FUNDAMENTALS OF NANOELECTRONICS

Basic Concepts

1. The New Perspective
2. Energy Band Model
3. What and Where is the Voltage?

Heat & Electricity:
Second Law & Information

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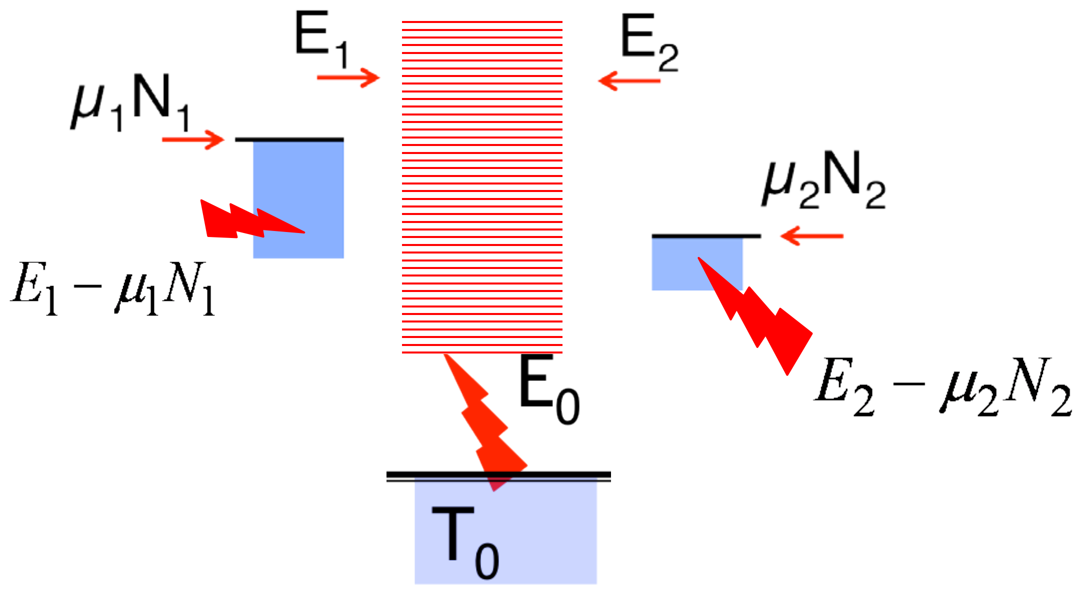
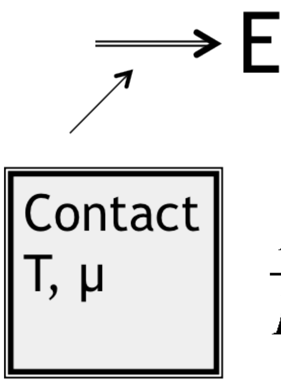
Spring 2015

http://nanohub.org/groups/lnebook

4.6a Entropy

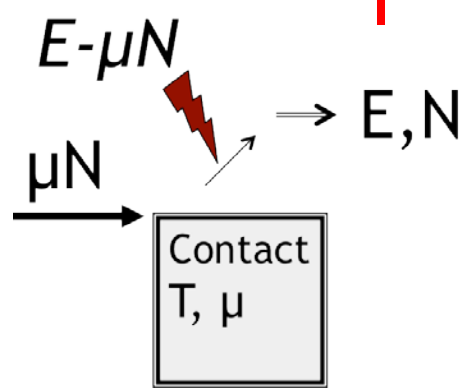


$$\frac{E_1 - \mu_1 N_1}{T_1} + \frac{E_2 - \mu_2 N_2}{T_1} + \frac{E_0}{T_0} \leq 0$$



