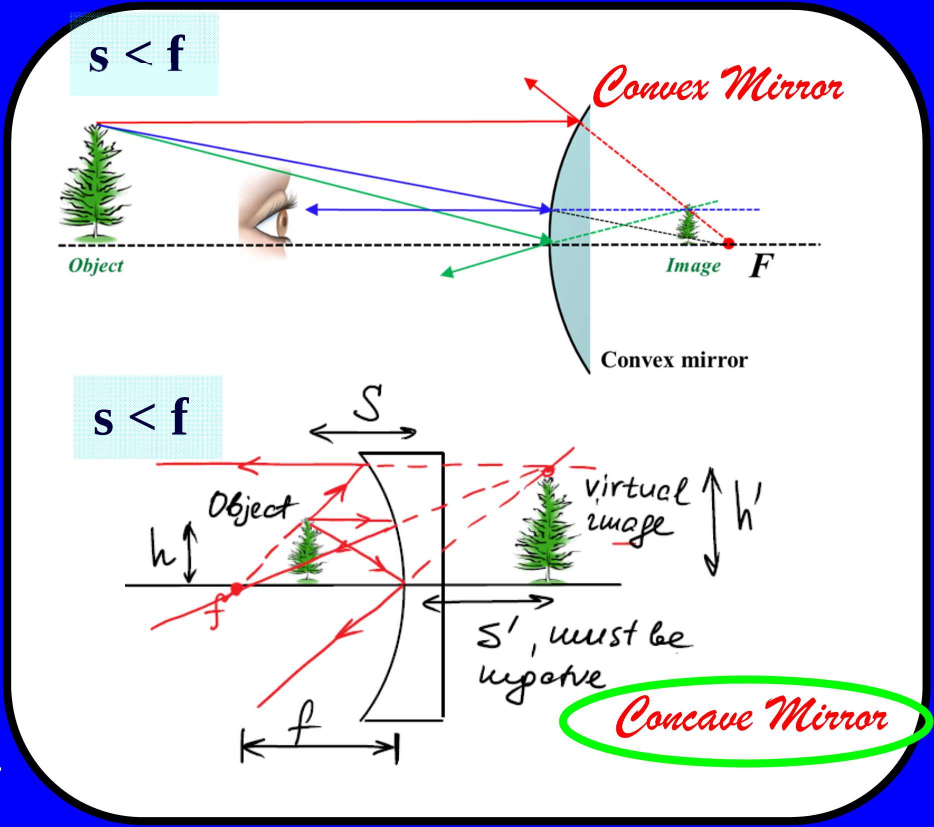
A. Flat Mirror

B. Concave Mirror

C. Convex Mirror

Since he stands right next to the mirror, it means that ***S < f.*** Let's consider both cases:

The image is upright and larger than the object. It is only possible with a concave mirror

