due 10/11/2017

HW 4

1. Exercise 1.1-1 on page 6 of the textbook.

Proof of Snell's Law. The proof of Snell's law is an exercise in the application of Fermat's principle. Referring to Fig. 1.1-4, we seek to minimize the optical pathlength $n_1\overline{AB} + n_2\overline{BC}$ between points A and C. We therefore have the following optimization problem: Minimize $n_1 d_1 \sec\theta_1 + n_2 d_2 \sec\theta_2$ with respect to the angles θ_1 and θ_2, subject to the condition $d_1 \tan\theta_1 + d_2 \tan\theta_2 = d$. Show that the solution of this constrained minimization problem yields Snell's law.

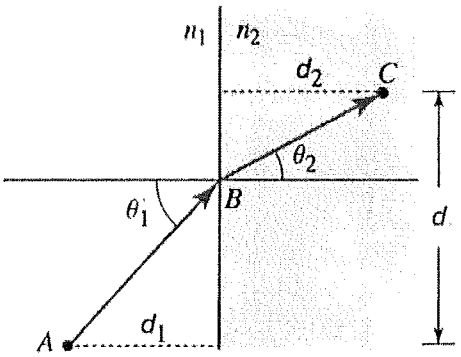
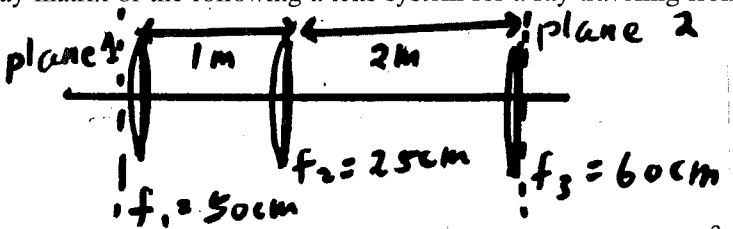


Figure 1.1-4 Construction to prove Snell's law.

2. a) Find the ray matrix of the following a lens system for a ray traveling from plane 1 to plane 2. (5 points)

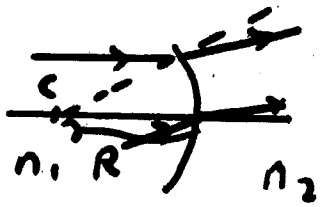


b) Find the ray matrix of a grade index fiber with profile of Eq. (1.3-9) ($n^2(y) = n_0^2(1 - \alpha^2 y^2)$) on page 20. (5 points)

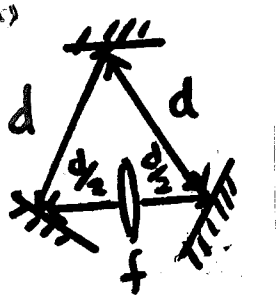
3. Derive the ray matrix for a ray entering the following spherical dielectric interface using the 2 speical ray paths on the diagram. (i. $r' = 0$ & $r \neq 0$ and ii. $r' \neq 0$ & $r = 0$)

Ans: $\begin{bmatrix} 1 & 0 \\ (1 - \frac{n_1}{n_2})\frac{1}{R} & n_1/n_2 \end{bmatrix}$.

(10 points)



4. Consider the ring laser cavity shown in the accompanying diagram.
a) Show an equivalent-lens waveguide for this cavity and identify a unit cell starting just after the lens and proceeding counterclockwise around the triangle. (5 points)
b) What is the ray matrix for this unit cell? (5 points)
~~c) What are the values of d/f that make this a stable cavity?~~



5) **Extra-Credit for undergraduate (regular problem for graduate)**
Determine the ray matrix for the following thick lens. b) Compare to the ray matrix of a thin lens and identify the focal length of the thick lens. c) When the thickness of the lens is very small, what is the focal length? (Hint: divide the lens into 3 pieces and apply the answer for question 3.) (10 points)

Extra-Credit

A common problem in the laser laboratory is to expand a collimated beam (with parallel ray) to a larger size beam.

Check the online catalogs, design a simple lens system that will expand a collimated 0.5 mm 50mW argon-ion beam up to a collimated 1cm beam. Your answer should include:

a. a sketch of the system.

b. a list of parts you need,

c. the cost and

d. supporting calculations based on ray optics (ray matrix) that demonstrate that the system will perform to specification. (10 points)

(You can check the websites: www.mellesgriot.com, www.newport.com, www.edsci.com or www.thorlabs.com to find out what are available and costs.

Note: the output ray must be parallel and the system must magnify the object.)

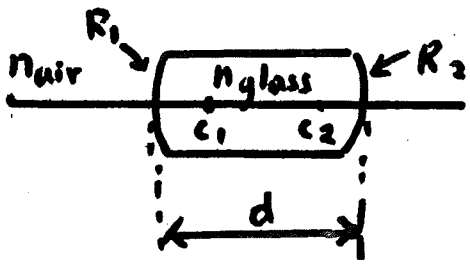


Diagram for thick lens in problem 5