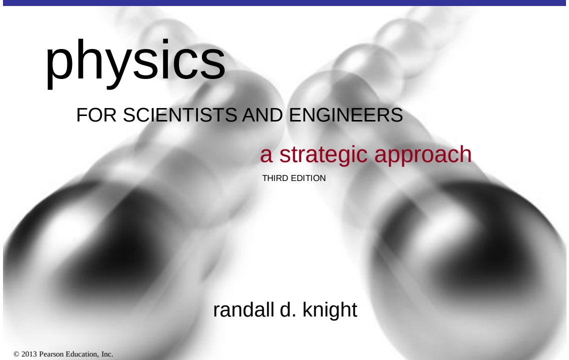
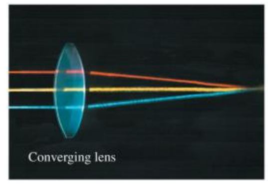
Class 6, Sections 23.6-23.8 Preclass Notes

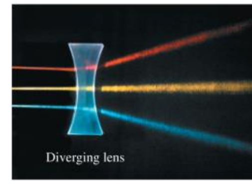


ALWAYS LEARNING PEARSON

Lenses

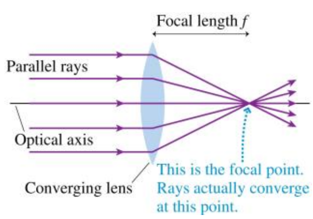
- The photos below show parallel light rays entering two different lenses.
- The left lens, called a **converging lens**, causes the rays to refract *toward* the optical axis.
- The right lens, called a **diverging lens**, refracts parallel rays *away from* the optical axis.





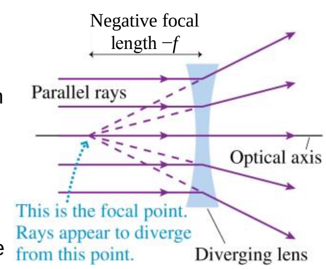
Converging Lenses

- A **converging lens** is thicker in the center than at the edges.
- The focal length *f* is the distance from the lens at which rays parallel to the optical axis converge.
- The focal length is a property *of the lens*, independent of how the lens is used.



Diverging Lenses

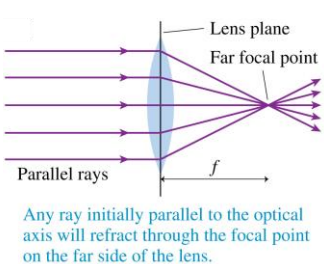
- A **diverging lens** is thicker at the edges than in the center.
- The focal length *f* is −1 times the distance from the lens at which rays parallel to the optical axis appear to diverge.
- The focal length is a property *of the lens*, independent of how the lens is used.



Thin Lenses: Ray Tracing

- Three situations form the basis for ray tracing through a thin **converging lens.**
- Situation 1:

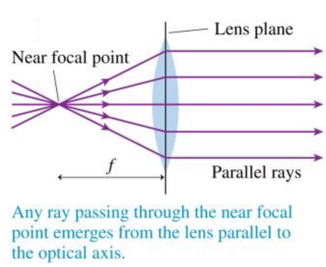
  A ray initially parallel to the optic axis will go through the far focal point after passing through the lens.



Thin Lenses: Ray Tracing

- Three situations form the basis for ray tracing through a thin **converging lens.**
- Situation 2:

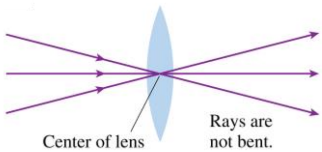
  A ray through the near focal point of a thin lens becomes parallel to the optic axis after passing through the lens.



Thin Lenses: Ray Tracing

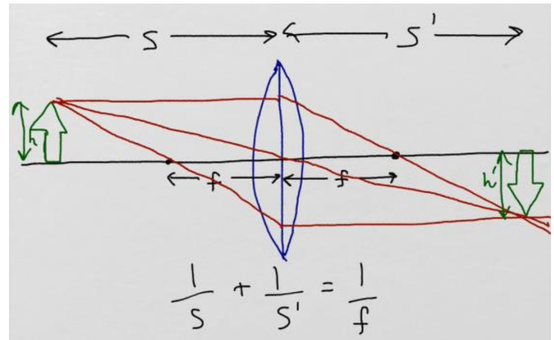
- Three situations form the basis for ray tracing through a thin **converging lens.**
- Situation 3:

  A ray through the center of a thin lens is neither bent nor displaced but travels in a straight line.



