PHYS 5243

Solid State Physics

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Contents

Chapter 1 - About Condensed Matter Physics

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

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)

$$R = k_B N_A$$

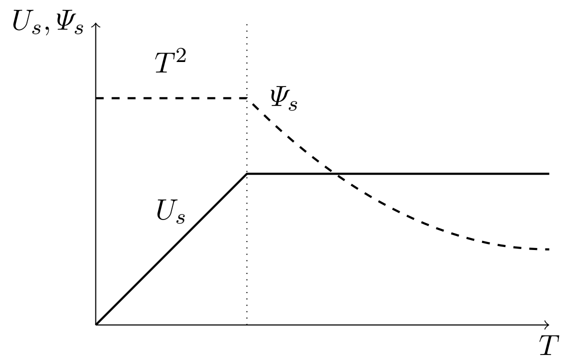
How do we know?
Start with the heat capacity per atom $\rightarrow$ which we get from the energy for each atom.

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

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

<u>Equipartition of energy</u>
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).

Temperature Dependence:



Chapter 15 - Electrons in a Periodic Potential

In Chapter 11 the tight binding method was applied to a 1 dimensional chain of atoms. The tight binding method assumes the electrons are very strongly bound to the atoms and weakly hop between sites.

Here we will do the opposite in the Nearly Free Electron model. The electrons are mostly free standing waves, but are weakly perturbed by a periodic lattice.

Nearly Free Electron Model

Completely free electrons with Hamiltonian:

$$H_0 = \frac{\mathbf{p}^2}{2m} \tag{1}$$

The eigenenergies for plane waves $|\mathbf{k}\rangle$ are:

$$\epsilon_0(\mathbf{k}) = \frac{\hbar^2|\mathbf{k}|^2}{2m} \tag{2}$$

Now a weak periodic potential perturbation is applied to the Hamiltonian:

$$H = H_0 + V(\mathbf{r}) \tag{3}$$

We know V is periodic, therefore:

$$V(\mathbf{r}) = V(\mathbf{r} + \mathbf{R}) \tag{4}$$