

# MAGNETOSPHERIC PHYSICS (Phys F672) - Spring 2008

**Instructor:** Antonius Otto

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**Course Website:** <http://what.gi.alaska.edu/ao/msp/index.html>

**Location and time:** REIC 165, MWF 10:30-11:30 am

## Scope and Contents of the Course:

The Earth's magnetosphere is a unique plasma system in many respects. The dynamics of the magnetosphere determines the plasma environment of the Earth and controls the physics of the ionosphere. Magnetospheric storms and substorms cause the magnificent auroral displays which we observe at high geomagnetic latitudes. The magnetosphere is a strongly inhomogeneous and nonlinear system in which plasma and magnetic field properties vary over many orders of magnitude. It is also in close proximity such that satellites can carry out in situ measurements thereby providing a test for our understanding of fundamental plasma processes. Typical length scales range from some hundred meters to a hundred thousand kilometers. Thus the magnetosphere provides information on microscopic plasma processes, equilibrium configurations, plasma instabilities, particle acceleration, highly nonlinear eruptive plasma processes, and global dynamics which involves the interaction of various regions of the magnetosphere. Therefore magnetospheric physics is an essential background for all areas of space physics.

The course will introduce these various aspects of magnetospheric physics with a systematic discussion of the structural elements of the magnetosphere, their dynamics, and of the relevant plasma physics. This will include basic aspects like particle dynamics and equilibrium theory as well as more advanced concepts like non-local instability processes and nonlinear dynamics. The course will combine observational results with the relevant plasma physics and theory. Analytic theory is limited with respect to the nonlinear processes. It is offered to provide plasma simulation codes to demonstrate and visualize some of these processes.

(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 Baumjohann and Treumann, *Basic Space Plasma Physics*. Further information is taken from the texts by Parks, *Physics of Space Plasmas*, by Kivelson and Russel (ed.), *Introduction to Space Physics*, and by Treumann and Baumjohann, *Advanced Space 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 analytical. 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 midterm test and a final exam.

## Grading Policy:

**Homework: 50%; Project: 15%; Final exam: 35%**

There will be no +/- grades.

## Textbooks:

**Baumjohann and Treumann**, *Basic Space Plasma Physics*, Imperial College Press (1997): A good introduction to many aspects of space plasma physics. The focus of this book is more on the plasma physical aspects compared to other books in the list. Magnetospheric physics is addressed in various parts of the book. The combination with the more advanced volume *Advanced Space Plasma Physics* by Treumann and Baumjohann provides a very thorough graduate level course in space plasma physics.

**Parks**, *Physics of Space Plasmas*, Addison-Wesley (1991): A good introduction to many aspects of space plasma physics. These include single particle dynamics, electromagnetic fields, plasma waves and discontinuities, and simple instabilities. The book has some shortcomings particularly in several areas of plasma physics. It has also limitations in the coverage of the various regions of the Earth's magnetosphere.

**Kivelson and Russell** (eds.), *Introduction to Space Physics*, Cambridge University Press (1995): A good introductory text book of various topics of space physics. The book presents a very good phenomenological overview of various aspects of magnetospheric physics but it has shortcomings in many aspects of the more advanced plasma physics.

**Melrose**, *Instabilities in space and laboratory plasmas*, Cambridge University Press (1986): A systematic discussion of many plasma instabilities, however, with focus on homogeneous plasmas and kinetic processes.

**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.

**Schedule of contents** (each chapter represents about a week of material with some variation):

1. **Introduction** (History of the magnetosphere, Structure of the magnetosphere, Coordinate systems)
2. **Basic Plasma Properties** (First principles, Kinetic plasma equations, Fluid plasma, Plasma parameters)
3. **Electric and Magnetic Fields in Space** (Magnetic fields, Electric fields)
4. **Particle Dynamics** (Motion in electromagnetic fields, Adiabatic invariants, Particles in the magnetosphere)
5. **The inner Magnetosphere** (Trapped particles and drifts, The ring current)
6. **The Bow Shock and the Magnetosheath** (Solar wind, MHD discontinuities and shocks, The bow shock and the magnetosheath)
7. **The Magnetopause** (Basic properties and observations, Kelvin-Helmholtz and tearing modes, Magnetopause structure and reconnection, Cusp and mantle)
8. **The Quiet Magnetotail** (Observations, properties, Equilibrium configuration, Convection in the magnetotail)
9. **Magnetosphere – Ionosphere Coupling** (Magnetospheric currents, Currents and convection in the ionosphere, Birkeland currents)
10. **Magnetospheric Activity** (Magnetic indices, The auroral substorm, The magnetospheric substorm, Magnetotail dynamics, Magnetic storms)

**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.