RADIATIVE AND DYNAMICAL PROCESSES: ASTR-5120

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.

Plasmas and Collisional Effects

Random walks and their relation to particle diffusion
Binary collisions (neutral vs. ion/electron); mean free paths
Kinetic theory; Liouville's theorem; Vlasov equation; intro to statistical mechanics
Fluid-moment conservation equations; kinetic origins of thermodynamics
Brief review of electromagnetic fields and the Lorentz force
Ideal & resistive MHD; magnetic pressure & tension; MHD waves
Brownian motion and the Langevin equation
Survey of plasma physics beyond MHD
Boltzmann collision term; Fokker-Planck equation; Chapman-Enskog transport
Force-free fields, MHD shocks, MHD instabilities (e.g., MRI), magnetic reconnection
Application: diffusion in planetary atmospheres/ionospheres
Application: star formation: ambipolar diffusion & the Hall effect
Application: planetary magnetospheres: adiabatic invariants, magnetopause pressure balance

Classical Gravitational Dynamics

Conservative forces; work-energy theorem; Euler-Lagrange formalism
Two-body Kepler orbits; restricted three-body problem (Roche lobes)
Basics of tidal forces
N-body stellar dynamics; relaxation times; dynamical friction
Motions in large-scale potentials; epicycle frequencies
N-body virial theorem; virial cluster masses
Hamiltonian dynamics; Noether's theorem
Mean-motion resonances (stable vs. unstable); Lidov-Kozai mechanism
Oort constants; spiral density waves; Lindblad resonances; Toomre stability
Application: orbital dynamics: Hohmann transfer orbits; gravitational slingshot effect
Application: accretion disks, molecular cloud collapse; planetary migration & gas drag
Application: structure of Milky Way: obs. constraints on bulge/disk/DM potentials

Radiative Processes

Defining the radiation field (specific intensity, moments, fluxes)
Equation of radiative transfer; emission, absorption, & the source function
Formal solution for the radiation field; analytic solutions in optically thin & thick cases
Mean opacities: qualitative survey of opacity sources vs. wavelength & temperature
Local thermodynamic equilibrium; gray atmosphere; limb darkening
Beyond the gray atmosphere: non-LTE scattering; non-plane-parallel geometries
Basics of spectral line formation & broadening; absorption vs. emission spectra
Spectral line equivalent widths & the curve of growth; going beyond the two-level atom
Ionization & recombination processes; Saha vs. nebular vs. coronal limits
Application: planetary atmospheres: radiative equilibrium & greenhouse effect
Application: irradiated bodies with chemistry: comet sublimation & the snow line
Application: H II regions and Strömgren spheres