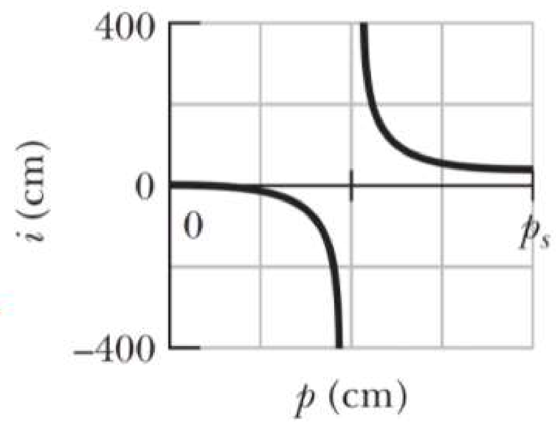
Problem 1

An object is placed against the center of a spherical mirror and then moved 70 cm from it along the central axis as the image distance i is measured. The figure gives i versus object distance p out to $p_s = 40$ cm. What is the image distance when the object is on the central axis and 70 cm from the mirror? (01小題)



i=______ cm

01: **ANS:=28**

Solution:

$$f = 20\,cm,\ \frac{1}{f} = \frac{1}{p} + \frac{1}{i}\ \frac{1}{20} = \frac{1}{70} + \frac{1}{i},\ i = 28$$

Problem 1

A concave shaving mirror has a radius of curvature of 35.0 cm. It is positioned so that the (upright) image of a man's face is 2.50 times the size of the face. How far is the mirror from the face? (01小題)

the distance of the mirror from the face=______ cm

02: **ANS:=10.5**

Solution:

$$m = -i/p,\ \frac{1}{f} = \frac{1}{p} + \frac{1}{i}$$

$$\frac{1}{p} - \frac{1}{pm} = \frac{1}{f} = \frac{2}{r},\ p = \frac{r}{2}[1 - \frac{1}{m}] = 10.5\,\text{cm}$$

Problem 2

A luminous point is moving at speed v_O=v_O toward a spherical mirror with radius of curvature r, along the central axis of the mirror. Find the speed of the image of this point. (01小題)

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v_I=______ [r,p,v_O]; p is the distance of the luminous point from the mirror at any given time.

03: **ANS:=-(r/(2*p-r))**2*v_O**

Solution:

Spherical Mirror:

$$\frac{1}{p}+\frac{1}{i}=\frac{1}{f}=\frac{2}{r},$$

$$i=\frac{pf}{p-f}=\frac{pr}{2p-r}.$$

Differentiating both sides with respect to time and using $v_O=-dp/dt$, we find

$$v_I=\frac{di}{dt}=\frac{d}{dt}\left(\frac{pr}{2p-r}\right)=\frac{-rv_O(2p-r)+2v_Opr}{(2p-r)^2}=\left(\frac{r}{2p-r}\right)^2 v_O.$$

Problem 2

A glass sphere has radius $R = 5.0$ cm and index of refraction 1.6. A paperweight is constructed by slicing through the sphere along a plane that is 2.0 cm from the center of the sphere, leaving height $h = 3.0$ cm. The paperweight is placed on a table and viewed from directly above by an observer who is distance $d = 8.0$ cm from the tabletop (see figure). When viewed through the paperweight, how far away does the tabletop appear to be to the observer? (01小題)

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the distance of tabletop appears to be to the observer=_____ cm

04: **ANS:=<u>7.4</u>**

Solution:

$$\frac{n_1}{p} + \frac{n_2}{i} = \frac{n_2 - n_1}{r}.$$

$n_1 = 1.6$ and $n_2 = 1$

$$\frac{1.6}{p} + \frac{1}{i} = \frac{1-1.6}{r}$$

Using the sign convention for r $r = -5.0$ cm

$i = -2.4$ cm for objects at $p = 3.0$ cm.

we conclude that the tabletop seems 7.4 cm

Problem 3

An object O stands on the central axis of a spherical refracting surface. For this situation, we have the index of refraction $n_1 = 1.0$ where the object is located, the index of refraction $n_2 = 1.5$ on the other side of the refracting surface and the radius of curvature $r = +30$ cm of the surface and the image distance $i = +600$. Find (a) the object distance p. (All distances are in centimeters. (b)whether the image is real (R) or virtual (V) and (c) on the same side of the surface as object O or on the opposite side. (03小題)

(a)p=______ cm (b)the image is _______ 1=real; 2=virtual (c)the image is _______ 1=on the same side; 2=on the opposite sides.

