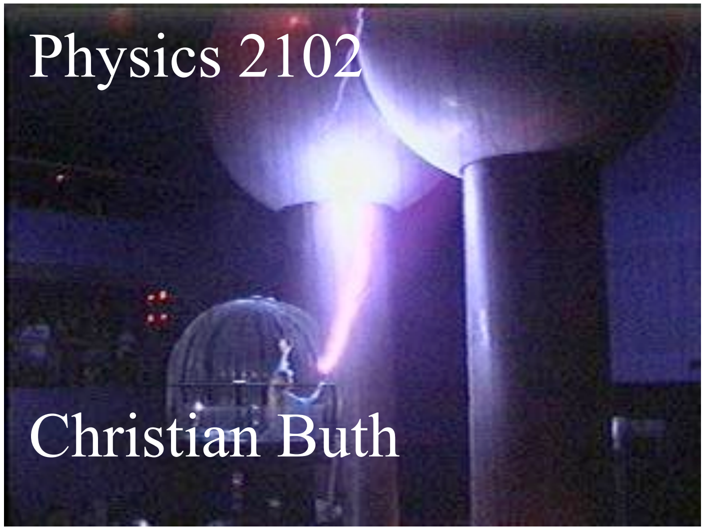
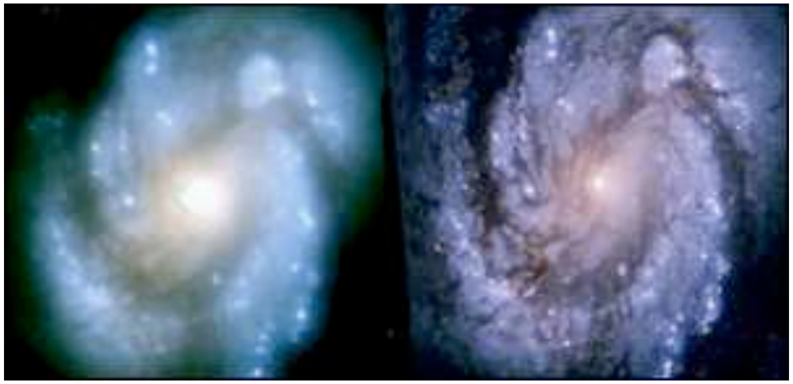
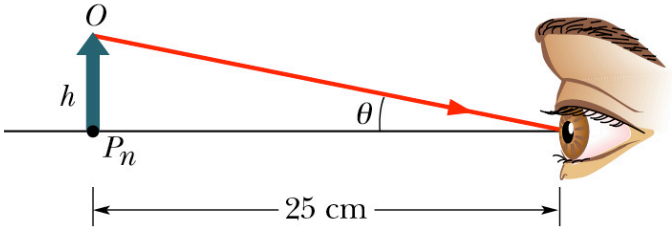




Lecture 37

Optics: Images 1

04/20/2009



Review

- **Real image** can be projected on a screen
- **Virtual image** exists only for observer
- **Plane mirror** is a flat reflecting surface

Plane Mirror: $i = -p$

- Convex mirrors make objects **smaller**
- Concave mirrors make objects **larger**

Spherical Mirror: $f = \frac{1}{2} r$

Images from spherical mirrors

Consider an object placed between the focal point and the mirror. It will produce a *virtual* image behind the mirror.

