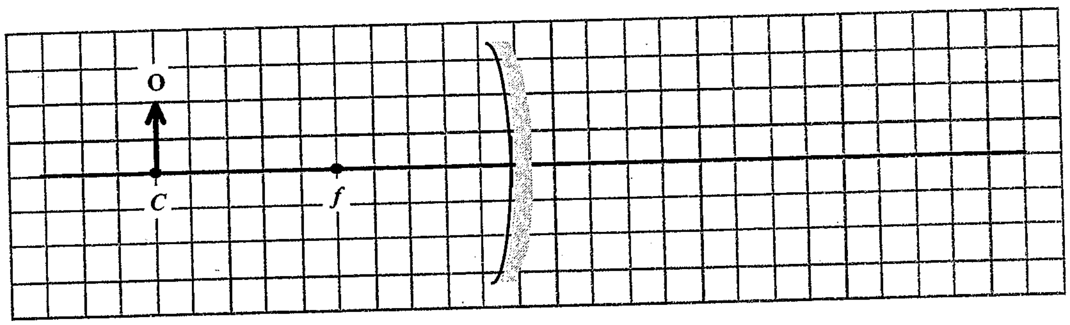
Key

PRACTICE EXERCISE

Formulas: $M = \frac{h_i}{h_o}$ $M = \frac{d_i}{d_o}$ $\frac{h_i}{h_o} = -\frac{d_i}{d_o}$ $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

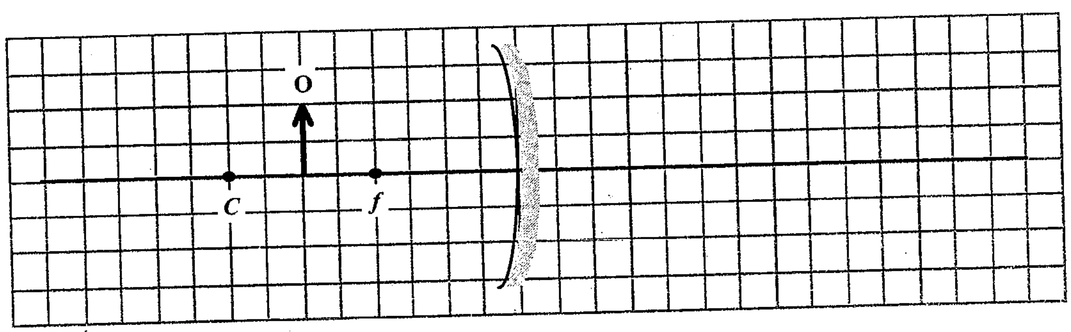
1. Complete the following ray diagrams and state the characteristics of the images (real/virtual, erect/inverted, larger/smaller/same size).

a)



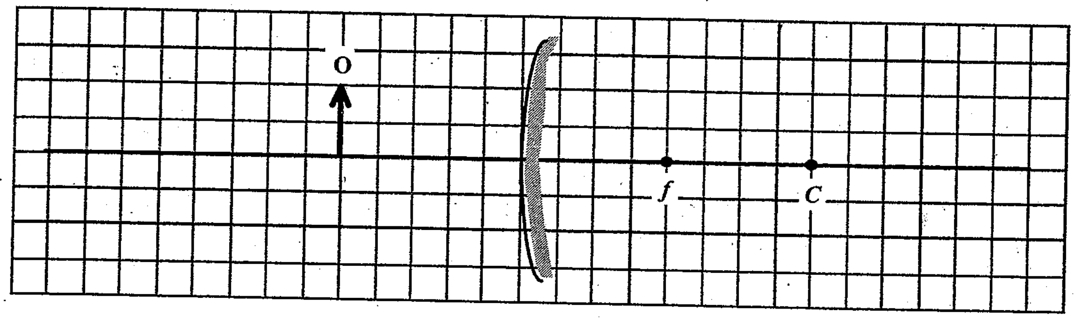
Characteristics:

b)



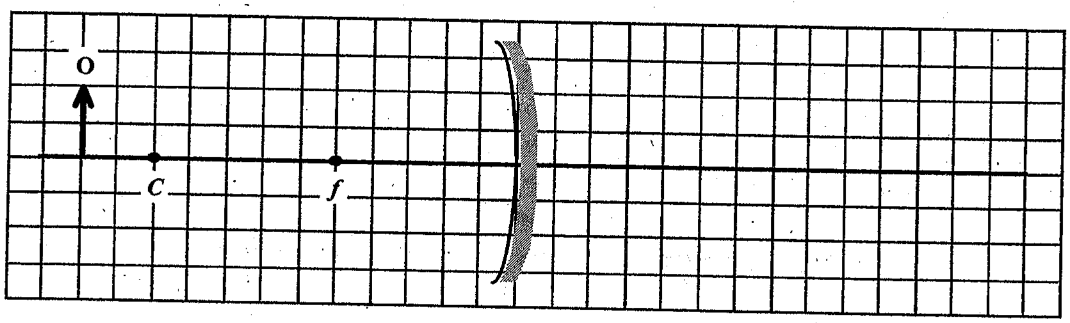
Characteristics:

c)



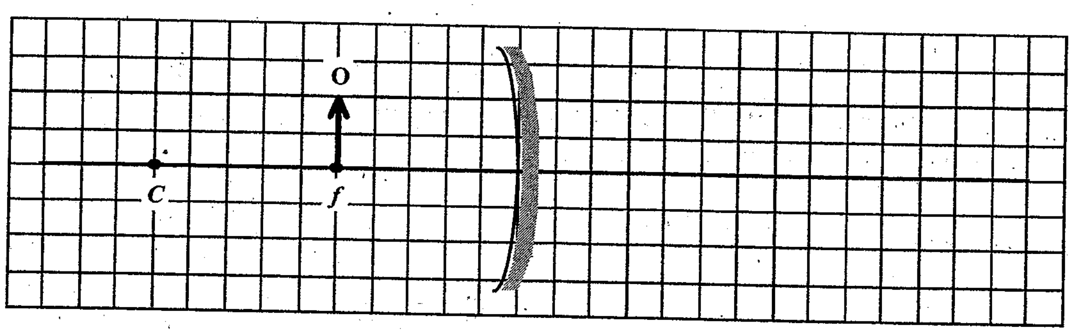
Characteristics:

d)



