PHYS3005 Thermodynamics and Statistical Mechanics
Fall 2025

Instructor:	Lei-Han Tang 汤雷翰 (E5-121)	office hr: 11:30 -12:00 (Tues)
TA:	Kaidian Wang 王开典 (E5-120)	office hr: TBA

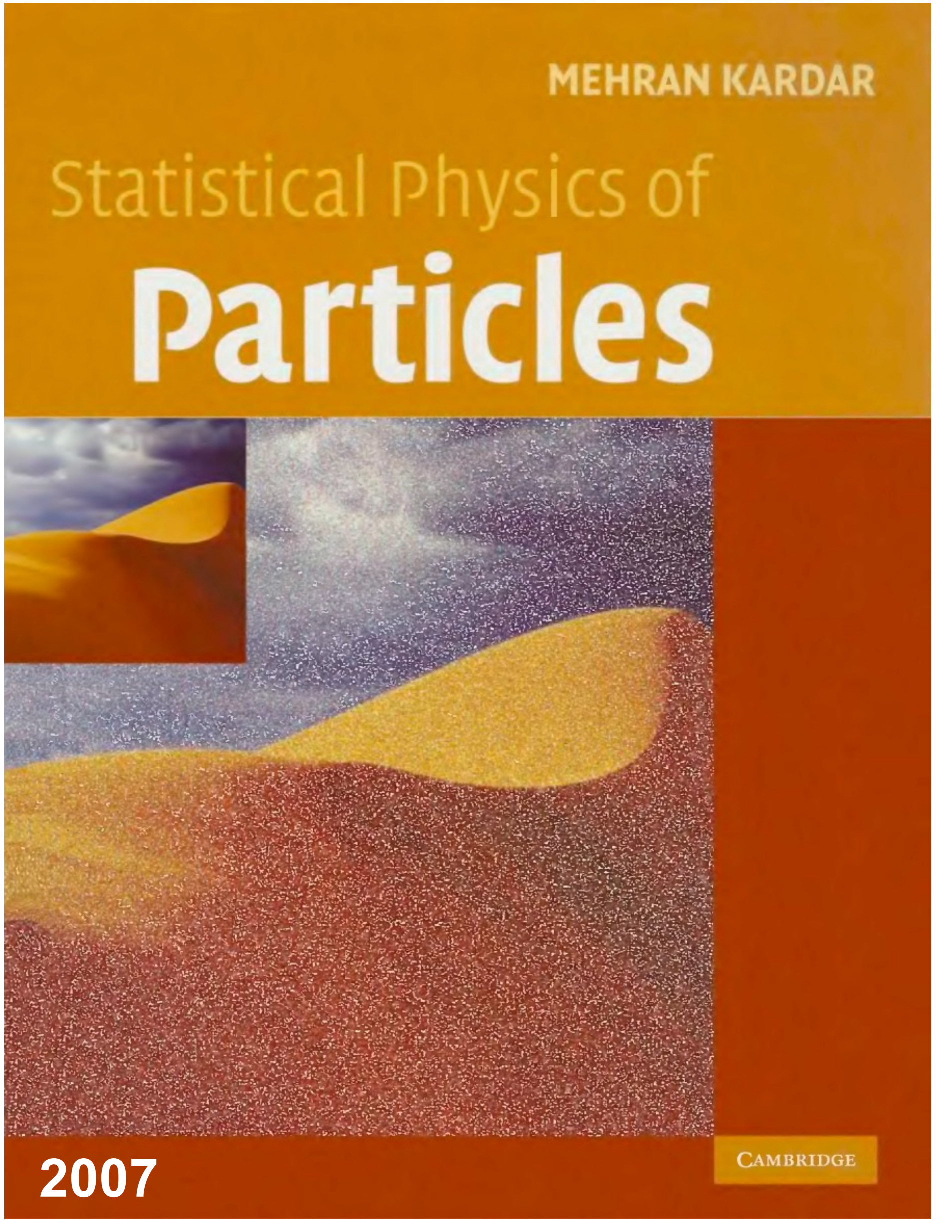
Meeting Time/Place:

Mon	**16:10 – 17:45**	**E13 - 206**
Tues	**9:50 – 11:25**	**E13 - 206**

Course description:

- Principles and tools of thermodynamics and statistical mechanics at an advanced UG level
- Focus on systems in thermal equilibrium, and also dissipative processes towards equilibrium
- Critical thinking and problem-solving skills by applying theoretical concepts and formalism to selected classical and quantum systems
- Examples to illustrate the prowess of the statistical approach in capturing emergent behavior from simple units—a concept increasingly relevant in engineering, social sciences, and biological sciences

https://ocw.mit.edu/courses/8-333-statistical-mechanics-i-statistical-mechanics-of-particles-fall-2013/



Course structure

review & thermodynamics 4 weeks

ensemble theory 3 weeks

Week	Session	Class Hour	Theme/Topic	Teaching activities（lecture/ practical）
Week 1	Lectures 1-3	3	Revision of thermal concepts, equation of state, the first law	Lecture
	Tutorial	1		Lecture
Week 2	Lectures 4-6	3	The second law, Carnot cycle, entropy, thermodynamic potentials	Lecture
	Tutorial	1		Lecture
Week 3	Lectures 7-9	3	Gibbs-Duhem and Maxwell relations, thermal stability, the third law	Lecture
	Tutorial	1		Lecture
Week 4	Lectures 10-12	3	Random variables, probability density function, moments, cumulants, generating function, joint distributions, the Central Limit Theorem, Stirling formula, information, Shannon entropy and estimation	Lecture
	Tutorial	1		Lecture
Week 5	Lectures 13-15	3	Kinetic theory, Liouville's theorem, BBGKY hierarchy, Boltzmann equation	Lecture
	Tutorial	1		Lecture
Week 6	Lectures 16-18	3	The H-theorem and irreversibility, equilibrium properties, conservation laws and transport, zeroth- and first-order hydrodynamics	Lecture
	Tutorial	1		Lecture
Week 7	Lectures 19-21	3	Microcanonical ensemble, ergodic hypothesis, Botzmann entropy, two-level systems and ideal gas, Gibbs paradox	Lecture
	Tutorial	1		Lecture
Week 8	Lectures 22-24	3	Canonical ensemble, Boltzmann distribution, partition function, free energies, thermal averages and fluctuations, examples	Lecture

advanced topics

	Tutorial	1		Lecture
Week 9	Lectures 25-27	3	Grand canonical ensemble, chemical potential, phase coexistence	Lecture
	Tutorial	1		Lecture
Week 10	Lectures 28-30	3	Interacting particle systems, cumulant and cluster expansions, virial equation of state, van der Waals equation of state and phase transitions	Lecture
	Tutorial	1		Lecture
Week 11	Lectures 31-33	3	Mean-field theory of condensation, variational methods, law of corresponding states, critical phenomena	Lecture
	Tutorial	1		Lecture
Week 12	Lectures 34-36	3	Quantum statistics, specific heat of polyatomic gases, vibrations of a solid, Debye theory	Lecture
	Tutorial	1		Lecture
Week 13	Lectures 37-39	3	Black-body radiation, many-particle quantum states, density matrix of mixed states in micro-canonical and canonical ensembles	Lecture
	Tutorial	1		Lecture
Week 14	Lectures 40-42	3	Ideal quantum gases, bosons and fermions, occupation number representation, Bose-Einstein and Fermi-Dirac distributions	Lecture
	Tutorial	1		Lecture
Week 15	Lectures 43-45	3	Non-relativistic gas, classical limit, degenerate Fermi gas, Fermi energy and temperature	Lecture
	Tutorial	1		Lecture
Week 16	Lectures 46-48	3	Degenerate Bose gas, Bose-Einstein condensation, superfluidity	Lecture
	Tutorial	1		Lecture

quantum systems 5 wks

Textbook and References

Mehran Kardar, *Statistical Physics of Particles*, Cambridge, 2007.

A. B. Pippard, *Elements of Classical Thermodynamics*, Cambridge, 1966.

F. Mandl, *Statistical Physics*, 2^{nd} Ed., Wiley, 1988.

Shang-Keng Ma, *Statistical Mechanics*, World Scientific, 1985.

Michael Plischke and Birger Bergersen, *Equilibrium Statistical Physics*, 3^{rd} Ed, World Scientific, 2006.

Jim Sethna, *Statistical Mechanics: Entropy, Order Parameters, and Complexity*, 2^{nd} Ed, Oxford, 2021.

David L Goodstein, *States of Matter*, Dover, 2014.

Assessment

Attendance	10%
Project	10%
Assignments	30%
Mid-term Tests	20%
Final Exam	30%

The learning spiral

ACTION

video lectures by Mehran Kardar
projects

taking notes in class and organize afterwards, mind maps, reading and discussion

problem sets, tests and exam