LAIKIPIA UNIVERSITY

UNIVERSITY EXAMINATIONS

SECOND SEMESTER 2023/2024 ACADEMIC YEAR

THIRD YEAR EXAMINATION FOR THE DEGREES OF BACHELOR OF EDUCATION (SCIENCE) AND BACHELOR OF SCIENCE (GENERAL)

PHYS 323 : PHYSICAL OPTICS

STREAM: R ***TIME: 2 HRS***

DAY: TUESDAY [8.30A.M – 10.30A.M] ***DATE: 16/04/2024***

THIS QUESTION PAPER CONSISTS OF FIVE (5) PAGES

PLEASE DO NOT OPEN UNTIL THE INVIGILATOR SAYS SO.

INSTRUCTIONS

- **(i) Read the question paper carefully**
- **(ii) Question one carries 40 marks and the rest carry 15 marks each**
- **(iii)Answer question ONE and any other TWO questions**
- **(iv)Do not write on the question paper**
- **(v) Show your working clearly**

QUESTION ONE (40 Marks)

a) Define the following terms:

i. Simple harmonic motion

ii. Interference

iii. Wavefronts

iv. Diffraction **(4 Marks)**

b) State Huygen's principle **(2 Marks)**

c) Show that $\nabla^2 B = \mu_0 \varepsilon_0 \frac{\partial^2 B}{\partial t^2}$ **(5 Marks)**

d) A laser light emits a 2mm diameter beam of highly collimated (parallel) light at a power level or radian flux of 100 mW. Neglecting any divergence of the beam, calculate its irradiance.

(3 Marks)

e) Light having a free space λ of λ_0 = 500nm passes from a vacuum diamond (n d = 2.4). Compute;

i. Wave speed

ii. Wavelength in diamond **(4 Marks)**

f) Monochromatic light from a helium–neon laser (632.8 nm) is incident normally on a diffraction grating containing 6000 grooves per centimeter. Find the angles at which the first- and second-order maxima are observed. **(4 Marks)**

g) Calculate i. Energy in J

ii. Frequency in Hz

iii. Free space λ in *nm*, of a photon of energy = 2 eV **(6 Marks)**

h) Light from a sodium lamp whose wavelength is λ_S = 589 nm passes through a tank of glycerin of n_g = 1.47 and whose length is 20 m in a time t_g sec. If it takes a time t_c sec to transverse the same tank when filled with CS_2 (Carbon disulphide), whose n_c = 1.63, determine the time difference $t_g - t_c$. **(4 Marks)**

i) Differentiate between Exitancy and Irradiance as used to describe flux density **(2 Marks)**

j) Why can you hear around corners, but not see around corners? **(2 Marks)**

k) Show that the two waves with wave functions given by $E_1 = 6.00 \sin(100\pi t)$ and $E_2 = 8.00 \sin(100\pi t + \pi/2)$ add to give a wave with the wave function $E_R \sin(100\pi t + \phi)$. Find the required values for E_R and ϕ. **(4 Marks)**

QUESTION TWO

(i) A diffraction grating 1 cm wide has N = 1,000 equally spaced slits across its width. The diffraction grating is illuminated at normal incidence by a sodium vapor yellow lamp. The yellow light (known as the sodium doublet) contains two colors, one with wavelengths λ_1 = 589.0 nm and the other with wavelength λ_2 = 589.6 nm.

