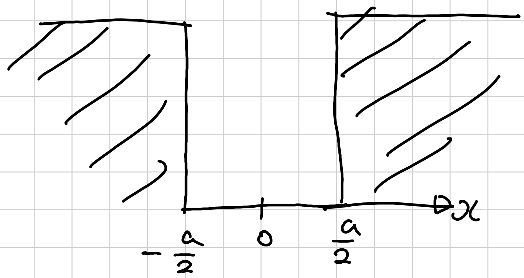
第一問.

$\hbar = \frac{h}{2\pi}$



[1].

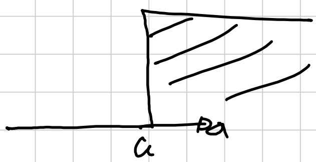
$\therefore\ -\frac{\hbar^2}{2m}\psi''(x) = E\psi(x)$ $\quad\therefore\ \psi(x) = A\cos(\lambda x) + B\sin(\lambda x)$, $\lambda = \frac{\sqrt{2mE}}{\hbar}$

$x = -a \wedge x = a$ で $\psi = 0$ の時

$A\cos(\lambda a) - B\sin(a\lambda) = 0 \wedge A\cos(\lambda a) + B\sin(a\lambda) = 0$

A or B = 0 であり.

※ p43. Potentialの問題」



$x > a$ での Schrödinger eq は.

$-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2} + V\phi_1 = E\phi_1$

$\therefore\ \psi_1 = A e^{-\lambda(x-a)} + B e^{\lambda(x-a)}$ $\quad \lambda = \sqrt{\frac{2m}{\hbar^2}(E-V)}$

$x \to \infty$ で Nonzero

$\psi_1 = A e^{-\lambda(x-a)}$

$\psi = A\cos(\lambda x)$ or $B\sin(\lambda x)$ である

$\lambda a = \frac{\pi}{2}\cdot n_o$ or $\lambda a = \frac{\pi}{2} n_e$

「奇数」 「偶数」

$\phi = A\cos\left(\frac{\pi n_o}{2a}x\right)$, $B\sin\left(\frac{\pi n_e}{2a}x\right)$

ここで $\int_{-a}^{a} \sin^2\left(\frac{n_o \pi}{2a}x\right)dx = a$ ← 規格化

$A = B = \sqrt{a}$ である

$\therefore\ \psi = \sqrt{a}\cos\left(\frac{\pi n_o}{2a}x\right)$, $\sqrt{a}\sin\left(\frac{\pi n_e}{2a}x\right)$ //

$\therefore\ \lambda = \frac{\pi}{2}\cdot n_o$ ∴ $2mE = \hbar^2\cdot\frac{\pi^2 n^2}{4a^2}$ $\quad\therefore\ E = \frac{\hbar^2\pi^2 n^2}{8ma^2}$ //

$\Psi(x_1, x_2) = \frac{1}{2}(\psi_1(x_1)\psi_2(x_2) + \psi_1(x_2)\psi_2(x_1))$ ：対称形

$g(x)$, $e(x)$

[2]

→ $(g(x_1)e(x_2) + g(x_2)e(x_1))$ ξ

$g(x_1).g(x_2)$, $e(x_1)g(x_2)$

→ $\frac{1}{2}(g(x_1)e(x_2) - g(x_2)e(x_1))$ // 反対称をなす

よって T=0における Fermi

粒子のスピン演算子: $\hat{S}_1 = (\hat{S}_{1x}, \hat{S}_{1y}, \hat{S}_{1z})$, $\hat{S}_2 = (\hat{S}_{2x}, \hat{S}_{2y}, \hat{S}_{2z})$

$\hat{S}_{1z}|\psi\rangle = ⓐ|\phi\rangle$

V_0

[3]

