Condensed Matter Physics

Subject Number – PH30204
LTP: 3-0-0; CRD – 3

Condensed Matter Physics

It is the field of physics that deals with the macroscopic and microscopic physical properties of matter. In particular, it is concerned with the "condensed" phases that appear whenever the number of constituents in a system is extremely large and the interaction between the constituents are strong. The most familiar examples of condensed phases are solids and liquids.

Why do we study condensed matter physics?

(a) Because it is the world around us
(b) Because it is useful – Use knowledge to engineer new materials and exploit their properties
(c) Because it is deep and enriching (almost fifty Nobel laureates)
(d) Because it is a laboratory – the best laboratory we have for studying quantum and statistical physics
(e) …

At least 4 Nobel Prizes in CMP in last 15 yrs

The Nobel Prize in Physics 2016

David J. Thouless, F. Duncan M. Haldane and J. Michael Kosterlitz "for theoretical discoveries of topological phase transitions and topological phases of matter"

The Nobel Prize in Physics 2014

Isamu Akasaki, Hiroshi Amano and Shuji Nakamura "for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources"

The Nobel Prize in Physics 2010

Andre Geim and Konstantin Novoselov "for groundbreaking experiments regarding the two-dimensional material graphene"

The Nobel Prize in Physics 2007

Albert Fert and Peter Grünberg "for the discovery of Giant Magnetoresistance"

Syllabus - To be discussed

- Free Electron Theory – Some accomplishments and Limitations
- Crystal binding, Structure of solids, Symmetry, unit cell, simple crystal structures
- Diffraction – Bragg's law, structure factor, different methods for structure determination
- Perioidic potential in one dimension, electrons in a weak periodic potential, tight-binding approximation, bands, Brillouin zone
- Vibration of lattice – Mono- and di- atomic chains, periodic lattice, phonons, phonon spectrum, heat capacity
- Thermal expansion and resistivity, Boltzman transport theory
- Discussions on magnetism

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Free electron theory

- Based on kinetic theory of gas
- Assumes some scattering time τ

Successes

- Wiedemann-Franz ratio $\frac{k}{\sigma T}$ comes out close to right
- Many transport properties predicted correctly
- Hall coefficient measurement of carrier density seems reasonable for many materials

Failures

- Hall coefficient is often measured to have opposite sign indicating a change in carrier opposite to that of electron
- Thermopower comes out wrong by a factor of 100

Then we shall discuss Sommerfeld's theory of metals
Treats electrons as fermions
Solves some of the above

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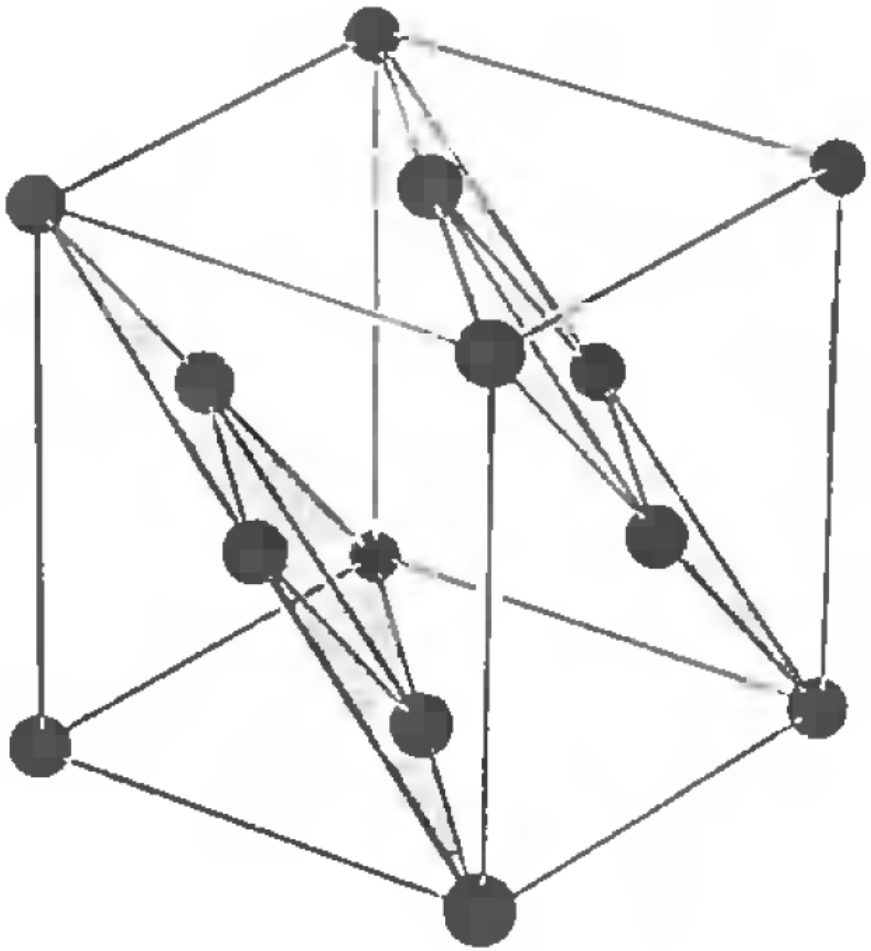
Investigation of some crystal structures