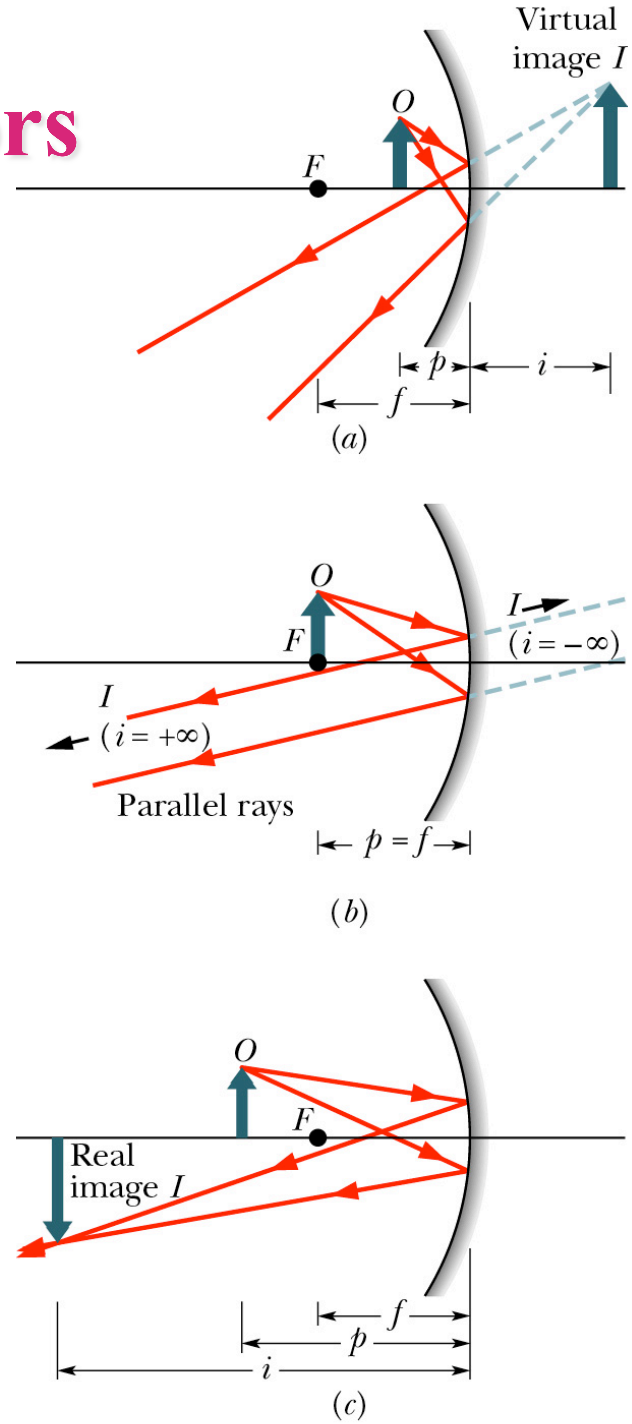
When the object is at the focal point the image is produced at *infinity*.

If the object is beyond the focal point, a *real* image forms at a distance *i* from the mirror.

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

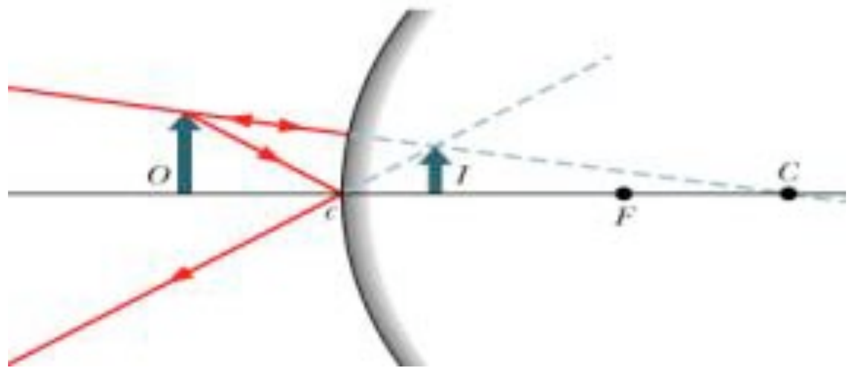
$$m=-\frac{i}{p}; \quad |m|=\frac{h'}{h}$$

lateral magnification



Example

An object 2cm high is located 10cm from a convex mirror with a radius of curvature of 10cm. Locate the image, and find its height.



Focal length: $f = r/2 = -10\text{cm}/2 = -5\text{cm}$.

