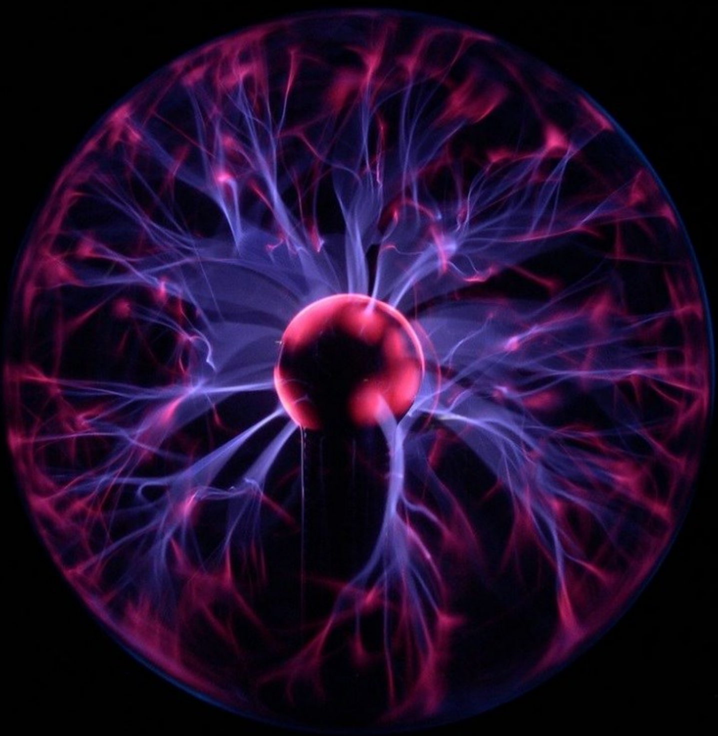
University of Glasgow | School of Physics & Astronomy



ASTRO5004
Plasma Theory and Diagnostics

Course Information Guide

Course Details

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		Schedule:	PTDI - 11 lectures, semester 1 PTDII - 11 lectures, semester 2
Credits:	15	ECTS Credits:	7.5
Assessment:	2 hour exam (100%)	Exam Diet:	April/May
Level:	Masters	SCQF Level:	11
Year Cycle:	A (odd years)	Course website:	Moodle Link

Course Aims

To provide students with an opportunity to develop knowledge and understanding of the key principles and applications of Plasma Theory and Diagnostics, and their relevance to current developments in astronomy, at a level appropriate for a professional astronomer.

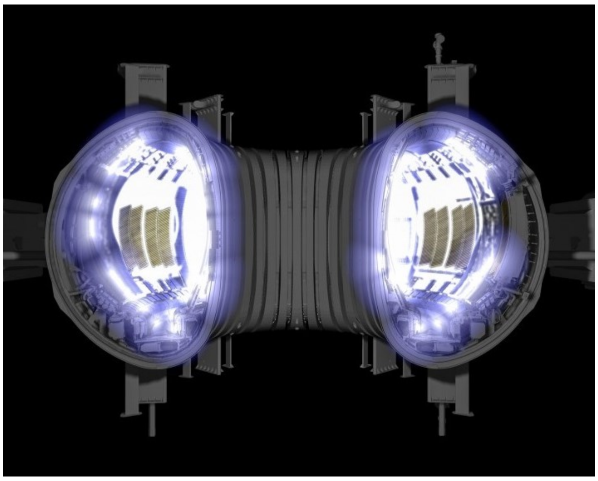
Intended Learning Outcomes

By the end of the course students should be able to:

- Demonstrate a knowledge and broad understanding of Plasma Theory and Diagnostics, and show a critical awareness of the significance and importance of the topics, methods and techniques discussed in the lectures and their relationship to concepts presented in other courses.
- Describe and analyse quantitatively processes, relationships and techniques relevant to the topics included in the course outline, applying these ideas and techniques to analyse critically and solve advanced or complex problems which may include unseen elements.
- Write down and, where appropriate, either prove or explain the underlying basis of astrophysical laws relevant to the course topics, and discuss their applications.

