HW #10 Solutions

CQ 2. At the altitude of the plane the surface of the Earth does not block off the lower half of the rainbow. Thus, you can see the full circle. You can show such a rainbow to your children by letting them climb a stepladder above a garden sprinkler in the middle of a sunny day.

23.6 (a) \( \frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{1.00 \text{ cm}} - \frac{1}{10.0 \text{ cm}} \), or \( f = 1.11 \text{ cm} \) and \( R = 2f = 2.22 \text{ cm} \).
(b) \( M = -\frac{q}{p} = \left(-\frac{10.0 \text{ cm}}{1.00 \text{ cm}}\right) = +10.0 \).

23.9 We know that for a convex mirror \( R \) and \( f \) are negative, and we also are given that \( M = 1/2 \). \( M \) is positive because convex mirrors only form erect virtual images of real objects. Therefore, \( M = -\frac{q}{p} = \frac{1}{2} \), or \( q = -\frac{p}{2} \). Thus, \( \frac{1}{p} = \frac{1}{f} - \frac{1}{q} = -\frac{1}{20.0 \text{ cm}} - \left(-\frac{2}{p}\right) \), which gives: \( p = 20.0 \text{ cm} \).

The object should be 20.0 cm in front of the mirror.

23.13 We know that \( R \) and \( f \) are positive for a concave mirror. Also, since a concave mirror only forms magnified, erect images when the image is virtual, we know that \( q \) is negative.

Thus, \( M = 2 \), and \( M = -\frac{q}{p} = 2.0 \), or \( q = -2.0(25 \text{ cm}) = -50 \text{ cm} \).

Thus, \( \frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{25 \text{ cm}} + \left(-\frac{1}{50 \text{ cm}}\right) = \frac{1}{50 \text{ cm}} \), and \( f = 50 \text{ cm} \).
But, \( R = 2f = 100 \text{ cm} = 1.0 \text{ m} \).

23.19 (a) In this case, both the object and the image are real. To form a real image of a real object, a concave mirror must be used.
(b) We are given \( q = +5.0 \text{ m} \), and \( M = -\frac{q}{p} = -5.0 \) (a concave mirror forms inverted real images, hence the negative sign on the value of the magnification.) Therefore, \( q = 5p \), and since we know that \( q = 5.0 \text{ m} \), we find that \( p = 1.0 \text{ m} \) as the distance the object must be from the mirror.
23.30 For a converging lens, \( f \) is positive. We use: 

\[
\frac{1}{p} + \frac{1}{q} = \frac{1}{f}.
\]

(a) \( \frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{20.0 \text{ cm}} - \frac{1}{40.0 \text{ cm}} = \frac{1}{40.0 \text{ cm}}, \) or \( q = 40.0 \text{ cm} \).

\[M = \frac{-q}{p} = \frac{-40.0}{40.0} = -1.00.\] (real, inverted, and 40.0 cm past the lens)

(b) \( \frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{20.0 \text{ cm}} - \frac{1}{20.0 \text{ cm}} = 0, \) giving \( q = \text{infinity}. \)

No image is formed. (parallel rays emerge from the lens)

(c) \( \frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{20.0 \text{ cm}} - \frac{1}{10.0 \text{ cm}} = \frac{1}{20.0 \text{ cm}}, \) or \( q = -20.0 \text{ cm} \).

\[M = \frac{q}{p} = \left(\frac{-20.0}{10.0}\right) = 2.00.\] (erect, virtual, and 20.0 cm in front of lens)

23.34 We want \( M = +2.00, \) so \( \frac{q}{p} = 2.00, \) or \( q = -2.00p. \)

\[\frac{1}{p} + \frac{1}{q} = \frac{1}{f}\] becomes: \[\frac{1}{p} + \frac{1}{-2.00p} = \frac{1}{15.0 \text{ cm}}, \] giving \( p = +7.50 \text{ cm}.\)

23.39 For a virtual image, the image distance is negative and the magnification is positive (assuming a real object).

Thus, \( M = -\frac{q}{p} = -\frac{1}{3}, \) and \( q = \frac{p}{3}. \)

So, \( \frac{1}{p} + \frac{1}{q} = \frac{1}{f} \) becomes \( \frac{1}{p} - \frac{3}{p} = \frac{1}{f}, \) or \( p = -2f. \)

23.42 Let us consider the first lens. We find the image position and magnification as:

\[
\frac{1}{q_1} = \frac{1}{f_1} - \frac{1}{p_1} = \frac{1}{15.0 \text{ cm}} - \frac{1}{30.0 \text{ cm}} = \frac{1}{30.0 \text{ cm}}, \] or \( q_1 = 30.0 \text{ cm}. \)

\[M_1 = \frac{q_1}{p_1} = \frac{30.0 \text{ cm}}{30.0 \text{ cm}} = -1.00. \]

Now consider the second lens. The image produced by the first lens becomes the object for this second lens. Thus,

\[p_2 = 40.0 \text{ cm} - q_1 = 40.0 \text{ cm} - 30.0 \text{ cm} = 10.0 \text{ cm}. \] The thin lens equation then gives: \( \frac{1}{q_2} \)

\[\frac{1}{f_2} - \frac{1}{p_2} = \frac{1}{15.0 \text{ cm}} - \frac{1}{10.0 \text{ cm}} = \frac{30.0 \text{ cm}}{30.0 \text{ cm}}, \] or \( q_2 = -30.0 \text{ cm}. \)

\[M_2 = \frac{q_2}{p_2} = \left(\frac{-30.0 \text{ cm}}{10.0 \text{ cm}}\right) = 3.00. \]

The overall magnification \( M \) is: \( M = (M_1)(M_2) = (-1.00)(3.00) = -3.00. \)