(a) What is the separation between the slits of the grating? **(1 Mark)**

(b) How many bright fringes are seen for both colors? **(3 Marks)**

(c) What must the resolving power of the grating be if the two colors are to be resolved (distinguished)? **(2 Marks)**

(d) How many slits of this grating must be illuminated in order to resolve these two colors in the fourth order? **(2 Marks)**

(ii) What is the necessary condition on the path length difference between two waves that interfere (a) constructively and (b) destructively? **(4 Marks)**

(iii) (a) In Young's double-slit experiment, why do we use monochromatic light? (b) If white light is used, how would the pattern change? **(3 Marks)**

QUESTION THREE

(i) Parallel rays of light with wavelength λ = 500 nm are incident on a slit of width a = 0.2 mm. A diffraction pattern is formed on a screen at a distance D = 2.5 m from the slit. Find the position of the first minimum and the width of the central bright fringe **(4 Marks)**

(ii) (a). A light source emits visible light of two wavelengths: λ_1 = 430 nm and λ_2 = 510 nm. The source is used in a double-slit interference experiment in which L = 1.50 m and d = 0.0250 mm.

Find the separation distance between the third-order bright fringes for the two wavelengths. **(3 Marks)**

(b) What if we examine the entire interference pattern due to the two wavelengths and look for overlapping fringes? Are there any locations on the screen where the bright fringes from the two wavelengths overlap exactly? **(3 Marks)**

(iii) A film with thickness d = 300 nm and index of refraction n = 1.5 is exposed to white light from one side. Which colors of white light are strongly *reflected*, and which are *transmitted*? **(3 Marks)**

(iv) Two slits are separated by 0.4 mm and illuminated by light of wavelength 442 nm. How far must the screen be placed in order for the first dark fringes to appear directly opposite both slits? **(2 Marks)**

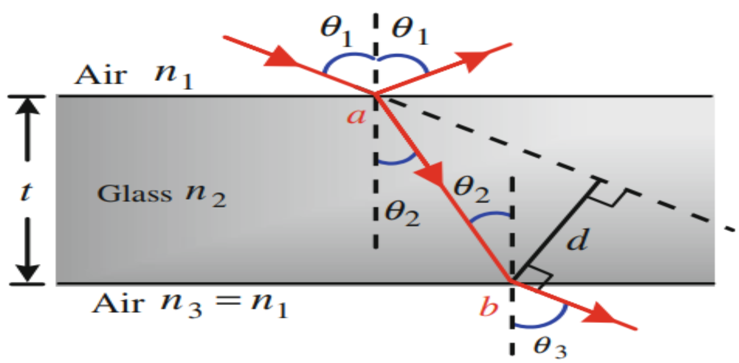
QUESTION FOUR (15 MARKS)

(i). A beam of monochromatic light traveling through air strikes a slab of glass at an angle $\theta_1 = 60^\circ$ to the normal, see Fig. below. The glass has a thickness t = 1 cm and refractive index n = 1.52.

(a) Find the angle of refraction θ_2. **(3 Marks)**

(b) Show that the emerging beam is parallel to the incident beam. **(3 Marks)**

(c) At what distance d does the beam shift from the original? **(3 Marks)**



(ii).(a). Light of wavelength 500 nm, near the center of the visible spectrum, enters a human eye. Although pupil diameter varies from person to person, let's estimate a daytime diameter of 2 mm. **(3 Marks)**

(b). Estimate the limiting angle of resolution for this eye, assuming its resolution is limited only by diffraction. **(3 Marks)**

QUESTION FIVE (15 MARKS)

(i) A viewing screen is separated from a double slit by 4.80 m. The distance between the two slits is 0.030 0 mm. Monochromatic light is directed toward the double slit and forms an interference pattern on the screen. The first dark fringe is 4.50 cm from the center line on the screen.

(a). Determine the wavelength of the light. (**2 Marks**)

(b). Calculate the distance between adjacent bright fringes (**3 Marks**)

(ii) Using a sketch of Michelson Interferometer equipment, describe how fringes are formed

(**5 Marks**)

(iii) Calculate the minimum thickness of a soap-bubble film that results in constructive interference in the reflected light if the film is illuminated with light whose wavelength in free space is λ = 600 nm. The index of refraction of the soap film is 1.33. (**2 Marks**)

(b). What if the film is twice as thick? Does this situation produce constructive interference? (**3 Marks**)