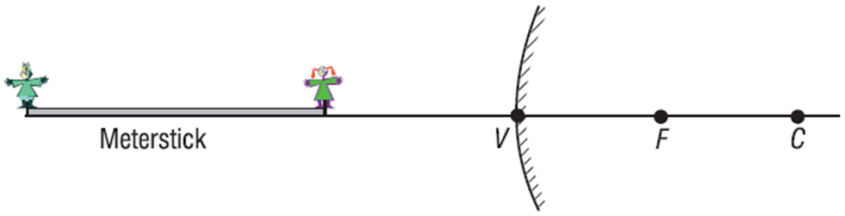
Geometrical Optics Problems

P1. A meterstick lies along the optical axis of a convex mirror of focal length 40 cm, with its near end 60 cm from the mirror surface. Five-centimeter toy figures stand erect on both the near and far ends of the meterstick. (a) How long is the virtual image of the meterstick? (b) How tall are the toy figures in the image, and are they erect or inverted?



P2. A double-convex thin lens can be used as a simple "magnifier." It has a front surface with a radius of curvature of 20 cm and a rear surface with a radius of curvature of 15 cm. The lens material has a refractive index of 1.52. Answer the following questions to learn more about this simple magnifying lens:

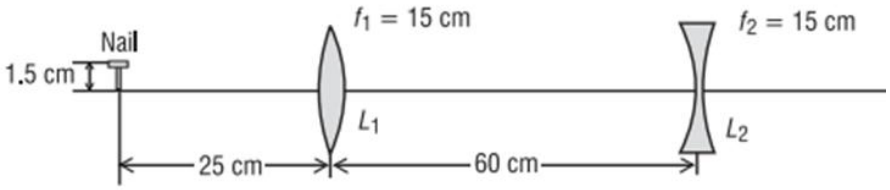
(a) What is its focal length in air?

(b) What is its focal length in water (n = 1.33)?

(c) Does it matter which lens face is turned toward the light?

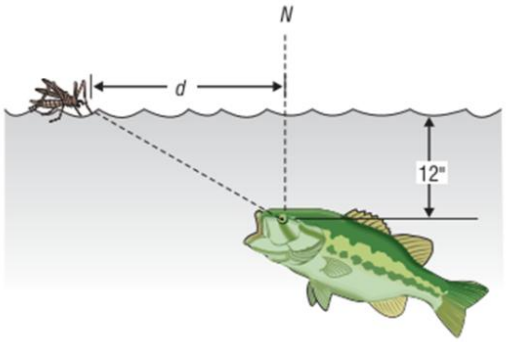
(d) How far would you hold an index card from this lens to form a sharp image of the sun on the card?

P3. A two-lens system is made up of a converging lens followed by a diverging lens, each of focal length 15 cm. The system is used to form an image of a short nail, 1.5 cm high, standing erect, 25 cm from the first lens. The two lenses are separated by a distance of 60 cm. See accompanying diagram. Locate the final image, determine its size, and state whether it is real or virtual, erect or inverted.



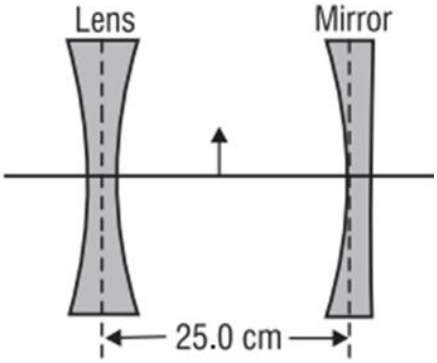
P4. An object 3 cm high is placed 20 cm to the left of (a) a convex and (b) a concave spherical mirror, each of focal length 10 cm. Determine the position and nature of the image for each mirror.

P5. Make a ray-trace diagram that locates the image of a 2-cm object placed 10 cm in front of a concave spherical mirror of curvature 6 cm. Make your drawing to scale. Where is the image located and what are its orientation and its size? Repeat this for a convex spherical mirror of the same curvature.

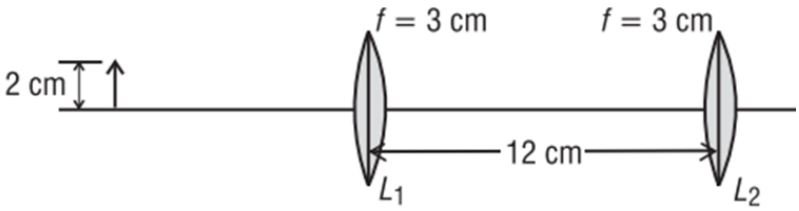


P6. A fish in a lake looks up at the surface of the water. At what distance d along the surface, measured from the normal, is a water-skimming insect safe from the roving eye of the fish?

P7. The object shown in the accompanying sketch is midway between the lens and the mirror. The radius of curvature of the mirror is 20 cm. The concave lens has a focal length of 16.7 cm. (a) Where is the light that travels first to the mirror and then to the lens finally imaged? (b) Where is the light finally imaged that travels first to the lens? (Note: Be especially careful of applying the sign convention!)



