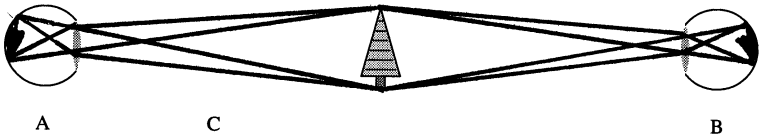
18 Ray Optics

Note: Please use a ruler or straight edge for drawing light rays.

18.1 The Ray Model of Light

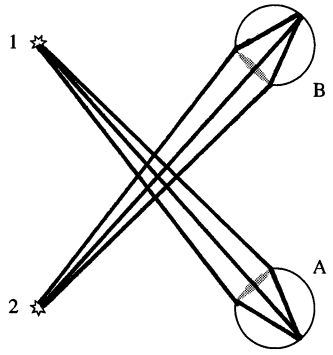
1. a. Draw four or five rays from the object that allow A to see the object.
   b. Draw four or five rays from the object that allow B to see the object.



   c. Describe the situations seen by A and B if a piece of cardboard is lowered at point C.

Light from the tree to A will be blocked by the cardboard. Light from the tree to B will not.

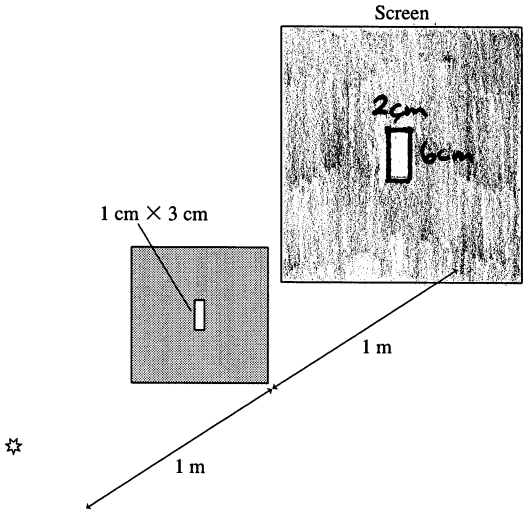
2. a. Draw three or four rays from object 1 that allow A to see object 1.
   b. Draw three or four rays from object 2 that allow B to see object 2.
   c. What happens to the light where the rays cross in the center of the picture?



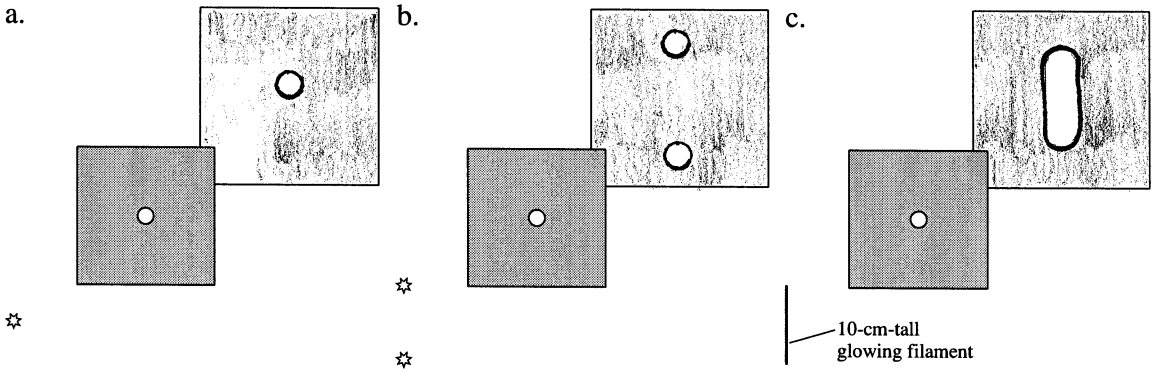
Nothing happens. The light passes through in both directions.

3. A point source of light illuminates a slit in an opaque barrier.
   a. On the screen, sketch the pattern of light that you expect to see. Let the white of the paper represent light areas; shade dark areas. Mark any relevant dimensions.
   b. What will happen to the pattern of light on the screen if the slit width is reduced to 0.5 cm?

