

ECE 659 Quantum Transport: Atom to Transistor

Lecture 5: Where is the resistance?

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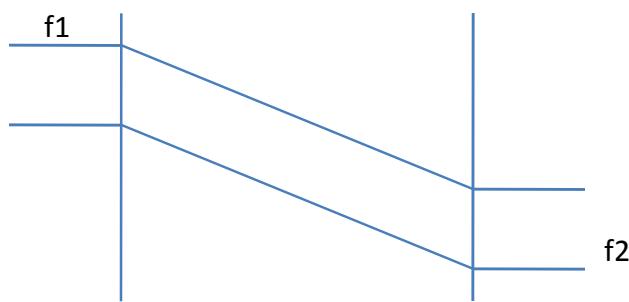
$$G = \sigma \frac{A}{L + \lambda}$$

$$R = \frac{\rho}{A} (L + \lambda)$$

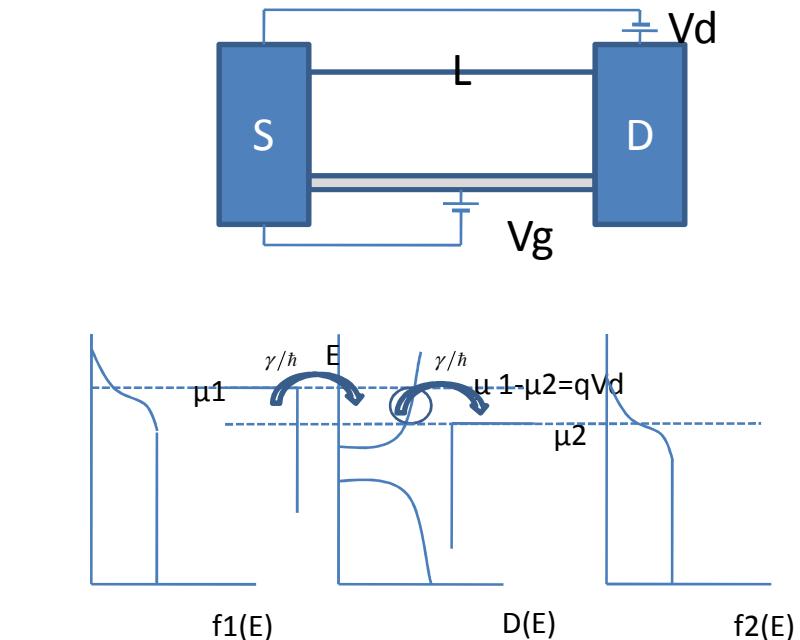
$$\sigma = q^2 \int dE f(E) \frac{d}{dE} \left(\frac{D}{AL} \frac{v_x \lambda}{2} \right)$$

$$\sigma = qn\mu_n$$

$$I = \frac{q}{h} \int dE \frac{hDv_z}{2L} (f^+ - f^-)$$

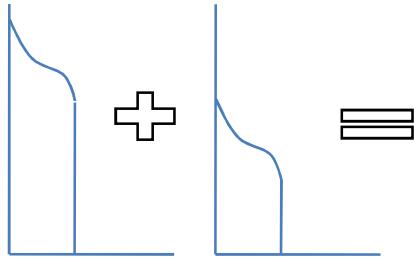


$$\frac{df^+}{dz} = \frac{df^-}{dz} = -\frac{(f^+ - f^-)}{\lambda}$$



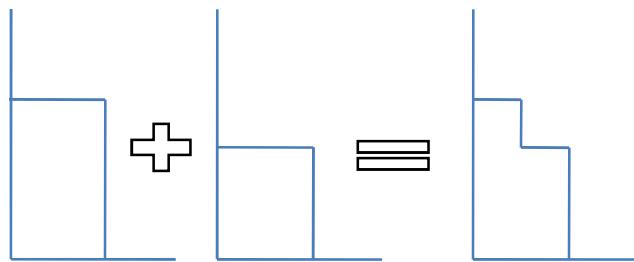
In ballistic: $\frac{df^+}{dz} = \frac{df^-}{dz} = 0$