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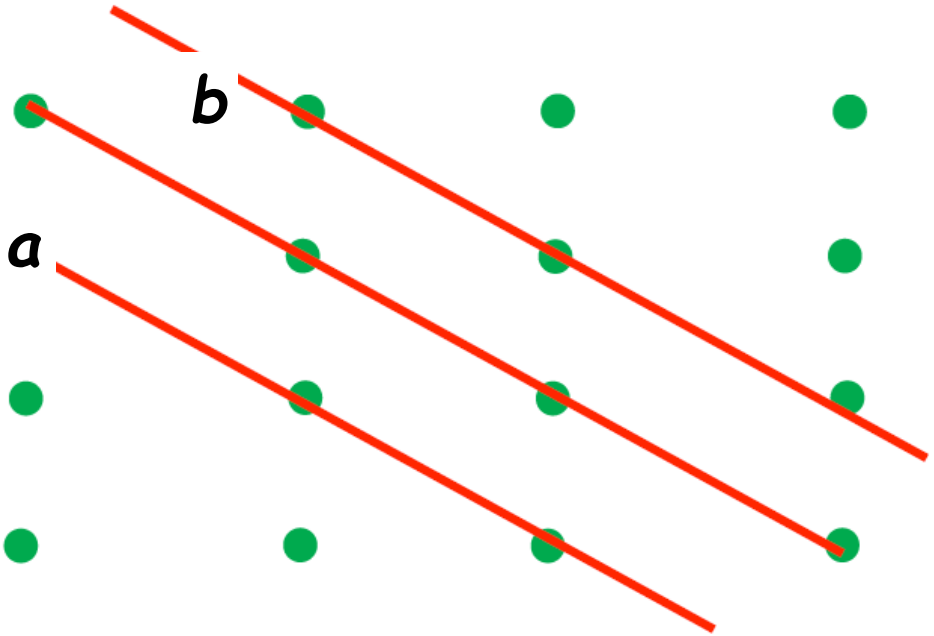
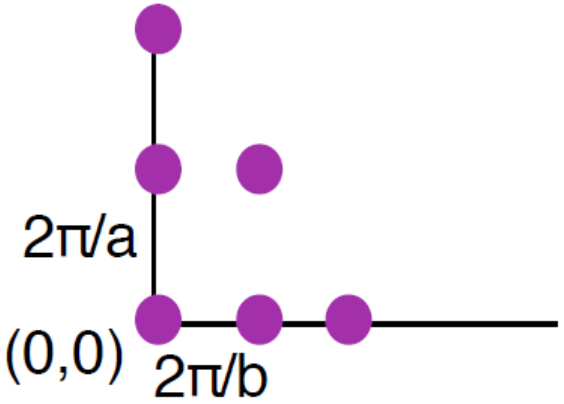
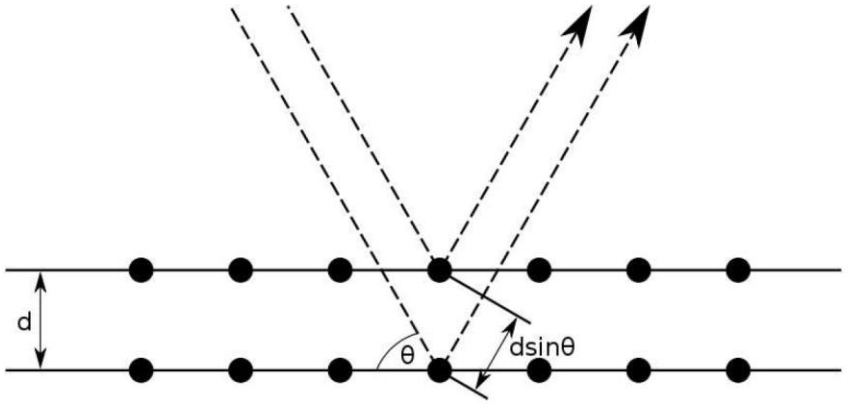
Experimental determination of structure

