

1. What is meant by phonons? Do phonons have mass? (2)

A phonon is a collective excitation in a periodic, elastic arrangement of atoms or molecules in condensed matter, specifically in solids and some liquids or Quantum of lattice vibration.

Acoustic phonons have an energy which is inversely proportional to their wavelength for long wavelength. Therefore, they are massless, like photons

2. What causes phonons in lattice vibration? Which crystals exhibit optical phonon modes? (3)
3. What is lattice wave? Calculate the value of cutoff frequency in a solid assuming a linear lattice. If velocity of sound in a solid is 3×10^3 m/s and interatomic distance is 5×10^{-10} m. (5)

Lattice wave is a disturbance propagated through a crystal lattice in which atoms oscillate about their equilibrium positions or A regular lattice with harmonic forces between atoms and normal modes of vibrations are called lattice waves.

Velocity and frequency related equation

$$V = v \lambda = v 2a$$

$$v = v/2a$$

Apply the known values in the equation. Critical frequency (v) = 3×10^{12} Hz.

4. What is lattice specific heat? Derive heat capacity of solid crystalline substances at room temperature is $3R$. (7)

Lattice vibration heat capacities of crystalline solids known as lattice specific heat explain two things:

1. Near room temperature, the heat capacity of most solids is around $3k$ per atom (the molar heat capacity for a solid consisting of n -atom molecules is $\sim 3nR$). This is the well-known Dulong and Petit law.
2. At low temperatures, C_v decreases, becoming zero at $T=0$. Heat capacities have a temperature dependence of the form $\alpha T^3 + \gamma T$, where the T^3 term arises from lattice vibrations, and the linear term from conduction electrons.

In classical theory, it is assumed that each atom of a crystal acts as a three-dimensional harmonic oscillator and all the atoms vibrate independent of each other. so, a system of N vibrating atoms or N independent three-dimensional harmonic oscillator is equivalent to a system of $3N$ identical and independent one-dimensional oscillator.

Therefore, the internal energy of a system of N particles is $\frac{3}{2} Nk_B T$

Monatomic particles have only 3 translational degrees of freedom. They possess no rotational or vibrational degrees of freedom. Thus, the average energy per degree of freedom is $\frac{1}{2} Nk_B T$

Each harmonic oscillator has 2 degrees of freedom and an average thermal energy of kT .

Memo For Physics Pgrade 2012

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