スピンの復習

$[J_x, J_y] = iJ_z$

$\hat{J}^{(+)}|j,m\rangle = \sqrt{(j-m)(j+m+1)}\,|j,m+1\rangle$

$\hat{J}^{(-)}|j,m\rangle = \sqrt{(j+m)(j-m+1)}\,|j,m-1\rangle$ が成立する

$J^2|j,m\rangle = j(j+1)|j,m\rangle$. $J_z|j,m\rangle = m|j,m\rangle$

$m \geq 0$ の時 $J_z|\phi\rangle = m|\phi\rangle$, $J^2|\phi\rangle = j(j+1)|\phi\rangle$

$m < 0$ の時 $J_z|\phi\rangle = m|\phi\rangle$, $J^2|\phi\rangle = j(j+1)|\phi\rangle$

$s = \frac{1}{2}$ より, $m = (\frac{1}{2}, -\frac{1}{2})$ のみ

$J_z|\phi\rangle = \frac{1}{2}|\phi\rangle$, $J^2|\phi\rangle = \frac{1}{2}\cdot\frac{3}{2}|\phi\rangle$

$J_z|\phi\rangle =$

- 角運動量の合成

$J = J_1 + J_2$ とすると. J_1, J_2は交換可能であるため

⇓

固有ベクトルと固有値はいくつか??

$J^2 = J_1^2 + J_2^2 + 2J_1 \cdot J_2$ であるため

$$J_z\,|J,m\rangle\rangle = \sum_{m_1=-J_1}^{J_1}\sum_{m_2=-J_2}^{J_2} |m_1,m_2\rangle\langle m_1,m_2|\,J,m\rangle\rangle$$

$J_1 = 1/2,\ m_1 = 1/2,\ -1/2\ ;\quad J = 1/2\ ;\ m_2 = \pm 1/2.$

$m_2 \backslash m_1$	$1/2$	$-1/2$	
$1/2$	1	0	$m=0$
$-1/2$	0	-1	$m \to J=1$

$J=1,\ m=0$ の固有

$|1,0\rangle\rangle$

$J=1,\ m=-1.\ |1,-1\rangle\rangle$

$|1,1\rangle\rangle = |\uparrow,\uparrow\rangle$

$J_z = (m)$

4つの状態がある

d : fix　　$N-1$ increse (X)

N : fix　　d : increse (ok)

$$\frac{XN}{(aN)^2} = \frac{X}{aN}$$

見え消し

[1]　$n_+\cdot(+a) + n_-(-a) = X$　　$W = \binom{N}{n_+}$

$$\frac{NX}{2((aN)^2 - X^2)} \qquad \frac{\frac{X}{aN}}{2\left(1-\left(\frac{X}{aN}\right)^2\right)} \to 0$$

[158]

$$\frac{\partial \mathcal{F}}{\partial x} = \frac{\partial \mathcal{F}}{\partial n}\cdot\frac{\partial n}{\partial x} \to \left(-\frac{N}{2}\cdot\frac{1}{\frac{N-n}{2}}\cdot\left(-\frac{1}{2}\right) + \frac{1}{2}\log\frac{N-n}{2} - \frac{N}{2}\cdot\frac{1}{\frac{N+n}{2}}\cdot\frac{1}{2} - \frac{1}{2}\log\frac{N+n}{2}\right)$$

$$= \frac{N}{4}\cdot\frac{2}{N-n} + \frac{1}{2}\log\frac{N-n}{2} - \frac{1}{2}\log\frac{N+n}{2} - \frac{N}{4}\cdot\frac{2}{N+n}$$

$$= \left[\frac{N}{2(N-n)} + \frac{1}{2}\log\frac{N-n}{N+n} - \frac{N}{2(N+n)}\right]\cdot\frac{1}{a}$$

