GHENT UNIVERSITY

Course Specifications

Valid as from the academic year 2025-2026

Statistical Physics (C004220)

Course size *(nominal values; actual values may depend on programme)*

Credits 6.0 **Study time 180 h**

Course offerings and teaching methods in academic year 2025-2026

A (semester 1)	Dutch	Gent	seminar
			lecture

Lecturers in academic year 2025-2026

Ryckebusch, Jan	WE05	lecturer-in-charge

Offered in the following programmes in 2025-2026	crdts	offering
Bachelor of Science in Physics and Astronomy	6	A
Master of Science in Teaching in Science and Technology(main subject Mathematics)	6	A
Master of Science in Mathematics	6	A
Preparatory Course Master of Science in Physics and Astronomy	6	A
Preparatory Course Master of Science in Physics and Astronomy	6	A

Teaching languages

Dutch

Keywords

Statistical physics, complex classical systems; complex quantum systems; energy and entropy; information

Position of the course

This course is part of the learning line Theoretical Physics in the BSc program Physics & Astronomy. It aims at providing a formal development of the techniques adopted in statistical physics. In a next step, these techniques are applied to outline the statistical physics of interacting - and non-interacting systems. A profound knowledge of statistiscal physics is a prerequisite for studying quantum field theory, astrophysics, condensed-matter physics and materials sciences. The link between statistical physics and numerical simulation techniques is established.

Contents

- First, second and third law of themodynamics from the microscopic perspective
- The canonical system (fluctuations and response functions, paramagnets, negative temperatures, defects in solids, systems of coupled and uncoupled harmonic oscillators, ensemble theory, introduction to information theory)
- Classical systems (ideal gases, real gases, cluster expansions, theory of liquids)
- Quantum statistics (relation between spin and statistics, ideal quantum gas, ideal photon gas, density matrix)
- The grand-canonical system and the Gibbs partition function (chemical potential, grand-canonical partition function)
- The ideal Fermi gas (equation of state, ideal relativistic Fermi gas, white dwarfs, Pauli paramagnetism)
- The ideal Bose gas (equation of state, superfluidity, Bose-Einstein condensation, low-temperature physics)
- Phase transtiions and critical phenomena (Ising system, order parameters, mean-field theory, correlation functions, universality, Monte-Carlo techniques)

Initial competences

The development of the theory of statistical physics relies on concepts of Newtonian mechanics and quantum mechanics. A good working knowledge of

thermal physics (at the level of an introductory course in thermodynamics), analysis, and algebra is essential.

Final competences

1 Master the basic techniques adopted in statistical physics for describing the physics of systems consisting of many degrees of freedom.
2 Acquaint the student with modelling and simulation techniques, as a powerful tool to learn about systems with many degrees-of-freedom.
3 To acquire insight into the link between the microscopic and macroscopic world.
4 To acquire insight into the role of information (entropy) for the emergent behaviour of complex systems.

Conditions for credit contract

Access to this course unit via a credit contract is determined after successful competences assessment

Conditions for exam contract

This course unit cannot be taken via an exam contract

Teaching methods

Seminar, Lecture

Extra information on the teaching methods

- Theory: lectures with frequent use of computer simulations.
- Problem sessions: small groups.

The students communicate their solutions to the group.

Study material

Type: Syllabus

Name: Syllabus "Statistical Physics"
Indicative price: Free or paid by faculty
Optional: no
Language : Dutch
Available on Ufora : Yes

Type: Slides

Name: Presentations that accompany the theory classes.
Indicative price: Free or paid by faculty
Optional: no
Language : Dutch
Available on Ufora : Yes

Type: Handouts

Name: Notes with exercises and model solutions that accompany the problem sessions
Indicative price: Free or paid by faculty
Optional: no
Language : Dutch
Available on Ufora : Yes

Type: Software

Name: Python Jupyter notebooks
Indicative price: Free or paid by faculty
Optional: no
Available on Athena : Yes
Online Available : No
Available in the Library : No
Available through Student Association : No
Usability and Lifetime within the Course Unit : regularly
Usability and Lifetime within the Study Programme : one-time
Usability and Lifetime after the Study Programme : not

References

- F. Mandl "Statistical Physics" (John Wiley & Sons, 1998)
- R,K. Pathria, Paul D. Beale "Statistical Mechanics" (Elsevier Academic Press, 2022)
- Mehran Kardar "Statistical Physics of Particles" (Cambridge University Press, 2007)
- James Sethna "Statistical Physics: Entropy, Order Parameters, and Complexity"

(Oxford University Press, 2021)

Course content-related study coaching

The lecturer offers the possibility to discuss the course material individually or with small groups of students. The electronic learning-environment is employed to discuss the course material with the students and to draw their attention to recent advances in statistical physics.

Assessment moments

end-of-term assessment

Examination methods in case of periodic assessment during the first examination period

Written assessment with open-ended questions

Examination methods in case of periodic assessment during the second examination period

Written assessment with open-ended questions

Examination methods in case of permanent assessment

Possibilities of retake in case of permanent assessment

not applicable

Extra information on the examination methods

- Theory : written exam
- Problems : written exam (use of the course material is allowed)

Calculation of the examination mark

- 40% for the open-book part of the written exam (problems)
- 60% for the closed-book part of the written exam