2.6 EXERCISES

Image by reflection

Ex 2.6.1. Two mirrors are inclined at an angle of 60° and an object is placed at a point that is equidistant from the two mirrors. Use a protractor to draw rays accurately and locate all images. You may have to draw several figures so that that rays for different images do not clutter your drawing.

Ex 2.6.2. Two parallel mirrors are facing each other and are separated by a distance of 3 cm. A point object is placed between the mirrors 1 cm from one of the mirrors. Find the coordinates of all the images. Ans: $x_{i+1} = -x'_i$; $x'_{i+1} = 6 - x_i$ $|x_0 = 1$ cm, $i = 0, 1, 2, \cdots$.

Ex 2.6.3. Use a ruler and a protractor to draw rays to find images in the following cases.

(a) A point object located on the axis of a concave mirror located at a point within the focal length from the vertex.

(b) A point object located on the axis of a concave mirror located at a point farther than the focal length from the vertex.

(c) A point object located on the axis of a convex mirror located at a point within the focal length from the vertex.

(d) A point object located on the axis of a convex mirror located at a point farther than the focal length from the vertex.

(e) Repeat a-d for a point object off the axis.

Ex 2.6.4. Where should a 3-cm tall object be placed in front of a concave mirror of radius 20 cm so that its image is real and 2-cm tall? Ans: 25 cm.

Ex 2.6.5. A 3-cm tall object is placed 5 cm in front of a convex mirror of radius of curvature 20 cm. Where is the image formed? How tall is the image? What is the orientation of the image? Ans: q = -10/3 cm, h = 2 cm, upright.

Ex 2.6.6. You are looking for a mirror so that you can see a 4 times magnified virtual image of an object when the object is placed 5 cm from the vertex of the mirror. What kind of mirror you will need? What should be the radius of curvature of the mirror? Ans: Concave, $R = 40/3$ cm.

Ex 2.6.7. Derive the following equation for a convex mirror:

$$\frac{1}{\mathrm{VO}} - \frac{1}{\mathrm{VI}} = -\frac{1}{\mathrm{VF}},$$

where VO is the distance to the object O from vertex V, VI the distance to the image I from V, and VF the distance to the focal point F from V. [Hint: use two sets of similar triangles]

Image by refraction

Ex 2.6.8. Derive the formula for the apparent depth of a fish in a fish tank by using Snell's law. Ans: Apparent depth = $(n_{\mathrm{air}}/n_{\mathrm{wat}}) \times$ actual depth.

Ex 2.6.9. Use a ruler and a protractor to find image by refraction in the following cases. Assume the interface is air/glass. Use refractive index of air 1 and refractive index 1.5.

(a) A point object located on the axis of a concave interface located at a point within the focal length from the vertex.

(b) A point object located on the axis of a concave interface located at a point farther than the focal length from the vertex.

(c) A point object located on the axis of a convex interface located at a point within the focal length from the vertex.

(d) A point object located on the axis of a convex interface located at a point farther than the focal length from the vertex.

(e) Repeat a-d for a point object off the axis.

Ex 2.6.10. An object is located in air 30 cm from the vertex of a concave surface made of glass with a radius of curvature 10 cm. Where does the image by refraction form and what are its orientation and magnification? Use $n_{\mathrm{air}} = 1$ and $n_{\mathrm{glass}} = 1.5$. Ans: q = -18 cm; $m = +3/5$.

Ex 2.6.11. An object is located in air 30 cm from the vertex of a convex surface made of glass with a radius of curvature 80 cm. Where does the image by refraction form and what are its orientation and magnification? Ans: $q = -55$ cm; $m = +1.8$.

Ex 2.6.12. An object is located in water 15 cm from the vertex of a concave surface made of glass with a radius of curvature 10 cm. Where does the image by refraction form and what are its orientation and magnification? Use $n_{\mathrm{water}} = 4/3$ and $n_{\mathrm{glass}} = 1.5$. Ans: $q = -14$ cm, $m = 0.95$.

Ex 2.6.13. An object is located in water 30 cm from the vertex of a convex surface made of plexiglass with a radius of curvature 80 cm. Where does the image by refraction form and what are its orientation and magnification? $n_{\text{water}} = 4/3$ and $n_{\text{plexiglass}} = 1.65$. Ans: $q = -41$ cm, $m = 1.4$.

Ex 2.6.14. An object is located in air 5 cm from the vertex of a concave surface made of glass with a radius of curvature 20 cm. Where does the image by refraction form and what are its orientation and magnification? Use $n_{\text{air}} = 1$ and $n_{\text{glass}} = 1.5$. Ans: $q = -6.7$ cm, $m = +4/3$.

