INTRODUCTION TO FLUID DYNAMICS: ASTR-5400

This document presents topical guidelines for instructors of one of the five APS core graduate courses. It is provided as a reference to support instructors in their syllabus preparation, and to assist the APS Examinations Committee in their review of those syllabi. Following each set of primary/recommended topics (in black), we list suggested optional topics (in *violet*) and example applications to APS research fields (in green) suitable for student projects, scientific coding, or homework exercises. It is anticipated that instructors focus at least two-thirds of class time on the primary course topics, with the remaining time spent on optional topics or other related topics of the instructor's choosing. Instructors are encouraged to draw upon a range of examples from astrophysics, planetary science, and solar/space physics to illustrate the core material. The current version of these guidelines was adopted by the AY20-21 and AY21-22 Graduate Curriculum and Concerns Committees (GCCC). Future changes/updates will be made regularly; alternately, changes can be proposed to the GCCC.

Inviscid Fluids

Eulerian & Lagrangian formulations of continuous fluid flows
Derivation of the inviscid Euler equations
Streamlines, stream functions
Application: example solutions for astrophysically relevant inviscid flows

Viscous Flows

Derivation of the Navier-Stokes equations (mass, momentum, energy conservation)
Relationships between stress and strain, the stress tensor
Reynolds number
Transformation to non-inertial frames (e.g., rotating frames)
Bernoulli's equations

Vorticity

Definition and significance of vorticity in fluid flows
Vortex dynamics; potential vorticity
Kelvin's circulation theorem; Taylor-Proudman theorem
Application: Jupiter's zonal bands and Great Red Spot

Waves in Incompressible Flows

Linearization; phase & group velocities; dispersion relations
Gravity waves in planetary atmospheres or the solar interior
Deep and shallow water waves

Compressible Fluid Dynamics

Thermodynamics of compressible flows; gas equations of state
Sound waves; subsonic & supersonic flows
Shocks & the Rankine-Hugoniot jump conditions (weak & strong limits)
Application: Sedov-Taylor blast waves & ionization/cooling fronts
Application: planetary bow shocks

Fluid Instabilities

Linearization of the fluid equations and growth rate of perturbations
Rayleigh-Taylor and Kelvin-Helmholtz instabilities
Turbulence: onset and cascade
Application: examples of turbulence in interstellar & interplanetary space

Boundary Layers

Definitions; self-similar solutions for viscous flows
Boundary layer separation
Jets