Academic Year	2021/22	**Semester**	1
Course Coordinator	Asst Prof Yong Ee Hou		
Course Code	PH4501		
Course Title	Statistical Mechanics 2		
Pre-requisites	PH3101 and PH3201		
No of AUs	4 AU		
Contact Hours	Lecture: 39 hours, Tutorial: 12 hours (3 hr – lecture; 1 hr – tutorial per week)		
Proposal Date	October 2020		

Course Aims

This course is an introduction to the physics of phase transitions. It will provide a framework to model systems with large degree of freedoms. You will use knowledge from previous courses in non-interacting systems to develop the theoretical framework of interacting systems. Through the course, you will build foundational knowledge in key topics in statistical mechanics such as mean field theory, transfer matrix, Monte Carlo simulations, renormalization group, which are critical in the study of phase transitions.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, you (as a student) would be **able to**:

Non-Interacting Systems

1. Derive random walks in different dimensions using Fourier methods.
2. Apply the concept of temperature and equilibrium in physical systems.
3. Apply the different ensembles to solve novel systems in Physics.
4. Apply the concept of entropy and free energy in problem solving.

Interacting Systems

5. Explain how to use perturbative methods to calculate interacting system.
6. Apply approximation methods such as Mean Field Theory and Landau Theory in different novel systems.
7. Analyse problems numerically using Monte Carlo methods.
8. Derive Ising model in 1 dimension using transfer matrix method.
9. Analyse real gases using van der Waal model.

Critical Phenomena

10. Explain the theory of abrupt and continuous phase transitions.
11. Explain scaling hypothesis, critical exponents and universality class.
12. Apply renormalization group techniques to different novel system.
13. Explain the concept of percolation.

Course Content

Random walks
Statistical ensemble
Thermodynamics
Interacting classical gas (Mayer cluster)
Phase transition
Ising Model
Landau Theory
Mean Field Theory
Transfer Matrix methods
Series expansions
Markov process, detail balance and Monte Carlo simulations
Scaling hypothesis
Real Space Renormalization Group
Liquid-Gas Phase Transition
Percolation Theory

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team / Individual	Assessment Rubrics
1. Final Examination	All	Competence (Written)	50%	Individual	Point-based marking (not rubric-based)
2. CA1: Problem Sets	All	Competence (Written) Creativity Character	25%	Individual	Point-based marking (not rubric-based)
3. CA2: Mid-term 1	1-6	Competence (Written) Communication (Written)	25%	Individual	Point-based marking (not rubric-based)
Total			100%		

Formative feedback

You will receive formative feedback is given through discussion within tutorial lessons.

Feedback will also be provided for each problem set, where any particularly problematic areas will be identified.

Finally, feedback will be given after the midterm on the common mistakes and level of difficulty of the problems. Past exam questions and examiner's report are also made available for you.

Learning and Teaching approach

Approach	**How does this approach support students in achieving the learning outcomes?**
Problem solving (tutorial and lecture)	Develop competence and perseverance in solving physics problems
Hands-on group activities (during tutorial)	Develop physical intuition and competence in solving real-life problems. Relate everyday phenomena to physics.
Peer Instruction (during lecture)	Develop communication skills and competence in physics. Students are encouraged to discuss their answers to the Clickers questions so that they can learn from one another.

Reading and References

1. J. Sethna, Statistical Mechanics Entropy, Order Parameters, and Complexity (2nd edition), free PDF download: http://pages.physics.cornell.edu/~sethna/StatMech/
2. J. M. Yeomans, Statistical Mechanics of Phase Transitions (Oxford Science Publications), ISBN-13: 978-0198517306.
3. M. Plischke and B. Bergerson, Equilibrium Statistical Physics (3rd edition), ISBN-13: 978-9812561558.
4. N. Goldenfeld, Lectures On Phase Transitions And The Renormalization Group, ISBN-13: 978-0201554090.
5. M. Kardar, Statistical Physics of Particles, ISBN-13: 978-0521873420.
6. M. Kardar, Statistical Physics of Fields, ISBN-13: 978-0521873413.

Course Policies and Student Responsibilities

Absence Due to Medical or Other Reasons

If you are sick and unable to attend your class / Mid-terms, you have to:

1. Send an email to the instructor regarding the absence and request for a replacement class and make-up mid-terms.
2. Submit the original Medical Certificate* or official letter of excuse to administrator.
3. Attend the assigned replacement class (*subject to availability*) and make-up mid-terms.

* The medical certificate mentioned above should be issued in Singapore by a medical practitioner registered with the Singapore Medical Association.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Asst. Prof. Yong Ee Hou	SPMS-PAP-04-05	6316 2966	eehou@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Intro, Random Walks	ILO1	Sethna Chp 1,2
2	Statistical ensembles	ILO2,3	Sethna Chp 3, Yeomans Chp 2
3	Entropy and thermodynamics	ILO3,4	Sethna Chp 5
4	Probability and Mayer	ILO5	Course notes
5	Phase transition	ILO5, 9,10	Sethna Chp 11
6	Mean field theory	ILO6	Yeomans Chp 4
7	Landau, Numerical	ILO6,7	Yeomans Chp 7
8	Transfer methods	ILO8	Yeomans Chp 5
9	Scaling	ILO11	Yeomans Chp 6,8
10	Renormalization group	ILO11,12	Sethna Chp 12, Yeomans Chp 8
11	Renormalization group	ILO11,12	Yeomans Chp 8, 9
12	Percolation	ILO13	Course notes
13	Student presentations		

Graduate Attributes

What we want our graduates from Physics and Applied Physics to be able to do:

Upon the successful completion of the PHY, APHY and PHMA programs, graduates should be able to:

Competency	1	demonstrate a rigorous understanding of the core theories and principles of physics involving (but not limited to) areas such as classical mechanics, electromagnetism, thermal physics and quantum mechanics demonstrate a rigorous understanding of the core theories and principles of mathematical sciences involving (but not limited to) areas such as analysis, algebra and statistical analysis
	2	read and understand undergraduate level physics content independently;
	3	make educated guesses/estimations of physical quantities in general;
	4	apply fundamental physics knowledge, logical reasoning, mathematical and computational skills to analyse, model and solve problems;
	5	develop theoretical descriptions of physical phenomena with an understanding of the underlying assumptions and limitations;
	6	critically evaluate and distinguish sources of scientific/non-scientific information and to recommend appropriate decisions and choices when needed;
	7	demonstrate the ability to design and conduct experiments in a Physics laboratory, to make measurements, analyse and interpret data to draw valid conclusions.

Creativity	1	propose valid approaches to tackle open-ended problems in unexplored domains;
	2	offer valid alternative perspectives/approaches to a given situation or problem.

Communication	1	describe physical phenomena with scientifically sound principles;
	2	communicate (in writing and speaking) scientific and non-scientific ideas effectively to professional scientists and to the general public;
	3	communicate effectively with team members when working in a group.

Character	1	uphold absolute integrity when conducting scientific experiments, reporting and using the scientific results;
	2	readily pick up new skills, particularly technology-related ones, to tackle new problems;
	3	contribute as a valued team member when working in a group.

Civic Mindedness	1	put together the skills and knowledge into their work in an effective, responsible and ethical manner for the benefits of society.