ENGINEERING PHYSICS

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➢ *Suggested Reading*

1. *Concepts of Modern Physics, Arthur Beiser, Chapter 10*
2. *Solid state Physics, S.O Pillai, Chapter 6*
3. *Learning material prepared by the department-Unit III*

➢ *Reference Videos*

1. *https://nptel.ac.in/courses/115/104/115104109/*

Class #31

- *Kronig Penny model,*
- *Allowed energy zones/energy bands*

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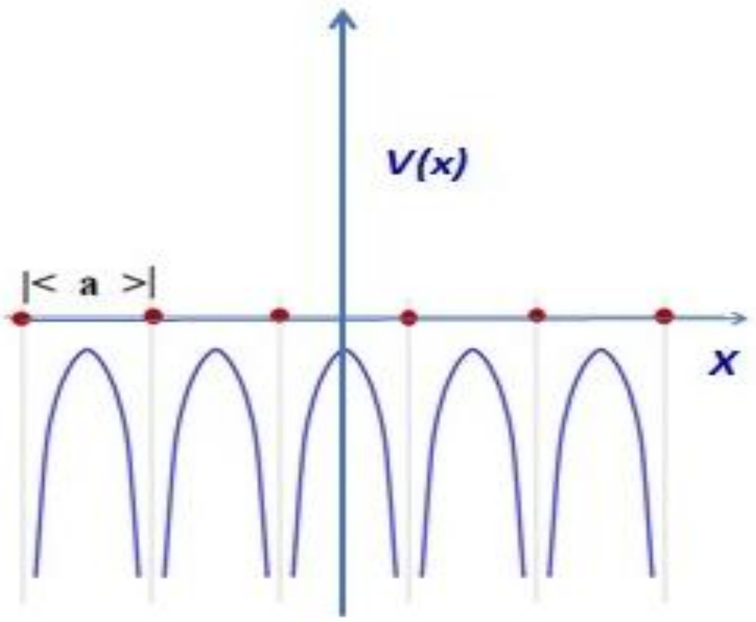
Kronig Penny model, Allowed energy bands

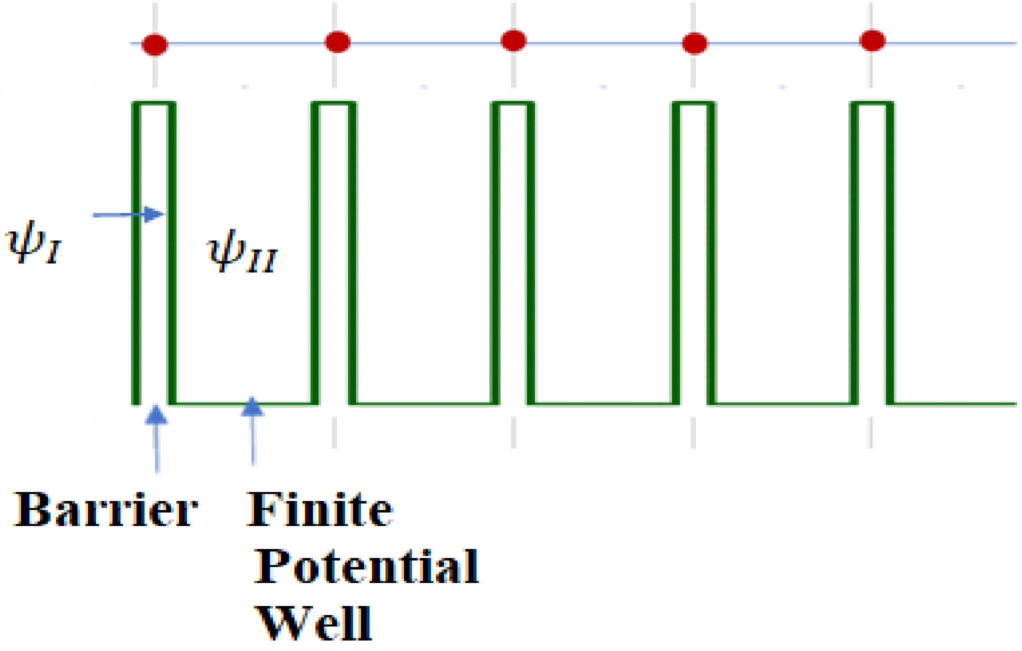
In real crystal, electrons move in a regularly arranged lattice of positive ions.

Observed potential is periodic – due to the periodicity of the lattice



Potentials of electron at the positive ion site is zero and maximum in between two ions.

Real potentials approximated as - long chain of coupled finite square wells and barrier with height V_o, period 'a' and barrier thickness b.



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Schrodinger equations in region I and II

$$\frac{d^2\psi_I}{dx^2} + \frac{2mE}{\hbar^2}\psi_I = 0 \qquad for\ 0 < x < a$$

$$\frac{d^2\psi_{II}}{dx^2} - \frac{2m(V_o - E)}{\hbar^2}\psi_{II} = 0 \quad for\ or - b < x < 0$$

Total energy (E < V) - define two real quantities K and α

$$K^2 = \frac{2mE}{\hbar^2} \qquad \text{and} \qquad \alpha^2 = \frac{2m(V_0 - E)}{\hbar^2}$$

$$\frac{d^2\psi_I}{dx^2} + K^2\psi_I = 0 \qquad for\ 0 < x < a$$

$$\frac{d^2\psi_{II}}{dx^2} - \alpha^2\psi_{II} = 0 \qquad for\ or - b < x < 0$$

The wave function of the electron is a modulated wave given by Bloch function $\psi_k(x) = V_k(x)e^{ikx}$

$V_k(x)$ is a periodic function , satisfies $V_k(x + a) = V_k(x)$

Applying the boundary conditions and solving SWE equation

$$P\,\frac{Sin(Ka)}{Ka} + \cos(Ka) = \cos ka$$

Where $P = \frac{ma}{\hbar^2} V_o . c$ *and* $K = \sqrt{\frac{2m(E)}{\hbar^2}}$

V_o c is the barrier strength and P is the scattering power of the potential barrier.

The values of k are obtained by solving this equation.

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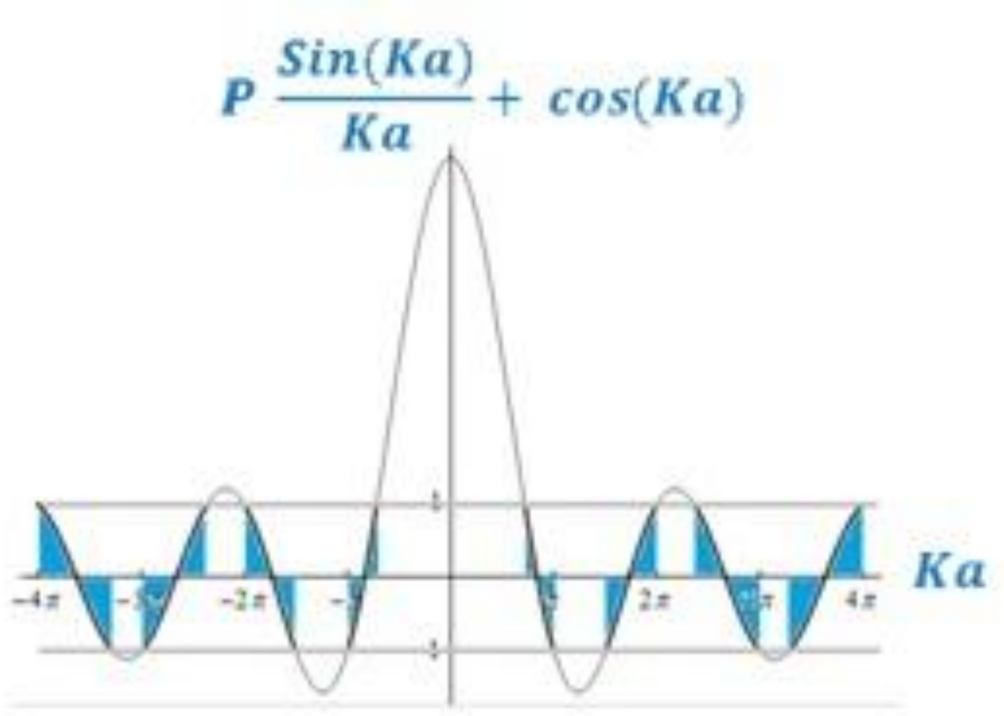
Kronig Penny model, Allowed energy bands

