PHY132 Introduction to Physics II
Class 6 – **Outline:**

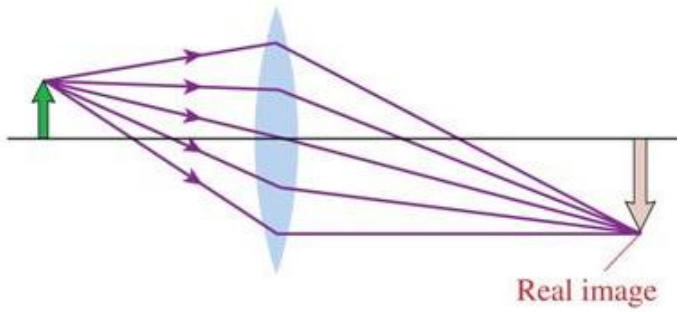
- Ch. 23, sections 23.6-23.8
- The Thin Lens Equation
- The Lens-Maker's Equation
- Image Formation with Spherical Mirrors

Class 6 Preclass Quiz on MasteringPhysics

- This was due this morning at 8:00am
- 642 students submitted the quiz on time
- 94% got: A lens which is thicker at the centre than at the edges is converging. (And a lens which is thinner at the centre than at the edges is diverging.)
- 90% got: The focal length of a converging lens is the distance at which parallel light rays are focused.
- 73% got: A virtual image is a point from which rays appear to diverge.

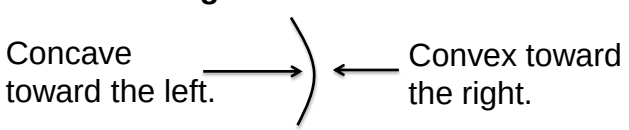
Class 6 Preclass Quiz on MasteringPhysics

- 71% got: If a real image is formed by a converging lens, that means the object distance was smaller than the focal length *f*.



Class 6 Preclass Quiz – Student Comments…

- *"Determining whether an image will be virtual or real was probably the most difficult aspect."*
- **Harlow thought:** If the rays actually converge at the image, then it is real. You could, in principle, place a screen at a real image, and see the image. If the rays only appear to be coming from the image, but they didn't actually touch it, then it is virtual.
- *"So I guess we should bring rulers to the exam?"*
- **Answer:** Yes. A ruler is an allowed aid on tests and the exam, and I would suggest you bring one just in case.
- *"is there an easy way to remember concave/convex?"*
- **Harlow thought:** A cave is concave.



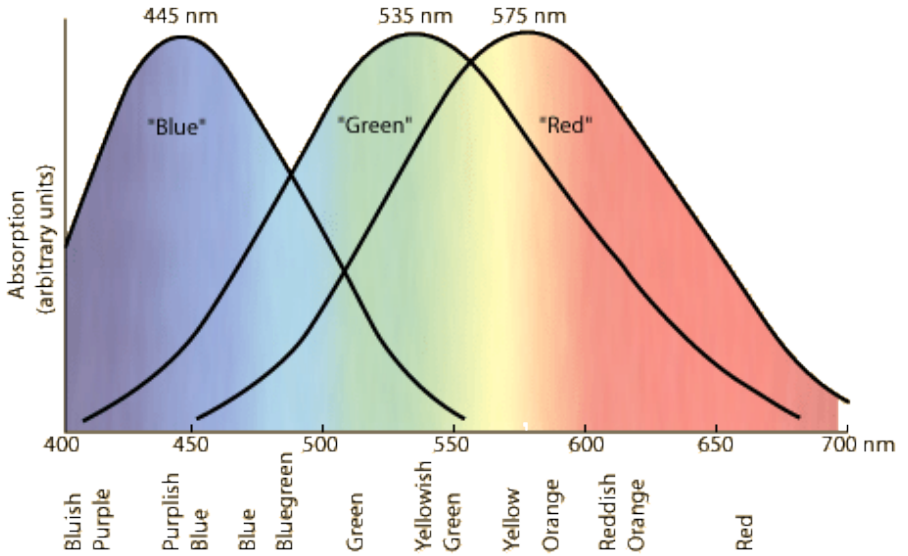
Class 6 Preclass Quiz – Student Comments…

- *“real image is still blurry in my mind”*
- *“Do we need to write down these equations onto our aid sheet or will they be provided ?”*
- **Answer**: No equations will be provided on the tests and exam. You must write every useful equation you don’t feel like memorizing on your aid sheet.
- *“Where does bad light go? In a prism.”*
- *“I think optical fiber imaging is really cool - Total Internal Reflection sounds like the name of an action movie. "Total Internal Reflection" Director: J. J. Abrams Cast: Matt Damon, Sandra Bullock, Jennifer Lawrence (for comic relief) Plot: The characters are trapped inside a giant endoscope...”*