$$\frac{P(E)}{P_r(E)} = \exp\left(-\frac{E}{kT}\right)$$

If N=0

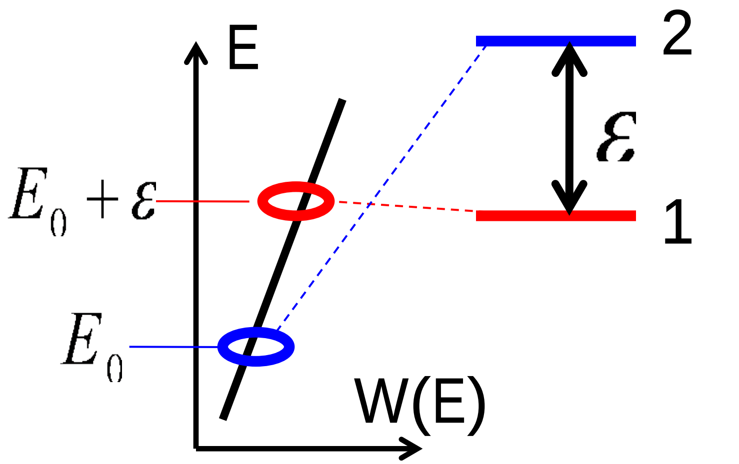


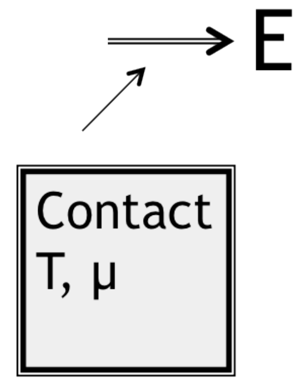
$$\frac{P(E,N)}{P_r(E,N)} = \exp\left(-\frac{E - \mu N}{kT}\right)$$

Why is it harder to take than to give

Contact ↔ "Reservoir" "System"

4.6b Entropy

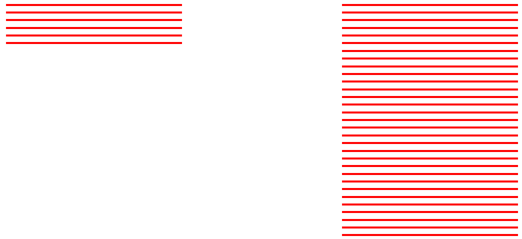




$$\frac{P(-\varepsilon)}{P_r(-\varepsilon)} = \frac{W(E_0+\varepsilon)}{W(E_0)}$$

$$\frac{P(E)}{P_r(E)} = \exp\left(-\frac{E}{kT}\right)$$

$$2 + C(E_0) \leftrightarrow C(E_0+\varepsilon) + 1$$



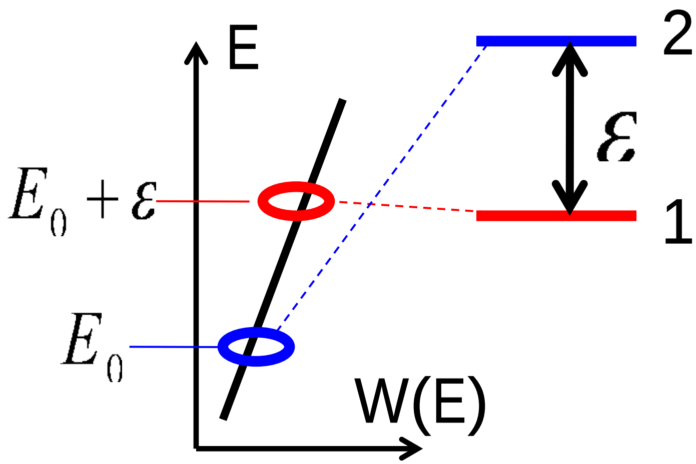
Why is it harder to take than to give

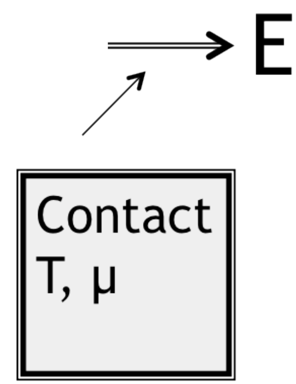
4.6c Entropy

Contact ↔ "Reservoir" "System"

$$S = k \ell n W$$

$$W = \exp\left(S/k\right)$$





$$\frac{P(E)}{P_r(E)} = \exp\left(-\frac{E}{kT}\right)$$

$$\frac{P(-\varepsilon)}{P_r(-\varepsilon)} = \frac{W(E_0+\varepsilon)}{W(E_0)} = \frac{\exp(S(E_0+\varepsilon)/k)}{\exp(S(E_0)/k)}$$

$$= \exp\frac{S(E_0+\varepsilon)-S(E_0)}{k} \approx \exp\left(\frac{dS}{dE}\varepsilon \times \frac{1}{k}\right)$$

