12.2.7: Double Convex Lenses

Refracting telescope at the Lick Observatory

Figure 14.7.1

Refracting telescopes, such as the one shown here, use lenses to focus the image. The telescope in this picture is one of the largest refracting telescopes in the world, and can be found in the Lick Observatory in San Jose, California.

Images in Double Convex Lenses

Lenses are made of transparent material such as glass or plastic with an index of refraction greater than that of air. At least one of the faces is a part of a sphere; a **convex lens** is thicker at the center than the edges, and a **concave lens** is thicker at the edges than the center. Convex lenses are called converging lenses, because they refract parallel light rays so that they meet. They are one of the most useful and important parts of all optical devices, and are found in eyeglasses, telescopes, microscopes, magnifying glasses, cameras and many other objects.

Both the mirror equation and the magnification equation also apply to lenses. However, when dealing with lenses, the mirror equation is renamed the Lens Equation.

Image formed by a convex lens

Figure 14.7.2

Double convex lenses have focal points on both sides of the lens, but it is also necessary to use points at twice the focal length to locate objects and images. Therefore, along the principal axis, there are points identified as *F* and as *2F* on both sides of the lens.

As with mirrors, we only need to trace two rays in order to locate the image for lenses. Both rays change direction while inside the lens, and their convergence point on the opposite side of the lens is the image location. As can be seen in the figure above, Ray 1 approaches the lens parallel to the principal axis and is refracted through the focal point on the other side. Ray 2 travels through the focal point and is then refracted parallel to the principal axis. The yellow arrow on the right of the lens is the inverted image.

The diagram above shows the situation when the object is outside *2F*. In this situation, the image will be between *F* and *2F* on the other side and will be inverted, diminished, and real. A real image can be projected on a screen. That is, if you placed a sheet of paper at the image position, the image would actually appear on the paper.

If the object is placed between *2F* and *F*, the image will appear beyond *2F* on the other side. The image will be real, inverted, and enlarged. You can do a ray tracing like the one shown to demonstrate this is true.

If the object is placed inside *F* (between *F* and the lens), the image will be on the same side of the lens as the object and it will be virtual, upright, and enlarged.

In the sketch below, the object is red and has been placed inside *F*. The ray that approaches the mirror parallel to the principal axis is dotted yellow. It refracts through the focal point, also shown in dotted yellow. The ray that approaches the mirror through the focal point is dotted blue and refracts parallel to the principal axis, also shown in dotted blue. As you can see, the refracted rays diverge, so there will be no real image. If the eye is placed beyond the object around the *2F* shown in the sketch, the eye will see the rays as if they have traveled in a straight line. These imaginary rays will converge at the tip of the green arrow which is the image position.

Virtual image formed by a convex lens

Figure 14.7.3

Examples

Example 14.7.1

An object is 40.0 cm to the left of a convex lens of +8.00 cm focal length. Determine the image distance.

Solution

$(1/d_o)+(1/d_i)=(1/f)$ *plugging in values (1/40.0)+(1/x)=(1/8.00)*

Multiplying both sides by 40x yields x+40=5x so 4x=40 and x=10.0 cm.

Example 14.7.2

An object 1.00 cm high is 8.00 cm to the left of a convex lens of 6.00 cm focal length. Find the image location and image height.

Solution

Add text here.

$(1/d_o)+(1/d_i)=(1/f)$ *plugging in values* (1/8.00)+(1/x)=(1/6.00)

Multiplying both sides by 24x yields 3x+24=4x so x=24.0 cm.

Since the image distance is three times the object distance, the image height will be three times the object height or 3.00 cm.

