Problem 3 (HW 7)

For the 0-DEG, derive all expressions when nanowire axis is changed from x-axis to z-axis and magnetic field is applied along z-axis (σ_z instead of σ_x)

$\Rightarrow$ we will have Landau gauge $\vec{A} = -Bx\hat{y}$

Then we have,

E in y direction, $H_R = \eta_R(E) \cdot [\sigma \times (p + eA)]$

B in z direction, $H_D = \gamma_D \sigma \cdot \kappa$

$$H_Z = -\frac{g}{2}\mu_B \sigma \cdot B$$

$$H = \frac{|p+eA|^2}{2m^*}[I] + V(x)[I] + V(y)[I] + V(z)[I] + H_Z + H_R + H_D$$

$$H = |p + e(-Bx)|^2 [I] + V(x)[I] + V(y)[I] + V(z)[I] + H_Z + H_R + H_D$$

$$H = \frac{1}{2m^*}[p_x^2 + (p_y - eBx)^2 + p_z^2][I] + V(x)[I] + V(y)[I] + V(z)[I] - \frac{g}{2}\mu_B B \sigma_z + \frac{\eta}{\hbar}(p_x\sigma_z - p_z\sigma_x) - \frac{\eta}{\hbar}(p_z\sigma_y - p_y\sigma_z) + \gamma_D(\sigma_x k_x + \sigma_y k_y + \sigma_z k_z)$$

$H = H_0 + H_{SO} \Rightarrow (H_0 + H_{SO})[\psi] = E[\psi]$

$[\psi] = a_\uparrow\{\phi^\uparrow\} + a_\downarrow\{\phi^\downarrow\}$

$$\begin{bmatrix} \langle H_1 \rangle & \langle H_{SO} \rangle_{12} \\ \langle H_{SO} \rangle_{21} & \langle H_2 \rangle \end{bmatrix} \begin{pmatrix} a_\uparrow \\ a_\downarrow \end{pmatrix} = E \begin{pmatrix} a_\uparrow \\ a_\downarrow \end{pmatrix}$$

$$\langle H_1 \rangle - \langle H_2 \rangle = g \mu_B B$$

$$H_{SO}{}^{k} = -(\eta/\hbar)\,[p_x \sigma_z - p_z \sigma_x]$$

$$H_{SO}{}^{D} = \frac{v}{2\hbar^3}\Big[p_x\{(p_y - eB_x)^2 - p_z^2\} + \{(p_y - eB_x)^2 - p_z^2\} p_x\Big]\sigma_x + \frac{v}{2\hbar^3}\Big[(p_y - eB_x)(p_z^2 - p_x^2) + (p_z^2 - p_x^2)(p_y - eB_x)\Big]\sigma_y + \frac{v}{2\hbar^3}\Big[p_z\{p_x^2 - (p_y - eB_x)^2\} + \{p_x^2 - (p_y - eB_x)^2\} p_z\Big]\sigma_z$$