ECE 659 Quantum Transport: Atom to Transistor

Lecture 2: Molecular Ballistic & Diffusive Transport

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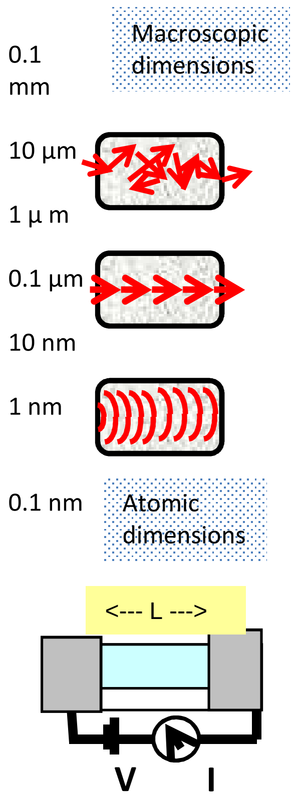
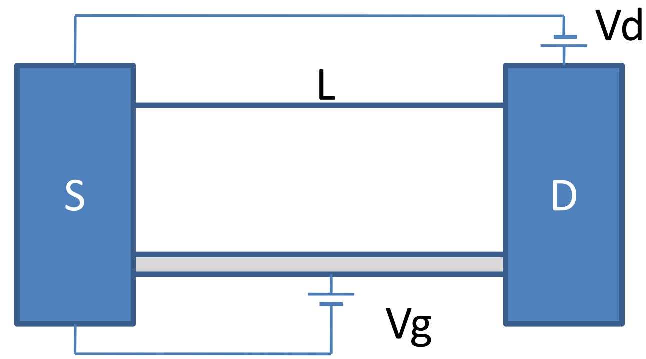
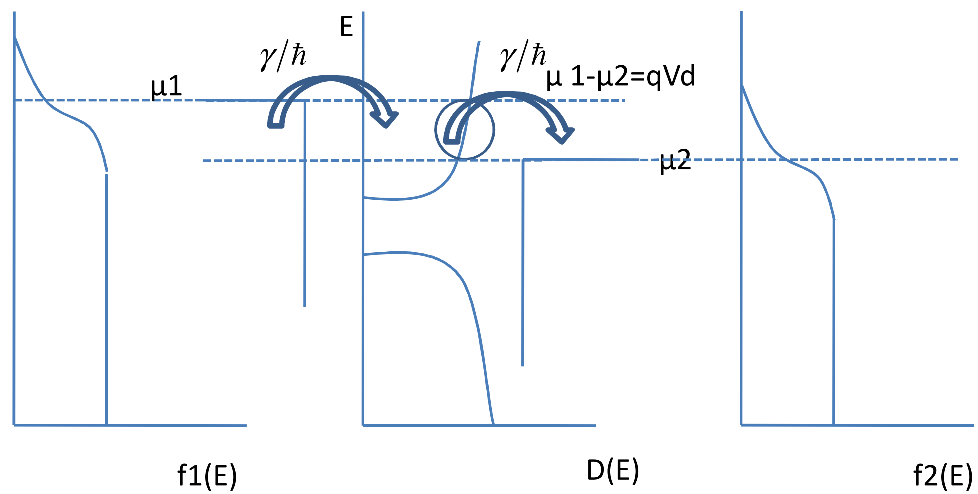


Traditionally : $G = qn\dfrac{q\tau}{m}$

τ,n,m -> not clear for small conductors



$$G = \frac{q^2}{h}\left(\pi D\gamma\right)$$



$$f\left(E\right) = \frac{1}{e^{(E-\mu)/kT} + 1}$$

$$I \sim \int dE D\left(E\right)\left(f_1\left(E\right) - f_2\left(E\right)\right)$$

$$I = q\int dE D(E)\frac{\gamma}{2\hbar}\left(f_1(E) - f_2(E)\right)$$

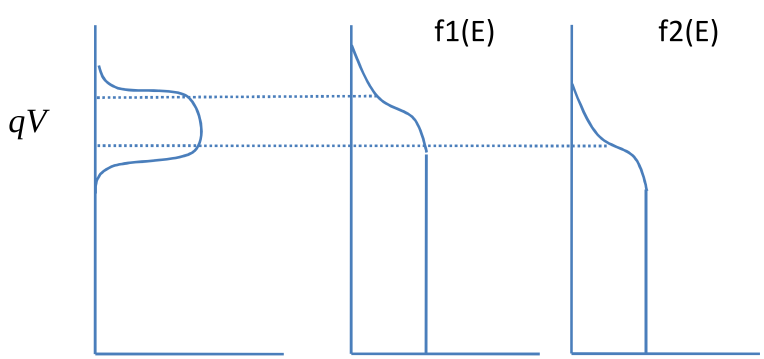
Factor of 2 :

- twice the time taken to travel from one contact to the other
- occupancy in the channel is average of the two contacts

$$\frac{\gamma}{\hbar}\left(f_1 - \frac{f_1 + f_2}{2}\right) = \frac{\gamma}{2\hbar}\left(f_1 - f_2\right)$$

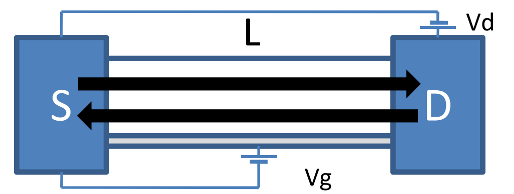
$$I = \frac{q}{h}\int dE \underbrace{\left(\pi D\gamma\right)}_{\bar{T}(E)}\left(f_1(E) - f_2(E)\right)$$

$$I = \frac{q}{h}\bar{T}(E)\underbrace{\int dE\left(f_1(E) - f_2(E)\right)}_{qV}$$



$$\frac{I}{V} = \frac{q^2}{h}\bar{T}(E)$$

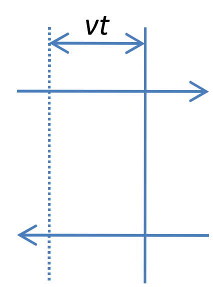
Ballistic Channel:



$$I = \frac{q}{h}\int dE\bar{T}(E)\left(f_1 - f_2\right)$$

$$I = q\frac{dED(E)}{2L}vf_1(E)$$

$$I = qnv$$

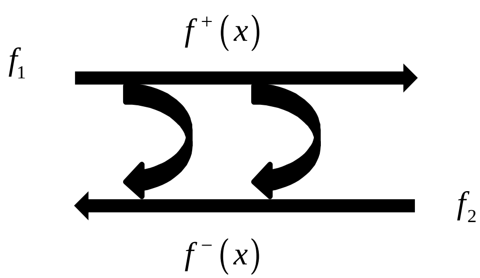


$$I = q\int dE \frac{D(E)}{2L} v\left(f_1 - f_2 \right)$$

$$I = \frac{q}{h}\int dE \frac{hD(E)v(E)}{2L}\left(f_1 - f_2 \right)$$

$$I = \frac{q}{h}\int dE \underbrace{\frac{\pi\hbar D v}{L}}_{\equiv M(E)}\left(f_1 - f_2 \right)$$

Diffusive Transport:



$$I = q\int dE \frac{D(E)}{2L} v\left(f^{+} - f^{-} \right)$$

$$f^{+} - f^{-} = \left(f_1 - f_2 \right)\frac{mfp}{mfp + L}$$

For diffusive transport modes:

$$M(E)\frac{mfp}{mfp + L}$$

If *L>>mfp*, we get Ohm’s law