

## QUANTUM MECHANICAL SPIN

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### Thuhma

Ka thuзиак hnuhnung berah khan quantum mechanics-a equation pawimawh ber Schrodinger equation kan zir tawh a. Khatah khan quantum particle energy chu a hrang (discrete/quantized) a ni tih kan hrethiam ta kha a ni a. Ziah zawm tur dang: desity of states te, quantum tunneling te, ldt., a awm nghal teuh a. Amaherawhchu, quantum mechanics – in a ken tel tlat: quantum numer zinga tel ve spin chungchang hi I thlirho phawt teh ang.

Ka thuзиак hi master zirlai thenkhatte-in an hlawk pui thu min lo hrilh ta zeuh zeuh a. A lawmawm ka ti hle mai! Mizo society tana ka tangkai ve theihna nia ka ngaih chu Quantum Mechanics hi mizo tawng ngeia awmlsam taka hriatthiam theih tura lehkhabu siam hi a ni a. Pathianin rem a tih chuan Mizote tana hnu ka hnutchhiah theih awm chhun a ni ve mah na.

### Thupuiah lut nghal ila

Physics zilrai tan pawh hian spin tih tawh chuan kan rilrua lo lang chu enge maw vir lai hi a ni a. Entirnan: ball vir lai te, kan khawel vir lai te, leh a dang tam tak rilruah a lo lang thin. Mahse helaia spin tih kan sawi mek hi chu chuti ang chu a ni miah lo a. Quantum mechanics a nih tawh chuan electron kan ti a ni emaw proton kan ti emaw engpawhnirawhse quantum particle an nih phawt chuan particle angin an awm tawh lova – fields emaw waves emaw angin an awm a ni kan tih tawh kha. Chuti angah chuan thil vir muai muai tur ang chi chu a awm thei lo hrim hrim a ni. A nihna takah chuan helaia kan sawi mek quantum mechanics spin hi a hming phuah sual a ni.

### Classical mechanics lamah let leh lawk ila

Classcial mechanics-ah khan angular momentum kan zawn dawnin engtin nge kan tih thin kha? Linear motion lamah thil rih zawng – mass leh velocity kan puntir ang chiah khan moment of inertia leh angular velocity kha kan pun tir veleh mai thin a nih kha...

Tunah Bohr's atomic model-ah khan let leh ta ila. Khata tang khan angular momentum chhuatchhuah tum chhin phawt teh ang:

Electron hi charge nei a ni a. A che a nih vah chuan current a nei dawn tihna a ni a, heti ang hian current value chu kan ziak thei a:

$$I = \frac{-ev}{2\pi r} \quad (1)$$

$$I = \frac{-e}{2m\pi r^2} mvr \quad (2)$$

$$I = \frac{-e}{2m\pi r^2} L \quad (3)$$

Helaia equation (3) ami – L hi electron tana angular momentum chu a ni ta a.

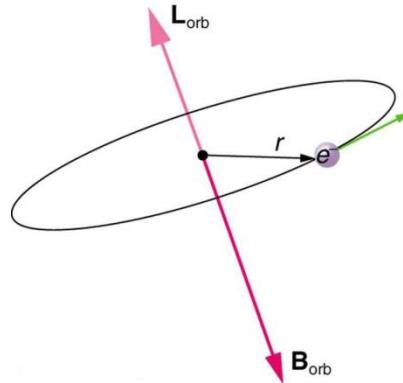


Fig 1: Elcetron –in nucleus a hel lai (<http://archive-cte-cnx-dev.cnx.org/contents/fea9523c-93cd-487c-bb4c-b2b367f5c279%402>)

