TOPICS

Content: This course continues the exposition of basic plasma physics begun in Physics 218A. The aim here is on macroscopic models, especially MHD, their origins in kinetic theory, and their use in the description of physical systems. Special emphasis is placed on stability theory. Problem sets will be used extensively to develop new material.

I.) Basics of MHD Dynamics

a.) MHD equations: Meaning and Content
b.) Freezing-in law: Local and Global; Relation to Kelvin's Theorem
c.) Conservation of Momentum, Energy, Angular Momentum in MHD
d.) Linear Waves in MHD
e.) Virial Theorem and Confinement, Aspects of Equilibrium
f.) Departures from Ideal Dynamics
  i.) Magnetic Reconnection; Sweet-Parker Theory (local)
  ii.) Flux Expulsion and Prandtl-Batchelor Theorem (global-2D)
  iii.) Magnetic Helicity and Taylor Relaxation (global-3D)

II.) Foundations and Derivation of MHD

a.) Traditional: Boltzmann Equation $\rightarrow$ 2-Fluid Theory $\rightarrow$ 1-Fluid Theory $\rightarrow$ Reduced MHD; Variations on Ohm's Law
b.) Drift-Kinetic Derivation:
  i.) Guiding-center-drifts, adiabatic invariants, orbits
  ii.) Describing field lines and their motion
  iii.) Drift-Kinetic Equation; Gyro-Kinetic Poisson Equation
  iv.) From Drift-Kinetics to Reduced MHD
  v.) Example: Kinetic Shear Alfven Wave

III.) Ideal and Resistive MHD Stability

a.) Basic Notions of Stability and the Energy Principle for MHD
b.) Four Basic Applications of the Energy Principles to Interchanges:
  i.) Thermal Bouyancy; Rayleigh-Benard Inst.
  ii.) Rayleigh-Taylor Inst.
  iii.) Interchange in Inhomogeneous Magnetic Field; Relation to TEP Pinch
  iv.) Interchanges 'w/o gravity': Minimum-B Criterion
c.) Line-Tying, etc. and Basics of Beta Limits
d.) Magnetic Shear and the Suydam Criterion
e.) Slow and Fast Resistive Interchange Modes
f.) Twisted Slicing Modes and Wave Packets
g.) Introduction to Ballooning Modes
h.) Sausage and Kink Modes
i.) Introduction to Tearing Modes and Spontaneous Reconnection: Linear and Rutherford Phase Evolution

III.) Nonlinear Waves and Turbulence in MHD

a.) Gas Dynamic and MHD Shocks
b.) Steepening in Weakly Compressible MHD; Quasi-Parallel DNLS Structures
c.) Aspects of Collisionless MHD Shocks
d.) Introduction to Wave-Wave Interaction
    i.) Coherent Interaction Models
    ii.) Stochastic Interaction and the Wave-Wave Collision Integral
    iii.) Wave Cascades
e.) Turbulence
    i.) Introduction to Navier-Stokes Turbulence
    ii.) Introduction to MHD Turbulence