real space

reciprocal space







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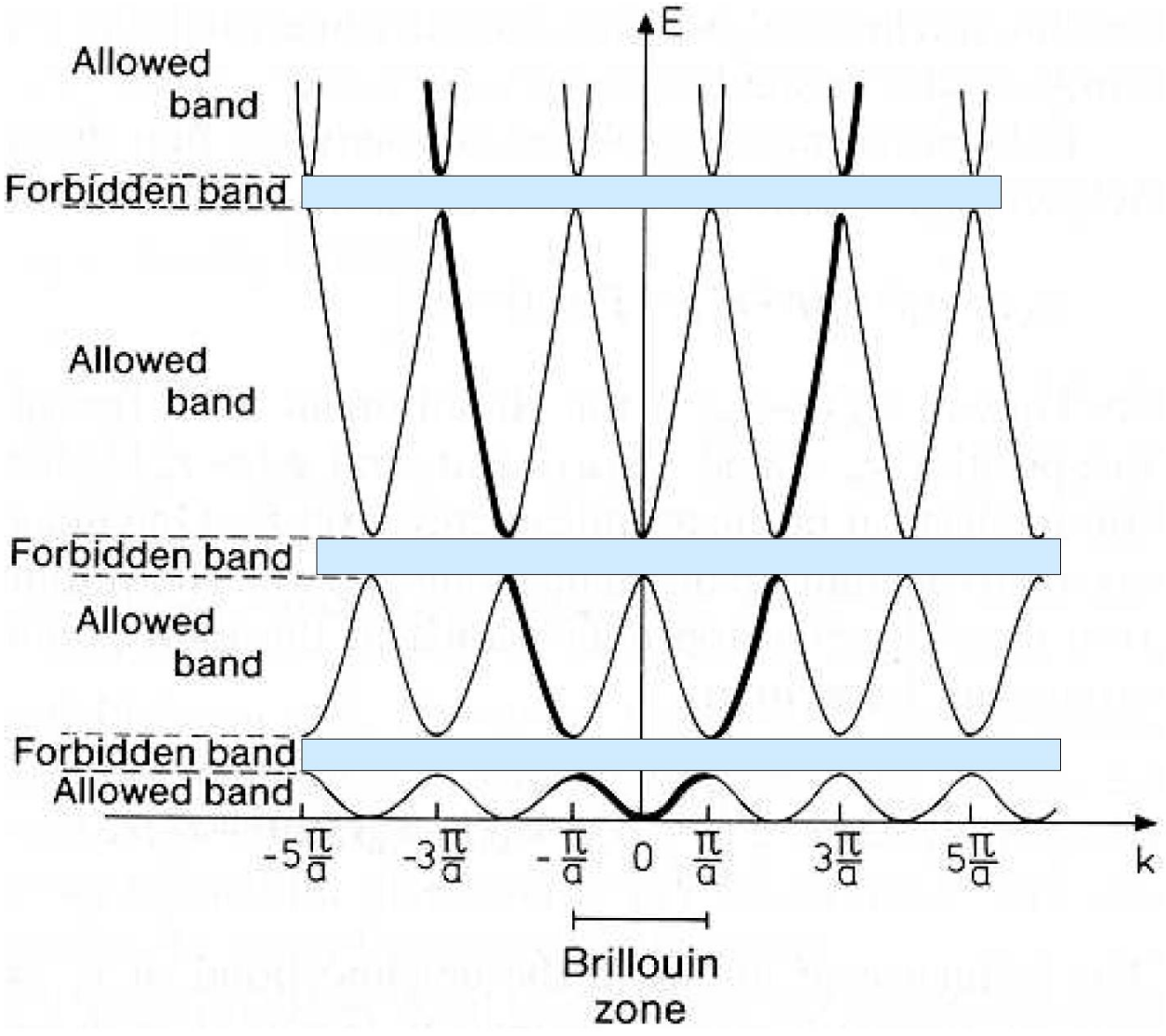