In non-ballistic: $(f^+ - f^-) = (f_1 - f_2) \frac{\lambda}{\lambda + L}$

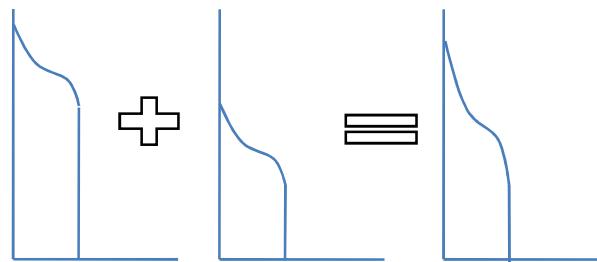


Fermi function? In general NO

(at T = 0K)



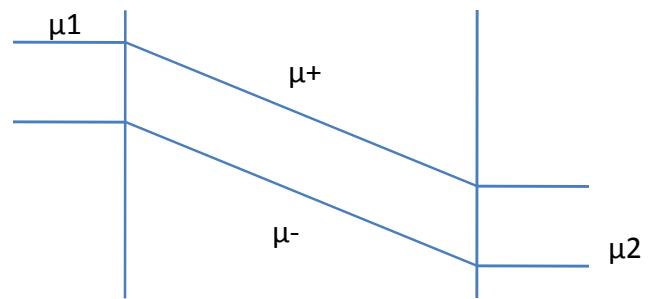
(at large T)



$$af_1 \approx f_0 + \left(-\frac{df}{dE} \right) (\mu_1 - \mu_2)$$

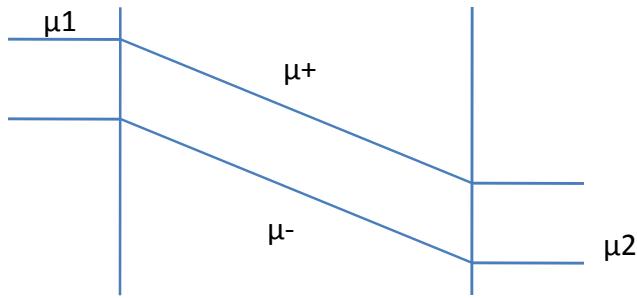
$$\begin{aligned} (1-a)f_1 &\approx f_0 + \left(-\frac{df}{dE} \right) (\mu_1 - \mu_2) \\ &\approx f_0 + \left(-\frac{df}{dE} \right) (a\mu_1 + (1-a)\mu_2) \end{aligned}$$

$$\frac{df^+}{dz} = \frac{df^-}{dz} = -\frac{(f^+ - f^-)}{\lambda} \Rightarrow \frac{d\mu^+}{dz} = \frac{d\mu^-}{dz} = -\frac{(\mu^+ - \mu^-)}{\lambda}$$



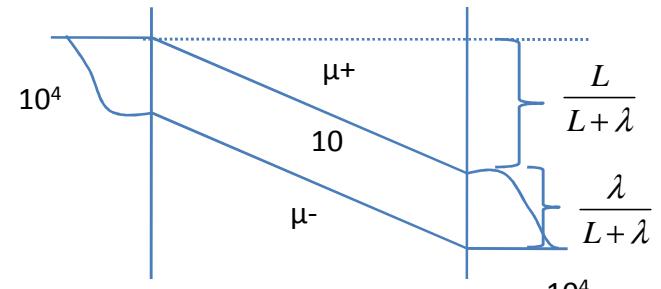
$$I = \frac{q}{h} \int dE \underbrace{\frac{hDv_z}{2L}}_M \left(-\frac{df}{dE} \right) \underbrace{\left(\mu^+ - \mu^- \right)}_{\frac{\lambda}{\lambda+L} (\mu_1 - \mu_2)}$$

$$I = \frac{q}{h} M \underbrace{\frac{\lambda}{L+\lambda} (\mu_1 - \mu_2)}_{(\mu^+ - \mu^-)}$$



$$I = \frac{q^2}{h} M \frac{\lambda}{L+\lambda} \left(\frac{\mu_1 - \mu_2}{q} \right)$$

$$G = \frac{q^2}{h} M \frac{\lambda}{L+\lambda}$$



$$10 [\mu^+ - \mu^-]_{channel} = 10^4 [\mu^+ - \mu^-]_{contact}$$

$$R = \frac{h}{q^2 M} \frac{L + \lambda}{\lambda}$$

$$R_c = \frac{h}{q^2 M}$$

$$R_d = \frac{h}{q^2 M} \frac{L}{\lambda}$$

$$\frac{h}{q^2} = 25 k\Omega$$

$$\frac{h}{2q^2 M} = \frac{12.5 k\Omega}{M}$$