Class 6 Preclass Quiz – Student Comments…

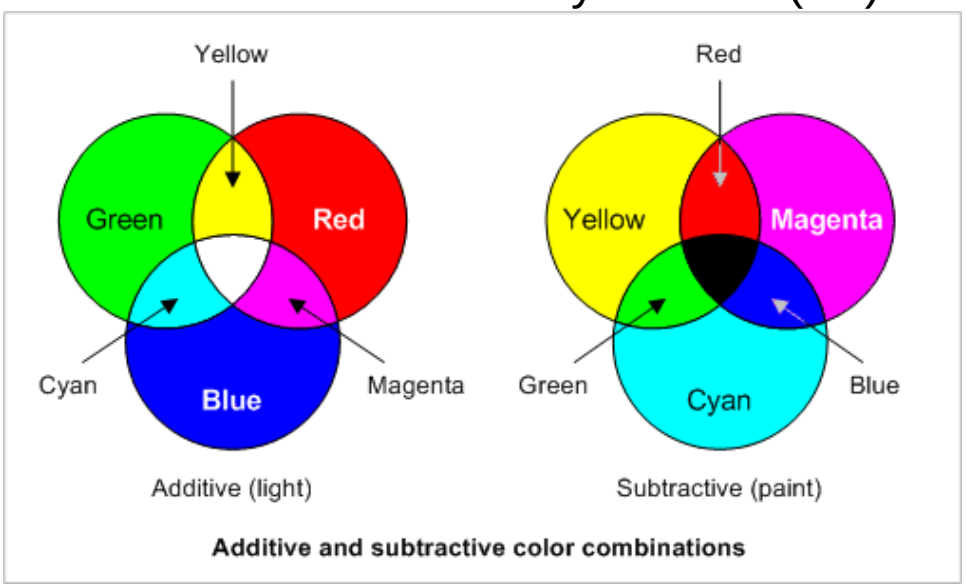
- *“Now I know how "the Bean" in Chicago works, and why we see miniature versions of ourselves!”*

Response Curves for the three types of cones in the retina of the human eye.



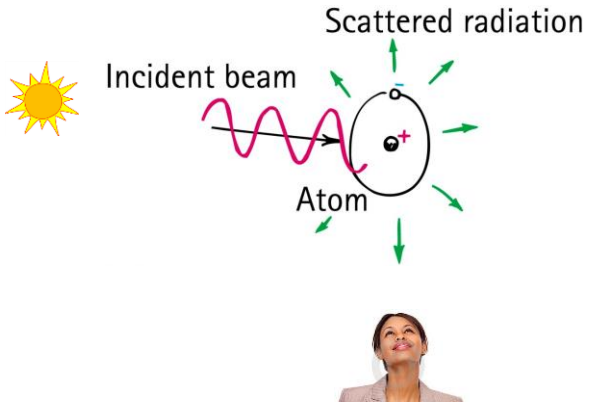
Slide from http://hyperphysics.phy-astr.gsu.edu/hbase/vision/colcon.html

Additive Primary Colours (light bulbs) and Subtractive Primary Colours (ink)

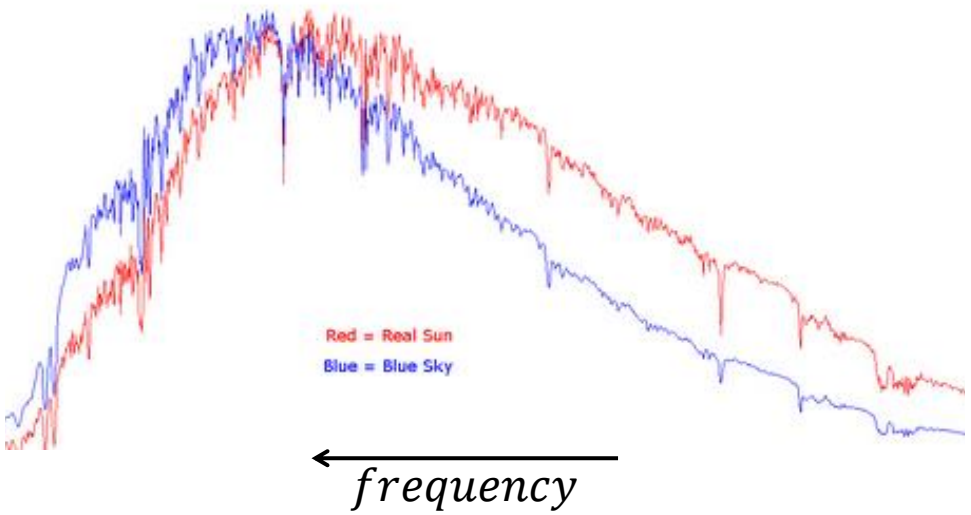


Why the Sky Is Blue

For small scattering particles, like nitrogen or oxygen molecules, higher frequency blue light is scattered much more readily than lower frequency red light.