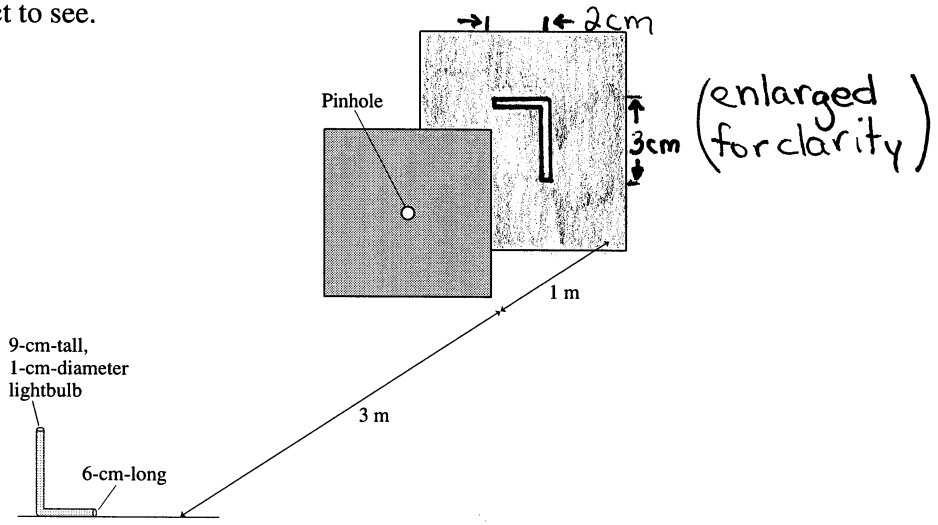
The pattern on the screen is also narrowed.



4. In each situation below, light passes through a 1-cm-diameter hole and is viewed on a screen. For each, sketch the pattern of light that you expect to see on the screen. Let the white of the paper represent light areas; shade dark areas.

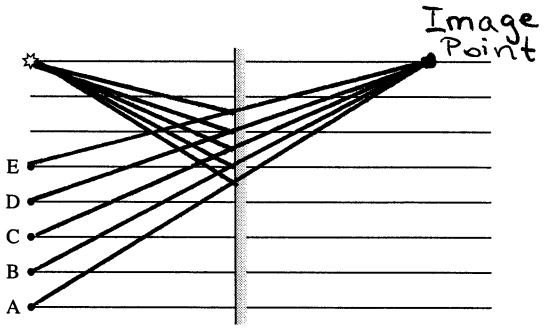


5. Light from an L-shaped bulb passes through a pinhole. On the screen, sketch the pattern of light that you expect to see.



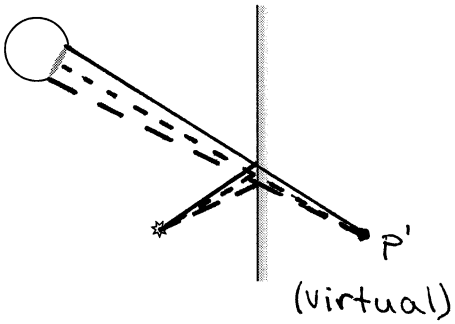
18.2 Reflection

6. a. Draw five rays from the object that pass through points A to E after reflecting from the mirror. Make use of the grid to do this accurately.
   b. Extend the reflected rays behind the mirror.
   c. Show and label the image point.



7. a. Draw *one* ray from the object that enters the eye after reflecting from the mirror.
   b. Is one ray sufficient to tell your eye/brain where the image is located?

No, the rays must intersect.

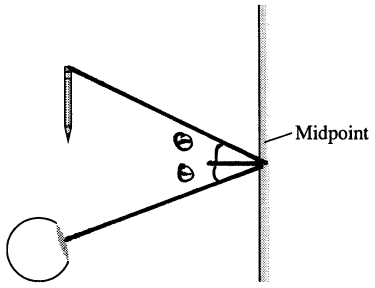


   c. Use a different color pen or pencil to draw two more rays that enter the eye after reflecting. Then use the three rays to locate (and label) the image point.
   d. Do any of the rays that enter the eye actually pass through the image point?

No, but they diverge as if they began at the image point.

8. You are looking at the image of a pencil in a mirror.
   a. What happens to the image you see if the top half of the mirror, down to the midpoint, is covered with a piece of cardboard? Explain.