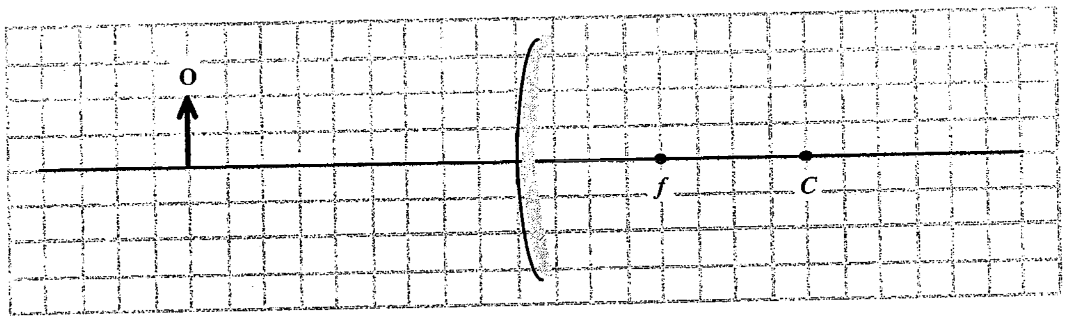
Characteristics:

e)



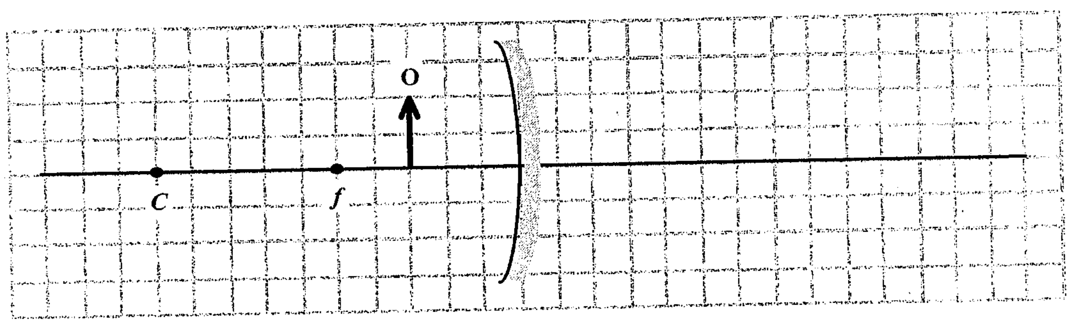
Characteristics:

f)



Characteristics:

g)



Characteristics:

2. A 5.0-cm tall object is placed 7.0 cm in front of a concave mirror. If a 5.0-cm real image is produced, what is the focal length of the mirror?

$h_o = 5.0\text{cm}$
$d_o = 7.0\text{cm}$
$h_i = (-)5.0\text{cm}$
$f = ?$

real image will be inverted.

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

$\therefore \frac{1}{f} = \frac{1}{7.0\text{cm}} + \frac{1}{7.0\text{cm}}$

$f = 3.5\text{cm}$

$d_i = ?$

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

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

$d_i = \frac{-(7.0\text{cm})(-5.0\text{cm})}{5.0\text{cm}}$

$d_i = 7.0\text{cm}$

3. A 3.0-cm tall object is placed 6.0 cm in front of a mirror. If a 1.0-cm tall virtual image is produced, what is the focal length of the mirror? What kind of mirror is used?

$h_o = 3.0\text{ cm}$
$d_o = 6.0\text{ cm}$
$h_i = 1.0\text{ cm}$
$f = ?$

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

$\therefore \frac{1}{f} = \frac{1}{(-2.0\text{ cm})} + \frac{1}{(6.0\text{ cm})}$

$f = -3.0\text{ cm}$

∴ convex mirror

$d_i = ?$

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

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

$d_i = -\frac{(1.0\text{ cm})(6.0\text{ cm})}{3.0\text{ cm}}$ $d_i = -2.0\text{ cm}$

4. A 9.0-cm tall object is placed at the focal point of a concave mirror. If the focal length is 5.0 cm, what is the size of the image?

$h_o = 9.0\text{ cm}$
$f = d_o = 5.0\text{ cm}$
$h_i = ?$

at $d_o = f$, no image is formed

5. A convex mirror produced ~~a 3.0-cm image~~ an image 3.0 cm behind the mirror. If the focal length of this mirror is 5.0 cm, at what distance from the mirror is the object placed?

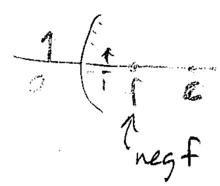
$d_i = -3.0\text{ cm}$ virtual
$f = -5.0\text{ cm}$
$d_o = ?$

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

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

$\frac{1}{d_o} = \frac{1}{-5.0\text{ cm}} - \frac{1}{-3.0\text{ cm}}$

$d_o = 7.5\text{ cm}$



6. An object is placed 8.0 cm in front of a convex mirror that has a radius of curvature of 8.0 cm. What is the magnification of this object?

$d_o = 8.0\text{ cm}$
$r = 8.0\text{ cm}$
$f = -4.0\text{ cm}$
$M = ?$

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

$M = -\frac{(-2.67\text{ cm})}{8.0\text{ cm}}$

$M = .33$

$d_i = ?$

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

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

$\frac{1}{d_i} = \frac{1}{-4.0\text{ cm}} - \frac{1}{8.0\text{ cm}}$

$d_i = -2.67\text{ cm}$

7. An object is placed 5.0 cm in front of a concave mirror. The magnification of the object is -2.5. If a real image is produced, what is the radius of curvature of the mirror?

$d_o = 5.0\text{ cm}$
$M = -2.5$
$r = ?$

$r = 2f$

$f = ?$

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

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

$d_i = -d_o M$

$d_i = -(5.0\text{ cm})(-2.5)$

$d_i = +12.5\text{ cm}$

$\frac{1}{f} = \frac{1}{12.5\text{ cm}} + \frac{1}{5.0\text{ cm}}$

$f = 3.6\text{ cm}$

$\therefore r = 2(3.6\text{ cm})$

$r = 7.1\text{ cm}$

8. A 4.0-cm tall object is placed 8.0 cm in front of a concave mirror. If the real image produced is – 6.0 cm tall, what is the focal length of the mirror?