Why the Sky Is Blue



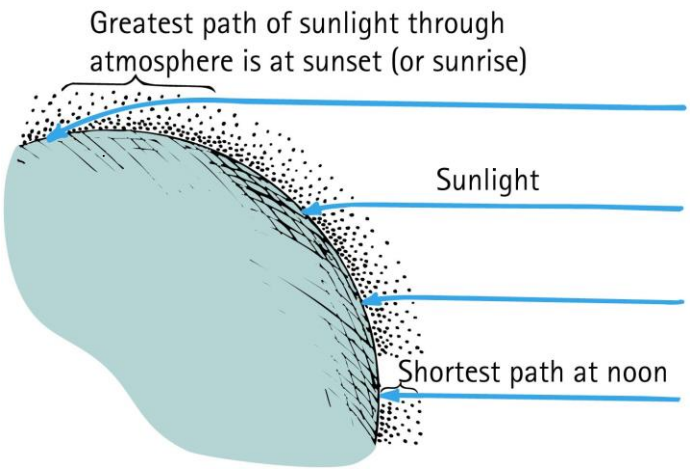
Why Sunsets Are Red
CHECK YOUR NEIGHBOUR

If molecules in the sky scattered orange light instead of blue light, the sky would be

A. orange.
B. yellow.
C. green.
D. blue.

Why Sunsets Are Red

Light that is least scattered is light of low frequencies, which best travel straight through air.

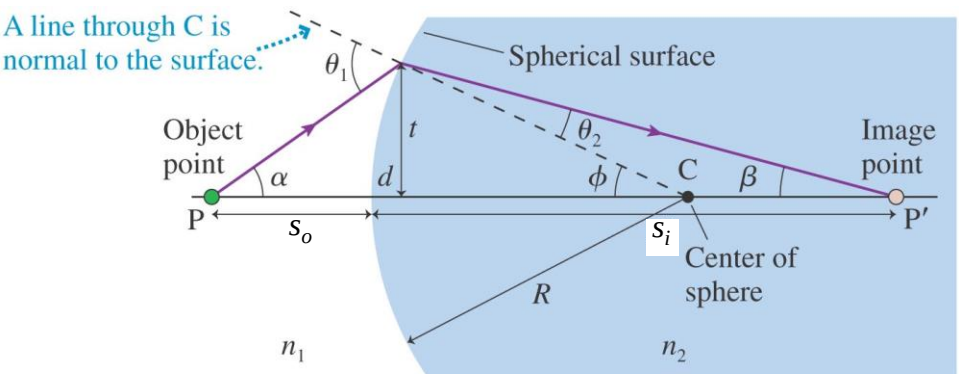


Why Sunsets Are Red
CHECK YOUR NEIGHBOUR

If molecules in the sky scattered orange light instead of blue light, sunsets would be

A. orange.
B. yellow.
C. green.
D. blue.

Image formation at a spherical interface



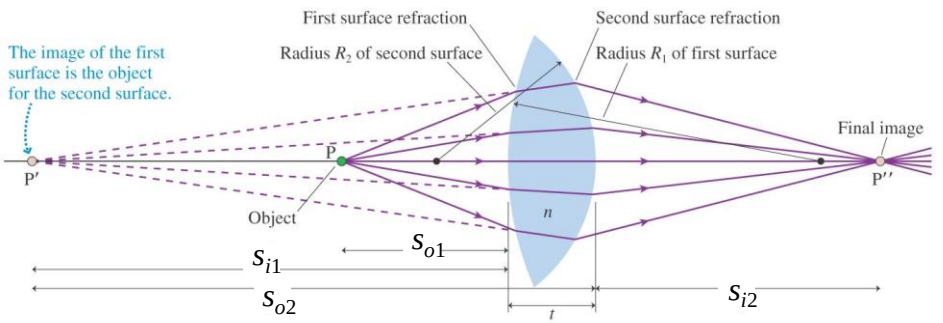
Sign conventions:

$$\frac{n_1}{s_o} + \frac{n_2}{s_i} = \frac{n_2 - n_1}{R}$$

← use this eq. with these conventions

R is positive means surface is convex toward the object
R is negative means surface is concave toward object
s_o is positive means object is to the left of interface
s_i is positive means image is real, to the right of interface

