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NPTEL

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Courses » Introduction to Solid State Physics

Announcements

Course

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Unit 8 - Two Atoms per Primitive Basis, Quantization of Elastic Waves, Phonon Momentum

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Course outline

How to access the portal

Introduction to Drude's free electron theory of metals, electrical conductivity Ohm's law and Hall effect

Introduction to Sommerfeld's model

Specific heat of an electron gas and the behaviour of thermal conductivity of a solid and relationship with electrical conductivity

Introduction to crystal structure and their classifications

Direct Imaging of Atomic Structure, Diffraction of Waves by Crystals, Reciprocal lattice, Brillouin Zones

Vibrations of Crystals with Monatomic Basis, Acoustic modes

Two Atoms per Primitive Basis, Quantization of Elastic Waves, Phonon Momentum

- Lattice with two atom basis: Optical Phonons
- Displacement of the atoms for the acoustic and optical Phonons
- Density of states of phonons
- Calculating the density of states of Phonons: The Einstein's and the Debye's Models
- Average energy of Phonons at Temperature T
- Debye's Model of specific heat of crystals
- Anharmonic effects in crystals: thermal expansion and Umklapp processes
- Quiz : ASSIGNMENT 7
- New Introduction to Solid State Physics : Feedback For Week 7
- Assignment 7 solutions

Bloch's theorem for wavefunction of a particle in a periodic potential, nearly free electron model, origin of energy band gaps, discussion of Bloch wavefunction

Band theory of metals, insulators and semiconductors, Kronig-Penney model, tight binding method of calculating bands, and semi-classical dynamics of a particle in a band

Introduction: Semiconductor

ASSIGNMENT 7

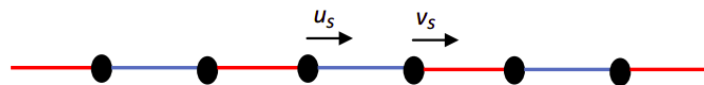
The due date for submitting this assignment has passed.
As per our records you have not submitted this assignment.

Due on 2019-03-20, 23:59 IST.

1)

1 point

Consider a one dimensional chain of atoms of mass m connected with two kinds of springs (see figure) with spring constants C_1 (shown by red line) and C_2 (shown with blue line). Denote the displacement of atom on s^{th} site with spring with constant C_1 to the left as u_s and of atom with spring with constant C_2 as v_s as shown in the figure.



The equation of motion for these atoms is then

$$m\ddot{u}_s = C_1(v_s - u_s) - C_1(u_s - v_{s-1}) \quad \& \quad m\ddot{v}_s = C_2(u_{s+1} - v_s) - C_2(v_s - u_s)$$

$$m\ddot{u}_s = C_1(v_s - u_s) - C_2(u_s - v_{s-1}) \quad \& \quad m\ddot{v}_s = C_2(u_{s+1} - v_s) - C_1(v_s - u_s)$$

$$m\ddot{u}_s = C_2(v_s - u_s) - C_1(u_s - v_{s-1}) \quad \& \quad m\ddot{v}_s = C_1(u_{s+1} - v_s) - C_2(v_s - u_s)$$

$$m\ddot{u}_s = C_2(v_s - u_s) + C_1(u_s - v_{s-1}) \quad \& \quad m\ddot{v}_s = C_1(u_{s+1} - v_s) + C_2(v_s - u_s)$$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$m\ddot{u}_s = C_2(v_s - u_s) - C_1(u_s - v_{s-1}) \quad \& \quad m\ddot{v}_s = C_1(u_{s+1} - v_s) - C_2(v_s - u_s)$$

2)

For question 1, if $C_1 < C_2$, frequency of the acoustic and optical modes at $ka = \pi$ are, respectively

1 point

$$\sqrt{\frac{C_1}{m}} \quad \text{and} \quad \sqrt{\frac{C_2}{m}}$$

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$$\sqrt{\frac{2C_1}{m}} \text{ and } \sqrt{\frac{2C_2}{m}}$$

$$\sqrt{\frac{|C_1 - C_2|}{m}} \text{ and } \sqrt{\frac{|C_1 + C_2|}{m}}$$

$$\sqrt{\frac{2|C_1 - C_2|}{m}} \text{ and } \sqrt{\frac{2|C_1 + C_2|}{m}}$$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\sqrt{\frac{2C_1}{m}} \text{ and } \sqrt{\frac{2C_2}{m}}$$

3) For question 1, the displacement ratio v_s/u_s at Brillouin zone boundary, for optical and acoustic modes are respectively

1 point

- 1 and +1
- +1 and -1
- 1 and -1
- +1 and +1

No, the answer is incorrect.

