

**CHUKA****UNIVERSITY****UNIVERSITY EXAMINATIONS****FOURTH YEAR EXAMINATION FOR THE AWARD OF DEGREE OF BACHELOR OF SCIENCE IN PHYSICS AND BACHELOR OF EDUCATION SCIENCE****PHYS: 487****PLASMA PHYSICS****STREAMS: BSc, BEd****TIME: 2 HOURS****DAY/DATE: MONDAY 23/04/2025****02:30 - 04:30 PM****INSTRUCTIONS:****Answer question ONE and any other TWO questions.****Clearly show your workings.****QUESTION ONE 30 Marks**

- a) Explain three natural occurrence of plasma. [6 Marks]
- b) Taking the plasma to consist of freely moving electrons in an immobile neutralizing background, show that the plasma oscillates at a frequency  $\omega^2 = \frac{4\pi n e^2}{m}$  (Symbols have their usual meaning.) [6 Marks]
- c) State the fundamental parameters that characterize plasma. Give their units. [6 Marks]
- d) State and explain four applications of plasma in physics. [8 Marks]
- e) Define plasma oscillation [2 Marks]
- f) Highlight two natural occurrence of plasma. [2 Marks]

**QUESTION TWO 20 Marks**

- a) Explain four main categories of instability in plasma. [8 Marks]
- b) For a particle of charge  $q$  and mass  $m$ , moving with a velocity  $v$  in a region of space where there is only magnetic field  $B$ , the equation of motion is  $\frac{mdv}{dt} = q(v \times B)$ . Show that the radius of gyration (Larmor radius) is  $r_c = \frac{v_{\perp}}{\Omega_c} = \frac{mv_{\perp}}{|q|B}$  [12 Marks]

**QUESTION THREE 20 Marks**

- a) State four characteristics of plasma [4 Marks]
- b) State two conditions for plasma equilibrium. [2 Marks]

- c) i) From the basic principles show that the equation that describes the motion of a fluid (Euler's equation) can be written as  $\rho_m(\frac{\partial v}{\partial t} + (U \cdot \nabla)U) = -\nabla P$  [7 Marks]
- ii) Taking the plasma as quasi-neutral non-relativistic gas, show that the expression in (b) (i) above can be written as  $\rho_m(\frac{\partial v}{\partial t} + (U \cdot \nabla)U) = -\nabla P + \frac{1}{4\pi} \nabla(B \times B)$  [7 Marks]

#### QUESTION FOUR 20 Marks

- a) State and explain the Maxwell's equations in vacuum and in medium [8 Marks]
- b) Using the Poisson's equation,  $\epsilon_0 \nabla^2 \phi = \epsilon_0 \frac{d^2 \phi}{dx^2} = -e(n_i - n_e)$ , show that for a potential  $\phi$  on a plane  $x = 0$  held at a value  $\phi = 0$  by a perfectly transparent grid, the Debye length is given by  $\lambda_D = (\frac{\epsilon_0 k T_e}{n e^2})^{1/2}$  [12 Marks]

#### QUESTION FIVE 20 MARKS

- a) A gas in thermal equilibrium has particles of all velocities, and the most probable distribution of these velocities is given by the Maxwellian distribution:  $f(u) = A \exp(-\frac{1}{2} m u^2 / K T)$ . Given that the number of particles per  $m^3$  is  $n = \int_{-\infty}^{+\infty} f(u) du$  show that the average energy is given by  $E_{av} = \frac{1}{2} K T$ . [14 Marks]
- b) High power lasers are used to compress gas plasma by radiation pressure. The reflectivity of plasma is unity if the electron density is high enough. A laser generating pulses of radiation of peak power 1.5 GW is focused onto  $1.3 \text{ mm}^2$  of high electron plasma. Find the pressure exerted on the plasma. [6 marks]
-