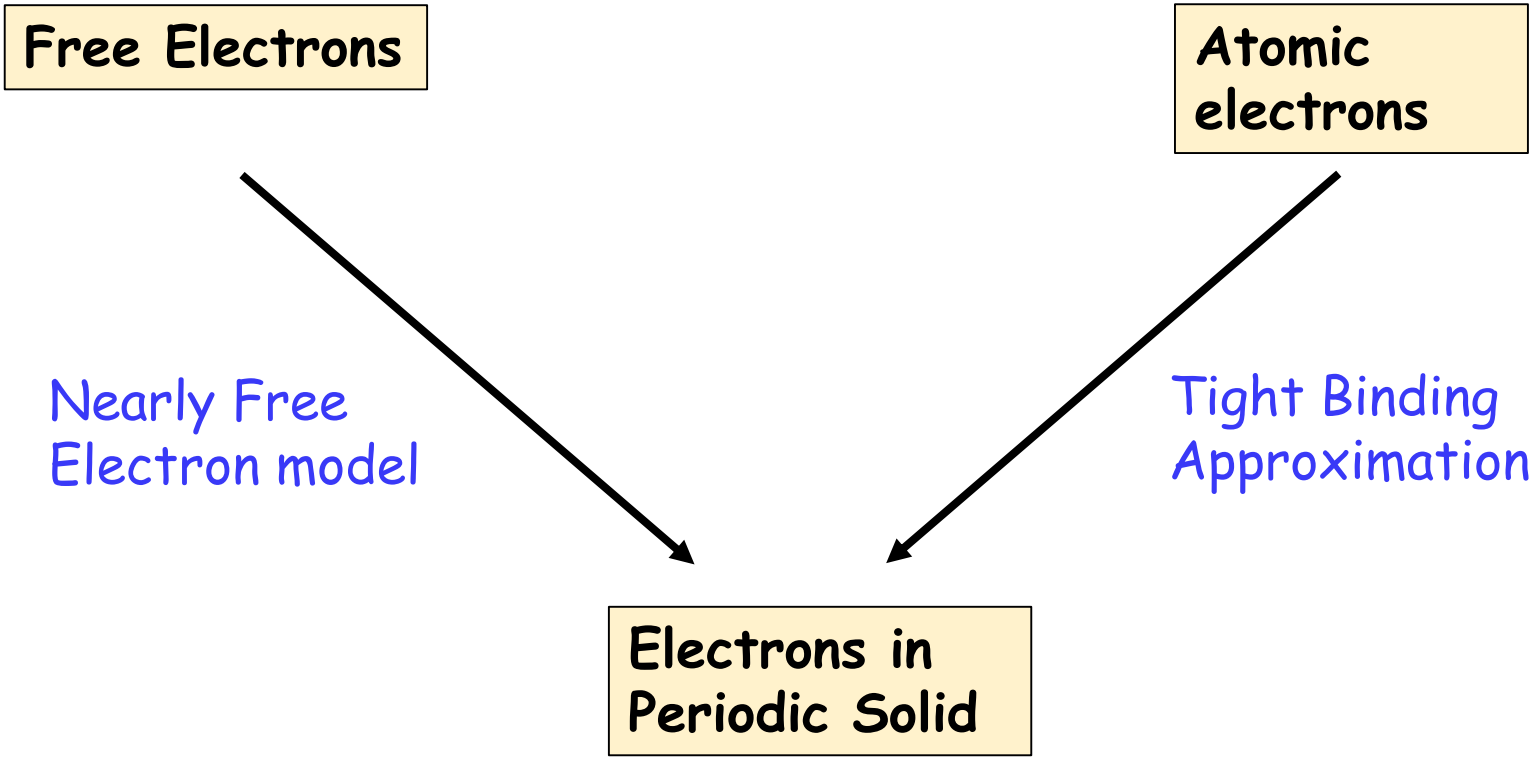
Nearly Free Electron Theory of electrons in a periodic solid