$$\frac{nN}{2(N^2-n^2)} \qquad N^2n - n^2N + nN$$

$(N - n^+)\ \exp(-\beta k) + n^+ \exp(\beta k)$

$\exp(\beta k) - \exp(-\beta k) = 2\sinh(\beta k)$

$= N\exp(-\beta k) + n^+(2\sinh(\beta k))$

$n^- = N - n^+ \rightarrow a(2n^+ - N) = x$

$n^-(N - n^+)\exp(-1) + n^+\exp(+1)$ $\quad \frac{2n^+ - N}{a} = \frac{x}{a}$

$n^+ = \left(\frac{x}{a} + N\right)\cdot\frac{1}{2}$

$N\exp(-1) - \frac{1}{2}\left(\frac{x}{a} + N\right)(\exp(+1) - \exp(-1))$

$\langle E \rangle = \frac{\sum E_n \exp(-\beta E_n)}{Z}$

$-\frac{1}{Z}\cdot 2^N \cdot N\sinh^{N-1}(\beta k)\cdot\cosh(\beta k)\cdot k$

$2^N\sinh^N(\beta k)$ $\quad -N\frac{k\cosh(\beta k)}{\sinh(\beta k)} = -\frac{Nk}{\tanh(\beta k)}$

$\beta|k| \ll 1$ $\quad \tanh(\beta k) \approx \beta k$ $\quad \therefore -\frac{N}{\beta u} = E$

$\langle x \rangle = \sum_n x_n P_n = \exp(-\beta E_n)$

$n^+\exp(\beta k) - n^-\exp$

$n^- = N - n^+$

$Z(\beta, x)$

$\|$

$-\frac{1}{Z}\cdot\left(-\beta N\exp(-\beta k) + \frac{1}{2}\left(\frac{x}{a} + N\right)\cdot 2\cosh(\beta k)\cdot k\right)$

$\langle x \rangle = \sum x_{(n)} P_n = \frac{1}{Z}\cdot\sum_n x_n \exp(-\beta E_n)$

$E = n^+(-k) - n^-(+k) = k(n^+ - n^-) =$ x で微分

$-Nk \cdot \frac{1}{\cosh^2(\beta k)}$

$E(x)$

$\langle E \rangle = \int E(x)\, \exp(-\beta E(x))\, dx$??

$\langle an \rangle = a \cdot \langle n \rangle$ $\quad \langle n \rangle = \alpha \sum_n n \cdot \exp(-\beta E(n))$

$Z = \sum_n^N \exp(-\frac{E_n}{kBT}) = n_+ \exp(-k\beta) + n_- \exp(k\beta)$

$\langle E \rangle = \sum_n E_n \exp(-\frac{E_n}{kBT})$

$\left(\begin{array}{l} n_+ \to -k \\ n_- \to k \end{array} \right) \to -k n(+) \exp(k\beta)$

$+k n(-) \exp(-k\beta) = \langle E \rangle$

(全ての粒子)

$k(-n^+ \exp(k\beta) + (N - n^+) \exp(-k\beta)) = \langle E \rangle$

$k(N \exp(-k\beta) - n^+ (2\cosh(k\beta))) = \langle E \rangle$

$\frac{x+N}{2} = n^+$

$Z = \exp(\beta E) + \exp(-\beta E)$

$Z = (\quad)^N$ → 平均

$\frac{2^N \cdot N \cosh^{N-1}(\beta k) \cdot \sinh(\beta k) \cdot k}{2^N \cosh^N(\beta k)}$

$x = na$ $= \frac{\sinh(\beta k)}{\cosh(\beta k)} \cdot k$

$= -\tanh(\beta k) \cdot k$

エネルギー:

$E = k(2n^+ - N)$. $\quad x = a(2n^+ - N)$

$\langle x \rangle = \frac{k}{a} \langle E \rangle$ //

◦ 第3問

◦ Equation of Motion

$$m\ddot{\mathbf{u}} = -e\mathbb{E}_{ex} - e\,\mathbf{u}\times\mathbb{B}_{ex} - m\nu\mathbf{u}$$

$$\dot{\mathbf{u}} = \begin{bmatrix} u_x \\ u_y \\ 0 \end{bmatrix} \cdot (-i\omega)\exp(-i\omega t)$$

$$\therefore \begin{bmatrix} u_x \\ u_y \\ 0 \end{bmatrix} \times \begin{bmatrix} 0 \\ 0 \\ B \end{bmatrix} = \begin{bmatrix} u_y B \\ -u_x B \\ 0 \end{bmatrix}$$

