Solve equation chapter one

Q

1.4 If the refractive index for a piece of optical glass is 1.5250, calculate the speed of light in the glass. *Ans.* 1.9659 x 108 *m/s*

Solution:

$n = \frac{c}{v} = \frac{3x\ 10^8}{\text{v}}$ =1.9672 * 10 ^{8} m/s

1.5 Calculate the difference between the speed of light in kilometers per second in a vacuum and the speed of light in air if the refractive index of air is 1.0002340. Use velocity values to seven significant figures.

Q1.5

Solution:

$c = \frac{d}{t} = \frac{1.734\ km}{1/18000s} = 3.12 * \ 10^5$ km /s

C= 3*10 ^{8} m/s

$n = \frac{c}{v}$

1.000234= $\frac{3*10^5}{v}$

C= 299931.01586635= 2.99931015 x 10^5 km/s

1.6 If the moon's distance from the earth is 3.840 x 105 km, how long will it take microwaves to travel from the earth to the moon and back again?

Q1.6

Solution

C= d/t

$t=\frac{3.84*10^5 km}{3*10^5\ km/s}$ ⟹ 2t= 1.28 *2 sec

2t= 2.56 sec.

Q1.7

Solution:

$$n = \frac{c}{v}$$

$$v = \frac{d}{t} = 1.5 * \ 10^8\ km$$

$$t = \frac{d}{v} = \ \frac{1.5 * \ 10^8}{3 * 10^5} = 500\ sec.$$

1 min =60 sec. = 8 min 20 sec.

1.8 A beam of light passes through a block of glass 10.0 cm thick, then through water for a distance of 30.5 cm, and finally through another block of glass 5.0 cm thick. If the refractive index of both pieces of glass is 1.5250 and of water is 1.3330, find the total optical path.

Q1.8

Solution:

Opl=$\Delta 1 + \Delta 2 + \Delta 3 = \ n_1 d_1 \ + \ n_2 d_2 + n_3 d_3$

= 1.525*10 cm + 1.333*30.5 + 5*1.525= 63.5315 cm

1.9 A water tank is 62.0 cm long inside and has glass ends which are each 2.50 cm thick. If the refractive index of water is 1.3330 and of glass is 1.6240, find the overall optical path.

Opl=$\Delta 1+\Delta 2+\Delta 3= \; n_1 d_1 \; + \; n_2 d_2 + n_3 d_3$

=2.5*1.624+62 *1.333+2.5*1.624
=90.766

1.11 A ray of light in air is incident on the polished surface of a block of glass at an angle of 10°. *(a)* If the refractive index of the glass is 1.5258, find the angle of refraction to four significant figures. *(b)* Assuming the sines of the angles in Snell's law can be Replaced by the angles themselves, what would be the angle of refraction? *(c)* Find
the percentage error.

Q1.11

Solution

$$n_1 \sin\theta_1 = \; n_2 \sin\theta_2$$

$$1 * \sin 10^{o} = \; 1.525\,8 \;\; \sin\theta_2$$

Sin $\theta_2 = 0.113807955$

$$\theta_2 = 6.53487^{o}$$

$$\frac{\phi}{\phi'} = \frac{n'}{n}$$

$$b)$$

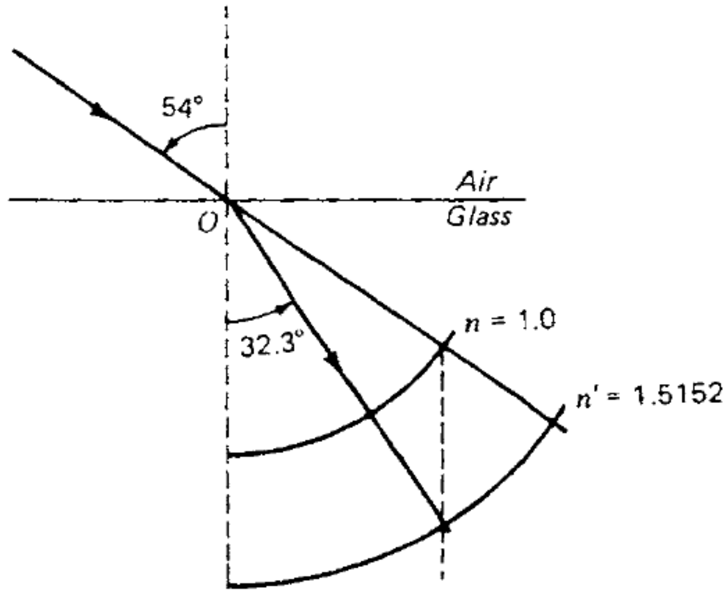
$$\frac{10}{\varphi'} = \frac{1.5258}{1}$$

$$\varphi' = 6.5539\;^{o}$$

ERROE= 100% * $\frac{6.5539-6.5348}{6.5539}$

0.29 %

Q1.13



a)

$n_1 \sin \theta_1 = n_2 \sin \theta_2$

1* sin 54 º = 1.5152 sin θ_r

Sin $\theta_r = 0.53393$

1.13 A ray of light in air is incident at an angle of 54.0° on the smooth surface of a piece of glass. *(a)* If the refractive index is 1.5152, find the angle of refraction to four significant figures. *(b)* Find the angle of refraction graphically. (See Fig. P1.13).
Ans. (a) 32.272°, (b) 32.3°

Q1.4

Solution:

$n = \frac{c}{v} = \frac{3x\ 10^8}{\mathrm{v}}$ =1.9672 * 10 ^{8} m/s

Q1.5

Solution:

$c = \frac{d}{t} = \frac{1.734\ km}{1/18000s} = 3.12 *\ 10^5$ km /s

C= 3*10 ^{8} m/s

$n = \frac{c}{v}$

1.000234= $\frac{3*10^5}{v}$

C= 299931.01586635= 2.99931015 x 10^5 km/s

Q1.6

Solution

C= d/t

t=$\frac{3.84*10^5 km}{3*10^5\ km/s}$ $\Longrightarrow$ 2t= 1.28 *2 sec

2t= 2.56 sec.

Q1.7

Solution:

$$n = \frac{c}{v}$$

$$v = \frac{d}{t} = 1.5 *\ 10^8\ km$$

$$t = \frac{d}{v} = \frac{1.5 *\ 10^8}{3 * 10^5} = 500\ sec.$$

1 min =60 sec. = 8 min 20 sec.

Q1.8

Solution:

Opl=$\Delta 1 + \Delta 2 + \Delta 3 = n_1 d_1 + n_2 d_2 + n_3 d_3$

= 1.525*10 cm + 1.333*30.5 + 5*1.525= 63.5315 cm

1.9

A water tank is 62.0 cm long inside and has glass ends which are each 2.50 cm thick. If the refractive index of water is 1.3330 and of glass is 1.6240, find the overall optical path. **(2-marks)**

Opl=$\Delta 1 + \Delta 2 + \Delta 3 = n_1 d_1 + n_2 d_2 + n_3 d_3$

=2.5*1.624+62 *1.333+2.5*1.624

=90.766

Q1.11

Solution

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$1 * \sin 10^{\circ} = 1.525\,8 \sin \theta_2$$

Sin $\theta_2 = 0.113807955$

$$\theta_2 = 6.53487^{\circ}$$

$$\frac{\phi}{\phi'} = \frac{n'}{n}$$

$b)$

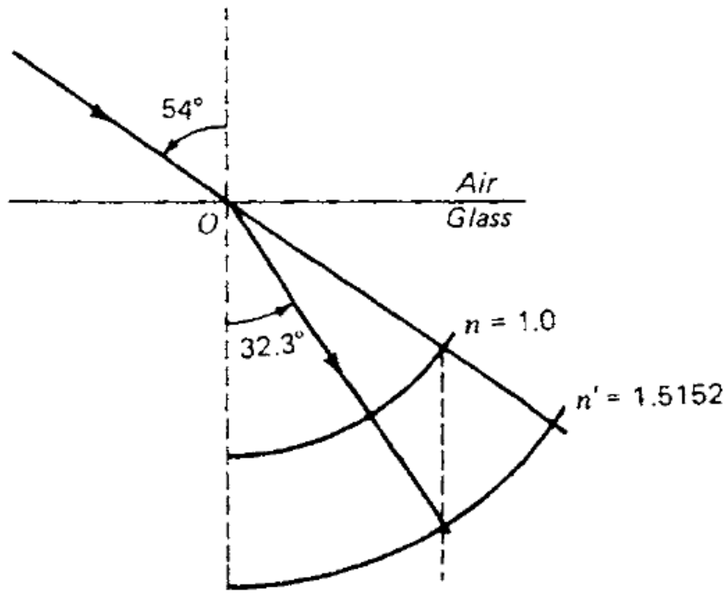
$$\frac{10}{\varphi'} = \frac{1.5258}{1}$$

$$\varphi' = 6.5539\ ^{o}$$

ERROE= 100% * $\frac{6.5539-6.5348}{6.5539}$

0.29 %

Q1.13



a)

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

1* sin 54 ^{o} = 1.5152 sin θ_r

Sin $\theta_r = 0.53393$

1.12 Find the answers to Prob. 1.11, if the angle of incidence is 45.0° and the refractive index is 1.4265.

PROBLEMS

Q1: A ray of light is incident on a piece of glass at an angle of 45.0°. If the angle of refractionis 25.37°, find *(a)* the refractive index and *(b)* the critical angle. *(c)* Solve *(b)*graphically (See Fig. P2.1). *Ans. (a)* 1.6504, *(b)* 37.30°, *(c)* 1.650 and 37.3°

Solution :

$$a) \quad n_1 \sin \emptyset_1 = n_2 \sin \emptyset'_r$$

$$1 * \sin 45° = n_2 \sin 25.37°$$

$$n_2 = \frac{\sin 45\ °}{\sin 25.37°} = \frac{0.707106}{0.42846} = 1.65034$$

b) $sin\theta_c = \frac{n_1}{n_2} \sin \theta_i \rightarrow a) \quad n_1 \sin \emptyset_1 = n_2 \sin \emptyset'_c$

$$\theta_c = \sin^{-1} \frac{1}{1.6505} \sin 90° \rightarrow \ = 0.6058$$

$$\theta_c = 37.29\ ° \ \approx 37.3\ °$$

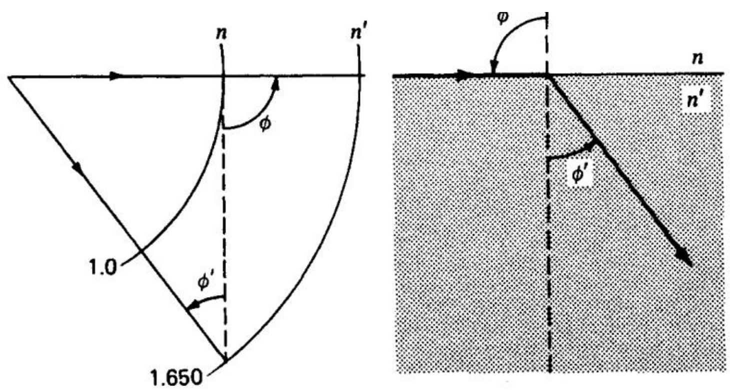


FIGURE P2.1
Graph for Prob. 2.1

Q2: Calculate the lateral displacements of rays of light incident on a block of glass with parallel sides at the following angles: *(a)* 5.0°, *(b)* 10.0°, *(c)* 15.0°, *(d)* 20.0°, *(e) 30.0°,*and *(f)* 40.0°. *(g)* Plot a graph of versus Φ. Assume the glass thickness to be 5.0 cm

Solution:

a) 5 °

$$d = t \sin \emptyset \left[1 - \frac{n}{n'} \frac{\cos \emptyset}{cos\emptyset\prime}\right]$$

$$n_1 \sin \emptyset_1 = n_2 \sin \emptyset'_r$$
$$1 * \sin 5° = 1.5 \sin \emptyset'_r$$

$$\sin \emptyset' = \frac{1 * \sin 5°}{1.5} = 0.0581$$

$$\emptyset' = 3.3307 °$$

$$d = 5 \sin 5° \left[1 - \frac{1}{1.5} \frac{\cos \emptyset}{cos\emptyset'}\right]$$
$$d = 5 \sin 5° \left[1 - \frac{1}{1.5} \frac{\cos 5°}{cos 3.3307}\right]$$
$$\therefore d = 0.1417\ cm$$
$$\therefore d = 1.417\ mm$$

b) 10 °

$$d = t \sin \emptyset \left[1 - \frac{n}{n'} \frac{\cos \emptyset}{cos\emptyset\prime}\right]$$

$$n_1 \sin \emptyset_1 = n_2 \sin \emptyset'_r$$
$$1 * \sin 5° = 1.5 \sin \emptyset'_r$$