Tight Binding Theory of electrons in a periodic solid



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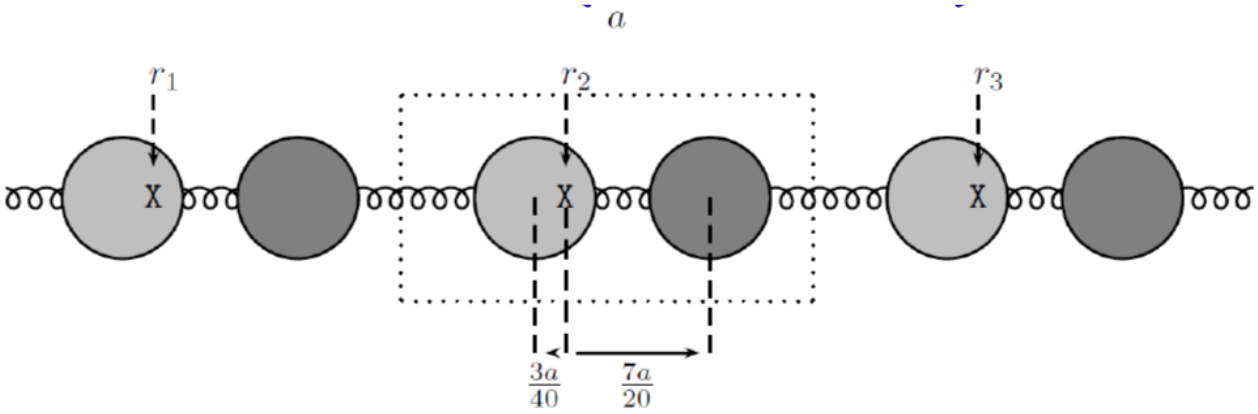
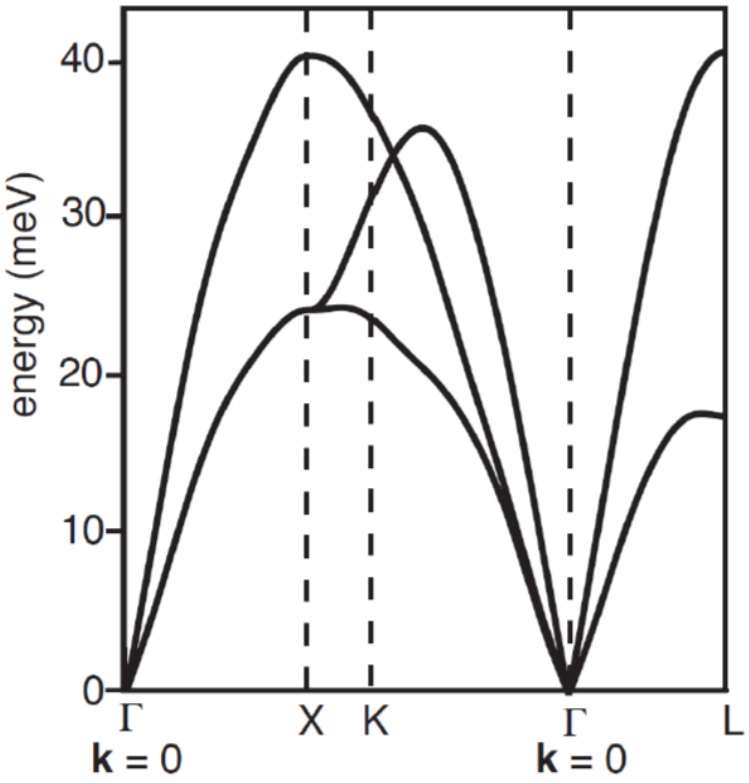
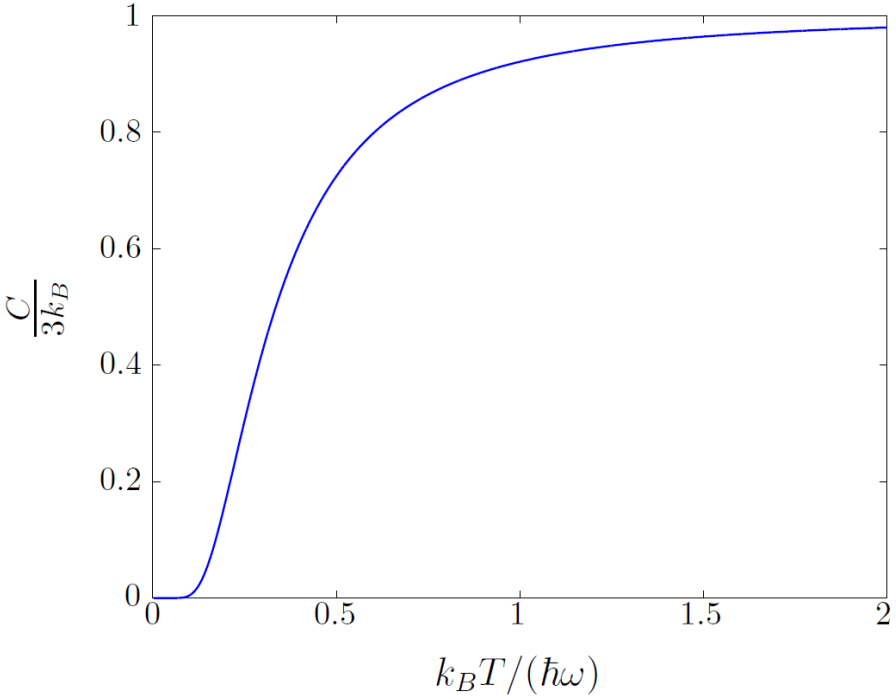
Vibration, Phonons, Heat Capacity