$$\therefore m\begin{bmatrix} u_x \\ u_y \\ 0 \end{bmatrix}(-\omega^2) = e\begin{bmatrix} E_x \\ E_y \\ 0 \end{bmatrix} - e\begin{bmatrix} u_x B \\ -u_y B \\ 0 \end{bmatrix}$$

$$\therefore\ -\omega^2 m u_x = eE_x - eu_x B \quad \therefore \boxed{u_x = \frac{eE_x}{\omega^2 m - eB}}$$

$$-\omega^2 m u_y = eE_y + eu_y B \quad \therefore \boxed{u_y = \frac{eE_y}{\omega^2 m + eB}}$$

$$\tilde{\varepsilon}\mathbb{E}_{ex} = \begin{bmatrix} \varepsilon_{xx} & i\gamma & 0 \\ -i\gamma & \varepsilon_{xx} & 0 \\ 0 & 0 & \varepsilon_{zz} \end{bmatrix}\begin{bmatrix} E_x \\ E_y \\ 0 \end{bmatrix} = \begin{bmatrix} \varepsilon_{xx}E_x + i\gamma E_y \\ -i\gamma E_x + \varepsilon_{xx}E_y \\ 0 \end{bmatrix}$$

$$\mathbb{P} = \varepsilon_0(\tilde{\varepsilon}\mathbb{E}_{ex} - \mathbb{E}_{ex}) = -ne\mathbf{u} \qquad \rightarrow (\exp(-i\omega t)\text{は省略})$$

⇕

$$\varepsilon_0\begin{bmatrix} (\varepsilon_{xx}-1)E_x + i\gamma E_y \\ -i\gamma E_x + (\varepsilon_{xx}-1)E_y \\ 0 \end{bmatrix} = -ne\begin{bmatrix} u_x \\ u_y \\ 0 \end{bmatrix}$$

$$\therefore\ \varepsilon_0\left((\varepsilon_{xx}-1)E_x + i\gamma E_y\right) = -ne\cdot\frac{eE_x}{\omega^2 m - eB} = AE_x$$

$$\varepsilon_0\left(-i\gamma E_x + (\varepsilon_{xx}-1)E_y\right) = -ne\,\frac{eE_y}{\omega^2 m + eB} = BE_y$$

$$E_x\left(\varepsilon_{xx} - 1 - \frac{A}{\varepsilon_0}\right) = -i\gamma E_y \quad \left[E_y = \frac{i}{\gamma}\cdot\left(\varepsilon_{xx} - 1 - \frac{A}{\varepsilon_0}\right)E_x\right]$$

$$-i\gamma E_x = \left(\frac{B}{\varepsilon_0} - \varepsilon_{xx} + 1\right)E_y$$

$$-i\gamma = \left(\frac{B}{\varepsilon_0} - \varepsilon_{xx} + 1\right)\cdot\frac{i}{\gamma}\cdot\left(\varepsilon_{xx} - 1 - \frac{A}{\varepsilon_0}\right)$$

$$+\gamma^2 = \left(\varepsilon_{xx} - 1 - \frac{B}{\varepsilon_0}\right)\left(\varepsilon_{xx} - 1 - \frac{A}{\varepsilon_0}\right)$$

③ 取り出せる情報量の定式化

$$\left(\gamma(\alpha|0\rangle + \beta|1\rangle) + \delta(\alpha|2\rangle + \beta|3\rangle) \right)|0\rangle$$

12番

$$\gamma\alpha|00\rangle + \gamma\beta|10\rangle + \delta\alpha|01\rangle + \delta\beta|11\rangle$$

↓ ×2 したい

↓ |1〉のは 一般的に自明ではない

$|00\rangle\langle 00|$
$+ |10\rangle\langle 10|$
$+ |20\rangle\langle 01|$ $= U$
$+ |30\rangle\langle 11|$

$$U^* U = (|00\rangle\langle 00| + |10\rangle\langle 10| + |01\rangle\langle 20| + |11\rangle\langle 30|)$$

→ ユニタリ演算ではない

(ただ、どのようにして、実行するかは非自明)

(メモリがどれくらいあるかで知る必要がある)

他にもいろいろ

(かくれているものがある かもしれない)

