Physics education requires computing education

$\bar{Q}]\rangle + \left\langle\frac{\partial Q}{\partial t}\right\rangle$

$|10\rangle = \frac{1}{\sqrt{2}}(\uparrow\downarrow + \downarrow\uparrow)$ } triplet

$\underbrace{|1\,-1\rangle = \downarrow\downarrow}$

symmetric
lower energy

singlet

$|s\,m\rangle = \sum_{m_1+m_2=m} C^{s_1 s_2 s}_{m_1 m_2 m}|s_1\,m_1\rangle|s_2\,m_2\rangle$

$i\hbar\frac{\partial\chi}{\partial t} = \hat{H}\chi$, $\chi(t) = a\chi_+ e^{i\gamma B_0 t/2} + b\chi_- e^{-i\gamma B_0 t/2}$, $H = -\vec{\mu}\cdot\vec{B} = -\gamma\vec{S}\cdot\vec{B}$

$\det(A - I\lambda) = 0$, $H\psi = E\psi$, $\chi = a\chi_+ + b\chi_-$

$n = 0,$
$l = 0,$
$m_l =$
$m_j =$
$m_s =$

$\psi_n^1 = \sum_{m\neq n}\frac{\langle\psi_m^0|H'|\psi_n^0\rangle}{(E_n^0 - E_m^0)}\psi_m^0$, $E_n^2 = \sum_{m\neq n}\frac{|\langle\psi_m^0|H'|\psi_n^0\rangle|^2}{E_n^0 - E_m^0}$, $E_\pm^1 = \frac{1}{2}\left[W_{aa} + W_{bb} \pm\sqrt{(W_{aa}-W_{bb})^2 + 4|W_{ab}|^2}\right]$

$j = (l + s)$, (

fine structure

$\begin{pmatrix}\alpha\\ \beta\end{pmatrix} = E_1\begin{pmatrix}\alpha\\ \beta\end{pmatrix}$, $W_{ij} = \langle\psi_i^0|H'|\psi_j^0\rangle$

$H_{hyd} = \frac{-\hbar^2}{2m}\nabla^2 - \frac{e^2}{4\pi\epsilon_0}\frac{1}{r}$, $T = \frac{p^2}{2m} = \frac{-\hbar^2}{2m}\frac{d^2}{dx^2}$, $H_r' = \frac{-p^4}{8m^3c^2}$, $E_r^1 = \frac{-1}{2mc^2}[E^2 - 2E$

$\frac{n}{l+\frac{1}{2}} - 3]$, SO: $H'_{SO} = \left(\frac{e^2}{8\pi\epsilon_0}\right)\frac{1}{m^2c^2r^3}\vec{S}\cdot\vec{L}$, $E^1_{SO} = \frac{(E_n)^2}{mc^2}\left\{\frac{n[j(j+1) - l(l+1) - 3/4]}{l(l+1/2)(l+1)}\right\}$, $E^1_{fs} = E^1_r + E^1_{SO} = \frac{(E_n)^2}{2mc^2}\left(3 - \frac{4n}{j+1/2}\right)$

$m_j)$: $E_{nj} = \frac{-13.6eV}{n^2}\left[1 + \frac{\alpha^2}{n^2}\left(\frac{n}{j+1/2} - \frac{3}{4}\right)\right] \leftarrow$ (i), $\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c}$

Z: $H'_Z = \frac{e}{2m}(\vec{L} + 2\vec{S})\cdot\vec{B}_{ext}$, $\mu_B = \frac{e\hbar}{2m}$.

$\int_a^b f\frac{dg}{dx}dx = fg|_a$

$\int_{-\infty}^{\infty} e^{-abx^2}dx =$

$e^{\pm i\theta} = \cos\theta \pm$

$\cos\theta = \frac{1}{2}(e^{+i\theta}$

$\sin\theta = \frac{1}{2i}(e^{+i\theta}$

$)$, $E_Z^1 = \langle n, l, j, m_j|H'_Z|n, l, j, m_j\rangle \Rightarrow E_Z^1 = \mu_B\left[1 + \frac{j(j+1) - l(l+1) + 3/4}{2j(j+1)}\right]B_{ext}m_j \leftarrow$ (ii), $E_{tot}(weak) =$ (i) + (ii)

$E_{n,m_l,m_s} = \frac{-13.6eV}{n^2} + \mu_B B_{ext}(m_l + 2m_s) \leftarrow$ (iii), $E^1_{fs} = \frac{13.6eV\alpha^2}{n^3}\left\{\frac{3}{4n} - \left[\frac{l(l+1) - m_l m_s}{l(l+1/2)(l+1)}\right]\right\} \leftarrow$ (iv), $E_{tot}(strong) =$ (iii) + (iv)

$m_j)$, $H' = H'_Z + H'_{FS} = \frac{e\hbar}{2m}B_{ext}(m_l + 2m_s) + \frac{13.6eV}{64}\alpha^2\left(3 - \frac{8}{j+1/2}\right)$