PhysicsByAaryan

CSIR NET . GATE . JEST . BARC - Physics

Tight binding model - CSIR NET Physics PYQs

Solid State Physics . All PYQs (2015-2025) with answer key

12 questions . Answer key included

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Q1. [Dec 2015] . 5.0 marks

Solid State Physics > Tight binding model

CSIR NET	2015 Dec	5 M

The dispersion relation of electrons in a 3 -dimensional lattice in the tight binding approximation is given by,

$$\varepsilon_k = \alpha\cos k_x a + \beta\cos k_y a + \gamma\cos k_z a$$

where a is the lattice constant and α, β, γ are constants with dimension of energy. The effective mass tensor at the corner of the first Brillouin zone $\left(\frac{\pi}{a}, \frac{\pi}{a}, \frac{\pi}{a}\right)$ is

1. $\frac{\hbar^2}{a^2}\begin{pmatrix} -\frac{1}{\alpha} & 0 & 0 \\ 0 & -\frac{1}{\beta} & 0 \\ 0 & 0 & \frac{1}{\gamma} \end{pmatrix}$

2. $\frac{\hbar^2}{a^2}\begin{pmatrix} -\frac{1}{\alpha} & 0 & 0 \\ 0 & -\frac{1}{\beta} & 0 \\ 0 & 0 & -\frac{1}{\gamma} \end{pmatrix}$

3. $\frac{\hbar^2}{a^2}\begin{pmatrix} \frac{1}{\alpha} & 0 & 0 \\ 0 & \frac{1}{\beta} & 0 \\ 0 & 0 & \frac{1}{\gamma} \end{pmatrix}$

4. $\frac{\hbar^2}{a^2}\begin{pmatrix} \frac{1}{\alpha} & 0 & 0 \\ 0 & \frac{1}{\beta} & 0 \\ 0 & 0 & -\frac{1}{\gamma} \end{pmatrix}$

Q2. [Dec 2015] . 5.0 marks

Solid State Physics > Tight binding model

CSIR NET	2015 Dec	5 M

For an electron moving through a one-dimensional periodic lattice of periodicity a, which of the following corresponds to an energy eigenfunction consistent with Bloch's theorem?

1. $\psi(x) = A\exp\left(i\left[\frac{\pi X}{a} + co\,s\left(\frac{\pi X}{2a}\right)\right]\right)$
2. $\psi(x) = A\exp\left(i\left[\frac{\pi x}{a} + co\,s\left(\frac{2\pi x}{a}\right)\right]\right)$
3. $\psi(x) = A\exp\left(i\left[\frac{2\pi x}{a} + i\cosh\left(\frac{2\pi x}{a}\right)\right]\right)$
4. $\psi(x) = A\exp\left(i\left[\frac{\pi x}{a} + i\left|\frac{\pi x}{2a}\right|\right]\right)$

Q3. [Dec 2016] . 5.0 marks

Solid State Physics > Tight binding model

CSIR NET	2016 Dec	5M

Consider a one-dimensional chain of atoms with lattice constant a. The energy of an electron with wave-vector k is $\epsilon(k) = \mu - \gamma\cos(ka)$, where μ and γ are constants. If an electric field E is applied in the positive x-direction, the time dependent velocity of an electron is (In the following B is the constant)

1. proportional to $\cos\left(B - \frac{eE}{\hbar}at\right)$
2. proportional to E
3. independent of E
4. proportional to $\sin\left(B - \frac{eE}{\hbar}at\right)$

Q4. [June 2016] . 5.0 marks

Solid State Physics > Tight binding model

CSIR NET	2016 June	5M

The band energy of an electron in a crystal for a particular k-direction has the form

$\varepsilon(k) = A - B\cos 2ka$, where A and B are positive constants and $0 < ka < \pi$. The electron has a hole-like behaviour over the following range of k :

1. $\frac{\pi}{4} < ka < \frac{3\pi}{4}$
2. $\frac{\pi}{2} < ka < \pi$
3. $0 < ka < \frac{\pi}{4}$
4. $\frac{\pi}{2} < ka < \frac{3\pi}{4}$

Q5. [Dec 2017] . 5.0 marks

Solid State Physics > Tight binding model

CSIR NET	2017 Dec	5M

A metallic nanowire of length l is approximated as a one-dimensional lattice of N atoms with lattice spacing a. If the dispersion of electrons in the lattice is given as $E(k) = E_0 - 2t\cos ka$, where E_0 and t are constants, then the density of states inside the nanowire depends on E as

1. $N^3\sqrt{\frac{t^2}{E-E_0}}$
2. $\sqrt{\left(\frac{E-E_0}{2t}\right)^2 - 1}$
3. $N^3\sqrt{\frac{E-E_0}{t^2}}$
4. $\frac{N}{\sqrt{(2t)^2-(E-E_0)^2}}$

