Phys – 625 SOLID STATE PHYSICS I Fall – 2010

- **Instructor: Dr. Igor Ostrovskii**
- **Lecture: T, Th 11:00 – 12:15, Room 211 Lewis Hall**
- **Office: Room 207 Lewis Hall, Email: iostrov@phy.olemiss.edu**
- **Office Hours: M, Th 3:30 – 4:30 p.m. (207 Lewis Hall) + by appointment**

- **TEXTS**

- **Main reading:**

1)"Introduction To Solid State Physics" by Charles Kittel, 8-th edition.
We cover chapters 1 through 9.

- **Additional reading:**

2) "Condensed Matter Physics" by Michael P. Marder, John Wiley & Sons, 1st edn.
3) "Semiconductor Physics" by K. Seeger, Springer, 7th edn.

A. Grading Scale:

A -------------------- 90 – 100,
B -------------------- 80 – 89,
C -------------------- 70 – 79, etc.

Grades will be based on the home works, chapter tests, and final examination:

Home works ----------------- 20%
Presentation ------------------ 5%
Two tests ---------------------- 50% (#1=25%, #2=25%)
Final examination ------------------- 25%
TOTAL --------------------- 100.

➢ **Chapter Tests and Final examination schedule:**

➢ **Test 1** (Chapters 1, 2, 3, 4)**: Tuesday, September, 28**
[Crystal structure, Binding, and Phonons in Solids]

➢ **Test 2** (Chapters 5, 6, 7)**: Tuesday, November 2**
[Electrons and Energy bands**]**

➢ **FINAL EXAMINATION ------------ *Tuesday, December 7, Noon.***

- - The dates of chapter tests are tentative, and may be changed;

BUT NOT the FINAL EXAMINATION DATE.

➢ **Requirements of the course and Homework rules:**

1. **Absence** *may jeopardize your standing in class* because you are responsible for any in-class activities and for anything presented. Show up for class on time & do not leave class early.

2. Homework is assigned after some sections are covered and **is due in a week**.
3. Homework paper should be 8.5’’ x 11’’ with no torn or tattered edges. HW-papers should be stapled.
4. Show all your work; the answer alone is not worth anything.
5. HW-problems must include diagrams, equations, calculations, enough English to be understandable.
6. Homework answers should have units and a reasonable number of significant digits.
7. **Important: Circle the finale answers that you want to be graded.**

COURSE CONTENTS:

1. Ch. 1: **CRYSTAL STRUCTURE.** [2.5 Classes]
Fundamental types of crystal lattices. Simple crystal structures.

2. Ch.2: **WAVE DIFFRACTION AND THE RECIPROCAL LATTICE**. [2.5 Classes]
Diffraction of X-rays and matter waves by crystals. Brillouin Zones.

3. Ch. 3: **CRYSTAL BINDING**. [2.5 Classes]
Binding in the crystals of inert gases, ionic crystals, covalent crystals, metals. Hydrogen bonds.

4. Ch.4: **PHONONS I: CRYSTAL VIBRATIONS**. [2.5 Classes]
Vibrations of crystals with monatomic basis. Two atoms per primitive basis.
Quantization of elastic waves. Phonon momentum. Inelastic scattering by phonons.

- **TEST #1 (Class #11) → Tuesday, September, 28**

5. Ch.5: **PHONONS II: THERMAL PROPERTIES.** [2.5 Classes]
Phonon heat capacity. Anharmonic crystal interactions. Thermal conductivity.

6. Ch.6: **FREE ELECTRON FERMI GAS.** [4 Classes]
Energy levels in one dimension. Effect of temperature on the Fermi-Dirac distribution.
Free electron gas in three dimensions. Heat capacity of the electron gas. Electrical conductivity and Ohm’s law. Hall Effect. Thermal conductivity of metals.

7. Ch. 7: **ENERGY BANDS.** [2.5 Classes]
Nearly free electron model. Bloch functions. Kronig-Penney Model. Wave equation of electron in a periodic potential. Number of orbitals in a band.

- **TEST #2 (Class 21) → Tuesday, November 2**

8. Ch. 8: **SEMICONDUCTOR CRYSTALS.** [4 Classes]
Band gap. Equations of motion. Intrinsic carrier concentration. Impurity conductivity.
Thermoelectric Effects. Semimetals. Superlattices. Applications.

9. Ch. 9: **FERMI SURFACES AND METALS.** [2 Classes]
Reduced and periodic zone schemes. Construction of Fermi surfaces.
Electron and hole orbits. Calculation of energy bands.

GRADUATE STUDENT PRESENTATIONS.

10. REVIEW [Last class #28]

- **FINAL EXAMINATION → Tuesday, December 7, Noon.**

- **<u>COURSE OBJECTIVES AND GOALS</u>**

1. Introduce the physics graduate students to contemporary Solid State Physics I.
2. Advance an understanding of the ideas of quantum physics applications to the solid state and condensed matter physics including semiconductors.
3. Expand an awareness of the current basis of knowledge in physics of solids including crystal structure, crystal binding, phonons and electrons in crystals, semiconductors, basic properties of solids including energy bands and Fermi surfaces.
4. Enhance the critical thinking, analytical reasoning, and problem solving skills for graduate level.
5. Expand an awareness of a scientific basis for advancements in contemporary scientific and technological issues.
6. To liven up the text with brief sketches of some historical developments in solid state physics in the 20th-century.
7. Usage of the Internet, Interactive demos, Lecture demonstrations, and scientific publications for assuring in-depth understanding of the covered chapters.
8. Discuss the problems confronting physics of solids and semiconductors in the 21-st century.

- **<u>COURSE LEARNING OBJECTIVES</u>** <u>(Intended learning outcomes):</u>

In the learning objectives / outcomes, we answer a question: "What will the graduate students know and be able to do as a result of taking the class of Phys-625 and passing the final examination." The learning outcomes for graduate students are as follow:

1. Understand <u>the basic principles</u> of Solid State Physics I.
2. Be aware and in depth understand the most important results in Physics of Solids that were discovered and developed mainly in the 2nd half of the 20th century *including following:*

   Crystal structure, Crystal lattice, Binding in solids, Phonons and Thermal properties, Properties of the electrons in solids, Band theory of solids, Semiconductor properties and applications, Fermi surfaces.

3. Understand the physical basis of numerous contemporary applications of Solid State Physics in science and engineering.
4. Graduates will develop a comprehension of <u>the current basis</u> of broad knowledge in Solid State and Condensed Matter physics.
5. They will know about the problems in Solid State applications, and practical problems confronting Solid State physics in 21st century.
6. Different learning expectations for graduate versus undergraduate students will be realized (*section B below*).
7. The graduates will contribute to their field of study (*section B below*).

- B. **<u>Different Learning Expectations for Graduate versus Undergraduate Students</u>**:

1. Theoretical and experimental results on “Solid State Physics ” will be understood at a level that helps graduate to pass a <u>comprehensive examination.</u>
2. In class, discussions of the Nobel Prizes in the fields of “Solid State Physics” will foster broad knowledge of the graduate students and especially will help them to pass an <u>oral part</u> of comprehensive examination.
3. Graduate students will be able to work out the particular problems of respectively high theoretical level that is needed to take successfully the <u>comprehensive examination</u>.

4. Doctor and Master Candidates will build on their critical thinking including "how to apply contemporary results in "Solid State Physics" to your individual work on dissertation/thesis."
5. Learners will build on a critical thinking, analytical reasoning, and problem solving skills at a level of MS and Ph. D. candidates.

- **FOSTERING INDEPENDENT LEARNING**

that enables the graduates to contribute to a profession or field of study:

2. Graduate students will make at least one presentation of a certain section/subsection from their textbook to foster independent learning and to practice their lecturing skills.
3. Graduates will have some special demonstrations fostering their practical experimental skills in the field.
4. Learners will have an opportunity to present shortly their research themes, literature reviews, etc., which enable graduates to contribute to their field of study including topics of their future dissertations/theses.
5. Learners will be recommended additional reading including texts, monographs, and particular Journal publications

- **To ensure ongoing graduate student engagement in research:**

6. The graduate students will have enough knowledge to understand contemporary needs in new high-technology applications, ways to find practical solutions, and corresponding needs in qualified work force.
7. The graduate students of this class will be given a particular homework consisting of a presentation on research topic of their choice, or to present in extended format a particular section.
8. Alternatively, the learners may choose to give a talk on latest results in the field, for example, "Nobel Prize in Physics", applications of Nano-Sciences & Engineering, etc.

- **To ensure appropriate professional practice and training experience:**

9. During coverage of major contemporary applications in Solid State Physics, to prompt learners to search for the publications in the scientific Journals for a particular physics phenomenon or effect.
10. The graduate students will know how to use interactive methods and Internet for their independent learning on "Solid State Physics" especially those parts that describe the latest results in Solid State and its contemporary applications..