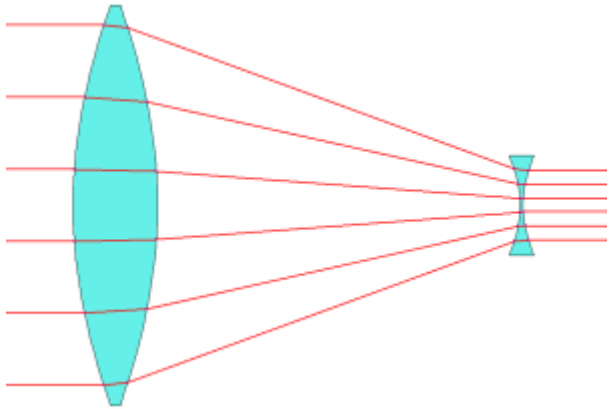
EP 324
Applied Optics

Problem Hour

1



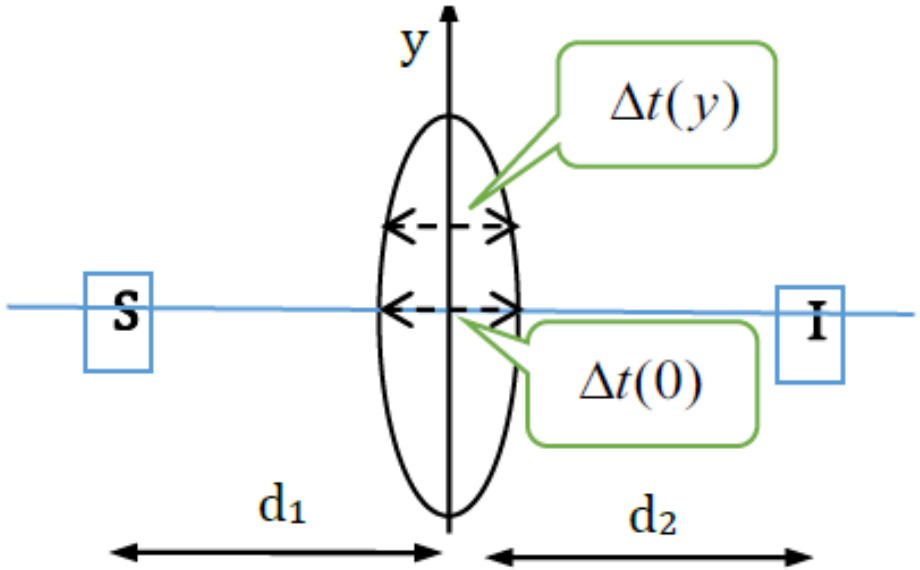
Nov 2015

Problem Hour

Solutions will be given in the lecture

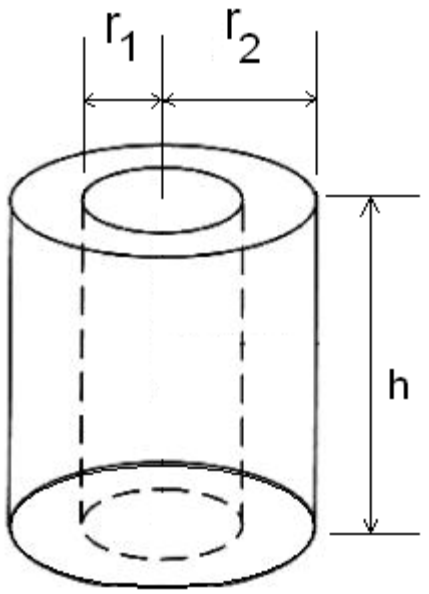
1) Consider a source S in front of a thin lens which forms the real image at the point I. Let the object and image distances be d_1 and d_2 respectively. The thickness of the lens varies with the vertical distance y, measured from the center of the lens, as $\Delta t(y)$. Apply Fermat's principle to show that S and I are conjugate points if

$$\Delta t(y) = \Delta t(0) - \frac{y^2}{2(n-1)D}$$ where $\Delta t(0)$ is the thickness of the lens at the center(y =0) and $D = \frac{d_1 d_2}{d_1 + d_2}$. Hint: use the binomial expansion where necessary assuming that d_1 and $d_2 >> \Delta t(0)$.



