MACHAKOS UNIVERSITY

University Examinations 2020/2021 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

THIRD YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)

SPH 327: LINEAR AND NONLINEAR OPTICS

DATE: 19/8/2021 **TIME: 8.30-10.30 AM**

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

You may need to use;

$\varepsilon_o = 8.85\times10^{-12}$F/m, $h = 6.626\times10^{-34}$m^{2}kg/s, $\mu_o = 4\pi\times10^{-7}$Tm/A, $1eV = 1.6\times10^{-19}$J.

QUESTION ONE (30 MARKS)

a) The speed of light in a certain material is 50% of its speed in vacuum. What is the refractive index of this material? (3 marks)

b) Calculate the phase velocity of a photon in a vacuum (3 marks)

c) Define the terms;

i. Phase velocity (2 marks)

ii. Phase matching (2 marks)

iii. Dispersion (2 marks)

d) During use, your home microwave projects 0.8 kW of microwaves onto a 25 by 42 cm area. Determine

i. The intensity in W/m^2 (3 marks)

ii. The peak electric field strength E_0 in these waves. (3 marks)

iii. The peak magnetic field strength B_0 (3 marks)

iv. The intensity of an electromagnetic wave with a peak electric field strength of 116 V/m? (4 marks)

e) By using the plane wave equation $\vec{E} = E_o\, cos(kr - \omega t)$, differentiate between the properties of monochromatic and non-monochromatic waves (5 marks)

QUESTION TWO (20 MARKS)

a) Derive the wave equation from the Maxwell equations. (6 marks)

b) Show that a plane wave satisfies the wave equation. (4 marks)

c) Identify the Maxwell's equations in;

i. Free-space (4 marks)

ii. In a medium (6 marks)

QUESTION THREE (20 MARKS)

a) Discuss the following phenomena;

i. Sum/difference frequency generation (3 marks)

ii. Optical Kerr effect (3 marks)

iii. Four-wave mixing (4 marks)

iv. Stimulated Raman Scattering (4 marks)

b) Show that the Poynting vector is given by

$\boldsymbol{S} = \frac{1}{\mu_o}\vec{E} \times \vec{B}$ (6 marks)

QUESTION FOUR (20 MARKS)

a) Prove that the Classical 1-D harmonic oscillator obeys the plane wave characteristics. (6 marks)

b) State if the equation $\vec{B}(r,t) = \sqrt{\frac{\varepsilon_o}{\mu_o}}\hat{k}xE_o\, cos(kr - \omega t)$, is a solution to the wave problem and support your answer. (6 marks)

c) Show that the nonlinear Maxwell's equation is given by (8 marks)

$$\nabla^2\vec{\mathrm{E}} - \mu_o\epsilon\frac{\partial^2\vec{E}}{\partial t^2} = \mu_o\frac{\partial^2\vec{P}_{NL}}{\partial t^2}$$

QUESTION FIVE (20 MARKS)

a) Describe the properties of the following media;

i. Isotropic (2 marks)

ii. Homogeneous (2 marks)

iii. Linear (2 marks)

b) Show that under high optical intensity, the refractive index of a fibre is given by

$\eta = \eta_0 + \eta_2 I = \eta_0 + \Delta\eta$ (10 marks)

c) Two waves oscillate and beat in an optical fibre via four-wave mixing. If the frequency difference between these wavelengths is 50 GHz, determine the frequency of the 4th generated wavelength if the first wavelength is 193.12 THz (4 marks)