(This Question paper contains 2 printed page)

Sr. No. of questions Paper	**:**	**8123**
Name of the Course	**:**	**B.Sc. Hons.–(Physics)_NEP: UGCF-2022**
Semester	**:**	**VIII- Semester (DSE Paper)**
Name of Paper	**:**	**Plasma Physics**
Unique Paper Code	**:**	**2223010043**
Duration	**:**	**3 Hours**
Maximum Marks	**:**	**90**

Instructions for Candidates:

(Write your Roll No. on the top immediately on receipt of this question paper)

Question No.1 is compulsory. Answer any four of the remaining five. Use of non-programmable scientific calculator is allowed.

Q1. ***Attempt any six questions:*** **(6 x 3 = 18)**

(a) Discuss the role of a plasma in thermonuclear fusion.

(b) What is the electron plasma frequency? How does it differ from the ion-plasma frequency?

(c) What is solar plasma? State two phenomena associated with it — solar wind and coronal heating, and their relevance to space plasma physics.

(d) A deuteron ($m_d = 3.34\times10^{-27}$ kg) moves in a uniform magnetic field B = 1.2 T with velocity, $V_\perp = 4\times10^6$ m/s perpendicular to the field. Calculate its Larmor radius and cyclotron frequency.

(e) Is plasma a diamagnetic or paramagnetic medium? Justify your answer.

(f) A plasma slab has electron density, $n_e = 9\times10^{16}$ m^{-3}. An electromagnetic wave of frequency f = 3 GHz is incident on it. Determine whether the wave propagates or is reflected.

(g) Explain the operating principle of an ion thruster in rocket propulsion, and state one advantage it has over chemical rockets in terms of specific impulse.

Q2) (a) State Saha's equation for the degree of ionization of a gas in thermodynamic equilibrium. Identify each term. Using the equation, explain why a higher temperature leads to a greater degree of ionization at a constant density. **(8)**

(b) A plasma has electron temperature, $T_e = 2$ eV and electron density, $n_e = 5\times10^{17}$ m^{-3}. (i) Calculate the Debye length (λ_D), (ii) Verify quasi-neutrality by checking that the plasma dimension L = 0.3 meter satisfies $L >> \lambda_D$, and (iii) Calculate the plasma frequency (ω_{pe}) **(10)**

Q3) (a) Derive the expression for curvature drift of a charged particle moving along curved magnetic field lines. Show that in a cylindrical geometry, the curvature drift and grad-B drift act in the same direction. Explain the consequence of this combined drift for plasma confinement. **(10)**

(b) An electron is trapped in a magnetic mirror device with $B_0 = 0.15$ T at the midplane and $B_m = 1.8$ T at the mirror throat. This electron has a total kinetic energy of 8 keV and a pitch angle, $\alpha_0 = 30°$ at the midplane. (i) Calculate the mirror ratio (R_M) (ii) Find the loss-cone angle. **(8)**

Q4) (a) If the electric field is 10 volt/m and the magnetic field is 1 Tesla what is the drift velocity of the guiding center? **(6)**

(b) Using physical arguments and schematic diagrams only, show that the electron plasma oscillations will not propagate in an infinite cold plasma. Explain the role of ions in these oscillations. **(6)**

(c) Write a set of fluid equations of plasmas and their significance for electrostatic wave propagation in an unmagnetized plasma. **(6)**

Q5) (a) Describe the motion of a charged particle in a uniform magnetic field. Show that the particle undergoes helical motion and derive expressions for (i) the gyroradius (r_L) and (ii) the gyrofrequency (ω_c). Extend this analysis, if an electric field is applied transverse to the magnetic field. **(10)**

(b) What is plasma processing of materials? How does plasma processing differ from conventional chemical processes? **(4)**

(c) Using the I-V curve, explain the measurement of plasma temperature using the Langmuir probe. **(4)**

Q6) a) Starting from the two-fluid equations of plasma, derive the dispersion relation for ion acoustic waves. Show that in the limit $k\lambda_D << 1$ and $T_e >> T_i$, the wave becomes non-dispersive with phase speed $c_s = \sqrt{(k_B T_e/m_i)}$. **(10)**

b) A plasma has electron density, $n_e = 4\times10^{18}$ m^{-3} and electron temperature, $T_e = 10$ eV. An electromagnetic wave of frequency, $f = 20$ GHz propagates through the plasma. (i) Calculate the electron plasma frequency, f_{pe} and (ii) Calculate the phase velocity, V_{ph} and group velocity, V_g. **(8)**

Physical Constants

$\varepsilon_0 = 8.85\times10^{-12}$ F/m, $\mu_0 = 4\pi\times10^{-7}$ H/m, $c = 3\times10^8$ m/s, $k_B = 1.38\times10^{-23}$ J/K, $m_e = 9.1\times10^{-31}$ kg, $e = 1.6\times10^{-19}$ C, 1 eV = $1.6\times1sss0^{-19}$ J, $h = 6.63\times10^{-34}$ J·s, Mass of proton, $m_p = 1.67\times10^{-27}$ kg, Deuteron mass, $m_d = 3.34\times10^{-27}$ kg, Atomic mass unit=1.66×10^{-27} kg.