Mirror Equation
(focal lengths and distances)

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

- Virtual images have negative distances
- Real images have positive distances
- Concave mirrors have positive focal lengths
- Convex mirrors have negative focal lengths

Determining Common Denominators

$\frac{1}{6} + \frac{1}{9}$

$\frac{9}{54} + \frac{6}{54}$

$\frac{15}{54}$

$= 0.278$

$\frac{1}{0.3} + \frac{1}{2.9}$

$\frac{2.9}{0.87} + \frac{0.3}{0.87}$

$\frac{3.2}{0.87} = 3.68$

Decimal Conversions

$\frac{1}{6} + \frac{1}{9}$ $\quad$ $\frac{1}{0.3} + \frac{1}{2.9}$

0.167 + 0.111 $\quad$ 3.33 + 0.345

0.278 $\quad$ 3.675

An object that is 20 cm tall is standing in front of a concave mirror with a focal length of 35cm. If the object is 5 cm in front of the mirror then how far away is the image and how tall is it?

$h_o = 20\,cm \quad d_o = 5\,cm$

$f = +35\,cm$

* $d_i = ?\ -5.83 \quad h_i = ?$

(A) Equation: $\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$

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

$\frac{1}{d_i} = \frac{1}{35} - \frac{1}{5}$

$= \frac{1}{35} - \frac{7}{35}$

$\frac{1}{d_i} = \frac{-6}{35}$ -0.17

$d_i = -\frac{35}{6}$ $-\frac{1}{0.17}$

$= -5.83\,cm$

(B) $h_i = ?$

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

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

$\left(\frac{h_i}{20\,cm}\right) = \frac{-(-5.83\,cm)(20\,cm)}{5\,cm}$

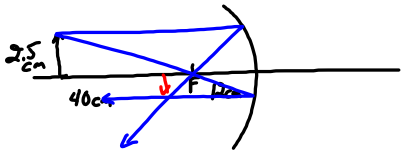
$h_i = \frac{(+5.83\,cm)(20\,cm)}{5\,cm}$

$= 23.32\,cm$

Sample Problem

f = 12 cm
do = 40 cm
ho = 2.5 cm

di = ?
hi = ?



17.1 cm

guess
d_i = 15-20 cm
h_i = -1 cm

Step 1: Formula options

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

Step 2: Rearrange formula

$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$ ($5 = 3 + 2$, $3 = 5 - 2$)

Step 3: Solve for d_i.

$\frac{1}{d_i} = \frac{1}{12} - \frac{1}{40}$

$= \frac{40 - 12}{12 \times 40}$

$\frac{1}{d_i} = \frac{28}{480}$

$\frac{1}{2} = \frac{2}{4}$

$\frac{2}{1} = \frac{4}{2}$

$d_i = \frac{480}{28}$

$d_i = 17.1$ cm

Step 4 solve for h_i

If $m = \frac{h_i}{h_o}$ and $m = \frac{-d_i}{d_o}$

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

Step 5 substitute

$2.5 \times \left(\frac{h_i}{2.5\text{ cm}}\right) = \left(\frac{-(17.1)}{40\text{ cm}}\right) \times 2.5$

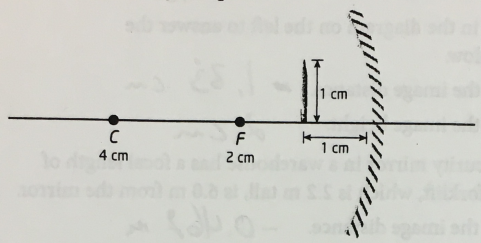
$h_i = \frac{-(17.1)(2.5)}{40}$

$= -1.1$ cm

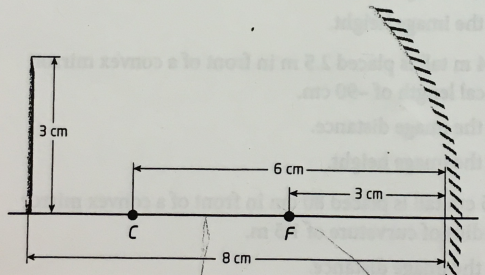
Practice Problems

1. A concave mirror has a focal length of 6.0 cm. An object with a height of 0.60 cm is placed 10.0 cm in front of the mirror.
   a. Calculate the image distance. 15 cm
   b. Calculate the image height. −0.9 cm

2. In the diagram below, the object is between the mirror and *F*. Use the data in the diagram to answer the questions below.
   a. Calculate the image distance. −2 cm
   b. Calculate the image height. 2 cm