$\sin \emptyset' = \frac{1 * \sin 5°}{1.5} = 0.0581$

$$\emptyset' = 3.3307\,°$$

$$d = 5 \sin 10° \left[1 - \frac{1}{1.5}\frac{\cos 10\,°}{cos 6.65°}\right]$$

$$d = 5 \sin 10° \left[1 - \frac{1}{1.5}\frac{0.9848}{cos 3.3300.9933}\right]$$

$$\therefore d = 0.2943\ cm$$

$$\therefore d = 2.944\ mm$$

c) 20 °

$d = t \sin \emptyset \left[1 - \frac{n}{n'}\frac{\cos \emptyset}{cos \emptyset\prime}\right]$

$$n_1 \sin \emptyset_1 = n_2 \sin \emptyset'_r$$

$$1 * \sin 20° = 1.5 \sin \emptyset'_r$$

$\sin \emptyset' = \frac{1 * \sin 20°}{1.5} = 0.2280$

$$\emptyset' = 13.18\,°$$

$$d = 5 \sin 20° \left[1 - \frac{1}{1.5}\frac{\cos 20}{cos 13.18}\right]$$

$$d = 0.6098$$

$$\therefore d \approx 6.1\ mm$$

d) 30 °

$$d = t \sin \emptyset \left[1 - \frac{n}{n'} \frac{\cos \emptyset}{cos\emptyset\prime}\right]$$

$$n_1 \sin \emptyset_1 = n_2 \sin \emptyset'_r$$
$$1 * \sin 30° = 1.5 \sin \emptyset'_r$$

$$\sin \emptyset' = \frac{1*\sin 30°}{1.5} = 0.94281$$

$$\emptyset' = 19.47°$$

$$d = 5 \sin 20° \left[1 - \frac{1}{1.5} \frac{\cos 30°}{cos 19.5°}\right]$$
$$d = 0.203\ cm$$
$$\therefore d \approx 2.03\ mm$$

e) 40 °

$$d = t \sin \emptyset \left[1 - \frac{n}{n'} \frac{\cos \emptyset}{cos\emptyset\prime}\right]$$

$$n_1 \sin \emptyset_1 = n_2 \sin \emptyset'_r$$
$$1 * \sin 20° = 1.5 \sin \emptyset'_r$$

$$\sin \emptyset' = \frac{1*\sin 20°}{1.5} = 0.42853$$

$$\emptyset' = 25.374°$$

$$d = 5 \sin 40° \left[1 - \frac{1}{1.5} \frac{\cos 40°}{cos 25.374°}\right]$$

$$d = 1.3943\ cm$$

$$\therefore d \approx 1.4\ cm$$

.Q3: A 55.0° prism made of dense flint glass is used at an angle of incidence of ϕ1 = 60.0°. Using the refractive index for D light given in Table lA, find *(a)* the angle of deviation β at the first surface, *(b)* the angle of deviation γ at the second surface, and *(c)* the total

deviation by the prism.

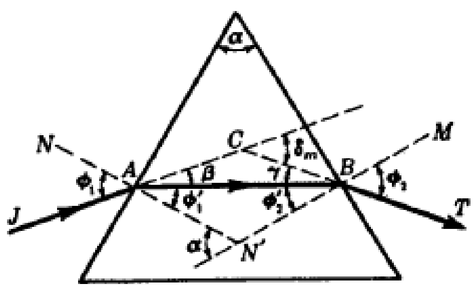
Solution:

Table Dlight n= 1.6705

$$\beta = \emptyset_1 - \emptyset'_1 angle\ of\ deviation$$

$$n_1 \sin \emptyset_1 = n_2 \sin \emptyset'_1$$

FIGURE 2H
The geometry of a light ray traversing a prism at minimum deviation.



$$1 * \sin 60 = 1.6705 \sin \emptyset'_1$$

$$\sin \emptyset'_1 = \frac{0.866}{1.6705}$$

$$\sin \emptyset'_1 = 0.518$$

$$\emptyset'_1 = 31.226^\circ$$

a) $\beta = \emptyset_1 - \emptyset'_1$
$= 60^\circ - 31.266^\circ$
$\beta = 28.773\,^\circ$

b) The angle of deviation $\gamma = \emptyset_2 - \emptyset'_2$

$$\emptyset_1{}' = \emptyset'_2$$
$$A = \emptyset'_1 + \emptyset'_1 \rightarrow 55° - 31.226° = \emptyset'_2$$
$$\emptyset'_2 = 23.774\,°$$

$$n_1 \sin \emptyset_2 = n_2 \sin \emptyset'_2$$

$$1 * \sin \emptyset_2 = 1.6705 \sin 23.774\,°$$

$$\sin \emptyset_2 = 0.67342° \rightarrow \emptyset_2 = 42.3322°$$

$$\gamma = \emptyset_2 - \emptyset'_2 = 42.3322\,° - 23.774°$$

$$\gamma = 18.55$$

c) $\delta_m = \beta + \gamma = 47.3316°$

Q4: A 45.0° flint glass prism has a refractive index of 1.6705 for sodium yellow light, and it is adjusted for minimum deviation. Find *(a)* the angle of minimum deviation and *(b)* the angle of incidence. *(c)* Solve graphically.

.

Solve problem 2.7

D$m\ or\ \delta = A(n-1)$

=(1.6705-1)*45

=30.1725

=30.2°δ

b) $i = \frac{\delta + A}{2} = \frac{30.2+45}{2} = 37.6°$

Q5: A 60.0° prism produces an angle of minimum deviation of 43.60° for blue light. Find

(a) the refractive index, *(b)* the angle of refraction, and *(c)* the angle of incidence.

Solution

$$\frac{n'}{n} = \frac{\sin \frac{1}{2}(\delta_m + \alpha)}{\sin \frac{1}{2}\alpha} = \frac{\delta_m + \alpha}{\alpha}$$

$$\delta = (n' - 1)\alpha$$

Thin prism in air

a)

$$n' = \frac{\frac{\sin(43.6+60)}{2}}{\sin\left(\frac{60}{2}\right)} = \frac{\sin 51.8^o}{\sin 30^o} = 1.5717$$

=1.572

b) The angle of refraction

A=2r

=60^o

r=A/2=60/2=30^o

c) The angle of incidence

δ=2i –A or Dm

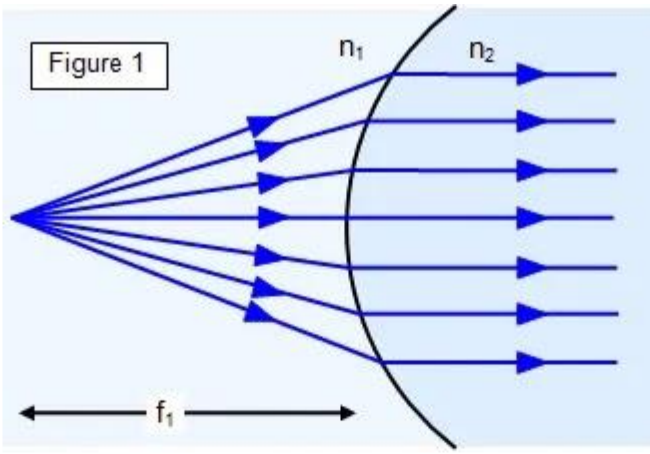
2i=δ+A

$i = \frac{\delta+A}{2} = \frac{43.6+60}{2} = 51.8^o$ *the angle of incidence*

PROBLEMS

3.1 The left end of a long glass rod of index 1.6350 is ground and polished to a convex spherical surface of radius 2.50 cm. A small object is located in the air and on the axis 9.0 cm from the vertex. Find *(a)* the primary and secondary focal lengths, *(b)* the power of the surface, *(c)* the image distance, and *(d)* the lateral magnification.

Ans. (a) +3.937 and *+6.43cm,(b)* +25.40D,(c) *+11.44cm,(d) -0.777*



a) $\frac{n}{f} = \frac{n_2 - n_1}{R}$

$$\frac{1}{f_1} = \frac{n_2 - 1}{R}$$

$$f1 = \frac{r}{n_2 - 1}$$

$$f_1 = \frac{2.5}{0.635} = +3.937\ cm$$

$$2) the\ secondary\ focal\ length$$

$$\frac{n_2}{f_2} = \frac{n_2 - 1}{R}$$

$$\frac{1.635}{f_2} = \frac{1.635 - 1}{2.5}$$

$$\frac{1.635}{f_2} = \frac{0.635}{2.5}$$

b) the power of the surface $p = \frac{1}{f(m)} = \frac{n_2 - 1}{R} = \frac{1.635 - 1}{0.025} = 25.40\ cm$

c) *c)* the image distance

$\frac{n}{s} + \frac{n'}{s'} = \frac{n' - n}{r}$

$\frac{1}{9} + \frac{1.635}{s\prime} = \frac{1.634 - 1}{2.5}$

$\frac{1.635}{s'} = \frac{1.635-1}{2.5} - \frac{1}{9}$

S'=+11.443 cm

(d) The lateral magnification

$$m = -\frac{s'-r}{s+r}$$

$$m = -\frac{11.44-2.5}{11.44+2.5}$$

$$m = -\frac{8.943}{13.94} = -0.71$$

3.3 The left end of a long plastic rod of index 1.530 is ground and polished to a convex spherical surface of radius 2.650 cm. An object 2.50 cm high is located in the air and on the axis 16.0 cm from the vertex. Find *(a)* the primary and secondary focal lengths,
(b) the power of the surface, *(c)* the image distance, and *(d)* the size of the image,

Solution

a)1-

$$\frac{n_1}{f_1} = \frac{n_2 - n_1}{R}$$

$$\frac{1}{f_1} = \frac{1.53 - 1}{2.65}$$

$$\frac{1}{f_1} = \frac{0.53}{2.65}$$

$$\boldsymbol{f_1 = +5\ cm}$$

2) $the\ secondary\ focal\ length$

$$\frac{n_2}{f_2} = \frac{n_2 - 1}{R}$$

$$\frac{1.53}{f_2} = \frac{1.53-1}{2.65} = \frac{0.53}{2.65} =$$

$$f_2 = +7.65 \text{ cm}$$

b) the power of the surface $p = \frac{1}{f(m)} = \frac{n_2 - 1}{R} = \frac{1.53-1}{0.0265}$

$$p = \frac{1}{f(m)} = \frac{n_2 - 1}{R} = \frac{1.53-1}{0.0265} = \frac{0.53}{0.0265}$$

P= +20 Diopter

c) the image distance

$$\frac{n}{s} + \frac{n'}{s'} = \frac{n}{f}$$

$$\frac{1}{16} + \frac{1.53}{s\prime} = \frac{1.53-1}{2.65}$$

$$\frac{1.53}{s\prime} = \frac{0.53}{2.65} - \frac{1}{16}$$

S'=+11.12 cm

(d) the size of the image,

The lateral magnification

$$m = -\frac{s'-r}{s+r} = \frac{y\prime}{y}$$

$$-\frac{11.12 \quad -2.65}{16+2.65} = \frac{y\prime}{y}$$

$$-\frac{8.4772}{18.65} = \frac{y\prime}{2.5}$$

Y'= -1.136 cm

3.5The left end of a water trough has a transparent surface of radius - 2.0 cm. A small object 2.5 cm high is located in the air and on the axis 10.0 cm from the vertex. Find *(a)* the primary and secondary focal lengths, *(b)* the power of the surface, *(c)* the imagedistance, and *(d)* the size of the image. Assume water to have an index 1.3330.