Semester 1 Course Outline

- *Plasma Basics*: Charge shielding. Derivation of the Debye length and the plasma frequency. The plasma parameter. Motion of single particles: gyromotion in a magnetised plasma, cyclotron frequency.
- *Cold Magnetised Plasmas*: The plasma oscillation. Formalism for the study of plasma wave propagation. The dielectric tensor and the dispersion relation. Cold plasma waves parallel and perpendicular to the magnetic field. Fast and Shear Alfven waves, whistler waves, O and X modes. Circularly polarised waves, plasma waves. The two-stream instability.
- *The MHD Description*: The fluid approximation. MHD equations: mass and momentum continuity, energy equation and Maxwell's equations. MHD waves: low frequency, non-



Cross-section of the Joint European Torus with an impression of a plasma.
Credit: **EUROfusion**

electromagnetic fluid disturbances; derivation of Alfven waves from the cold plasma limit, magnetoacoustic waves; proof of the frozen-flux condition for ideal MHD. Resistive diffusion. MHD equilibrium – magnetohydrostatics. Magnetic pressure and tension; the plasma beta. Plasma confinement - cylindrical plasma (Bennet Pinch, z-pinch). The diamagnetic current, sausage and kink instabilities.

Semester 2 Course Outline

- *Orbit Theory*: Gyromotion; the Larmor Radius and cyclotron frequency; the guiding centre; derivation of E x B drift in a uniform electric and magnetic field. Derivation of expressions for gradient and curvature drift in a non-uniform magnetic field; generalised drifts; ring currents in planetary magnetospheres. Motion in a convergent magnetic field; the magnetic moment, adiabatic invariants; magnetic mirroring; the loss cone; plasma mirror devices.
- *Radiation by an Accelerated Charge*: Power radiated by a single electron in a magnetic field; relativistic and non-relativistic limits; radiation beaming; spectrum from an accelerated charge. Cyclotron emission line and synchrotron spectrum, Faraday rotation; synchrotron loss time; observations from solar and nonsolar astrophysics.
- *Diffusion and resistivity*: The effect of collisions, collision frequency; diffusion in a magnetic field (ambipolar diffusion); concept of plasma resistivity; relation between current and resistivity; diffusion timescale.
- *Plasma kinetics*: kinetic equation and particle distribution function, Langmuir waves, Landau damping and wave-particle interactions.

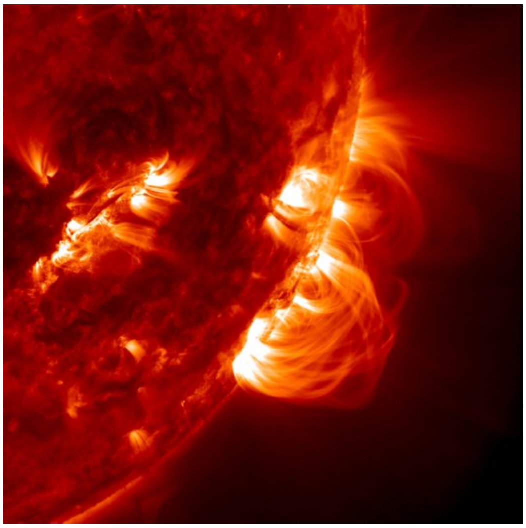


Image of solar loops.
Credit: Courtesy of **NASA/SDO** and the AIA, EVE, and HMI science teams

Further Information

Recommended texts

F Chen	*Introduction to Plasma Physics And Controlled Fusion*	Plenum Press	1984 (2nd)
Malcolm S Longair	*High Energy Astrophysics*	CUP	2011 (3rd)
Landau, Lifshitz	*The Classical Theory of Fields: Vol 2*	Pergamon	1980 (4th)
Pitaevskii, Lifshitz	*Physical Kinetics: Volume 10*	Pergamon	1981

Physics & Astronomy reading lists.

Course specifications - More details about the course in relation to other courses and degree paths on the course catalogue website.
Time and location of lectures - will be available during term time on the course website via Moodle.
Enrolment - Through MyCampus, details on the Astronomy 345 Moodle page.