3. In the diagram below, the object is beyond *C*. Use the data in the diagram to answer the questions below.
   a. Calculate the image distance. 4.8 cm
   b. Calculate the height of the image. − 1.8 cm



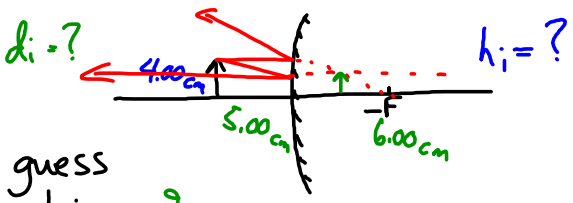
$\frac{4.8}{8} = \frac{c}{3}$ $\frac{1}{3} - \frac{1}{8}$ $\frac{8-3}{24}$ $\frac{24}{5}$

4. A dancer is applying make-up using a concave mirror. The dancer's face is 35 cm in front of the mirror, and the image is 72 cm behind the mirror. Use the mirror equation to calculate the focal length of the mirror. 68 cm

5. A concave mirror magnifies an object placed 30.0 cm from the mirror by a factor of +3.0. Calculate the radius of curvature of the mirror. 90 cm

Mirror Equation: Convex Mirrors

A 4.00 cm tall stick is placed 5.00 cm in front of a convex mirror. The focal length is 6.00 cm. What is the distance and height of the image formed?



guess

$h_i = 2$ cm

$d_i = -3$ cm

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

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

Solve for d_i

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

$$\frac{1}{d_i} = \frac{1}{-6.00} - \frac{1}{5.00}$$

(alter) $$\frac{1}{d_i} = -\frac{1}{6.00} - \frac{1}{5.00}$$

$$\frac{1}{d_i} = \frac{-5.00 - 6.00}{6 \times 5}$$

$$\frac{1}{d_i} = \frac{-11}{30}$$

$$d_i = -\frac{30}{11}$$

$$d_i = -2.73 \text{ cm}$$

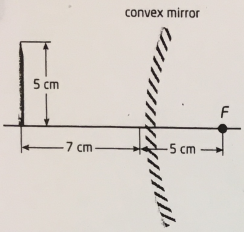
Solve for h_i

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

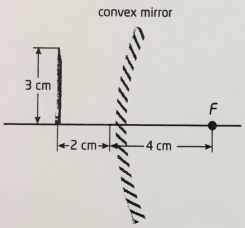
$$\frac{h_i}{4.0 \text{ cm}} = \frac{-(-2.73 \text{ cm})}{5.00}$$

$$h_i = \frac{(4)(2.73)}{5}$$

$$= +2.18 \text{ cm}$$



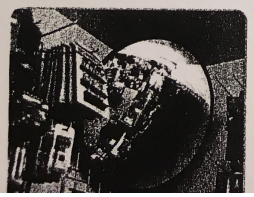
Use this diagram to solve problem 2.



Use this diagram to solve problem 3.

Practice Problems

1. A convex mirror has a focal length of −0.90 m. An object with a height of 0.40 m is 2.5 m from the mirror.
   a. Calculate the image distance. -0.64 m
   b. Calculate the image height. 0.1056 m
2. Use the data in the diagram on the left to answer the questions below.
   a. Calculate the image distance. −2.92
   b. Calculate the image height of the image. 2.08
3. Use the data in the diagram on the left to answer the questions below.
   a. Calculate the image distance. = 1.33 cm
   b. Calculate the image height. 2 cm
4. A convex security mirror in a warehouse has a focal length of −0.50 m. A forklift, which is 2.2 m tall, is 6.0 m from the mirror.
   a. Calculate the image distance. −0.462 m
   b. Calculate the image height. 0.1694 m
5. A convex security mirror has a focal length of −0.25 m. A person with a height of 1.5 m is 4.0 m from the mirror.
   a. Calculate the image distance.
   b. Calculate the image height.
6. An object 0.4 m tall is placed 2.5 m in front of a convex mirror that has a focal length of −90 cm.
   a. Calculate the image distance.
   b. Calculate the image height.
7. An object 25 cm tall is placed 80 cm in front of a convex mirror that has a radius of curvature of 1.5 m.
   a. Calculate the image distance.
   b. Calculate the image height.



Applications of Convex Surfaces

You have probably seen mirrors like the one in **Figure 10.27** in convenience stores. The image is quite distorted, but this convex security mirror allows a clerk in the store to see a very large area. If the store is small, the clerk can stand at the till and see almost everything in the store