PHYS 5243

Solid State Physics

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Contents

Chapter 1 - About Condesned Matter Physics - (2015-01-09)

Syllabus

Read Chapters 1 and 2 before next lecture
Graduate Student → 15% of the grade is HW.
2 Midterms: Wednesday nights (∼ 4 hours are given to do them).
The Final counts for ∼ 25% of grade for Graduate and Undergraduate Students.
Get the other books required for class → they are important!
Graduate Studnet difference → potentially a physics simulation will be required.

Class Notes

$\boxed{\text{Solid State Physics}}$
(Condensed Matter Physics)

↪Physics of complexity → statistical physics (thermodynamics)

Collections of atoms

Somewhat under atomic physics field

Solids, liquids, and polymers

Hamiltonian:

$$\hat{H} = \underbrace{\frac{\mathbf{p_n}^2}{2M_n}}_{\substack{momentum\\ of\\ ions}} + \underbrace{\frac{\mathbf{p_e}^2}{2M_e}}_{\substack{momentum\\ of\\ electrons}} + \underbrace{\frac{e^2}{r_{i1} - r_{j1}}}_{\substack{repulsion\\ between\\ ions}} + \underbrace{\frac{e^2}{r_{i2} - r_{j2}}}_{\substack{repulsion\\ between\\ electrons}} - \underbrace{\frac{e^2}{r_{i1} - r_{j2}}}_{\substack{attraction\\ between\\ electrons\ and\ ions}}$$

At the moment only ∼100 atoms can be solved (using supercomputer) → very difficult!

Emergent phenomenon is common

Superconductivity is emergent from collection of atoms

Book Notes

1.1 - What is Condensed Matter Physics?

Number of consituents is large

interactions among constituents is strong

1.2 - Why study Condensed Matter Physics?

Good Questions

Why are metals shiny and cold?
Why is glass transparent?
Why is water fluid, why is it wet?
Why is rubber soft?

Engineering

Awesomeness

Higgs-Anderson mechanism → ties to Higgs Boson and superconductivity (Anderson coined Condensed Matter)
Renormalization group
Topological QFT → in lab of CMP
black hole string theory → CMP

reductionism doesn't work

Just accept it ..... :(

QM and Stat Mech are basis for CMP

1.3 - Why Solid State?

Subfield of CMP → very large

$\boxed{\text{Chapter 2 - Heat Capacity and Specific Heat}}$

$C = \frac{dE}{dT}$
How much energy you need to increase the temperature.
$C_v = C_p$ for solids, so we do not need to specify $C_{v,p}$ subscripts.
Heat Capacity per mole at room temperature is $3R$. (for solids)

$$R = k_B N_A$$

How do we know?
Start with the heat capacity per atom $\rightarrow$ which we get from the energy for each atom.

We construct a 3D particle in a box connected by springs along each axis and find the energy:

$$E = \underbrace{\frac{1}{2}mv_x^2 + \frac{1}{2}mv_y^2 + \frac{1}{2}mv_z^2}_{kinetic\ energy} + \underbrace{\frac{1}{2}k_x^2 + \frac{1}{2}k_y^2 + \frac{1}{2}k_z^2}_{potential\ energy}$$

Equipartition of energy
each DOF gives $\frac{1}{2}k_BT$ (but only when quadratic! (power of 2))
Therefore, for solids $\rightarrow 6]frac12k_BT = 3k_BT$.
$\Rightarrow \langle E \rangle = 3k_BT$.
and Law of Dulon Petit (1819) is $C = \frac{d\langle E \rangle}{dT} = 3k_B$ (or $3R$ for molar).