$h_o = 4.0\text{ cm}$
$d_o = 8.0\text{ cm}$
$h_i = -6.0\text{ cm}$
$f = ?$

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

$\frac{1}{f} = \frac{1}{12\text{ cm}} + \frac{1}{8.0\text{ cm}}$

$f = +4.8\text{ cm}$

$d_i = ?$

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

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

$d_i = \frac{-(8.0\text{ cm})(-6.0\text{ cm})}{(4.0\text{ cm})}$

$d_i = 12\text{ cm}$

9. A 3.0-cm tall object produces a 2.0-cm tall virtual image. If the image is 2.5 cm behind the mirror, what is the focal length of the mirror? What kind of mirror is used?

$h_o = 3.0\text{ cm}$
$h_i = +2.0\text{ cm}$
$d_i = -2.5\text{ cm}$
$f = ?$

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

$\frac{1}{f} = \frac{1}{-2.5\text{ cm}} + \frac{1}{+3.75\text{ cm}}$

$f = -7.5\text{ cm}$ ← Convex

$d_o = ?$

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

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

$d_o = \frac{-(-2.5\text{ cm})(3.0\text{ cm})}{(2.0\text{ cm})}$

$d_o = +3.75\text{ cm}$

Convex mirror will always $d_i < d_o$
• Concave mirror will produce virt image where $d_i > d_o$

10. A 5.0-cm tall object produces an image that is 7.0 cm behind the mirror. If the radius of curvature of this mirror is 10.0 cm, what is the magnification of the object? What kind of mirror is used? Concave

$h_o = 5.0\text{ cm}$
$d_i = -7.0\text{ cm}$
$r = 10.0\text{ cm}$
$f = 5.0\text{ cm}$
$M = ?$

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

$\therefore M = \frac{-7.0\text{ cm}}{2.92\text{ cm}}$

$M = +2.4x$

$d_o = ?$

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

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

$\frac{1}{d_o} = \frac{1}{5.0\text{ cm}} - \frac{1}{-7.0\text{ cm}}$

$d_o = 2.92\text{ cm}$

Virtual Images with Mirrors
Convex: $d_i < d_o$, always
Concave: $d_i > d_o$
$\therefore$ this is a concave mirror.

11. A student wishes to place an object in front of a concave mirror to produce an inverted image one-half the object's size. If the focal length of the mirror is 5.0 cm, how far from the mirror should the object be placed?

$h_i = -.5 h_o$
$f = +5.0\text{ cm}$
$d_o = ?$

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

$\frac{-.5 h_o}{h_o} = \frac{-d_i}{d_o}$

$d_i = +.5 d_o$

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

$\frac{1}{f} = \frac{1}{.5 d_o} + \frac{1}{d_o}$

$\frac{1}{f} = \frac{+2}{d_o} + \frac{1}{d_o}$

$\frac{1}{5.0\text{ cm}} = \frac{3}{d_o}$

$d_o = +15.0\text{ cm}$

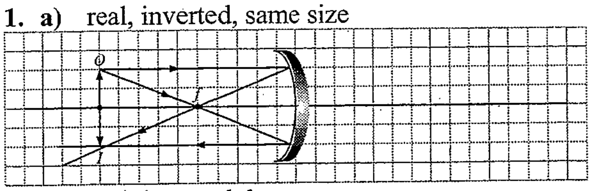
~~**12.**~~ An object is placed 2.0 cm beyond the centre of curvature of a concave mirror. If the magnification of this object is 0.30, what is the radius of curvature of this mirror?

Don't Do - Algebra nightmare!

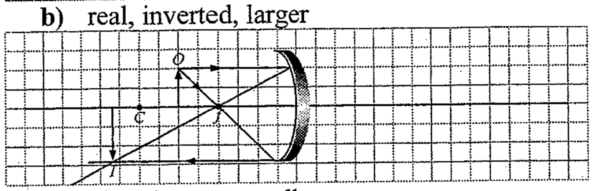
Lesson 4—Reflection from Curved Mirrors

PRACTICE EXERCISE
Answers and Solutions

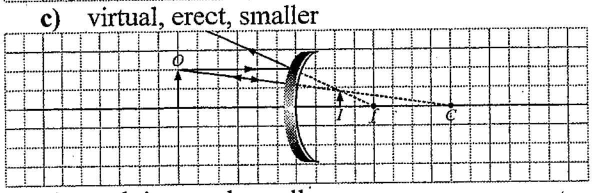
1. a) real, inverted, same size



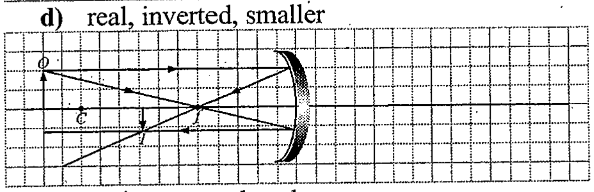
b) real, inverted, larger



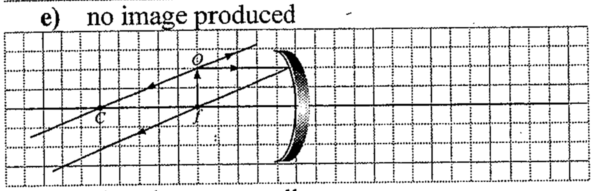
c) virtual, erect, smaller



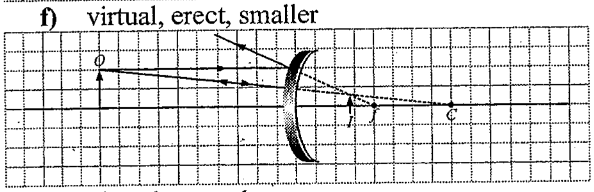
d) real, inverted, smaller



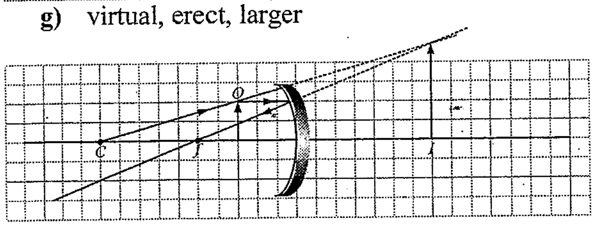
e) no image produced



f) virtual, erect, smaller



g) virtual, erect, larger



3. $\frac{h_i}{h_o} = -\frac{d_i}{d_o} \Rightarrow d_i = -\frac{h_i d_o}{h_o}$

$d_i = -\frac{(1.0\text{ cm})(6.0\text{ cm})}{(3.0\text{ cm})} = -2.0\text{ cm}$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{6.0\text{ cm}} + \frac{1}{(-2.0\text{ cm})} = -\frac{2}{6\text{ cm}}$

$f = -3.0$ cm, convex

Because the object was placed outside of the focal point and it still created a virtual image, the mirror must be a convex mirror.

