PROB. 6 DA L6: TRANSIÇÃO HIPERFINA $F=1 \to F=0$

$\mathcal{E} \to m_s = \mathcal{E}/2$

$$|\varphi_0\rangle = \frac{1}{\sqrt{2}}\left[|+-\rangle - |-+\rangle\right] \Rightarrow F=0$$

1º Nº QUÂNTICO SE REFERE AO ELÉTRON

$$F=1 \qquad |\varphi_m\rangle = \begin{cases} |++\rangle & M_F = 1 \\ \frac{1}{\sqrt{2}}\left[|+-\rangle + |-+\rangle\right] & M_F = 0 \\ |--\rangle & M_F = -1 \end{cases}$$

$J_\pm |j,m\rangle = \hbar\sqrt{j(j+1)-m(m\pm1)}\,|j,m\pm1\rangle$

SE $|\varphi_m\rangle = |++\rangle$

$$\langle ++|S_x|\varphi_0\rangle = \frac{1}{2\sqrt{2}}\langle ++|(S_+ + S_-)\left[|+-\rangle - |-+\rangle\right]$$

$$= \frac{\hbar}{2\sqrt{2}}\langle ++|\left(-|++\rangle + |--\rangle\right) = -\frac{\hbar}{2\sqrt{2}}$$

S_y, S_z

$$\omega_{m0} = \frac{E_m - E_0}{\hbar} = 2\pi f = \frac{2\pi c}{\lambda} \qquad \lambda = 21\text{ cm}$$

PROB. 1 DA L7:

$$E_n = E_1 n^2 \qquad E_1 = \frac{h^2}{8ma^2}$$

$$E_1(m_1) = \frac{h^2}{8m_1a^2} \qquad E_1(m_2) = \frac{h^2}{8m_2a^2}$$

SE $m_1 < m_2 \Rightarrow E_1(m_1) > E_1(m_2)$

a) $m_1 < m_2 \Rightarrow$ PARTÍCULAS DISTINGUÍVEIS

$m_1 \quad m_2$

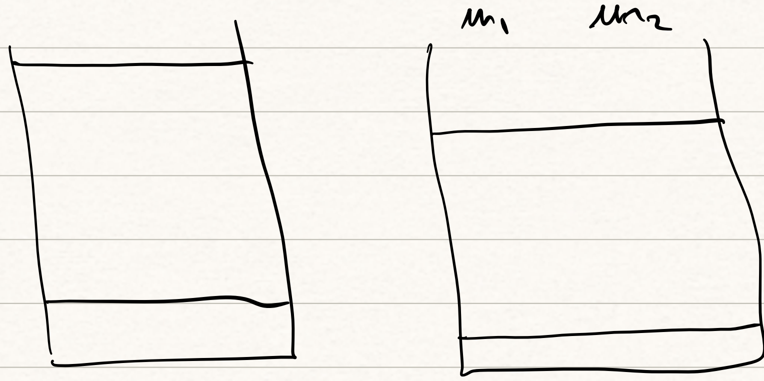
$$|E_0\rangle \rightarrow |1,1\rangle \qquad |E_1\rangle \rightarrow |1,2\rangle$$

$$E_0 = E_1(m_1) + E_1(m_2) \qquad E_1 = E_1(m_1) + 4E_1(m_2)$$

$$|E_2\rangle = \begin{cases} |1,3\rangle \rightarrow E_2^{(a)} = E_1(m_1) + 9E_1(m_2) = \dfrac{h^2}{8a^2}\left(\dfrac{1}{m_1} + \dfrac{9}{m_2}\right) \\ |2,1\rangle \rightarrow E_2^{(b)} = E_1(m_1)\times 4 + E_1(m_2) = \\ \qquad = \dfrac{h^2}{8a^2}\left(\dfrac{4}{m_1} + \dfrac{1}{m_2}\right) \end{cases}$$

$E_2^{(a)} < E_2^{(b)}$ SE $\dfrac{1}{m_1} + \dfrac{9}{m_2} < \dfrac{4}{m_1} + \dfrac{1}{m_2}$

$$\Rightarrow \frac{3}{m_1} > \frac{8}{m_2} \Rightarrow \frac{m_2}{m_1} > \frac{8}{3}$$



m_1

b) 2 BÓSONS:

$$|0\rangle \Rightarrow |1:1;2:1\rangle \qquad E_0 = 2E_1$$

$$S|0\rangle = \frac{1}{2}(1+P_{21})|1:1;2:1\rangle =$$

$$= \frac{1}{2}\left[|1:1;2:1\rangle + |1:1;2:1\rangle\right] = |1:1;2:1\rangle$$

FUNÇÃO DE ONDA:

$$\psi(x_1,x_2) = \langle x_1 x_2|1:1;2:1\rangle$$

$$= \frac{2}{a}\sin\left(\frac{\pi x_1}{a}\right)\sin\left(\frac{\pi x_2}{a}\right)$$

