

## 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**

[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 statistical 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 thermodynamics 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 transitions 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