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：2
単位数　　Credit	科目区分　　Course type
2	

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 and an introduction to renormalization group theory (the spatial renormalization group). 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 opens many doors.

履修要件　　Prerequisite

Statistical Physics II; or Consent of Instructor

履修取り下げについて　　Course withdrawal

<可否>　Possible
<条件>
Withdraw by the official deadline in May.

成績評価　　Grading

Attendance: 5%; Weekly quizzes or other written assessment: 25%; Mid-term exam: 35%; Final Exam: 35%

不可（F）と欠席の基準　　Criteria for "Absent" &"Fail" grades

The “ Absent ” grade is reserved for students who withdraw by the official May deadline. 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
Physics Tutorial IV. It is strongly advised that students concurrently register for Physics Tutorial IV.
教室　　Class room
Check the Course Timetable.

授業内容　　Content

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

Lecture 1. 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.

Lecture 2. 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 3. Dispersion of fluctuations. The classical/quantum crossover. Mean energy in the classical limit. Maxwell-Boltzmann statistics; resolution of the "Gibbs Paradox".

Lecture 4. 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 5. The ideal Fermi fluid: conduction electrons in metals. Specific heat and ground state energy in 3D, 2D, 1D. Sommerfeld expansion.

Lecture 6. 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 7. Systems of interacting particles (1). The Debye Model of solids. Normal modes. Specific heat.

Lecture 8. 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 9. 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 10. 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 11. The Fluctuation-Dissipation Theorem. Response functions and correlations. Quantitative explanation of critical opalescence.

Lecture 12. 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 13. Magnetic systems: ferromagnetism and models for it. Ising model. Mean field theory treatment of the 1D Ising chain. Critical exponents.

Lecture 14. 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 15. 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.

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

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

3. Blundell, S. and Blundell, K., Concepts in Thermal Physics, 2nd Ed., Oxford University Press,　2010. (Elementary explanations. Many copies available in the library.)

4. Cardy, J., Scaling and renormalization in statistical physics, Cambridge Univ. Press, 1996.

5. Huang, K., Statistical Mechanics, Wiley. (Advanced.)

連絡方法　　Contact method

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 IV. 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!