Ans. (a) - 6.01 and - 8.01 em, *(b)* -16.65 0, *(c)* - 5.0 cm, *(d)* +0.938 cm

a) **solution**

a)1-

$$\frac{1}{f_1} = \frac{n_2 - 1}{R}$$

$$\frac{1}{f_1} = \frac{1.33 - 1}{-2}$$

$$\frac{1}{f_1} = \frac{0.33}{-2}$$

$$\boldsymbol{f_1 = -6.01\ cm}$$

2) $the\ secondary\ focal\ length$

$$\frac{n_2}{f_2} = \frac{n_2 - n_1}{R}$$

$$\frac{1.33}{f_2} = \frac{1.33-1}{-2} = \frac{0.53}{2.65} =$$

$$f_2 = -8.01 \text{ cm}$$

b) the power of the surface $p = \frac{1}{f(m)} = \frac{n_2 - 1}{R} = \frac{1.333-1}{-0.02}$

OR $p = \frac{1}{f(m)} = -\frac{1}{6.01} - 16.65\ D$

c) the image distance

$$\frac{n}{s} + \frac{n'}{s'} = \frac{n}{f}$$

b) $\frac{1}{10}+\frac{1.33}{s\prime}=\frac{1.333-1}{-2}$

$\frac{1.33}{s\prime}=\frac{0.33}{-2}-\frac{1}{10}$

c) *S'= - 5.001 cm*

d)

(d) the size of the image,

e) The lateral magnification

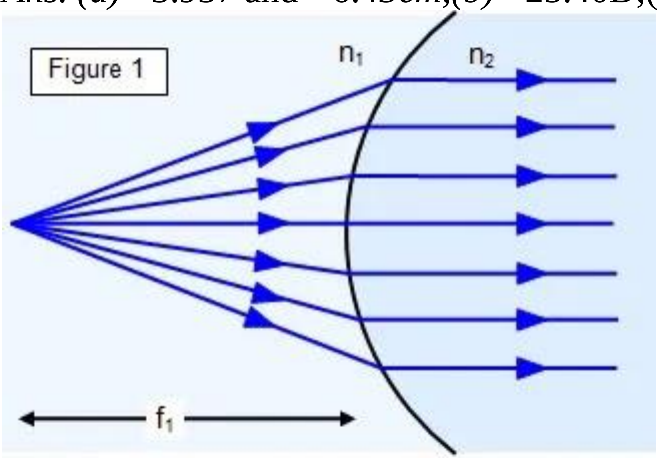
f) $m = -\frac{s'-r}{s+r}=\frac{y\prime}{y}$

$-\frac{-5+2}{10-2}=\frac{y\prime}{2.5}$

PROBLEMS

3.1 The left end of a long glass rod of index 1.6350 is ground and polished to a convex spherical surface of radius 2.50 cm. A small object is located in the air and on the axis 9.0 cm from the vertex. Find *(a)* the primary and secondary focal lengths, *(b)* the power of the surface, *(c)* the image distance, and *(d)* the lateral magnification.

Ans. (a) +3.937 and *+6.43cm,(b)* +25.40D,(c) *+11.44cm,(d) -0.777*



d) $\frac{n}{f}=\frac{n_2-n_1}{R}$

$$\frac{1}{f_1}=\frac{n_2-1}{R}$$

$$f1 = \frac{r}{n_2 - 1}$$

$$f_1 = \frac{2.5}{0.635} = +3.937\ cm$$

$2)the\ secondary\ focal\ length$

$$\frac{n_2}{f_2} = \frac{n_2 - 1}{R}$$

$$\frac{1.635}{f_2} = \frac{1.635 - 1}{2.5}$$

$$\frac{1.635}{f_2} = \frac{0.635}{2.5}$$

e) the power of the surface $p = \frac{1}{f(m)} = \frac{n_2 - 1}{R} = \frac{1.635 - 1}{0.025} = 25.40\ cm$

f) *c)* the image distance

$$\frac{n}{s} + \frac{n'}{s'} = \frac{n' - n}{r}$$

$$\frac{1}{9} + \frac{1.635}{s\prime} = \frac{1.634 - 1}{2.5}$$

$$\frac{1.635}{s\prime} = \frac{1.635 - 1}{2.5} - \frac{1}{9}$$

S'=+11.443 cm

(d) The lateral magnification

$$m = -\frac{s' - r}{s + r}$$

$$m = -\frac{11.44 - 2.5}{11.44 + 2.5}$$

$$m = -\frac{8.943}{13.94} = -0.71$$

3.3 The left end of a long plastic rod of index 1.530 is ground and polished to a convex spherical surface of radius 2.650 cm. An object 2.50 cm high is located in the air and on the axis 16.0 cm from the vertex. Find *(a)* the primary and secondary focal lengths,
(b) the power of the surface, *(c)* the image distance, and *(d)* the size of the image,

Solution
a)1-

$$\frac{n_1}{f_1} = \frac{n_2 - n_1}{R}$$

$$\frac{1}{f_1} = \frac{1.53 - 1}{2.65}$$

$$\frac{1}{f_1} = \frac{0.53}{2.65}$$

$$\boldsymbol{f_1 = +5\ cm}$$

2) $the\ secondary\ focal\ length$

$$\frac{n_2}{f_2} = \frac{n_2 - 1}{R}$$

$$\frac{1.53}{f_2} = \frac{1.53-1}{2.65} = \frac{0.53}{2.65} =$$

$f_2 = +$ 7.65 cm

b) the power of the surface $p = \frac{1}{f(m)} = \frac{n_2 - 1}{R} = \frac{1.53-1}{0.0265}$

$$p = \frac{1}{f(m)} = \frac{n_2-1}{R} = \frac{1.53-1}{0.0265} = \frac{0.53}{0.0265}$$

P= +20 Diopter

c) the image distance

$$\frac{n}{s}+\frac{n'}{s'}=\frac{n}{f}$$

$$\frac{1}{16}+\frac{1.53}{s\prime}=\frac{1.53-1}{2.65}$$

$$\frac{1.53}{s\prime}=\frac{0.53}{2.65}-\frac{1}{16}$$

S'=+11.12 cm

(d) the size of the image,

The lateral magnification

$$m = -\frac{s'-r}{s+r}=\frac{y\prime}{y}$$

$$-\frac{11.12\quad -2.65}{16+2.65}=\frac{y\prime}{y}$$

$$-\frac{8.4772}{18.65}=\frac{y\prime}{2.5}$$

Y'= -1.136 cm

3.5The left end of a water trough has a transparent surface of radius - 2.0 cm. A small object 2.5 cm high is located in the air and on the axis 10.0 cm from the vertex. Find *(a)* the primary and secondary focal lengths, *(b)* the power of the surface, *(c)* the imagedistance, and *(d)* the size of the image. Assume water to have an index 1.3330.

Ans. (a) - 6.01 and - 8.01 em, *(b)* -16.65 0, *(c)* - 5.0 cm, *(d)* +0.938 cm

g) **solution**

a)1-

$$\frac{1}{f_1}=\frac{n_2 - 1}{R}$$

$$\frac{1}{f_1}=\frac{1.33 - 1}{-2}$$

$$\frac{1}{f_1} = \frac{0.33}{-2}$$

$$\boldsymbol{f_1 = -6.01\ cm}$$

2) $the\ secondary\ focal\ length$

$$\frac{n_2}{f_2} = \frac{n_2 - n_1}{R}$$

$$\frac{1.33}{f_2} = \frac{1.33 - 1}{-2} = \frac{0.53}{2.65} =$$

$$f_2 = -8.01 \text{ cm}$$

b) the power of the surface $p = \frac{1}{f(m)} = \frac{n_2 - 1}{R} = \frac{1.333 - 1}{-0.02}$

OR $p = \frac{1}{f(m)} = -\frac{1}{6.01} - 16.65\ D$

c) the image distance

$$\frac{n}{s} + \frac{n'}{s'} = \frac{n}{f}$$

h) $\frac{1}{10} + \frac{1.33}{s\prime} = \frac{1.333-1}{-2}$

$$\frac{1.33}{s\prime} = \frac{0.33}{-2} - \frac{1}{10}$$

i) *S'= - 5.001 cm*

j)

(d) the size of the image,

k) The lateral magnification

l) $m = -\frac{s'-r}{s+r} = \frac{y\prime}{y}$

$$-\frac{-5+2}{10-2} = \frac{y\prime}{2.5}$$

$$-\frac{-3}{8}=\frac{y'}{2.5}$$

$$-\frac{-3}{8}=\frac{y'}{2.5}$$

$$-\frac{-3}{8}=\frac{y'}{2.5}$$

$$+0.375=\frac{y'}{2.5}$$

Y= +0.9375 cm

Y'= +.938 cm

$$-\frac{-3}{8}=\frac{y'}{2.5}$$

$$-\frac{-3}{8}=\frac{y'}{2.5}$$

$$-\frac{-3}{8}=\frac{y'}{2.5}$$

$$+0.375=\frac{y'}{2.5}$$

Y= +0.9375 cm

Y'= +.938 cm

4.1 An object located 12.0 cm in front of a thin lens has its image formed on the opposite side 42.0 cm from the lens. Calculate *(a)* the focal length of the lens and *(b)* the lens power. *Ans. (a)* +9.33 cm, *(b)* + 10.72 D

Solution

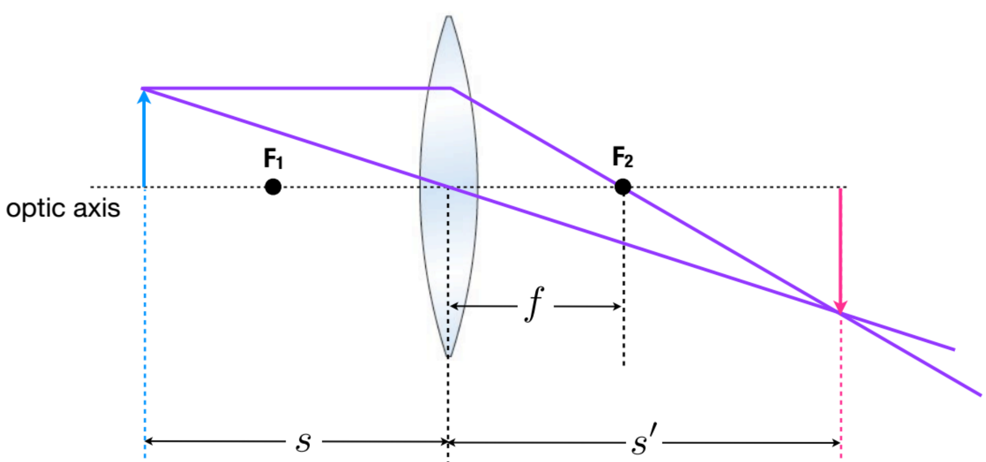
$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

a) $f = \frac{uxv}{u+v} = \frac{42*12}{42+12} = +\frac{504}{54} = +9.333\ cm$

b) P=$\frac{1}{f(m)} = \frac{100}{9.333} = 10.72\ D$

4.2 An object 2.50 cm high is placed 12.0 cm in front of a thin lens of focal length 3.0 cm.
Calculate *(a)* the image distance, *(b)* the magnification, and *(c)* the nature of the image.*(d)* Check your answers by a graph.

➜ we draw the rays as though they refract at the center - this is OK for ‘thin’ lenses



Solution
a)

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

a) $v = \frac{fxu}{u-f} = \frac{3*12}{12-3} = +\frac{36}{9} = +4cm$

b) P=$\frac{1}{f(m)} = \frac{100}{3} = 33.33\ \ D$

c) $m = -\frac{v}{u} = -\frac{4}{12} = -\frac{1}{3}$

We know this lens is real, inverted and minimized

4.3 The two faces of a thin lens have radii'l = + 10.0 cm and'2 = - 25.0 cm, respectively.The lens is made of glass of index 1.740. Calculate *(a)* the focal length and *(b)* the power of the lens.

Solution

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

$$\frac{1}{f} = (1.74 - 1)(\frac{1}{10} - \frac{1}{-25)}$$

$$\frac{1}{f} = (1.74 - 1)(\frac{1}{10} - \frac{1}{-25)}$$

$$\frac{1}{f} = (0.74)(\frac{1}{10} + \frac{1}{25)}$$

$\frac{1}{f} = (0.74)(\frac{25+10}{250)})=\frac{25.9}{250}$

$$\frac{1}{f} = (0.74)(\frac{35}{250})$$

f=9.65 cm

b) P=$\frac{1}{f(m)} = \frac{100}{9.653} = 10.36\ D$

4.4 An object 3.50 cm high is located 10.0 cm in front of a lens whose focal length *f*= - 6.0 cm. Calculate *(a)* the power of the lens, *(b)* the image distance, and *(c)* the lateral magnification. Graphically locate the image by *(d)* the parallel-ray method and *(e)* the oblique-ray method.

