

# PHYS 5243

## Solid State Physics

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## 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).

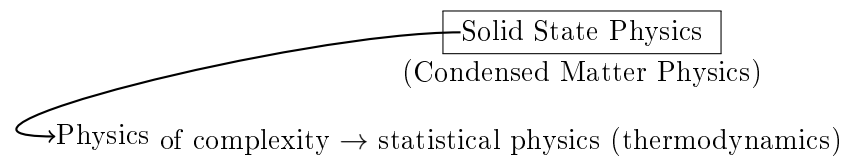
The Final counts for ~ 25% of grade for Graduate and Undergraduate Students.

Get the other books required for class → they are important!

Graduate Studnet difference → potentially a physics simulation will be required.

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### Class Notes



Collections of atoms

Somewhat under atomic physics field

Solids, liquids, and polymers

Hamiltonian:

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

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 constituents 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  $\rightarrow$  ties to Higgs Boson and superconductivity (Anderson coined Condensed Matter)

Renormalization group

Topological QFT  $\rightarrow$  in lab of CMP

black hole string theory  $\rightarrow$  CMP

### **reductionism doesn't work**

Just accept it ..... :(

## **QM and Stat Mech are basis for CMP**

### **1.3 - Why Solid State?**

Subfield of CMP  $\rightarrow$  very large

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:

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

Equipartition of energy

each DOF gives  $\frac{1}{2}k_B T$  (but only when quadratic! (power of 2))

Therefore, for solids  $\rightarrow 6 \frac{1}{2}k_B T = 3k_B T$ .

$\Rightarrow \langle E \rangle = 3k_B T$ .

and Law of Dulong Petit (1819) is  $C = \frac{d\langle E \rangle}{dT} = 3k_B$  (or  $3R$  for molar).