PHYS-762

Atomic and radiative processes in plasmas

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Cursus	Sem.	Type
Physics		Opt.

Language of teaching	English
Credits	4
Session	
Exam	Oral
Workload	120h
Hours	**56**
Courses	28
Exercises	28
Number of positions	**20**

Frequency

Every 2 years

Remark

Next time: Spring 2026

Summary

The course covers atomic structure, collisional-radiative (CR) processes, and spectroscopic techniques. Students learn to critically apply CR models, evaluate spectroscopic tools, and interpret experimental data obtained in different plasmas.

Content

Atomic and radiative processes are essential for understanding the behavior of both space and laboratory plasmas. This course provides a comprehensive introduction to the theoretical foundations of atomic and radiative processes relevant to various plasma regimes, along with practical tools for studying plasmas through spectroscopic techniques. Students will explore the fundamentals of atomic structure and collisional-radiative (CR) processes, gaining a basic understanding of CR models and their critical application to interprete spectral line intensities. The course will also cover a range of spectroscopic techniques, spanning from x-ray to infrared wavelengths, with a focus on data analysis methods commonly used in low-temperature plasma sources, magnetic confinement fusion, and space plasmas.
Practical examples will be drawn from EPFL's TCV tokamak, providing hands-on insights into real-world applications.

Detailed course content:

1) Atomic energy structure
Electron in central potential, Hydrogen atom (Hamiltonian with relativistic correction) - 2h
Many electron atoms and spectroscopic notations - 3h
Zeeman effect, Stark effect - 1h

2) Radiation processes
Spontaneous emission - 2h
Induced emission & absorption (opacity, laser absorption) - 2h
Continuum emission: Bremsstrahlung, free-bound emission, black body - 2h

3) Collisional-radiative models
Overview of collisional-radiative processes, theoretical (Born approximation) and experimental determination of cross sections - 2h
Reaction rates, the rate equation and its solution - 2h
Plasma regimes (Local Thermodynamic Equilibrium, Corona equilibrium, collisional-radiative equilibrium), Approximations, and testing of CR models - 2h

4) Spectroscopic diagnostics and analysis
Spectroscopic instruments - 1h

Passive emission spectroscopy: continuum radiation, spectral line intensity, spectral line shape analysis - 3h
Spectroscopy of high energy photons - 2h
Cyclotron radiation - 2h
Active spectroscopy: Absorption spectroscopy, Laser induced fluorescence techniques, Thomson scattering - 2h
The exercise sessions will be held by Dr. Franciszek Sobczuk.

Note

For admission to the oral exam, each student is required to present at least one exercise problem during an exercise session.

Keywords

Plasma, Atomic Physics, Spectroscopy, Collisional-radiative modeling

Learning Prerequisites

Recommended courses

Statistical Physics, Quantum Mechanics, Electrodynamics

Learning Outcomes

By the end of the course, the student must be able to:

- Understand the energy structure of many-electron atoms and key collisional and radiative processes in plasmas.
- Understand the principles of collisional-radiative models (CRMs).
- Use of CRMs and critical assessment of their results.
- Develop fundamental knowledge of spectroscopic methods for plasma diagnostics and gain the ability to evaluate and select appropriate tools for specific applications.
- Understand of working principles of TCV spectroscopic diagnostics and which information they can provide about the plasma as well as perform basic data analysis routines.

Resources

Bibliography

The theory of atomic structure and spectra, R. D. Cowan, Ch. 2-5
Atomic Physics, P. Ewart, Ch. 2-5, 8
Advanced Quantum Mechanics, J. J. Sakurai, Ch. 2.4-2.5
Atomic physics in hot plasmas, David Salzman; Oxford University Press
Introduction to Plasma Spectroscopy, Hans-Joachim Kunze; Springer
Principles of Plasma Diagnsotics, I.H. Hutchinson; Cambridge University Press ISBN 0-521-32622-2
Radiation Processes in Plasmas, G. Bekefi, J. Wiley & Sons

Ressources en bibliothèque

- Find the references at the Library

Moodle Link

- https://go.epfl.ch/PHYS-762