Image position: $1/i = 1/f - 1/p = -1/5\text{cm} - 1/10\text{cm} = -3/10\text{cm}$

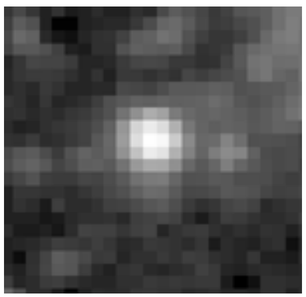
$i = -10/3\text{cm} = -3.33\text{ cm}$: the image is **virtual**.

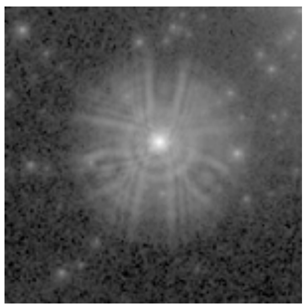
Magnification: $m = -i/p = -(-3.33\text{cm})/(10\text{cm}) = 0.33$ (smaller).

If the object image is 2cm, the image height is 0.33 x 2cm=0.67 cm.

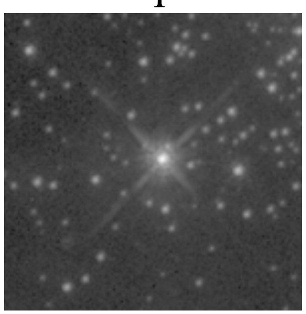
How important is it to know where the image is?

Hubble mirror: The central region of the mirror was flatter than it should be - by just one-fiftieth of the width of a human hair. This is equivalent to only four wavelengths of visible light, but it was enough. One insider said that the Hubble mirror was "very accurate, very accurately the wrong shape".

