PHY 392K: Solid State Physics I, spring 2020
(tentative)

Unique #: 55190
T-Th 2:00-3:30 p.m. in RLM 5.116

Instructor: Prof. Alex Demkov
Office: RLM 13.206
Phone: 471-8560
e-mail: demkov@physics.utexas.edu
Office hours: Monday 2-4 p.m., and by appointment

TA: Wente Li
Office: RLM 7.202
Phone: 232 7588
e-mail: wenteli_utasutin@utexas.edu
Office hours: Wednesday 4:30 – 6:30 p.m. and by appointment

Reference Books:

- M. P. Marder, "Condensed matter physics", Wiley, 2000.
- N. Ashcroft & D. Mermin, "Solid State Physics", Clarendon Press, Oxford 1995.
- C. Kittel, "Introduction to Solid State Physics" Wiley, any edition.
- O. Madelung, "Introduction to solid-state theory", Springer, 1981.
- J. M. Ziman, "Principles of the theory of solids", Cambridge U. Press, 1999.
- W. A. Harrison, "Electronic Structure and the Properties of Solids", Dover, 1989.

Class website: http://web2.ph.utexas.edu/classes/demkov/phy392k/

Syllabus:

The class will be hard. A solid grasp of Quantum mechanics, E&M and Stat. Mech. is expected. Homework assignments will be tedious and will often require some computing. It is possible to fail this class. Best of luck.

Part I: Molecular Physics

1. Hydrogen Molecule; Born Oppenheimer approximation
2. Two electron problem: Heitler-London and Hartree-Fock theories
3. Heisenberg and Hubbard Hamiltonians
4. Harmonic approximation; Transformation to normal coordinates
5. Point group symmetry

Part II: Crystal state

6. Bravais lattice, Lattice with a basis
7. Symmetry: Crystal classes, Space groups
8. Mathematics of periodicity, Periodic Boundary Conditions;
9. Bloch theorem
10. Reciprocal lattice

Part III: Vibrations in solids

11. Dynamical matrix, dispersion relations
12. Simple nearest neighbor chain, density of vibrational modes
13. General monoatomic chain, speed of sound, diatomic chain
14. Square lattice with 2^{nd} NN interactions, 3D
15. Specific heat (Dulong-Petit)
16. Quantum description, phonons
17. Specific heat (Einstein and Debye theories), more on the density of modes

Part V Electron in a periodic potential (single electron picture)

18. Bloch waves, lattice sums, and periodic boundary conditions
19. Kronig-Penney Model
20. Empty Lattice, simple classification of solids according to the band theory
21. Nearly free electrons, band structure, band gaps, Brillouin zone, etc.
22. Philips-Kleinman pseudopotential
23. Cohen-Bergstresser empirical pseudopotential
24. Tight binding and LCAO
25. Basis functions, overlap, Bloch waves
26. Electronic structure, band population, density of states

Part VI: Semiconductors

27. Lattice with the basis, the origin of band gaps
28. ***kp*** Theory
29. Effective mass, two band model
30. Electronic structure of Si, minimal $\mathbf{sp^3}$ basis, Chadi-Cohen Hamiltonian
31. Band structure of semiconductors, spin-orbit interaction

Part VII: Experimental techniques

32. ARPES
33. Neutron scattering, elastic, inelastic, Einstein model, Debye-Waller factor

- **~6 homework assignments**

- **February, Midterm I**
- **April, Midterm II**

- **There will be several make-up classes TBD**

- **May XX, X:00-Y:00 Final**

- **Grading:** homework 40%, two mid-terms 20% each, final 20%