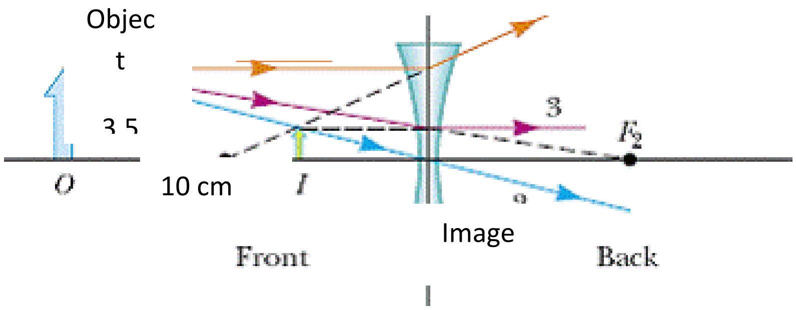
Solution

a) P=$\frac{1}{f(m)} = -\frac{100}{6} = -16.66\ D$

b) $v' = \frac{uxf}{u+f} = \frac{10x-6}{10+6} = -\frac{60}{16} = -3.75\ cm$

$$c)\ m = -\frac{v}{u} = \frac{3.75}{10} = 0.375$$

d)



d)

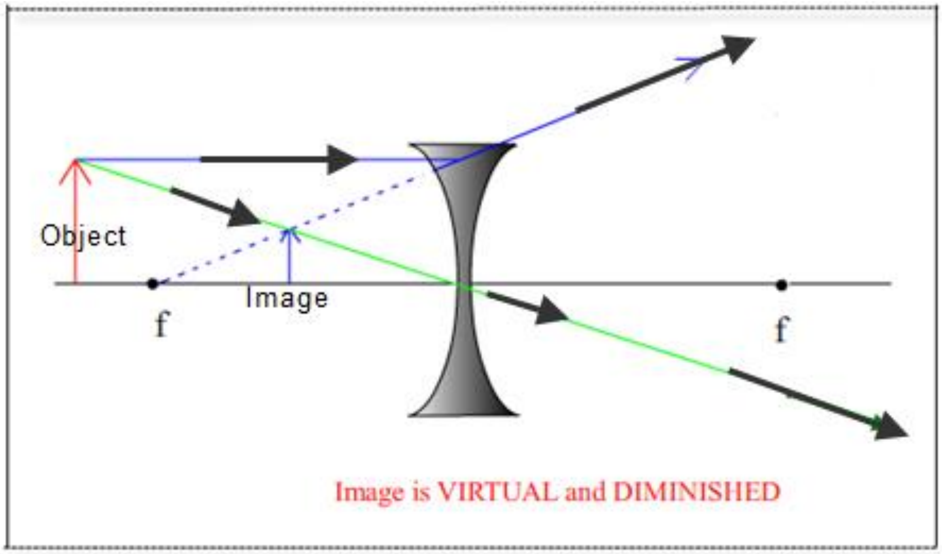
4.5 An equiconcave lens is to be made of flint glass of index 1.750. Calculate the radii of curvature if it is to have a power of - 3.0 D. *Ans.* Both 50.0-cm radius

Solution

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

$$-3 = (1.75-1)\left(\frac{-1}{r} - \frac{-1}{r}\right)$$

-3 = $\frac{-0.75x\ 2}{r}$ r = 0.5 m ⟹ r = 50 cm



4.6 A plano-convex lens is to be made of light flint glass of index 1.680. Calculate the radius of curvature necessary to give the lens a power of 4.5 D

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

=0

$$p = (n-1)\left(\frac{1}{r_1} - \frac{1}{\infty}\right)$$

$$p = \frac{1.68 - 1}{r_1}$$

$4.5 = \frac{0.68}{r_1}$

r_1= 15.11 cm   the radius of curvature

4.7 Two lenses with focal lengths f_1 = +5.0 cm and f_2 = + 10.0 cm are located 5.0 cm apart. If an object 2.50 cm high is located 15.0 cm in front of the first lens, find *(a)* the position and *(b)* the size of the final image.
Ans. (a) +2.00 cm from second lens, *(b)* -1.0 cm

Solution

$$\frac{1}{u_1} + \frac{1}{v_1} = \frac{1}{f_1}$$

$$v_{11} = \frac{f_1 x u_1}{u_1 - f_1} = \frac{15x5}{15-5} = +\frac{75}{10} = +7.5cm$$

$$u_{o2} = d - v_1 = 5 - 7.5 = -2.5\ cm$$

$$v_2 = \frac{f_2 x\ u_2}{u_2 - f_2} = \frac{10\ x - 2.5}{-2.5 - 10} = \frac{+25}{-12.5} = +2$$

$$m_{t=} m_1 m_2 = \left(\frac{-v_1}{u_1}\right)\left(\frac{-v_2}{u_2}\right) = \left(\frac{-7.5}{15}\right)\left(\frac{+2}{-2.5}\right)$$

$$\frac{y'}{y} = \frac{-15}{15x\ 2.5}$$

$$\frac{y'}{2.5} = \frac{-1}{2.5}$$

$$y' = -1\ cm$$

4.8 A converging lens is used to focus a sharp image of a candle flame on a screen. Without
moving the candle flame a second lens with radii'l = + 10.0 cm and'2 = -20.0 cm
and index 1.650 is placed in the converging beam 30.0 cm from the screen. *(a)* Calculate
the power of the second lens. *(b)* How close to the second lens should the screen now
be placed to obtain a sharp image of the flame? *(c)* Make a graph of this experiment

4. 4.8 A converging lens is used to focus a sharp image of a candle flame on a screen. Without
moving the candle flame a second lens with radii'l = + 10.0 cm and'2 = -20.0 cm
and index 1.650 is placed in the converging beam 30.0 cm from the screen. *(a)* Calculate
the power of the second lens. *(b)* How close to the second lens should the screen now
be placed to obtain a sharp image of the flame? *(c)* Make a graph of this experiment.

4.9 A double-convex lens is to be made of glass having a refractive index of 1.580. If one
surface is to have twice the radius of the other and the focal length is to be +6.0 cm,
find the radii.

Solution

1. $R_1=2R_2$ p= 1/f(m) $\therefore f = 6\ cm$
2. $\frac{1}{f} = (n' - 1)(\frac{1}{R_1} - \frac{1}{R_2})$
3. $\frac{1}{6} = (1.58 - 1)(\frac{1}{2R_2} + \frac{1}{R_2})$

R2=5.22 cm, R1=10.44 cm

$R_1=2R_2$ =2*3.9

$R_{1=}$ 7.8 cm

4.10 Two lenses having focal lengths $f1$ = +9.0 cm and $f2$ = -18.0 cm are placed 3.0 cm apart. If an object 2.50 cm high is located 20.0 cm in front of the first lens, calculate *(a)* the position and *(b)* the size of the final image.

Solve problems

Q1: *An object located 12.0 cm in front of* a thin lens has its image formed on the opposite side 42.0 cm from the lens. Calculate *(a)* the focal length of the lens and *(b)* the lens power.

Solution

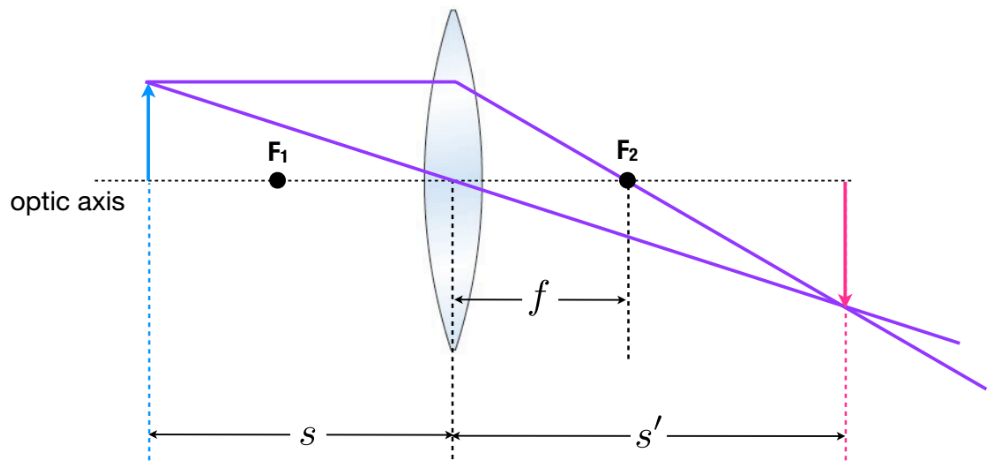
$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

c) $f = \frac{uxv}{u+v} = \frac{42*12}{42+12} = +\frac{504}{54} = +9.333\ cm$

d) $P=\frac{1}{f(m)} = \frac{100}{9.333} = 10.72\ D$

Q2: An object 2.50 cm high is placed 12.0 cm in front of a thin lens of focal length 3.0 cm.Calculate *(a)* the image distance, *(b)* the magnification, and *(c)* the nature of the image.*(d)* Check your answers by a graph.

➜ we draw the rays as though they refract at the center - this is OK for ‘thin’ lenses



Solution

a)

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

d) $v=\frac{fxu}{u-f}=\frac{3*12}{12-3}=+\frac{36}{9}=+4cm$

e) $P=\frac{1}{f(m)}=\frac{100}{3}=33.33\ D$

f) $m=-\frac{v}{u}=-\frac{4}{12}=-\frac{1}{3}$

We know this lens is real, inverted and minimized

Q3: The two faces of a thin lens have radii r_l = + 10.0 cm and r_2 = - 25.0 cm, respectively. The lens is made of glass of index 1.740. Calculate *(a)* the focal length and *(b)* the power of the lens.

Solution

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

$$\frac{1}{f}=(1.74-1)(\frac{1}{10}-\frac{1}{-25)}$$

$$\frac{1}{f}=(1.74-1)(\frac{1}{10}-\frac{1}{-25)}$$

$$\frac{1}{f} = (0.74)(\frac{1}{10} + \frac{1}{25})$$

$\frac{1}{f} = (0.74)(\frac{25+10}{250)})=\frac{25.9}{250}$

$$\frac{1}{f} = (0.74)(\frac{35}{250})$$

f=9.65 cm

c) P=$\frac{1}{f(m)} = \frac{100}{9.653} = 10.36\ D$

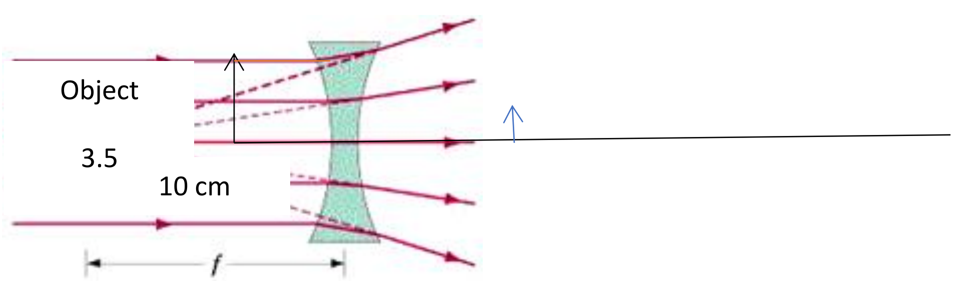
Q4: An object 3.50 cm high is located 10.0 cm in front of a lens whose focal length *f*= - 6.0 cm. Calculate *(a)* the power of the lens, *(b)* the image distance, and *(c)* the lateral magnification. Graphically locate the image by *(d)* the parallel-ray method and *(e)* the oblique-ray method.

