PH202-1G
Spring 2014

Worksheet March 12

Thin lenses

What is a converging lens? What is the sign of its focal length?

A converging lens refracts light toward a focal point. Its Focal length is positive.

What is a diverging lens? What is the sign of its focal length?

A diverging lens refracts light away from a Focal point. Its Focal length is negative.

Describe the sign conventions for the object distance, image distance, and magnification for thin lenses.

Object distance is positive to the left of the lens and negative to the right.

Image distance is positive For a real image and negative For a virtual image.

Magnification is positive for an upright image and negative For an inverted image.

Give a mathematical expression for the thin lens equation.

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

Same as the mirror equation, but sign convention is different.

Give a mathematical expression for the magnification of a lens.

$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

Describe the three rays necessary for a ray diagram for a converging lens.

1) Parallel to principal axis. This will be refracted toward the far focal point.

2) Through the center of the lens. This will not be refracted.

3) Through the near Focal point. This will be refracted parallel to the principal axis.

What kind of images are formed by converging lenses? Does it depend on the object distance?

If $d_o > 2f$, then the image will be real, inverted, and smaller.

If $2f > d_o > F$, then the image will be real, inverted, and larger.

If $F > d_o$, then the image will be virtual, upright, and larger.

Describe the three rays necessary for a ray diagram for diverging lens.

Same as converging lens {

1) Parallel to principal axis. This will be refracted away from the near Focal point.

2) Through the center of the lens. This will not be refracted.

}

3) Through the Far Focal point. This will intersect the lens and be refracted parallel to the principal axis before reaching the Far Focal point.

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What kind of images are formed by a diverging lens? Does it depend on the object distance?

The image will be virtual, upright, and smaller. It does not depend on object distance.

What happens in a compound lens? How does it form an image?

The image formed by the first lens becomes the object for the second lens.

Problems

1. An object placed 4.00 cm in front of a thin lens produces a virtual image at a distance of 2.22 cm from the lens. a) Is this image upright or inverted? b) Is this a converging or diverging lens? c) What is the focal length of the thin lens?

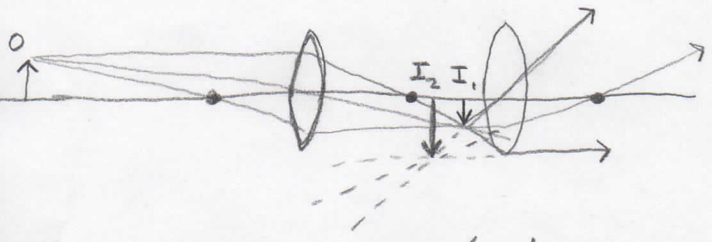
a) Virtual images are always upright. Image distance is negative for a virtual image, so $M = -\frac{d_i}{d_o}$ is a positive number.

b) The image is smaller because $M = -\frac{d_i}{d_o} = \frac{2.22\text{ cm}}{4.00\text{ cm}} < 1$.

Since the image is virtual, upright, and diminished, the lens must be a diverging lens.

c) $f = \left(\frac{1}{d_i} + \frac{1}{d_o}\right)^{-1} = \left(\frac{1}{-2.22\text{ cm}} + \frac{1}{4.00\text{ cm}}\right)^{-1} = -4.99\text{ cm}$

2. Two identical converging lenses with focal lengths of 10.0 cm are located 20.0 cm apart. If an object is placed 30.0 cm in front of the first lens, find the image distance with respect to the second lens and the magnification of the two-lens system.



Since the object is greater than twice the focal length away from a converging lens, we expect the first image to be real, inverted, and diminished.

$d_1 = \left(\frac{1}{f} - \frac{1}{d_o}\right)^{-1} = \left(\frac{1}{10.0\text{ cm}} - \frac{1}{30.0\text{ cm}}\right)^{-1} = 15.0\text{ cm}$

$M_1 = -\frac{d_1}{d_o} = -\frac{15.0\text{ cm}}{30.0\text{ cm}} = -\frac{1}{2}$

Image distance is positive, and magnification is negative and less than one, so our prediction is correct. Now the first image becomes the object for the second lens, and it is closer than the focal length. Thus, we expect the second image to be virtual, upright, and enlarged with respect to the first image.

$d_2 = \left(\frac{1}{f} - \frac{1}{d_1}\right)^{-1} = \left(\frac{1}{10.0\text{ cm}} - \frac{1}{20.0\text{ cm} - 15.0\text{ cm}}\right)^{-1} = -10.0\text{ cm}$

$M_2 = -\frac{d_2}{d_1} = \frac{10.0\text{ cm}}{5.0\text{ cm}} = +2.0$

The combined magnification is $M = -\frac{d_2}{d_o} = \frac{-30.0\text{ cm}}{20.0\text{ cm} - (-10.0\text{ cm})} = -1.00 = M_1 \cdot M_2$