Launch the Magnifying Glass simulation below to investigate how this double convex lens causes the image of a candle to appear larger, smaller, and upside down:

Summary

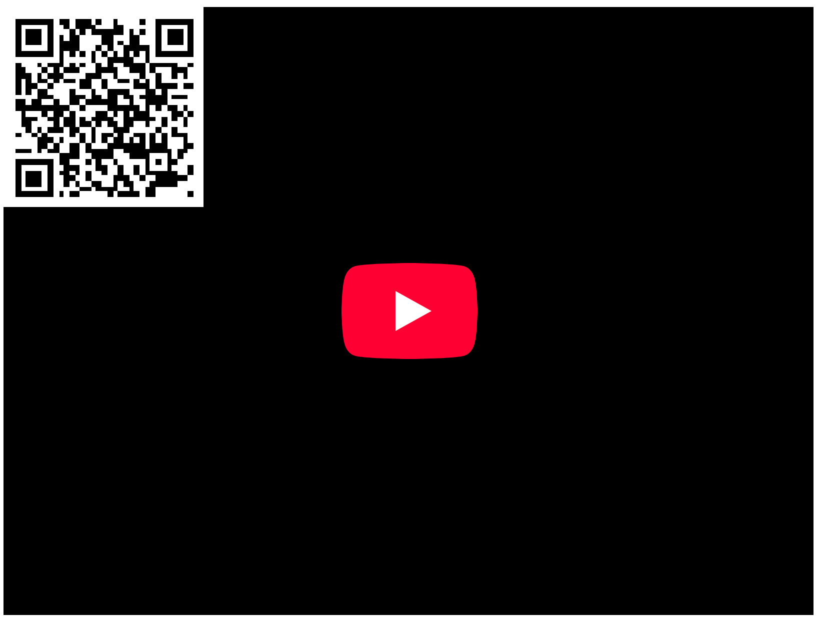
- Lenses are made of transparent materials, such as glass or plastic, with an index of refraction greater than that of air.
- One or both of the lens faces is part of a sphere and can be concave or convex.
- A lens is called a convex lens if it is thicker at the center than at the edges.
- Both the mirror equation and the magnification equation apply to lenses. Generally, when dealing with lenses, the mirror equation is renamed the Lens Equation.
- Double convex lenses have focal points on both sides of the lens; these and the points at twice the focal length are used to locate objects and images.
- When the object is outside *2F*, the image will be between *F* and *2F* on the other side and will be inverted, diminished, and real.
- If the object is placed between *2F* and *F*, the image will appear beyond *2F* on the other side. The image will be real, inverted, and enlarged.
- For convex lenses, when the object is placed inside *F*, the image will be on the same side of the lens as the object and it will be virtual, upright, and enlarged.

Review

1. An object is placed to the left of a 25 cm focal length convex lens so that its image is the same size as the object. Determine the object and image locations.
2. A lens is needed to create an inverted image twice as large as the object when the object is 5.00 cm in front of the lens. What focal length lens is needed? Hint: 1di+1do=1f
3. If you have a convex lens whose focal length is 10.0 cm, where would you place an object in order to produce an image that is virtual?
4. Describe how a convex lens could be used to make a magnifying lens.
5. Determine the image distance and image height for a 5.00 cm tall object placed 45.0 cm from a double convex lens with a focal length of 15.0 cm.
6. Determine the image distance and image height for a 5.00 cm tall object placed 30.0 cm from a double convex lens with a focal length of 15.0 cm.
7. Determine the image distance and image height for a 5.00 cm tall object placed 20.0 cm from a double convex lens with a focal length of 15.0 cm.
8. Determine the image distance and image height for a 5.00 cm tall object placed 10.0 cm from a double convex lens with a focal length of 15.0 cm.

Explore More

Use this resource to answer the questions that follow.



1. What four points are marked on the principal axis of a lens?
2. A ray of light from the object that passes through the focal point on the same side of the lens as the object will refract ___________.
3. Under what circumstances will a convex lens form a virtual image?

Additional Resources

Study Guide: Geometric Optics Study Guide

Interactive: Contact Lens

PLIX: Play, Learn, Interact, eXplore: Double Convex Lens

Video: