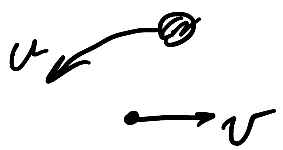
Weak antilocalisation

Spin-orbit interaction.

So far we have not considered quasiparticle spins when studying transport and weak localisation effects.

In fact, quasiparticles have spins, and there is a chance of spin flip in any collision



Magnetic field in the reference frame of the electron

$$\vec{B} = \frac{1}{c}\,\vec{v}\times\vec{E}$$

This magnetic field interacts with the magnetic moment of the electron

$$H_{int} = -\vec{\mu}\,\vec{B}$$

Dygression: one may estimate it for an atom

$$\sim \frac{v}{c}\,\frac{e^2 Z}{r_e^2}\,\frac{e\hbar}{2m_e c} \sim (\alpha Z)^2 \underbrace{Ry}_{\frac{2\pi^2 m e^4}{c h^3}} \quad (CGS)$$

$$\alpha = \frac{e^2}{\hbar c} \approx \frac{1}{137}$$

During a collision the probability to flip spin is $\propto (Z\alpha)^4$

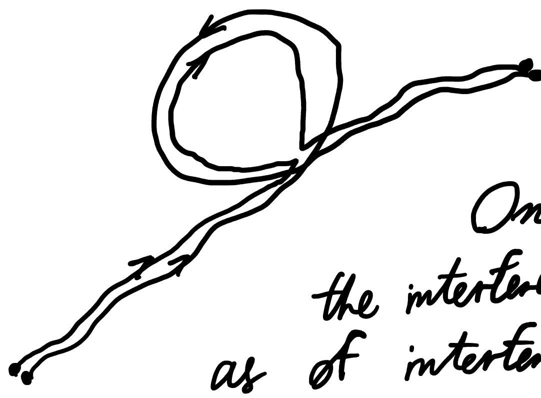
Usually $\boxed{\tau_{so} \gg \tau}$

Usually $\boxed{\tau_{SO} \gg \tau}$

At low temperatures $\tau_\varphi \xrightarrow{T\to 0} \infty$,

so $\tau \ll \tau_{SO} \ll \tau_\varphi$

Effect of spin-orbit scattering on WL



One may think about the interference of these processes as of interference of a pair of electrons.

Wavefunctions of a pair of electrons:

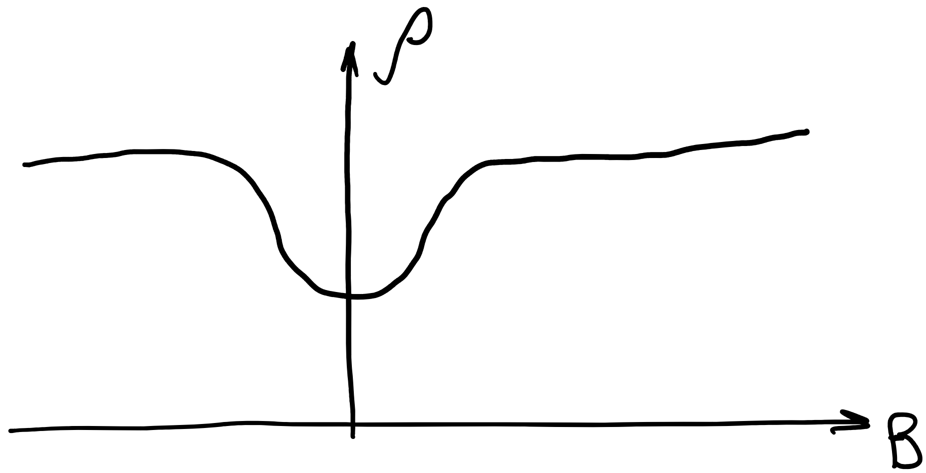
$$\Psi = \begin{pmatrix} \Psi_{00} \\ \Psi_{1,1} \\ \Psi_{1,0} \\ \Psi_{1,1} \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{2}}\left(\varphi_\uparrow(r_1)\varphi_\downarrow(r_2) - \varphi_\downarrow(r_1)\varphi(r_2)\right) \\ \varphi_\uparrow(r_1)\varphi_\uparrow(r_2) \\ \frac{1}{\sqrt{2}}\left(\varphi_\uparrow(r_1)\varphi_\downarrow(r_2) + \varphi_\uparrow(r_2)\varphi_\downarrow(r_1)\right) \\ \varphi_\downarrow(r_1)\ \varphi_\downarrow(r_2) \end{pmatrix} \begin{array}{l} \} \text{Singlet} \\ \left.\begin{array}{l} \\ \\ \\ \end{array}\right\} \text{Triplet (the spin part is odd)} \end{array}$$

