3C43 LASERS AND MODERN OPTICS

Problem sheet 1 – Matrix optics

(Answers to be handed in on Tuesday, 22nd January 2002)

Question 1.

a. State the conditions under which a 2x2 ray transfer matrix can be employed to describe an optical system [2]

b. An optical system has a transfer matrix $\begin{pmatrix} A & B \\ C & D \end{pmatrix}$. Describe, with the aid of suitable diagrams, the effect of the system if

i. $C = 0$ and $D = M_1$
ii. $B = 0$ and $A = M_2$ [6]

c. Given that the system matrix for the human eye is

$$\begin{pmatrix} 0.5 & 0.125 \\ 2 & 2 \end{pmatrix}$$

determine the refractive index of the vitreous humour. [2]

Question 2.

An optical system occupies the region of space $0 < z \leq z_0$. In this region, the ray transfer matrix is

$$\begin{pmatrix} -3 & z \\ 0 & a \end{pmatrix}$$

i. If the refractive index in the regions $z \leq 0$ and $z \geq z_0$ is n = 1, what is the value of a? [2]
ii. By considering the ray transfer matrix in the region $z > z_0$, and using the value of a found in i., find the location and magnification of the image of an object placed at $z=0$. [8]

{ You may assume that the ray transfer matrix for translation through a distance d is $\begin{pmatrix} 1 & d \\ 0 & 1 \end{pmatrix}$ }

Question 3.

Show that the ray transfer matrix for refraction at an interface, of radius of curvature *R*, from a medium of refractive index *n* to a medium of refractive index *n'* is

$$\begin{pmatrix} 1 & 0 \\ \frac{1}{R}\left(\frac{n}{n'}-1\right) & \frac{n}{n'} \end{pmatrix} \qquad [5]$$

Hence show that the ray transfer matrix for a thin convex lens made of glass with refractive index n_L and having spherical surfaces of radii *R* is

$\begin{pmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{pmatrix}$ where $\frac{1}{f}=\frac{2}{R}\left(\frac{n_L}{n_0}-1\right)$ and n_0 is the refractive index of the air. [5]

Question 4.

State the ray transfer matrices for

a. translation through a distance d,
b. a thin-lens of focal length *f*. [2]

A lens of focal length f is used as a magnifying glass. If the lens is held a distance u from the object under examination, show, using the system transfer matrix, that the image formed is a virtual one. [4]

If $f=10\ cm$ and $u=7.5\ cm$, find the value of the magnification obtained. [4]