

# PHY580: Astrophysical Magnetohydrodynamics

Spring 2007, TR 12:45 – 2:00

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”. The structure of the course is intended to develop one of the most valuable skill in scientific research: scientific writing.

Grading:

- Homework assignments
  - Assignments every  $\sim 2$ –3 weeks
  - You may collaborate but must write up **independent** solutions.
  - Solutions must be written<sup>1</sup> **in full, correct paragraphs** — probably including mathematics (properly punctuated).
- 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 **Feb. 27**
  - Final draft due 5:00pm **April 16**
  - Draft will be refereed
  - Revised version due 5:00pm **May 4**

Texts:

- ★ *The Physics of Fluids and Plasmas* Arnab Rai Choudhuri
- † *Hydrodynamic and Hydromagnetic Stability*, S. Chandrasekhar (on reserve)
- † *Fluid Mechanics*, L. D. Landau and E. M. Lifshitz (on reserve)

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<sup>1</sup>Either typed or neatly hand-written

## SYLLABUS

### I. Hydrodynamics

#### A. Fluid equations

1. Derivation from physical principles (4.1)
2. Variants of the energy equation (6.1)
3. Incompressible HD (4.2) — Mach number

#### B. Equilibrium solutions

1. Hydrostatic atmospheres (4.4)
2. Steady flows (4.5)
3. 2d flows via stream functions (4.8)
4. Coronal loop equilibria (radiation & conduction)

#### C. Linearized solutions: waves

1. General linearization techniques
2. Waves in homogeneous fluid: acoustic, shear & entropy (6.2)
3. Waves in a stratified atmosphere: g-modes & p-modes (7.2)

#### D. Stability of equilibria

1. Rayleigh-Bénard convection (7.3)
2. Kelvin-Helmholtz instability (7.4.3)

#### E. Gas Dynamics (Ch. 6)

1. Burger's equation (6.4)
2. Shocks — Rankine-Hugoniot conditions (6.5)
3. Spherical accretion/the Parker wind (6.8)

### II. Magnetohydrodynamics (MHD)

#### A. The MHD equations (14.1)

#### B. Equilibrium solutions

1. Force-free fields (general properties)
2. Constant- $\alpha$  fields — Lundquist field
3. 2d equilibria using flux functions — Grad-Shafranov equation: spheromaks, arcades, current singularities
4. Magnetic merging solution (resistive reconnection)

#### C. The Induction equation and its consequences (14.2)

1. Frozen-in-flux & field lines
2. 2d induction equation
3. Helicity conservation (15.3)

#### D. MHD waves: Alfvén, fast MS & slow MS

E. Stability of MHD equilibria (7.1)

1. Cylindrical: Kink mode, Sausage mode (14.3.2)
2. LOE in arcades
3. Tearing mode

III. Underpinnings of fluid equations

A. Collisionless (ideal) fluid equations

1. Distribution functions & Boltzmann's equation (1.4 & 1.5)
2. Moments of the distribution function (3.1)
3. Entropy and the Maxwellian distribution (2.3 & 2.4)

B. Collisions

1. Physical basis of mean-free-path from cross section  $\sigma$
2. Rutherford cross section for charged particles (13.3)
3. Non-thermal particles — failure to relax
4. Transport phenomena — viscosity & conductivity (3.4)
5. Effects of magnetic field (13.2)