P8. Two positive thin lenses, each of focal length f = 3 cm, are separated by a distance of 12 cm. An object 2 cm high is located 6 cm to the left of the first lens. See sketch. Make a drawing of the two-lens system, to scale. (a) Use ray-tracing techniques to locate the final image and describe its size and nature. (b) Use the thin-lens equation to locate the position and size of the final image. How well do your results for (a) and (b) agree?



C26.43. An object (*h = 2 cm*) is placed at a distance of 15 cm from a convex lens with the focal length of 0.1 m. Find the size and position of the image formed by the lens.

C26.44. Find focal length of a convex lens if $x_1 \cdot x_2 = l$, where x_1 is the distance between the object and the object-side focus, and x_2 is the distance between the image and the image-side focus.

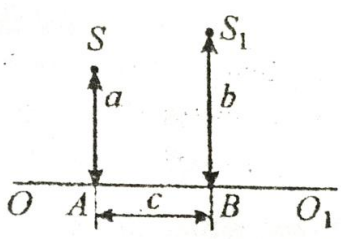
C26.56. Two convex lenses ($F_1 = 12$ *cm*, $F_2 = 7$ *cm*) are placed by *l cm* apart along the common optical axis. An object (*h = 2 cm*) is placed at the focal plane of the first lens. Find the size of the image.

C26.57. Two lenses (convex lens L_1 with $F_1 = 10\ cm$, and concave lens L_2 with $F_2 = 20\ cm$) are placed by $l = 30\ cm$ apart along the common optical axis. An object is placed at a distance of 10 cm from the L_2 (opposite to the L_1 direction). Find the distance between the image (produced by the system of lenses) and L_1.

C26.58. A convex lens (with focal length F) and a flat mirror are placed by l *cm* apart along the common optical axis. In front of the lens there is a point light source S separated by the distance d from the lens. Find position of the image. What d leads to formation of a real image? What d leads to formation of a virtual image?

F23. An object is placed at a distance of $a = 25\ cm$ from the object-side focus, and the image is formed at a distance $b = 35\ cm$ from the image-side focus. Find the focal length of the lens.

F25. A point source S is placed above the optical axis by $a = 20\ cm$, and its image is above the same axis by $b = 30\ cm$. Find the lens focal length if the projections of S and S_1 on the optical axis are $l = 15\ cm$ apart.



F26. Distance between the object and object-side focus is $n = 4$ smaller than that between the real image formed and the image-side focus. Find magnification with which the object has been imaged.

F27. A distant source light is incident onto a concave lens L_1 ($F_1 = -30\ cm$). A convex lens L_2 ($F_2 = 45\ cm$) is placed $a = 40\ cm$ apart from the L_1. Find the distance between L_2 and the image of the source if the lenses have a common optical axis.

F28. A candle stick flame is 5 cm high. Its image on a screen is 15 cm high. By moving the candle by 1.5 cm further away from the lens and adjusting position of the screen, another image (10 cm high) of the flame have been obtained. Find the focal length of the lens if the latter has not been moved during the experiment.

F29. An object placed at a point A is imaged with magnification $M = 2$, the same object placed at a point B is imaged with magnification $M = 3$. Find magnification if the object is placed in the middle between the former points A and B?

F30. Find the smallest possible distance between an object and its real image if the lens focal length is F?

F31. With aid of a lens, two times magnified image of an object is formed. By shifting the object towards the lens by $l = 1\ cm$, the image becomes three times magnified. Find the focal length of the lens.

R1. Height of a virtual image produced by a concave mirror in the water is 4 times larger than the object height. The object is placed at a distance of 20 cm from the mirror. Find the curvature radius of the mirror.

R2. Prove that for a convex lens with $|R_1| = |R_2|$ and $n = 1.5$ focuses coincide with the centres of the curvature in air.

R3. Prove that for a concave lens with $|R_1| = |R_2|$ and $n = 1.5$ virtual focuses coincide with the centres of the curvature in air.

R4. Height of an image is 2 times larger than the object height. The distance between the object and the image is 15 cm. Find the focal length of the mirror.

R5. With use of a couple of same convex lenses (i.e., L_1 is the same as L_2) with n = 1.5, and R = 20 cm, placed in air 20 cm apart from each other, an image of an object $h = 1$ *cm* placed 40 cm to the left from the first lens is formed. Find position and size of the image.

R6. A concave mirror ($R = 30$ *cm*) is placed at the focal plane of a convex lens ($F = 10$ *cm*). At the other side of the lens an object ($h = 1$ *cm*) is placed at a distance of 15 cm from the lens. Find size and position of the image.

R7. A concave mirror ($R = 40$ *cm*) produces a real image which is 2 times smaller than the object. Find position of the object and its image.

R8. With use of a lens ($F = 16$ *cm*) a clear image is formed at two different positions of the lens which are 6 cm apart. Find distance between the object and the screen.

R9. With a concave mirror ($R = 60$ *cm*) an image is formed which height is 30% of the height of the object. \find positions of the object and image.

R10. An object ($h = 1$ *cm*) is placed to the left from a concave lens L_1 ($F = -20$ *cm*), and to the right at 20 cm distance from the L_1 is a convex lens L_2 ($F = 20$ *cm*). Find size and position of the image.