Physics 541: Advanced Statistical Mechanics Spring, 2022

Instructor: Prof. R. Shrock, email: robert.shrock@stonybrook.edu

Mode of Lecture Delivery: This will depend on the COVID situation in the spring.
Meeting Time/Place: first meeting: Mon. Jan. 24, 11:45 AM. If the mode is in-person or hybrid, then the room location is to be announced.
Technical: This depends on the mode of lecture delivery.
Office hrs. - by appointment; use email.

Recommended preparation: PHY 540 or equivalent course.

Textbooks - We will not follow any one book, but will provide references to several recommended books and articles throughout the course.

Course requirements include homework, class participation, and a possible final exam. If a student has an A on the homework at the end of the semester, the final exam will be waived for that student. For students who do take the final, the grade weighting is: 50 % (homework), 10 % (class), 40 % (final).

This course will cover modern statistical mechanics, including a subset of the topics in the list below (in different years we will cover a different subsets of topics)

- Brief review of thermodynamics and discussion of statistical ensembles
- Phase transitions and critical phenomena: examples with liquid-gas-solid systems and magnetic systems; experimental data; phase diagrams; order of transition; critical singularities; correlation length.
- van der Waals theory of liquid-gas transition; mean field theory and Ginzburg-Landau theory.
- Analysis of some models, including Ising, q-state Potts, O(N) vector, and ice models; exact solutions for 1D and quasi-1D cases; transfer matrix method.
- Potts model and connection to Tutte and chromatic polynomials in graph theory; ground state entropy
- Modern theory of second-order phase transitions: renormalization group; universality classes and critical exponents, dependence on spatial dimensionality and symmetry group of Hamiltonian; scaling relations, upper and lower critical dimensionalities; conformal algebra.
- Approximate methods: high-temperature and low-temperature series expansions, low-density series expansions, Padé approximants, Monte Carlo simulations
- Quantum statistics: Fermi-Dirac and Bose-Einstein distribution functions and applications to phonons, photons, Bose-Einstein condensation.
- Other types of phase transitions, e.g., Kosterlitz-Thouless, transition, liquid crystals and orientational ordering.
- Lattice field theory and connections with quantum field theory

- Methods of energy generation and options for reducing production of CO_2.

Learning goals: Students will gain (i) an understanding of the principles and methods of modern statistical mechanics (SM); (ii) familiarity with models used in SM; and (iii) a working knowledge of applications of SM and connections with condensed matter physics and quantum field theory.

See http://www.stonybrook.edu for general university course and COVID policies,including vaccinations, COVID testing, and mask mandate.