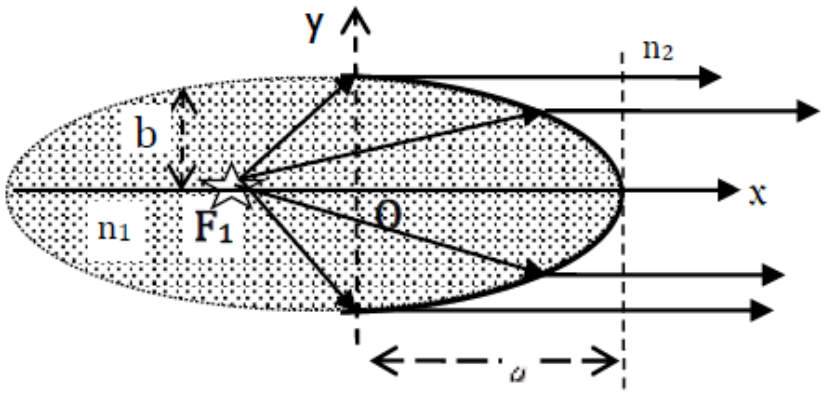
2) For commercial purposes,
perfume bottles are made from thick glasses.

Consider a concertric cylindrical bottle:
Innder radius $r_1 = 1cm$
Outer radius $r_2 = 2$ cm
Refractive index $n = 1.33$
Height $h = 5$ cm



Compute the real volume and
seen volume of the liquid in the bottle.

3) An elliptical refracting surface may behave like an ideal image forming system under certain conditions. As shown in the figure the source is placed at the focal point F_1 in a medium of refractive index n_1. All the rays transmitted to the medium n_2 are parallel to the optical axis.

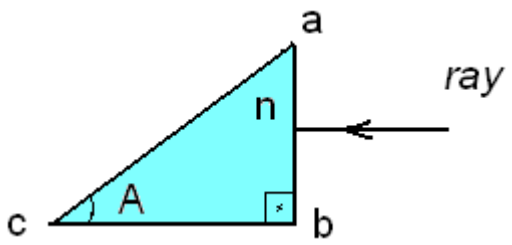


(a) Find the relation between n_1 and n_2 in terms of a and b.

Note that the equation of the ellipse is $\frac{x^2}{a^2}+\frac{y^2}{b^2}=1$. The focal length is given by $f=\overline{OF_1}=\sqrt{a^2-b^2}$, where a and b are the lengths of the semi-major and semi-minor axes, respectively.

(b) Discuss what happens when $a=b$.

4. A light ray is incident normally on a face ab of a glass prism (n=1.52) as shown.
(a) Assume that the prism is immersed in air, find the largest value of the angle A so that the ray is totally reflected at face ac.
(b) Find the angle A if the prism is immersed in water.



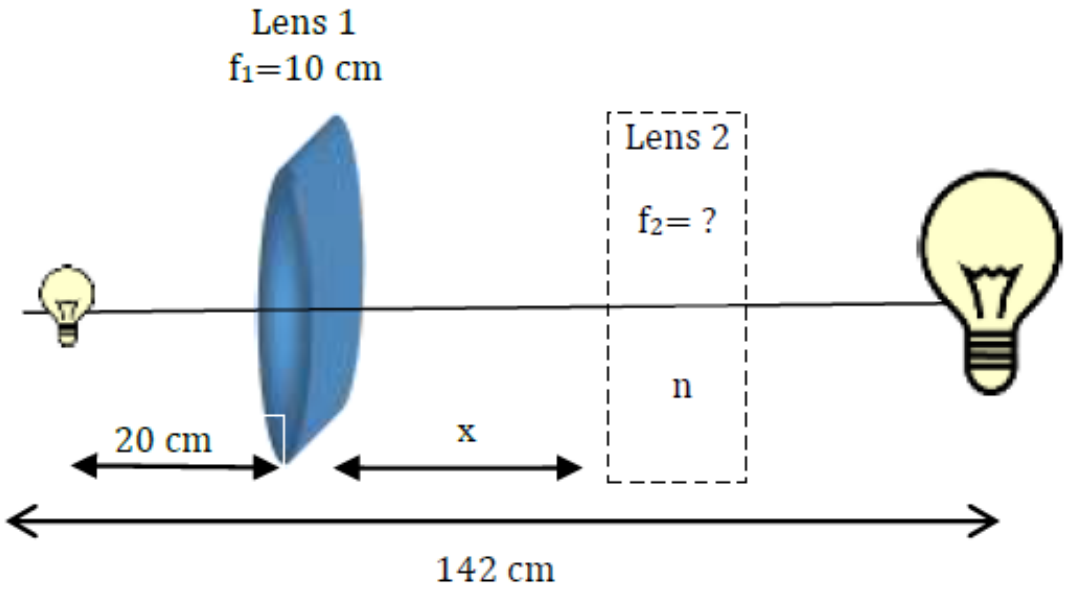
5. The atmosphere is a layer of gas whose index of refraction is n = 1.0003 and width is D = 100 km. The radius of Earth is approximately given by R = 6400 km. Calculate the time difference in seconds for the sun rise at the sea level on the equator if the index of refraction was *n* = 1.0000?