Tin, electron hi a virkual a. Bohr's atomic model hmang khan a vir kual a nih chuan fields a pe chhuak thei a ngem? A chhanna chu awlsamte a ni a. Class XII Physics lama kan zir tawh angin electron vir kual avanga fields lo awma chu magnetic fields a ni. Chumi awmzia chu khi laia current kan ziah chhuah khi magnet angina awm a tum dawn tihna a lo ni, north pole leh south pole pawh a nei ve ve dawn a ni. Figure 1-a kan hmuu ang khian angular momentum chuan chunglam a hawi a, mahse electron vir kual avanga magnetic field lo awma chuan hnuai lam a hawi daih thung dawn a ni. Chumi awmzia chu a in opposite chiah chiah dawn tihna a lo ni a. Kan hriat fo thin magnetic dipole kha a ni. Tunah hian magnetic dipole moment hlutna  $\mu$ , zawng chhuak lawk ta ila, heti angin:

$$\mu = I\pi r^2 \quad (4)$$

Tunah equation (3) khi hmang ta chiah ila:

$$\vec{\mu} = \frac{-e}{2m} \vec{L} \quad (5)$$

Awle, ngun taka kan en chuan khilai equation-a L lo awm kua khi mechanical quantity nei a ni tih kan hre thei ang a. Tin, a veilam pang ami khian magnetic quantity a nei bawk a, a bak zawng  $\frac{-e}{2m}$  hi chu constant of proportionality an tih thin kha a ni. Chumi awmzia chu electron hian angular momentum a neih tam poh leh magnetic moment a nei tam veleh dawn tihna a lo ni a, inlaichinna awmze nei tak – direct proportionality kha an nei ve reng a lo ni a. Entirnan: Pu Schrodinger-a theoryah khan lut lawk ta ila – electron kha  $s$  orbitalah awm ta sela angular

momentum khan zero a tluk avangin magnetic moment pawhin zero a tluk ve mai dawn tihna a ni.

### **Thil pakhat pawihmawh deuh-ah lut tawh ang**

Equation (5) hmang khian angular momentum leh magnetic moment chu direct proportionality hmangin an inlaichin tih kan hre chiang tawh ta a. Helaia angular momentum hi a value kha quantized a ni tih kan hria a, heti angin:

$$L = \sqrt{l(l+1)}\hbar \quad (6)$$

$$L_z = m_l \hbar \quad (7)$$

A nih chuan equation-ah reng reng a ding lampang nihna chu a veilamin a nei ve tur a ni a. Chumi awmzia chu magnetic moment pawh hi a quantize tihna a lo ni a. Angular momentum aiin magnetic moment hi hmuhchhuah a awlsam zawk avangin particle tereuh tete-ah pawh an angular momentum tur ang chu kan chawk chhuak zel mai dawn a lo ni. Chumi awmzia chu space quantization nihphung kan hriatchian a ngai dawn tihna a lo ni a. Classical mechanics nen chuan ngaih pawlh loh ta ila. Quantum mechanics-ah chuan angular momentum khan value neih theih chin (quantize) a nei a. Chumi chu cone inzawm teuh angin kan ziah thin kha; a hnuai figure ami ang hian:

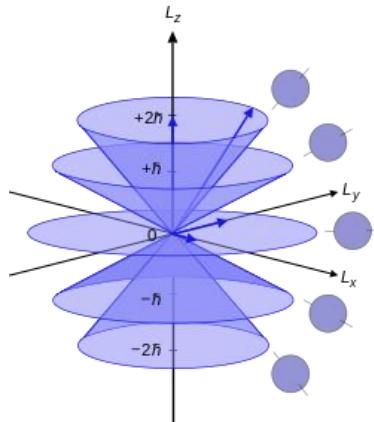


Figure 2: Angular momentum -in value neih theih bik a nei (quantization)  
[https://en.wikipedia.org/wiki/Azimuthal\\_quantum\\_number](https://en.wikipedia.org/wiki/Azimuthal_quantum_number)

Figure 2-a angular momentum hlutna theuh khian angle hran vek an nei a. Entirnan:  $+\hbar$  leh  $+2\hbar$  khian angle hran ve ve an nei a ni. Hei hi space quantization an tiha kha a ni a. Hemi concept hi Pu Schrodinger-a khan a hmuchhuah laiin Pu Einstein-a te, Pu Bohr-a te, Pu Born-a leh quantum theory chhuah theihna tura thawhhlawk deuh deuhte khan an pawm ve thei lo a. Experiment taka finfiah theih a nih an ring lo a ni. Anni kha chuan mathematical concept mai main i turah an ngai tlat a. A ni lah taka space quantization concept nei chi hi chu han hriathiam mai pawh hi a har

