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Construction of hybrids

$$|h_1\rangle = \frac{1}{\sqrt{2}} (|s\rangle + |p_z\rangle)$$

$$|h_2\rangle = \frac{1}{\sqrt{2}} (|s\rangle - |p_z\rangle)$$

$$t_{\text{up}} = \langle s | H | h_1(\Delta z) \rangle = \frac{1}{\sqrt{2}} (\langle s | H | s(\Delta z) \rangle + \langle s | H | p_z(\Delta z) \rangle)$$

$$= \frac{1}{\sqrt{2}} (V_{ss\sigma} + \sin\theta V_{sp\sigma}) = \frac{1}{\sqrt{2}} \left( V_{ss\sigma} + \frac{\Delta z}{\sqrt{a^2 + \Delta z^2}} V_{sp\sigma} \right)$$

$$t_{\text{down}} = \langle s | H | h_2(\Delta z) \rangle = \frac{1}{\sqrt{2}} (\langle s | H | s(\Delta z) \rangle - \langle s | H | p_z(\Delta z) \rangle)$$

$$= \frac{1}{\sqrt{2}} (V_{ss\sigma} - \sin\theta V_{sp\sigma}) = \frac{1}{\sqrt{2}} \left( V_{ss\sigma} - \frac{\Delta z}{\sqrt{a^2 + \Delta z^2}} V_{sp\sigma} \right)$$

$$t_{\text{up}} - t_{\text{down}} = \frac{\sqrt{2} \Delta z}{\sqrt{a^2 + \Delta z^2}} V_{sp\sigma}.$$