Plot LHS of the equation as a function of αa



Whenever LHS goes beyond ± 1, the equation has no solution

as the RHS lies between ± 1

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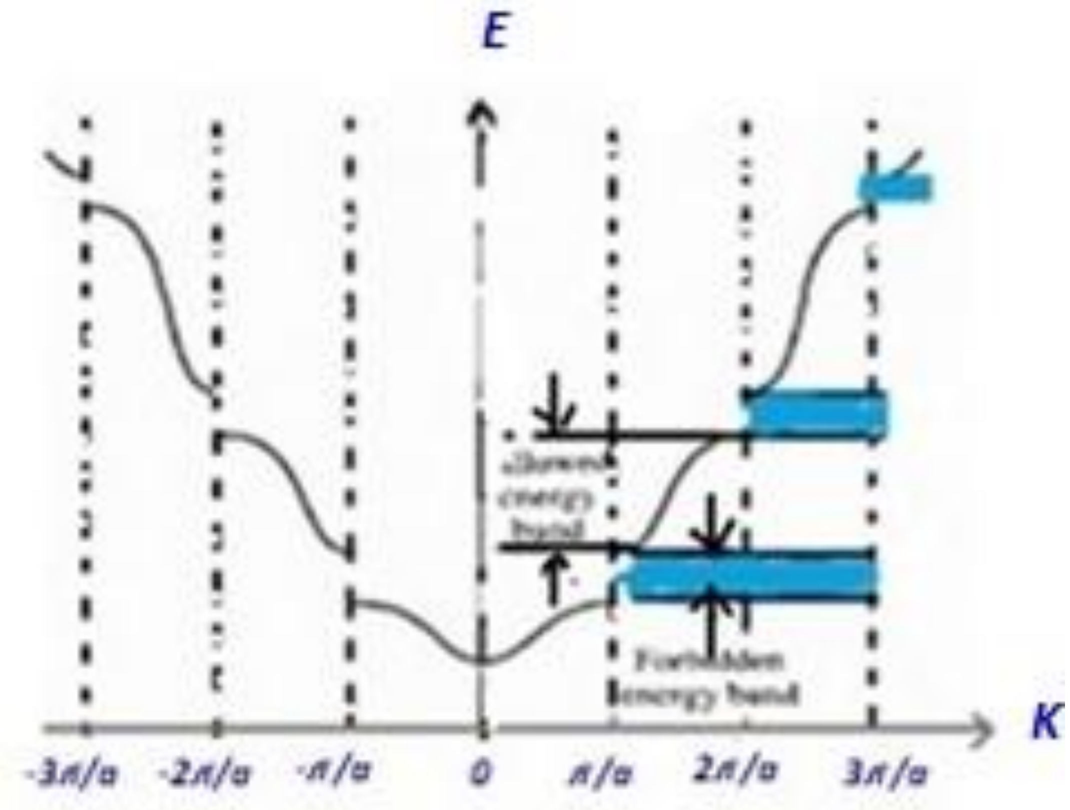
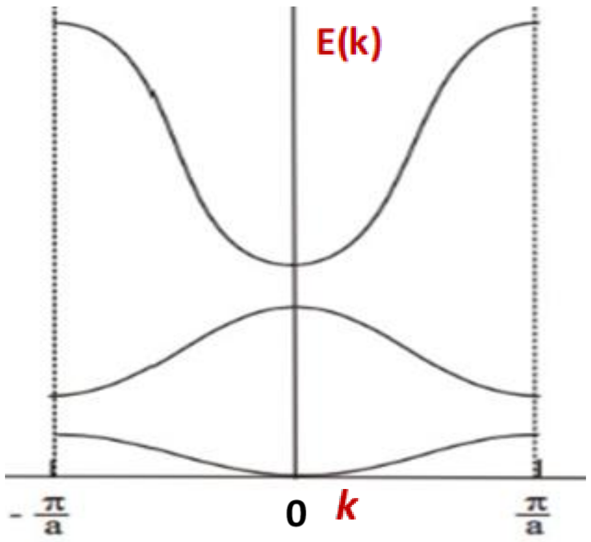
Kronig Penny model, Allowed energy bands

E– k diagram



Lowest band is completely filled followed by forbidden energy states (shaded).

Classification of Material based on band structure:



Metal- partially filled conduction band

- *Semiconductors-fully filled valence band and empty conduction band, energy gap 3 -5 eV*
- *Insulators- energy band gap > 5 eV*

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Class 31 . Quiz …

The concepts which are correct are….

1. *In the Kronig-Penney model the periodic potential is approximated as a long chain of coupled infinite square wells*
2. *The potential of the electron at the positive ionic site is maximum and zero between the site .*
3. *Scattering power is the measure of the strength with which electrons in a crystal are attracted to the ions on the crystal lattice sites.*
4. *Metal are characterized by a fully filled conduction band.*

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THANK YOU

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