

# Pu Bloch-a Function leh Band Theory

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## Thuhma

Ka thuзиак hnuhnung pakhat, ‘Pu Pauli Exclusion Principles leh Quantum Mechanics’ tih kha kan chhiar theuh ka ring a. Khatah khan eng vangin nge energy bands a lo awm theih chiang takin quantum mechanics hmangin kan hrilhfiah a ni. Tin, chumai bakah a tawp lama kan thuзиак kha in en chuan energy bands chu a kual nguai thin thu kan sawi a. Chumi chu engvanga lo awm nge tih sawifiah turin kan insawi ba bawk a nih kha.

Tuna kan topic pawh hriatfuh har ve tak a ni a, mizotawng ngei a chhiar tur a awm erawh chuan mi tam tak a pui dawn a ni. Ka thuзиак hi Pawl X zirlai leh a hnuailam tante pawh a pawimawh vek tho a ni.

## Class XI Sc lama inziak dan

Class XII Sc zirlai emaw a hmaa ka thuзиак lo chhiar tawh tan chuan Energy bands chu a hnuai ami ang hian kan ziak thei tih kan hre thei ang a. Bands 2 kan nei thin a. A chung zawk ami hi Conduction bands a ni a, tin a hnuai ami hi valence bands a ni. A inkar zau zawng hian Energy band gap kha a entir a. Electric field emaw eng (light) emaw chakna kan pek chuan electron chu valence band atangin conduction band – ah a chho ang a, conduction current emaw a awlsam zawngin electric current kan lo nei thei dawn a ni. Thuзиак hmasa ka sawifiah tawh Fermi level hi Zero Kelvin a electron – te ebergy bands – a an awm theihna san zawng a ni bawk a. Ngun taka kan en chuan conduction current nei turin band gap energy aia tam electron khan energy a neih a ngai tih kan hre thei ang. A nih chuan Semiconductor – ah chuan electron khan energy nei tlem deuh mah se awlsam tein electric current a pe chhuak thei dawn tihna a ni a. Chuan, metalah phei chuan pawn lam atanga energy pe lem lovin electric current kan nei thei dawn tihna a ni, mahse a takah chuan pawn lam atanga energy pe loa current kan neih theih chu a tlem em em thung a ni.

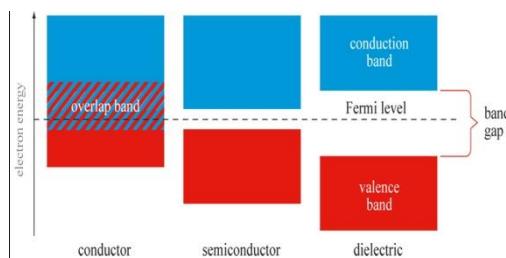
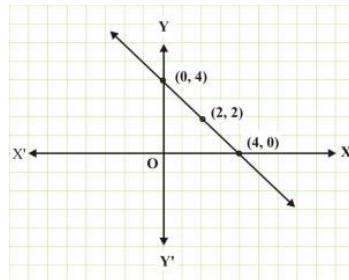


Figure 1 Energy bands

## Mahse mawms...

A hma zawng a energy bands diagram kan siam khi ngun taka kan en chuan Y – axis chiahan hlutna a nei a, chu chu Energy tam lam a ni. X – axis erawh chuan hlutna a nei lo a, X – axis tam lam tehnain engmah awmzia a nei lo tihna a nih chu. Pawl X emaw IX emaw Mathematics lamah khan graph kha kan zir nasa hle a, graph kha Linear Equaion in Two Variables chawh chhuah nan kan hmang thin a nih kha. X hlut zawng azrin Y paw'n hlutna a nei zel a, chuvangin X leh Y – axis te kha an pawimawh ve ve a ni.