6. What component powers are necessary in a two-element lens system if one requires a 20-cm focal length, a 10-cm back focus, and a 5-cm air space?

7) You are asked to design a 2 thin lens system to produce an erect image of the object with a magnification of *50* onto a screen *142 cm* away from the object. The first lens is convergent with f_1 *=10.0 cm* and must be located *20 cm* from the object. You have a freedom to choose the position and the shape of the second lens.

(a) Find the focal length f_2 and the position of the second lens, *x*.

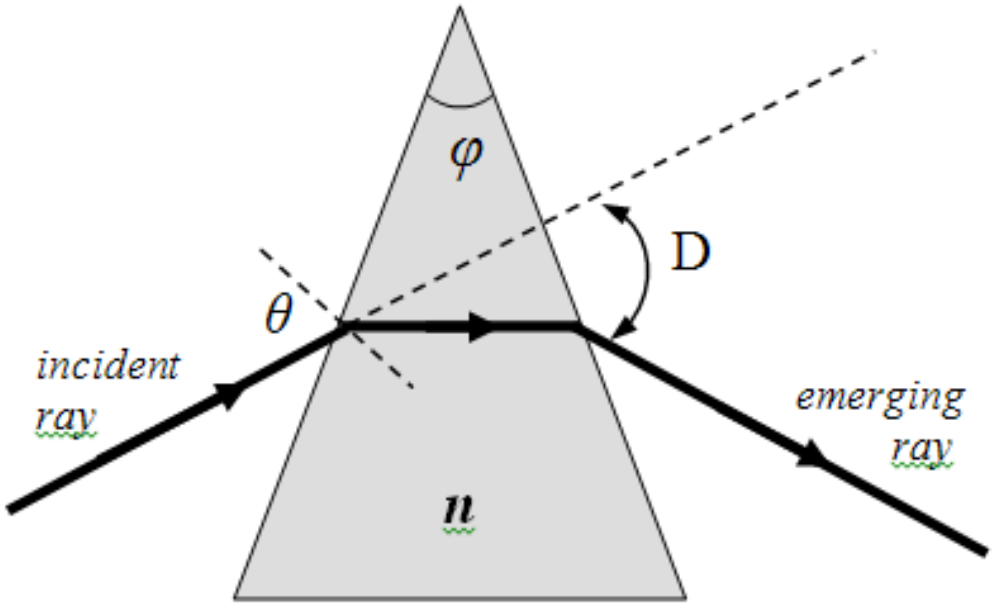
(b) Suggest some alternative choices for the radii of the surfaces (R_1 and R_2) that give the same focal length for *lens 2* if the refractive of the second lens is n=*1.5*.



8)

