Plasma Physics

Aim: This course continues the exposition of basic plasma physics begun in Physics 218A. The emphasis here is on macroscopic models especially MHD, their use in description of physical systems (Part I) and their foundations in particle dynamics and kinetic theory (Part II). An effort is made to develop material via a 'systems approach' - i.e. in the context of the phenomenology of actual systems.

Note: Additional related material will be developed in problem sets and discussed in the problems sessions.

Topics

Part I: MHD and Selected Applications

i.) *Basics of MHD*
- a.) MHD equations, Frozen-in law, conservation laws
- b.) Virial Theorem and confinement, MHD equilibria
- c.) Flux Freezing, basic ideas of magnetic reconnection (Sweet-Parker theory) and current layers, magnetic helicity and its significance
- d.) 'reduced MHD' for strongly magnetized systems

ii.) *MHD Wave and Stability Theory*
- a.) linear waves in MHD-Alfven, fast, slow, etc.
- b.) steepening of Alfven waves: shocks and collisionless shocks
- c.) basic notions of stability and the Energy Principle for MHD
- d.) simple applications of the Energy Principle

iii.) *Case Studies in the Application of MHD Stability Theory to Plasma Phenomenology*
- a.) Case Study I - the Sun as a Flux-Driven system
  - 1.) overview of solar phenomenology, emphasizing flux drive
  - 2.) Rayleigh-Benard instability and solar convection
  - 3.) magneto-convection and its implication for sun spots
  - 4.) the solar cycle, magnetic buoyancy instability, Parker instability
  - 5.) overview of solar corona, coronal heating and Parker's theory of the solar wind
- b.) Case Study II - Pinch Confinement as a Flux-Driven process
  - 1.) overview of thermal confinement phenomenology for pinches
  - 2.) ideal stability interchanges, line-tying effects, Suydam limit
  - 3.) resistive stability: basic ideas, resistive interchange modes, 'twisted slicing' quasi-modes
- c.) Case Study III - Stability Constraints on Ohmic Heating in Pinches
  - 1.) overview of current profile and disruption phenomenology for pinches
  - 2.) 'sausage stability' and the need for toroidal field
  - 3.) kink stability, Kruskal-Shafranov criterion and limits on plasma current
  - 4.) resistive stability: the tearing mode
  - 5.) introduction to Rutherford theory of nonlinear tearing

Part II: Foundations of Macroscopic Descriptions

i.) *Particle Dynamics and Gyrokinetics*

a.) guiding center drifts and adiabatic invariants; orbits in mirrors and tokamaks

b.) drift-kinetic description, drift-kinetic equation

c.) deriving the linear gyrokinetic equation, gyrokinetic description of dynamics

ii.) *Developing Macroscopic Models*

a.) deriving MHD from two fluid models, MHD variants

b.) deriving reduced MHD from drift and gyro kinetics, the kinetic Alfven wave

c.) introduction to the kinetic theory of pressure stability limits

d.) Alfven waves and the confinement of α-particles in burning plasmas