Advanced Plasma Physics (PHYS F627) Spring 2012

Instructor: Antonius Otto

Contact: Geophys. Inst. 708C; phone: 6169; email: ao@how.gi.alaska.edu

Course Website: http://how.gi.alaska.edu/ao/adv_plasma/index.html

Location and Time: REIC 138, TR 9:45-11:15 am

Scope and Contents of the Course:

The collective interaction of particles with electromagnetic fields is intrinsically nonlinear and is one of the most interesting and challenging areas of modern physics. This interaction is important in the structure and properties of space and laboratory plasma environments. Particularly the stability and the eruptive release of energy are fascinating and challenging problems of modern space physics. This release as manifested in geomagnetic storms and substorms, in solar flares, and in major disruptions of fusion plasma devices often occurs as a result of gradual changes of the system. In many cases microscopic properties such as micro-turbulence and wave-particle interaction are critical for the spontaneous energy release.

This advanced plasma physics course will provide a systematic and extensive coverage of advanced topics in plasma physics. These include a detailed discussion of kinetic and macro plasma instability, magnetic reconnection, turbulence, and collective transport in a plasma. Particular attention is given to inhomogeneous plasma systems. The material should enable graduate students to understand and to examine complex plasma processes as needed for their research.

(Prerequisites: Plasma physics recommended; Graduate standing or permission of instructor; 3 + 0 credits)

Conduct of the Course:

For most of the class a web manuscript will be provided. Most supplemental material can be found in the textbook by Treumann and Baumjohann, *Advanced Space Plasma Physics*. Further background material is considered from the texts by K. Schindler, *Space Plasma Activity*, Kulsrud, *Plasma Physics for Astrophysics*, Baumjohann and Treumann, *Basic Space Plasma Physics*, P. Bellan, *Fundamentals of Plasma Physics*, Chandrasekhar, *Hydrodynamic and Hydromagnetic Stability*, Krall and Trivelpiece, *Principles of Plasma Physics*, and Nicholson, *Introduction to Plasma Physics*. No textbook currently available covers all relevant aspects of magnetospheric physics. Additional original literature will be provided as necessary. The simulation codes will be written in FORTRAN and access to computer resources and visualization software (IDL) can be provided if necessary.

Homework will be mostly analytic. Some exercises in the second half of the course may make use of a provided simulation codes. Every student is expected to make a short presentation on a specific topic which may be the presentation of a specific research paper or of a simulation project.

There will be a final exam.

Grading Policy:

Homework: 50%; Class participation: 10%; Project: 15%; Final exam: 25%

There will be no +/- grades.

Textbooks:

Treumann and **Baumjohann**, *Advanced Space Plasma Physics*, Imperial College Press (1997): A good text on many advanced aspects of space plasma physics. The book probably provides the best coverage of many advanced plasma physics topics. The combination with the volume *Basic Space Plasma Physics* by Baumjohann and Treumann Imperial College Press (1997) provides a very thorough graduate level course in space plasma physics.

Schindler, *Space Plasma* Activity, Addison-Wesley (2007): A good introduction to the aspects of space plasma physics that is important for stability and instability of space plasma systems. Particular focus on magnetospheric and solar processes.

Kulsrud, *Plasma Physics for Astrophysics*, Princeton University Press (2005): Good and balanced coverage of advanced and basic plasma physics with particular focus on astrophysical applications.

Bellan, *Fundamentals of Plasma Physics*, Cambridge University Press (2006): Good and balanced coverage of a basic and some advanced plasma physics.

Chandrasekhar, *Hydrodynamic and Hydromagnetic Stability*, Oxford University Press (1970): A classic on the physics of macroscopic instabilities such as various interchange type instabilities.

Krall and Trivelpiece, Principles of Plasma Physics, San Francisco Press (1986): Very detailed text on plasma physics but not particularly written for space plasmas. While coverage of traditional plasma physics is excellent, it also lacks many of the nonlinear aspects of plasma theory.

Nicholson, Introduction to Plasma Physics (Krieger Publ., '92): An excellent introductory text with complete coverage of basic plasma physics. Unfortunately this text is out of print but it is available in the Mather Library.

Advanced Plasma Physics - Content

- Plasma Kinetic Equations and Collisions

    - Klimontovich Equation
    - Liouville Equation and BBGKY Hierarchy
    - Lenard-Balescu Equations

- Kinetic Dispersion Relation

    - Electrostatic waves and Landau damping
    - Electromagnetic waves

- Plasma Equilibria and Associated Properties

- Instabilities

  - Concept of Instability (Bunemann and Beam instabilities)
  - Macroinstabilities (Rayleigh-Taylor, Kelvin-Helmholtz, Firehose, Mirror)
  - Electrostatic Instabilities
  - Electromagnetic Instability
  - Drift waves
  - Tearing Mode

- Magnetic Reconnection

  - Simple Models of Reconnection
  - Effects of Hall Physics and Dissipation
  - Three-Dimensional Reconnection and Magnetic Topology

- Wave-Particle Interaction and Collective Effects

  - Nonlinear Waves
  - Turbulence
  - Collective Effects (Anomalous Resistivity, Diffusion, Particle Acceleration)

The following policies and services are included because they are mandated for UAF course syllabi:

- Attendance and class participation (questions, comments etc.) are strongly recommended.

- A make-up exam will be offered if attendance of the final exam was not possible.

- Homework is expected to be handed in on time and plagiarism is strongly discouraged.

- If needed computer access and access to IDL can be provided.

- The instructor will work with the Office of Disabilities Services (203 WHIT, 474-7043) to provide reasonable accommodation to students with disabilities.