

## MIRROR AND MAGNIFICATION EQUATION

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### Curved Mirror Equation

Ray diagrams for mirrors take a considerable time to draw and are prone to errors.

A mathematical equation may be derived that relates the position of the object, the position of the image and the focal length of a curved mirror, either for a converging or a diverging mirror. The equation is:

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

where  $d_o$  is the object distance (distance of the object from the vertex)  
 $d_i$  is the image distance (distance of the image from the vertex)  
 $f$  is the focal length of the mirror.

Given any two of these quantities, the equation can be used to solve for the third.

### Magnification Equation

Magnification,  $m$ , is defined as the ratio between the size of the image and the size of the object i.e. it is the measure of how much larger or smaller an image is compared with the object itself.

$$\text{magnification, } m = \frac{\text{height of image}}{\text{height of object}} = \frac{h_i}{h_o}$$

If the magnification is 1, the image is the same size as the object,

A magnification of more than 1 means that the image is larger than the object.

A magnification of less than 1 means that the image is reduced in size compared to the object.

Magnification may also be determined by taking the ratio of the distance from the image to the mirror and the distance from the object to the mirror:

$$\text{magnification, } m = \frac{\text{image distance}}{\text{object distance}} = \frac{d_i}{d_o}$$

Either of the above formula may be used to determine magnification.

Note the units for both heights and both distances must be the same in the calculation, however magnification has no units as the units cancel out during the calculation.

An inverted image is considered to have a negative height relative to the object, this is indicated in the equation with a negative sign.

## Sign Conventions for Curved Mirrors

The curved mirror equations are valid for any object distance and can be applied to both converging and diverging mirror by using the following sign conventions:

Quantity	Positive	Negative
Focal length, $f$	converging mirror	diverging mirror
Object distance, $d_o$	real object	
Image distance, $d_i$	real image	virtual image
Magnification, $m$	erect image	inverted image

### PROBLEMS

1. A converging mirror has a focal length of 12.0 cm. An object with a height of 2.50 cm is placed 40.0 cm in front of the mirror. Calculate:
- the image distance
  - the image height

(Answer: a. 17.1 cm, b.  $-1.07$  cm, the image is inverted)

2. A microscope produces an image that is  $5.50 \times 10^{-4}$  m high from an object that is  $2.00 \times 10^{-6}$  m high. What is the magnification of this microscope?

(Answer: the magnification of the microscope is 275 times)

3. A candle is placed 22 cm from a converging mirror. A virtual image is produced 53 cm from the mirror. What is the magnification?

(Answer: the magnification of the converging mirror is 2.4 times)

4. A converging 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. Calculate:
- the image distance
  - the image height

5. A candle is placed 15 cm from the vertex of a converging mirror that has a focal length of 10 cm. Calculate:
- the image distance from the mirror
  - the magnification of the image

(Answer: a. 30 cm b.  $-2.0$ , the image is real but inverted, thus the magnification is negative)

6. A diverging mirror with a focal length of 15 cm is used to produce an image 7.5 cm from the mirror.
- Where must the object be placed?
  - What is the magnification?

(Answer: a diverging mirror has a negative focal length, the image distance is negative since a diverging mirror always produces a virtual image.

- (a) 15 cm  
(b) + 0.50, erect and 0.50 times as large as the object)

7. When a butterfly is 10 cm from a converging mirror, its image is 15 cm behind the mirror.  
Calculate: (a) the focal length of the mirror (b) the magnification

(Answer: a. 30 cm b. + 1.5)

8. A diverging mirror, used as a wing mirror on a car, has a focal length of 0.70 m. If an approaching car is 4.0 m from the mirror, calculate:
- The location of the image
  - the magnification
  - explain why the driver might think the car is further away than it is.

(Answer: a. — 0.60 m b. 0.15)

9. An insect is magnified 12 times by a converging mirror. If the image is real, inverted and 6 cm from the mirror, how far away is the insect?

10. A human hair is placed 3 mm from a powerful microscope lens that has a magnification of 40 times. How far from the lens will the image be formed?