

# Ph135a (2016 -- 2017): "Applications of Quantum Mechanics to Condensed Matter Physics"

INSTRUCTOR: Professor Nai-Chang Yeh  
(Office: 120 Bridge Phone: x-4313 E-mail: [ncyeh@caltech.edu](mailto:ncyeh@caltech.edu))

SCHEDULE: Tuesday & Thursday 1:00 – 2:30 PM

LOCATION: Downs 107

TEACHING ASSISTANT: Ming-Feng Tu  
(Office: West Bridge 155 E-mail: [mtu@caltech.edu](mailto:mtu@caltech.edu))

INFORMATION: [http://www.yehgroup.caltech.edu/Ph135a\\_2016](http://www.yehgroup.caltech.edu/Ph135a_2016)

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## I. Introduction

- Overview of condensed matter physics.

## II. Crystalline Structures & Phonons

- Translational symmetry & periodic wave functions.
- The reciprocal lattice.
- Bloch theorem & the Brillouin zone.
- Classification of Bravais lattices and crystalline structures.
- Lattice dynamics and lattice waves.
- Lattice specific heat and spectra.
- Phonons.
- Diffraction by a crystal with lattice vibrations.

## III. Electronic States and Band Structures

- The nearly-free-electron model.
- The tight-binding method.
- The  $\mathbf{k} \cdot \mathbf{p}$  perturbation theory.
- Other band structure theories: cellular method; augmented-plane-wave (APW) method; orthogonalized-plane-wave (OPW) method; pseudo-potential method; Green function method.

## IV. Fermi Statistics of Electrons & Electron-Electron Interactions

- Classifications of solids in terms of band and bond pictures.
- Fermi statistics and specific heat of conduction electrons.
- Perturbative approximations.
- Screening effects and the dielectric constant.

- The Friedel sum rule and Friedel oscillations.
- Plasma oscillations.
- Mott transitions and Wigner's hypothesis.

## **V. Symmetries & Group Theory**

- Groups and representation theory.
- Point groups and the selection rules for optical transitions.
- Space groups.

## **VI. Optical Properties of Solids**

- Macroscopic theory.
- Microscopic theory for dispersion and absorption.
- Photon-phonon interaction.
- Interband transitions and excitons.

## **VII. Transport Properties of Solids & the Fermi Surface**

- The Boltzmann equation.
- Scattering mechanisms and longitudinal resistivity in solids.
- Thermal transport properties.
- Effects of high magnetic fields & quantization of orbits.
- High-field magnetoresistance and quantum oscillations.
- Transverse resistivity and the Hall effects.
- Quantum Hall effects in semiconductors.

## **Reference Books:**

1. "*Principles of the Theory of Solids*", J. M. Ziman, Cambridge University Press (1972).  
[Link to Caltech Library e-book can be found at <http://caltech.tind.io/record/902799?ln=en>]
2. "*Solid State Physics*", N. W. Ashcroft and N. D. Mermin, W. B. Saunders Company, (1976).