viau zel a ni. Amaherawhchu, a chunga kan ziah tawh angin magnetic moment kan thei chuan angular momentum chu awlsamtein kan hmuchhuak mai dawn a lo ni:

$$\mu = \frac{-e\hbar}{2m} \sqrt{l(l+1)} \quad (8)$$

$$\mu = \frac{-e\hbar}{2m} m_l \quad (9)$$

A nih chuan a chunga equation pahnih hmangte khian  $l$  leh  $m_l$  hlutna chu awlsam takin kan hmu thei dawn a ni. Amaherawchu, chiang taka ka sawi chu quantization of angular momentum hi chu Bohr-a model atanga lo kal a ni hauh lo a, Pu Schrodinger-a ngaihtuah chhuah a ni. Tin, equation dinglamah khian  $\frac{-e\hbar}{2m}$  tih loh khi chuan dimension an nei lo a. Chuti a nih chuan magnetic moment hian  $\frac{-e\hbar}{2m}$  dimension hi a tluk tihna a ni. Helaia parameter lo langte hi constant vek an ni a, a hmingah Bohr magneton an ti a nih kha.

$$\mu_B = \frac{-e\hbar}{2m} \quad (10)$$

He Bohr magneton hlutna hi magnetic moment unit atan hman thin a ni.

### **Experiment lam hawi chhin tawh teh ang**

Kum 1922 khan German scientist pahnih Pu Stern leh Pu Gerlach te chuan experiment pawimawh tak mai an ti a. Pu Stern-a hi Physical Chemist a ni a, Pu Gerlach-a erawh chu Physicist a thung a. Vanlal-Hitleran a chhawte an ni ve ve a ni. Mahse department hranah ve ve an awm thung a. Pu Stern-a hi Pu Born-a student a ni a. Ani hian Bohr's angular momentum quantization kha a dik leh dik loh a experiment duh a. Amaherawchu, apu hian experiment theih chi a ni lo tiin chuti ang hna chu thawk lo turin a sawi hnawm sak nasa mai a.

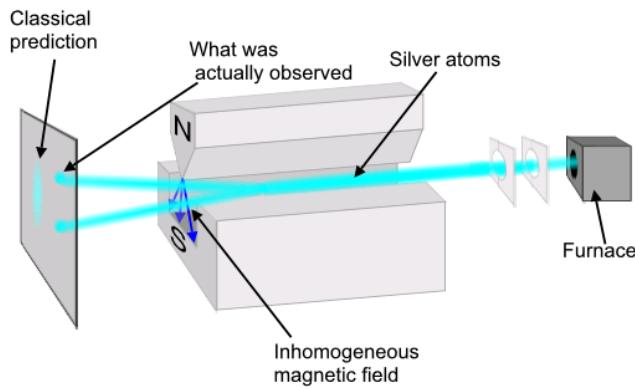


Figure 3: Stern – Gerlach experiment (<http://www.astronomycast.com/2015/05/ep-374-stern-gerlach-experiment/>)

Figure 3-ah hian Stern – Gerlach experiment awm dan chu a ni a. Khi laia furnace atang khian Silver atom a lo chhuak a. Slit pahnih awmte khian a zawna kalte chauh a lo kaltlang tir a. A

dawt lehah magnetic pole pahnih – North leh South inkarah a kallang leh a, a tawpah glass plate a va su ta a ni. Helaiah hian South pole hian uniform magnetic field a pe chhuak a. A chung ami zawk erawh hi chuan cone pianhmang a neih avangin non – uniform field a pe chhuak thung a. Hei hi a chhan chu magnetic dipole hian uniform field a patlang chuan force a hmachhawn dawn lo a, amaherawhchu non – uniform magnetic field chhungah erawh chuan magnetic dipole chuan force a dawng tawh tihna a lo ni.

