

PHY565: Astrophysical Plasma Physics

Fall 2011, MWF 3:10 – 4:00 AJM 222

This is an advanced graduate course whose aim is to introduce the fundamentals of hydrodynamics and magnetohydrodynamics relevant to astrophysics. The basics will be presented with an emphasis on “classic problems” — astrophysical systems exhibiting some aspect of fluid dynamics. The structure of the course is intended to develop one of the most valuable skills in scientific research: scientific writing.

Web site: <http://solar.physics.montana.edu/dana/ph565/>

Grading:

- Homework assignments
 - Assignments every \sim 1–2 weeks
 - You may collaborate but must write up **independent** solutions¹.
- Final project
 - To resemble a research publication in form and quality
 - Topic can be anything hydrodynamic or magnetohydrodynamic — it need not be original work. Why not do something related to your thesis research?
 - One-page proposal due **Oct. 17**
 - Final draft due 5:00pm **Nov. 22**
 - Draft will be refereed
 - Revised version due 5:00pm **Dec. 14**

Recommended Resources

- ★ *The Physics of Fluids and Plasmas* Arnab Rai Choudhuri
- *An Introduction to Astrophysical Fluid Dynamics*, M. J. Thompson
- † *Plasma Physics for Astrophysics*, R. M. Kulsrud (on reserve)
- *Fluid Mechanics*, L. D. Landau and E. M. Lifshitz (on reserve)
- ‡ *Hydrodynamic and Hydromagnetic Stability*, S. Chandrasekhar (on reserve)
- ‡ *Physics of the Solar Corona*, M.J. Aschwanden, (on reserve)

★—comprehensive, ○—fluid mechanics, †—MHD, ‡—specialized

¹Either typed or neatly hand-written

SYLLABUS

I. Hydrodynamics

- A. Fluid equations
- B. Equilibrium solutions
 - 1. hydrostatics: coronal loops, stellar structure
 - 2. equilibria w/ flows: Laval's nozzle, solar wind
- C. Linearized equations (waves)
 - 1. General linearization techniques
 - 2. Waves in homogeneous fluid: acoustic, shear & entropy modes
 - 3. Waves in a stratified atmosphere: g-modes & p-modes
- D. Nonlinear hydrodynamics
 - 1. Shocks — Rankine-Hugoniot conditions
 - 2. Turbulence & multi-scale analysis — turbulent diffusion

II. Magnetohydrodynamics (MHD)

- A. The MHD equations
- B. Tools for MHD intuition: field lines, frozen field lines, magnetic tension
- C. Equilibrium solutions
 - 1. Force-free fields (general properties)
 - 2. Constant- α fields — Lundquist field
 - 3. 2d equilibria using flux functions — Grad-Shafranov equation: spheromaks, arcades, current singularities
 - 4. Magnetic merging solution (resistive reconnection)
- D. MHD waves: Alfvén, fast MS & slow MS
- E. Stability of MHD equilibria
 - 1. Cylindrical: Kink mode, Sausage mode
 - 2. LOE in arcades
 - 3. Tearing mode

III. Underpinnings of fluid equations

- A. Deriving fluid equations
 - 1. Distribution functions & Boltzman's equation
 - 2. Moments of the distribution function
 - 3. Entropy and the Maxwellian distribution
 - 4. Collisions - viscosity, thermal conductivity
- B. Plasma physics
 - 1. two-fluid equations
 - 2. two-fluid waves