PHY460: Condensed Matter Physics **T Th 03:30 PM- 04:50 PM**
Room: 136 Loomis Laboratory

Instructor: Prof. Gregory MacDougall Offce: MRL 216, Email: gmacdoug@illinois.edu
Office Hours: Friday, 02:00 PM - 04:00 PM

Textbook: *The Oxford Solid State Basics* by Steven Simon.

Prerequisites: PHYS 435; PHYS 485 or PHYS 486. Quantum mechanics is a required pre-requisite for a reason and will be used. If you don't have this pre-requisite make sure you are comfortable enough with the material before the drop date.

Grade Structure: Homework will be 20% of the total grade, exams will count for 80%. Mid-term exam is 30%, and final exam is 50%.

Course Objectives: The goal of this course is to set the foundation for future coursework and research in condensed matter physics. We will cover topics such as electronic structure of crystalline systems, metals, semi-conductors, magnetically ordered materials, and possibly more advanced topics such as magnetism, low-dimensional systems and superconductors. The hope is that this course will lay the conceptual framework needed by all experimentally and theoretically minded students to understand the basics of codensed matter physics.

Grading: Partial credit will be given on homework and exams if and only if the work is coherent. A random scattering of thoughts will not be awarded points. Simple numerical errors will not be strongly punished, however errors which give incorrect physical results will be. The steps to receiving partial credit are: (i) write your solution neatly and coherently using equations and words to describe what you are doing (ii) checking your answer for consistency e.g. are units correct, does the solution behave correctly in known limits. When writing solutions on homework or exams the best mindset to have is that you are explaining your method to a fellow class mate at your same level. That will require that you show your steps logically and lead the grader/reader through your solutions. This way of communicating your results will be beneficial for both yourself and the grader. Expect the exams to be challenging but to be curved accordingly.

Homework: There will be roughly one problem set every week or two, posted on Fridays at 10:00 AM. The homework will consist of problems from the textbook and original problems. Homework will be due the following Friday at 04:30 PM. Assignments which are late, but handed in by Monday will receive only 70% credit. The student will lose an additional 20% for every additional day the homework is late. Academic dishonesty is a very serious matter. Any indications that homework solutions were derived from online internet sources will be acted upon accordingly.

Topics Covered: Lectures will be structured to follow the chapters from Simon, supplemented with material from outside sources. The course will include the topics listed below, roughly in the order given. Students should be aware, however, that both topics and order are subject to change without notice. Several topics will take more than one lecture. Lectures will cover:

• Electrons in metals, and the Drude model (Chapter 3)

• Sommerfeld theory and the effects of quantum mechanics (Chapter 4)

• Chemical bonding: covalent, ionic and molecular bonds in materials (Chapters 5 and 6)

• Bravais lattices and description of periodic structures (Chapter 12)

• Reciprocal lattices and Fourier transforms (Chapter 13)

• Indexing lattice planes and exploration with scattering (Chapters 13 and 14)

• Introduction to phonons: toy models and 1D calculations (Chapters 2, 9 and 10)

• Phonons in three dimensions and inelastic neutron scattering (Chapters 13.3, 14.4 and additional notes)

• Electrons in a periodic potential: the nearly free electron model and Bloch's theorem. (Chapter 15)

• Band theory: metals vs. insulators. (Chapter 16)

• The tight-binding model. (Chapters 11 and 16.3)

• The effective mass approximation. Metals and Fermi-surfaces. (Chapters 16 and 17)

• Measuring Fermi surfaces: ARPES and de Haas-van Alphen. (Notes)

• Semiconductor physics. (Chapter 17)

- Semiconducting devices (Chapter 18)

- Introduction to magnetism: Hund's rules, local spins, origin of interactions (Chapters 19 and 23)

- Spontaneous symmetry breaking and magnetic order (Chapters 20 and 22)

- Introduction to superconductivity. (Notes)