05: **ANS:=71** 06: **ANS:=1** 07: **ANS:=1**

$$\frac{n_1}{p} + \frac{n_2}{i} = \frac{n_2 - n_1}{r}.$$

$n_1 = 1.6$ and $n_2 = 1$

$$\frac{1.6}{p} + \frac{1}{i} = \frac{1-1.6}{r}$$

Using the sign convention for r $r = -5.0$ cm

$i = -2.4$ cm for objects at $p = 3.0$ cm.

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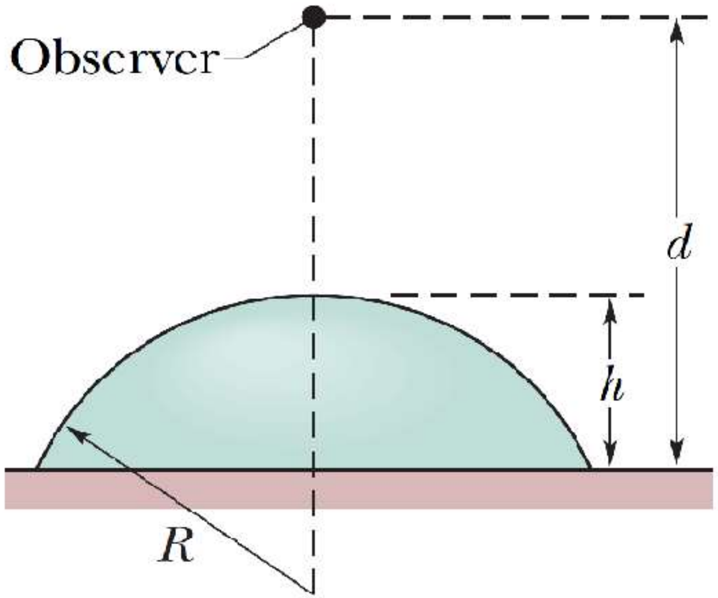


Problem 4

A double-convex lens is to be made of glass with an index of refraction of 1.5. One surface is to have twice the radius of curvature of the other and the focal length is to be 60 mm. What is the (a) smaller and (b) larger radius? (02小題)

(a) smaller radius=______ mm

08: **ANS:=45**

(b) larger radius=_

09: **ANS:=90**

We use the lens maker's equation,

$$\frac{1}{f}=(n-1)\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$$

where f is the focal length, n is the index of refraction, r_1 is the radius of curvature of the first surface encountered by the light and r_2 is the radius of curvature of the second surface. Since one surface has twice the radius of the other and since one surface is convex to the incoming light while the other is concave, set $r_2 = -2r_1$ to obtain

$$\frac{1}{f}=(n-1)\left(\frac{1}{r_1}+\frac{1}{2r_1}\right)=\frac{3(n-1)}{2r_1}.$$

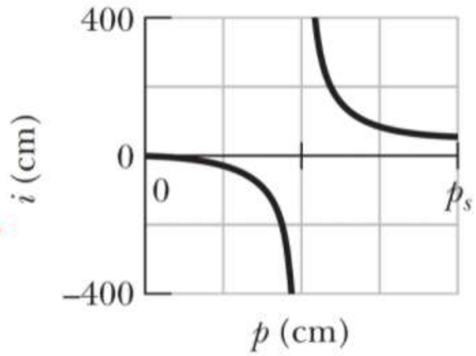
(a) We solve for the smaller radius r_1:

$$r_1=\frac{3(n-1)f}{2}=\frac{3(1.5-1)(60\text{ mm})}{2}=45\text{ mm}.$$

(b) The magnitude of the larger radius is $|r_2|=2r_1=90\text{ mm}$.

Problem 4

An object is placed against the center of a thin lens and then moved away from it along the central axis as the image distance i is measured. The figure gives i versus object distance p out to $p_s = 60$ cm. What is the image distance when $p = 100$ cm? (01小題)



i=_____ cm

10: **ANS:=43**

Solution:

The singularity of the graph (where the curve goes to $\pm\infty$) is at $p = 30$ cm, which implies ($\frac{1}{f} = \frac{1}{p} + \frac{1}{i}$) that f = 30 cm > 0 (converging type lens).

For $p = 100$ cm, $\frac{1}{f} = \frac{1}{100} + \frac{1}{i}$, $i = +43$ cm.