Solution

b) P=$\frac{1}{f(m)} = -\frac{100}{6} = -16.66\ D$

b) $v' = \frac{uxf}{u+f} = \frac{10x-6}{10+6} = -\frac{60}{16} = -3.75\ cm$

$c)\ m = -\frac{v}{u} = \frac{3.75}{10} = 0.375$



d)

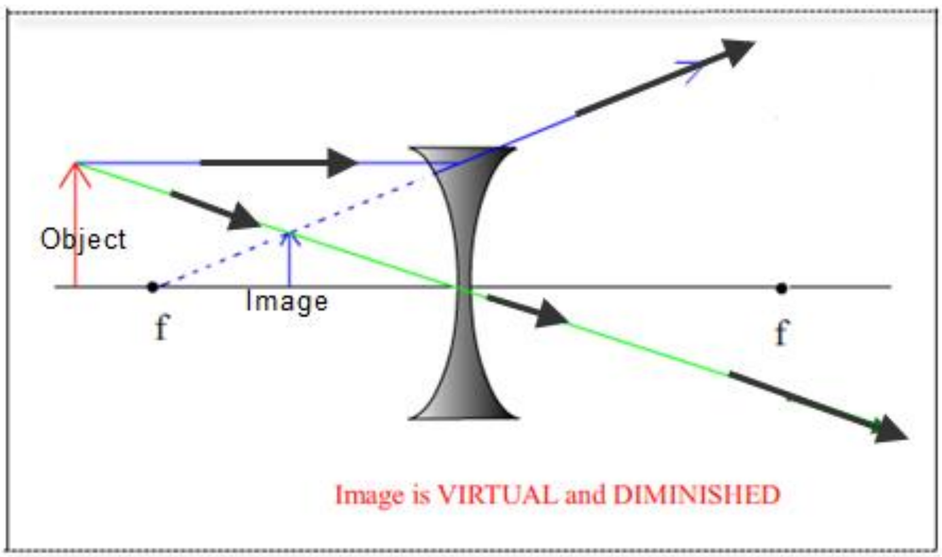
Q5: An equiconcave lens is to be made of flint glass of index 1.750. Calculate the radii of curvature if it is to have a power of - 3.0 D.

Solution

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

$$-3 = (1.75 - 1)\left(\frac{-1}{r} - \frac{-1}{r}\right)$$

-3 = $\frac{-0.75x\ 2}{r}$ r = 0.5 m → r = 50 cm



Q6: A plano-convex lens is to be made of light flint glass of index 1.680. Calculate the radius of curvature necessary to give the lens a power of 4.5 D

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

$$p = (n - 1)\left(\frac{1}{r_1} - \frac{1}{\infty}\right)$$

$$p = \frac{1.68 - 1}{r_1}$$

4.5 = $\frac{0.68}{r_1}$

r_1= 15.11 cm   the radius of curvature

Q7: Two lenses with focal lengths f_1 = +5.0 cm and f_2 = + 10.0 cm are located 5.0 cm apart. If an object 2.50 cm high is located 15.0 cm in front of the first lens, find *(a)* the position and *(b)* the size of the final image.

Solution

$$\frac{1}{u_1}+\frac{1}{v_1}=\frac{1}{f_1}$$

$v_{11}=\frac{f_1 x u_1}{u_1-f_1}=\frac{15x5}{15-5}=+\frac{75}{10}=+7.5cm$

$$u_{o2}=d-v_1=5-7.5=-2.5\ cm$$

$$v_2=\frac{f_2 x\ u_2}{u_2-\ f_2}=\frac{10\ x-2.5}{-2.5-10}=\frac{+25}{-12.5}=+2$$

$m_{t=}\,m_1 m_2=\left(\frac{-\,v_1}{u_1}\right)\left(\frac{-v_2}{u_2}\right)=\left(\frac{-7.5}{15}\right)\left(\frac{+2}{-2.5}\right)$

$$\frac{y'}{y}=\frac{-15}{15x\ 2.5}$$

$$\frac{y'}{2.5}=\frac{-1}{2.5}$$

$$y'=-1\ cm$$

Q8: A converging lens is used to focus a sharp image of a candle flame on a screen. Without moving the candle flame a second lens with radii r_1 = + 10.0 cm and r_2 = -20.0 cm and index 1.650 is placed in the converging beam 30.0 cm from the screen. *(a)* Calculate the power of the second lens. *(b)* How close to the second lens should the screen now be placed to obtain a sharp image of the flame? *(c)* Make a graph of this experiment

4.10 Two lenses having focal lengths f_1 = +9.0 cm and f_2 = -18.0 cm are placed 3.0 cm apart. If an object 2.50 cm high is located 20.0 cm in front of the first lens, calculate *(a)* the position and *(b)* the size of the final image. *(c)* Check your answer graphically.

Solution:

$$\frac{1}{s_{o1}} + \frac{1}{{s'}_{i_1}} = \frac{1}{f_1}$$

$$a) {s'}_{i1} = \frac{f_1 x s_{o1}}{s_{o1} - f_1} = \frac{9x20}{20-9} = +\frac{180}{11} = +16.363cm$$

$$s_{o2} = 3 - 16 = 3 - 16.363 = -13.363\ cm$$

The position of the final image

$${s'}_{i2} = \frac{f_2 x\ s_{o2}}{s_{o2} - f_2} = \frac{-18\ x - 13.636}{-13.636+18} = \frac{+240.545}{4.637} = +51.875\ \text{cm}$$

$$m_{t=} m_1 m_2 = \left(\frac{-s'_{i1}}{s_{o1}}\right)\left(\frac{-s'_{i2}}{s_{o2}}\right) = \left(\frac{-16.363}{20}\right)\left(\frac{-51.875}{-13.636}\right)$$

(b) The size of the final image

$$\frac{y'}{y} = -3.1124$$

$$\frac{y'}{2.5} = -3.1124$$

$$y' = -7.781\ cm$$

4.11 A lantern slide 8.0 cm high is located 3.50 m from a projection screen. What is the focal length of the lens that will be required to project an image 1.0 m high?

4.12 An object is located 1.60 m from a white screen. A lens of what focal length will be required to form a real and inverted image on the screen with a magnification of - 6.0?

Ans. 19.59 cm

Thin lens equation is $\frac{1}{u_o} + \frac{1}{v_i} = \frac{1}{f}$

$\frac{1}{x} + \frac{1}{D-x} = \frac{1}{f}$

$\frac{1}{x} + \frac{1}{1.6-x} = \frac{1}{f}$

The lateral magnification $m = -\frac{v_i}{u_0} =$

$$-6 = -\frac{1.6-x}{x}$$

$The\ distance\ of\ object\ \ u_o = x = 0.2286$ m

The distance of image $v_i = 1.6 - x = 1.3714$ m

$$\frac{D}{x(D-x)} = \frac{1}{f}$$

$$\frac{1.6}{0.2286(1.3714)} = \frac{1}{f}$$

$$\therefore f = 0.1959\ m = 19.59\ cm$$

4.13 Three thin lenses have powers + 1.50, - 2.80, and 3.40 D, respectively. What are all the possible powers that can be obtained with these three lenses using one, two, or three at a time in contact?

4.14 Two thin lenses having the following radii of curvature and index are placed in contact. For the first lens r_1 = + 12.0 cm r_2 = -18.0 cm, and n = 1.560, and for the second lens r_1 = -30.0 cm, r_2 = +20.0 cm, and n = 1.650. Find their *(a)* individual powers, *(b)* combined power, *(c)* individual focal lengths, and *(d)* combined focal length.

Solution:

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

$$1 - \ P_1 = (1.56 - 1)(\frac{1}{0.12} - (-\frac{1}{0.18})$$

P_1= 7.7 8 D

$$2 - \ P_2 = (1.65 - 1)(\frac{1}{0.3} - (\frac{1}{0.2})$$

P_2= -5.41 D

P= P_1+P_2

P = + 2.361 Diopter

4.15 An object 2.50 cm high is located 15.0 cm in front of a lens of + 5.0 cm focal length. A lens with a focal length of -12.0 cm is placed 2.50 cm beyond this converging lens. Find *(a)* the position and *(b)* the size of the final image.
Ana. (a) +8.57 cm, *(b)* -2.143 cm

4.16 An object 2.50 cm high is located 8.0 cm in front of a lens of - 2.40 cm focal length. A lens of + 5.0 cm focal length is placed 1.50 cm behind the first lens. Find *(a)* the position and *(b)* the size of the final image

$$\frac{1}{s_{o1}} + \frac{1}{s'_{i_1}} = \frac{1}{f_1}$$

$$s'_{i1} = \frac{f_1 x s_{o1}}{s_{o1} - f_1} = \frac{9x20}{20-9} = +\frac{180}{11} = +16.363cm$$

$$s_{o2} = a - s'_{i1} = 5 - 7.5 = -2.5\ cm$$

The position of the final image

$$s'_{i2} = \frac{f_2 x\ s_{o2}}{s_{o2} - f_2} = \frac{-18\ x - 13.636}{-13.636 + 18} = \frac{+240.545}{4.637} = +51.875 \text{ cm}$$

$$m_{t=}\ m_1 m_2 = \left(\frac{-s'_{i1}}{s_{o1}}\right)\left(\frac{-s'_{i2}}{s_{o2}}\right) = \left(\frac{-16.363}{20}\right)\left(\frac{-51.875}{-13.636}\right)$$

(b) The size of the final image

$$\frac{y'}{y} = -3.1124$$

$$\frac{y'}{2.5} = -3.1124$$

$$y' = -7.781\ cm$$

4.17 Three lenses with focal lengths of +8.40, -4.60, and +6.20 cm, respectively, are located one behind each other in this order and 2.0 cm apart. *(a)* If parallel light is incident on the first lens, how far behind the third lens will the light be brought to a focus? *(b)* Draw a scale diagram.

4.18 An object 3.50 cm high is located 8.0 cm in front of a lens of -7.0 cm focal length. A lens of +4.50 cm focal length is placed 3.5 cm behind the first lens. Find *(a)* the position and *(b)* the size of the image. *(c)* Make a diagram to scale

$$\frac{1}{s_{o1}} + \frac{1}{s'_{i_1}} = \frac{1}{f_1}$$

$$s'_{i1} = \frac{f_1 x s_{o1}}{s_{o1} - f_1} = \frac{-7x8}{8+7} = +\frac{180}{11} = -3.733cm$$

$$s_{o2} = a - s'_{i1} = 3.5 + 3.733 = 7.233\ cm$$

The position of the final image

$$s'_{i2} = \frac{f_2 x\ s_{o2}}{s_{o2} - f_2} = \frac{4.5\ x7.233}{7.233-4.5} = \frac{+32.5485}{2.733} = +11.91\ \text{cm}$$

$$m_{t=} m_1 m_2 = \left(\frac{-s'_{i1}}{s_{o1}}\right)\left(\frac{-s'_{i2}}{s_{o2}}\right) = \left(\frac{-11.91}{7.233}\right)\left(\frac{3.733}{8}\right)$$

(b) The size of the final image

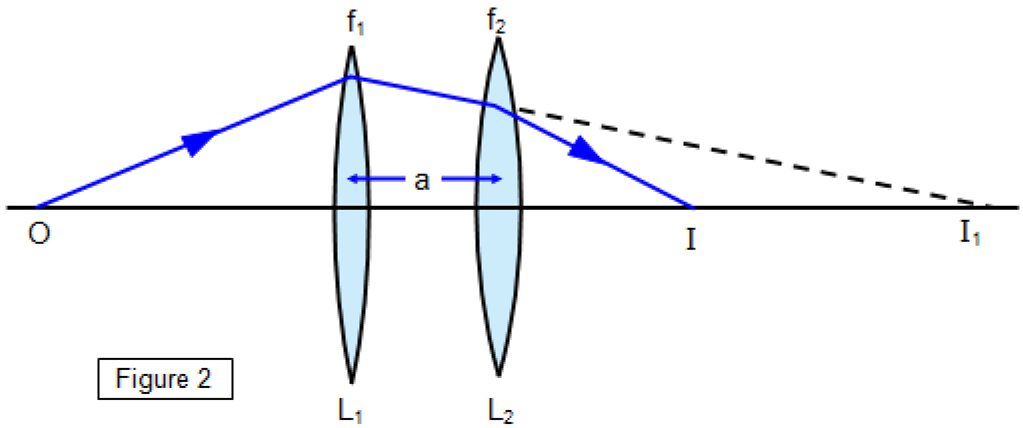
$$\frac{y'}{y} = -0.7683$$

$$\frac{y'}{3.5} = -0.7683$$

$$y' = -2.68\ cm$$

4.7 Two lenses with focal lengths f_1 = +5.0 cm and f_2 = + 10.0 cm are located 5.0 cm apart. If an object 2.50 cm high is located 15.0 cm in front of the first lens, find *(a)* the position and *(b)* the size of the final image.

