From the spherical-mirror equation or the thin-lens equation, $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$, we have

$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{d_o - f}{d_o f}$. Or $d_i = \frac{d_o f}{d_o - f}$. This is used in the solutions of many exercises.

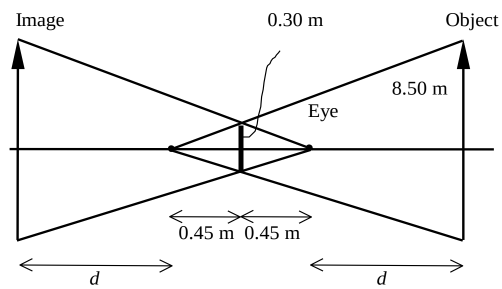
1. (b).
2. (b).
3. (c).
4. It is infinite, because it cannot focus light to a point.

9. (a) Image distance equals object distance. The distance from object to image is 2.0 m + 2.0 m = 4.0 m.

(b) Upright, virtual, and same size.

12. $A = a^2$, ☞ $a = \sqrt{A} = \sqrt{900\text{ cm}^2}$ = 30 cm = 0.30 m.

Use similar triangles. $\frac{d + 0.45\text{ m} + 0.45\text{ m}}{8.50\text{ m}} = \frac{0.45\text{ m}}{0.30\text{ m}}$, ☞ d = 12 m.



13. (a) Image distance equals object distance, and so it is 1.5 m behind the mirror.

(b) The image also moves at 0.5 m/s toward the dog, and so the relative velocity of the dog to the image is 0.5 m/s + 0.5 m/s = 1.0 m/s.

16. (a) The mirror needs to be half as tall as the object as explained in Example 23.7. So it is 0.85 m tall.

(b) It is independent of object distance, and it is still 0.85 m.

19. (d).
20. (a).
21. (a) concave. A shaving mirror forms larger images then object. Plane and convex mirrors cannot form larger images.
22. (a) The plane mirror gives a large view of the area immediately around that side of the truck. The small convex mirror gives a wide-angle perspective of the road in back of both sides of the truck (but the image is smaller).
(b) These are convex mirrors that give a better field of view, but also images are smaller than objects (so the image distances are smaller than object distances) and hence appear closer than they actually are.
(c) Yes, it can be considered as a converging mirror, because it collects a large amount of radio waves and focuses them onto a small area.

28. d_o = 20 cm, $f = \frac{R}{2} = \frac{30\text{ cm}}{2}$ = 15 cm. $d_i = \frac{d_o f}{d_o - f} = \frac{(20\text{ cm})(15\text{ cm})}{20\text{ cm} - 15\text{ cm}}$ = 60 cm.

$M = -\frac{d_i}{d_o} = -\frac{60\text{ cm}}{20\text{ cm}} = -3.0$. So $h_i = Mh_o = -3.0\ (3.0\text{ cm}) = -9.0$ cm. It is 9.0 cm tall.

29. $d_i = \frac{(10\text{ cm})(15\text{ cm})}{10\text{ cm} - 15\text{ cm}}$ = −30 cm. $M = -\frac{-30\text{ cm}}{10\text{ cm}} = +3.0$.

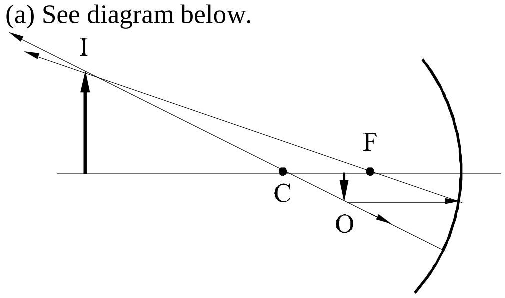
So $h_i = +3.0\ (1.5\text{ cm})$ = 9.0 cm; virtual, upright, and magnified.

30. (a) d_o = 5.0 cm, d_i = −10 cm (virtual image). $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{5.0\text{ cm}} + \frac{1}{-10\text{ cm}} = \frac{1}{10\text{ cm}}$,

so $f = \boxed{10\text{ cm}}$, and $R = 2f = \boxed{20\text{ cm}}$.

(b) $M = -\dfrac{d_i}{d_o} = -\dfrac{-10\text{ cm}}{5.0\text{ cm}} = +2$ So $h_i = Mh_o = +2\ (1.5\text{ cm}) = \boxed{3.0\text{ cm}}$.

45. (a) See diagram below.



(b) $f = \dfrac{R}{2} = \dfrac{30\text{ cm}}{2} = 15\text{ cm}$, $d_o = 20\text{ cm}$. $d_i = \dfrac{d_o f}{d_o - f} = \dfrac{(20\text{ cm})(15\text{ cm})}{20\text{ cm} - 15\text{ cm}} = \boxed{60\text{ cm}}$.

$M = -\dfrac{d_i}{d_o} = -\dfrac{60\text{ cm}}{20\text{ cm}} = \boxed{-3.0\text{, real and inverted}}$.

50. $d_i = \dfrac{d_o f}{d_o - f}$. For concave, $M = -\dfrac{d_i}{d_o} = \dfrac{f}{f - d_o} = +1.8$, ☞ $f = \dfrac{9}{4} d_o$.

For convex, we replace f with $-|f| = -f$.

So $M = \dfrac{f}{f + d_o} = \dfrac{9/4\ d_o}{9/4\ d_o + d_o} = \dfrac{9}{13} = \boxed{0.69}$.

53. $\boxed{\text{Yes}}$, it is possible. One is a real image, and the other is a virtual image.

$f = \dfrac{R}{2} = \dfrac{40\text{ cm}}{2} = 20\text{ cm}$, $M = \pm 3.0$, the + is for a virtual image, and the – is for a real image.