Problem 5

A movie camera with a (single) lens of focal length 75 mm takes a picture of a person standing 27 m away. If the person is 180 cm tall, what is the height of the image on the film? (01小題)

the height of the image on the film=______ mm

11: **ANS:=5**

Solution:

$$i = \left(\frac{1}{f} - \frac{1}{p}\right)^{-1} = \frac{fp}{p-f}.$$

$$h_i = mh_p = \left(\frac{i}{p}\right)h_p = \frac{fh_p}{p-f} = \frac{(75\text{ mm})(1.80\text{ m})}{27\text{ m} - 0.075\text{ m}} = 5.0\text{ mm}.$$

An illuminated slide is held 44 cm from a screen. How far from the slide must a lens of focal length 11 cm be placed (between the slide and the screen) to form an image of the slide's picture on the screen? (01小題)

The length of the lens from the slide=_____ cm

12: **ANS:=22**

Solution:

noting that $p + i = d = 44$ cm, we obtain

$$p^2 - dp + df = 0.$$

$$p = \frac{1}{2}(d \pm \sqrt{d^2 - 4df}) = 22\text{ cm} \pm \frac{1}{2}\sqrt{(44\text{ cm})^2 - 4(44\text{ cm})(11\text{ cm})} = 22\text{ cm}.$$

Problem 6

Object O stands on the central axis of a thin symmetric lens. For this situation, object distance $p = +10$ cm, the type of lens is diverging, and the distance between a focal point and the lens is 6.0 cm. Find (a) the image distance i and (b) the lateral magnification m of the object, including signs. Also, determine whether the image is (c) real or virtual, (d) inverted from object O or noninverted, and (e) on the same side of the lens as object O or on the opposite side. (05小題)

(a)i=______ cm

13: **ANS:=-3.8**

(b)m=_____

14: **ANS:=+0.38**

(c) the image is real or virtual? Ans.=_____ 1=real, 0=virtual

15: **ANS:=0**

(d) the image is inverted or noninverted? Ans.=_____ 1=inverted; 0=noninverted

16: **ANS:=0**

(e) the image ison the same side or opposite side? Ans.=_____ 1=same, 0=opposite

17: **ANS:=1**

Problem 6

Object O stands on the central axis of a thin symmetric lens. For this situation, object distance $p = +12$ cm, the type of lens is converging, and the distance between a focal point and the lens is 16.0 cm. Find (a) the image distance i and (b) the lateral magnification m of the object, including signs. Also, determine whether the image is (c) real or virtual, (d) inverted from object O or noninverted, and (e) on the same side of the lens as object O or on the opposite side. (05小題)

(a)i=______ cm

18: **ANS:=-48**

(b)m=_____

19: **ANS:=+4.0**

(c) the image is real or virtual? Ans.=_____ 1=real, 0=virtual

20: **ANS:=0**

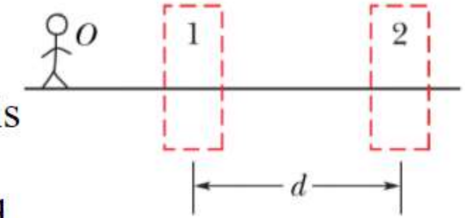
(d) the image is inverted or noninverted? Ans.=_____ 1=inverted; 0=noninverted

21: **ANS:=0**

(e) the image ison the same side or opposite side? Ans.=_____ 1=same, 0=opposite

22: **ANS:=1**

Problem 7



In the figure, the object O stands on the common central axis of two thin, symmetric lenses, which are mounted in the boxed regions. Lens 1 is mounted within the boxed region closer to O, which is at object distance $p_1 = +8.0$ cm. It is a diverging lens with focal length 6.0 cm. Lens 2, a converging lens with focal length 6.0 cm is mounted within the farther boxed region, at distance $d = 12$. Find (a) the image distance i_2 for the image produced by lens 2 (the final image produced by the system) and (b) the overall lateral magnification M for the system, including signs. Also, determine whether the final image is (c) real or virtual, (d) inverted from object O or noninverted, and (e) on the same side of lens 2 as object O or on the opposite side. (05小題)

(a)i_2=______ cm

23: **ANS:=9.8**

(b)m=_____

24: **ANS:=-0.27**

(c) the image is real or virtual? Ans.=_____ 1=real, 0=virtual

25: **ANS:=1**

(d) the image is inverted or noninverted? Ans.=_____ 1=inverted; 0=noninverted

26: **ANS:=1**

(e) the image ison the same side or opposite side? Ans.=_____ 1=same, 0=opposite

27: **ANS:=0**

(a) The image from lens 1 (which has f_1 = –6 cm) is at i_1 = –3.4 cm

This serves as an "object" for lens 2 (which has f_2 = +6 cm) with $p_2 = d - i_1$ = 15.4 cm.

$\frac{1}{p}+\frac{1}{i}=\frac{1}{f}$ (applied to lens 2) yields i_2 = +9.8 cm.

(b) $m=-\frac{i}{p}$. M = –0.27.