$d = 4.$

$(|00\rangle\langle 00|$
$+ |10\rangle\langle 10|$
$+ |01\rangle\langle 01|$
$+ |11\rangle\langle 11|)$
$+ \cdots$ 加える

↓ 適当に

$$-eE_x = m u_x(\omega^2 - \omega_0^2) + e u_x B$$

$$u_x = \frac{+eE_x}{-m(\omega^2 - \omega_0^2) + eB}$$

$$u_y = \frac{eE_y}{-m(\omega^2 - \omega_0^2) + eB}$$

$$(\varepsilon_{xx}-1)E_x + i\gamma E_y = -\frac{ne}{\varepsilon_0} A E_x \qquad \left(\varepsilon_{xx}-1+\frac{ne}{\varepsilon_0}a\right)E_x = -i\gamma E_y$$

$$-i\gamma E_x + (\varepsilon_{xx}-1)E_y = -\frac{ne}{\varepsilon_0}\beta E_y$$

$$\left(\varepsilon_{xx}-1+\frac{ne}{\varepsilon_0}B\right)E_y = i\gamma E_x \quad \therefore E_x = -i\frac{1}{\gamma}\cdot\left(\varepsilon_{xx}-1+\frac{ne}{\varepsilon_0}b\right)E_y$$

$$\left(\varepsilon_{xx}-1+\frac{ne}{\varepsilon_0}a\right)\cdot\frac{1}{\gamma}\cdot\left(\varepsilon_{xx}-1+\frac{ne}{\varepsilon_0}b\right) = \gamma$$

$$(\varepsilon_{xx}-1)^2 + (\varepsilon_{xx}-1)\cdot\frac{ne}{\varepsilon_0}(a+b) + \frac{n^2e^2}{\varepsilon_0^2}ab = \gamma^2$$

$$\dot{u} \times B = -i\omega\cdot\begin{bmatrix} u_y B \\ -u_x B \\ 0 \end{bmatrix}$$

$$\begin{pmatrix} u_x \\ u_y \\ 0 \end{pmatrix} \times \begin{pmatrix} 0 \\ 0 \\ B \end{pmatrix}$$

u_x 0

$$-i\omega$$

$$-e(u)\times B$$

$$i\omega e\cdot\left[u_y B\right.$$

$$m(\omega_0^2 - \omega^2)u_x = -eE_x + ie\omega u_y B$$

$$m(\omega_0^2 - \omega^2)u_y = -eE_y - ie\omega u_x B$$

$$\begin{bmatrix} m(\omega_0^2-\omega^2) & -ie\omega B \\ ie\omega B & m(\omega_0^2-\omega^2) \end{bmatrix}\begin{bmatrix} u_x \\ u_y \end{bmatrix} = \begin{bmatrix} eE_x \\ eE_y \end{bmatrix}$$

$$\frac{1}{m^2(\omega_0^2-\omega^2)^2 - (e\omega B)^2}\circ\begin{bmatrix} m(\omega_0^2-\omega^2) & ie\omega B \\ -ie\omega B & m(\omega_0^2-\omega^2) \end{bmatrix}\begin{bmatrix} eE_x \\ eE_y \end{bmatrix}$$

$$(\varepsilon_{xx}-1)E_x + i\gamma E_y = -\frac{ne}{\varepsilon_0}\cdot\frac{1}{A}\cdot\left[m(\omega_0^2-\omega^2)E_x - i e\omega B\cdot E_y\right]$$

$$-i\gamma E_x + (\varepsilon_{xx}-1)E_y = -\frac{ne}{\varepsilon_0}\cdot\frac{1}{A}\left[i e\omega B\, E_x + m(\omega_0^2-\omega^2)E_y\right]$$

$$\therefore \quad i\gamma = -i e\omega B\cdot\left(-\frac{ne}{\varepsilon_0}\right)\cdot\frac{1}{A} = \frac{e^2 n\omega B}{A\varepsilon_0}$$

$$\varepsilon_{xx}-1 = -\frac{ne}{\varepsilon_0}\cdot\frac{1}{A}\cdot m(\omega_0^2-\omega^2)$$

$$\varepsilon_{xx} = -\frac{ne}{\varepsilon_0}\cdot\frac{1}{A}\cdot m(\omega_0^2-\omega^2)$$

