Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2020/21	**Semester**	2
Course Coordinator	Asst. Prof. Yang Bo		
Course Code	PH3201		
Course Title	Statistical Mechanics I		
Pre-requisites	PH3101		
No of AUs	4 AU		
Contact Hours	Lecture: 39 hours, Tutorials: 12 hours (3 hr – lecture; 1 hr – tutorial)		
Proposal Date	November 2020		

Course Aims

This course aims to equip you with the fundamental concepts and problem-solving skills in in statistical mechanics, including topics such as definition of temperature, microcanonical ensemble, canonical ensemble, grand canonical ensemble, Boltzmann, Bose, and Fermi distributions, paramagnets, harmonic oscillators and Debye solids, blackbody radiation, chemical potential, Gibbs free energy, and phase transitions.

Intended Learning Outcomes (ILO)

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

Foundations (F)

1. Explain the concept of temperature and equilibrium in physical systems.
2. Apply the different ensembles to solve simple systems in Physics (such as diatomic gases and ideal gases).
3. Apply the concept of equipartition of energy in various model systems.
4. Solve problems using partition function.
5. Apply the concept of entropy and free energy in problem solving.
6. Derive the statistical mechanics of the classical ideal gas.
7. Explain concepts of chemical potential and chemical reactions.

Quantum Statistical Mechanics (QSM)

8. Derive the statistical mechanics of photon gas and black body radiation.
9. Derive the Einstein and Debye model and solve related problems.
10. Explain the statistics of non-interacting quantum gases (Fermi and Bose-Einstein).
11. Explain Bose-Einstein condensation.

Applications of Statistical Mechanics (ASM)

12. Describe basic concepts of semiconductors.
13. Describe how phase transition are classified.
14. Explain the difference between ideal and real gases using the van der Waal gas model.

Course Content

Discrete, continuous probability distributions
Mean, variances, and the different moments
Thermal equilibrium

Macrostates and microstates
Statistical definition of temperature
Different statistical ensembles
State probabilities
Boltzmann factor
Partition function
Different free energies
Legendre transformation
Thermodynamic relation
Gibbs' entropy formula
Distinguishable and indistinguishable particles
Information theory
Chemical potential
Chemical reaction
Photons and lasers
Density of states
Black body radiation
Phonons (Einstein model, Debye model)
Phonon contribution to heat capacity
Bose-Einstein and Fermi-Dirac distributions
Bose gas
Fermi gas
Bose-Einstein condensation
Phase transitions
Classification of phase transitions

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)	40%	Individual	Point-based marking (not rubri based)
2. CA1: Problem Sets	All	Competence (Written) Creativity Character	20%	Individual	Point-based marking (not rubri based)
3. CA2: Mid-term 1	Test scope	Competence (Written) Communication (Written)	20%	Individual	Point-based marking (not rubri based)
4. CA3: Mid-term 2	Test scope	Competence (Written) Communication (Written)	20%	Individual	Point-based marking (not rubri 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. Concepts in Thermal Physics (2nd edition), Stephen J. Blundell and Katherine M. Blunder, Oxford University Press. (ISBN-13 : 978-0199562091)
2. Statistical Physics, D. J. Amit and Y. Verbin. (ISBN-13 : 978-9810231927)
3. Thermal Physics (2nd edition), C. Kittel and H. Kroemer. (ISBN-13 : 978-0716710882)
4. The Feynman lectures on Physics (vol 1), R. Feynman. (ISBN-13 : 978-0465024933)

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. Yang Bo	SPMS-PAP-04-09	6592 1806	Yang.bo@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Introduction to Statistical Mechanics, Temperature	Foundations 1,2	Blundell Chpt 3,4
2	Ensembles, Boltzmann, equipartition	ILO 2,3	Blundell Chpt 19,20
3	Partition function	ILO 3,4,5	Blundell Chpt 20
4	Thermodynamics	ILO 5	Blundell Chpt 16
5	Ideal gas	ILO6	Blundell Chpt 21
6	Chemical potential, chemical reaction	ILO7	Blundell Chpt 22
7	Photon	ILO8	Blundell Chpt 23
8	Phonons	ILO9	Blundell Chpt 24
9	Bose Gas	ILO10,11	Blundell Chpt 29
10	Fermi Gas	ILO10	Blundell Chpt 29
11	Semiconductor Physics	ILO12	Course notes
12	Real gases	ASM 13	Blundell Chpt 26
13	Phase transitions	ASM 13, 14	Blundell Chpt 28

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.