Ans. (a) +2.00 cm from second lens, *(b)* -1.0 cm



Solution

$$\frac{1}{s_{o1}} + \frac{1}{s'_{i_1}} = \frac{1}{f_1}$$

$$s'_{i1} = \frac{f_1 x s_{o1}}{s_{o1} - f_1} = \frac{15x5}{15-5} = +\frac{75}{10} = +7.5cm$$

$$s_{o2} = a - s'_{i1} = 5 - 7.5 = -2.5\ cm$$

The position of the final image

$$s'_{i2} = \frac{f_2 x\ s_{o2}}{s_{o2} - f_2} = \frac{10\ x - 2.5}{-2.5 - 10} = \frac{+25}{-12.5} = +2 \text{ cm}$$

$$m_{t=} m_1 m_2 = \left(\frac{-s'_{i1}}{s_{o1}}\right)\left(\frac{-s'_{i2}}{s_{o2}}\right) = \left(\frac{-7.5}{15}\right)\left(\frac{+2}{-2.5}\right)$$

(b) The size of the final image

$$\frac{y'}{y} = \frac{-15}{15x\ 2.5}$$

$$\frac{y'}{2.5} = \frac{-1}{2.5}$$

$$y' = -1\ cm$$

Q 4.9 A double-convex lens is to be made of glass having a refractive index of 1.580. If one surface is to have twice the radius of the other and the focal length is to be +6.0 cm, find the radii.

Solution

4. $R_1=2R_2$ p= 1/f(m) $\therefore f = 6\ cm$

5. $\frac{1}{f} = (n' - 1)(\frac{1}{R_1} - \frac{1}{R_2})$

6. $\frac{1}{6} = (1.58 - 1)(\frac{1}{2R_2} + \frac{1}{R_2})$

R2=5.22 cm, R1=10.44 cm

$R_1=2R_2$ =2*5.22

$R_{1=}$ 10.44 cm

4.11 A lantern slide 8.0 cm high is located 3.50 m from a projection screen. What is the focal length of the lens that will be required to project an image 1.0 m high?

Solution

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

$$m = -\frac{s'}{s} = \frac{y'}{y}$$

$$-\frac{s'}{3.5\ m} = \frac{1\ m}{0.08\ m}$$

S’ = - 43.74

$$f = \frac{s'xs}{s - s'}$$

$$f = \frac{-43.75x0.08\ m * m}{0.08 - (-43.75)m}$$

$$f = \frac{3.5\ m}{43.83}$$

$$f = 0.079\ m$$

$$f = 7.98\ cm$$

4.13 Three thin lenses have powers + 1.50, - 2.80, and 3.40 D, respectively. What are all the possible powers that can be obtained with these three lenses using one, two, or three at a time in contact?

Solution

$P = p_1 + p_2 + p_3$

= +1.5- 2.8 + 3.4

P= 2.1 D

4.15 An object 2.50 cm high is located 15.0 cm in front of a lens of + 5.0 cm focal length. A lens with a focal length of -12.0 cm is placed 2.50 cm beyond this converging lens. Find *(a)* the position and *(b)* the size of the final image.

Ana. (a) +8.57 cm, *(b)* -2.143 cm

Solution

$$\frac{1}{s_{o1}} + \frac{1}{s'_{i_1}} = \frac{1}{f_1}$$

$$s'_{i1} = \frac{f_1 x s_{o1}}{s_{o1} - f_1} = \frac{15x5}{15-5} = +\frac{75}{10} = +7.5cm$$

$$s_{o2} = a - s'_{i1} = 2.5 - 7.5 = -5\ cm$$

The position of the final image

$$s'_{i2} = \frac{f_2 x\ s_{o2}}{s_{o2} - f_2} = \frac{-12\ x - 5}{-5+12} = \frac{+60}{7} = +8.57 \text{ cm}$$

$$m_{t=}\ m_1 m_2 = \left(\frac{-s'_{i1}}{s_{o1}}\right)\left(\frac{-s'_{i2}}{s_{o2}}\right) = \left(\frac{-7.5}{15}\right)\left(\frac{-8.57}{-5}\right)$$

(b) The size of the final image

$$\frac{y'}{2.5} = \frac{-64.275}{7.5}$$

$$y' = -2.1425\ cm$$

The properties of the final image is **inverted real and minimized**

4.17 Three lenses with focal lengths of +8.40, -4.60, and +6.20 cm, respectively, are located one behind each other in this order and 2.0 cm apart. *(a)* If parallel light is incident on the first lens, how far behind the third lens will the light be brought to a focus? *(b)* Draw a scale diagram

Solution:

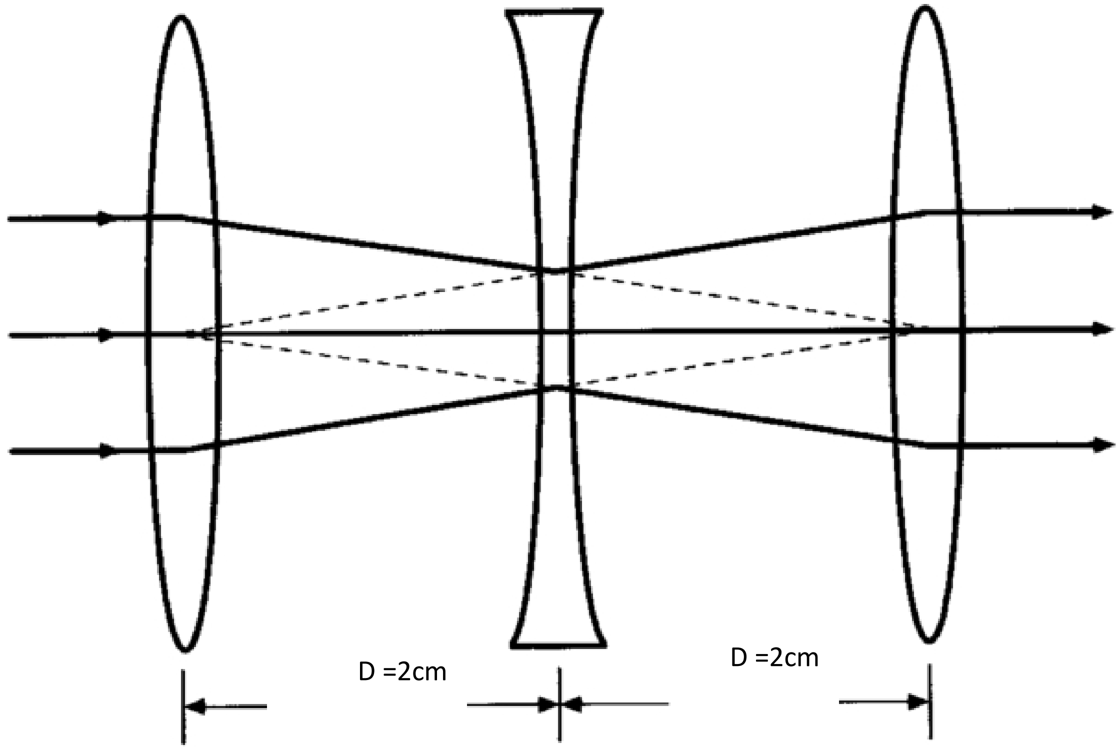
$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

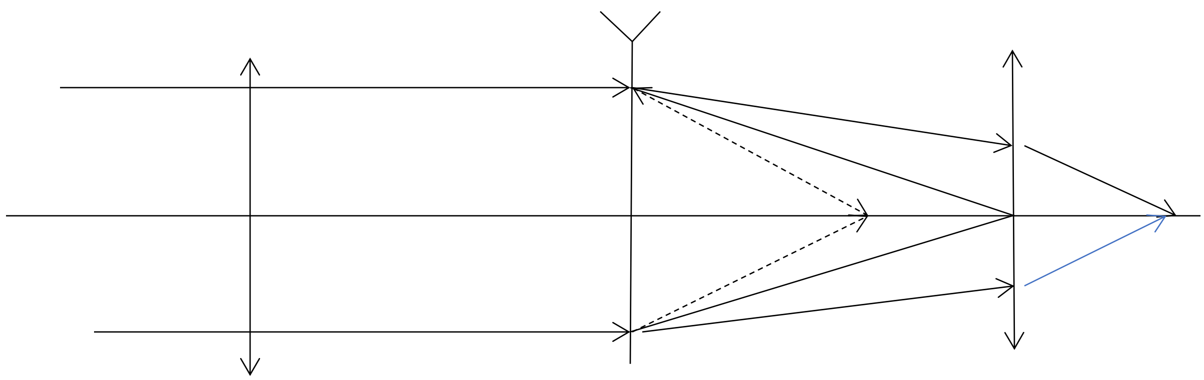
$$\frac{1}{f} = \frac{1}{8.4} + \frac{1}{-4.6} - \frac{d}{8.4 * -4.6}$$

F_{system} = -21.5 cm

$$\frac{1}{f_{final}} = \frac{1}{-21.5} + \frac{1}{6.2} - \frac{2}{-21.5 * 6.2}$$

$f_{final\ optical\ system}$ = + 7.7 cm





PROBLEMS

5.1 An equiconvex lens located in air has radii of 5.20 cm, an index of 1.680, and a thickness of 3.50 cm. Calculate *(a)* the focal length and *(b)* the power of the lens. Find *(c)* the distances from the vertices to the focal points and *(d)* the principal points.

Ans. (a) +4.43 cm, *(b)* +22.59 D, *(c)* A_1F = -3.222 cm, and A_2F = +3.222 cm, *(d)* A_1H = + 1.206 cm, and A_2H'' = -1.206 cm

Solution:

a)

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2} - \frac{(n-1)t}{nR_1R_2}\right)$$

$$\frac{1}{f} = (1.68-1)\left(\frac{1}{5.2} + \frac{1}{-5.2} - \frac{(1.68-1)*3.5}{1.68*-5.2*5.2}\right)$$

F = +4.43 cm

b) P= 1/f(m)

= +22.57 D

c)

1- $first\ focal\ point \quad A_1F_1 = -f\left(1 - \frac{t}{f_2{}'}\right)$

$$\frac{n'}{f_2'} = \frac{n'-n}{r_2}$$

$$\frac{1.68}{f_2'} = \frac{1.68-1}{-5.2}$$

$$f_2' = -3.22\ cm$$

2- $second\ focal\ point \quad A_2F_2 = +f\left(1 - \frac{t}{f_1{}'}\right)$

$$\frac{n'}{f_1'} = \frac{n'-n}{r_1}$$

$$\frac{1.68}{f_1'} = \frac{1.68 - 1}{5.2}$$

$$A_2F_2 = +f\left(1 - \frac{t}{f_1{}'}\right)$$

$$A_2F_2 = +3.222\ cm$$

d) The principal points.

$$1 - first\ principle\ point\ A_1H_1 = f\,\frac{t}{f_2'}$$

$$A_1H = 4.43\,\frac{3.5}{12.84}$$

$$A_1H_1 = 1.2068\ cm$$

$$2 - second\ principle\ point\ A_2H_2 = -f\,\frac{t}{f_1'}$$

2-

$$2 - second\ principle\ point\ A_2H'' = -4.43\,\frac{3.5}{12.847}$$

A_2H''= -1.2068 cm

5.3 A plano-convex lens 2.80 cm thick is made of glass of index 1.530. If the second surface has a radius of 3.50 cm, find *(a)* the focal length of the lens and *(b)* the power of the lens. Find the distances from the vertices to *(c)* the focal points and *(d)* the principal points.

Solution: anther Method

$\frac{1}{f} = (n-1)(\frac{1}{R_1}+\frac{1}{R_2} - \frac{(n-1)t}{nR_1R_2})$

$\frac{1}{f} = (1.53-1)(\frac{1}{\infty}+\frac{1}{-3.5} - \frac{(1.53-1)*2.8}{1.53*\infty*-3.5})$

f = - 6.605cm

b) P= 1/f(m)

= -15.44 D

c) $1 - first\ focal\ point$

$$A_1F_1 = -f\left(1 + \frac{(n-1)t}{nR_2}\right)$$

$$A_1F_1 = -6.603\left(1 + \frac{(1.53-1)*2.8}{1.53*-3.5}\right)$$

= -4.7733 cm

$$2 - the\ second\ focal\ length$$

$A_2F_2\ or\ A_2F'' = f\left(1 - \frac{(n-1)t}{nR_1}\right)$

$$A_2F_2 = f\left(1 - \frac{(n-1)t}{nR_1}\right)$$

$A_2F_2 = 6.603$ cm

d) The principal points.