Score: 0

Accepted Answers:

-1 and +1

4) In terms of Debye temperature θ_D , the internal energy of a lattice in Debye Model is given by the universal formula (R is the universal gas constant)

1 point

$$12RT \left(\frac{T}{\theta_D}\right)^3 \int_0^{\theta_D/T} \frac{x^3}{e^x - 1} dx$$

$$9RT \left(\frac{T}{\theta_D}\right)^3 \int_0^{\theta_D/T} \frac{x^3}{e^x - 1} dx$$

$$6RT \left(\frac{T}{\theta_D}\right)^3 \int_0^{\theta_D/T} \frac{x^3}{e^x - 1} dx$$

$$3RT \left(\frac{T}{\theta_D}\right)^3 \int_0^{\theta_D/T} \frac{x^3}{e^x - 1} dx$$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$9RT \left(\frac{T}{\theta_D} \right)^3 \int_0^{\theta_D/T} \frac{x^3}{e^x - 1} dx$$

- 5) KCl has Debye temperature of 230K. Its specific heat at 5K is $3.8 \times 10^{-2} \text{ Jmol}^{-1}\text{K}^{-1}$, its specific heat at 2K will be close to

1 point

- $2.4 \times 10^{-3} \text{ Jmol}^{-1}\text{K}^{-1}$
- $0.5 \times 10^{-3} \text{ Jmol}^{-1}\text{K}^{-1}$
- $5.7 \times 10^{-3} \text{ Jmol}^{-1}\text{K}^{-1}$
- $8.7 \times 10^{-3} \text{ Jmol}^{-1}\text{K}^{-1}$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$2.4 \times 10^{-3} \text{ Jmol}^{-1}\text{K}^{-1}$$

- 6) NaCl has the same crystal structure as KCl and Debye Temperature 310K. Lattice specific heat of NaCl at 5K will be

1 point

- $2.45 \times 10^{-2} \text{ Jmol}^{-1}\text{K}^{-1}$
- $6.77 \times 10^{-2} \text{ Jmol}^{-1}\text{K}^{-1}$
- $9.07 \times 10^{-2} \text{ Jmol}^{-1}\text{K}^{-1}$
- $1.55 \times 10^{-2} \text{ Jmol}^{-1}\text{K}^{-1}$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$1.55 \times 10^{-2} \text{ Jmol}^{-1}\text{K}^{-1}$$

- 7) The following data for germanium is given:

1 point

Thermal conductivity: $80 \text{ Wm}^{-1}\text{K}^{-1}$; Debye Temperature $\theta_D=360\text{K}$; atomic weight = 72.6 and density = 5500kgm^{-3}

Mean free path of phonons in germanium at 300K using this data will be(keep in mind that in $K = \frac{1}{3} C v l$, C is the specific heat per unit volume):

- 3mm
- $30\mu\text{m}$
- 30nm
- 30\AA

No, the answer is incorrect.

Score: 0

Accepted Answers:

30nm

- 8) Debye temperature of diamond is 2000K. At 4K and at 50K its thermal conductivity is K_4 and K_{50} , respectively. Then

1 point

Thermal conductivity at both temperatures is determined by scattering by defects, sample boundary and $\frac{K_4}{K_{50}} = 5 \times 10^{-4}$

-

Thermal conductivity at 4K is determined by scattering by defects, sample boundary but at 50K it is determined by Umklapp processes.



Umklapp processes are important at both 4K and 50K



Thermal conductivity at both temperature is determined by scattering by defects, sample boundary but nothing definite can be said about their relation



No, the answer is incorrect.

Score: 0

Accepted Answers:

Thermal conductivity at both temperatures is determined by scattering by defects, sample boundary and $\frac{\kappa_4}{\kappa_{50}} = 5 \times 10^{-4}$

9)

1 point

By using Debye approximation in a one-dimensional monoatomic crystal lattice with interatomic space a and speed of sound v , the Debye temperature θ_D is

$\theta_D = \frac{hv}{k_B a}$

$\theta_D = \frac{3hv}{2k_B a}$

$\theta_D = \frac{hv}{2k_B a^2}$

$\theta_D = \frac{hv}{2k_B a}$



No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\theta_D = \frac{hv}{2k_B a}$$

10)

For the system defined in above question the specific heat C_v at temperature T is

1 point

$C_v = \frac{3\pi^2 k_B T}{2a\theta_D}$

$C_v = \frac{\pi^2 k_B T}{2a\theta_D}$

$C_v = \frac{\pi^2 k_B T}{3a\theta_D}$

$C_v = \frac{\pi^2 k_B T}{3a^2\theta_D}$



No, the answer is incorrect.

Score: 0

Accepted Answers:

$$C_v = \frac{\pi^2 k_B T}{3a\theta_D}$$

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