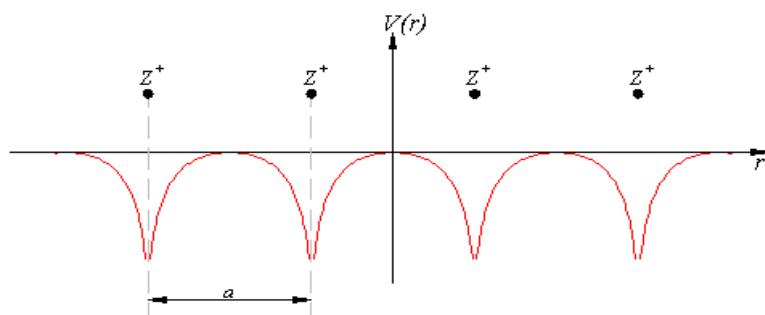


**Figure 2D Graph of Linear Equations**

Figure 2ah khian X hlutna 2 a nih chuan Y hlutna chu 2 ve tho tih chiang takin kan hmu a. Mahse Figure 1, Energy bands diagram khi ngun taka kan en chuan X hlutna khian Y lamah engmah danglamna a pe lo tih kan hmu thei ang. Y chiahan pawimawhna a nei a ni. A nih chuan Energy bands diagram kan siam chu a famkim tawk lo viau tihna a ni a. Energy gap leh electric current awm theih dan vel bak a hrilhfiah thei miah lo a ni a. Metal, Semiconductor leh Insulator danglamna sawi nan bak a tlak vak lo a nih chu! A bik takin Electrical leh Optical Properties hi quantum mechanics takin kan zir chian duh chuan Energy band diagram kan neih khi a dik tawk loa a aia tha zawk leh dik zawk kan mamawh a ni.

### **Thupuiah lut tawh mai ila**

Ahmaa kan ziak ang khan atom chhunga core nucleus te khan positive charge an pe chhuak a. Chu chuan electron chu a lo hip (attract) thin a, a nih chuan core nucleus chuan potential energy a nei tihna a nih chu. A nih chuan thil sakhat (solid) zawng zawng chhungah atom tam tak awm tih kan hria a, a chhunga core nucleus te khan potential energy an pe theuh a ni. Entirman, core nucleus inhlat zawng chu ‘ $a$ ’ theuh nit a se, an potential energy X leh Y zawnga danglam dan chu a hnuai diagram ka lo dah ang hian a ni.



**Figure 3 Periodic Potential**

Ngun takin diagram khi han en ta ila X – axis khian nucleus inkar hlat zawng a entir a, Y – axis lam chuan core nucleus avanga potential energy lo awm chu a entir a ni. Core nucleus vang khan positive charge a lo awm a, electron hi negative charge a nih bawk avangin potential energy chu negative a ni ve dawn tihna a ni a. Chuvangin potential energy chu negative Y – axis lamah a chhukin a tam tulh tulh tihna ni.

Ngun leh zualin han en chik ta ila. Potential energy danglam dan khi core nucleus pakhat zel kan kal pelhin a inang chiah chiah zel tihna a ni a. Veilam atangin han tan ta ila potential energy graph khi ‘ $a$ ’ kan kal pelin a in ang zel a. Hetiang hi periodic kan tih thin ang kha a ni a. Periodic chu eng parameter emaw ( time emaw space emaw engpawh) a lo danglama a nihna ang chiah zel a nih leh khan periodic kan ti thin. Entirna tha deuh mai chu Sine emaw Cosine wave emaw ang hi a ni a, time period a zawhin a ngai ang bawkin an awm leh thin a ni. Mathematics takin hetiangin kan ziak thei ang:

$$F(x + a) = F(x) \dots \dots \dots \quad (1)$$

### **Harsatna ni si mahse ngaihtuahna thar petu chu...**

Crystal emaw solid chhungah emaw electron a chet dan hi a hmaa kan ziak ang khan quantum mechanics – in a hrilhfiah (govern) tlat a. Schrodinger equation awmzia leh a chawh dan kha kan hriat theuh ka ring a. Hydrogen atom hian nucleus – ah proton 1 leh electron 1 chiah a neih avangin awlsamtein Schrodinger equation hmangin a energy eigenvalue kan chawk chhuak mai thin a. Amaherawhchu, atomic number a lo tam zelin atom chu a lo complex tulh tulh a, tin electron tam lam pawh a pung ve zel a, chu tiang anga tana schrodinger equation chawh chhuah chu thil theih loh tluk a ni a, approximation lak a lo ngai ta thin a nih kha.