1- The first principle point h_1 or $A_1 H_1$ or

$$\mathbf{A_1\ H} = -f\,\frac{(n-1)t}{nR_2}$$

$$\mathbf{A_1\ H} = -6.603\,\frac{(1.53-1)*2.8}{1.53*-3.5}$$

h_1 or $A_1 H_1$ or A_1 H= 1.8298 =1.83 cm

2-h_2 The second principle point h_1 or $A_2 H_2$ or

$$\mathbf{A_2\ H''} = -f\,\frac{(n-1)t}{nR_{1\infty}}$$

0

H2 or $A_2 H_2 = 0$

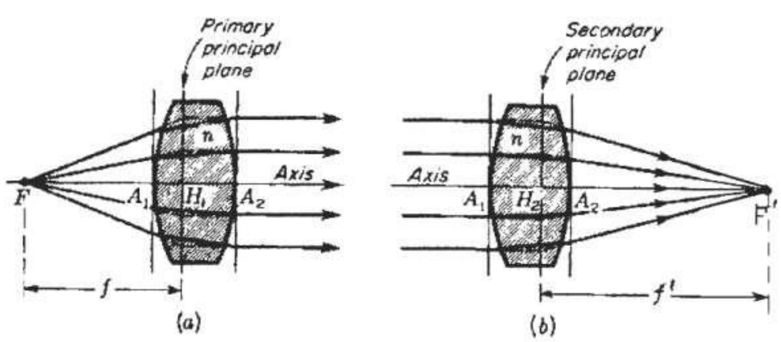


Figure 2. Primary and secondary principal planes of a thick lens. A_1 and A_2 are the vertexes.

5.5 A glass lens with radii r_1 = +2.50 cm and r_2 = +4.50 cm has a thickness of 2.90 cm and an index of 1.630. Calculate *(a)* the focal length and *(b)* the power of the lens.

Find the distances from the vertices to *(c)* the focal points and *(d)* the principal points.
Ans. (a) +5.73cm,(b) *+17.46D,(e)*A_1F= -7.163 cm, and A_2F = +3.162cm, *(d)* A_1H = -1.433 cm, and A_2H'' = - 2.568 cm

5.7 A glass lens with radii r_l = + 6.50 cm and r_2 = + 3.20 cm has a thickness of 2.80 cm and an index of 1.560. Calculate *(a)* the focal length and *(b)* the power of this lens in air. Find the distances from the vertices to *(c)* the focal points and *(d)* the principal points.

$$a)\ \frac{1}{f} = (1.560\text{-}1)\left[\frac{1}{6.5} - \frac{1}{3.2} + \frac{(1.56-1)*2.8}{1.56*6.5*3.2}\right]$$

F= -16.207 cm

b) the power of this lens in air

P= P= 1/f(m)= -6.223 Diopter

c) $1 - first\ focal\ point$

$$A_1F_1 = -f\left(1 + \frac{(n-1)t}{nR_2}\right)$$

$$A_1F_1 = -(-16.207)\left(1 + \frac{(1.56-1)*2.8}{1.56*+3.2}\right)$$

A_1F_1= +21.2925 cm

$$2 - the\ second\ focal\ length$$

$$A_2F_2\ or\ A_2F'' = f\left(1 - \frac{(n-1)t}{nR_1}\right)$$

$$A_2F_2 = -16.207\left(1 - \frac{(1.56-1)2.8}{1.56*6.5}\right)$$

0

$A_2F_2 = -13.7008$ cm

d) The principal points.

1- The first principle point h_1 or A_1 H_1 or

$$\mathbf{A_1\ H = -f\ \frac{(n-1)t}{nR_2}}$$

$$\mathbf{A_1\ H = -(-16.603\ \frac{(1.53-1)*2.8}{1.53*\ -3.5}}$$

h_1 or A_1 H_1 or A_1 H= 1.8298 =1.83 cm

2-h_2 The second principle point h_1 or A_2 H_2 or

$$\mathbf{A_2\ H'' = -f\ \frac{(n-1)t}{nR_{1\infty}}}$$

0

H2 or A_2 H_2 = 0

5.9 A thick lens with radiir$_1$ = - 4.50 cm and r$_2$ = - 3.60 cm has a thickness of 3.0 cm and an index of 1.560. Calculate *(a)* the focal length and *(b)* the power of the lens.
Find also the distances from the vertices to the corresponding *(c)* focal points and
(d) principal points.

Ans. (a) + 14.64 cm, *(b)* +6.83 D, *(c) A1F* = -10.26 cm, and *A2P''* = + 18.14 cm,
(d) A1H = +4.38 cm, and *A2H''* = +3.502 cm

$$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n-1)*d}{nR_1R_2}\right]$$

where R_1 and R_2 are the radii of the first and the second surfaces.

d:thickness of lens. Fig 2

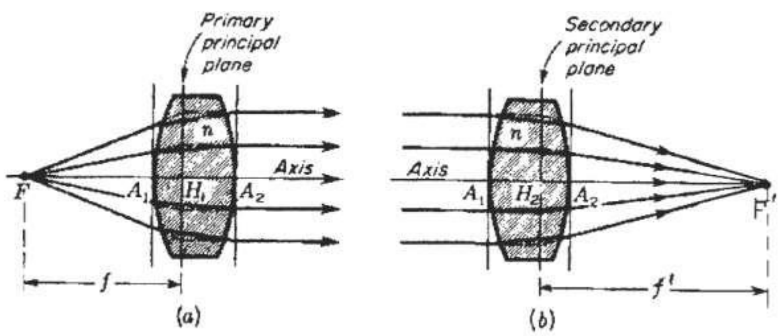


Figure 2. Primary and secondary principal planes of a thick lens. A_1 and A_2 are the vertexes.

Step 2: The focal points

The first focal point $$A_1F_1 = -f\left[1 + \frac{(n-1)d}{nR_2}\right]$$

The second focal point $$A_2F_2'' = -f\left[1 - \frac{(n-1)d}{nR_1}\right]$$

Step 3: The principal points

The first principal point

$$A_1H_{1=}\ -f.\frac{(n-1)d}{nR_2}$$

PROBLEMS

6.1 A spherical mirror has a radius of - 24.0 cm; An object 3.0 cm high is located in front of the mirror at a distance of *(a)* 48.0 cm, *(b)* 36.0 cm, *(c)* 24.0 cm, *(d)* 12.0 cm, and *(e)* 6.0 cm. Find the image distance for each of these object distances.

Ans. (a) + 16.0 cm, *(b)* + 18.0 cm, *(c)* + 24.0 cm, *(d)* + 12.0 cm, *(e)* - 12.0 cm

Solution

a) $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}\leftrightarrow f=-\frac{r}{2}=\ -\left(\frac{-24}{2}\right)=\ +12\ cm$

$$\frac{1}{48}+\frac{1}{v}=\frac{1}{12}$$

$$v=\frac{u*f}{u-f}=\ \frac{48*12}{48-12}=\frac{576}{36}=+16$$

b) $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}\leftrightarrow f=-\frac{-24}{2}=\ -\left(\frac{-24}{2}\right)=\ +12\ cm$

$$\frac{1}{36}+\frac{1}{v}=\frac{1}{12}$$

$$v = \frac{u * f}{u - f} = \frac{36 * 12}{36 - 12} = \frac{432}{24} = +18$$

c) $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \leftrightarrow f = -\frac{r}{2} = -\left(\frac{-24}{2}\right) = +12\ cm$

$$\frac{1}{24} + \frac{1}{v} = \frac{1}{12}$$

$$v = \frac{u * f}{u - f} = \frac{24 * 12}{24 - 12} = \frac{288}{12} = +24$$

d) u=12 ; since f =12

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \leftrightarrow f = -\frac{r}{2} = -\left(\frac{-24}{2}\right) = +12\ cm$$

$$\frac{1}{12} + \frac{1}{v} = \frac{1}{12}$$

$$v = \frac{u * f}{u - f} = \frac{12 * 12}{12 - 12} = \frac{144}{0} = \infty$$

e) $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \leftrightarrow f = -\frac{r}{2} = -\left(\frac{-24}{2}\right) = +12\ cm$

$$\frac{1}{6} + \frac{1}{v} = \frac{1}{12}$$

$$v = \frac{u * f}{u - f} = \frac{6 * 12}{6 - 12} = \frac{72}{-6} = -12\ cm$$

6.3 A spherical mirror has a radius of - 15.0 cm. An object 2.50 cm high is located in front of the mirror at a distance of *(a)* 45.0 cm, *(b)* 30.0 cm, *(c)* 15.0 cm, *(d)* 10.0 cm, and *(e)* 5.0 cm. Find the image distance for each of these object distances.

Solution

a) $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \leftrightarrow f = -\frac{r}{2} = -\left(\frac{-15}{2}\right) = +7.5\ cm$

$$\frac{1}{45} + \frac{1}{v} = \frac{1}{7.5}$$

$$v = \frac{u * f}{u - f} = \frac{7.5 * 45}{45 - 7.5} = \frac{337.5}{37.5} = +9\ cm$$

b) $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \leftrightarrow f = -\frac{r}{2} = -\left(\frac{-15}{2}\right) = +7.5\ cm$

$$\frac{1}{30} + \frac{1}{v} = \frac{1}{7.5}$$

$$v = \frac{u * f}{u - f} = \frac{7.5 * 30}{30 - 7.5} = \frac{225}{22.5} = +10\ cm$$

c) $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \leftrightarrow f = -\frac{r}{2} = -\left(\frac{-15}{2}\right) = +7.5\ cm$

$$\frac{1}{15} + \frac{1}{v} = \frac{1}{7.5}$$

$$v = \frac{u * f}{u - f} = \frac{7.5 * 15}{15 - 7.5} = \frac{112.5}{7.5} = +15\ cm$$

d) $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \leftrightarrow f = -\frac{r}{2} = -\left(\frac{-15}{2}\right) = +7.5\ cm$

$$\frac{1}{10} + \frac{1}{v} = \frac{1}{7.5}$$

$$v = \frac{u * f}{u - f} = \frac{7.5 * 10}{10 - 7.5} = \frac{75}{2.5} = +30\ cm$$

(e) 5.0 cm

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \leftrightarrow f = -\frac{r}{2} = -\left(\frac{-15}{2}\right) = +7.5\ cm$$

$$\frac{1}{5} + \frac{1}{v} = \frac{1}{7.5}$$

$$v = \frac{u * f}{u - f} = \frac{7.5 * 5}{5 - 7.5} = \frac{37.5}{-2.5} = -15\ cm$$

6.5 The radius of a spherical mirror is + 18.0 cm. An object 4.0 cm high is located in front of the mirror at a distance of *(a)* 36.0 cm, *(b)* 24.0 cm, and *(c)* 12.0 cm. Find the image distance and image size for each of these object distances.

Ans. (a) -7.20 cm from vertex and +0.80 cm high, *(b)* -6.55 cm from vertex and + 1.092 cm high, *(c)* - 5.40 cm from vertex and + 1.712 cm high.

Solution

a) 36 cm

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \leftrightarrow f = -\frac{r}{2} = -\left(\frac{18}{2}\right) = -9\ cm$$

$$\frac{1}{36} + \frac{1}{v} = \frac{1}{-9}$$

$$v = \frac{u * f}{u - f} = \frac{-9 * 36}{36 + 9} = \frac{-324}{45} = -7.2\ cm$$

$$m = \frac{-(-7.2)}{36} = +0.2 \leftrightarrow = \frac{y'}{y} = \frac{y'}{4}$$

y'=0.8

b) u=24 cm

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \leftrightarrow f = -\frac{r}{2} = -\left(\frac{18}{2}\right) = -9\ cm$$

$$\frac{1}{24} + \frac{1}{v} = \frac{1}{-9}$$

$$v = \frac{u * f}{u - f} = \frac{-9 * 24}{24 + 9} = \frac{-216}{33} = -6.545\ cm$$

$$m = \frac{-(-6.454)}{24} = +0.272\ \leftrightarrow = \frac{y'}{y} = \frac{y'}{4}$$

y'=1.092

c) u=12 cm

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \leftrightarrow f = -\frac{r}{2} = -\left(\frac{18}{2}\right) = -9\ cm$$

$$\frac{1}{12} + \frac{1}{v} = \frac{1}{-9}$$

$$v = \frac{u * f}{u - f} = \frac{-9 * 12}{12 + 9} = \frac{-108}{21} = -5.1428\ cm$$

$$m = \frac{-(-5.1428)}{12} = +0.4285\ \leftrightarrow = \frac{y'}{y} = \frac{y'}{4}$$

y'=+1.71428 cm

6.7 The radius of a spherical mirror is + 8.0 cm. An object 3.50 cm high is located in front of the mirror at a distance of *(a)* 16.0 cm, *(b)* 8.0 cm, *(c)* 4.0 cm, and *(d)* 2.0 cm.
Find the image distance and image size for each of these object distances.

