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Exercise for Solid State Physics for Nanoscience
SS 2019
Exercise sheet 3

3.1 Einstein Model

Einstein model of lattice heat capacity assumes that all lattice vibration modes are at the same frequency.

a) Assuming Einstein approximation, how many phonon modes (Density of States) exist for a crystal of N unit cells each containing 2 atoms.
b) Write down the total energy in the phonon representation.
c) Calculate the specific heat of phonons for this model and describe the low and high temperature behaviours.
d) Is Delong-Petit law fulfilled at high temperatures?

3.2 Brillouin Scattering

A laser beam of wavelength λ = 694 nm passes through a quartz crystal. The laser beam can be scattered by the mechanical vibrations in the crystal. An elastic interaction between photons and phonons takes place, with no recoil in the lattice. Calculate the maximum frequency of the mechanical vibrations induced in the lattice and the relative frequency change of the scattered light. Make use of momentum and energy conservation laws and the fact that the scattering is elastic (k = k'). (Speed of sound: vs = 6000 m/s, refractive index: n = 1.54)

3.3 Band Structure

Draw schematically the band structure of a 1D crystal for a_0= 5.43 Å considering a mean potential of V=1 eV and effective mass of m*=0.1 m_e. Estimate the energetic width of the 1st, 2nd and 3rd band. How it changes for a= $\sqrt{3}$ a_0 ?

3.4 Fermi-Dirac distribution

Estimate the percentage of electrons above the Fermi-energy for a cubic metal crystal with a= 5.43 Å at T=10 K and T= 1000 K.