Q6. [Dec 2018] . 5.0 marks

Solid State Physics > Tight binding model

CSIR NET	2018 Dec	5M

The dispersion relation of optical phonons in a cubic crystal is given by $\omega(k) = \omega_0 - ak^2$ where ω_0 and a are positive constants. The contribution to the density of states due to these phonons with frequencies just below ω_0 is proportional to

1. $(\omega_0 - \omega)^{1/2}$
2. $(\omega_0 - \omega)^{3/2}$
3. $(\omega_0 - \omega)^2$
4. $(\omega_0 - \omega)$

Q7. [June 2019] . 5.0 marks

Solid State Physics > Tight binding model

CSIR NET	2019 June	5M

Consider an array of atoms in one dimension with an ensemble averaged periodic density distribution as shown in the figure.

If k is the wave number and $S(k,\Delta)$ denotes the Fourier transform of the density-density correlation function, the ratio $\frac{S(k,\Delta)}{S(k,0)}$ is

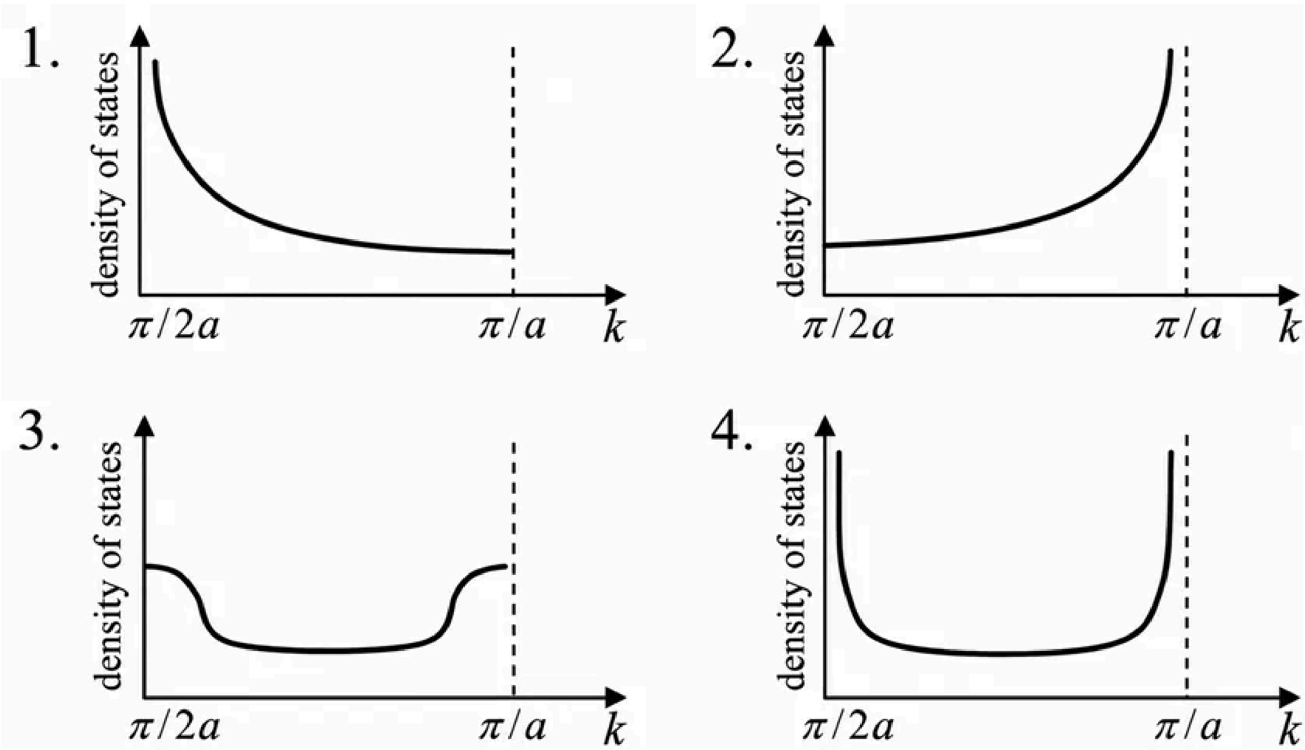
1. $\cos\left(\frac{k\Delta}{2}\right)$
2. $\cos^2\left(\frac{k\Delta}{2}\right)$
3. $\frac{2}{k\Delta}\sin\left(\frac{k\Delta}{2}\right)$
4. $\frac{4}{k^2\Delta^2}\sin^2\left(\frac{k\Delta}{2}\right)$

Q8. [June 2020] . 5.0 marks

Solid State Physics > Tight binding model

CSIR NET	2020 June	5M

A tight binding model of electrons in one dimension has the dispersion relation $\varepsilon(k) = -2t(1 - \cos ka)$, where $t > 0$, a is the lattice constant and $-\frac{\pi}{a} < k < \frac{\pi}{a}$. Which of the following figures best represents the density of states over the range $\frac{\pi}{2a} \leq k < \frac{\pi}{a}$?