Ex 2.6.15. Derive the following equation for refraction at a concave surface (Fig. 2.18).

$$\frac{n_1}{\text{VP}} - \frac{n_2}{\text{VQ}} = -\frac{n_2 - n_1}{\text{VC}}.$$

Using thin lens equation

Ex 2.6.16. An object of height 3 cm is placed 5 cm in front of a converging lens of focal length 20 cm and observed from the other side. Where and how large is the image? Ans: $q = -20/3$ cm, $h_i = 4$ cm.

Ex 2.6.17. An object of height 3 cm is placed at 5 cm in front of a diverging lens of focal length 20 cm and observed from the other side. Where and how large is the image? Ans: $q = -4$ cm, $h_i = 2.4$ cm.

Ex 2.6.18. Two convex lenses of focal lengths 25 cm and 10 cm are placed 59 cm apart. An object of height 2 cm is placed 50 cm in front of the lens of focal length 25 cm. Find the location, orientation and magnification factor of the final image. Ans: q_{final}= 90 cm to the left of L_2, $m = -10$.

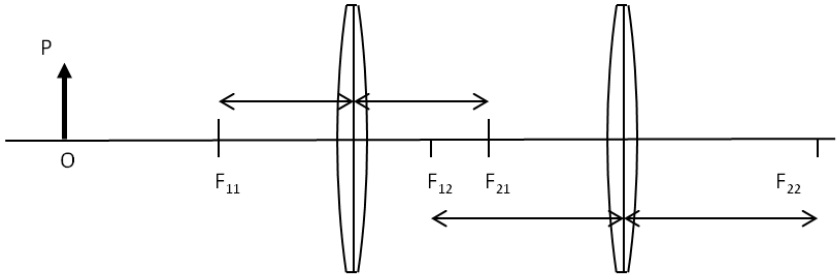
Ex 2.6.19. Two convex lenses of focal length 35 cm and 5 cm are placed 41 cm apart. An object of height 2 cm is placed 5000 cm in front of the lens of focal length 35 cm. Find the location, orientation and magnification factor of the image. Ans: $q = 38.3$ cm behind L_2, $m = +0.05$.

Ex 2.6.20. An object of height 3 cm is placed at 25 cm in front of a diverging lens of focal length 20 cm. Behind the diverging lens there is a converging lens of focal length 20 cm. The distance between the lenses is 5 cm. Find the location, orientation and size of the final image. Ans: 83 cm to the right of L_2, $m = -2.3$, h_i= 6.9 cm.

Ex 2.6.21. Two convex lenses of focal lengths 20 cm and 10 cm are placed 30 cm apart. An object of height 2 cm is placed in the middle between them and looked at through each lens from left and from right. Describe what you will see, such as where the image(s) will appear, whether they will be upright or inverted and their magnifications.

Ray tracing in lens

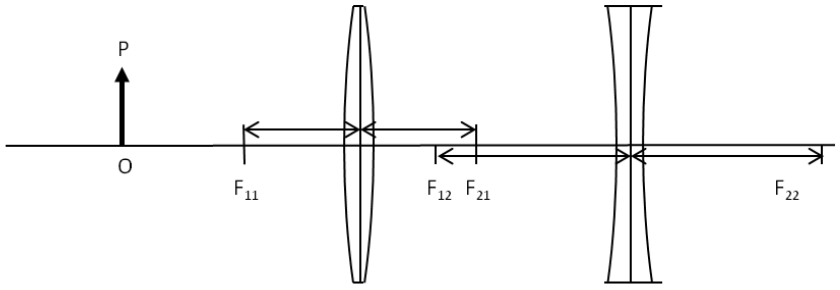
Ex 2.6.22. Copy the figure and draw rays accurately to find the image of the object OP.



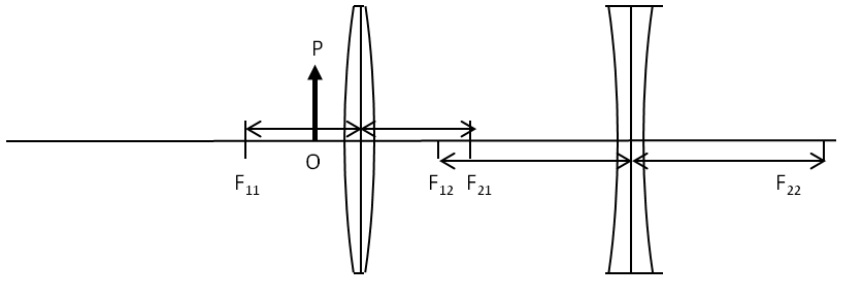
Ex 2.6.23. (a) Draw rays to form an image of an object OP vertically on the axis in front of a converging lens placed outside the focal length. (b) Use plane geometry in you figure and prove the following relation.

$$m \equiv \frac{h_i}{h_o} = -\frac{q}{p}.$$

Ex 2.6.24. Copy the figure and draw rays to find the image.



Ex 2.6.25. Copy the figure and draw rays to find the image.



Ex 2.6.26. Copy and draw rays to find the image.