AS 726: Cosmic Gas Dynamics   Course Perspective and Syllabus   Spring 2016

Instructor: Professor Jeffrey Hughes
Office: CAS Rms 402 and 112; e-mail: hughes@bu.edu; tel: 3-2471, 3-2690.
Time: Mondays and Wednesdays, 9:30 – 11:00
Place: Room CAS 502
Office Hours: Monday 11:00-12:00, Friday 9:00-10:30, or by appointment.
Text: Physics of Fluids and Plasmas, an Introduction for Astrophysicists, Arnab Rai Choudhuri, Cambridge Univ. Press, 1998, (ISBN 0 521 55487 X)

Other Relevant/Useful Books:
Principals of Astrophysical Fluid Dynamics, C.J. Clarke and R.F. Carswell, Camb. Univ. Press, 2007, (ISBN 978 0 521 85331 6)
The Physics of Astrophysics. Vol. II: Gas Dynamics, Frank Shu, Univ. Sci. Books, 1992.
An Introduction to Astrophysical Hydrodynamics, S.N. Shore, Academic Press, 1992.
Waves in Fluids, James Lighthill, Cambridge Univ. Press, 1978, (ISBN 0 521 29233 6)
Fluid Mechanics, L.D. Landau and E.M. Lifshitz, Pergamon, 1987.

Course Objectives and Scope: This course provides an introduction to fluid mechanics (including ionized fluids) and gas dynamics, and their application to astrophysics and space physics, at the graduate level. It is one of a series of five courses that cover the physics needed in astrophysics and space physics that is recommended as preparation for the comprehensive exam in astronomy. As few physics or astronomy majors study fluid dynamics as undergraduates, no prior knowledge of fluids will be assumed, but mathematical tools and physical concepts learned as an undergraduate physicist will be assumed.

On the macroscopic scale, most of the universe can be considered a fluid. The only exceptions are solid bodies such as smaller planets. Much of the universe is ionized. The separate subject of plasma physics (which is another course taught next year) deals with ionized media, but on the large scale an ionized fluid can be treated as an electrically conducting fluid and shares much in common with un-ionized fluids, so I will cover magnetohydrodynamics near the end of the semester.

With the exception of the section on MHD (where I will be following my own notes) the course is primarily structured around the first half of Choudhuri's book, *Physics of Fluids and Plasmas, an Introduction for Astrophysicists* which covers both un-ionized fluids and plasmas. Except for the chapter on MHD, I will not cover the second half of the book.

As this course is recommended for students preparing for the astronomy comprehensive exams, I will try to emphasize physical insight, application, and problem solving rather than spend a lot of time on formal derivations. These can be found in texts. Of course I welcome any student who wants to learn about astrophysical fluids whether or not they are preparing for the astronomy comps. However, students not in the graduate program in astronomy are urged to discuss their participation in the course with the instructor.

Problem Sets, Exams, and Grades: 60% of the grade will be based on problem sets (expect one every 2 weeks), and 40 % on the **Final Exam** (Wednesday, May 4, 9-11am in CAS 502).

AS 726 **Cosmic Gas Dynamics** **Spring 2016**

Course Outline

I. **Introduction** (Chapter 1)
1. What is a Fluid?

II. **Deriving the Hydrodynamic Equations** (Chapters 2 & 3)
1. Distribution Function
2. Boltzmann Equation
3. Equations of Hydrodynamics
4. Transport – viscosity and heat conduction

III. **Gravity and Ideal Fluids** (Chapter 4)
1. Physics within the Hydrodynamic Equations
2. Example: Stellar Winds
3. Steady State Flows – Bernoulli's Equation
4. Potential flows – Flow past a sphere

IV. **Viscous Flows –** Transport of Momentum (Chapter 5)
1. Shear Stress and the Navier-Stokes Equation
2. Viscous Boundary Layers
3. Accretion Disks

V. **Waves** (Chapter 6)
1. Sound Waves
2. Linear wave theory – internal gravity waves

VI. **Shocks and Blast Waves** (Chapter 6)
1. Propagation of small step changes
2. Structure of Shocks -- Rankine-Hugoniot Relations
3. Blast Waves
4. Oblique Shocks
5. Dissipation within Shocks

VII. **Instabilities** (Chapter 7)
1. Linear instabilities and growth
2. Convective Instabilities
3. Instabilities at Fluid Interfaces - Rayleigh Taylor and Kelvin-Helmholtz
4. Jeans Instability

VIII. **Turbulence** (Chapter 8)
1. Kolmogorov Spectrum
2. Turbulent Diffusion and Transport

IX. **Magnetohydrodynamics** (Chapter 14)
1. The Equations of MHD
2. Frozen-in-Flux
3. The Pressure Tensor
4. MHD Waves
5. Momentum Transfer via waves
6. MHD Shocks and Discontinuities