23SC802 **Space Plasma Physics** **4 0 0 4**

Course Overview

This course provides an introduction to Space Plasma Physics (Space Physics) encompassing the space environment from the Sun to the outer heliosphere, using basic Plasma Physics concepts. Within this space environment are structure of the Sun, Interplanetary Magnetic Field (IMF), Solar spectrum & wind, its interaction with both magnetized (Magnetosphere) and unmagnetized planets with/without atmospheres, Transient disturbances (Shocks), Solar-Terrestrial relations, Moons, Comets, Asteroids, and Cosmic rays. This course is ideally suited to progress toward a more detailed courses on Magnetospheric and Ionospheric physics, i.e.; physics of partially ionized gases. The basic measurements that help us to understand the space plasma environment will be discussed. Back-of-the-envelope estimates in Space Physics will be stressed.

Course Outcomes

CO1: Use adequate terminology to describe the structure of the Sun, basic properties of the Solar Wind, including its behavior near the Sun & Planets and at the boundary of the heliosphere.
CO2: Explain how certain important plasma populations in the solar system, e.g. the Earth's Ionosphere and Magnetosphere get their basic properties, and how these properties differ between planets.
CO3: Use adequate terminology to describe Solar Wind interaction with magnetized planets (e.g. Earth).
CO4: Apply key concepts in plasma physics (such as particle drifts, adiabatic invariants, magnetic mirroring, frozen-in field theorem, hydromagnetic equilibria) to analyze the structures in, and dynamics of the solar system.
CO5: Conduct literature survey and systematic review on any instrument in Space Physics and highlight some of the most significant scientific discoveries using measurements from the instrument.

Course Syllabus

Unit – 1

Introduction: What is Space Physics?, Solar-Terrestrial Physics – Evolution as a discipline, Review of single particle motion – particle orbit theory, Kinetic theory – Vlasov equation & MHD – Generalized Ohm's law & Frozen-in flux, Applications

Unit – 2

The Sun, Solar Wind and its embedded magnetic field: Introduction – Solar interior & atmosphere, Magnetic Sun & Solar Cycle, Coronal expansion and Solar Wind, Interplanetary transients, Structures (Shocks) – Shock basics, Rankine-Huginot equations, Observations of parallel and perpendicular shocks, Shock dissipation; Heliosphere, Measurement of particle fluxes & relation to Plasma distribution functions, Measuring magnetic fields.

Unit – 3

Solar Wind interaction with Magnetized obstacles: Planetary Magnetic fields: Basics, Field lines & L-parameter, Spherical Harmonic expansions, Variations in Earth's field, Size of Magnetospheric cavity, Empirical models; Using geomagnetic activity to probe Solar Wind-Magnetosphere coupling: Structure of the outer magnetosphere, Solar Wind pressure on Magnetosphere, Observed Magnetopause, Magnetospheric convection, Magnetic Reconnection – Basic Physics, Magnetic storms & Ring Current, Magnetic Tail & Substorms – Plasma Sheet, Auroral Current systems, Empirical model, Space Weather.

Unit – 4

Terrestrial Magnetosphere: Structure, Polar cusp, Near-Earth Plasma Sheet, Ring Current, Plasmasphere, Radiation belts: Bounce motion & 1st and 2nd Adiabatic invariants, Bounce averaged gradient/curvature drift, Magnetospheric Waves – Classification & generation, Radiation belt formation & Loss; Planetary Magnetospheres (Briefly).

Unit – 5

Auroras: Introduction, Auroral emissions, Magnetosphere-Ionosphere (M-I) coupling & auroras, Magnetospheric sources of Field Aligned Currents (FACs), Ionospheric currents, Inverted-V auroras, Consequences of Aurora induced conductivity channels,

Text Books

1. "Space Physics: An Introduction", Russell CT, Luhmann JG & Strangeway RJ, CUP, 2016
2. "Introduction to Space Physics", Kivelson M and Russell CT, CUP, 1995
3. "Space Physics : An Introduction to Plasmas and Particles in the Heliosphere and Magnetospheres", May-Britt Kallenrode, 3E, Springer, 2004
4. "Physics of Space Plasmas: An Introduction", George Parks, Westview Press, 2003
5. "Basic Space Plasma Physics", Baumjohann W and Treumann RA, World Scientific Publishing Company, 1996

Reference Books

1. "Physics of Solar System Plasmas", Cravens TE, CUP, 1997
2. "Dynamics of Magnetically Trapped Particles: Foundations of the Physics of Radiation Belts and Space Plasmas", Juan G Roederer and Hui Zhang, 2E, Springer, 2014
3. "Advanced Space Plasma Physics", Treumann RA and Baumjohann W, World Scientific Publishing Company, 1997

Evaluation Pattern

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

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