$d_i = -Md_o = \mp 3.0 d_o$. $\dfrac{1}{f} = \dfrac{1}{d_o} + \dfrac{1}{d_i}$, so $\dfrac{1}{20\text{ cm}} = \dfrac{1}{d_o} + \dfrac{1}{\mp 3.0 d_o}$,

or $\dfrac{3 \mp 1}{3d_o} = \dfrac{1}{20\text{ cm}}$. Solving, $d_o = \dfrac{20\text{ cm}}{3}(3 \mp 1) = \boxed{13\text{ cm or }27\text{ cm}}$.

54. (c).

55. (d).

56. (d).

57. When the fish is inside the focal point, the image is upright, virtual, and magnified.

58. $\boxed{\text{Yes}}$. If the object is inside the focal point ($\boxed{d_o < f}$), the image of a real object is virtual, upright, and magnified.

59. You can $\boxed{\text{locate the image of a distant object}}$. The distance from the converging lens to the image is the focal length. $\boxed{\text{No}}$, the same method won't work for a diverging lens because a diverging lens does not form real images of real objects.

60. The object distance should be between the focal length and twice the focal length, i.e., $\boxed{2f > d_o > f}$. In this region, the image is real, inverted, and magnified.

67. (a) $f = 12\text{ cm}$, $M = -2.0$ (real). $d_i = -Md_o = 2.0d_o$.

$\dfrac{1}{f} = \dfrac{1}{d_o} + \dfrac{1}{d_i} = \dfrac{1}{d_o} + \dfrac{1}{2.0d_o} = \dfrac{3}{2d_o}$, ☞ $d_o = \dfrac{3}{2} f = \dfrac{3}{2}(12\text{ cm}) = \boxed{18\text{ cm}}$.

(b) $M = +2.0$ (virtual). $d_i = -Md_o = -2.0d_o$.

$\dfrac{1}{f} = \dfrac{1}{d_o} + \dfrac{1}{-2.0d_o} = \dfrac{1}{2d_o}$, ☞ $d_o = \dfrac{1}{2} f = \dfrac{1}{2}(12\text{ cm}) = \boxed{6.0\text{ cm}}$.

77. (a) $d_o = 30\text{ cm}$, $f = -45\text{ cm}$. $d_i = \dfrac{d_o f}{d_o - f} = \dfrac{(30\text{ cm})(-45\text{ cm})}{30\text{ cm} - (-45\text{ cm})} = \boxed{-18\text{ cm}}$.

(b) $d_i = \dfrac{(30\text{ cm})(57\text{ cm})}{30\text{ cm} - 57\text{ cm}} = \boxed{-63\text{ cm}}$.

82. For L_1, $d_{i1} = \dfrac{d_{o1} f_o}{d_{o1} - f_o} = \dfrac{(50\text{ cm})(30\text{ cm})}{50\text{ cm} - 30\text{ cm}} = 75\text{ cm}$.

$M_1 = -\dfrac{d_{i1}}{d_{o1}} = -\dfrac{75\text{ cm}}{50\text{ cm}} = -1.5.$ The image by L_1 is the object for L_2.

For L_2, $d_{o2} = d - d_{i1} = 60\text{ cm} - 75\text{ cm} = -15\text{ cm}$, where d is the distance between the lenses. A negative object means that the "object" is on the image side.

$d_{i2} = \dfrac{d_{o2} f_2}{d_{o2} - f_2} = \dfrac{(-15\text{ cm})(20\text{ cm})}{-15\text{ cm} - 20\text{ cm}} = \boxed{8.6\text{ cm}}$. $M_2 = -\dfrac{d_{i2}}{d_{o2}} = -\dfrac{8.57\text{ cm}}{-15\text{ cm}} = 0.57.$

So $M_{total} = M_1 M_2 = (-1.5)(0.57) = -0.86 = \boxed{0.86\text{; real and inverted}}$.

85. (b).

86. (b).

87. (b). It cannot focus light or the focal length is at infinity.

88. $\boxed{+, +; +, \infty; +, -; -, -; \infty, -; +, -}$.

95. $P = \dfrac{1}{f} = (n-1)\left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right) = (1.35 - 1)\left(\dfrac{1}{\infty} + \dfrac{1}{-0.50\text{ m}}\right) = \boxed{-0.70\text{ D}}$.

103. For the first lens, $d_{o1} = 15\text{ cm}$, $f_1 = 10\text{ cm}$. $d_{i1} = \dfrac{d_{o1} f_1}{d_{o1} - f_1} = \dfrac{(15\text{ cm})(10\text{ cm})}{15\text{ cm} - 10\text{ cm}} = 30\text{ cm}$.

$M_1 = -\dfrac{d_{i1}}{d_{o1}} = -\dfrac{30\text{ cm}}{15\text{ cm}} = -2.0.$ The image of the first lens is the object for the second lens.

For the second lens, $d_{o2} = d - d_{i1} = 60\text{ cm} - 30\text{ cm} = 30\text{ cm}$, where d is the distance between the lenses.

$d_{i2} = \dfrac{d_{o2} f_2}{d_{o2} - f_2} = \dfrac{(30\text{ cm})(20\text{ cm})}{30\text{ cm} - 20\text{ cm}} = \boxed{60\text{ cm to right of second lens}}$.

$M_2 = -\dfrac{d_{i2}}{d_{o2}} = -\dfrac{60\text{ cm}}{30\text{ cm}} = -2.0.$ $M_{total} = M_1 M_2 = (-2.0)(-2.0) = \boxed{4.0\text{, real and upright}}$.