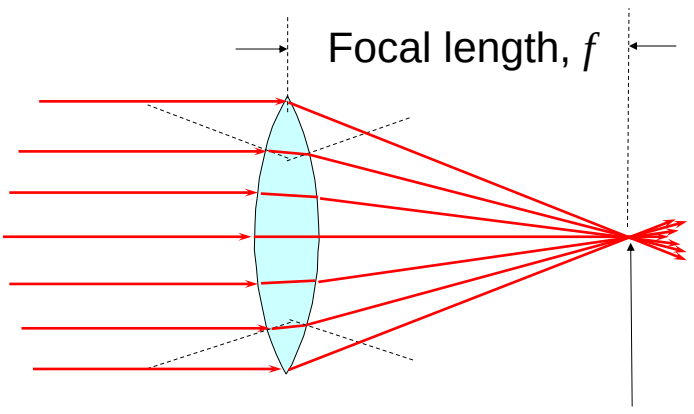
Lensmaker's Formula



$$\frac{1}{s_{o1}} + \frac{1}{s_{i2}} = (n_l - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \approx \frac{1}{f}$$

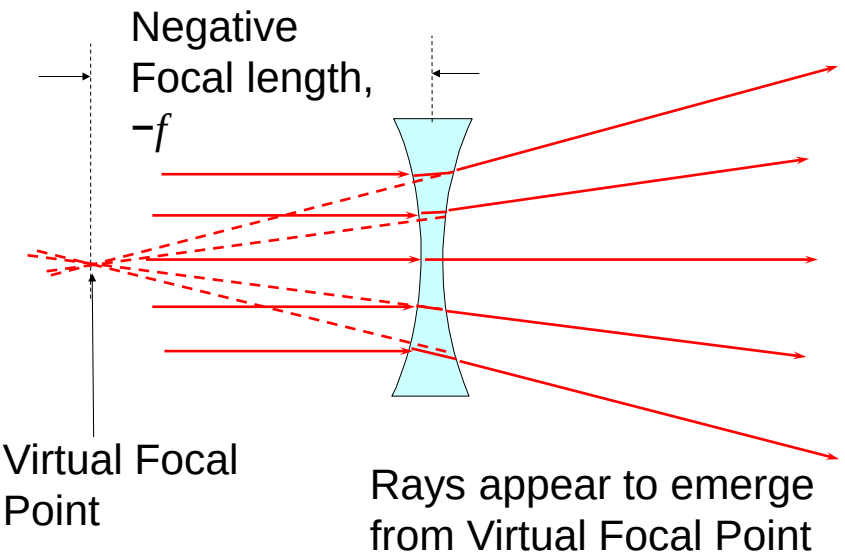
The important property of any lens = f.

Converging Lens



NOTE: Focal length is defined for initially *parallel* rays.

Diverging Lens



You can use the sun's rays and a lens to start a fire. To do so, you should use

A. A converging lens.
B. A diverging lens.
C. Either a converging or a diverging lens will work if you use it correctly.

Focusing Power

- Traditionally, lenses are specified not by their focal length, but by the inverse of their focal length.
- This is called "focusing power"

$$P = \frac{1}{f}$$

  - The S.I. unit of focusing power is m^{-1}
  - Traditionally, this unit is called the "diopter," abbreviated D.

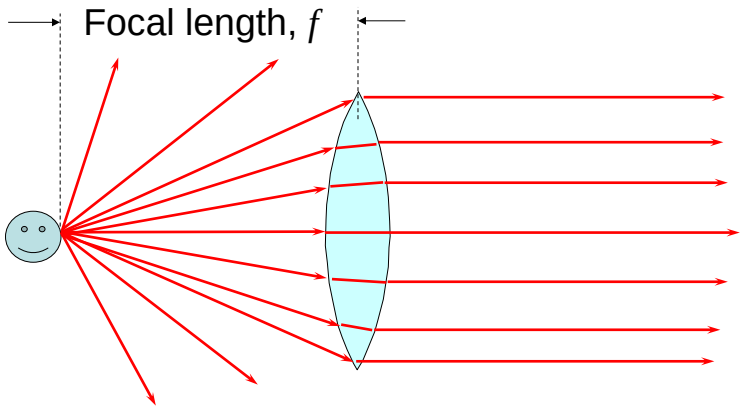
$$1\ \mathrm{D} = 1\ \mathrm{m}^{-1}$$

Announcement

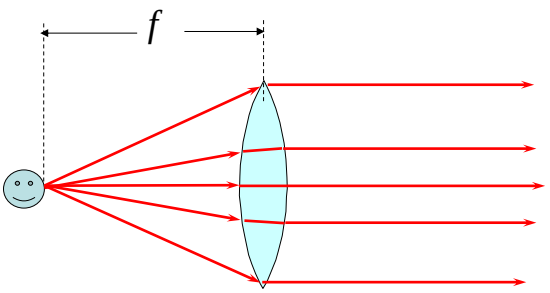
- Test 1 is Tuesday Feb. 4th from 6:00-7:30pm.
- Room To Be Announced

- If you have a conflict with the above time, the **alternate sitting** will be from 4:30-6:00pm on Tuesday Feb. 4th
  - To register, students should submit the Alternate Sitting Registration Form, available now in the PHY132S Portal course menu.
  - The location will be emailed on Jan. 31 to the people who have registered.
  - You have until Jan. 30 at 4:00pm to do it (the form will not be available after).

