Lecture 18

Quantum dot in a magnetic field

Short length of carbon nanotube

- small spin-orbit coupling with opposite sign to real atoms

$$\widehat{H}_{\mathrm{mag}} = -\frac{\mathcal{E}_{\mathrm{so}}}{\hbar^2}\widehat{L}_z\widehat{S}_z + \frac{e}{2m}\left(g_l\widehat{L}_z + g_s\widehat{S}_z\right)B$$

States with definite $L_z = m_l\hbar$ and $S_z = m_s\hbar$: energy eigenvalues

$$E_{m_l m_s} = -\mathcal{E}_{\mathrm{so}}\, m_l m_s + \frac{e\hbar}{2m}(g_l m_l + g_s m_s)B$$

Four degenerate states split into pairs by spin-orbit coupling

- pair with same signs for m_l, m_s has lower energy

Pairs then split by interaction with external field B

- states with same signs for m_l, m_s have stronger dependence on B

Experiment shows this pattern with

$$\Delta E_{\text{so}} = |m_l|\, \mathcal{E}_{\text{so}} \simeq 0.4 \times 10^{-3}\ \text{eV}$$

$$g_s \simeq 2 \qquad \text{as in free space}$$

$$g_l\,|m_l| \simeq 26$$

- large $g_l\,|m_l|$ from “relativistic” behaviour of electrons in graphene