MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

FOURTH YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)

SPH 429: LASER PHYSICS AND TECHNOLOGY

DATE: 24/8/2022 **TIME: 8.30-10.30 AM**

INSTRUCTIONS:

- Question One (1) is **compulsory** (30 marks).
- Answer any **two** questions (each 20 marks).

Use the following constants:

$h = 6.626 \times 10^{-34} m^2 kg/s$, mass of electron=$9.1 \times 10^{-31} kg$, $1ev = 1.6 \times 10^{-19} J$

QUESTION ONE (30 MARKS)

a) Describe the two forms of coherence of a laser beam (4 marks)

b) The output power of a given laser is 1 mW and the emitted wavelength is 630 nm. Calculate the number of photons emitted per second. If the area of the laser beam is $10^{-6}m^2$, calculate the intensity of the beam (3 marks)

c) Define an attosecond and identify any one application (3 marks)

d) State the Beer-Lambert's law of absorption (2 marks)

e) Define the following terms;

i. Q-switching (2 marks)

ii. Mode-locking (2 marks)

f) In a laser, the total number of lasing particles are 2.8×10^{19}. If the laser emits radiation of wavelength $7000\,\text{Å}$, then calculate the energy of the emitted photon and total energy available per pulse. Assume the efficiency of the laser is 100% (4 marks)

g) Define population inversion (2 marks)

h) Discuss any two industrial applications of coherence of light (4 marks)

i) List any two methods by which a light beam can propagate (2 marks)

j) Identify any two processes involved in pumping of a laser (2 marks)

QUESTION TWO (20 MARKS)

a) Consider a red laser whose wavelength is $0.6\ \mu m$ and beam diameter of 2 mm. Calculate its angle of divergence. (3 marks)

b) Calculate the ratio of transition rates of spontaneous emission to the stimulated emission for light of wavelength 10^4m, and cavity temperature of 100K and hence determine which type of emission will dominate (3 marks)

c) Derive the relationship between the Einstein's coefficients under spontaneous and stimulated emissions. What are the necessary conditions for the laser action to take place?(9 marks)

d) What is four-level laser? Explain the theory and working of any four-level laser (5 marks)

QUESTION THREE (20 MARKS)

a) Show that the variation of the laser beam waist is given by

$$w(z) = w_o\sqrt{1 + (\frac{Z}{Z_R})^2}$$ (5 marks)

b) Describe the operation of a laser under the three fundamental processes (9 marks)

c) Describe the following scattering phenomena

i. Raman scattering (3 marks)

ii. Brillouin scattering (3 marks)

QUESTION FOUR (20 MARKS)

a) Consider a Gaussian beam emerging from a laser. Sketch and label the components of this Gaussian beam (5 marks)

b) Describe the transitions and derive the mathematical expressions that enable a three-level laser system to take place and give an example of this laser (8 marks)

c) Sketch the structure of a laser, label and describe the role of each part (7 marks)

QUESTION FIVE (20 MARKS)

a) Discuss applications of lasers in the following fields and industries

i. Medical field (3 marks)

ii. Telecommunication (3 marks)

b) Describe the characteristics, structure, principle, and advantages of the following lasers

i. Semiconductor laser (7 marks)

ii. HeNe laser (7 marks)