The numerical values in the solution above were rounded when written down, yet unrounded numbers were used in all calculations. The final answer is rounded to the third significant digit.

To determine the image height, the magnification equation is needed. Since three of the four quantities in the equation (disregarding the M) are known, the fourth quantity can be calculated. The solution is shown below.

$h_i/h_o = - d_i/d_o$

$h_i/(4.0 \text{ cm}) = - (-18.2 \text{ cm})/(8.3 \text{ cm})$

$h_i = - (4.0 \text{ cm}) * (-18.2 \text{ cm})/(8.3 \text{ cm})$

$h_i = 8.8$ cm

The negative value for image distance indicates that the image is a virtual image located behind the mirror. Again, a negative or positive sign in front of the numerical value for a physical quantity represents information about direction. In the case of the image distance, a negative value always means behind the mirror. Note also that the image height is a positive value, meaning an upright image. Any image which is upright and located behind the mirror is considered to be a virtual image.

From the calculations in the second sample problem it can be concluded that if a 4.0-cm tall object is placed 8.3 cm from a concave mirror having a focal length of 15.2 cm, then the image will be enlarged, upright, 8.8-cm tall and located 18.3 cm behind the mirror. The results of this calculation agree with the principles discussed earlier in this lesson. In this case, the object is located in front of the focal point (i.e., the object distance is less than the focal length), and the image is located behind the mirror. This falls into the category of Case 5: The object is located in front of F.

2

1. Determine the image distance and image height for a 5-cm tall object placed 45.0-cm from a concave mirror having a focal length of 15.0 cm.

di = ?
hi = ?
ho = 5cm
do = 45.0cm
f = 15.0

$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \rightarrow \frac{1}{45.0\text{cm}} + \frac{1}{d_i} = \frac{1}{15.0\text{cm}}$

$\frac{1}{d_i} = \frac{1}{15.0\text{cm}} - \frac{1}{45.0\text{cm}} \rightarrow \frac{1}{d_i} = 0.067 - 0.022$

$\frac{1}{d_i} = 0.045 \text{ cm}^{-1} \rightarrow d_i = 22.2 \text{ cm}$

$\frac{h_i}{h_o} = -\frac{d_i}{d_o} \rightarrow h_i = (-d_i)(h_o)/(d_o)$

$= (-22.2\text{cm})(5\text{cm})/(45.0\text{cm})$

$h_i = -2.47$ cm (∴ inverted)

2. Determine the image distance and image height for a 5-cm tall object placed 30.0-cm from a concave mirror having a focal length of 15.0 cm.

1/2

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

$h_i = \frac{-(d_i)(5)}{30}$ $\frac{1}{30} + \frac{1}{d_i} = \frac{1}{15} \rightarrow \frac{1}{d_i} = \frac{1}{15} - \frac{1}{30}$

$h_i = -0.167\, d_i$ $\frac{1}{d_i} = 0.033$

$h_i = -0.167\,(30cm)$ $d_i = 30cm$ real

$h_i = -5.01\,cm$ (∴ inverted)

3. Determine the image distance and image height for a 5-cm tall object placed 20.0-cm from a concave mirror having a focal length of 15.0 cm.

1/2

$\frac{h_i}{h_o} = -\frac{d_i}{d_o}$ $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \rightarrow \frac{1}{20} + \frac{1}{d_i} = \frac{1}{15}$

$\frac{1}{d_i} = \frac{1}{15} - \frac{1}{20}$

$\frac{h_i}{5} = -\frac{60}{20}$ $\frac{1}{d_i} = 0.0166$

$h_i = -15cm$ (∴ inverted) $d_i = 60cm$ real

1/2

4. Determine the image distance and image height for a 5-cm tall object placed 10.0-cm from a concave mirror having a focal length of 15.0 cm.

