

## Refraction

**Problem B****LENSES****PROBLEM**

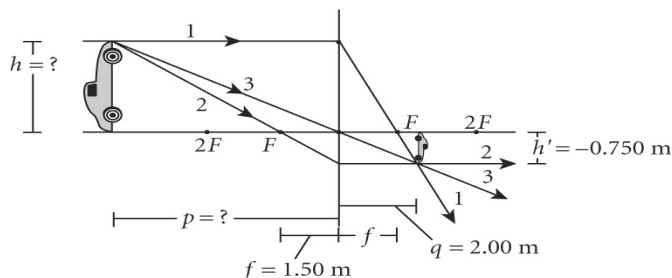
Suppose the smallest car that is officially allowed on United States roads is placed upright in front of a converging lens. The lens, which has a focal length of 1.50 m, forms an image 75.0 cm tall and 2.00 m away. Calculate the object distance, the magnification, and the object height.

**SOLUTION****1. DEFINE**

**Given:**  $q = +2.00 \text{ m}$        $f = +1.50 \text{ m}$        $h' = -0.750 \text{ m}$

The image is behind the lens, so  $q$  is positive. The lens is converging, so the focal length is positive ( $f > 0$ ). The image is inverted, so  $h'$  is negative.

**Unknown:**  $p = ?$        $M = ?$        $h = ?$

**Diagram:**

**2. PLAN Choose the equation(s) or situation:** Use the thin-lens equation to calculate the image distance. Then use the equation for magnification to calculate the magnification and the object height.

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \quad M = -\frac{q}{p} = \frac{h'}{h}$$

**Rearrange the equation(s) to isolate the unknown(s):**

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q}$$

**3. CALCULATE**

**Substitute the values into the equation(s) and solve:**

$$\frac{1}{p} = \frac{1}{1.50 \text{ m}} - \frac{1}{2.00 \text{ m}} = \frac{0.667}{1 \text{ m}} - \frac{0.500}{1 \text{ m}} = \frac{0.167}{1 \text{ m}} \quad p = 6.00 \text{ m}$$

$$M = -\frac{q}{p} = -\frac{(2.00 \text{ m})}{(6.00 \text{ m})} = -0.333$$

$$h = \frac{h'}{M} = \frac{(-0.750 \text{ m})}{(-0.333)} = 2.25 \text{ m}$$

#### 4. EVALUATE

Because  $-1 < M < 1$ , the image must form at a distance less than  $2f$  but greater than  $f$ , which is the case. At this position the image is real and inverted.

#### ADDITIONAL PRACTICE

1. The National Museum of Photography, Film & Television, in England, has a huge converging lens with a diameter of 1.37 m and a focal length of 8.45 m. Suppose you use this lens as a magnifying glass. At what distance would a friend have to stand for the friend's image to appear 25 m in front of the lens? What is the image magnification?
2. The largest of seals is the elephant seal, while the smallest seal, the Galápagos fur seal, is only 1.50 m in length. Suppose you use a diverging lens with a focal length of 8.58 m to observe an elephant seal. The elephant seal's image turns out to have the exact length of a Galápagos fur seal and forms 6.00 m in front of the lens. How far away is the elephant seal, and what is its length?
3. The common musk turtle, also called a "stinkpot," has a length of 7.60 cm at maturity. Suppose a turtle with this length is placed in front of a diverging lens that has a 14.0 cm focal length. If the turtle's image is 4.00 cm across, how far is the turtle from the lens? How far is the turtle's image from the lens?
4. The largest mammal on land, the elephant, can reach a height of 3.5 m. The largest mammal in the sea, however, is much bigger. A blue whale, which is also the largest animal ever to have lived on Earth, can be as long as 28 m. If you use a diverging lens with a focal length of 10.0 m to look at a 28.0-m-long blue whale, how far must you be from the whale to see an image equal to an elephant's height (3.50 m)?
5. The largest scorpions in the world live in India. The smallest scorpions live on the shore of the Red Sea and are only about 1.40 cm in length. Suppose a diverging lens with a focal length of 20.0 cm forms an image that is 1.40 cm wide. If the image is 19.00 cm in front of the lens, what is the object distance and size?
6. The ocean sunfish, *Mola mola*, produces up to  $30 \times 10^6$  eggs at a time. Each egg is about 1.3 mm in diameter. How far from a magnifying glass with a focal length of 6.0 cm should an egg be placed to obtain an image 5.2 mm in size? How far is it between the image and the lens?
7. In 1992, Thomas Bleich of Austin, Texas, produced a photograph negative of about 3500 attendants at a concert. The negative was more than 7 m long. Bleich used a panoramic camera with a lens that had a focal length of 26.7 cm. Suppose this camera is used to take a picture of just one concert attendant. If the attendant is 3.00 m away from the lens, how far should the film be from the lens? What is the image magnification?

8. Komodo dragons, or monitors, are the largest lizards, having an average length of 2.25 m. This is much shorter than the largest crocodiles. If a crocodile is viewed through a diverging lens with a focal length of 5.68 m, its image is 2.25 m long. If the crocodile is 12.0 m from this lens, what is the image distance? How long is the crocodile?
9. The body of the rare thread snake is as thin as a match, and the longest specimen ever found was only 108 mm long. If a thread snake of this length is placed a distance equal to four times its length from a diverging lens and the lens has a focal length of 216 mm, how long is the snake's image? How far from the lens is the image?
10. Tests done by the staff of *Popular Photography* magazine revealed that the zoom lenses available in stores have a focal length different from what is written on them. Suppose one of these lenses, which is identified as having a focal length of 210 mm, yields an upright image of an object located 117 mm away. If the image magnification is 2.4, what is the true focal length of the lens?
11. In 1994, a model car was made at a scale of 1:64. This car traveled more than 600 km in 24 h, setting a record. If this model car is placed under an opaque projector, a real image will be projected. Suppose the image on the screen has the same size as the actual, full-scale car. If the screen is 12 m from the lens, what is the focal length of the lens? Is the image upright or inverted?
12. The tallest man in history, Robert Wadlaw, was 2.72 m tall. The smallest woman in history, Pauline Musters, had a height of 0.55 m. Suppose Wadlaw is 5.0 m away from a converging lens. If his image is the same size as Musters, what is the focal length of the lens?
13. Hummingbirds' eggs, which have an average size of 10.0 mm, are the smallest eggs laid by any bird. Suppose an egg is placed 12.0 cm from a magnifying glass. A virtual image with a magnification of 3.0 is produced. What is the focal length of the lens?
14. In 1876, the *Daily Banner*, a newspaper printed in Roseberg, Oregon, had pages that were 7.60 cm wide. What would be the width of this newspaper's image if the newspaper were placed 16.0 cm from a diverging lens with a focal length of 12.0 cm?
15. Estimates show that the largest dinosaurs were 48 m long. Suppose you take a trip back in time with a camera that has a focal length of 110 mm. Coming across a specimen of the largest dinosaur, you take its picture, but to be safe and inconspicuous you take it from a distance of 120 m. What length will the image have on the film?
16. The smallest spiders in the world are only about 0.50 mm across. On the other hand, the goliath tarantula, of South America, can have a leg span of about 280 mm. Suppose you use a diverging lens with a focal length of 0.80 m to obtain an image that is 0.50 mm wide of an object that is 280 mm wide. How far is the object from the lens? How far is the image from the lens?