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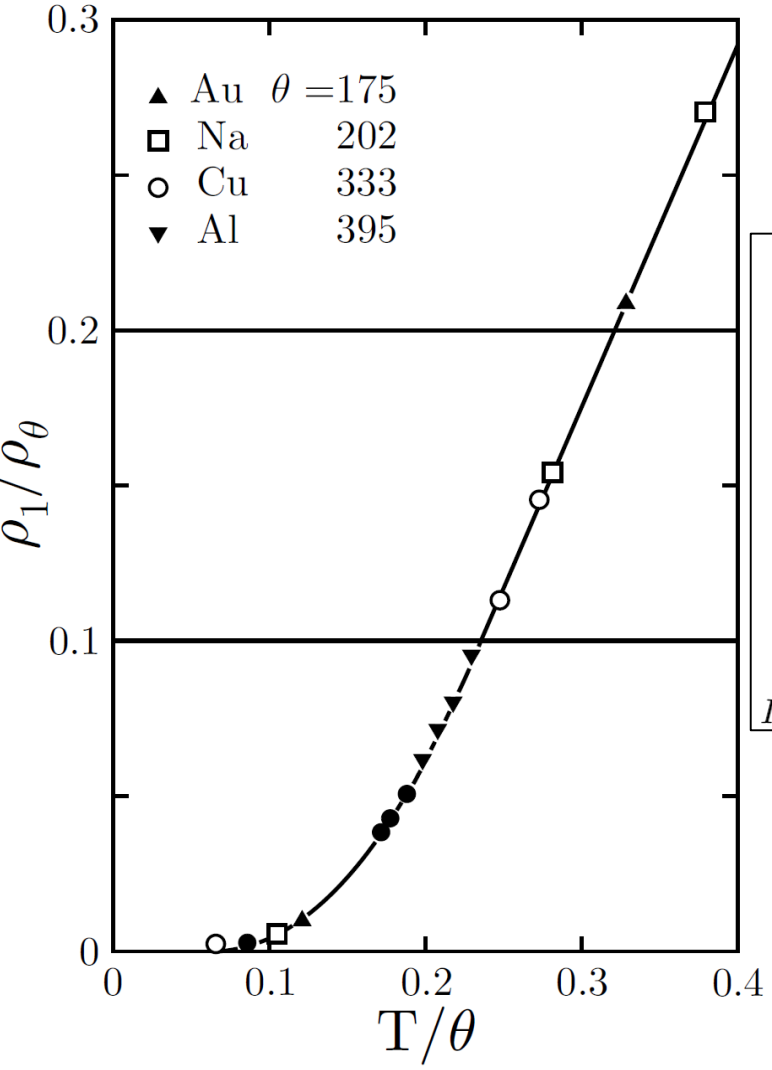
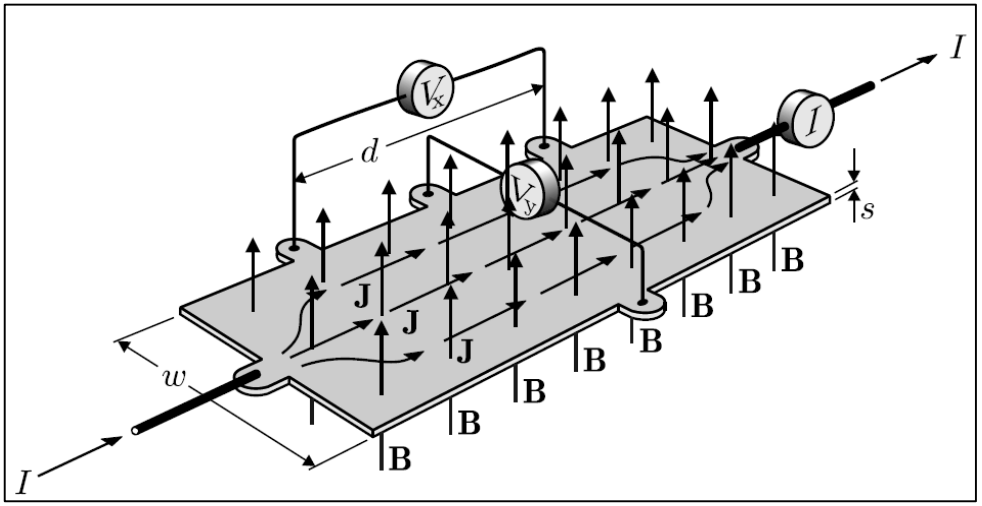
Resistivity of metals and Hall Effect