### **Pu Bloch – a ngaihtuahchhuah chu...**

Pu Vanlal – Blocha chuan thil thar awmze nei lutuk a ngaihtuahchhuak hlauh mai. A chunga kan sawi ang khian potential khi periodic-a an danglam avangin electron kan hmuh theihna probability pawh periodic takin a danglam ve tur a ni tih chu a ngaihtuah chhuak ta a. Chumi awmzia chu electron wave function kha periodic takin an danglam tur a ni tihna a nih chu. Hei hi kan hrethiam ang em aw... Electron kan hmuh theihna probability kha wave function absolute value vawi hnih puntir (square) a nih avanga hetiang nei hi kan ni. Hetiangin:

$$\text{Probability of finding electron} = |\psi|^2 \dots \dots \dots \quad (2)$$

A nih chuan wave function leh electron kan hmuh theihna chance chu a inhne tlat tihna a nih chu. Wave function a periodic chuan a probability pawh a periodic dawn tihna a lo ni.

A chunga kan sawi tak avang khian Pu Bloch – a chuan periodic medium – ah chuan electron chuan hetiang ang hian wave function a nei tur a ni tih a hmuchhuak ta a:

$$\psi_k(\mathbf{r}) = u_k(\mathbf{r}) e^{i\mathbf{k}\cdot\mathbf{r}} \dots \dots \dots \quad (3)$$

Elecron wave function chu function pahnih inpuntir hmangin a dah theih tih a postulate ta a ni. Helaia  $e^{i\mathbf{k}\cdot\mathbf{r}}$  hi Green Function a kan sawi ang(MSJ issue hluiah ka ziak tawh), plane wave

kha a ni a, tin  $u_k(\mathbf{r})$  hi periodic function a ni a, cell function pawh an ti mai bawk thin a. Hetiangin:

$$u_k(\mathbf{r} + \mathbf{a}) = u_k(\mathbf{r}) \dots \dots \dots (4)$$

A nih chuan  $u_k(\mathbf{r})$  hian  $\mathbf{a}$  chen a kalin  $u_k(\mathbf{r})$  bawk a ni leh thin tihna a ni mai a ni. Tin, a hmaa kan sawi ang khan ‘ $a$ ’ hi atom inkar (nucleus inkar) kha a ni.

Chuan, equation (3) lama kan wave function khi a hnuaia Schrodinger equationah khan han dah tai la( $\psi$  aiah equation number 3 khi kan dah dawn tihna a ni) hetiang hi kan nei ang a:

$$\nabla^2 \psi_k(\mathbf{r}) + \frac{2m}{\hbar^2} (E - V) \psi_k(\mathbf{r}) = 0 \dots \dots \dots (5)$$

Mahse equation number 5 hi ahmaa Schrodinger equation te angin awlsam tea han chawh chhuah erawh a theih dawn lo a. Mahse numerical method hmangin chawh chhuah thei a, tin analytical methods pangngai pawhin a chawh chhuah theih bawk e. Khi laia wave function khi Pu Bloch-a wave function kha a ni a, ‘ $m$ ’ khi electron rih zawng a ni a, tin ‘V’ khi potential a kha a ni. Chuan equation 5 khi kan chawh chuan energy eigenvalue lo chhuak a chu  $k$  value-ah innghatin ‘ $k$ ’ ah a periodic ve tat lat mai. Khi laia  $u_k(\mathbf{r})$  khi ‘ $a$ ’ ah a periodic a chutiang bawkin electron energy pawh chu ‘ $k$ ’ ah a periodic ve leh zel a ni. A nih chuan Energy vs  $k$  diagram kan siam chuan hetiang hi kan nei thei dawn tihna a lo ni:

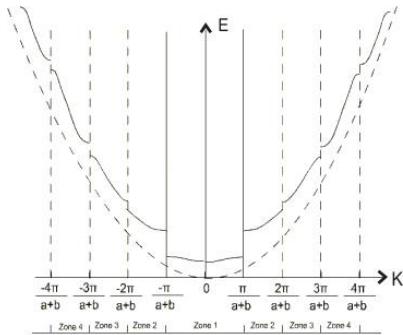


Figure 4:  $E$  vs  $k$  Pu Bloch-a thereroem atangin

### Sawi chhunzawm zel ang...

Helaia  $k$  kan tih khi propagation vector a ni a. Atom inkar kha ‘ $a$ ’ a ni a,  $k$  chuan  $\frac{\pi}{a}, \frac{2\pi}{a}, \frac{3\pi}{a}, \dots$  hlutna a nei thei a ni. Khitah khian energy leh  $k$  te khi a periodic a ni tih chiang takin kan hmu thei a.  $k$  hlutna khian  $\frac{\pi}{a}$  a pelhin a ngai chiahin an awm leh zel a ni. Mahse lehkhabus tamtakah chuan hetiang hian  $E$  vs  $k$  diagram hi an ziak mai thin a.