Diverging rays through a Converging Lens

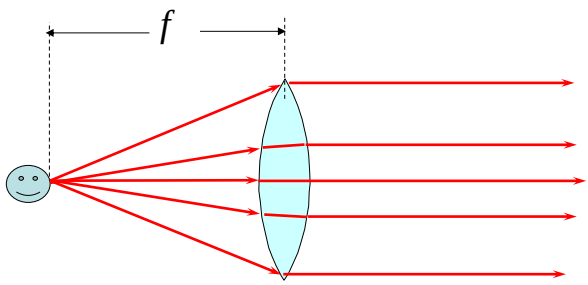


If an object emits rays at the focal point, they end up being parallel on the other side of the converging lens.



What will happen to the rays emerging to the right of the lens if the face is moved a little closer to the lens?

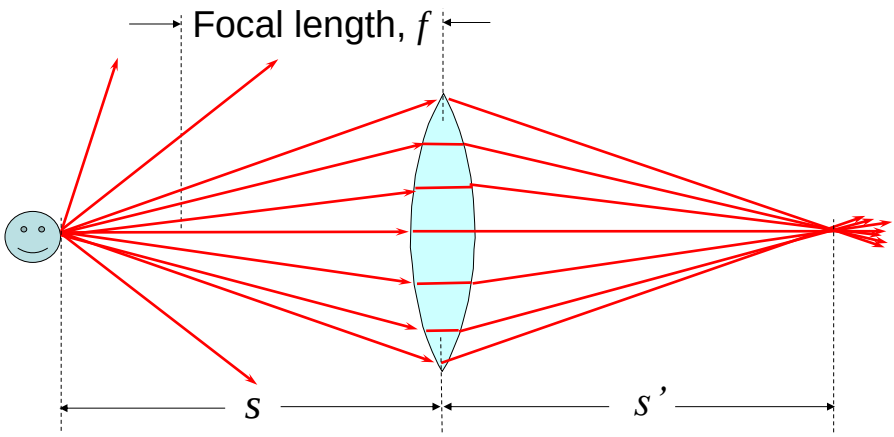
A. They will remain parallel.
B. They will diverge (spread out).
C. They will converge (toward a focus).



What will happen to the rays emerging to the right of the lens if the face is moved a little further away from the lens?

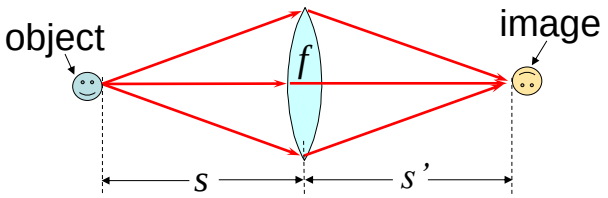
A. They will remain parallel.
B. They will diverge (spread out).
C. They will converge (toward a focus).

Diverging rays through a Converging Lens



Thin Lens Equation: $\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$

Thin Lens Equation: sign conventions



$$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$$

s is positive for objects to the left of lens, negative for objects to the right of lens (virtual objects).

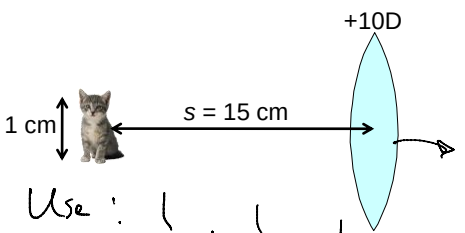
s' is positive for images to the right of lens, negative for images to the left of lens (virtual images).

f is positive for converging lenses, negative for diverging lenses.