1º ESTADO EXCITADO:

$$|1:1;2:2\rangle \xrightarrow{\text{SIMETRIZANDO}} \frac{1}{2}(1+P_{21})|1:1;2:2\rangle$$

$$= \frac{1}{2}\left[|1:1;2:2\rangle + |1:2;2:1\rangle\right] \xrightarrow{\text{NORMALIZANDO}}$$

$$= \frac{1}{\sqrt{2}}\left[|1:1;2:2\rangle + |1:2;2:1\rangle\right]$$

FUNÇÃO DE ONDA:

$$\psi(x_1,x_2) = \frac{1}{\sqrt{2}}\left(\frac{2}{a}\right)\left[\sin\left(\frac{\pi x_1}{a}\right)\sin\left(\frac{2\pi x_2}{a}\right) + \sin\left(\frac{2\pi x_1}{a}\right)\sin\left(\frac{\pi x_2}{a}\right)\right]$$

C) 2 FÉRMIONS

$$|0\rangle = |1:1,\uparrow;2:1,\downarrow\rangle \xrightarrow{\text{ANTI-SIMETRIZAR}}$$

$$\frac{1}{2}(1-P_{21})|1:1,\uparrow;2:1,\downarrow\rangle$$

$$=\frac{1}{2}\left[|1:1,\uparrow;2:1,\downarrow\rangle - |1:1,\downarrow;2:1,\uparrow\rangle\right]$$

$$\xrightarrow{\text{NORM}} \frac{1}{\sqrt{2}}\left[|1:1,\uparrow;2:1,\downarrow\rangle - |1:1,\downarrow;2:1,\uparrow\rangle\right]$$

$$=\frac{1}{\sqrt{2}}\begin{vmatrix} |1:1\uparrow\rangle & |1:1\downarrow\rangle \\ |2:1\uparrow\rangle & |2:1\downarrow\rangle \end{vmatrix}$$

FUNÇÕES DE ONDA, NESSE CASO, SÃO SPINORES
CONVENCIONAMOS:

$$[\psi](x_1,x_2) = \begin{bmatrix} \psi_{++}(x_1,x_2) \\ \psi_{+-}(x_1,x_2) \\ \psi_{-+}(x_1,x_2) \\ \psi_{--}(x_1,x_2) \end{bmatrix}$$

$$\psi_{++}(x_1,x_2) = \langle 1:x_1,\uparrow;2;x_2,\uparrow|0\rangle = 0$$

$$=\frac{1}{\sqrt{2}}\langle 1;x_1,\uparrow;2:x_2,\uparrow|\left[|1:1,\uparrow;2:1,\downarrow\rangle - |1:1,\downarrow;2:1,\uparrow\rangle\right]$$

$$=0 = \psi_{--}(x_1,x_2)$$

$$\psi_{+-}(x_1, x_2) = \frac{1}{\sqrt{2}} \langle 1: x_1, +; 2: x_2, - | \left[|1:1,+; 2:1,-\rangle - |1:1,-; 2:1,+\rangle \right]$$

$$= \frac{1}{\sqrt{2}} \langle 1: x_1, +; 2: x_2, - | 1:1,+; 2:1,-\rangle$$

$$= \frac{1}{\sqrt{2}} \sqrt{\frac{2}{a}} \sin\left(\frac{\pi x_1}{a}\right) \sqrt{\frac{2}{a}} \sin\left(\frac{\pi x_2}{a}\right)$$

$$= \frac{1}{\sqrt{2}} \left(\frac{2}{a}\right) \sin\left(\frac{\pi x_1}{a}\right) \sin\left(\frac{\pi x_2}{a}\right) = \psi_{+-}(x_1, x_2)$$

$$\psi_{-+}(x_1, x_2) = -\frac{1}{\sqrt{2}} \left(\frac{2}{a}\right) \sin\left(\frac{\pi x_1}{a}\right) \sin\left(\frac{\pi x_2}{a}\right)$$

$$[\psi](x_1, x_2) = \begin{bmatrix} 0 \\ \frac{1}{\sqrt{2}} \left(\frac{2}{a}\right) \sin\left(\frac{\pi x_1}{a}\right) \sin\left(\frac{\pi x_2}{a}\right) \\ -\frac{1}{\sqrt{2}} \left(\frac{2}{a}\right) \sin\left(\frac{\pi x_1}{a}\right) \sin\left(\frac{\pi x_2}{a}\right) \\ 0 \end{bmatrix}$$

$$= \frac{1}{\sqrt{2}} \left(\frac{2}{a}\right) \sin\left(\frac{\pi x_1}{a}\right) \sin\left(\frac{\pi x_2}{a}\right) \begin{pmatrix} 0 \\ 1 \\ -1 \\ 0 \end{pmatrix}$$

$$|0\rangle = \frac{1}{\sqrt{2}}\left[|1:1,+;\ 2:1,-\rangle - |1:1,-;\ 2:1,+\rangle\right]$$

$$= |1:1;\ 2:1\rangle \underbrace{\left[\frac{1}{\sqrt{2}}\left[|1:+;\ 2:-\rangle - |1:-;\ 2:+\rangle\right]\right]}_{|S=0,\,M=0\rangle}$$

TRIPLETO: $|++\rangle$

$$\frac{1}{\sqrt{2}}\left[|+-\rangle + |-+\rangle\right]$$

$$|--\rangle$$

$$|1\rangle = \frac{1}{\sqrt{2}}\left[|1:1;\ 2:2\rangle - |1:2;\ 2:1\rangle\right]|++\rangle$$

$$= \frac{1}{\sqrt{2}}\left[|1:1,+;\ 2:2,+\rangle - |1:2,+;\ 2:1,+\rangle\right]$$