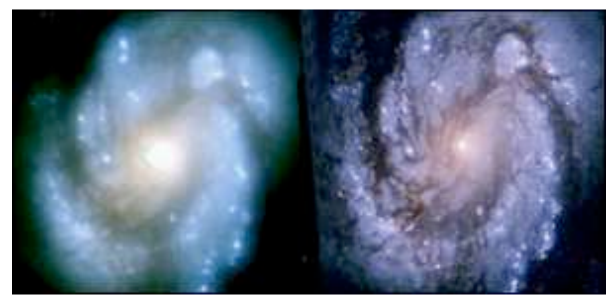




A star seen with a ground telescope and with "old" Hubble

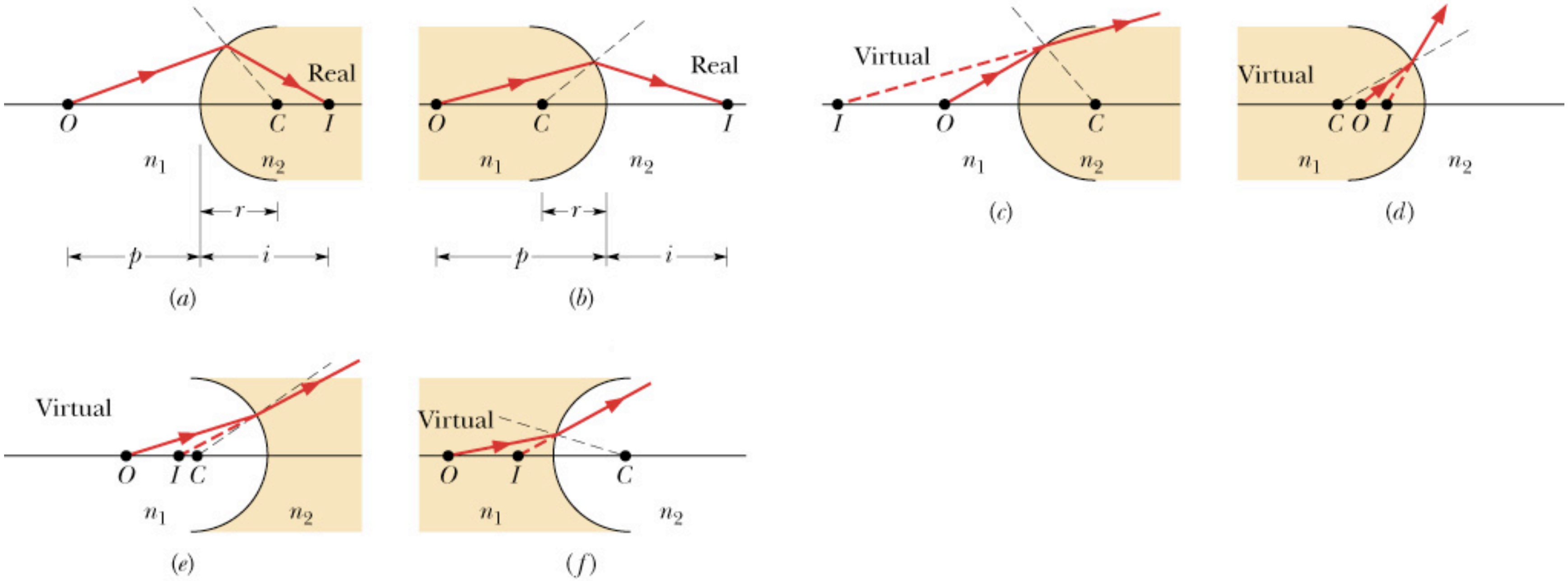


The same star seen with the "new" Hubble



Before and after...

Spherical Refracting Surfaces

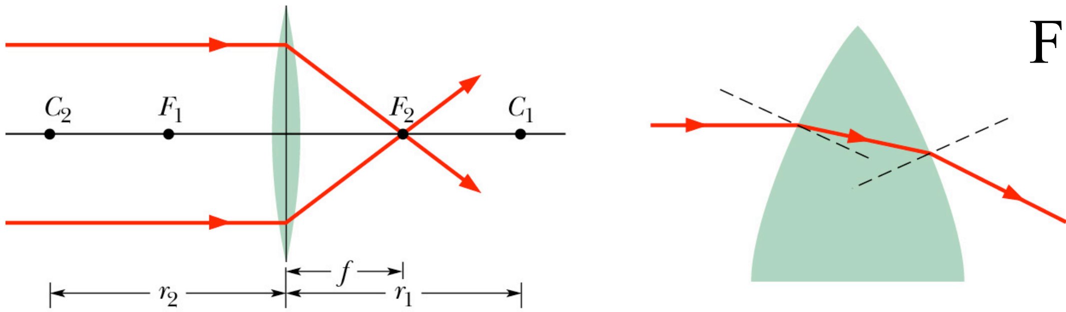


Real images form on the side of a refracting surface that is opposite the object (side to which light is going). Virtual images form on the same side as the object.

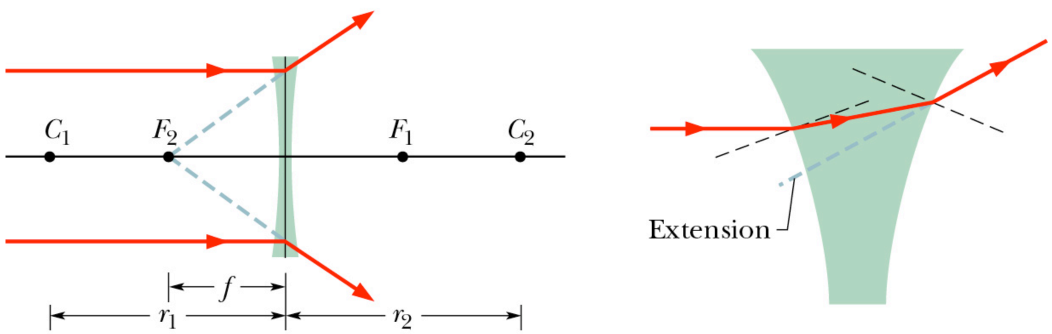
Spherical Refracting Surface: $$\frac{n_1}{p} + \frac{n_2}{i} = \frac{n_2 - n_1}{r}$$

When object faces a convex refracting surface *r* is positive. When it faces a concave surface, *r* is negative. CAUTION: This is reverse of mirror sign convention!