5. $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \Rightarrow \frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i}$

$\frac{1}{d_o} = \frac{1}{5.0\text{ cm}} - \frac{1}{3.0\text{ cm}} = \frac{-2}{15\text{ cm}}$

$d_o = 7.5$ cm

7. $M = \frac{d_i}{d_o} \Rightarrow d_i = Md_o = 2.5(5.0\text{ cm}) = 12.5\text{ cm}$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{5.0\text{ cm}} + \frac{1}{12.5\text{ cm}} = \frac{7}{25.0\text{ cm}}$

$f = 3.6\text{ cm} \Rightarrow \text{O} = 7.1\text{ cm}$

9. $\frac{h_i}{h_o} = -\frac{d_i}{d_o} \Rightarrow d_o = -\frac{h_o d_i}{h_i} = -\frac{3.0\text{ cm}(-2.5\text{ cm})}{2.0\text{ cm}}$

$d_o = 3.75$ cm

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{3.75\text{ cm}} + \frac{1}{-2.5\text{ cm}} = \frac{-2}{15\text{ cm}}$

$f = \frac{-15\text{ cm}}{2} = -7.5$ cm, convex.

11. $M = \frac{d_i}{d_o} \Rightarrow d_o = \frac{d_i}{M} = 2d_i$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{2d_i} + \frac{1}{d_i} = \frac{3}{2d_i}$

$\frac{1}{f} = \frac{1}{5.0\text{ cm}} = \frac{3}{2d_i} \Rightarrow 15\text{ cm} = 2d$

$d_i = 7.5$ cm

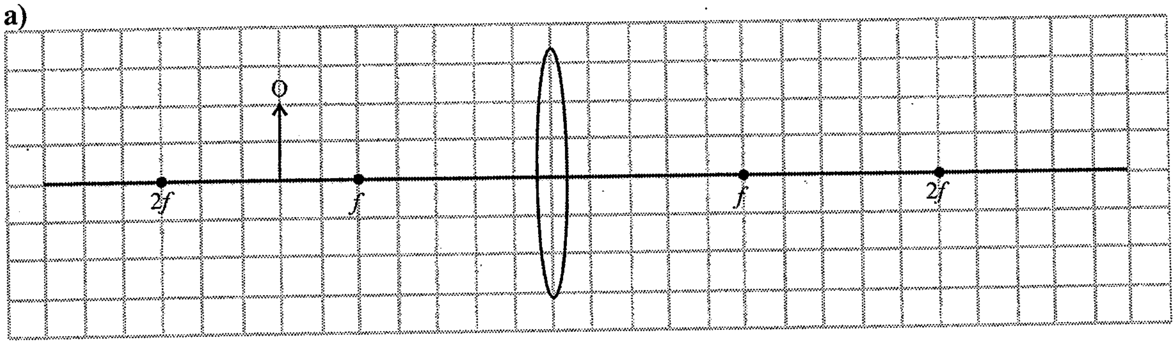
$d_o = 2d_i = 15$ cm

PRACTICE EXERCISE

Formulas: $M = \frac{h_i}{h_o}$ $M = \frac{d_i}{d_o}$ $\frac{h_i}{h_o} = \frac{d_i}{d_o}$ $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

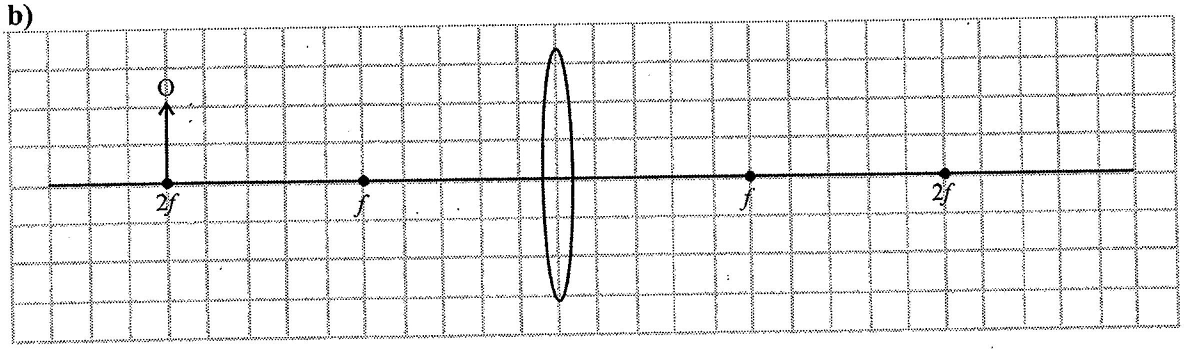
1. Complete the following ray diagrams and state the characteristics of the images (real/virtual, erect/inverted, larger/smaller/same size).

a)



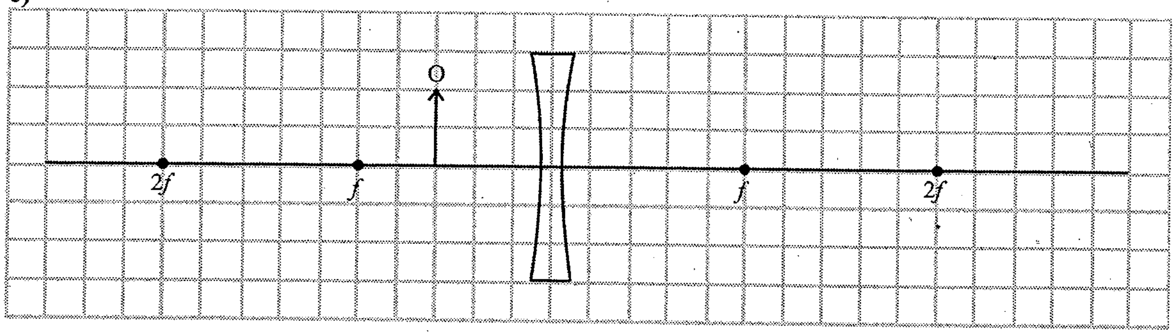
Characteristics:

b)