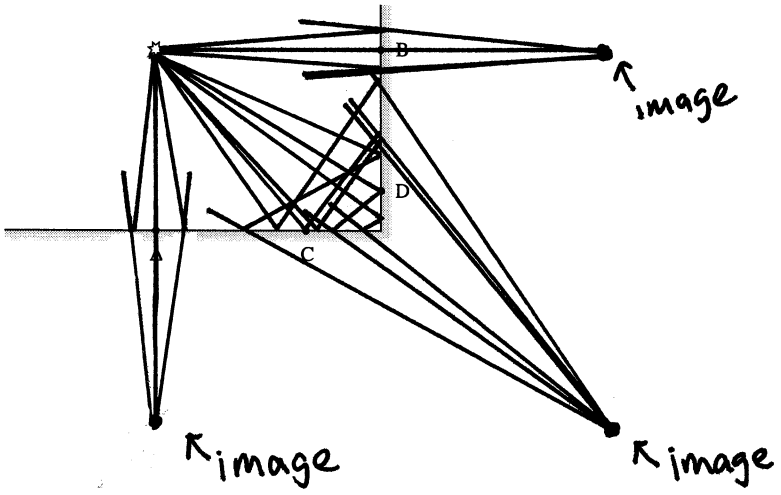
Nothing. The reflected rays from the top half do not reach your eyes.



   b. What happens to the image you see if the bottom half of the mirror is covered with a piece of cardboard? Explain.

The image would no longer appear. The rays from the pencil that would have reached your eye from the mirror are blocked.

9. The two mirrors are perpendicular to each other.
   a. Draw a ray directly from the object to point A. Then draw two rays that strike the mirror *very close* to A, one on either side. Use the reflections of these three rays to locate an image point.

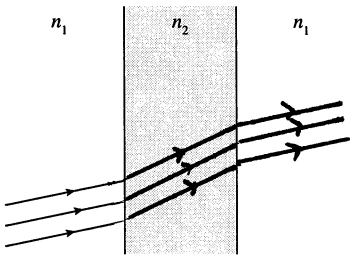


   b. Do the same for points B, C, and D.
   c. How many images are there? Identify them on the sketch above.

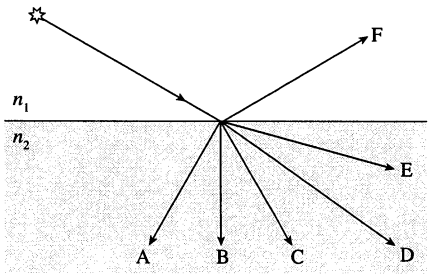
3 images

18.3 Refraction

10. Complete the trajectories of these three rays through material 2 and back into material 1. Assume $n_2 < n_1$.



11. The figure shows six conceivable trajectories of light rays leaving an object. Which, if any, of these trajectories are impossible? For each that is possible, what are the requirements of the index of refraction n_2?



Impossible A, B

Requires $n_2 > n_1$ C

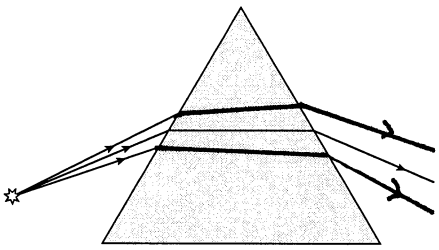
Requires $n_2 = n_1$ D

Requires $n_2 < n_1$ E

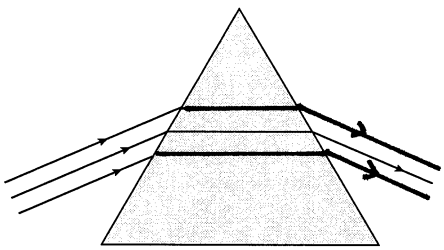
Possible for any $n_2 \neq n_1$ F

12. Complete the ray trajectories through the two prisms shown below.

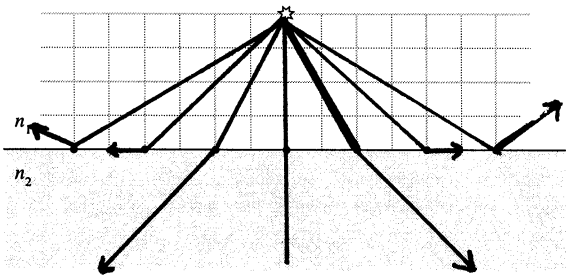
a.



b.

