ECE 659 Quantum Transport: Atom to Transistor

Lecture 33: Thermoelectricity

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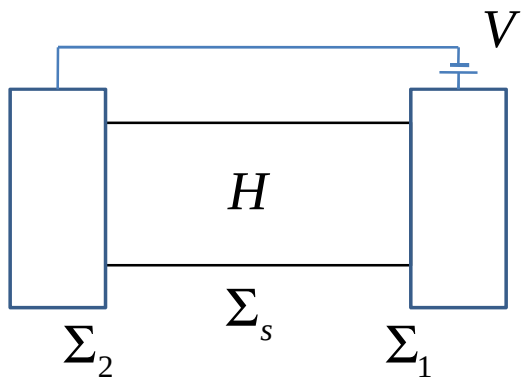
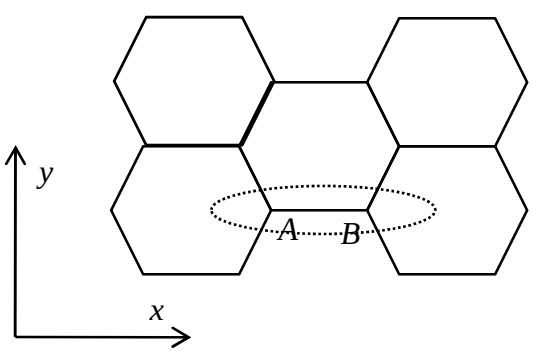
Notes prepared by Samiran Ganguly

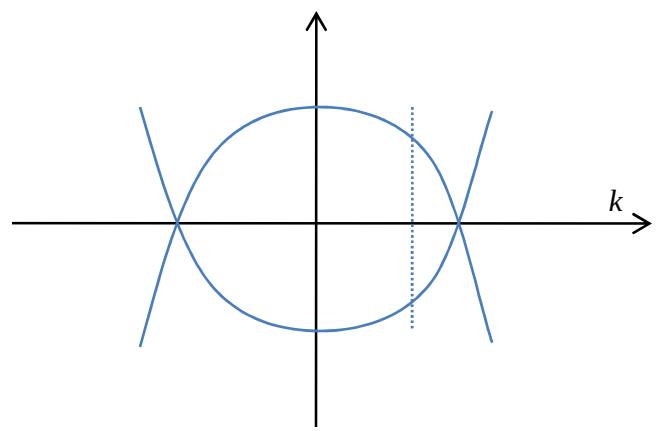


$$I = \frac{q}{h}\int dE\,(f_1 - f_2)\,T(E)$$

An aside on pseudo-spins and graphene:



$$\begin{matrix} A \\ B \end{matrix}\begin{pmatrix} \\ \\ \end{pmatrix} e^{i\vec{k}\cdot\vec{r}_n}$$

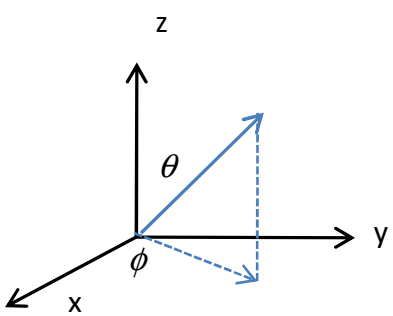


$$h\left(\vec{k}\right) = t\begin{bmatrix} \sigma_x \underbrace{\left(1+2\cos k_x a \cos k_y b\right)}_{B_x} \\ +\sigma_y \underbrace{\left(2\sin k_x a \cos k_y b\right)}_{B_y} \end{bmatrix}$$

$$H = \mu_B\left(\sigma_x B_x + \sigma_y B_y + \sigma_z B_z\right)$$

Eigenvalues:

$$\pm\mu_B\sqrt{B_x^2 + B_y^2 + B_z^2}$$



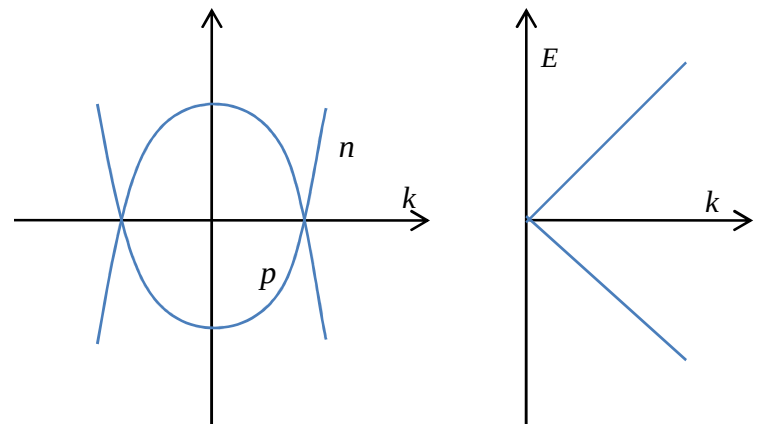
$$up \quad \begin{pmatrix} \cos\theta/2\, e^{-i\phi/2} \\ \sin\theta/2\, e^{+i\phi/2} \end{pmatrix}$$

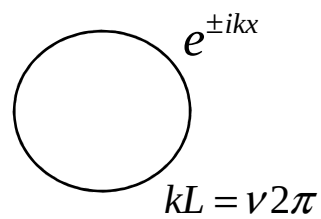
$$down \quad \begin{pmatrix} -\sin\theta/2\, e^{-i\phi/2} \\ \cos\theta/2\, e^{+i\phi/2} \end{pmatrix}$$

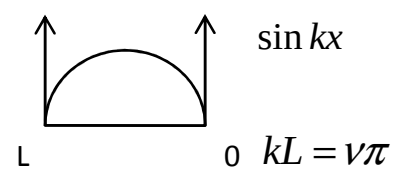
$$\theta = \pi/2$$

Eigenvalues: $\frac{1}{\sqrt{2}}\begin{pmatrix} e^{-i\phi/2} \\ e^{+i\phi/2} \end{pmatrix}$ $\quad \tan\phi = \frac{B_y}{B_x} = \frac{2\sin k_x a \cos k_y b}{1+2\cos k_x a \cos k_y b}$

Graphene p-n junctions:



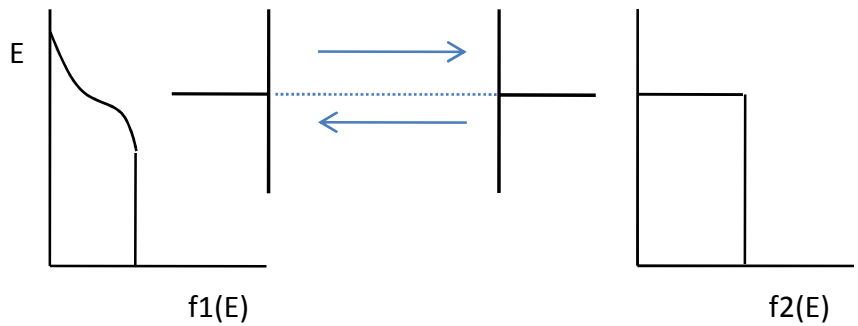


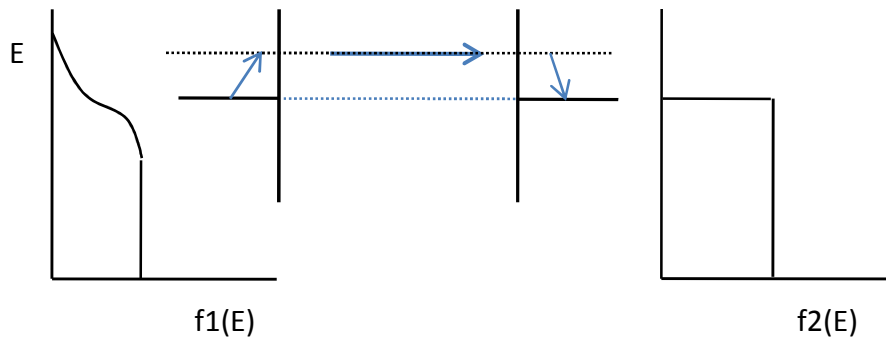


$\sin kx$ solution: $\{\quad\} e^{+ikx} + \{\quad\} e^{-ikx}$

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

$$f(E) = \frac{1}{e^{(E-\mu)/k_B T} + 1}$$





$$I_{Q1} = \frac{1}{h}\int dE\,T(E)\left(E-\mu_1\right)\left(f_1 - f_2\right)$$

$$I_{Q2} = \frac{1}{h}\int dE\,T(E)\left(E-\mu_2\right)\left(f_1 - f_2\right)$$