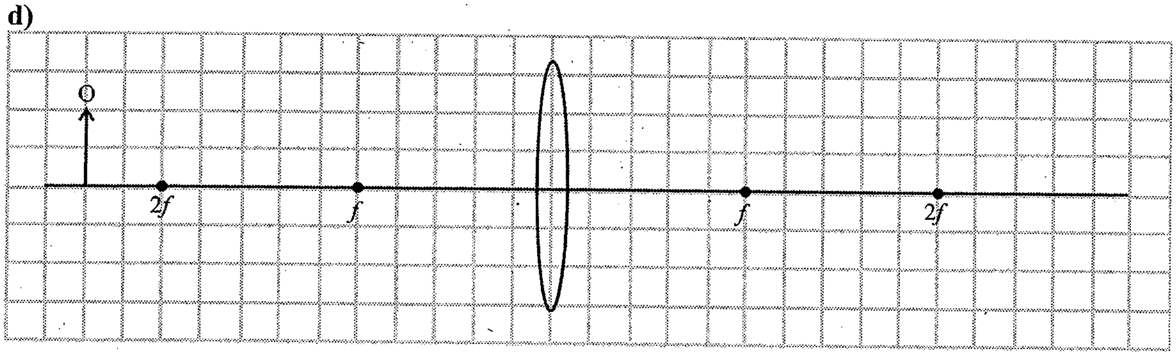
Characteristics:

c)



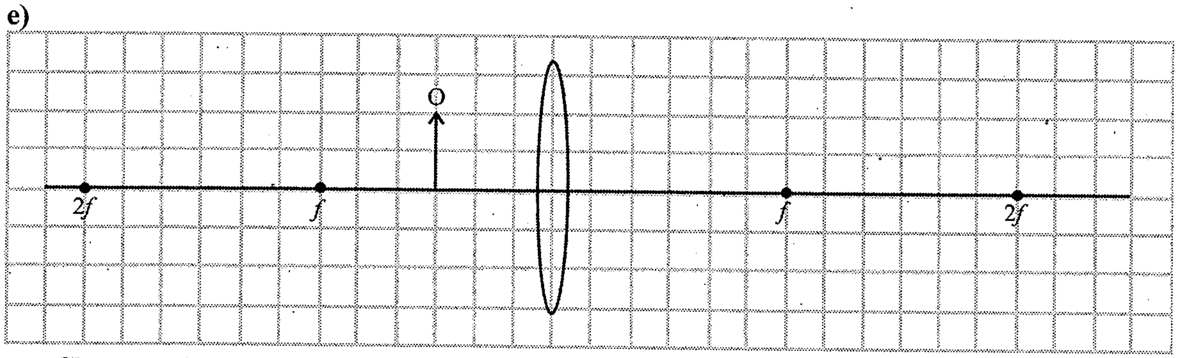
Characteristics:

d)



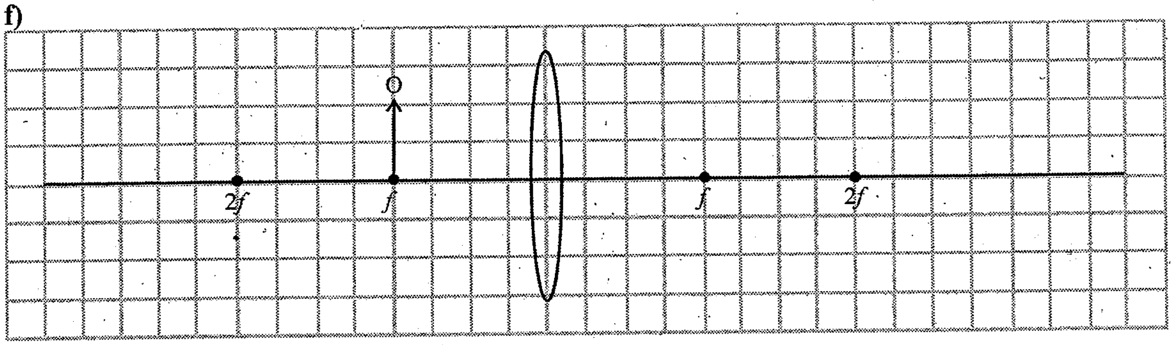
Characteristics:

e)



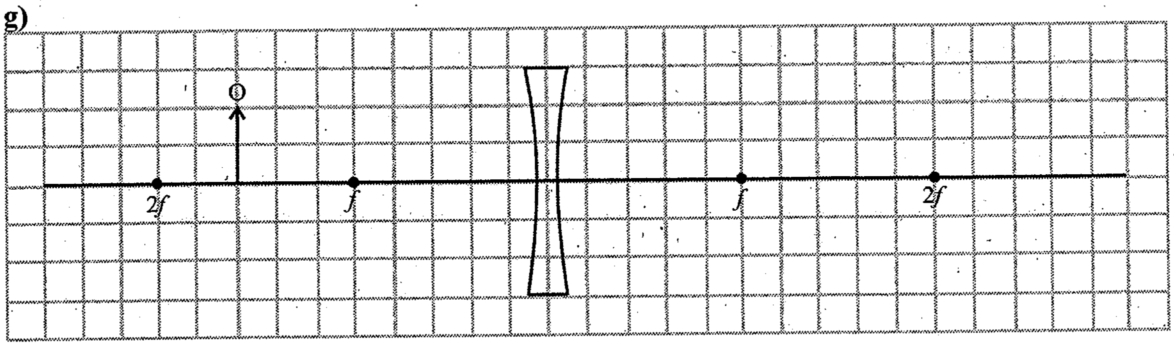
Characteristics:

f)



Characteristics:

g)



Characteristics:

2. A glowing, 6.0-cm tall object is placed 9.0 cm from a convex lens. If the lens has a focal length of 8.0 cm,

a) what is the distance of the image from the lens?

