



Unit 7 - Vibrations of Crystals with Monatomic Basis, Acoustic modes

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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

- Wave equation in a continuous medium and generalization to a discrete medium
- Derivation of wave equation for motion of atoms in a crystal
- Solution of the wave equation for a crystal and the relation between frequency ω and wavevector k
- Group velocity of waves and speed of sound in a crystal
- Waves in a crystal considering interaction among atoms beyond their nearest neighbours
- Normal modes in a crystal : Phonons and their momenta and energy
- Experimental determination of Phonon dispersion curves
- Quiz : Assignment 6
- Introduction to Solid State Physics : Feedback For Week 6
- Assignment 6 Solution

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

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,

Assignment 6

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

Due on 2019-03-13, 23:59 IST

1)

1 point

Of the following functions, which ones describe a traveling wave? All the letters used have their usual m

i: $e^{-(x+10t)^2/4}$

ii: $e^{-x^2}e^{-10t^2}$

iii: $\sin(x/4)\cos(t/2)$

iv: $\frac{1}{(\frac{x}{2} - \frac{t}{3})^2 + 4}$

- (i) and (ii)
- (ii) and (iv)
- (ii) and (iii)
- (i) and (iv)

No, the answer is incorrect.

Score: 0

Accepted Answers:

(i) and (iv)

2)

1 point

If $\omega^2 = \omega_p^2 + c^2k^2$ for light wave in a plasma, where ω_p and c are constants, the group velocity of light in plasma is ,

- $\omega(k)/k$
- $kc/\omega(k)$
- $\omega(k)/kc^2$
- $kc^2/\omega(k)$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$kc^2/\omega(k)$

3)

1 point

Consider point on of mass m and charge e immersed in a uniform sea of conduction electrons. These are equilibrium at lattice points. If one ion is displaced from its equilibrium position by a distance r , the force on it is mainly due to electronic charge within the sphere of radius r . In that case, frequency of os of an ion will be (Take the number density of ions to be $\frac{3}{4\pi R^3}$),

- $\sqrt{\frac{e^2}{4\pi\epsilon_0 m R^3}}$
- $\sqrt{\frac{e^2}{\epsilon_0 m R^3}}$
- $\sqrt{\frac{3e^2}{4\pi\epsilon_0 m R^3}}$
- $\sqrt{\frac{3e^2}{\epsilon_0 m R^3}}$

Physics
Magnetism in materials
Superconductivity
Solutions of Assignments

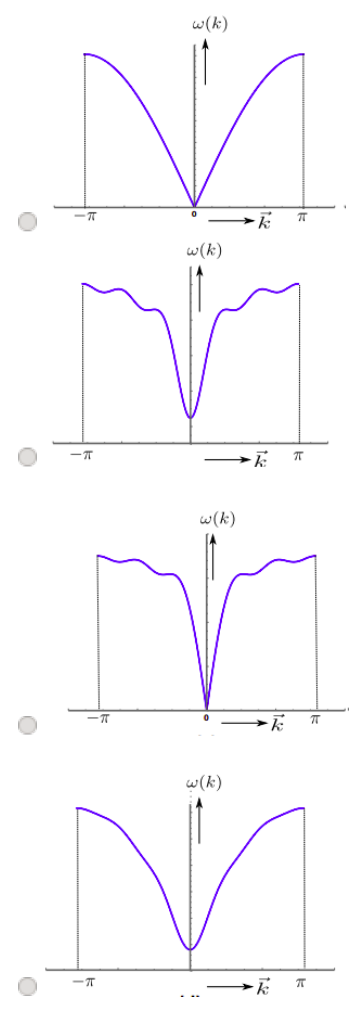
4) 1 point
 For sodium $R = 4a_0$, where a_0 is the Bohr radius. Using result of question 3, the speed of sound in ms^{-1} will be in the range ,

- 0 - 500
- 500 - 1000
- 1000 - 2000
- Greater than 2000

No, the answer is incorrect.
 Score: 0

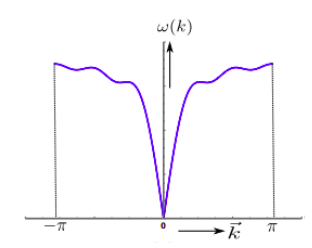
Accepted Answers:
 Greater than 2000

5) 1 point
 Suppose that the interaction coefficient in a one-dimensional crystal is non zero for atoms beyond nearest n and is of the form $c_s \propto 1/|s|$ for $s = 1, 2, \dots, 5$. In that case the dispersion curve will appear as (use a c to generate the points),



No, the answer is incorrect.
 Score: 0

Accepted Answers:



6) 1 point

Consider a long chain of atoms of mass m in a one-dimensional crystal performing vibrations in longitudinal direction. The displacement of atoms is given as $Ae^{i(ksa-wt)}$ with all symbols having their standard meaning. Then the momentum carried by N atoms will be proportional to,

- N
 $\sin(Nka)/\sin(ka)$
 $\sin(Nka/2)/\sin(ka/2)$
 Nka

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\sin(Nka/2)/\sin(ka/2)$$

7) De Broglie Wavelength of a thermal neutron carrying energy corresponding to 300K is,

1 point

- 0.5 Å
 1.0 Å
 1.5 Å
 2.0 Å

No, the answer is incorrect.

Score: 0

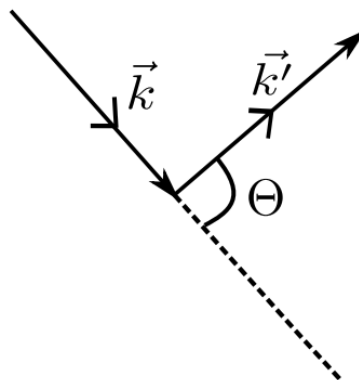
Accepted Answers:

$$1.5 \text{ \AA}$$

8)

1 point

Consider a light wave of frequency ω travelling in a crystal of refractive index n (since wavelength of light is larger than the spacing between atoms, one can talk about refractive index). Its wavevector in the medium is \vec{k} . After exciting a phonon of frequency ω_q and wavevector \vec{q} , it changes to \vec{k}' with the scattering angle θ (see figure),



Considering energy conservation and the conservation rule $\vec{k} = \vec{q} + \vec{k}'$, which of the following describe the relationship describing the scattering event,

- $q^2 c^2 = 4\omega(\omega - \omega_q) \sin^2(\frac{\theta}{2}) + \omega_q^2$
 $n^2 q^2 c^2 = 4\omega(\omega - \omega_q) \sin^2(\frac{\theta}{2}) + \omega_q^2$
 $\frac{q^2 c^2}{n^2} = 4\omega(\omega - \omega_q) \sin^2(\frac{\theta}{2}) - \omega_q^2$
 $\frac{q^2 c^2}{n^2} = 4\omega(\omega - \omega_q) \sin^2(\frac{\theta}{2}) + \omega_q^2$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\frac{q^2 c^2}{n^2} = 4\omega(\omega - \omega_q) \sin^2(\frac{\theta}{2}) + \omega_q^2$$

9)

1 point

If a 532 nm laser light is incident in a solid of refractive index of 2.1 and a small fraction of photons scattering after exciting an acoustic phonon. What is the magnitude of the wavevector of the phonon and the change in the wavelength of light if the scattering angle is 90° and the speed of sound in the is 5000 ms^{-1} (to calculate the wavevector of phonon, you may neglect the energy of phonon in the question 8),

- $q = 0.5 \text{ \AA}^{-1}$ and $\delta\lambda = 5 \text{ nm}$
 $q = 0.05 \text{ \AA}^{-1}$ and $\delta\lambda = 0.10 \text{ nm}$
 $q = 0.0017 \text{ \AA}^{-1}$ and $\delta\lambda = 0.026 \text{ nm}$
 $q = 5 \text{ \AA}^{-1}$ and $\delta\lambda = 0.0 \text{ nm}$

No, the answer is incorrect.

Score: 0

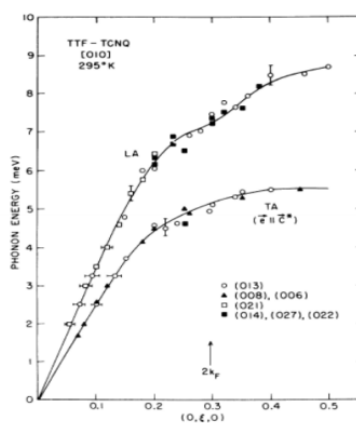
Accepted Answers:

$$q = 0.0017 \text{ \AA}^{-1} \text{ and } \delta\lambda = 0.026 \text{ nm}$$

10)

1 point

Given below is the experimentally determined curve for phonon energy $\omega(k)$ versus the wavevector k TCNQ at 295K along the (010) direction which is the direction of the one-dimensional conductor chain et al., Phys. Rev. B 14, 2325 (1976)]. If the reciprocal lattice constant is $1.646/\text{\AA}$ along the chain direction of sound along this direction will be close to,



- 1200
 2500
 3200
 4400

No, the answer is incorrect.

Score: 0

Accepted Answers:

3200

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