Q9. [Dec 2024] . 5.0 marks
Solid State Physics > Tight binding model

CSIR NET	2024 Dec	5M

Consider N mutually non-interacting electrons moving in a crystal where the ionic potential seen by an electron satisfies the condition $V(\vec{r}) = V(\vec{r} + \vec{R})$, where $\vec{R}$ is one of the lattice translation vectors. The energy eigenstates of the electrons are labelled as $\psi_{\vec{k}}(\vec{r})$ where $\vec{k}$ is a vector in the first Brillouin zone. Which of the following is true?

1. $|\psi_{\vec{k}}(\vec{r})|$ is constant.
2. $\psi_{\vec{k}}(\vec{r})$ is also an eigenstate of the momentum operator.
3. $\psi_{\vec{k}}(\vec{r}) = \psi_{\vec{k}}(\vec{r} + \vec{R})$
4. $|\psi_{\vec{k}}(\vec{r})| = |\psi_{\vec{k}}(\vec{r} + \vec{R})|$

Q10. [June 2024] . 5.0 marks
Solid State Physics > Tight binding model

CSIR NET	2024 June	5M

The band dispersion of electrons in a two-dimensional square lattice (lattice constant a) is given by,

$$E(k_x, k_y) = -2(t_x \cos k_x a + t_y \cos k_y a)$$

where $t_x, t_y > 0$. The effective mass tensor $m^* = \begin{pmatrix} m_{xx} & m_{xy} \\ m_{yx} & m_{yy} \end{pmatrix}$ of electrons at $\vec{k} = \left(\frac{\pi}{a}, \frac{\pi}{a}\right)$ is

1. $\begin{pmatrix} 0 & \frac{\hbar^2}{2a^2\sqrt{t_x t_y}} \\ \frac{\hbar^2}{2a^2\sqrt{t_x t_y}} & 0 \end{pmatrix}$

2. $\begin{pmatrix} \frac{\hbar^2}{2a^2 t_x} & 0 \\ 0 & \frac{\hbar^2}{2a^2 t_y} \end{pmatrix}$

3. $\begin{pmatrix} -\frac{\hbar^2}{2a^2 t_x} & 0 \\ 0 & -\frac{\hbar^2}{2a^2 t_y} \end{pmatrix}$

4. $\begin{pmatrix} 0 & -\frac{\hbar^2}{2a^2(t_x + t_y)} \\ -\frac{\hbar^2}{2a^2(t_x + t_y)} & 0 \end{pmatrix}$

Q11. [Dec 2025] . 5.0 marks

Solid State Physics > Tight binding model

CSIR NET	2025 Dec	5M	SSP

In a one-dimensional chain of atoms, the phonon energy dispersion is given by $E = A|\sin(ka)|$. Here, A is a constant, k is a vector in the reciprocal space and a is lattice spacing. The density of states is proportional to

1. $\frac{1}{\sqrt{A^2-E^2}}$
2. $\frac{1}{\sqrt{A^2+E^2}}$
3. $\frac{1}{\sqrt{A-E}}$
4. $\frac{1}{\sqrt{A+E}}$

Q12. [Dec 2025] . 5.0 marks

Solid State Physics > Tight binding model

CSIR NET	2025 Dec	5M	SSP

Consider a one-dimensional chain of atoms with lattice constant a. The energy of an electron with wave-vector k is $\epsilon(k) = \mu - 2\gamma\cos(ka)$, where μ and γ are constants. If an electric field $\vec{E}$ is applied along the chain, the time dependent velocity of the electron is proportional to (assume initial wave vector $k = k_0$ at $t = 0$)

1. $\sin^2\left(k_0 a - \frac{eEa}{\hbar}t\right)$.
2. $\cos\left(k_0 a - \frac{eEa}{\hbar}t\right)$.
3. $\sin\left(k_0 a - \frac{eEa}{\hbar}t\right)$.
4. $\cos^2\left(k_0 a - \frac{eEa}{\hbar}t\right)$.

Answer Key

12 questions . Subject and topic for quick revision

Q. No	Subject	Topic	Answer
Q1	Solid State Physics	Tight binding model	**3**
Q2	Solid State Physics	Tight binding model	**2**
Q3	Solid State Physics	Tight binding model	**1 or 4**
Q4	Solid State Physics	Tight binding model	**1**
Q5	Solid State Physics	Tight binding model	**4**
Q6	Solid State Physics	Tight binding model	**1**
Q7	Solid State Physics	Tight binding model	**3**
Q8	Solid State Physics	Tight binding model	**2**
Q9	Solid State Physics	Tight binding model	**4**
Q10	Solid State Physics	Tight binding model	**3**
Q11	Solid State Physics	Tight binding model	**1**
Q12	Solid State Physics	Tight binding model	**3**

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