$\frac{h_i}{h_o} = -\frac{d_i}{d_o}$ $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \rightarrow \frac{1}{10} + \frac{1}{d_i} = \frac{1}{15} \rightarrow \frac{1}{d_i} = \frac{1}{15} - \frac{1}{10}$

$\frac{1}{d_i} = -0.033$

$h_i = -\frac{(-30)(5)}{10} = 15cm$ UPRIGHT $d_i = -30cm$ virtual

5. A magnified, inverted image is located a distance of 32.0 cm from a concave mirror with a focal length of 12.0 cm. Determine the object distance and tell whether the image is real or virtual.

4/✓

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

$\frac{1}{d_o} + \frac{1}{32} = \frac{1}{12}$ $-\frac{32}{19.2} = M = -1.66$

$\frac{1}{d_o} = \frac{1}{12} - \frac{1}{32} = 0.052$

$d_o = 19.2\text{cm}$ ← d_o is +ive ∴ image is real

6. **ZINGER**: An inverted image is magnified by 2 when the object is placed 22 cm in front of a concave mirror. Determine the image distance and the focal length of the mirror.

$d_o = 22$ $M = -\frac{d_i}{d_o} \rightarrow -2 = \frac{-d_i}{22}$ $d_i = 44$

$M = -2$ $\frac{1}{f} = \frac{1}{22} + \frac{1}{44}$ $f = 14.67\text{cm}$

CONVEX MIRRORS - The Mirror Equations

1/✓

1. A convex mirror has a focal length of -10.8 cm. An object is placed 32.7 cm from the mirror's surface. Determine the image distance.

$f = -10.8\text{cm}$ $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \rightarrow \frac{1}{32.7} + \frac{1}{d_i} = \frac{1}{-10.8}$

$d_o = 32.7\text{cm}$ $\frac{1}{d_i} = -\frac{1}{10.8} - \frac{1}{32.7} \rightarrow \frac{1}{d_i} = -0.093 - 0.031$

$d_i = ?$

$d_i = -8.06\text{ cm}$

2. Determine the focal length of a convex mirror which produces an image which is 16.0 cm behind the mirror when the object is 28.5 cm from the mirror.

d_i → virtual ∴ -16.0cm

1/✓

$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ $\frac{1}{28.5} - \frac{1}{16.0} = \frac{1}{f}$ $f = -36.48\text{cm}$

3. A 2.8-cm diameter coin is placed a distance of 25.0 cm from a convex mirror which has a focal length of -12.0 cm. Determine the image distance and the diameter of the image.

h_o d_o f d_i h_i

$1/d_o + 1/d_i = 1/f \rightarrow 1/25 + 1/d_i = 1/-12.0 \rightarrow 1/d_i = -\frac{1}{12} - \frac{1}{25}$

$\frac{1}{d_i} = -0.123$ $d_i = -8.11\text{cm}$

$\frac{h_i}{h_o} = \frac{-d_i}{d_o}$ $h_i = \frac{-(-8.11)(2.8)}{25.0} = 0.908\text{cm}$

$h_i = 0.908\text{cm}$

4. The focal point is located 20.0 cm from a convex mirror. An object is placed 12 cm from the mirror. Determine the image distance.

