(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

UNIVERSITY EXAMINATIONS

2021/2022 ACADEMIC YEAR

SECOND YEAR SECOND SEMESTER MAIN EXAMINATIONS

FOR THE DEGREE

OF

BACHELOR OF EDUCATION SCIENCE

AND

BACHELOR OF SCIENCE IN PHYSICS WITH APPROPRIATE TECHNOLOGY

COURSE CODE: SPH 214

COURSE TITLE: PHYSICAL OPTICS

DATE: TUESDAY 26TH SPRIL, 2022 **TIME:** 3:00 PM - 5:00 PM

INSTRUCTIONS TO CANDIDATES

TIME: 2 Hours

Answer question ONE and any TWO of the remaining.
Symbols used bear the usual meanings.

MMUST observes ZERO tolerance to examination cheating

You may require;

(a). Refractive index of normal glass, $\eta_g = 1.5$.
(b). Refractive index of water $\eta_w = 1.33$

QUESTION ONE (30 marks)

(a). By examining the phase, determine the direction of motion of the progressive waves represented by;

$$\psi_1(y,t) = A\cos 2\pi\left(\frac{t}{\tau} + \frac{y}{\lambda} - \varepsilon\right)$$

$$\psi_2(z,t) = A\cos\pi\left(t - \frac{z}{v} + \varepsilon\right)$$

(4 marks)

(b). The phase of an electromagnetic wave is $\phi = \vec{k}(x \pm vt) + \varepsilon$, where x is the displacement, v is the velocity of the wave and $\varepsilon$is the initial phase. Show that the velocity of the wave is the rate of change of displacement. (3 marks)

(c). Monochromatic light is incident on a water- glass boundary. Using Fresnel's equations, calculate the percentage of light reflected (3 marks)

(d). Two linearly polarized waves having the forms;

$E_1(z,t) = iE_{0x}\cos(\omega t - kz) + jE_{0y}\cos(\omega t - kz)$

$E_2(z,t) = iE_{0x}{}'\cos(\omega t - kz) + jE_{0y}{}'\cos(\omega t - kz)$ overlap in space, show that the resultant is also linearly polarized (4 marks)

(e). Show that a plane electromagnetic wave must have its electric field transverse to the propagation direction. (3 marks)

(f). Calculate the value of transmission coefficient at normal incidence for light incident at 30^0 on an air-glass interface $\eta_{ti} = 1.5$ and show that $t_\perp + (-r_\perp) = 1$ for this case. (4marks)

(g). Show that the optical path length is the product of speed of light and time (3 marks)

(h). State and explain 3 properties of a LASER beam (6 marks)

QUESTION TWO (20 marks)

(a). Given that the central peak of a diffraction has its half- maximum value at $\beta_{\frac{1}{2}} = 1.39$ rad, derive an expression for the angular width at half- maximum irradiance $\Delta\theta_{\frac{1}{2}}$ of the central peak of a single slit. (5 marks)

(b). Define pointing vector s and show that $S = \frac{1}{\mu_0}\boldsymbol{EB}$ (4 marks)

(c). Show that $\psi(x,t) = f(x \pm vt)$ is a solution of the one dimensional differential wave equation. (6 marks)

(d). Show that the expression $\psi(z,t) = Ae^{-(2z+\frac{3t}{2})^2}$ is a progressive wave and verify that it is a solution to the wave equation. (5 marks)

QUESTION THREE (20 marks)

(a). Suppose that a Michelson interferometer is illuminated by a source emitting a doublet of vacuum wavelengths λ_1 and λ_2. As one of the mirrors is moved, the fringes periodically disappear and then reappear. If a displacement Δd of the mirror causes a one cycle variation in the viscibility, obtain an expression for Δd in terms of $\Delta\lambda$ (7 marks)

(b). Given the wave function for a light wave to be $\psi(x,t) = 1953\cos\pi(1.5 \times 10^6 x - 3 \times 10^{14} t)$, determine;

(i) The speed of the wave (4 marks)

(ii) The frequency of the wave (3 marks)

(iii) The period (2 marks)

(iv) Amplitude (1 mark)

(c). State the three laws of reflection. (3 marks)

QUESTION FOUR (20 marks)

(a). Write an expression for the profile (t=0) of a harmonic wave moving in the positive x-direction such that at x=0, $\psi(x,t) = 10$, at $x = \frac{\lambda}{6}$, $\psi(x,t) = 20$ and at $x = \frac{5\lambda}{12}$, $\psi(x,t) = 0$ (9 marks)

(b). Suppose that we have a linearly polarized electromagnetic plane wave whose electric field is of the form $\vec{E} = E_x(z,t)\hat{\imath}$, show that $\vec{B} = B_y(z,t)\hat{\jmath}$ (8 marks)

(c). State three types of LASERs (3 marks)

QUESTION FIVE (20marks)

(a). Verify that the harmonic wave function $\psi(x,t) = A\sin(kx - \omega t)$ is a solution of the one dimensional differential wave equation. (5 marks)

(b). By getting rid of the explicit dependence of $r_\perp$ and $r_\parallel$ on η_i and η_t, obtain the expressions for the amplitude reflection coefficients as a function of θ_i and θ_t only (Symbols carry usual meanings) (5 marks)

(c). Beginning with Maxwell's equation , derive the wave equation for electric fields (6 marks)

(d). Distinguish between electronic polarization and ionic polarization (4 marks)