23SC801 **Physics of Plasmas** **4 0 0 4**

Course Overview

This course provides an introduction to Physics of Plasmas, and its application to Space Physics, at the beginning graduate/doctoral student level. No prior knowledge of Plasmas will be assumed, but Mathematical tools and basic physical concepts learned as an Undergraduate will be assumed. This course is recommended for students with research interests in Space Physics. Emphasis will be on physical insights, application, and problem solving rather than formal derivations.

Course Outcomes

CO1: To be able to define a Plasma, explain concepts of Plasma Oscillations and Debye Shielding.
CO2: To be able to describe motion of charged particles in various prescribed (coupled/otherwise) electric and/or magnetic field configurations (including a dipole magnetic field), and the adiabatic invariants.
CO3: Be familiar with various approaches to Plasma Physics and under what conditions these can be used.
CO4: Understand Fluid description of Plasma, what kind of waves are supported, Physics of such waves, and be able to derive the Dispersion relations.
CO5: Understand the Physics of Instabilities and be familiar with their characteristics.
CO6: Be able to apply Plasma Physics theories to real-world plasma systems – e.g. Solar Wind – Magnetosphere interactions

Course Syllabus

Unit – 1

Introduction: What is a Plasma? Characteristic Parameters – Spatial Scale of an unmagnetized Plasma: Debye Length, Time scale of an unmagnetized plasma: Plasma period, Gyroradius & Gyrofrequency of magnetized plasma, Plasma Physics : Self consistency between fields and particles

Unit – 2

Single particle motion in prescribed E&B fields : **E x B** drifts, Grad-**B** drift, Curvature drift, Magnetic moment, Adiabatic invariants of the particle motion, Magnetic mirror, Motion in a dipole magnetic field

Unit – 3

Two fluid description of Plasmas: Two - Fluid Plasma equations, Electron Plasma Waves or Langmuir Waves in B_o= 0 Plasmas, Electrostatic ion waves or Ion Acoustic waves (in B_o= 0 Plasmas), High frequency electromagnetic (EM) waves in B_o= 0 Plasmas, Upper hybrid waves in magnetized plasmas, Electrostatic ion waves in a magnetized plasma, Instabilities -- Two-Stream Instability

Unit – 4

One fluid equations & MagnetoHydroDynamic (MHD) equations: Simplified one-Fluid equations, MHD equations, MHD Waves: Low Frequency Electromagnetic Waves : Alfven & Magnetosonic modes, Portraits of MHD Waves, Nonlinear MHD Alfven Wave Solution (Walen, 1944), Current propagation via Alfven waves, MHD Discontinuities : Standard MHD equations, MHD discontinuities (Steady State), Summary; Non-linear Electrostatic Waves: Constant profile nonlinear solutions of the fluid-Poisson equations

Unit – 5

Vlasov description of Collisionless plasmas: Vlasov equation, Equilibrium or steady-state solutions – Examples, Electrostatic waves & Landau Damping, Current sheet structures

Text Books

1. "Introduction to Plasma Physics and Controlled Fusion", Francis F Chen, 3E, Springer, 2016
2. "Introduction to Plasma Physics: With Space, Laboratory and Astrophysical applications", Donald A Gurnett & Amitava Bhattacharjee, 2E, CUP, 2017
3. "Principles of Plasma Physics for Engineers and Scientists", Umran Inan and Marek Golkowski, CUP, 2011

Reference Books

1. "Physics of Space Plasmas: An Introduction", George Parks, Westview Press, 2003
2. "Waves in Plasmas", TH Stix, Springer, 1992
3. "Dynamics of Magnetically Trapped Particles: Foundations of the Physics of Radiation Belts and Space Plasmas", Juan G Roederer and Hul Zhang, 2E, Springer, 2014
4. "The Physics of Plasmas", Boyd, T.J.M., and Sanderson, J J, CUP, 2003
5. "Introduction to Plasma Theory", Nicholson D R, John Wiley & Sons, 1983

Evaluation Pattern

Internal (70%) : Problem sets (Once every week)

External (30%): Final Exam (Closed book)