I. Overview

- Solid State Physics is a very different subject, compared with those you have taken so far.

  It is not a "fundamental" subject!

  Instead, it aims at explaining the properties of solids by techniques in the other fundamental branches (Classical Mechanics (CM), Quantum Physics/Mechanics (QM), thermodynamics and Statistical Physics (SP), electromagnetism (EM)) of physics.

  It is, therefore, important to review for yourself what you have learnt in CM, QP/QM, EM, SP courses.

- Some find it easy: Applying other subjects to solid state!
- Some find it hard: As there is no single standard method (or formula) to handle ALL solid state problems!

But, ALL will find the subject interesting and exciting!
See how physics works!

A. Objectives:

- Give an introductory survey on the physical properties of crystalline solids, with emphasis on the underlying physics
- To arouse the students' interest in solid state physics
- To illustrate how physics works in the context of solids
- To prepare students for going deeper into the subject in the future and for self-learning of other topics not covered in the course
- To cultivate an appreciation on the far-reaching contributions of physics to mankind, within the context of SSP
- To cultivate an appreciation on using qualitative arguments
- To provide experience on peer-learning

B. Topics to be discussed:

- Crystal Structures
- Reciprocal space
- Scattering of waves off solids
- Lattice Vibrations
- Electrons in Solids
- Thermal Properties
- Electrical/Transport Properties
- (Magnetic Properties)
- (Dielectric/Optical Properties)

(...) – depends on time constraint

C. Our Strategy:

Solids: Crystalline Solids (晶態)
Amorphous (非晶態) solids
Polycrystalline (多晶) solids

Crystals: Equilibrium positions of atoms (ions) form a repeating (periodic) pattern

Note: The atoms are not fixed! There are vibrations about equilibrium positions.

Amorphous: No repeating pattern

Polycrystalline: Made up of a large number of small crystals, called crystallites.
Regular pattern in each crystallite, but orientation of pattern changes abruptly at crystallite boundaries

- As a first course on SSP, we will focus on crystalline solids.

- Usually, we shall assume:
  - infinite, perfectly periodic crystals
    - infinite: to avoid complications due to surface, although surface science forms an important subject
    - perfectly periodic: to include deviations from perfect periodicity later for explaining physical properties

  and try to understand properties of materials from the particles (electrons + nuclei) making up the solid together with periodicity

  - start with:

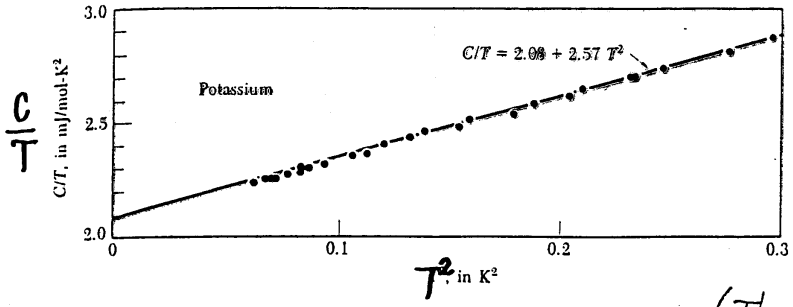
    separate discussions on: Lattice Vibration

    Electrons in periodic potential

  - then include effects of imperfections and interactions (e.g. electron-lattice vibration interaction) to explain materials properties

- An example of what we shall study:

  specific heat of a metal (e.g. potassium)



Experimental heat capacity values for potassium, plotted as C/T versus T^2.

(Thermal Property)

Data indicate:

$$C = AT + BT^3$$

AT: contribution from electrons

BT^3: contributions from lattice vibrations

To understand this, we need:

- to know the properties of electrons in solids
- statistical physics as applied to fermi gas
- Fermi surface effect

To understand this, we need:

- what is the crystal structure?
- How do ions vibrate about equilibrium positions
- statistical physics as applied to a collection of oscillators (Debye model)

Q: What are the physical quantities that one can measure in a laboratory? (Ex.)

- You should have learnt some SSP in other courses†

  QP/QM: Schrödinger Equation, eigenvalue problems Harmonic Oscillators, atoms, bonding‡, molecules, solid state

  CM: Normal modes in coupled oscillators

  EM: Maxwell's eqs, Polarization, dielectric constant, magnetisation, propagation of EM waves in a dielectric/metal, relation with optics

  SP: Fermi gas, Bose gas, Harmonic Oscillators, Paramagnetism, methods to calculate thermal properties (e.g. heat capacity), ensemble theory

† Review these topics for yourself

‡ Read Kittel (8th edition), Ch. 3 (p.47-72) for a review on bonding (a topic in Quantum Physics).

D. Level of our course

- The level will be gauged at that of Kittel's book, Christman's book, and Hook and Hall's book
- I intend to explain the physics slightly deeper than in Kittel's book. Therefore, I will not be able to cover as many topics as in Kittel's book.
- The aim is that, after having a solid foundation on lattice vibrations and electrons in solids, students will be able to read and learn from Kittel's or other SSP books on whatever topics they may be interested in.

"Solid State Physics" scattered in other PHYS courses

- Quantum Physics II
  - Bonding
  - Solid State :- bands, metal, insulator, semiconductor
    [sometimes including superconductor]
- Statistical Mechanics
  - Collection of harmonic Oscillators, contribution to heat capacity (Einstein model, Debye model)
  - Defects, Paramagnetism)
  - Fermi-Dirac and Bose-Einstein distributions
  - 3D Ideal Fermi Gas
    Fermi energy, low temperature heat capacity
  - Density of states
- EM courses
  - dielectric constant (relative permittivity)
  - Reflection and transmission of EM waves through a layer of material
  - Lorentz oscillator model of dielectric constant
- Mechanics
  - Normal Modes of a chain of balls and springs including an infinite chain.
- Year 1 Laboratory Class
  - Resistivity of metal and semiconductor
- Applied Solid State Physics
  - A whole course introducing solid state physics in a more descriptive tone and more on applications