Magnetic dipole moment  $\mu_B$  hi magnetic field  $B$  chhungah awm ta se, a energy chu:

$$E = -\mu_B \cdot B \quad (11)$$

Chumi awmzia chu energy a neih tlem theih ber dan chu magnetic filed leh dipole hian angle zero an siamin a ni a, an neih san theih ber dan erawhchu an inkar hi 180 degree a nihin a ni thung a ni. Dipole hian hemi energy avanga force a neih theih zat chu heti ang hian kan hmu leh thei a:

$$F = \nabla(\mu_B \cdot B) \quad (12)$$

$$F = \nabla(\mu_x B_x + \mu_y B_y + \mu_z B_z) \quad (13)$$

Awle, khilaia experiment kan tarlanah khian  $x$ ,  $y$  leh  $z$  zingah khian  $z$  component chuah kan nei thei a a chhan chu non uniform filed kan siam dan a nih avangin. Chuvangin equation hnuhnung ber khi heti angin a lo awm tawh ang a:

$$F = \left( \mathbf{i} \frac{d}{dx} + \mathbf{j} \frac{d}{dy} + \mathbf{k} \frac{d}{dz} \right) (\mu_z B_z \mathbf{k}) \quad (14)$$

$$F = \mu_z \frac{dB_z}{dz} \mathbf{k} \quad (15)$$

Equation (15) hi dipole a force nektu awma kha a ni. Force chuan  $\mathbf{z}$  hawina lam chuah a hawi dawn tihna a ni a. Tin, fields hi a uniform lo tih pawh a chiang chiah ta a ni, a chhan chu gradient a awm avangin.

Classical angular momentum quantization hmangin value pahnih chauh a awm dawn chuan khilaia equation (15) hmang khian Silver atomte khian a chung leh hnuaih chauh an va su tur a ni a. Amaherawhchu, chuti ang result chu an hmu thei hauh lo mai! An awmna universityte an thlak a, harsa takin expereriment chu an han chhunzawm leh a, mahse engmah a ang chuan lem hlei lo va. Pu Stern-a hi meizial heh deuh mai a ni a. A meizial zukah chuan sulphur a awm a. Sulphur leh Silver an in react chuan Silversulphide a chhuak a, chu chu photographic film siam ang kha a ni mai a. Chutah chuan plate-ah chuan spot pahnih an hmu ta a. Bohr's atomic model-a angular momentum quantization chu an proof ta niin an inhria a.

Kum 1925 khan Hydrogen atom leh Sodium atom hmangin experiment hi an ti leh a result inang chiah chiah an hmu leh zel a. Anni hian quantization of angular momentum entir mah se an interpret dan erawh a dik lo thung a ni.

### **Lal than a lo piang ta!**

Bohr's quantization chu proof dik niin lang mah se Schrodinger picture-ah chuan  $s$  orbitalah an awmin angular momentum khan zero a tluk a. A nih chuan Hydrtogen, Sodium leh Silverte khan valence electron kha 1s, 3s leh 5s-ah theuh an neih avangin angular momentum zero an nei anga, plate-ah chuan spot pakhat mah an hmu tur a ni lo a ni.

Hemi avang hian electron hian nihna dang a nei a nih rinna a lo piang ta a. Electron nihna kan tih chuan a rihzawng (mass) te, a charge te hi a ni a. Chuti ang bawkin spin pawh hi a awm ve ngei rinna a lo lang a, chumi chiah chuan he experiment hi a hrilhfiah ta a ni. Angular momentum ang bawkin hlutna a nei a, tin projection pawh a nei bawk a ni, heti angin:

$$S = \sqrt{s(s+1)}\hbar \quad (16)$$

$$S_z = m_s\hbar \quad (7)$$

Chumi awmzia chu equation (17) ami avangin  $S_z$  hian value pahnih a nei a: +1/2 leh -1/2, hei hian Silver, Hydrogen leh Sodium valence electron-te chu Schrodinger theory hmangin  $s$  orbitalah awm vek mah se glass plate-ah chuan a chung leh a hnuaiah spot pakhat ve ve an lo pe zel a lo ni.

### **Titawp leh tawh mai ang**

A sei leh fu mai a. Remchang hmasa berah electron spin leh a kaihhnawih kan lo ziak leh dawn nia. MRI kan tih fote pawh hi he spin avanga lo awm a ni a. Quantum mechanics hrinchhuah zingah chuan spin quantum number hi a fuh deuh ber mai awm e...