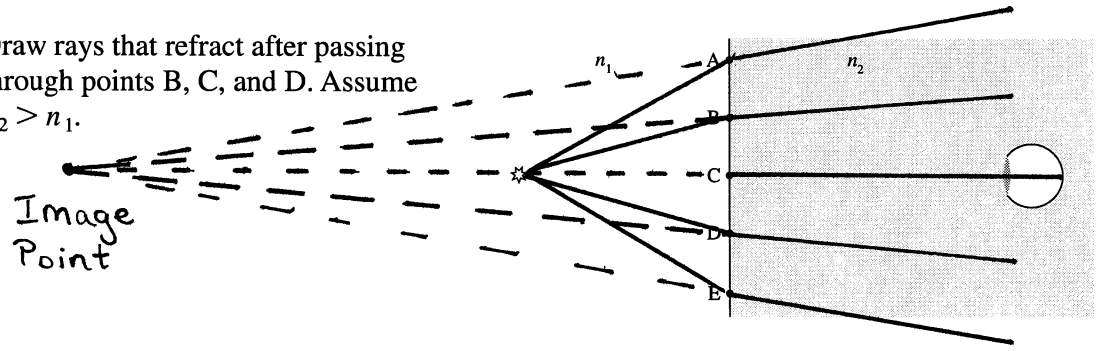


13. Draw the trajectories of seven rays that leave the object heading toward the seven dots on the boundary. Assume $n_2 < n_1$ and $\theta_c = 45°$



18.4 Image Formation by Refraction

14. a. Draw rays that refract after passing through points B, C, and D. Assume $n_2 > n_1$.



b. Use dotted lines to extend these rays backward into medium 1. Locate and label the image point.

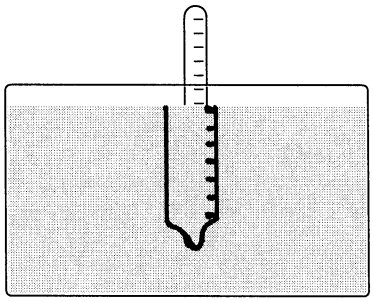
c. Now draw the rays that refract at A and E.

d. Use a different color pen or pencil to draw three rays from the object that enter the eye.

e. Does the distance to the object *appear* to be larger than, smaller than, or the same as the true distance? Explain.

The distance appears to be larger than the true distance. The image point is behind the object.

15. A thermometer is partially submerged in an aquarium. The underwater part of the thermometer is not shown.

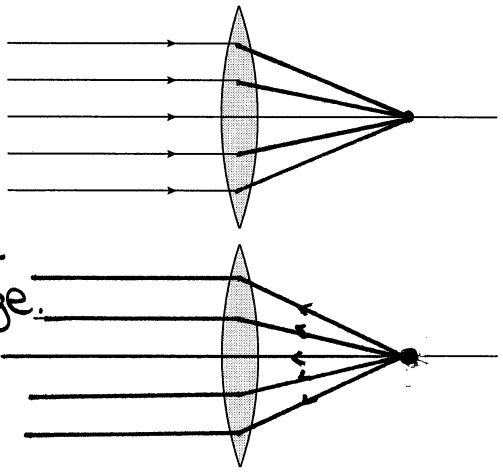


a. As you look at the thermometer, does the underwater part appear to be closer than, farther than, or the same distance as the top of the thermometer?

It appears closer.

b. Complete the drawing by drawing the bottom of the thermometer as you think it would look.

18.5 Thin Lenses: Ray Tracing



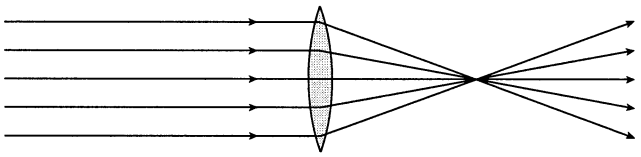
16. a. Continue these rays through the lens and out the other side.
    b. Is the point where the rays converge the same as the focal point of the lens? Or different? Explain.

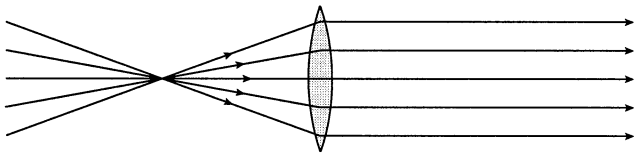
Yes, it is the focal point where parallel incident rays converge.

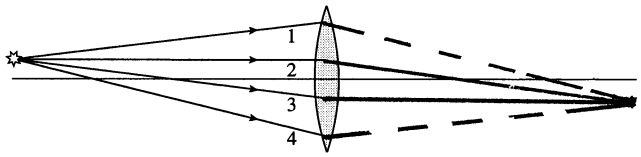
    c. Place a point source of light at the place where the rays converged in part b. Draw several rays heading left, toward the lens. Continue the rays through the lens and out the other side.
    d. Do these rays converge? If so, where?