Solution

a) u=16 cm

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \leftrightarrow f=-\frac{r}{2}=-\left(\frac{8}{2}\right)=-4\ cm$$

$$\frac{1}{16}+\frac{1}{v}=\frac{1}{-4}$$

$$v=\frac{u*f}{u-f}=\frac{-4*16}{16+4}=\frac{-64}{20}=-3.2\ cm$$

$$m=\frac{-(-3.2)}{16}=+0.2\ \leftrightarrow=\frac{y'}{y}=\frac{y'}{3.5}$$

y’=0.7 cm

b) u=8 cm

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \leftrightarrow f=-\frac{r}{2}=-\left(\frac{8}{2}\right)=-4\ cm$$

$$\frac{1}{8}+\frac{1}{v}=\frac{1}{-4}$$

$$v=\frac{u*f}{u-f}=\frac{-4*8}{8+4}=\frac{-32}{12}=-2.6666\ cm$$

$$m=\frac{-(-2.666)}{8}=+0.3333\ \leftrightarrow=\frac{y'}{y}=\frac{y'}{3.5}$$

y’=1.1666 cm

c) u= 4 cm

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \leftrightarrow f=-\frac{r}{2}=-\left(\frac{8}{2}\right)=-4\ cm$$

$$\frac{1}{4}+\frac{1}{v}=\frac{1}{-4}$$

$$v=\frac{u*f}{u-f}= \frac{-4*4}{4+4}=\frac{-16}{8}=-2\ cm$$

$$m=\frac{-(-2)}{4}=+0.5\ \leftrightarrow= \frac{y'}{y}=\frac{y'}{3.5}$$

y'=1.75 cm

d) u= 2 cm

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}\leftrightarrow f=-\frac{r}{2}= -\left(\frac{8}{2}\right)= -4\ cm$$

$$\frac{1}{2}+\frac{1}{v}=\frac{1}{-4}$$

$$v=\frac{u*f}{u-f}= \frac{-4*2}{2+4}=\frac{-8}{6}=-1.3333\ cm$$

$$m=-\frac{v}{u}=\frac{-(-1.3333)}{2}=+0.66666\ \leftrightarrow= \frac{y'}{y}=\frac{y'}{3.5}$$

y'=2.333 cm

6.9 A concave mirror is to be used to focus the image of a tree on a photographic film 8.50 m away from the tree. If a lateral magnification of -1/20 is desired, what should be the radius of curvature of the mirror? , *Ans.* - 85.2 cm

Solution:
Concave Mirror f = -r/2
u= 8.5 m

$$m = -\frac{v}{u} \leftrightarrow -\frac{1}{20} = -\frac{v}{8.5\, m}$$

$$v = f = -\frac{r}{2}$$

$$v = f = 42.5\ cm \leftrightarrow r = -2f = -2 * 42.5 = -85\ cm$$

6.10 A thin equiconvex lens of index 1.530 and radii of 16.0 cm is silvered on one side.
Find the *(a)* focal length and *(b)* power of this system if light enters the unsilvered side.

Solution:

$$\frac{n}{f} = \frac{n' - n}{r_1}$$

$$\frac{1}{f} = \frac{1.53 - 1}{16}$$

$$f = 30.1886\ cm$$

$$P_1 = \frac{1}{f(m)} = 3.3125\ D$$

$$P_2 = \frac{-2n'}{r2} = \frac{-2*1.53*100}{-16} = +19.125\ D$$

$P = 2P_1 + P_2$
= 2*3.3125+ 19.125

P= 25.75 Diopters

P= 1/f(m)
f=1/p = 1/25.75 m=3.884 cm

6.11 A thin lens of index 1.650 has radii' r_1 = + 5.0 cm and r_2 = -15.0 cm. If the second surface is silvered, what is *(a)* the focal length and *(b)* the power of the system?

Solution

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

$$\frac{n}{f} = (1.65-1)(\frac{1}{5} + \frac{1}{15})$$

$$f = 5.7\ cm$$

$$b)\ P_1 = \frac{n' - n}{r_1} = \frac{1.65 - 1}{0.05} = +13\ D$$

$$P_2 = \frac{-2n'}{r2} = \frac{-2*1.65*}{-0.15} = +22\ D$$

P= $2P_1 + P_2$
= 2*13+ 22

P= 48 Diopters

6.12 A thin lens of index 1.720 located in air has radii r_1 = - 6.0 cm and r_2 =) -12.0 cm. If the second surface is silvered, what is the power of the system? Use the special-case formulas (6q) and (6r).

$$b)\ P_1 = \frac{1.72 - 1}{-.06} == -12\ D$$

$$P_2 = \frac{-2n'}{r2} = \frac{-2*1.72}{-0.12} = +28.66\ D$$

P= $2P_1+P_2$
= 2*-12+ 28.66= -24+28.66

P= 4.66 Diopters

6.13 A thin lens with a focal length of + 10.0 cm is located 2.00 cm in front of a spherical mirror with a radius of -18.0 cm. Find *(a)* the power, *(b)* the focal length, *(c)* the principal point, and *(d)* the focal point of this thick-mirror optical system.
Ans. (a) +23.11 D, *(b)* +4.33 cm, *(c) H1H* = +2.50cm, *(d)* -1.83 cm

Solution:

a) p_1= 1/f(m)
   = 1/0.1 = 10 D

$$P_2 = \frac{-2n}{r_2} = \frac{-2 * 1}{-0.18} = +11.11\ D$$

$$c = \frac{d}{n} = 0.02m$$

a) $P = (1 - cP_{1)}(2P_1 + P_2 - c\ P_1P_2)$

$$= (1 - 0.02 * 10)(2 * 10 + 11.11 - 0.02 * \ 10 * 11.11)$$

$$P = 23.11\ D$$

b) f=1/P= +4.33 cm

c) The principal point

$$HH' = \frac{c}{1 - cP_1}$$

$$= \frac{0.02}{1-0.02*10} = \frac{0.02}{0.8}$$

HH'= 0.025=2. 5 cm

d) AF1 = 2.5-4.33

= -1.83

6.15 A thin lens with a focal length of -12.30 cm is placed 2.50 cm in front of a spherical mirror of radius -9.20 cm. Find the power of

(a) The first lens and *(b)* the second power.

Calculate *(c)* the power of the system and (4) its focal length. Locate *(e)* the principal point and *(f)* the focal point.

Solution

a) $\boldsymbol{P_1} = \frac{\mathbf{1}}{\boldsymbol{f(m)}}$= **1**/-12.3*$10^{-2}$

= -8.13 D

b) $P_2 = \frac{-2n}{r_3} = \frac{-2*1}{-9.2*10^{-2}} = 21.74\ D$

$$c = \frac{d}{n} = \frac{0.025}{1} = 0.025\ m$$

c) P= (1-c P_1)(2p_1+P_2- c P_1P_2)

P = (1- 0.025*-8.13) (2*-8.13+21.74-.025*-8.13*21.74)

P= 11.9 D

d)f= $\frac{1}{P} = 8.403\ cm$

e) HH' = $\frac{c}{1-c\,P_1} = \frac{0.025}{1-0.025*-8.13}$

HH' = 2.07 cm

F.F.l= f – HH'= 8.43 -2.07 = 6.35 cm

6.17 A thick lens of index 1.560 has radii r_1 = + I5.0cm and r_2 = - 30.0 cm. If the second surface is silvered and the lens is 5.0 cm thick, find *(a)* the power, *(b)* the focal length, *(c)* the principal point, and *(d)* the focal point.
Ans. (a) +14.67 D, *(b)* +6.82 cm, *(c)* H_1H = +3.640 cm, *(d)* H_1F = +3.180 cm

Solution

$$P_1 = \frac{n' - n}{r_1} = \frac{1.56 - 1}{0.15} = +3.7\,D$$

$$P_2 = \frac{-2n'}{r2} = \frac{-2*1.56}{-0.3} = +10.4\,D$$

$$c = \frac{d}{n'} = \frac{.05}{1.56} = 0.032\,m$$

a) $P = (1 - c\,P_1)(2P_1 + P_2 - c\,P_1P_2)$

$= (1 - 0.032 * 3.7)(2 * 3.7 + 10.4 - 0.032 * 3.7 * 10.4\,)$

$P = 14.67\,D$

b) the focal length

f = $\frac{1}{P} = \frac{1}{14.67} = 6.8166\,cm$

c) the principle point

HH' = $\frac{c}{1-c\,P_1} = \frac{0.032}{1-0.032*-3.7} = 3.6297\,cm$

H_1F=f – HH' = 6.849-3.6297 =+3.18 cm

6.19 A lens 4.50 cm thick has an index of 1.720 and radii

r_1 = - 6.0 cm and, r_2 = -12.0 cm. If the second surface is silvered, find *(a)* the power, *(b)* the focal length, *(c)* the position of the principal point, and *(d)* the position of the focal point.
Solution

$$P_1 = \frac{n' - n}{r_1} = \frac{1.72 - 1}{-0.06} = -12\,D$$

$$P_2 = \frac{-2n'}{r2} = \frac{-2*1.72}{-0.12} = +28.666\,D$$

$$c = \frac{d}{n'} = \frac{0.045}{1.72} = 0.02616\,m$$

a) $P = (1 - c\,P_1)(2P_1 + P_2 - c\,P_1P_2)$
$= (1 - 0.02616 * -12)(2 * -12 + 28.666 - .02616 * -12 * 28.666)$
$P = 9.37\,5145\,D$

b) the focal length
$f = \frac{1}{P} = \frac{1}{9.375145} = 10.666\,cm$

c) the principle point
$HH' = \frac{c}{1 - c\,P_1} = \frac{0.02616}{1 - 0.02616 * -12} = 3.812\,cm$
$H_1F = f - HH' = 10.666 - 3.812 = +6.854$ cm

6.21 The curved surface of a plano-convex lens has a radius of 20.0 cm. The refractive index of the glass is 1.650, and the thickness is 2.750 cm. If the curved surface is silvered, find *(a)* the power,
(b) the focal length, *(c)* the principal point, and
(d) the focal point.
Ans. (a) + 16.50 **D,** *(b)* + 6.06 cm, *(c)* + 1.667 cm, *(d)* +4.394 cm
Solution
Solution

$$P_1 = \frac{n' - n}{r_1} = 0$$

$$P_2 = \frac{-2n'}{r2} = \frac{-2*1.65}{-0.2} = +16.5\ D$$

$$c = \frac{d}{n'} = \frac{0.0275}{1.65} = 0.01667\ m$$

a) $P = (1 - c\ P_1)(2P_1 + P_2 - c\ P_1 P_2)$

$$P = 16.5\ D$$

b) the focal length

f = $\frac{1}{P} = \frac{1}{16.5} = 6.06\ cm$

c) the principle point

HH' = $\frac{c}{1 - c\ P_1} = \frac{0.01667}{1-0} = 1.667 cm$

H_1F=f – HH' = 6.06-1.667 =+4.394 cm

$$P_1 = \frac{n' - n}{r_1} = 0$$

$$P_2 = \frac{-2n'}{r2} = \frac{-2*1.65}{-0.2} = +16.5\ D$$

$$c = \frac{d}{n'} = \frac{0.0275}{1.65} = 0.01667\ m$$

d) $P = (1 - c\ P_1)(2P_1 + P_2 - c\ P_1 P_2)$

$$P = 16.5\ D$$

e) the focal length

$f = \frac{1}{P} = \frac{1}{16.5} = 6.06\ cm$

f) the principle point

$$HH' = \frac{c}{1-c\,P_1} = \frac{0.01667}{1-0} = 1.667cm$$

$H_1F = f - HH' = 6.06 - 1.667 = +4.394$ cm

6.23 If the plane surface of the lens given in Prob. 6.21 is silvered in plac