PhyzExamples: Mirrors and Lenses

Physical Quantities • Symbols • Units • Brief Definitions

PLEASE SEE PHYZGUIDES FOR DIAGRAMS SHOWING THE FOLLOWING QUANTITIES

Focal Length • f • centimeter: cm • The distance, along the optical axis, from the center of the optical device (mirror or lens) to its focal point.

Radius • r • centimeter: cm • The distance, along the optical axis, from the center of the optical device (mirror or lens) to the center of a circle having the same radius of curvature as the device.

Object Distance • o • centimeter: cm • The distance, along the optical axis, from the center of the optical device (mirror or lens) to the object to be viewed in through the device.

Image Distance • i • centimeter: cm • The distance, along the optical axis, from the center of the optical device (mirror or lens) to the image of the object formed by the device.

Object Height • h_o • centimeter: cm • The distance, measured perpendicular to the optical axis, of the object to be viewed through an optical device (mirror or lens).

Image Height • h_i • centimeter: cm • The distance, measured perpendicular to the optical axis, of the image of the object formed by the optical device (mirror or lens).

Magnification • m • unitless • The ratio of the image height to the object height.

Equations

$r = 2f$ • the radius of curvature of a lens is twice the focal length of the lens

$1/f = 1/o + 1/i$ • The Thin Lens Equation • the reciprocal of the focal length = the reciprocal of the object distance + the reciprocal of the image distance

$m = h_i/h_o = -i/o$ • magnification = image height / object height = –image distance / object distance

Smooth Operations Examples

1. An object stands 18 cm from a concave mirror. An image forms 36 cm from the mirror. What is the focal length of the mirror?

1. $o = 18$ cm $i = 36$ cm $f = ?$
$1/f = 1/o + 1/i$
$f = 1 / (1/o + 1/i)$
$f = 1 / (1/18\text{ cm} + 1/36\text{ cm})$
$f = 12$ cm

2. An object is 6 cm away from a converging lens with a focal length of 24 cm. Where does the image form?

2. $o = 6$ cm $f = 24$cm $i=?$
$1/f = 1/o + 1/i$
$1/i = 1/f - 1/o$
$i = 1 / (1/f - 1/o)$
$i = 1 / (1/24\text{ cm} - 1/6\text{ cm})$
$i = -8$ cm

3. What is the magnification factor in the optical arrangement in problem 1 above?

3. $o = 18$ cm $i = 36$ cm $m = ?$
$m = -i/o$
$m = -i/o$
$m = -36\text{ cm} / 18\text{ cm}$
$m = -2$

4. If the object in problem 2 above is 10 cm tall, what is the height of the image?

4. $o = 6$ cm $i = -8$ cm $h_o = 10$ cm $h_i = ?$
$h_i/h_o = -i/o$
$h_i = -ih_o/o$
$h_i = -(-8\text{ cm})\ (10\text{ cm}) / 6\text{ cm}$
$h_i = 13$ cm

5. A 7.2 cm image of a *Star Wars* action figure (Chewbacca) has a distance –9.6cm from a diverging lens with a focal length of –16 cm.

a. Where is the object?

a. $i = -9.6$ cm $f = -16$ cm $o = ?$
$o = 1 / (1/f - 1/i)$
$o = 1 / (1/-16\text{ cm} - 1/-9.6\text{ cm})$
$o = 24$ cm

b. How tall is the object?

b. $h_i = 7.2$ cm $h_o = ?$
$h_o = -oh_i/i$
$h_o = -(24\text{ cm})(7.2\text{ cm})/-9.6\text{ cm}$
$h_o = 18$ cm

c. Magnification?

$m = h_i/h_o$
$m = 7.2\text{ cm} / 18\text{ cm}$
$m = 0.4$

Welcome to the Real World Example

6. A 3 cm arrow stands 9 cm from a double-concave lens. The image formed is 1 cm tall.

a. What is the magnification of this configuration?

$m = h_i/h_o = 1\text{ cm} / 3\text{ cm} = 0.33$

b. Where does the image form?

$h_i/h_o = -i/o$

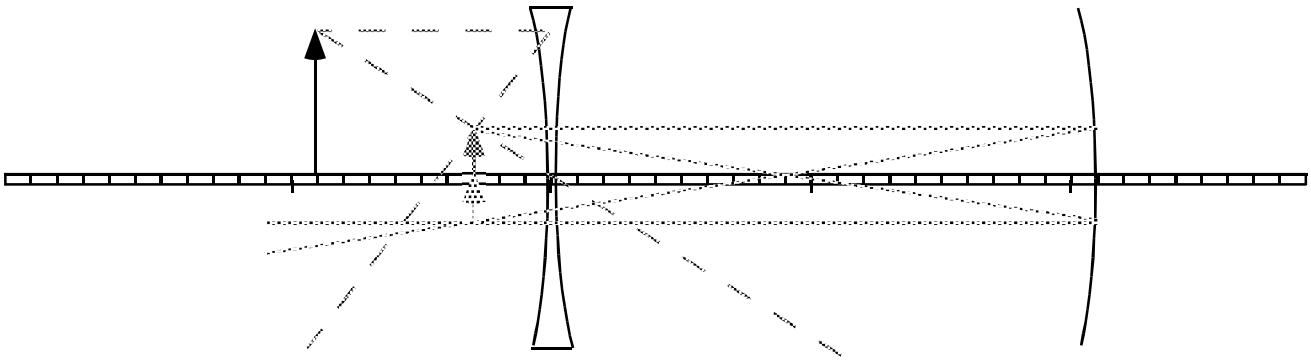
$i = -oh_i/h_o = -(9\text{ cm})(1\text{ cm}) / (3\text{ cm})$

i = −3 cm: the image forms 3 cm in front of the lens (on the object side)

c. What is the focal length of the lens?

$1/f = 1/o + 1/i$

$f = 1 / (1/o + 1/i) = 1 / (1/9\text{ cm} + 1/-3\text{ cm}) = -4.5\text{ cm}$



d. A concave mirror (f = 12 cm) lies 21 cm beyond the lens. Where does the image formed by the lens/mirror combination form?

o = 21 cm + 3 cm = 24 cm f = 12 cm i = ?

$1/f = 1/o + 1/i$

$i = 1 / (1/f - 1/o) = 1 / (1/12\text{ cm} - 1/24\text{ cm}) = 24\text{ cm}$

e. Draw three sets of principle rays to show the formation of the image in the lens alone and in the combination.

—Draw principal rays for the lens alone first. Use the image formed by the lens as the OBJECT for the mirror—

f. What are the characteristics of the image of the lens and of the lens/mirror combination?

The image formed by the lens alone is reduced, upright, and virtual.

The image formed by the combination is reduced, inverted, and virtual (a real image of a virtual image).