Thin Lenses



(a) Convergent lens (b)



(c) (d)

Divergent lens

For small angles and thin lenses,

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

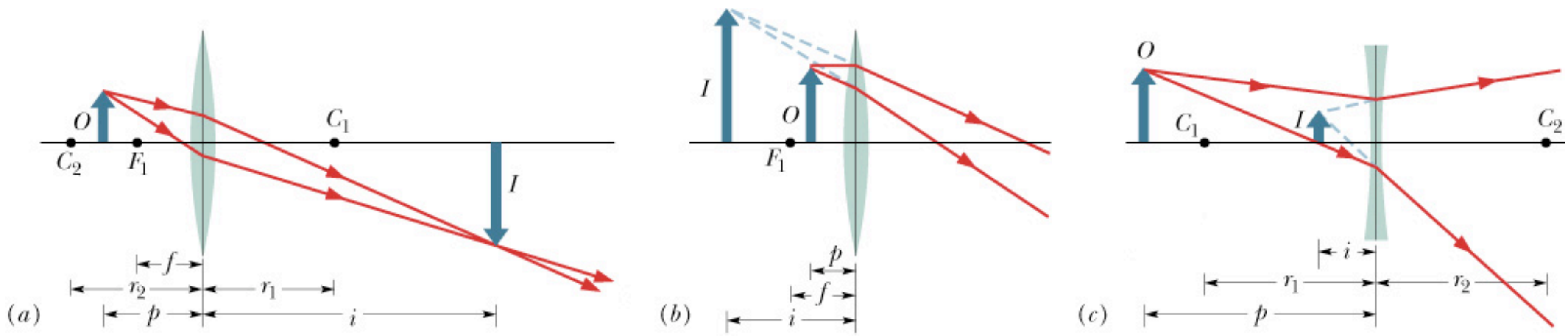
Convergent: f positive

Divergent: f negative

$$\frac{1}{f}=(n-1)\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$$

Lens maker's equation

Images from Thin Lenses



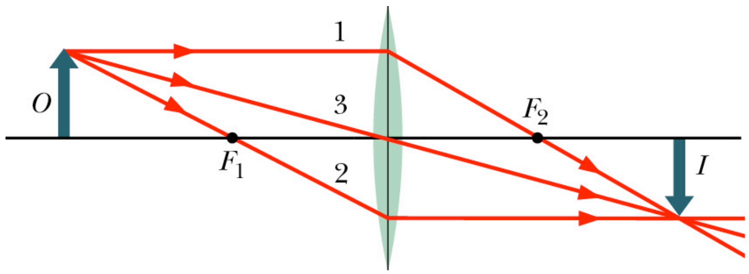
• An object placed beyond a convergent lenses' focal point, will produce a real, inverted image on the other side of the lens. This is the principle used in projectors.

• An object placed between a convergent lens and its focal point will produce a virtual image on the same side as the object.

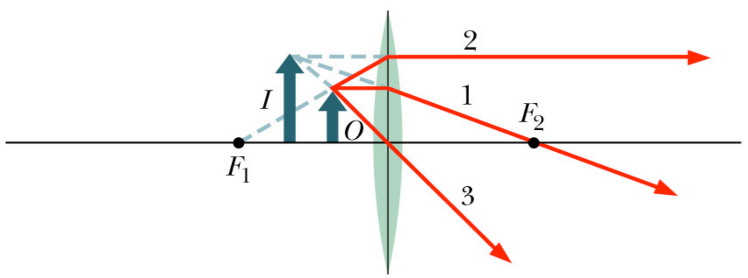
• Divergent lenses always produce a virtual image on the same side as the object.