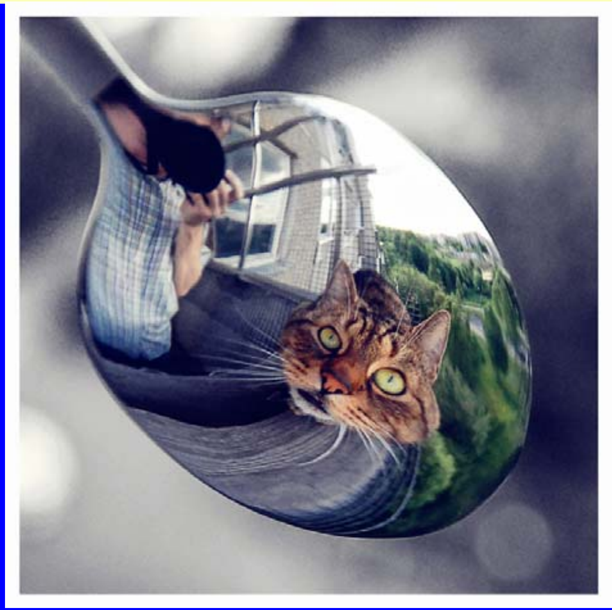


ConcepTest Cat in a spoon

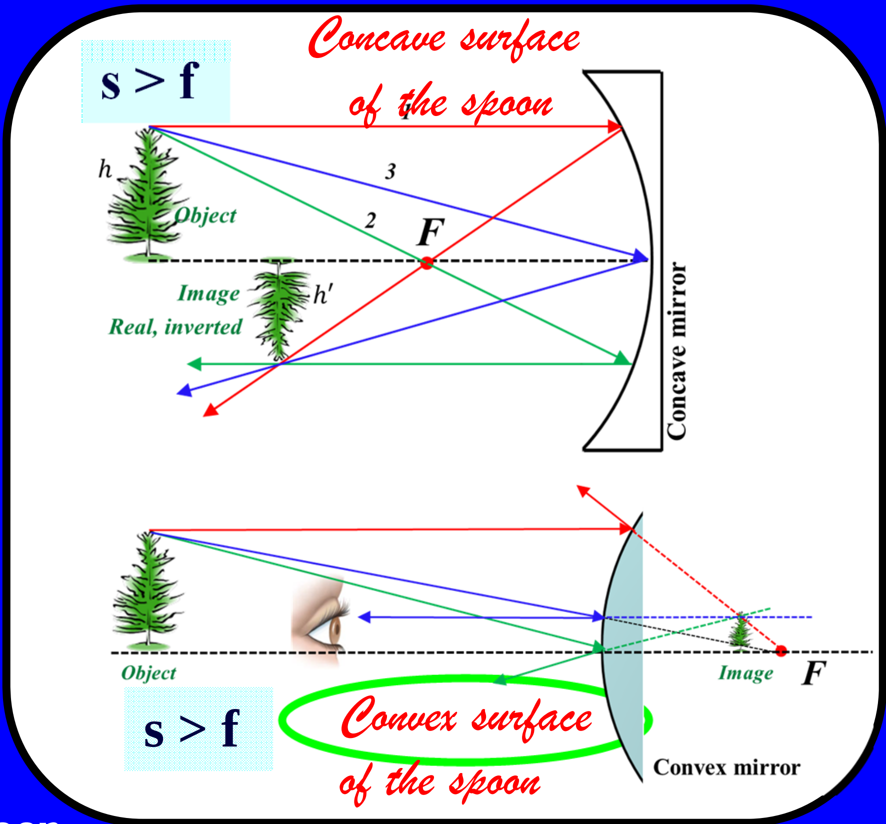
- A cat looks at his reflection in the bowl of spoon. The cat stands at some large distance from the spoon.
  Is his image created by:

A. Concave surface?

B. Convex surface?



Since he stands far from the spoon, it means that ***S*** > ***f*** (usually f=R/2 of the spoon is small). Let's consider both cases:



The image is upright.

