PHYS/AP 295A:
Introduction to the Quantum Theory of Solids

Fall 2020

Instructor 1:	Prineha Narang,	**email:**	prineha@seas.harvard.edu
Instructor 2:	David Bell,	**email:**	dcb@seas.harvard.edu
Lectures:	Mon, Wed 9:00-10:15AM		
Office Hours:	Mon, Tue, Thu 11:00-Noon.		

Course Websites:

1. https://canvas.harvard.edu/courses/76851
2. https://canvas.harvard.edu/courses/73878

Teaching Fellow: Maria Tikhanovskaya (tikhanovskaya@g.harvard.edu)
Section: TBD by class poll to accommodate time-zones.
TF's Office Hours: TBD.
Paper Discussion with Prof. Bell and Narang: TBD by class poll.

Main References: The course will be largely based on the books below. They will be available online for students taking the class.

- Ashcroft and Mermin, *Solid State Physics*
- S. G. Girvin and K. Yang, *Modern Condensed Matter Physics*, Cambridge University Press

Objectives: This is an introductory graduate level course in solid-state physics. Advanced undergraduate students interested in the course should contact the instructors.

Prerequisites: Physics 181 or equivalent, Applied Physics 195 or equivalent, and a graduate level quantum mechanics course similar to Physics 251a. Physics 251b might be helpful and could be taken concurrently.

Fall 2020 Plan and Important Changes:

- All course content delivery, discussions, and office hours will be remote for Fall 2020.
- We will meet at the lecture times listed (MW 9-10:15am) *via* Zoom.
- Times for sections and seminal paper discussions led by Prof. Narang and Bell will be based on student polls during the shopping week. We will accommodate students in different time-zones based on these critical polls, so please respond.
- Some (not all) lecture content will be recorded and made available to make class time more interactive and to better accommodate time zone differences. Recorded lecture content is intended to supplement in-class work and is not a replacement for in-class content.
- We will hold expanded office hours and discussion sessions this Fall.
- PHYS/AP 295A will use a dedicated Slack to facilitate discussions between students. Working in groups and collaboration is highly encouraged.

Tentative Course Outline:

Lectures 1-3. Bravais lattices

- Density of states, Symmetries

Lectures 4-6. Phonons

- Brillouin zone, 1D lattice
- Quantum theory of phonons, quantized 3D harmonic oscillator
- Partition function, heat capacity
- Debye model

Lectures 7-11. Electronic Structure of Crystals

- Drude model, Hall effect
- Bloch theorem
- Band Structure: OPW, APW, Tight-binding treatment
- Electrons in a weak periodic potential
- Thermodynamics, energy density, number density, susceptibility

Lecture 12-14. Semiclassical Transport Theory

- Semiclassical Equation of Motion
- Electron and Phonon Scattering and Electron-Phonon Interaction
- Motion in a magnetic field: 1D, 2D, 3D (de Haas van Alphen)
- Boltzmann transport equation
- Thermal conductivity

Lecture 15-17. Semiconductors

- Impurity levels
- $p-n$ junction

Lecture 18-20. Introduction to Superconductors

- General properties, perfect conductivity, Meissner Effect.
- Thermodynamics of Superconductors
- Introduction to Microscopic Description of Superconductivity.

Lecture 21. Integer Quantum Hall Effect

- Landau levels
- Edge states
- Quantized Hall conductance

Lectures 22-23. Topology and Berry Phase

- Adiabatic theorem
- Spin-1/2 Berry phase
- Berry curvature and Bloch bands

- Hofstadter model

Lecture 24-25. Topological Insulators and Semimetals

Grading Policy: Problem Sets (70%), Class Engagement (10%), Take-Home Final (20%).