WL correction

$$\frac{\delta\sigma}{\sigma} \sim -\int^{\tau_\varphi} \frac{v\lambda_F^{d-1}\,dt}{(Dt)^{\frac{d}{2}}}\left(\frac{3}{2}e^{-\frac{t}{\tau_{SO}}} - 1\right)$$

$$\frac{\delta\sigma}{\sigma} \sim - \int_{\tau} \frac{\cdots}{(Dt)^{\frac{d}{2}}} \left(\frac{3}{2} e^{\cdots} - 1 \right)$$

On times $\tau_{so} < t < \tau_{\varphi}$ the last term dominates $\longrightarrow$ <u>antilocalisation</u>



There is the hierarchy of times

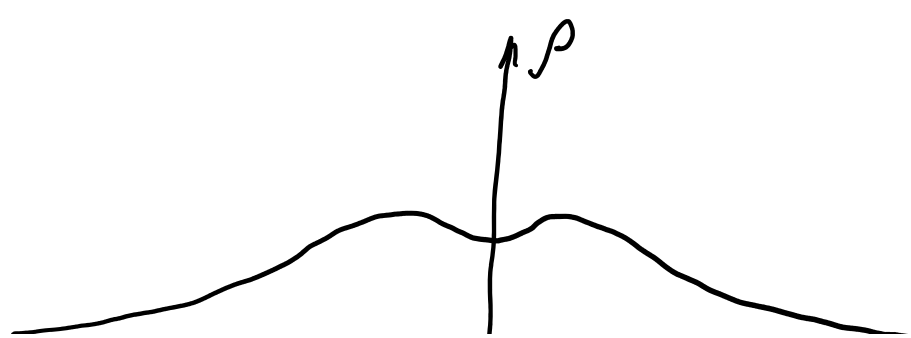
$$\tau \ll \tau_{so} \ll \tau_{\varphi}$$

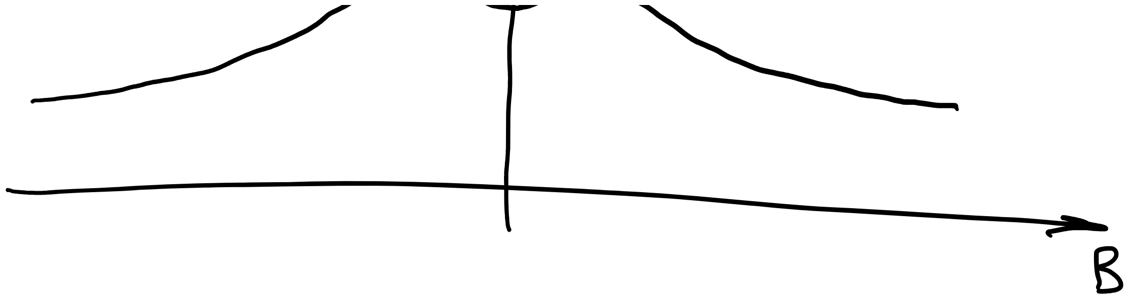
When we apply magnetic field B we first reach the regime

$$\tau \ll \tau_{so} \ll \tau_B, \text{ where } \tau_B = \frac{l_B}{v}$$

$$l_B^2 B = \varphi_0 \sim \frac{c\hbar}{e} \rightarrow l_B = \sqrt{\frac{c\hbar}{eB}}$$

and then $\tau \ll \tau_B \ll \tau_{so}$

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