

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

Siddappa N.Byrareddy



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Table of Contents Memo For Physics Pgrade 2012

1. Understanding the eBook Memo For Physics Pgrade 2012
 - The Rise of Digital Reading Memo For Physics Pgrade 2012
 - Advantages of eBooks Over Traditional Books
2. Identifying Memo For Physics Pgrade 2012
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Memo For Physics Pgrade 2012
 - User-Friendly Interface
4. Exploring eBook Recommendations from Memo For Physics Pgrade 2012
 - Personalized Recommendations
 - Memo For Physics Pgrade 2012 User Reviews and Ratings
 - Memo For Physics Pgrade 2012 and Bestseller Lists

5. Accessing Memo For Physics Pgrade 2012 Free and Paid eBooks
 - Memo For Physics Pgrade 2012 Public Domain eBooks
 - Memo For Physics Pgrade 2012 eBook Subscription Services
 - Memo For Physics Pgrade 2012 Budget-Friendly Options
6. Navigating Memo For Physics Pgrade 2012 eBook Formats
 - ePub, PDF, MOBI, and More
 - Memo For Physics Pgrade 2012 Compatibility with Devices
 - Memo For Physics Pgrade 2012 Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Memo For Physics Pgrade 2012
 - Highlighting and Note-Taking Memo For Physics Pgrade 2012
 - Interactive Elements Memo For Physics Pgrade 2012
8. Staying Engaged with Memo For Physics Pgrade 2012
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Memo For Physics Pgrade 2012
9. Balancing eBooks and Physical Books Memo For Physics Pgrade 2012
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Memo For Physics Pgrade 2012
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Memo For Physics Pgrade 2012
 - Setting Reading Goals Memo For Physics Pgrade 2012
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Memo For Physics Pgrade 2012
 - Fact-Checking eBook Content of Memo For Physics Pgrade 2012
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
- Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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