$\omega_0 >> \omega > 0$. $\omega_0 >> eB/m$.

$$\nabla\times E_0 = \mu_0\omega$$

$$\nabla\times(\nabla\times E_0) = \mu_0\omega\left(-\tilde{\varepsilon}\,\varepsilon_0\omega\right)E_0$$

$$= -\mu_0\varepsilon_0\omega^2\,\tilde{\varepsilon}E_0$$

$$\left(\frac{\omega}{c}\right)^2$$

$$\nabla\times(\nabla\times E_0) = \qquad A\times(B\times C) = (C\cdot A)B - (B\cdot A)\cdot C$$

$$(\nabla\cdot E_0)\nabla - |\nabla|^2 E_0$$

$$(EZ)\cdot\begin{bmatrix}0\\0\\k_z\end{bmatrix} - (k_z^2)\cdot\begin{pmatrix}E_x\\E_y\\E_z\end{pmatrix} + \left(\frac{\omega}{c}\right)^2\cdot\begin{bmatrix}\tilde{\varepsilon}\\ \\ \end{bmatrix} = 0$$

E_x

$$\left(k_z^2 - \left(\frac{\omega}{c}\right)^2 \varepsilon_{xx}\right) E_y = -i\gamma \left(\frac{\omega}{c}\right)^2 E_x$$

$$\begin{bmatrix} k_z^2-\left(\frac{\omega}{c}\right)^2\varepsilon_{xx} & i\gamma\left(\frac{\omega}{c}\right)^2 \\ i\gamma\left(\frac{\omega}{c}\right)^2 & k_z^2-\left(\frac{\omega}{c}\right)^2\varepsilon_{xx} \end{bmatrix}$$

$$\left(k_z^2 - (\omega/c)^2 \varepsilon_{xx}\right)^2 - \gamma^2 (\omega/c)^4 = 0$$

$$k_z^2 - (\omega/c)\varepsilon_{xx} = \pm \gamma (\omega/c)$$

$$k_z^2 = \left(\frac{\omega}{c}\right)\left(\varepsilon_{xx} \pm \gamma\right)$$

VO

$$\left(\left(\frac{\omega}{c}\right)^2(\varepsilon_{xx} \pm \gamma) - (\omega/c)^2 \varepsilon_{xx}\right) E_x = i\gamma \left(\frac{\omega}{c}\right)^2 E_y$$

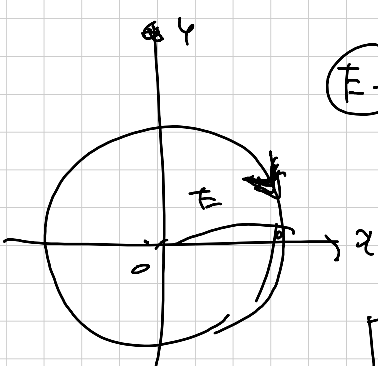
$$(\pm\gamma) E_x = i\gamma E_y$$

$$\pm E_x = i E_y.$$

$$E_x^2 + E_x^2 = E^2 \qquad \therefore E_x = \frac{1}{\sqrt{2}} E$$

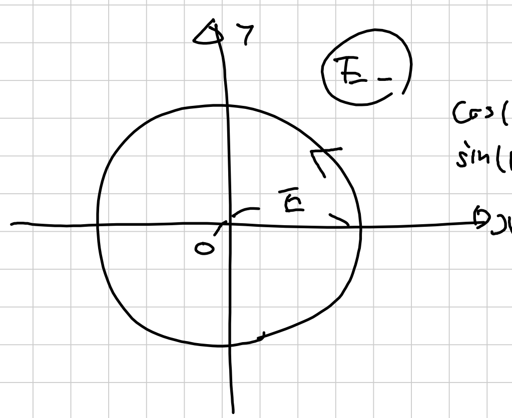
$$E_0 = \begin{bmatrix} \frac{1}{\sqrt{2}} E \\ i \frac{1}{\sqrt{2}} E \end{bmatrix} = \frac{1}{\sqrt{2}} E \begin{bmatrix} 1 \\ i \end{bmatrix}$$