Example

- A lens has a focal power of +10 D. → $\frac{1}{f} = 10\ m^{-1}$
- A 1 cm high object is placed 15 cm in front of the lens.
- Where does the image form?

object lateral height
$h = 1$ cm
object distance from lens $s = 15$ cm
Find s'



Use: $\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$

solve for s':

$$s' = \left[\frac{1}{f}-\frac{1}{s}\right]^{-1}$$

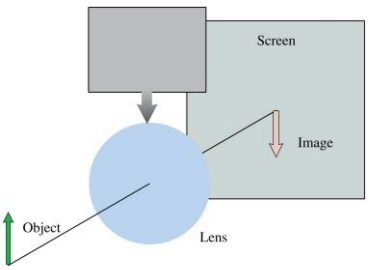
$s = 0.15$ m

$$s' = \left[10-\frac{1}{0.15}\right]^{-1}$$

$s' = 0.3$ m ← real

Image forms 30 cm to the right of the lens

A lens produces a sharply focused, inverted image on a screen. What will you see on the screen if a piece of dark paper is lowered to cover the top half of the lens?



A. An inverted but blurry image.
B. An image that is dimmer but otherwise unchanged.
C. Only the top half of the image.
D. Only the bottom half of the image.
E. No image at all.

Lateral Magnification

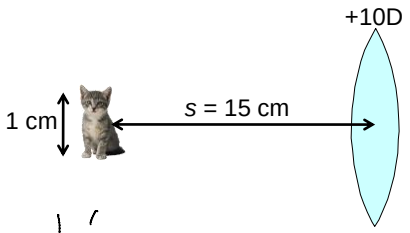
by definition

$$|M| \equiv \frac{h'}{h} = \frac{\text{image height}}{\text{object height}} \qquad M = -\frac{s'}{s}$$

- The absolute magnitude of the magnification $|M|$ is defined to be the ratio of image height to object height.
- A positive value of M indicates that the image is upright relative to the object. A negative value of M indicates the image is inverted relative to the object.
- Note that when s and s' are both positive, M is negative.

Example

- A lens has a focal power of +10 D.
- A 1 cm high object is placed 15 cm in front of the lens.
- How large is the image, and is it upright or inverted?



Recall: $s' = 30\,cm$

Use $M = -\frac{s'}{s} = \frac{-30\,cm}{15\,cm}$

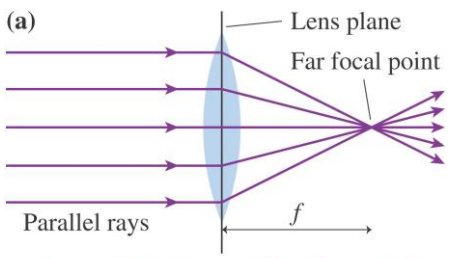
$M = -2$ ← negative means image is inverted.

$\frac{h'}{h} = M$

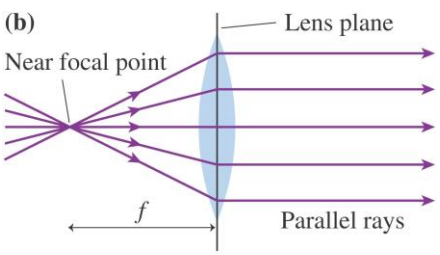
$h' = Mh = 2(1\,cm)$

$h' = 2\,cm$

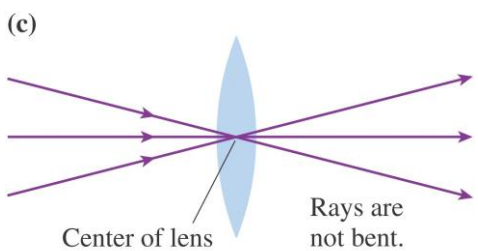
Ray Tracing
With a converging thin lens



Any ray initially parallel to the optical axis will refract through the focal point on the far side of the lens.

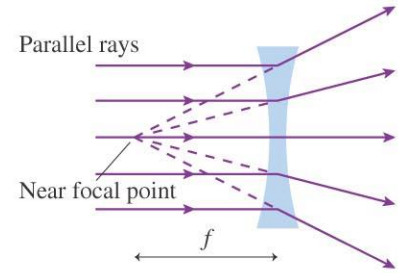


Any ray passing through the near focal point emerges from the lens parallel to the optical axis.

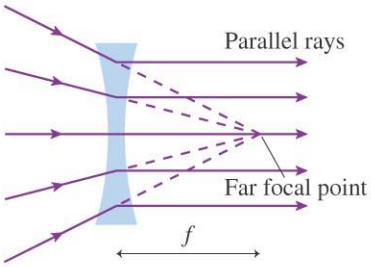


Any ray directed at the center of the lens passes through in a straight line.

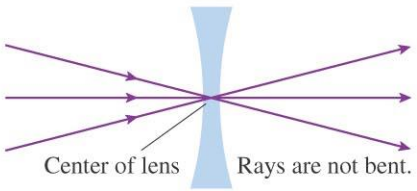
Ray Tracing
With a diverging thin lens



Any ray initially parallel to the optical axis diverges along a line through the near focal point.