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

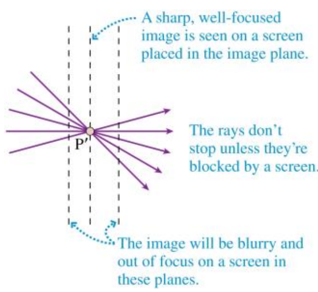
Thin Lenses: Ray Tracing



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

Image Formation

- The figure is a close-up view of the rays very near the image plane.
- To focus an image, you must either move the screen to coincide with the image plane or move the lens or object to make the image plane coincide with the screen.



Lateral Magnification

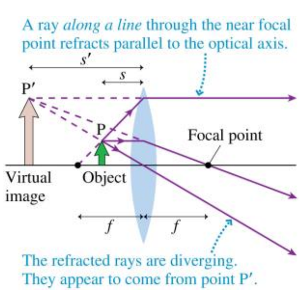
- The image can be either larger or smaller than the object, depending on the location and focal length of the lens.
- The **lateral magnification** m is:

$$m \equiv \frac{h'}{h} = -\frac{s'}{s}$$

- A positive value of m indicates that the image is upright relative to the object.
- A negative value of m indicates that the image is inverted relative to the object.
- The absolute value of m gives the size ratio of the image and object: $h'/h = |m|$.

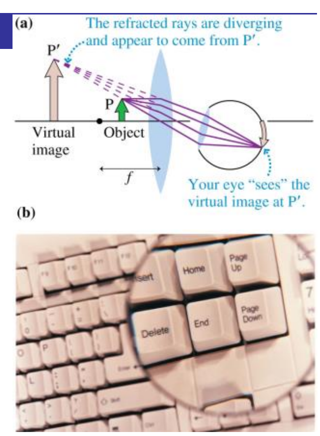
Virtual Images

- Consider a converging lens for which the object is *inside* the focal point, at distance $s < f$.
- You can see all three rays appear to diverge from point P′.
- Point P′ is an upright, **virtual image** of the object point P.



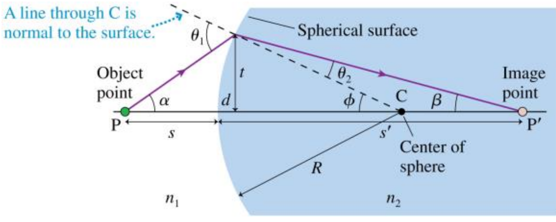
Virtual Images

- You can "see" a virtual image by looking through the lens.
- This is exactly what you do with a magnifying glass, microscope or binoculars.



Thin Lenses: Refraction Theory

- Consider a spherical boundary between two transparent media with indices of refraction n_1 and n_2.
- The sphere has radius of curvature R and is centered at point C.



Thin Lenses: Refraction Theory

If an object is located at distance s from a spherical refracting surface, an image will be formed at distance s' given by:

$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}$$

TABLE 23.3 Sign convention for refracting surfaces

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

The Thin Lens Equation

The object distance s is related to the image distance s' by:

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

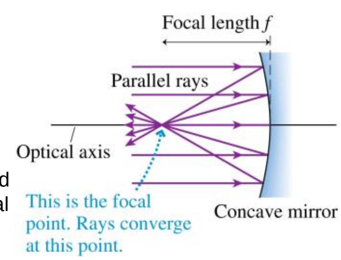
where f is the focal length of the lens, which can be found from:

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad \text{(lens maker's equation)}$$

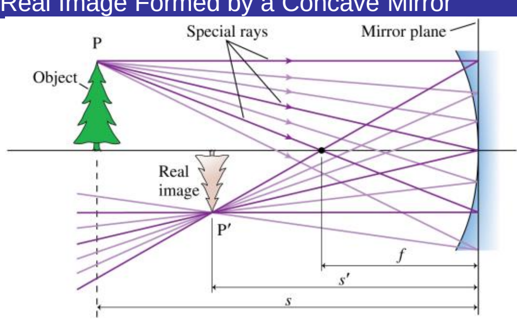
where R_1 is the radius of curvature of the first surface, and R_2 is the radius of curvature of the second surface, and the material surrounding the lens has $n = 1$.

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.



A Real Image Formed by a Concave 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