

Unit 9 - 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

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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

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

- Going beyond free electron model: Periodic crystal potential and Bloch's theorem for the wavefunction
- Applying perturbation theory to free electron wavefunctions and nearly free electron model
- Applying perturbation theory to free electron wavefunctions and creation of energy gap at zone boundaries
- Mixing of plane waves to get Bloch Wavefunction - I
- Mixing of plane waves to get Bloch Wavefunction - II
- Equivalence of wave vectors k and $k+G$ and reduced zone scheme
- Applying periodic boundary condition to Bloch wavefunction and counting the number of states
- Quiz : Assignment 8
- Introduction to Solid State Physics : Feedback For Week 8

Assignment 8

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

Due on 2019-03-27, 23:59 IST.

1) 1 point
Consider the wavefunction $\Psi(x) = C_0 e^{ikx} + C_1 e^{i(k+G)x} + C_{-1} e^{i(k-G)x}$ where $G = \frac{2\pi}{a}$ for a particle m moving in a periodic potential $V(x) = V_0 \cos(Gx)$ in a one-dimensional crystal of periodicity a . corresponding Hamiltonian is diagonalised, the resulting equation for the energy E is, (here, $E_0 = E_{\pm} = \frac{\hbar^2(k \pm G)^2}{2m}$)

- $(E_0 - E)(E_1 - E)(E_{-1} - E) - (E_1 - E)|V_G|^2 + (E_{-1} - E)|V_G|^2 = 0$
- $(E_0 - E)(E_1 - E)(E_{-1} - E) + (E_1 - E)|V_G|^2 - (E_{-1} - E)|V_G|^2 = 0$
- $(E_0 - E)(E_1 - E)(E_{-1} - E) + (E_1 - E)|V_G|^2 + (E_{-1} - E)|V_G|^2 = 0$
- $(E_0 - E)(E_1 - E)(E_{-1} - E) - (E_1 - E)|V_G|^2 - (E_{-1} - E)|V_G|^2 = 0$

No, the answer is incorrect.

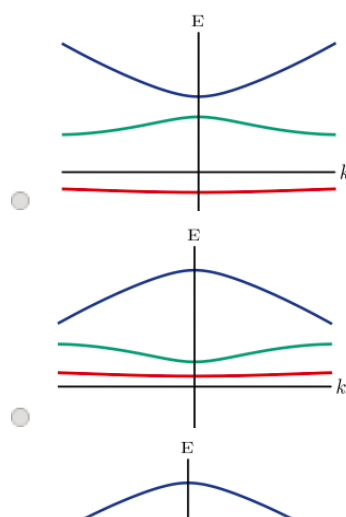
Score: 0

Accepted Answers:

$$(E_0 - E)(E_1 - E)(E_{-1} - E) - (E_1 - E)|V_G|^2 - (E_{-1} - E)|V_G|^2 = 0$$

2) 1 point
{Note : The equation above can be solved easily using a computer or a programmable calculator by over the energies E and finding those which satisfy the equation (for this value of zero is to be taken small values; you would have to experiment a bit with your calculations for this). Answer up to question based on this by taking $a = m = \hbar = 1, V_0 = \frac{G^2}{2}$. }

The band structure for question 1 is given as



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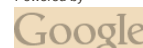
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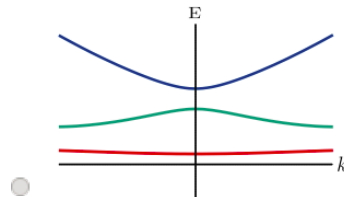
and semi-classical dynamics
of a particle in a band

Introductory Semiconductor
Physics

Magnetism in materials

Superconductivity

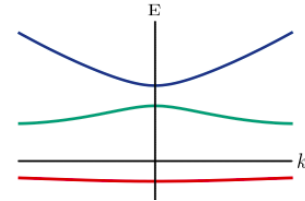
Solutions of Assignments



No, the answer is incorrect.

Score: 0

Accepted Answers:



3) For question 1, the lowest value of energy in the first band is close to

1 point

- 12
- 7
- 7
- 12

No, the answer is incorrect.

Score: 0

Accepted Answers:

-7

4) The highest value of energy in the second band is close to

1 point

- 20
- 28
- 80
- 50

No, the answer is incorrect.

Score: 0

Accepted Answers:

20

5) The energy band gap between the first and the second band is close to

1 point

- 25
- 19
- 10
- 13

No, the answer is incorrect.

Score: 0

Accepted Answers:

19

6) The energy band gap between the second and the third band is close to

1 point

- 15
- 25
- 12
- 7

No, the answer is incorrect.

Score: 0

Accepted Answers:

7

7) When free electron energy is plotted in the reduced zone scheme, the ratio of the energy width of the third band to that of the second band is

1 point

- 5/3
- 3/2
- 5/4
- 3/4

No, the answer is incorrect.

Score: 0

Accepted Answers:

5/3

8) In a simple square lattice, the kinetic energy of a free electron at the corner of the first 1 point
zone is higher than that of
the midpoint of the side of the first zone by a factor of f . The value of f is close to

- 3
 1.4
 1
 2

No, the answer is incorrect.

Score: 0

Accepted Answers:

2

9) Consider a two dimensional square lattice with the crystal potential $V(x, y) = -4U \cos(2\pi x/a) \cos(2\pi y/a)$ 1 point
 $U > 0$. Take, $G_x = G_y = \frac{2\pi}{a}$, $G_{11} = G_x \hat{i} + G_y \hat{j}$, $G_{11'} = G_x \hat{i} - G_y \hat{j}$, $G_{1'1} = -G_x \hat{i} - G_y \hat{j}$, and $G_{1',1} = -G_x \hat{i} + G_y \hat{j}$.

Then

- $V_{G_x} = V_{G_y} = 0$ and $V_{G_{11}} = V_{G_{1'1}} = V_{G_{11'}} = V_{G_{1'1'}} = -U$
 $V_{G_x} = V_{G_y} = -4U$ and $V_{G_{11}} = V_{G_{1'1}} = V_{G_{11'}} = V_{G_{1'1'}} = 0$
 $V_{G_x} = V_{G_y} = 0$ and $V_{G_{11}} = V_{G_{1'1}} = V_{G_{11'}} = V_{G_{1'1'}} = 2U$
 $V_{G_x} = V_{G_y} = -U$ and $V_{G_{11}} = V_{G_{1'1}} = V_{G_{11'}} = V_{G_{1'1'}} = -U$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$V_{G_x} = V_{G_y} = 0$ and $V_{G_{11}} = V_{G_{1'1}} = V_{G_{11'}} = V_{G_{1'1'}} = -U$

10) The energy gap between the at the corner point of the Brillouin zone will be 1 point

- $2U$
 $4U$
 U
 0

No, the answer is incorrect.

Score: 0

Accepted Answers:

$2U$

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