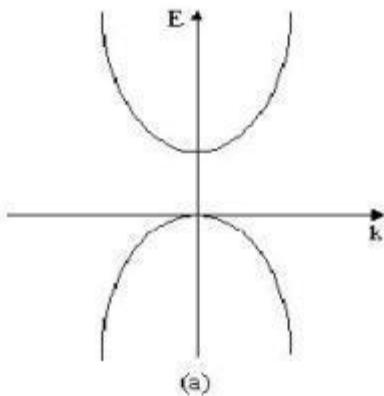


Figure 5: Reduced  $E$  vs  $k$  diagram, ziak dan tlanglawn ber chu

A chunga kan  $E$  vs  $k$  diagram ziah dan khi ziah dan tlanglawn ber a ni a, reduced  $E$  diagram (zone) tih a ni thin a. Extended periodic zone ang pawn'n an ziak thin a mahse chu chu Kronig – Penny Model avanga lo chhuak a ni a, a thui lutuk loh nan sawi zau lo mai ila. Khilaia reduced zone hmanga kan entir khian  $-\frac{\pi}{a}$  atanga  $\frac{\pi}{a}$  inkar chhunga thil tleng min hmuh tir a ni a. Kan diagram khi a periodic avangin hmun dangah pawh hetiang tho hi kan hmuh dawn avangin reduced zone – a kan ziah hi a tawk tiu teu viau a ni. A hnuaia kan ziah ang hian valence band – a a sang lai ber leh conduction band – a hniam lai ber khi Band gap kan tih kha a lo ni ta a.

### Enge hatianga band diagram ziah a tulna?

Pu Bloch – a idea ringawt pawh hi a awmzia tawh em em a. Chu aia awmzia leh em em chu a theorem hian energy leh  $k$  hlutna a thlunzawm thei hi a awmzia leh zual em em a ni.  $E$  vs  $k$  ka ziah ang khian  $k$  value a danglamin  $E$  pawhin value dang a nei zel a. Chumi awmzia chu  $E$  leh  $k$  value te chuan schrodinger equation solution an nei zel tihna a lo ni a ni.

### **Titawp tawh mai ila...**

A sei leh dawn viau mai a. Chuvangin kan rek bung leh mai a ni ang chu. Pu Bloch-a hi physics thiam tam tak angin Pathian hnam thlan Juda chhungkua atanga lo piang a ni a. Graduate level a zir laiin Physics thiam turu, kan hriat lar Pu Debye-a te, Pu Schrodinger-a te lecture leh seminarah te a kal nasa hle a, ngun takin a ngaithla thin a ni. A graduate hnuin University of Leipzig, Germany lamah a thianpa, Quantum mechanics lama pawimawh lutuk – uncertainty principle ngaihtuah chhuak tu Pu Heisenberg-a nen PhD an ti dun veleh a. Tuna ka lo ziah a hi a PhD tih laia a ngaihtuah chhuah ho a ni. Pu Pauli te, Pu Fermi te, Pu Bohr-a te ho nen Europe lamah physics an zir ho nasa hle a. Mahse Pu Vanlal-hitlera a hran tak em avangin America lama University tha – Stanford leh University of California lamah a insawn ta a. Stanford University-a Theoretical Physics Professor ni hmasa ber a ni ta a ni. Heta a awm lai hian sorkar leh ram tana project pawimawh tak tak a bik takin Nuclear magnetism lam a ti nasa hle.

Nobel Prize dawn dan te leh nihna pawimawh tak tak a neih te, kum zabi hnuhnunga Physics tihmasawntu pawimawh berte zinga ami a nih zia te chu nakinah know your scientist column – ah an lo ziak turah ngai tawh mai i la. USA lama a retire hnuah a seilenna leh a pianna khua Zurich, Switzerland lamah a kir leh a. Mahse kum 77 mi chauh niin Lungphuchawl avangin Pu Bloch-a chuan rihsang min lo kai san ta a ni. Azara thiamna leh finna mai bakah malsawmna kan dawn zawng zawng hi a thahnem viau asin...