

NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

APPLIED OPTICS I - SPH 4170

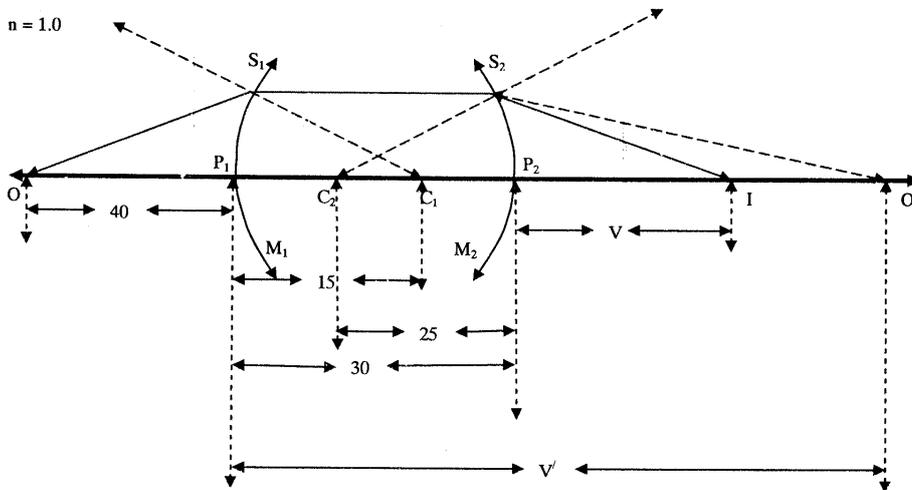
EXAMINATION

BSc HONOURS PART IV : DECEMBER 2004 DURATION : 3 HOURS

ANSWER ALL QUESTIONS IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

SECTION A

1. (a) (i) State Fermat's principle. [1]
- (ii) With the aid of neat diagrams, obtain the laws of reflection and refraction from Fermat's principle. [6]
- (b) Explain what you understand by a thin lens in Gaussian Optics. [2]
- (c) Starting from Snell's law of refraction and making use of paraxial approximation, show that the Gaussian Formula for a single spherical surface is given by:
- $$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$
- where n_1 and n_2 are the refractive indices of medium 1 and 2 respectively, v and u are the image and object distances respectively, and R is the radius of curvature of the surface. [5]
- (d) (i) Distinguish between, paraxial and meridional rays. [2]
- (ii) A medium of refractive index 1.5 is bounded by two spherical surfaces $S_1 P_1 M_1$ and $S_2 P_2 M_2$ as shown in the diagram below:



The radii of curvature of the two surfaces are 15 and 25 cm with their centres at C_1 and C_2 respectively. There is an object at a distance of 40 cm (from P_1) on the line joining C_1 and C_2 . Determine the position of the paraxial image. [4]

- (e) (i) Derive the lens maker's formula, clearly explaining each term used in the derivation. [3]
- (ii) Find the focal length in air of a thin planar - convex lens having a radius of curvature of 5 cm and an index of 1.5, if light is incident on
- the planar surface, [2]
 - the curved surface. [2]
 - Comment on your answers to both (a) and (b) above [1]
- (iii) An object is placed at a distance of 6 cm from the lens. Find the distance at which the image will be formed. [2]
- (f) Consider an object of height 1 cm placed at a distance of 24 cm from a convex lens of focal length 15 cm. A concave lens of focal length -20 cm is placed beyond the convex lens at a distance of 25 cm.
- Draw the ray diagram and determine the position and size of the final image. [7]
 - Describe the image formed. [3]

SECTION B

2. (a) Explain the meaning of the terms:
- (i) Aplanatic points, [2]
 - (ii) Aplanatic surface, and; [2]
 - (iii) give two applications of this surface. [2]

- (b) A complex optical system is represented by the following matrix:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & v \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{bmatrix} \begin{bmatrix} 1 & -u \\ 0 & 1 \end{bmatrix}$$

Obtain the

- (i) focal length,
 - (ii) linear magnification,
 - (iii) angular magnification, [5]
 - (iv) hence or otherwise, obtain Newton's formula for the system. [4]
- (c) Describe in detail the Oil immersion objective and state its advantages over other objectives, hence its application. [5]

3. (a) What are the cardinal points of a thick lens system. [2]

- (b) List the common defects of images in a lens system. [5]

© Briefly explain the following:

- (i) spherical aberration,
- (ii) curvature of field and,
- (iii) chromatic aberration.
- (iv) What are the problems faced by an optical designer in reducing aberrations? [9]

- (d) It is found that sunlight focused to a spot 29.6 cm from the back face of a thick lens, has its principal points at $H_1 = +0.2$ cm and $H_2 = -0.4$ cm. Calculate the locations of the image of a candle that is placed 49.8 cm in front of the lens. [4]

- (a) A Gaussian pulse is given by the following expression

$$\psi(x=0,t) = E_0 e^{-x^2/2\tau^2} e^{-i\omega_0 t}$$

where τ is the temporal duration of the pulse.

- (b) Obtain the function $G(x,t)$, the envelope of the pulse, hence determine

$$G(x,t) \text{ at } x = 0. \quad [10]$$

- (b) Find the modulus of $|G(x,t)|$. What deductions can be obtained from the final expression of $G(x,t)$. [6]

- (c) Obtain the ratio $\frac{\Delta t}{\tau}$, explaining each step. [4]

5. (a) Describe Michelson Interferometer. How does it differ from the Fizeau Interferometer. [6]
- (b) Obtain the conditions of interference for the Fizeau Interferometer. [2]
- (c) Describe a Fabry Perot Interferometer. Obtain an expression for the transmission peak for this device. Discuss your result. [12]
6. (a) State the condition for total internal reflection. [1]
- (b) What are the distinct vapour deposition methods used for the fabrication of fibres? Describe fully the vapour Axial Deposition (VAD) method indicating the refractive index profile and attenuation loss. [10]
- (c) An optical fibre has refractive index $n_{\text{core}} = 1.52$. Two lengths of smooth fibre perpendicular to the core axis are butted together. Considering that fibre axes are perfectly aligned, calculate the loss in decibels at the joints due to Fresnel reflection when the refractive index of the medium between the jointed fibres is $n = 1$. [4]
- (d) State and describe two major sources of losses in fibres. [5]

- END OF EXAMINATION -