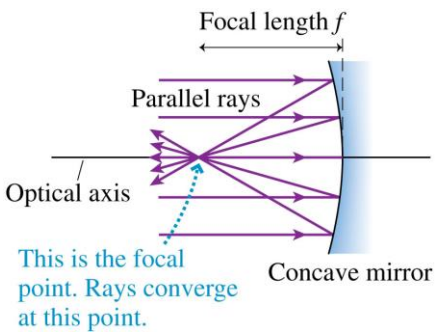
Any ray directed along a line toward the far focal point emerges from the lens parallel to the optical axis.

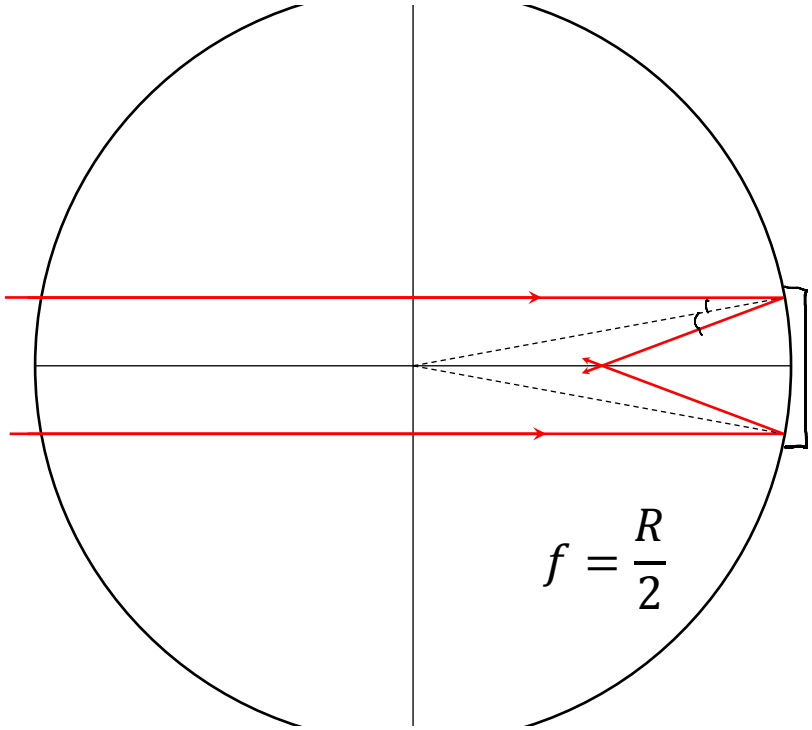


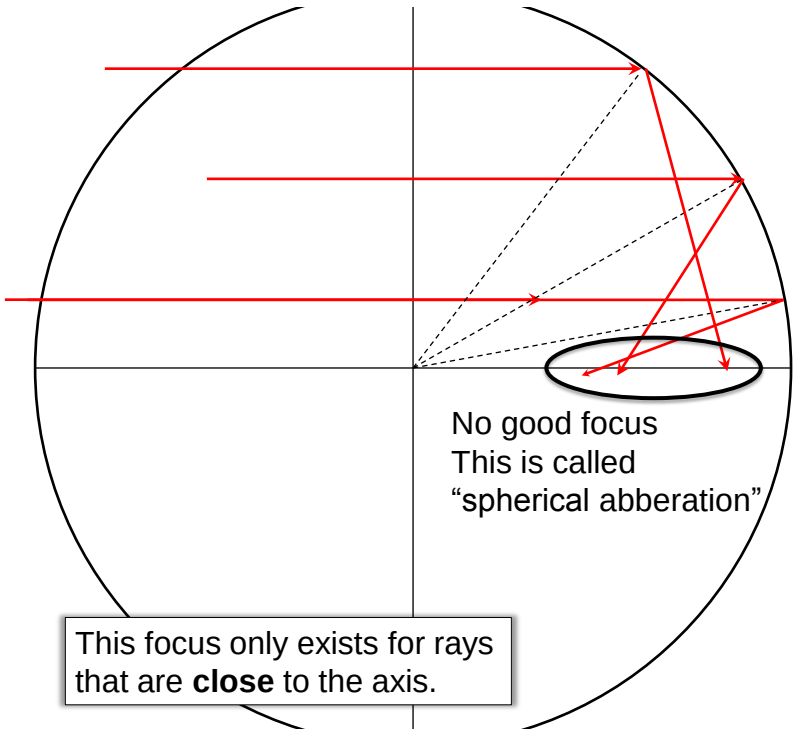
Any ray directed at the center of the lens passes through in a straight line.