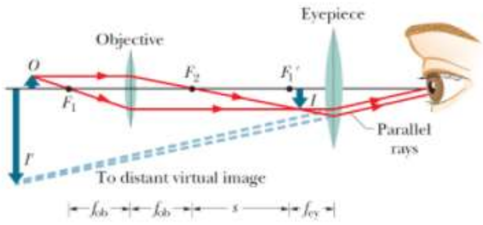
(c) The fact that the (final) image distance is a positive value means the image is real (R).

(d) The fact that the magnification is a negative value means the image is inverted (I).

(e) The image it is on the side opposite from the object (relative to lens 2).

Problem 8

An object is 10.0 mm from the objective of a certain compound microscope. The lenses are 300 mm apart, and the intermediate image is 50.0 mm from the eyepiece. What overall magnification is produced by the instrument? (01小題)



overall magnification=_____

28: **ANS:=-125**

For the intermediate image $p = 10$ mm and

$$i = (f_{ob} + s + f_{ey}) - f_{ey} = 300 \text{ m} - 50 \text{ mm} = 250 \text{ mm},$$

so

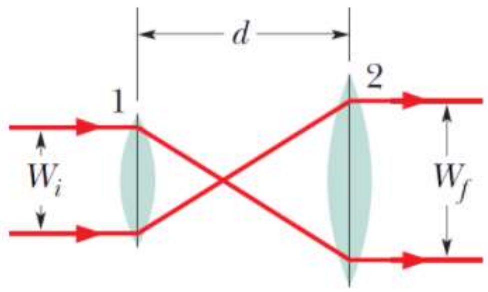
$$\frac{1}{f_{ob}} = \frac{1}{i} + \frac{1}{p} = \frac{1}{250 \text{ mm}} + \frac{1}{10 \text{ mm}} \Rightarrow f_{ob} = 9.62 \text{ mm},$$

$$s = (f_{ob} + s + f_{ey}) - f_{ob} - f_{ey} = 300 \text{ mm} - 9.62 \text{ mm} - 50 \text{ mm} = 240 \text{ mm}.$$

$$M = -\frac{s}{f_{ob}} \frac{25 \text{ cm}}{f_{ey}} = -\left(\frac{240 \text{ mm}}{9.62 \text{ mm}}\right)\left(\frac{150 \text{ mm}}{50 \text{ mm}}\right) = -125.$$

Problem 9

The figure shows a beam expander made with two coaxial converging lenses of focal lengths f_1 and f_2 and separation $d = f_1 + f_2$. The device can expand a laser beam while keeping the light rays in the beam parallel to the central axis through the lenses. Suppose a uniform laser beam of width $W_i = 2.5$ mm and intensity $I_i = 9.0\ \text{kW/m}^2$ enters a beam expander for which $f_1 = 12.5$ cm and $f_2 = 30.0$ cm. What are (a) W_f and (b) I_f of the beam leaving the expander? (c) What value of d is needed for the beam expander if lens 1 is replaced with a diverging lens of focal length $f_1 = -26.0$ cm? (03小題)



(a) W_f=______ mm

29: **ANS:=6.0**

(b) I_f=______ kW/m^2

30: **ANS:=1.6**

(c)d=______ cm

31: **ANS:=4.0**

(a) Parallel rays are bent by positive-f lenses to their focal points F_1, and rays that come from the focal point positions F_2 in front of positive-f lenses are made to emerge parallel. The key, then, to this type of beam expander is to have the rear focal point F_1 of the first lens coincide with the front focal point F_2 of the second lens. Since the triangles that meet at the coincident focal point are similar (they share the same angle; they are vertex angles), then $W_f/f_2 = W_i/f_1$ follows immediately. Substituting the values given, we have

$$W_f = \frac{f_2}{f_1} W_i = \frac{30.0\ \text{cm}}{12.5\ \text{cm}}(2.5\ \text{mm}) = 6.0\ \text{mm}.$$

(b) The area is proportional to W^2. Since intensity is defined as power P divided by area, we have

$$\frac{I_f}{I_i} = \frac{P/W_f^2}{P/W_i^2} = \frac{W_i^2}{W_f^2} = \frac{f_1^2}{f_2^2} \quad \Rightarrow \quad I_f = \left(\frac{f_1}{f_2}\right)^2 I_i = 1.6\ \text{kW/m}^2.$$

(c) The previous argument can be adapted to the first lens in the expanding pair being of the diverging type, by ensuring that the front focal point of the first lens coincides with the front focal point of the second lens. The distance between the lenses in this case is

$$f_2 - |f_1| = 30.0\ \text{cm} - 26.0\ \text{cm} = 4.0\ \text{cm}.$$