Check

$f = -20\text{cm}$ d_i

$1/d_o + 1/d_i = 1/f \rightarrow \frac{1}{12} + \frac{1}{d_i} = -\frac{1}{20}$

$\frac{1}{d_i} = -\frac{1}{20} - \frac{1}{12}$ ~~$d_i = -30\text{cm}$~~ virtual

$\frac{1}{12} + \frac{1}{d_i} = -\frac{1}{20}$

$\frac{1}{d_i} = -\frac{1}{20} - \frac{1}{12}$

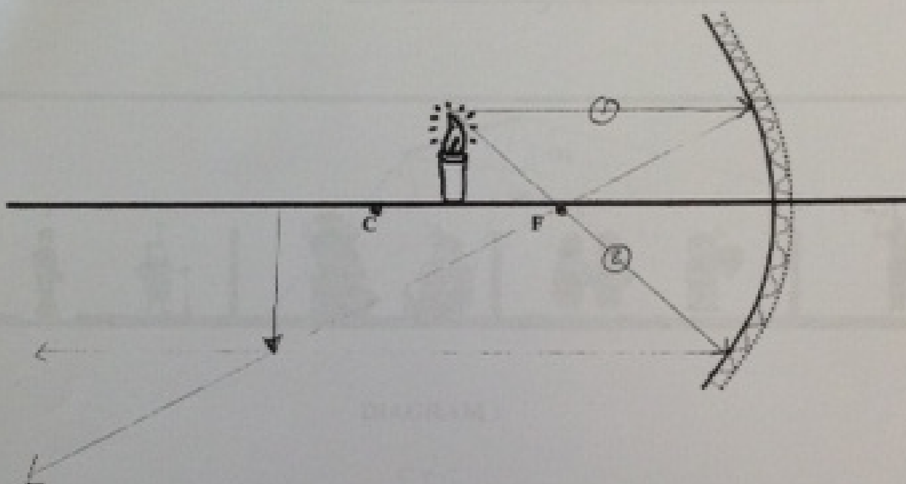
$\frac{1}{d_i} = -0.05 - 0.083 = -0.133$

$\frac{1}{d_i} = -0.133$ $= -7.5\text{cm}$

COMBINATION – Ray Diagrams & Mirror Equations

1. A candle 10 cm high (h_o) is placed 40 cm (d_o) in front of a concave mirror whose focal length is 30 cm (f). Find the distance, height, and nature (magnification and orientation) of the image.

4



ANSWER: Distance of image: 120 cm = d_i

Height of image: -30 cm = h_i

Nature of image: INVERTED, MAGNIFIED -3

MAGNIFICATION =

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

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \rightarrow \frac{1}{40} + \frac{1}{d_i} = \frac{1}{30}$$

$$\frac{1}{d_i} = \frac{1}{30} - \frac{1}{40} \rightarrow \frac{1}{d_i} = 0.0083$$

$$h_i = -\frac{(120)(10)}{40}$$

$$d_i = 120\text{ cm}$$

$$h_i = -30\text{cm}$$

$$M = \frac{h_i}{h_o} = \frac{-30}{10} = -3$$

2. Oscar, our security officer at Access, is on duty. Groups of students are gathered between walls placed at the side of the school. If Oscar is using a plane mirror in one situation, and a convex mirror in another situation (placed at the same height), which type of mirror would allow him the greatest field of vision? Oscar's eye (**O**) is located at the same distance from each of these mirrors. Using the appropriate ray diagrams on both of the figures below, indicate the fields of vision produced by each of the two mirrors. Determine whether Oscar will be able to see all of the students using each of the mirrors.

ANSWER – with the Plane Mirror: (3) PARTIALLY, (4)

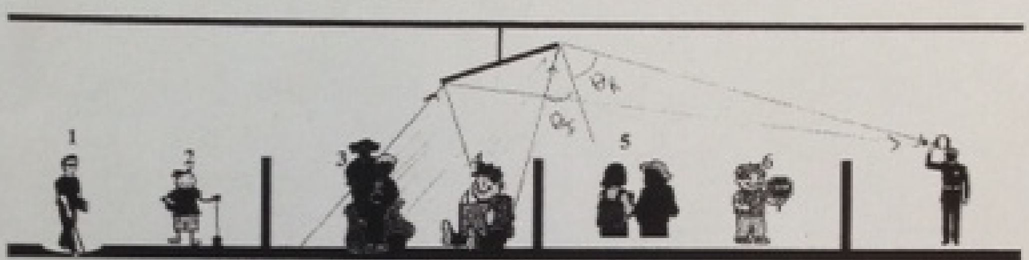


DIAGRAM 1

DIAGRAM 2

ANSWER – with the convex mirror: (1) (2) (3) (4) (5) (6)