It is only possible with a convex surface of the spoon

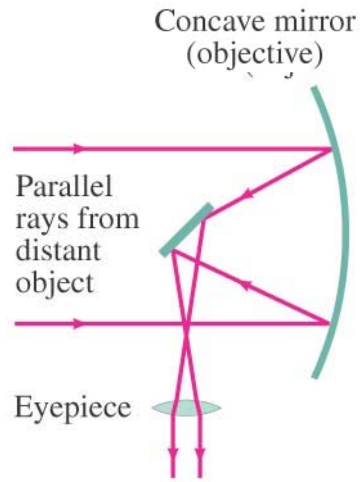
Image in a spoon

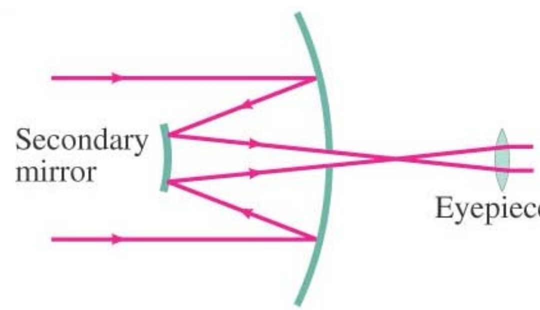
Convex Mirror

Concave Mirror

Telescopes

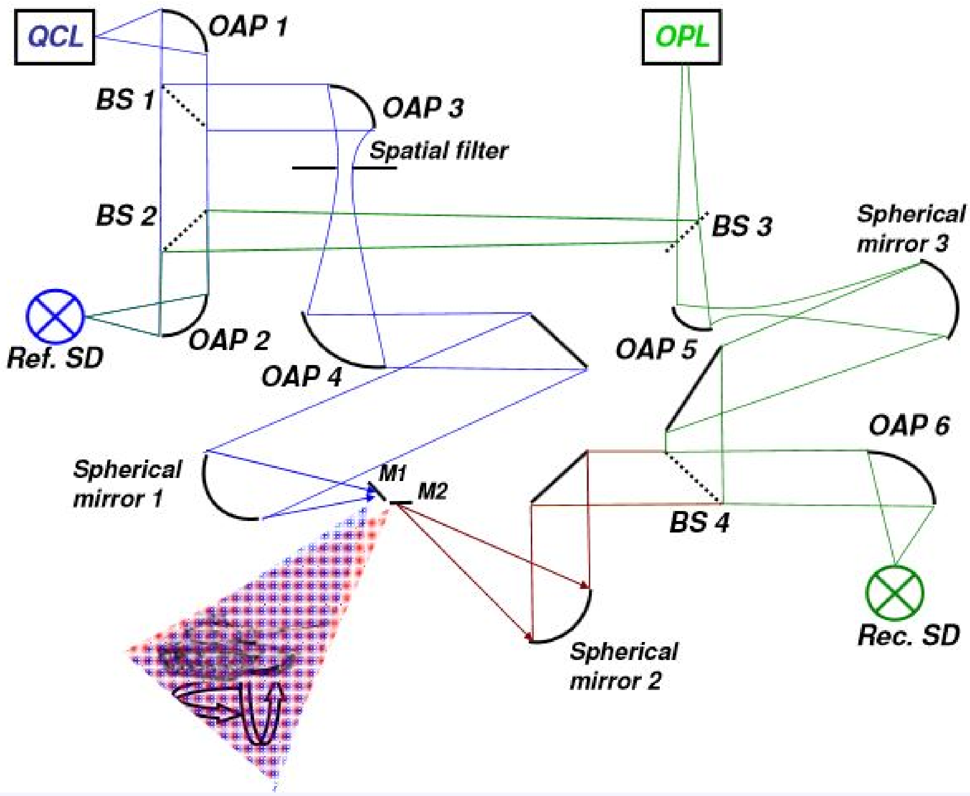
Astronomical telescopes need to gather as much light as possible, meaning that the objective must be as large as possible. Hence, mirrors are used instead of lenses, as they can be made much larger and with more precision.

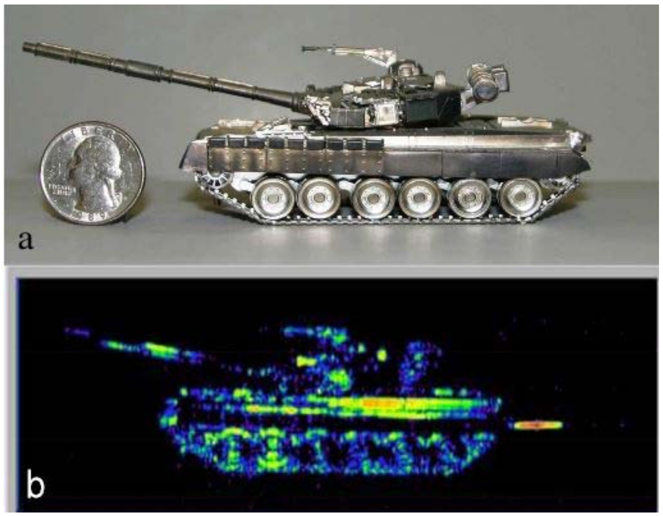




Lenses-vs-mirrors

In my imaging experiment I only used mirrors (spherical, parabolic (OAP)).
Why did I prefer mirrors to lenses?
Lenses work with transmitted light and, as a result, light can be absorbed.
Which means we might have significant amount of laser power loss.
But mirrors work with reflected light and losses are much smaller.





What you should read

Chapter 23 (Knight)

Sections

- ***23.7 skip it***
- ***23.8***

Thank you

See you on Tuesday