$$\exp(-i\omega t) = \cos(\omega t) + i\sin(\omega t)$$



$$\begin{bmatrix} \cos(\omega t) \\ -\sin(\omega t) \end{bmatrix}$$

E_x



$\cos(\omega t)$

$\sin(\omega t)$

$E_+ = \frac{1}{\sqrt{2}} E\begin{bmatrix}1\\ i\end{bmatrix}$. $E_- = \frac{1}{\sqrt{2}} E\begin{bmatrix}1\\ -i\end{bmatrix} \exp(\quad)$

$\exp(\quad)$

$\frac{1}{\sqrt{2}} E\begin{bmatrix}a+b\\ a\hat{i}-b\hat{i}\end{bmatrix}$ $a=b$

$(E_{0z})\hat{k}z - k^2 E_{0z} + \left(\frac{\omega}{c}\right)^2 \cdot E_{0z} \varepsilon_{zz} = 0$

$E = E_+ + E_-$

---

[4].

from [2]. → get $\begin{pmatrix} g(x_1)g(x_2), & \frac{1}{\sqrt{2}}(g(x_1)e(x_2) + e(x_1)g(x_2)) \\ e(x_1)e(x_2) & \end{pmatrix}$ → Boson

S $\left(\frac{1}{\sqrt{2}}(g(x_1)e(x_2) - e(x_1)g(x_2))\right)$ Fermion.

A

S $\begin{pmatrix} |\uparrow\rangle|\uparrow\rangle \\ \frac{1}{\sqrt{2}}(|\uparrow\rangle|\downarrow\rangle + |\downarrow\rangle|\uparrow\rangle) \\ |\downarrow\rangle|\downarrow\rangle \end{pmatrix}$

A $\left(\frac{1}{\sqrt{2}}(|\uparrow\rangle|\downarrow\rangle - |\downarrow\rangle|\uparrow\rangle)\right)$ → Fermion - Assymetric

$S \rightarrow A$ 3×1

$A \rightarrow 3$ no S. 3×1) = 6 ?

No magnetic field → Energy should be from

$g \cdot g$: $\frac{\hbar^2\pi^2}{ma^2}$, $\frac{5\hbar^2\pi^2}{2ma^2}$, $\frac{4\hbar^2\pi^2}{ma^2}$

$$\because \langle (x_1 - x_2)^2 \rangle_{\psi_1} = \frac{1}{\sqrt{2}} \left(\langle \uparrow\downarrow | + \langle \downarrow\uparrow | \right) \left(\int_{R_1} dx_1 \int_{R_2} dx_2 \; g(x_1) g(x_2) g(x_1) g(x_2) \cdot (x_1 - x_2)^2 \right) \frac{1}{\sqrt{2}} \left(|\uparrow\downarrow\rangle + |\downarrow\uparrow\rangle \right)$$

$x_1^2 - 2x_1x_2 + x_2^2$

Cancelled

Orbital part.

$$= \underbrace{\int g^2(x_2)\,dx_2}_{1} \int x_1^2 g_1^2(x_1)\,dx_1 + \underbrace{\int g^2(x_1)\,dx_1}_{1} \int x_2^2 g_2^2(x_2)\,dx_2 - 2 \int dx_1 \, \underbrace{x_1}_{\text{odd}} \underbrace{g^2(x_1)}_{\text{even}} dx_1 \cdot \int x_2 g^2(x_2)\,dx_2$$

$0 \cdot B$

$\Rightarrow 2A_H$

$\langle (x_1 - x_2)^2 \rangle_{\psi_3} = 2B_H$

$$\langle (x_1 - x_2)^2 \rangle_{\psi_2} = \frac{1}{2} \int (\underbrace{x_1^2}_{\text{even}} - \underbrace{2x_1x_2}_{\text{odd}\;\text{odd}} + x_2^2)_{\text{even}} \left(g^2(x_1) e^2(x_2) + g(x_1) g(x_2) e(x_1) e(x_2) + g^2(x_2) e^2(x_1) \right)$$

even, even, odd

$$\downarrow$$

$$= \frac{1}{2}(A+B) + 2(B+A) - C^2 = A + B - 2C^2$$

$$\langle (x_1 - x_2)^2 \rangle_{\psi_4} = A + B + 2C^2$$

(ψ_6)

$\rightarrow$ Consider the parity.