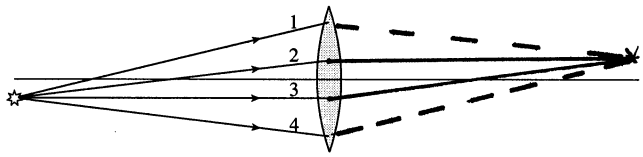
No, the rays all emerge parallel to the optical axis.

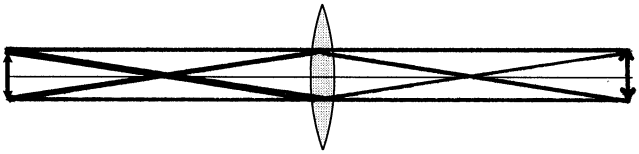
17. The top two figures show test data for a lens. The third figure shows a point source near this lens and four rays heading toward the lens.











    a. For which of these rays do you know, from the test data, its direction after passing through the lens?

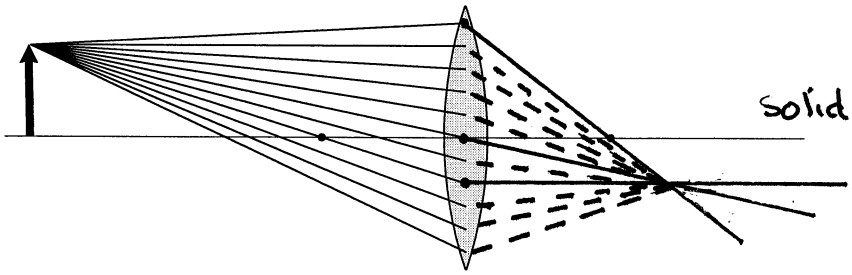
Ray 2 passes through the focal point. Ray 3 emerges parallel to the optical axis.

    b. Draw the rays you identified in part a as they pass through the lens and out the other side.
    c. Use a different color pen or pencil to draw the trajectories of the other rays.
    d. Label the image point. What kind of image is this?

Real, inverted

    e. The fourth figure shows a second point source. Use ray tracing to locate its image point.
    f. The fifth figure shows an extended object. Have you learned enough to locate its image? If so, draw it.

18. An object is near a lens whose focal points are marked with dots.

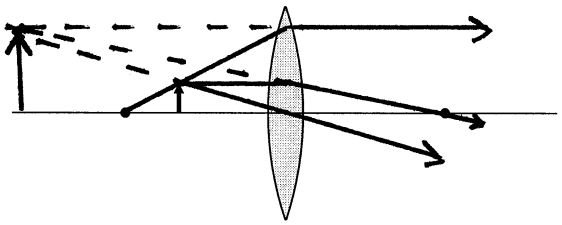


solid lines = special rays

a. Identify the three special rays and continue them through the lens.

b. Use a different color pen or pencil to draw the trajectories of the other rays.

19. An object is near a lens whose focal points are shown.



a. Use ray tracing to locate the image of this object.

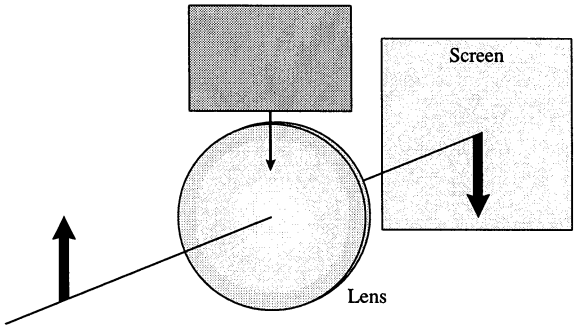
b. Is the image upright or inverted? upright

c. Is the image height larger or smaller than the object height? larger

d. Is this a real or a virtual image? Explain how you can tell.

Virtual, the rays do not converge to the image point, but appear to have come from there as they diverge from the lens. The actual light does not pass through the image point.

20. An object and lens are positioned to form a well-focused, inverted image on a viewing screen. Then a piece of cardboard is lowered just in front of the lens to cover the *top half* of the lens. Describe what happens to the image on the screen. What will you see when the cardboard is in place?

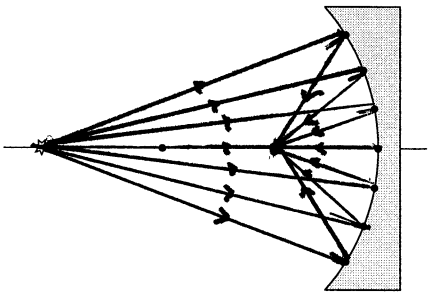


The image will still be found in the same place and orientation on the screen but it will be dimmer because less light passes through the lens. (All points on the lens contribute to the image.)

