

AS726

Cosmic Fluid Dynamics

Spring 2000

Instructor: Harry Petschek

Time: 9:30-11:00 Tuesday & Thursday

Place: The Astronomy and Space Physics Conference Room (Room CAS 500)

Purpose

This course is designed to acquaint the student with fluid flow problems that appear in ordinary gases as well as in space physics and astronomy. Understanding ordinary flows that are simpler and make the basic physics easier to absorb will be discussed in parallel with the corresponding plasma flows. The goal is to provide students with a sufficient basis for understanding research papers in space and cosmic fluid flows as well as to explore similar problems that have been dealt with in ordinary fluid mechanics. For students in the graduate program in astronomy, this course is considered preparatory to the comprehensive examinations.

Level of Presentation and Prerequisites

Consistent with the purpose of this course, students would normally take this course during the first two years of graduate study, ideally the first year. As a result there are no formal prerequisites for this course, but graduate standing is required. The presentation will assume a good grasp of the principles encountered in undergraduate physics, particularly in electromagnetic theory, classical mechanics, and to some extent thermodynamics and statistical mechanics. No prior knowledge of space physics, astronomy, fluid mechanics or plasma physics will be assumed. Complex mathematics will be avoided as far as possible. Students not in the graduate program in astronomy are urged to discuss their participation in the course with the instructor.

Course Content

The course is primarily concerned with understanding the physical fundamentals of cosmic flows. The fluid flow equations will be derived from the particle mechanics (Boltzmann Equation) with emphasis on the effects of collisions or lack thereof in plasmas. The fluid flow in various situations, which occur or are closely related to cosmic events, will be studied building from the ordinary hydrodynamic cases to the collisionless plasma cases. Conflicting theories some phenomena which are as yet unexplained but likely to involve dynamics and related research ongoing at the university will be discussed.

Assessment and Grades

Grades will be based on a combination of 5 or 6 problem sets, a final exam and on classroom participation in a ratio of 60, 30, and 10%.

Since this course is also intended to help astronomy graduate students prepare for the comprehensive exam-style questions.

Primary Text:

The Physics of Fluids and Plasmas: An Introduction for Astrophysicists, Arnab Rai Choudhuri, Cambridge Univ. Press

The text matches very well with the course objectives. The author is knowledgeable in both fluid mechanics in general as well as its application to astronomy. We will follow the outline of the book fairly closely although usually using a different approach to the same subject. Only the minimal necessary treatment of plasma physics itself will be covered in class since this will be covered in a separate course.

Other Texts:

Choudhuri provides a list of other texts related to each chapter at the end of the book. This is an excellent list.

Introduction:

1. Where do fluid flows occur in space and astronomy?
2. Justification of fluid equations
 - a. Judgment required

Incompressible Flows

1. Inviscid \rightarrow potential
2. d'Alambert paradox
3. Viscous time and spatial solutions
4. Boundary layer separation
5. Turbulent boundary layer separation

Turbulence

1. Effect on boundary layer and drag
2. Kolmogorov spectrum
3. OHD and plasma turbulence
4. Solar and stellar turbulent heat conduction

Compressible flows

1. Isentropic
2. 1 dimensional \rightarrow wind tunnel \rightarrow solar wind
3. Atmospheric scale height
4. Star formation and accretion discs
5. OHD characteristics, shock waves and shock structure
6. Standing shocks, attached and unattached

MHD Equations

1. Derive equations
2. Characteristics, shock waves and structure
3. Group velocity and standing waves
4. Collisionless dissipation
5. Coronal heating

Reconnection

1. Motivation and derivation
2. Significance of result
3. Fluid computer calculations
4. Particle calculations
5. CME's
 - a. Initiation?
6. OHD spherical explosion

Magnetosphere

1. Bow shock and magnetosheath
2. Internal flows
3. Plasma sphere and plasmopause
4. Ionosphere motions