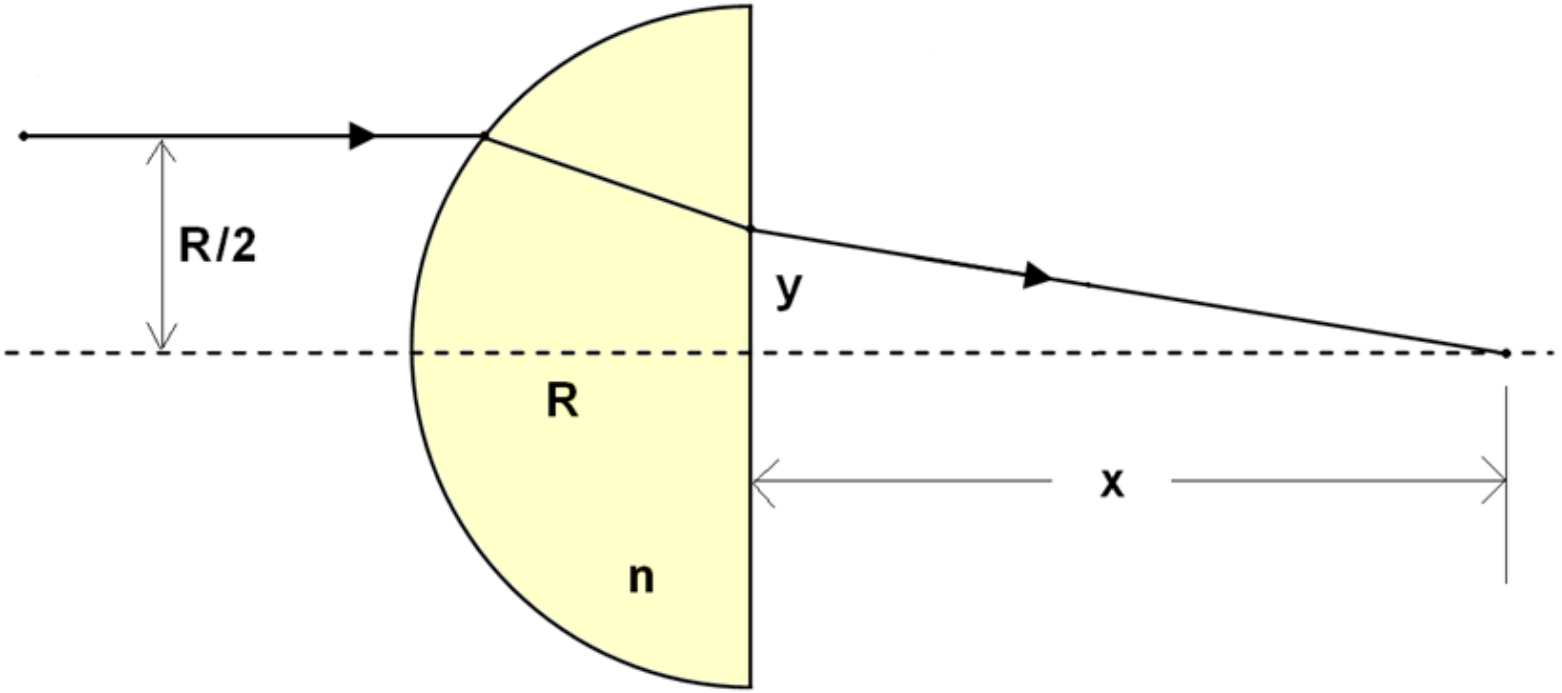
A light ray falls on a glass prism whose apex angle of $\varphi = 20^{\circ}$. An incident ray makes an angle θ with respect to the normal of the prism as shown in Figure. The ray emerges from the other surface and it is deviated by the angle $D = D_{min} = 40^{\circ}$.
If the prism is in the air,

(a) What is the refractive index of the prism?
(b) What is the value of the angle of incidence, θ?



9)

A light ray fall on a semi-sphere whose refractive index is $n = 1.33$ and radius is $R = 10$ cm as shown in figure. Determine the distance x.

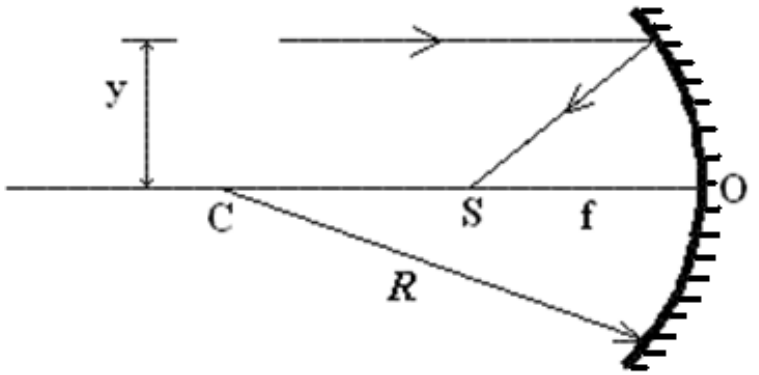


10)

A light ray traveling parallel to the principal axis at a distance *y* from the principal axis strike a concave mirror having a radius of curvature *R* as shown. The ray is focused on point S such that |OS| = *f*.

(a) Find an expression for *f* in terms of *y* and *R*.

(b) What is the value of *f* when *R* >> *y*? Conclude the result. *Hint*: $\tan 2\theta = 2\tan\theta/(1-\tan 2\theta)$



11)

The transmissivity *T* of a transparent material 1.5 cm thick to normally incident light is 0.80. If the index of refraction of this material is 1.5, compute the thickness of material that will yield a transmissivity of 0.70. All reflection losses should be considered.