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NPTEL

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Courses » Introduction to Solid State Physics

Announcements Course Ask a Question Progress FAQ

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

Register for Certification exam

Course outline

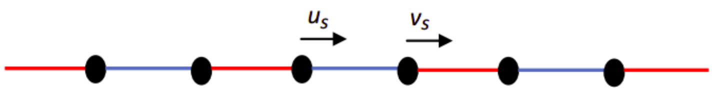
ASSIGNMENT 7

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 (se figure) with spring constants C_1 (shown by red line) and C_2 (shown with blue line). Denote th displacement of atom on sth sight with spring with constant C_1 to the left as u_s and of atom w spring with constant C_2 as v_s as shown in the figure.



The equation of motion for these atoms is then

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

No, the answer is incorrect.
Score: 0

Accepted Answers:

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

2) *1 point*

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

- $\sqrt{\frac{C_1}{m}}$ and $\sqrt{\frac{C_2}{m}}$

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

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

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

No, the answer is incorrect.
Score: 0

Accepted Answers:

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

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 3.8×10^{-2} $Jmol^{-1}K^{-1}$, its specific heat at 2K will be close to *1 point*

- 2.4×10^{-3} $Jmol^{-1}K^{-1}$
- 0.5×10^{-3} $Jmol^{-1}K^{-1}$
- 5.7×10^{-3} $Jmol^{-1}K^{-1}$
- 8.7×10^{-3} $Jmol^{-1}K^{-1}$

No, the answer is incorrect.
Score: 0
Accepted Answers:
2.4×10^{-3} $Jmol^{-1}K^{-1}$

6) NaCl has the same crystal structure as KCl and Debye Temperature 310K. Lattice specific heat of NaCl at 5K will be *1 point*

- 2.45×10^{-2} $Jmol^{-1}K^{-1}$
- 6.77×10^{-2} $Jmol^{-1}K^{-1}$
- 9.07×10^{-2} $Jmol^{-1}K^{-1}$
- 1.55×10^{-2} $Jmol^{-1}K^{-1}$

No, the answer is incorrect.
Score: 0
Accepted Answers:
1.55×10^{-2} $Jmol^{-1}K^{-1}$

7) The following data for germanium is given: *1 point*

Thermal conductivity: 80 $Wm^{-1}K^{-1}$; Debye Temperature θ_D=360K ; 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 $K = \frac{1}{3}Cvl, C$ is the specific heat per unit volume):

- 3mm
- 30μm
- 30nm
- 30Å

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 $\frac{K_4}{K_{50}} = 5 \times 10^{-4}$

9) **1 point**

By using Debye approximation in a one-dimensional monoatomic crystal lattice with interatomic spa 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) **1 point**

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

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

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

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

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

No, the answer is incorrect.
Score: 0

Accepted Answers:

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

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