• Real images have i positive in formulas, virtual images have i negative.

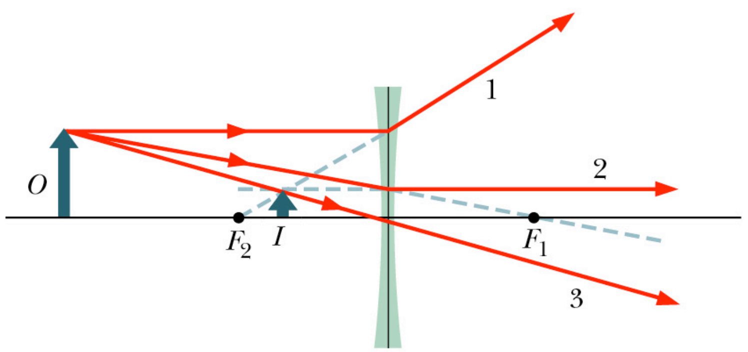
Locating Images of Extended Objects by Drawing Rays



(a)



(b)



(c)

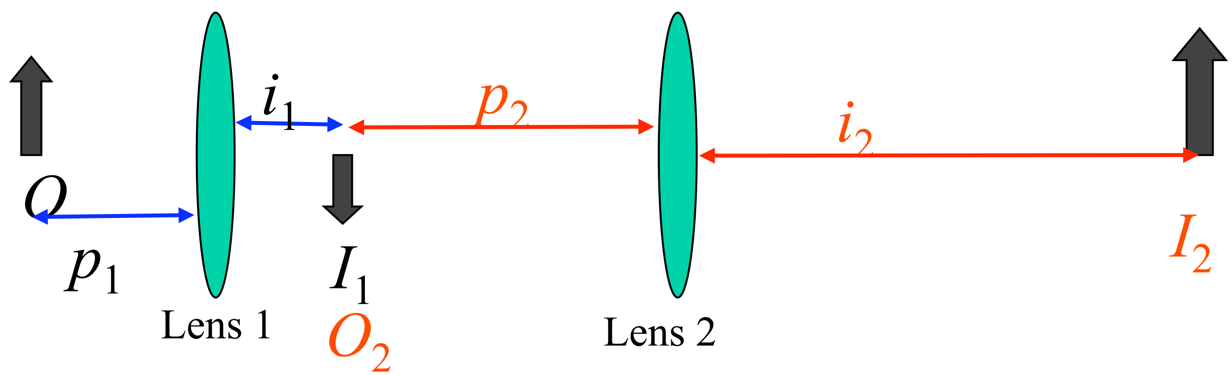
• A ray of direction initially parallel to the axis will pass through the focal point.

• A ray that initially has a direction that passes through the focal point will emerge parallel to the central axis.

• A ray going through the center of the lens will be undeflected.

• The image of a point appears where all rays emanating from a point intersect.

Two-Lens System



1. Let p_1 be the distance of object O from Lens 1. Use equation and/or principle rays to determine the distance to the image of Lens 1, i_1.

3. Ignore Lens 1, and use I_1 as the object O_2. If O_2 is located beyond Lens 2, then use a negative object distance p_1. Determine i_2 using the equation and/or principle rays to locate the final image I_2.

The net magnification is: $M = m_1 m_2$

Summary

- Extended objects from spherical mirrors and lenses are located by **drawing rays**

Spherical Mirror: $\frac{1}{p}+\frac{1}{i}=\frac{1}{f}$

Lateral Magnification: $|m|=\frac{h'}{h}$

Lateral Magnification: $m=-\frac{i}{p}$

Spherical Refracting Surface: $\frac{n_1}{p}+\frac{n_2}{i}=\frac{n_2-n_1}{r}$

Thin Lens: $\frac{1}{f}=\frac{1}{p}+\frac{1}{i}$

Thin Lens in Air: $\frac{1}{f}=(n-1)\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$