$h_o = 6.0\text{ cm}$
$d_o = 9.0\text{ cm}$
$f = +8.0\text{ cm}$
$d_i = ?$

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

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

$\frac{1}{d_i} = \frac{1}{8.0\text{ cm}} - \frac{1}{9.0\text{ cm}}$

$d_i = +72\text{ cm}$

b) what is the size of the image?

$h_i = ?$

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

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

$h_i = -\frac{(6.0\text{ cm})(72\text{ cm})}{(9.0\text{ cm})}$

$h_i = -48\text{ cm}$

c) what are the characteristics of the image?

Real Inverted larger

3. A glowing, 5.0-cm tall object is placed 4.5 cm from a concave lens. If the lens has a focal length of 4.5 cm,

a) what is the distance of the image from the lens?

$h_o = 5.0\text{ cm}$
$d_o = 4.5\text{ cm}$
$f = -4.5\text{ cm}$
$d_i = ?$

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

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

$\frac{1}{d_i} = \frac{1}{-4.5\text{ cm}} - \frac{1}{4.5\text{ cm}}$

$d_i = -2.3\text{ cm}$

b) what is the size of the image?

$h_i = ?$

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

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

$h_i = \frac{-(-2.3\text{ cm})(5.0\text{ cm})}{(4.5\text{ cm})}$

$h_i = +2.5\text{ cm}$

c) what are the characteristics of the image?

Virtual, erect, larger

4. A glowing, 3.0-cm tall object is placed 6.0 cm from a concave lens. If a virtual image is produced that is 1.0 cm tall, what is the focal length of the lens?

$h_o = 3.0\text{ cm}$
$d_o = 6.0\text{ cm}$
$h_i = +1.0\text{ cm}$
$f = ?$

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

$\frac{1}{f} = \frac{1}{-2.0\text{ cm}} + \frac{1}{6.0\text{ cm}}$

$f = -3.0\text{ cm}$

$d_i = ?$

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

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

$d_i = -\frac{(1.0\text{ cm})(6.0\text{ cm})}{(3.0\text{ cm})}$

$d_i = -2.0\text{ cm}$

5. A glowing, 2.0-cm tall object is placed 5.0 cm from a lens. If a virtual image is produced that is 4.0 cm tall, what is the focal length of the lens? What kind of lens is used?

$h_o = 2.0\text{ cm}$
$d_o = 5.0\text{ cm}$
$h_i = +4.0\text{ cm}$
$f = ?$

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

$\therefore \frac{1}{f} = \frac{1}{-10\text{ cm}} + \frac{1}{5.0\text{ cm}}$

$f = +10\text{ cm}$

$\therefore$ convex

$d_i = ?$

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

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

$d_i = -\frac{(4.0\text{ cm})(5.0\text{ cm})}{(2.0\text{ cm})}$

$d_i = -10\text{ cm}$

6. A glowing, 8.0-cm tall object is placed 11.0 cm in front of a convex lens. If the focal length is 5.5 cm, what is the magnification of the object?

$h_o = 8.0\text{ cm}$
$d_o = 11.0\text{ cm}$
$f = +5.5\text{ cm}$
$M = ?$

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

$\therefore M = -\frac{11\text{ cm}}{11\text{ cm}}$

$M = -1.0$

$d_i = ?$

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

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

$\frac{1}{d_i} = \frac{1}{5.5\text{ cm}} - \frac{1}{11.0\text{ cm}}$

$d_i = 11\text{ cm}$

produces virtual image always!

7. A concave lens produces an image that is 2.5 cm from the lens. If the focal length of this lens is 6.0 cm, at what distance from the lens is the object?

$d_i = -2.5\text{cm}$
$f = -6.0\text{cm}$
$d_o = ?$

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

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

$\frac{1}{d_o} = \frac{1}{-6.0\text{cm}} - \frac{1}{-2.5\text{cm}}$

$d_o = 4.3\text{cm}$

8. A glowing object is 8.0 cm from a concave lens that has a focal length of 4.0 cm. What is the magnification of this object?

$d_o = 8.0\text{cm}$
$F = -4.0\text{cm}$
$M = ?$

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

$\therefore M = \frac{-(-2.7\text{cm})}{8.0\text{cm}}$

$M = 0.33$

$d_i = ?$

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

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

$\frac{1}{d_i} = \frac{1}{-4.0\text{cm}} - \frac{1}{8.0\text{cm}}$

$d_i = -2.7\text{cm}$

9. A glowing object is 7.0 cm from a convex lens. If a real image is produced that is 2.0 times larger than the object, what is the focal length of the lens?

$d_o = 7.0\text{cm}$
$M = -2.0$
$f = ?$

because convex lens produces an inverted image

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

$\therefore \frac{1}{f} = \frac{1}{14\text{cm}} + \frac{1}{7\text{cm}}$

$f = 4.7\text{cm}$

$d_i = ?$

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

$d_i = -d_o M$

$d_i = -(7.0\text{cm})(-2.0)$

$d_i = +14.0\text{cm}$

10. A glowing, 4.0-cm tall object is 9.0 cm from a convex lens. If the real image produced is 6.0-cm tall, what is the focal length of the lens?

$h_o = 4.0\text{cm}$
$d_o = 9.0\text{cm}$
$h_i = -6.0\text{cm}$
$f = ?$

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

$\therefore \frac{1}{f} = \frac{1}{13.5\text{cm}} + \frac{1}{9.0\text{cm}}$

$f = 5.4\text{cm}$

$d_i = ?$

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

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

$d_i = -\frac{(-6.0\text{cm})(9.0\text{cm})}{(4.0\text{cm})}$

$d_i = 13.5\text{cm}$

11. A glowing, 3.0-cm tall object is 7.0 cm from a convex lens. If the virtual image produced is 6.0-cm tall, what is the focal length of the lens?

virtual has to be erect.

