NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4180 - PLASMA PHYSICS

BSc HONOURS PART IV: DECEMBER 2001 *DURATION: 3 HOURS*

ANSWER **ALL** PARTS OF QUESTION 1 IN SECTION **A** AND ANY **THREE** QUESTIONS FROM SECTION **B**. SECTION **A** CARRIES 40 MARKS WHILE SECTION **B** CARRIES 60 MARKS. DRAW NEAT DIAGRAMS WHEREVER NECESSARY.

Planck's Constant	$h = 6.63 \times 10^{-34}$ Js
Boltzmann's Constant	$k = 1.38 \times 10^{-23}$ JK^{-1}
Speed of light	$c = 2.998 \times 10^{8}$ ms^{-1}
Charge on an electron	$e = 1.60 \times 10^{-19}$ C
Mass of an electron	$m_e = 9.11 \times 10^{-31}$ kg
Permittivity of free space	$\varepsilon_o = 8.85 \times 10^{-12}$ Fm^{-1}
Permeabilty of free space	$\mu_o = 4\pi \times 10^{-7}$ Hm^{-1}

SECTION A

1. (a) Calculate the energy of a photon of wavelength $\lambda = 125.0$ nm. Hence or otherwise explain the experimental observation that u-v radiation $\lambda = 125.0$ nm can ionize gases like O_2, N_2, H_2 etc. whose ionizing energies are 12.5eV, 15.6 eV, 15.4 eV, etc.respectively. [4]

(b) Explain the nomenclature $3^2 D_{5/2}$ of an excited state of an atom. [2]

(c) Define recombination coefficient. Explain briefly various processes by which recombination can occur in gaseous plasma. [6]

(d) Obtain an expression for the diffusion current in plasma in which concentration gradient varies with time. [6]

(e) The current flowing through a gas discharge tube was found to be 4 A. The area of cross-section of the electrodes is 10 cm^2, inter-electrode separation is 1 m, the voltage across the tube is 24V and the electron density in the tube is$1.5 \times 10^{17} m^{-3}$. Calculate the mobility of the electrons. Derive the necessary formula you will use. [6]

(f) In a plasma focus experiment the peak current flowing in the tube is 189 kA, the inter-electrode separation is 6cm, the inner electrode has a radius of 0.95 cm and is 16.0 cm long. If the filling gas has density of 0.00865kg m^{-3}, calculate the axial transit time. Give the importance of this parameter in the focus device. [6]

(g) Calculate the Debye length in a plasma at T= 5000 K , pressure = 0.1 torr and degree of ionization = 0.1. What is the importance of this parameter? [4]

(h) In a certain region of earth's ionosphere the electron density is $2x\ 10^{11}$ electrons m^{-3}. Calculate plasma frequency and cutoff frequency for sonic waves. [6]

SECTION B

2 (a) Explain the following terms:

(i) Townsend's first and second ionization coefficients,
(ii) Penning Effect and
(iii) Step ionization. [8]

(b) Derive an expression relating the Townsend's second ionization coefficient β and the ionization current in a discharge tube with an inter-electrode separation of d cm. Hence obtain the condition for self sustained discharge. [8]

(c) In an experiment to measure α, in a certain gas, it was found that the steady state current is 3.8×10^{-8} A at a voltage of 8 kV with an inter-electrode separation of 0.4 cm. Keeping the field constant and reducing the distance to 0.1 cm resulted in a current of 3.8×10^{-9} A. Calculate Townsend's first ionization coefficient. [4]

3 (a) Explain the following terms:

(i) Plasma,
(ii) Debye Length
(iii) Electron Temperature and
(iv) Floating Potential. [6]

(b) Describe an experiment to evaluate electron temperature in a positive column of a discharge tube by double probe method. Discuss necessary theory on which the experiment is based. [10]

(c) Give the limitations of the probe theory? [4]

4 (a) Describe the plasma focus device. Your description should include the energy transfer mechanism from the capacitor bank to the focus tube. [8]

(b) Draw an equivalent circuit of the focus device assuming that the plasma offers very low resistance. Write the circuit equation and the plasma and magnetic pressure balance equation in the axial phase. You may assume the snow plough model. Draw the flow chart for the computer simulation. [8]

(c) Discuss the radial phase and explain the focussing action of the focus device. [4]

5 (a) How is fusion energy produced? Give the conditions and advantages of a fusion reactor. [8]

(b) Explain the principle of a Tokamak reactor. [4]

(c) Outline the theoretical considerations of magnetic confinement in a Tokamak reactor. Give in brief the operational details of the fusion power plant. [8]

6 Write short notes on:

(a) Plasma Torch.
(b) Plasma in Material Processing.
(c) Magnetic Mirror.
(d) Plasma Sputtering. [20]

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