2017 Spring Semester

2017

431 Physics
"Theory of solids"

Instructor: Prof. Slava V. Rotkin
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610-758-3904; Office: Lewis 414
Class: 10:45 am - 12:00 pm TR Lewis 512

Prerequisites: PHY 424 (or equivalent), PHY 363 (or equivalent), PHY 422 (or instructor consent).
Credits: 3
Grades will be based on

- homework and quiz points (20%)
- textbook reading assignments and class/discussion activity (20%)
- final exam (60%)

Expectations:
You should expect to spend at least an hour of outside class study for every hour in class in addition to approximately an hour doing a homework assignment. Many students find it helpful to form study groups to work and discuss homework assignments with other students which is encouraged. It is an excellent way to learn physics. However, it is expected that finally each student will know how to work his problem for quiz, midterm or final without help. If you get stuck on a homework problem, see your instructor for help.
Office hours: TR by appointment

Textbooks:

- H. Haken, *Quantum Field Theory of Solids: An Introduction*, Elsevier Science (1983), # ISBN-10: 0444867376 # ISBN-13: 978-0444867377
- Charles Kittel, *Quantum Theory of Solids*, Wiley; (1987), # ISBN-10: 0471624128 # ISBN-13: 978-0471624127

Recommended reading:

- J. M. Ziman, *Principles of the Theory of Solids*, Cambridge University Press; 2 edition (1979), # ISBN-10: 0521297338 # ISBN-13: 978-0521297332
- more elementary courses:
  - Charles Kittel, *Introduction to Solid State Physics*, Wiley; 8 edition (2004), # ISBN-10: 047141526X # ISBN-13: 978-0471415268
  - Neil W. Ashcroft, N. David Mermin, *Solid State Physics*, Brooks Cole (1976), # ISBN-10: 0030839939 # ISBN-13: 978-0030839931
- Walter A. Harrison, *Solid State Theory*, Dover Publications (1980), # ISBN-10: 0486639487 # ISBN-13: 978-0486639482
- Gerald D. Mahan, *Condensed Matter in a Nutshell*, Princeton University Press (2010), # ISBN-10: 0691140162 # ISBN-13: 978-0691140162
- H.-S. Philip Wong, Deji Akinwande, *Carbon Nanotube and Graphene Device Physics*; Cambridge University Press (2010), # ISBN-9780521519052 (http://dx.doi.org/10.1017/CBO9780511778124)
- J.S. Blakemore, *Solid State Physics*, Cambridge University Press; 2 ed. (1985) # ISBN-10: 0521313910 # ISBN-13: 978-0521313919

Accommodations for Students with Disabilities: If you have a disability for which you are or may be requesting accommodations, please contact both your instructor and the Office of Academic Support Services, Williams Hall, Suite 301 (610-758-4152) as early as possible in the semester. You must have documentation from the Academic Support Services office before accommodations can be granted.
The Principles of Our Equitable Community: Lehigh University endorses The Principles of Our Equitable Community [http://www.lehigh.edu/~inprv/initiatives/PrinciplesEquity_Sheet_v2_032212.pdf]. We expect each member of this class to acknowledge and practice these Principles. Respect for each other and for differing viewpoints is a vital component of the learning environment inside and outside the classroom.

Expected final competences for the course:
You should expect to have a solid understanding of the following concepts:
- elementary excitations: phonons, plasmons, excitons (Frenkel and Wannier-Mott), polaritons
- many-body Hamiltonians and second quantization approach
- field formalism, interaction between fields
- algebra of many-body operators, Green Functions

You should be able to solve many-body problems using these concepts.

Course Syllabus

0. Principles of Classical and Quantum Mechanics, basics of Crystal Theory.

Reading assignment:

Refresh your memories on fundamentals of Classical & Quantum Mechanics: Lagrange and Hamilton approach, EOM, operators in Heisenberg representation, evolution operator, harmonic oscillator. Remember from Introduction in Solid State: Brillouin zone and reciprocal lattice, Bloch theorem.

Part I. Introduction

1. Basic formalism
- 1.1 Harmonic oscillator and lattice phonon in one and more dimensions
- 1.2 Field quantization, EM field
- 1.3 Schrödinger field: Bosons and fermions
- 1.4 Heisenberg and interaction picture

2. Applications of the formalism
- 2.1 Bloch theory and method of Wannier
- 2.2 Many-body problem
- 2.3 Electrons and holes: All together
- 2.4 Excitons of Wannier and Frenkel
- 2.5 Polarization and dielectric function
- 2.6 Plasmons
- 2.7 Polaritons
- 2.8 Magnons
- 2.9 Frohlich interaction: Polarons

Part II. Advanced applications

3. Dynamics and kinetics of many-body particles.
- 3.1 Kinetic equations
- 3.2 Quasi-equilibrium solutions, resistance
- 3.3 Out of equilibrium, ballistic transport
- 3.4 Green's function formalism

4. Basics of quantum optics
- 4.1 Light-matter interaction
- 4.2 Polaritons revisited

Part III. Additional topics

Graphene and 2D Layered Materials. Dirac electrons in solids.
Spin-Orbit interaction.
TBD