[6]

$H = H_0 + \lambda H_1$

$|\psi_n\rangle = |\psi_n^{(0)}\rangle + \lambda |\psi_n^{(1)}\rangle + \cdots$

$E_n = E_n^{(0)} + \lambda E_n^{(1)} + \lambda E_n^{(2)}$

$(H|\psi_n\rangle = E_n|\psi_n\rangle)$

$\lambda = 0$

$H_0|\psi_n^{(0)}\rangle = E_n^{(0)}|\psi_n^{(0)}\rangle$

$\lambda = 1$.

$\sum_{n \neq m} \frac{|\langle \psi_m^{(0)}|V|\psi_n^{(0)}\rangle|^2}{E_n^{(0)} - E_m^{(0)}}$

$E_1^{(1)} = \langle \psi_n^{(0)}|V|\psi_n^{(0)}\rangle$

$\psi_n^{(0)} \Rightarrow gg$, $V \Rightarrow V_0 a_1 a_2$, $\psi_n^{(0)} \Rightarrow gg$

$E\psi_1 = E_{\psi_1}^{(0)} + \langle gg|V a_1 a_2|gg\rangle = \frac{\pi^2\hbar^2}{ma^2} + V \int g_1 g^2(a_1) da_1 \int a_2 g^2(a_2)$

$= \frac{\pi^2\hbar^2}{ma^2}$

$E\psi_2 = E_{\psi_2}^{(0)} + \frac{1}{2}(\langle ge| + \langle eg|)(V a_1 a_2)(|ge\rangle + |eg\rangle)$

$= \frac{5\pi^2\hbar^2}{2ma^2} + V_0 \int a_1 g(a_1) e(a_2) da_{12} \int a_2 g(a_2) e(a_2) da_{12}$

$= \frac{5\pi^2\hbar^2}{2ma^2} + V_0 c^2$

$E\psi_3 = \frac{\hbar^2\pi^2}{ma^2}$

$E\psi_4 = E\psi_5 = E\psi_6 = E_{\psi_6}^{(0)} - V_0 c^2 = \frac{5\hbar^2\pi^2}{2ma^2} - V_0 c^2$

$\left(-\hbar^2\left(\left(\frac{\omega_0}{\omega}\right)^2 - 1\right)^2 + (e\beta)^2\right)\omega^2$

$$\frac{1}{\sqrt{2}}\left(\vec{F}_+ + \vec{F}_-\right)$$

$\vec{F}_+$: $\begin{pmatrix}1\\ i\\ 0\end{pmatrix} \exp\left(i\left(\frac{\omega}{c}\right)(x_1 - ct)\right)$, k_+

$\vec{F}_-$: $\begin{pmatrix}1\\ -i\\ 0\end{pmatrix} \exp\left(i\left(\frac{\omega}{c}\right)(x_1 + ct)\right)$, k_-

k

$$\vec{F}_{\text{tot}} = \frac{1}{2}\vec{e}\exp(i(k_+ x_1 - \omega t)) + \frac{\vec{e}}{2}\exp(i(k_- x_1 - \omega t))$$

$$\frac{\vec{e}}{2}\exp(-i\omega t)\left(\exp(ik_+ x_1) + \exp(ik_- x_1)\right)$$

$\hookrightarrow$ (exp

$$\vec{F}_{\text{tot}} = \vec{e}\begin{pmatrix}\cos\left(\frac{k_+ - k_-}{2}x_1\right)\\ -\sin\left(\frac{k_+ - k_-}{2}x_1\right)\\ 0\end{pmatrix}$$