Module	***Condensed Matter Theory C: Phase Transitions in Condensed Matter Systems***
Code	76069
Instruction language	English
ECTS credits	6
Credit hours	5
Duration	1 semester
Cycle	every second Summer Semester in turn with Condensed Matter Theory C
Coordinator	Dean of Physics Studies
Lecturer	Prof. Joachim Ankerhold, Dr. Björn Kubala, Dr. Ciprian Padurariu
Allocation to study programmes	Physics M.Sc., elective module, 1st or 2nd semester
Formal prerequisites	None
Recommended prerequisites	Quantum Mechanics, Solid State Physics, Thermodynamics/Statistics
Learning objectives	Students who successfully passed this module • understand fundamental concepts in the description of phase transitions and critical phenomena, such as: order parameters and symmetry breaking, scaling laws and renormalization ideas, universality • understand the interplay of microscopic and effective mean-field descriptions • understand the appearance of critical behaviour in important condensed matter phenomena and how general concepts are transferred to these examples • are able to read relevant original literature to present it and know current experimental realizations
Syllabus	The transition between different phases of matter (e.g., from ice, to (liquid) water, to vapour) is probably one of the most fascinating concepts in physics; and it is one of the most complex ones. Why does one actually observe a succession of phases in many systems as for example temperature rises? The basic reason is the competition between lowering energy and increasing disorder (and whereby entropy) in the free energy, which has to be minimized by a thermal equilibrium state. Phase transitions are thus intimately related to a change in the order of the system (leading to the concept of an order parameter) and often also connected with a "breaking" of a symmetry, which is another very fundamental concept in physics. In the first part of this lecture, we will focus on generic aspects of phase transitions. We will learn how to identify universal aspects, for instance, in critical exponents of power laws for various experimental observables close to a phase transition. Methods and models to describe critical phenomena at phase transitions, like Ginzburg-Landau theory, the concept of scaling, and renormalization group ideas will be introduced. In the second part of the lecture, we will look in more detail at some of the phase transitions being of particular relevance in modern condensed matter theory, like superconductivity and superfluidity. • A short introduction to phase transitions and critical phenomena

	• The Ising model • Mean-field theory • Anomalous dimensions and scaling • Renormalization group • Examples of phase transitions in condensed matter systems: • superfluidity and superconductivity
Literature	This course is not based on any particular book. Below an (incomplete) list of books on phase transitions and critical phenomena, helpful for certain parts of the lecture. • E. Stanley: Phase transitions and critical phenomena • Pfeuty and Toulouse: Introduction to the Renormalization Group and to Critical Phenomena • N. Goldenfeld: Lectures on Phase Transitions and the RG • L. Kadanoff: Statistical Physics: Statics, Dynamics, and Renormalization • J. Sethna: Statistical Mechanics: Entropy, Order Parameters, and Complexity
Teaching and learning methods	Lecture (3 hours per week) Exercise (2 hours per week)
Workload	45 hours lecture (attendance time) 30 hours exercise (attendance time) 105 hours self-study and exam preparation Total: 180 hours
Assessment	The module examination consists of graded weekly assignments and a larger end-of-term project. The latter will be presented in a seminar-style short talk or in written form, depending on the number of participants. While the weekly assignments cover the taught topics and closely follow the lecture, in the end-of-term project students will go deeper into one particular topic and apply acquired methods and concepts to read, understand, and present research-level material. A passing grade in the weekly assignments counts as study achievement and is required for participation in the end-of-term project work. Topics and material will be assigned after the first half of the course. Marking will be based 50% on the assignments and 50% on the presentation.
Examination	16569 Condensed Matter Theory C: Phase Transitions in Condensed Matter Systems (precourse) 16069 Condensed Matter Theory Phase Transitions in Condensed Matter Systems
Grading procedure	The module grade is the examination grade.
Basis for	Research in the field of Condensed Matter