科目名　Course Title	
統計物理学3(Statistical Physics III)	
学科・専攻　Department/Program	**受講年次　Grade**
G30 Physics	3rd
授業形態　Class style	**必修・選択の別　Compulsory or Elective**
講義	* See "Remarks"
時間割コード　Registration code	**開講期・曜日・時限　Semester,Day & Period**
0680180	春学期 木：5
単位数　Credit	**科目区分　Course type**
2	Specialized Course

担当教員　Instructor	WOJDYLO John Andrew(WOJDYLO John Andrew)
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居室　Room	ES035

講義の目的とねらい　Course purpose

This is an intermediate-advanced course in statistical mechanics and thermodynamics. Students learn quantum statistics of ideal gases, introductory statistical mechanics of systems of interacting particles and introductory theory of phase transitions and critical phenomena, and some modern theory such as the scaling hypothesis, an introduction to renormalization group theory (the spatial renormalization group), and the Bogolyubov Variational Theorem and its application to constructing an optimal Mean Field Theory. If time permits, we will also cover Callen Ch 14 on irreversible thermodynamics, including the Onsager Reciprocity, with an application to thermoelectricity: the Seebeck Effect, Peltier Effect and Thomson Effect.

In this unit applications are considered in condensed matter physics, solid state physics, cosmology, chemistry, materials science and biology. For chemistry majors, this course together with Statistical Physics II provides a powerful boost to your skills set and can open many doors.

履修要件　Prerequisite

Statistical Physics II; or Consent of Instructor

• Students must have passed Statistical Physics II to take Statistical Physics III.

履修取り下げの方法について　How to Apply for Course Withdrawal

<「履修取り下げ届」提出の要・不要 Necessity/Unnecessity to submit "Course Withdrawal Request Form">
Necessary
<条件等 Conditions>
A formal withdrawal form must be signed by the lecturer and submitted to the Student Office by the official withdrawal date around mid-May.

成績評価　Grading

Attendance: 5%; Weekly quizzes or other written assessment: 30%; Mid-term exam: 32.5%; Final Exam: 32.5%

不可（F）と欠席（W）の基準　　Criteria for "Absent(W)" &"Fail" grades
The “ Absent ” grade is reserved for students who withdraw by the official deadline in May. After that day, a letter grade will be awarded based on marks earned from all assessment during the semester.
関連する科目　　Related courses
It is strongly advised that students concurrently register for Physics Tutorial IVa.
教室　　Class room
Check the Course Timetable. ES035 or online using MS Teams. (To be advised.)

到達目標　　Goal
At the end of this course, students will have mastered basic aspects of quantum statistics of ideal gases, statistical mechanics of systems of interacting particles, and the theory of phase transitions and critical phenomena, including modern topics such as the scaling hypothesis, an introduction to renormalization group theory (the spatial renormalization group), and the Bogolyubov Variational Theorem and its application to constructing an optimal Mean Field Theory.

授業内容　　Content

Some topics are covered in assignments. The precise order and content of the lectures might vary slightly.

Lecture 1. Revision of quantum statistical mechanics. Quantum states of a single particle. Reflecting boundary conditions, periodic boundary conditions. Density of states in 3, 2 and 1 dimensions, for linear and quadratic dispersion relations. Turning sums into integrals. Example: EM radiation. The quantum distribution functions: Fermi-Dirac, Bose-Einstein distributions. Photon statistics: Planck distribution. Systems with varying number of particles: the Grand Canonical ensemble and partition function. Occupation number formalism: mean occupation number and dispersion. Role of the chemical potential.

Lecture 2. Examples. Vapour pressure of a solid. Diatomic molecules. Black body radiation: Stefan-Boltzmann Law; Wien ' s Displacement Law; radiation pressure; Grand Canonical partition function and probability of a many-body state at temperature T. Example: adsorption of a gas onto a 2D surface.

Lecture 3. The ideal Fermi fluid: conduction electrons in metals. Specific heat and ground state energy in 3D, 2D, 1D. Sommerfeld expansion.

Lecture 4. The ideal Bose fluid: Bose-Einstein condensation in 3D. What about in 2D or 1D? Critical temperature. Mean energy, specific heat. The possibility of BEC in a photon gas. Breakdown of the Grand Canonical description.

