Imperial College London

Module Specification (Curriculum Review)

Basic details

UID		Cohorts covered	Earliest cohort: 2024-25	Latest cohort:

Long title: Statistical Mechanics

New code	PHYS60009	New short title	Statistical Mechanics

Brief description of module *(approx. 600 chars.)*

Surprisingly, systems near phase transitions have universal properties that do not depend on microscopic details. Instead, the key is to understand how phase transitions are related to spontaneously broken symmetry and scale invariance. The development of a conceptual framework to understand this notion was one of the most significant scientific advances of the late 20th century and culminated in Wilson's renormalisation group (1982 Nobel Prize in Physics). This mathematical framework can be applied to a broad range of systems made up of many interacting degrees of freedom, e.g. superconductors, quantum magnets, electroweak theory, flocks of birds, and neural networks.

679 characters

Available as a standalone module/ short course? N

Statutory details

	ECTS	CATS	Non-credit
Credit value	7.5	15	N

HECOS codes:

FHEQ level: Level 6

Allocation of study hours

	Hours	
Lectures	26	
Group teaching	10	*Incl. seminars, tutorials, problem classes.*
Lab/ practical		
Other scheduled	12	*Incl. project supervision, fieldwork, external visits.*
Independent study	139.5	*Incl. wider reading/ practice, follow-up work, completion of assessments, revisions.*
Placement		*Incl. work-based learning and study that occurs overseas.*
Total hours	187.5	
ECTS ratio	25.00	

Project/placement activity

Is placement activity allowed? No

Module delivery

Delivery mode	Taught/ Campus	Other	
Delivery term		Other	Term 1, exam in term 3

Ownership

Primary department	Physics
Additional teaching departments	None
Delivery campus	South Kensington

Collaborative delivery

Collaborative delivery?	N

External institution	N/A
External department	N/A
External campus	N/A

Associated staff

Role	CID	Given name	Surname
Module leader	7039	Tim	Evans
Lecturer		Frank	Schindler

Learning and teaching

Module description

Learning outcomes

On completion of this module you will be able to:
Phase Transitions:
1. describe the notion of an order parameter in a phase transition
2. explain the relationship between a diverging correlation length and scale invariance at the critical point
3. write down and explain the form of the Landau free energy for a system with a scalar order parameter near a phase transition
4. deduce the critical behaviour predicted by Landau theory

Scaling Hypothesis:
5. describe and apply the concept of scale invariance in a statistical fractal structure
6. describe the role of scale invariance at a phase transition
7. describe the importance of a divergent characteristic length scale near a phase transition
8. use the scaling hypothesis to deduce scaling relations among critical exponents
9. use the scaling hypothesis as the foundation of the renormalisation group.

Module content	Phase Transitions and the Scaling Hypothesis: 1. describe the notion of an order parameter in a phase transition 2. understand the relationship between the divergence of the characteristic length scale and the onset of scale invariance as a critical point is approached 3. use the scaling hypothesis to obtain scaling forms for critical quantities and derive scaling relations between critical exponents 4. write down and explain the form of the mean-field Landau free energy for a system with a scalar order parameter near a phase transition; deduce the critical behaviour predicted by Landau theory 5. use a simple decimation-based real-space renormalisation group (RSRG) procedure to estimate critical points and exponents 6. discuss qualitatively Wilson's Renormalisation Group Theory Percolation 1a. derive exact solutions in one dimension and on the Bethe lattice for the mean cluster size, cluster size distribution, and strength of the percolating cluster 2a. describe near-threshold percolation in terms of a divergent cluster length scale; write down the scaling hypothesis and derive the scaling relations for percolation 3a. use the RSRG procedure to obtain estimates for the percolation threshold and the power law divergence of the cluster length scale Ising model 1b. define magnetisation, magnetic susceptibility, the spin correlation function and the spin correlation length for the Ising model 2b. understand the role of magnetisation as an order parameter 3b. use transfer matrices to solve the 1D Ising model analytically 4b use the Landau mean-field theory of the Ising model to find its behaviour near the critical point, including critical exponents 5b derive the Widom scaling form for the singular part of the free energy and derive the scaling relations 6b apply the RSRG procedure to the Ising model in zero field in 1D and 2D; identify and interpret the fixed points
Learning and Teaching Approach	The module is in two halves, one on Percolation and one on the Ising Model, with the same format for each. The main delivery will be through lectures (up to thirteen). These will be supported by weekly rapid feedback classes with a demonstrator which reinforce and develop concepts through worked examples taken from problem sheets. The associated problem sheets have additional problems which, with solutions provided, allow for independent student learning. Additional feedback from the lecturers will be given through office hours or interactive Q&A sessions.
Assessment Strategy	Formative assessment is provided through the weekly rapid feedback. Summative assessment is through one written exam.
Feedback	Individual written feedback on answers to the Rapid Feedback questions is provided by the demonstrator of the Rapid Feedback classes. The Rapid Feedback presentations then give feedback of this work in a wider group context. Office hours or interactive Q&A sessions provide feedback from the lecturers on any aspect of the coursework. Group feedback on the exam questions is provided after the exam.
Reading list	Complete and comprehensive lecture notes are given to studetns. They are basically the first two chapters in the book by Christensen and Moloney, "Complexity and Criticality", IC Press, 2005. (This book was developed for this specific Statistical Mechanics course at Imperial.)

Quality assurance

Date of first approval	
Date of last revision	
Date of this approval	
Module leader	Tim Evans
Notes/ comments	

Office use only

QA Lead	
Department staff	
Date of collection	
Date exported	
Date imported	

Template version 16/06/2017

Programme structure

Associated modules

UID	Legacy code	Module title	Requisite type

Assessment details

Grading method	Numeric	Pass mark	40%

Assessments

Assessment type	Assessment description	Weighting	Pass mark	Must pass?
Examination	2h final examination	100%	40%	N
		100%		