$h_o = 3.0\text{cm}$
$d_o = 7.0\text{cm}$
$h_i = +6.0\text{cm}$
$f = ?$

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

$\therefore \frac{1}{f} = \frac{1}{-14\text{cm}} + \frac{1}{7.0\text{cm}}$

$f = 14\text{cm}$

$d_i = ?$

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

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

$d_i = -\frac{(7.0\text{cm})(6.0\text{cm})}{(3.0\text{cm})}$

$d_i = -14\text{cm}$

12. A glowing, 3.0-cm tall object produces a virtual image 2.0-cm tall. If the image is 3.0 cm from the lens, what is the focal length of the lens? What kind of lens is used?

virtual

$h_o = 3.0\text{cm}$
$h_i = +2.0\text{cm}$
$d_i = -3.0\text{cm}$
$f = ?$
type = ?

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

$\therefore \frac{1}{f} = \frac{1}{-3.0\text{cm}} + \frac{1}{4.5\text{cm}}$

$f = -9.0\text{cm}$

concave lens, virtual F

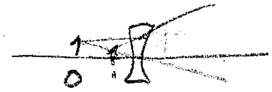
$d_o = ?$

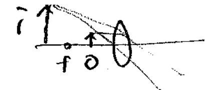
$\frac{h_i}{h_o} = -\frac{d_i}{d_o}$

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

$d_o = -\frac{(-3.0\text{cm})(3.0\text{cm})}{(+2.0\text{cm})}$

$d_o = 4.5\text{cm}$





makes smaller image and $d_i < d_o$ — makes bigger image and $d_i > d_o$

(3.04)

13. A glowing, 6.0-cm tall object produces a virtual image 6.0 cm from the lens. If the focal length of the lens is 4.0 cm, what is the magnification of the object? What kind of lens is used?

$h_o = 6.0$ cm
$d_i = -6.0$ cm
$f = +4.0$ cm
type?
must be convex (above)

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

$\therefore M = -\frac{(-6.0\text{ cm})}{(2.4\text{ cm})}$

$M = +2.5$

$d_o = ?$

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

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

$\frac{1}{d_o} = \frac{1}{4.0\text{ cm}} - \frac{1}{-6.0}$

$d_o = 2.4$ cm

14. A student wishes to place ~~a glowing~~ object at a distance from a convex lens to produce an image one-third the size of the object. If the focal length of the lens is 6.0 cm, how far from the lens should the object be placed?

$d_i = \frac{1}{3} d_o$
$f = +6.0$ cm
$d_o = ?$

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

$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{3d_i}$

$\frac{1}{f} = \frac{4}{3d_i}$

$d_i = \frac{4}{3} f$

$d_i = \frac{4}{3}(6.0\text{ cm})$ $d_i = 8.0$ cm

$d_i = \frac{1}{3} d_o$

$d_o = 3 d_i$

$\therefore d_o = 3(8.0\text{ cm})$

$d_o = 24$ cm

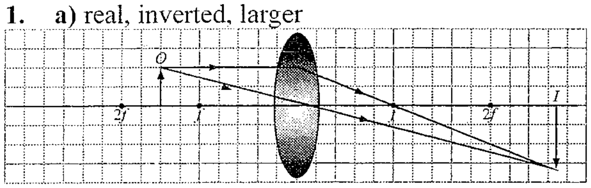
~~**15.**~~ A compound microscope has two convex lenses that are 10.0 cm apart: the objective lens ($f = 1.6$ cm) and the eyepiece ($f = 3.0$ cm). If the object being studied is 1.5-cm tall and it is placed 2.0 cm from the objective lens, what is the magnification produced by this instrument?

Don't Do

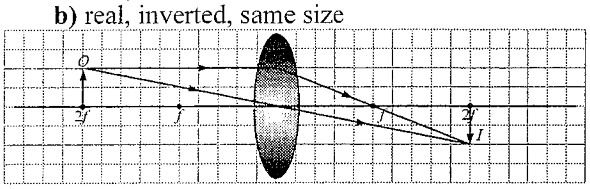
Lesson 5—Lenses

PRACTICE EXERCISE
Answers and Solutions

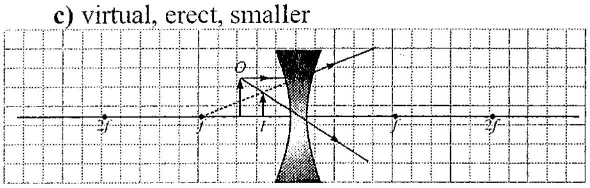
1. **a)** real, inverted, larger



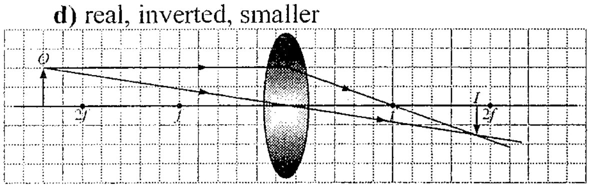
b) real, inverted, same size



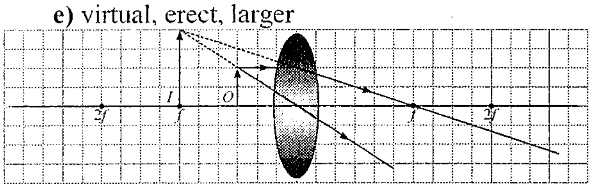
c) virtual, erect, smaller



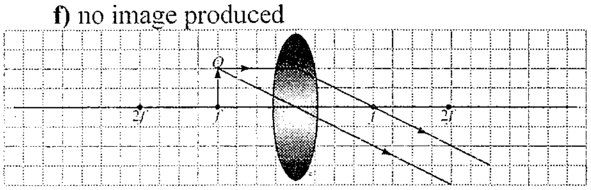
d) real, inverted, smaller



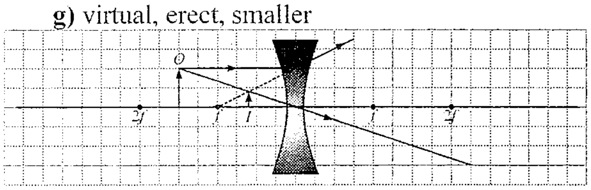
e) virtual, erect, larger



f) no image produced



g) virtual, erect, smaller



3. **a)** $\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}\Rightarrow\frac{1}{d_i}=\frac{1}{f}-\frac{1}{d_o}$

Note: the focus is virtual, so it is negative.