Lecture 5. Systems of interacting particles (1). The Debye Model of solids. Normal modes. Specific heat.

Lecture 6. Systems of interacting particles (2). Weakly nonideal gases: virial expansion. Derivations of the Van der Waals equation of state for a weakly non-ideal gas, as well as for a fluid using a self-consistent mean field approach.

Lecture 7. Irreversible Thermodynamics. Entropy production. Onsager Reciprocity; Thermoelectric Effect; Seebeck Effect; Peltier Effect.

Lecture 8. Stability of thermodynamic systems. Concavity/convexity of thermodynamic potentials. Le Chatelier ' s Principle. First Order phase transitions, features of the free energy. Discontinuity in the entropy: latent heat. Slope of the coexistence curves: Clausius-Clapeyron Equation.

Lecture 9. Van der Waals fluid: unstable isotherms, physical isotherm, Maxwell equal-area rule. Multicomponent systems: Gibbs phase rule. Why does the phase diagram of water not have more than three phases coexisting at the same point?

Lecture 10. The Fluctuation-Dissipation Theorem. Response functions and correlations. Quantitative explanation of critical opalescence.

Lecture 11. Examples of phase transitions (order-disorder transition, which is a structural phase transition). Why do fluctuations get out of control near the critical point? Alben ' s Model. Landau Theory: classical theory in the critical region. Order parameter and the critical exponents $\alpha, \beta, \gamma, \delta$; their classical values.

Lecture 12. Magnetic systems: ferromagnetism and models for it. Ising model. Mean field theory treatment of the 1D Ising chain. Critical exponents.

Lecture 13. Ising model continued. No phase transition in the 1D Ising chain: proof by a simple argument; and by solving the model exactly – no phase transition but at any finite field, magnetisation gets saturated if temperature is low enough. Ising model in 2D (just mention): critical exponents, behaviour of the specific heat. Spin correlation function: exact calculation for the 1D Ising chain. Phase diagram of ferromagnetic systems. Cause of the breakdown of the classical theory (qualitative).

Lecture 14. Breakdown of the classical theory and advent of the modern theory. Derivation of an inequality involving critical exponents – but all experiments suggest equality holds. Scaling hypothesis: ad hoc argument. Justification of the scaling hypothesis using Kadanoff ' s block spins. Spatial renormalization group theory and sample calculation for the 1D Ising chain.

Lecture 15. Bogolyubov Variational Theorem. Order-Disorder Transition: constructing the Hamiltonian and deriving the optimal Mean Field Theory for its solution. Mean Field Theory for 1D Ising Model revisited.

教科書　Textbook

1. Callen, Herbert, Thermodynamics and an Introduction to Thermostatistics, 2nd Ed., Wiley. (The Japanese translation has fewer misprints.)

2. Reif, F., Fundamentals of Statistical and Thermal Physics, McGraw-Hill, 1965.

3. Plischke, M. & Bergersen, B., Equilibrium Statistical Mechanics, 3rd Ed., World Scientific, 2006.

参考書　Recommended reading

1. Hill, T., An Introduction to Statistical Thermodynamics, Dover, 1986. (Excellent introduction to Statistical Mechanics at Year 3 level. Alternative textbook. Highly recommended. Cheap to buy.)

2. Kittel, C., Elementary Statistical Physics, Dover, 2004. (Highly recommended. Cheap to buy.)

3. Kubo R., Statistical Mechanics, North Holland, 1965. (More of a second course on Stat Mech, but contains many examples and worked solutions.)

4. Huang, K., Statistical Mechanics, Wiley. (Advanced reference.)

5. Kittel, C. and Kroemer, H., Thermal Physics, W.H. Freeman. (Try as alternative.)

6. Landau, L.D. and Lifshitz, E.M., Statistical Physics, Part I, by E.M. Lifshitz and L.P. Pitaevskii, Pergamon Press. (A classic book: thorough, advanced treatment.)

連絡方法　Contact method

Consultation or help is available at anytime online using MS Teams.

I can also be contacted by email.

その他　Remarks

*See Course List and Graduation Requirements for your program for your enrollment year.
Students taking Statistical Physics III should also take Physics Tutorial IVa. No solutions are handed out in class: you must obtain any solutions during the tutorial. It pays to come prepared and pay attention during the tutorial!