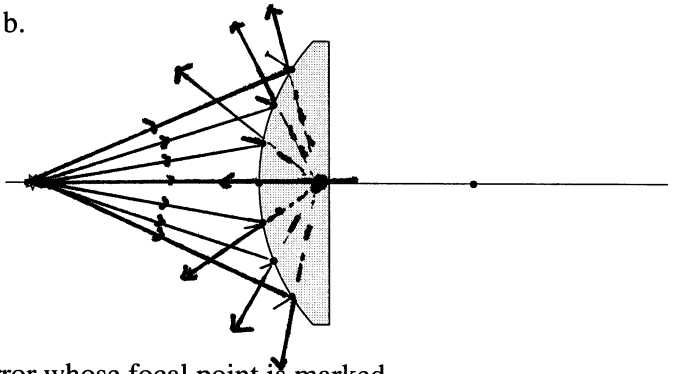
18.6 Image Formation with Spherical Mirrors

21. Two spherical mirrors are shown. The center of each is marked. For each:
    i. Draw the normal to the surface at the seven dots on the boundary.
    ii. Draw the trajectories of seven rays that strike the mirror surface at the dots and then reflect, obeying the law of reflection.
    iii. Trace the reflected rays either forward to a point where they converge or backward to a point from which they diverge.

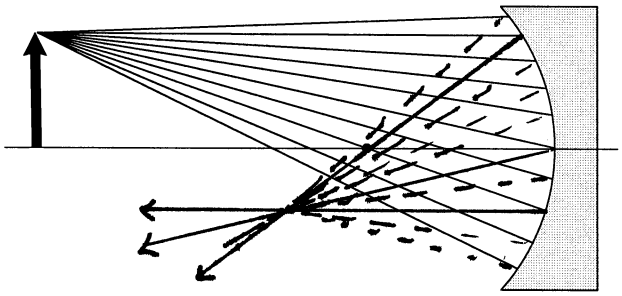
a.



b.

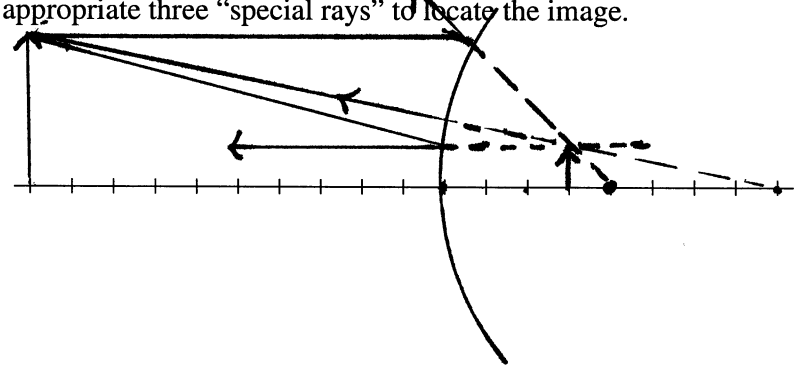


22. An object is placed near a spherical mirror whose focal point is marked.



    a. Identify the three special rays and show their reflections.
    b. Use a different color pen or pencil to draw the trajectories of the other rays.

23. A 3.0-cm-high object is placed 10.0 cm in front of a convex mirror with a focal length of −4.0 cm. Use ray tracing to determine the location of the image, the orientation of the image, and the height of the image. Please scale your drawings appropriately using the optical axis shown.
    - Locate the mirror on the optical axis shown.
    - Represent the object with an upright arrow at distance 10.0 cm from the mirror.
    - Draw the appropriate three "special rays" to locate the image.



24. A converging lens forms a real image. Suppose the object is moved farther from the lens. Does the image move toward or away from the lens? Explain.

As the object moves farther from the lens, the image moves towards the lens. The reciprocals of the object and image distance add to give the constant reciprolal of the focal length. As one increases, the other must decrease.

25. A converging lens forms a virtual image. Suppose the object is moved closer to the lens. Does the image move toward or away from the lens? Explain.

The object is already inside the focal length to form a virtual image behind the object. As the object moves closer to the lens, the image also moves closer because the rays are more highly divergent after the lens.

26. The object and final image formed by a pair of lenses is shown. Complete the diagram by drawing three principal rays and indicating the location of the intermediate image.