$$\frac{1}{d_i}=\frac{1}{-4.5\text{ cm}}-\frac{1}{4.5\text{ cm}}=-\frac{2}{4.5\text{ cm}}$$

$$d_i=-2.3\text{ cm}$$

b) $\frac{h_i}{h_o}=-\frac{d_i}{d_o}\Rightarrow h_i=-\frac{d_i h_o}{d_o}$

$$h_i=-\frac{(-2.3\text{ cm})(5.0\text{ cm})}{4.5\text{ cm}}=2.5\text{ cm}$$

c) virtual, erect, smaller

5. $\frac{h_i}{h_o}=-\frac{d_i}{d_o}\Rightarrow d_i=-\frac{h_i d_o}{h_o}$

$$d_i=-\frac{(4.0\text{ cm})(5.0\text{ cm})}{2.0\text{ cm}}=-10\text{ cm}$$

$$\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{5.0\text{ cm}}+\frac{1}{-10\text{ cm}}=\frac{1}{10\text{ cm}}$$

$f=10$ cm, convex

7. $\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}\Rightarrow\frac{1}{d_o}=\frac{1}{f}-\frac{1}{d_i}$

$$\frac{1}{d_o}=\frac{1}{-6.0\text{ cm}}-\frac{1}{-2.5\text{ cm}}=0.23\text{ cm}^{-1}$$

$$d_o=4.3\text{ cm}$$

9. $M=\frac{d_i}{d_o}\Rightarrow d_i=Md_o$

$$d_i=(2.0)(7.0\text{ cm})=14\text{ cm}$$

$$\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{7.0\text{ cm}}+\frac{1}{14\text{ cm}}=\frac{3}{14\text{ cm}}$$

$$f=4.7\text{ cm}$$

11. $\frac{h_i}{h_o}=-\frac{d_i}{d_o}\Rightarrow d_i=-\frac{h_i d_o}{h_o}$

$$d_i=-\frac{(6.0\text{ cm})(7.0\text{ cm})}{3.0\text{ cm}}=-14\text{ cm}$$

$$\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{7.0\text{ cm}}+\frac{1}{(-14\text{ cm})}=\frac{1}{14\text{ cm}}$$

$$f=14\text{ cm}$$

13. $\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}\Rightarrow\frac{1}{d_o}=\frac{1}{f}-\frac{1}{d_i}$

$\frac{1}{d_o}=\frac{1}{4.0\text{ cm}}-\frac{1}{6.0\text{ cm}}=\frac{5}{12\text{ cm}}$

$d_o=2.4\text{ cm}$

$M=\frac{d_i}{d_o}=\frac{6.0\text{ cm}}{2.4\text{ cm}}=2.5$

15. $\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}\Rightarrow\frac{1}{d_i}=\frac{1}{f}-\frac{1}{d_o}$

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

for the objective lens:

$\frac{1}{d_i}=\frac{1}{f}-\frac{1}{d_o}=\frac{1}{1.6\text{ cm}}-\frac{1}{2.0\text{ cm}}=\frac{1}{8}\text{ cm}^{-1}$

$d_i=8.0\text{ cm}$

$h_i=-\frac{d_i h_o}{d_o}=-\frac{(8.0\text{ cm})(1.5\text{ cm})}{2.0\text{ cm}}$

$h_i=-6.0\text{ cm}$

for the eyepiece:

$\frac{1}{d_i}=\frac{1}{f}-\frac{1}{d_o}=\frac{1}{3.0\text{ cm}}-\frac{1}{2.0\text{ cm}}=-\frac{1}{6}\text{ cm}^{-1}$

$d_i=-6.0\text{ cm}$

$h_i=-\frac{d_i h_o}{d_o}=-\frac{(6.0\text{ cm})(-6.0\text{ cm})}{2.0\text{ cm}}$

$h_i=18\text{ cm}$

so the total magnification is:

$M=\frac{h_i}{h_o}=\frac{18\text{ cm}}{1.5\text{ cm}}=12$

Lesson 6—The Wave Nature of Light

PRACTICE EXERCISE
Answers and solutions

1. $\lambda=\frac{d\sin\theta}{n}\Rightarrow\sin\theta=\frac{n\lambda}{d}$

$\sin\theta=\frac{(1)(4.10\times10^{-7}\text{ m})}{6.00\times10^{-6}\text{ m}}$

$=6.83\times10^{-2}$

$\theta=3.92°$

3. $\lambda=\frac{d\sin\theta}{n}\Rightarrow d=\frac{n\lambda}{\sin\theta}$

$d=\frac{(1.5)(5.30\times10^{-7}\text{ m})}{\sin16.0°}$

$=2.88\times10^{-6}\text{ m}$

$\frac{x}{1\text{ m}}=\frac{1\text{ line}}{2.88\times10^{-6}\text{ m}}$

$x=3.47\times10^{5}\text{ lines/m}$

5. $d=\frac{1}{5.00\times10^{4}\text{ lines/m}}=2.00\times10^{-5}\text{ m}$

$\lambda=\frac{dx}{nl}$

$=\frac{(2.00\times10^{-5}\text{ m})(3.11\times10^{-2}\text{ m})}{(1)(1.5\text{ m})}$

$=4.15\times10^{-7}\text{ m}$

7. $d=\frac{1}{5.00\times10^{5}\text{ lines/m}}=2.00\times10^{-6}\text{ m}$

$\lambda=\frac{d\sin\theta}{n}\Rightarrow n=\frac{d\sin\theta}{\lambda}$

$n=\frac{(2.00\times10^{-6}\text{ m})\sin\theta}{(5.80\times10^{-7}\text{ m})}$

$n=3.45\sin\theta$

The maximum value of $\sin\theta$ is 1, so the maximum value of n is 3.45; however, n must be a whole number, so the number of orders of maxima that can be observed is 3.

9.

$\lambda=\frac{c}{f}=\frac{3.00\times10^{8}\text{ m/s}}{6.50\times10^{14}\text{ Hz}}=4.62\times10^{-7}\text{ m}$

$d=\frac{1}{4.00\times10^{4}\text{ lines/m}}=2.50\times10^{-5}\text{ m}$

$\lambda=\frac{dx}{nl}\Rightarrow x=\frac{\lambda nl}{d}$

$x=\frac{(4.62\times10^{-7}\text{ m})(1)(1.10\text{ m})}{2.50\times10^{-5}\text{ m}}$

$x=2.03\times10^{-2}\text{ m}$