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NPTEL

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Courses » Introduction to Solid State Physics

Announcements Course Ask a Question Progress FAQ

Unit 10 - 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

Register for Certification exam

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

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

Band theory of metals, insulators and semiconductors

Kronig-Penney model

Bloch wavefunction as a linear combination of atomic orbitals: Tight Binding Model-I

Tight Binding Model-II

Semiclassical dynamics of a particle in a band and Bloch oscillations

Experimental observations of Bloch oscillations

Quiz : Assignment 9

Introduction to Solid State Physics : Feedback For Week 9

Introductory Semiconductor Physics

Magnetism in materials

Superconductivity

Solutions of Assignments

Assignment 9

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

Due on 2019-04-03, 23:59 IST.

1)

1 point

In free electron model energy $E(\vec{k})$, for an arbitrary wavevector \vec{k} on the Bragg plane, measured at $\vec{k}/2$, is given by $E(\vec{k}) = E_{\vec{k}/2} + E_{\vec{k}}$. In case of weak periodic potential, the expression for modified energy is $E_{modified}(\vec{k}) = E_{\vec{k}/2} + E_{\vec{k}} \pm |U_{\vec{k}}|$. For $E_{modified}(\vec{k})$, Fermi surface intersects with the Bragg plane at two points with radius r_1 and r_2 . Difference between the area enclosed by the circles of radius r_1 and r_2 is

- $4m\pi U_K$
- $2m\pi U_K$
- $m\pi U_K$
- $8m\pi U_K$

No, the answer is incorrect.

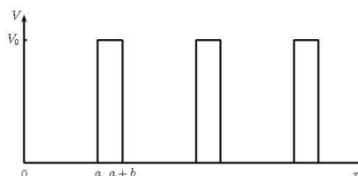
Score: 0

Accepted Answers:

 $4m\pi U_K$

2)

1 point



In the potential model used in connection with Kronig-Penney calculation, if the potential is allowed to be infinitely large i.e. $V_0 \rightarrow \infty$ and $b \rightarrow 0$ (delta function potential) in such a way that $V_0 b$ remains finite then allowed energy values are given by the equation

$$\frac{P \sin(aa)}{aa} + \cos(aa) = \cos(ka) \quad \text{where } P = \frac{mV_0 ab}{\hbar^2} \dots (1)$$

If P is large (but not infinite) then what happens?

- The allowed bands are narrower and the forbidden bands are wider
- The allowed bands are wider and the forbidden bands are narrower
- Band reduces to one single energy level
- Can't say anything

No, the answer is incorrect.

Score: 0

Accepted Answers:

The allowed bands are narrower and the forbidden bands are wider

3)

1 point

In equation (1) if P is very small. Then it leads to

- Tight binding model
- Free electron model
- Intermediate case
- Can't say anything

No, the answer is incorrect.

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The energy wave vector dispersion relation for a one-dimensional crystal of lattice constant a is given by

$$E(k) = E_0 - \alpha - 2\beta \cos(ka), \text{ where } E_0, \alpha, \beta \text{ are constants}$$

The effective mass m^* of the electron at the bottom and at the top of the band are-

- $\frac{\hbar^2}{2\beta\alpha^2}$ and $\frac{\hbar^2}{2\beta\alpha^2}$
- $\frac{\hbar^2}{2\beta\alpha^2}$ and $-\frac{\hbar^2}{2\beta\alpha^2}$
- $\frac{\hbar^2}{2\alpha^2}$ and $-\frac{\hbar^2}{2\beta\alpha^2}$
- $\frac{\hbar^2}{\beta\alpha^2}$ and $-\frac{\hbar^2}{\beta\alpha^2}$

No, the answer is incorrect.
Score: 0

Accepted Answers:

$$\frac{\hbar^2}{2\beta\alpha^2} \text{ and } -\frac{\hbar^2}{2\beta\alpha^2}$$

5)

1 point

For the Kronig–Penney model with $P (= \frac{mV_0ba}{\hbar^2}) \ll 1$, at $K = 0$, the energy of the lowest energy band is approximately

- $E_0 \approx P \frac{\hbar^2}{md^2}$
- $E_0 \approx P \frac{\hbar}{mb^2}$
- $E_0 \approx P \frac{\hbar^2}{md}$
- $E_0 \approx P \frac{\hbar^2}{ma^2}$

No, the answer is incorrect.
Score: 0

Accepted Answers:

$$E_0 \approx P \frac{\hbar^2}{md^2}$$

6)

1 point

Imagine a 1D crystal with an energy band described by $E(K) = E_B + (E_T - E_B) \sin^2\left(\frac{Kd}{2}\right)$; (E_T and E_B are top and bottom of band) where that contains only a single electron. Effective mass depends on K as

- $\frac{\hbar^2}{d^2 \cos(Kd)}$
- $\frac{\hbar^2}{d \cos(Kd)}$
- $\frac{\hbar^2}{d^2 \cos(Kd/2)}$
- $\frac{2\hbar^2}{d^2 \cos(Kd)}$

No, the answer is incorrect.
Score: 0

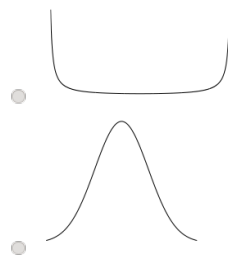
Accepted Answers:

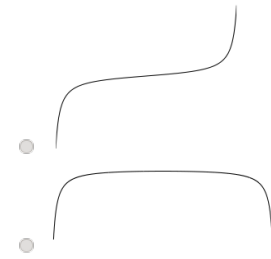
$$\frac{2\hbar^2}{d^2 \cos(Kd)}$$

7)

1 point


In Problem 6, effective mass depends on K . Which graph best describe dependence of effective mass on K (in the range $-\pi/2$ to $\pi/2$):





No, the answer is incorrect.
Score: 0

Accepted Answers:



8) 1 point

If the lattice spacing is 2 \AA and the field strength is 200 N/C , what is the period of oscillation:

- 97 MHz
- 61 MHz
- 55 MHz
- 10 MHz

No, the answer is incorrect.
Score: 0

Accepted Answers:

61 MHz

9) 1 point

If force F is applied, what will be amplitude of oscillation if the band width is Δ

- $\Delta/2F$
- Δ/F
- $\Delta/4F$
- $2\Delta F$

No, the answer is incorrect.
Score: 0

Accepted Answers:

$\Delta/2F$

10) 1 point

In a cubic lattice the nearest neighbour lattice sites are $(\pm a, 0, 0)$, $(0, \pm a, 0)$ and $(0, 0, \pm a)$. The dispersion relation is given by

$$E(k) = E_0 - 2t(\cos(k_x a) + \cos(k_y a) + \cos(k_z a))$$

Considering hopping parameters are the same in all directions: $t_a = t$, the width of the band is given by

- $12t$
- 0
- $-12t$
- $6t$

No, the answer is incorrect.
Score: 0

Accepted Answers:

$12t$

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