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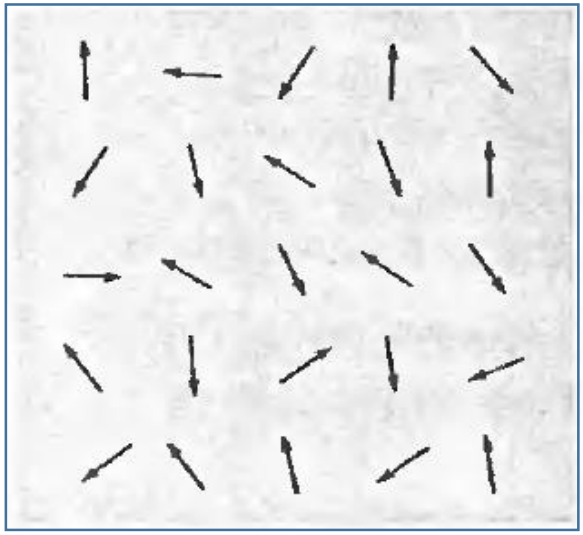

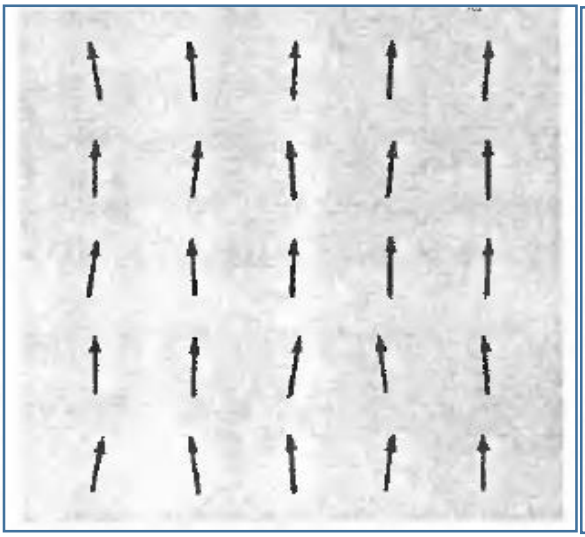

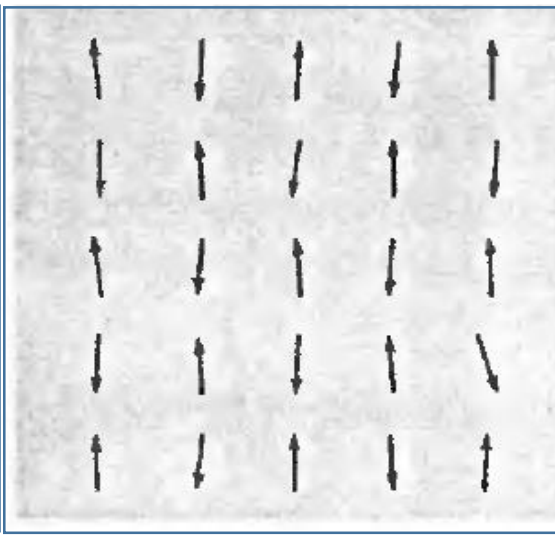

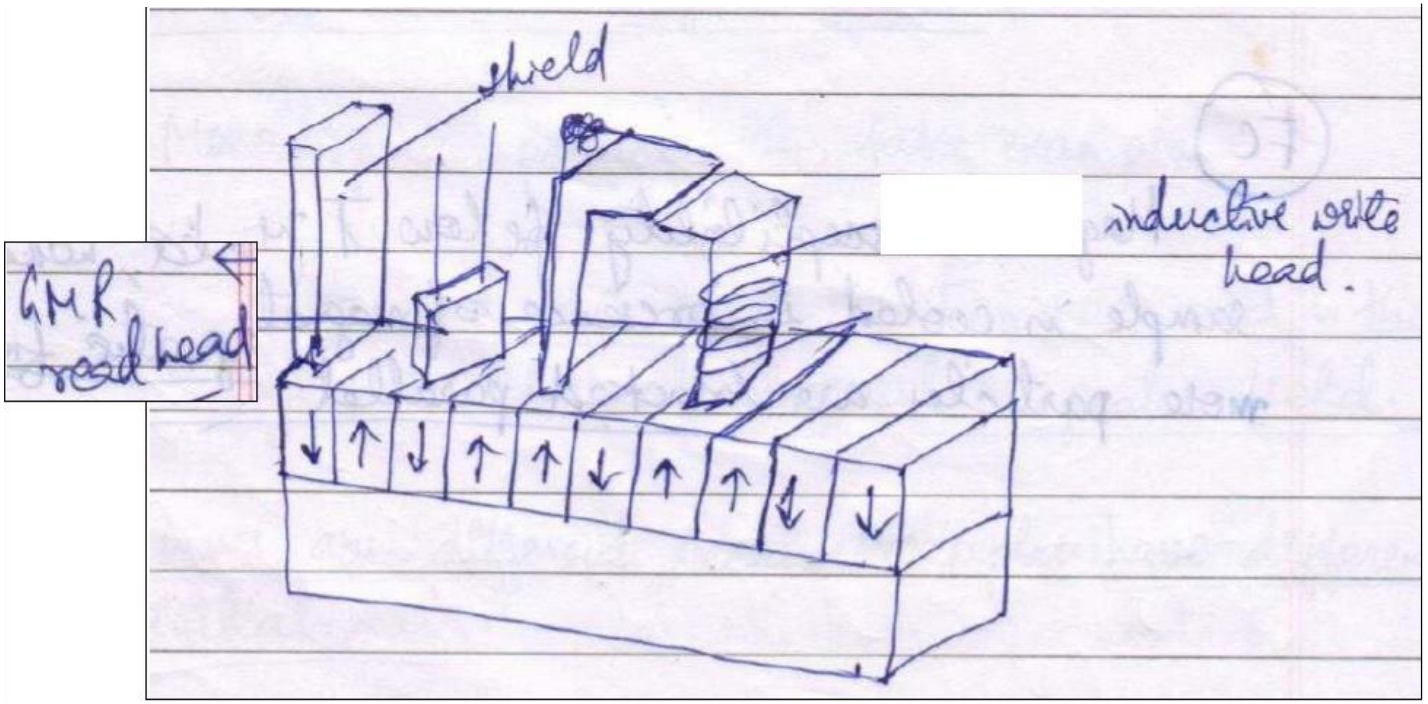

Nobel Prize 2007

References

1) Solid State Physics –
By N. W. Ashcroft and N. D. Mermin

2) Crystallography Applied To Solid State Physics –
By A. R. Verma and O. N. Srivastava

3) The Oxford Solid State Basics –
By Steven H. Simon

4) Band Theory and Electronic Properties of Solids –
J. Singleton

5) Solid State Physics –
Charles Kittel

Teachers for this course

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My Research Webpage –
https://sites.google.com/view/debrajchoudhury/home

Teaching Assistant:

Ph.D Research Scholar
To be decided (Will communicate later)