Image Formation with Concave Spherical Mirrors

- The figure shows a **concave mirror**, a mirror in which the edges curve *toward* the light source.
- Rays parallel to the optical axis reflect and pass through the focal point of the mirror.

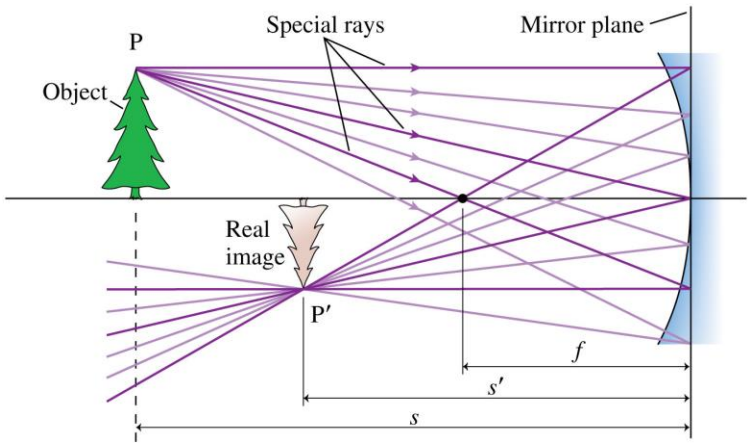






This focus only exists for rays that are **close** to the axis.

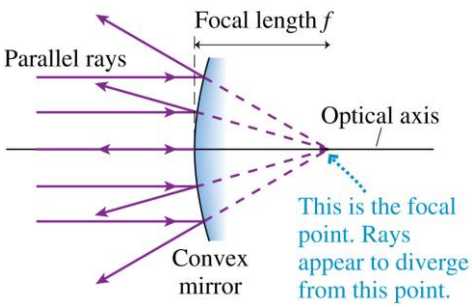
A Real Image Formed by a Concave Mirror



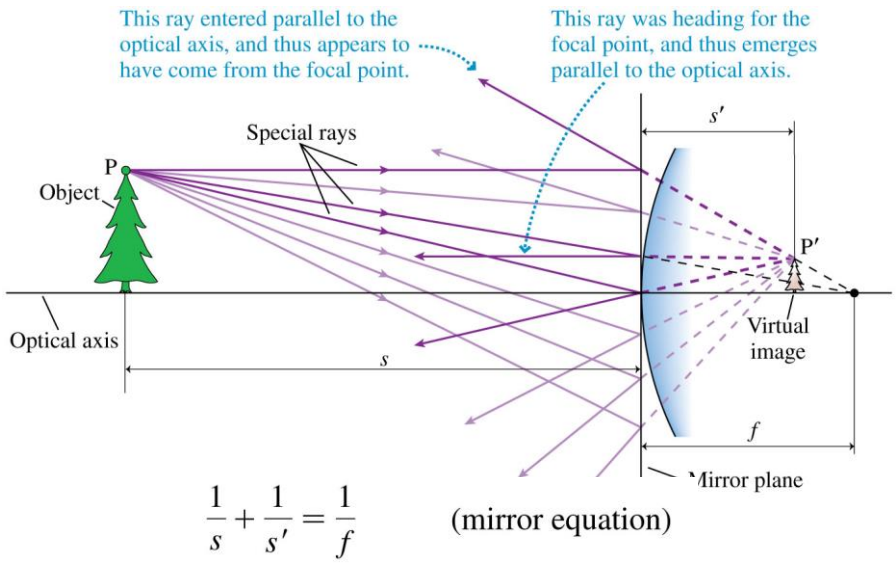
$$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f} \qquad \text{(mirror equation)}$$

Image Formation with Convex Spherical Mirrors

- 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.



A Real Image Formed by a Convex Mirror



$$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f} \qquad \text{(mirror equation)}$$

The Mirror Equation

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

$$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f} \qquad \text{(mirror equation)}$$

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

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

TABLE 23.5 Sign convention for spherical mirrors

	Positive	Negative
R, f	Concave toward the object	Convex toward the object
s'	Real image, same side as object	Virtual image, opposite side from object

Clicker Question

You see an upright, magnified image of your face when you look into magnifying “cosmetic mirror.” The image is located

A. In front of the mirror’s surface.
B. On the mirror’s surface.
C. Behind the mirror’s surface.
D. Only in your mind because it’s a virtual image.

Before Class 7 on Monday

- Complete Problem Set 2 on MasteringPhysics due Sunday at 11:59pm on Ch. 23.
- Please read Knight Pgs. 694-711: Ch.24
- Please do the short pre-class quiz on MasteringPhysics by Sunday night.

- Something to think about: When you look at an object with a telescope, it looks bigger. What, exactly, about the object is bigger? What are the units of image size?