$$= \exp\left(\frac{\varepsilon}{kT}\right)$$

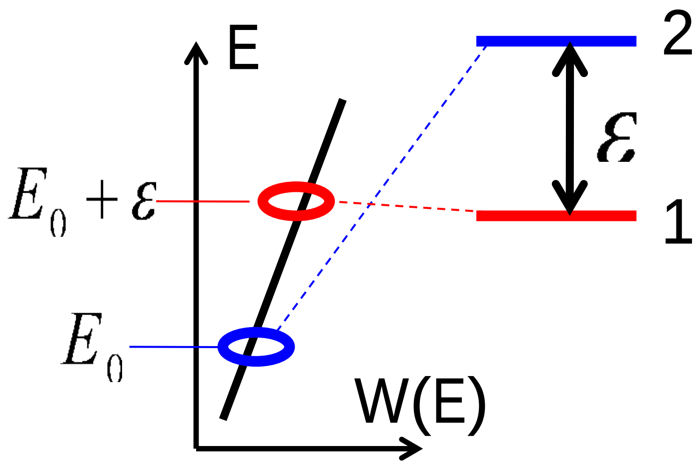
$$\boxed{\left(\frac{dS}{dE}\right)_{E=E_0} = \frac{1}{T}}$$

Contact "System"

4.6d Entropy

$$S = k\,\ell n W$$

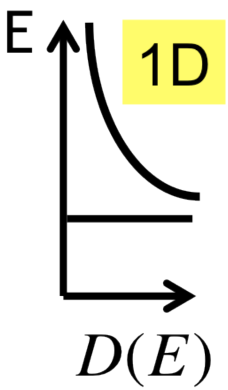
$$W = \exp\left(S/k\right)$$



$$\left(\frac{dS}{dE}\right)_{E=E_0} = \frac{1}{T}$$

$$W = \Delta E\, D(E) \sim E^{\frac{d}{2}-1} \rightarrow E^{\frac{Nd}{2}-1}$$

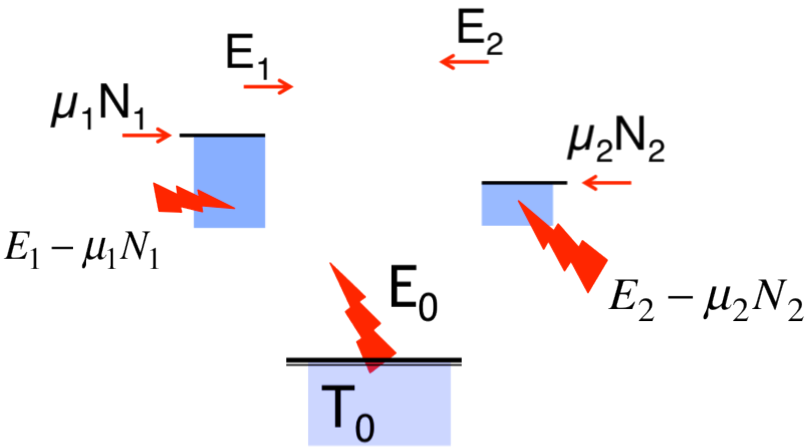
$$E_0 = \frac{kT}{2}\,Nd$$

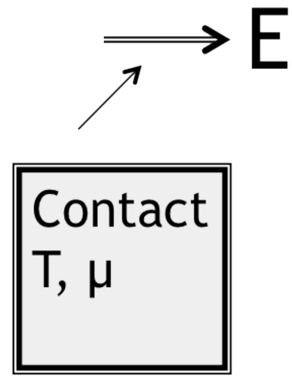


$$\frac{S}{k} = \left(\frac{Nd}{2}-1\right)\ell n\, E$$

$$\rightarrow \left(\frac{dS}{dE}\right)_{E=E_0} = \frac{k}{E_0}\left(\frac{Nd}{2}\cancel{-1}\right) = \frac{1}{T}$$

4.6e Entropy





$$\frac{E_0}{T_0} + \frac{E_1 - \mu_1 N_1}{T_1} + \frac{E_2 - \mu_2 N_2}{T_1} \leq 0$$

$$\frac{P(E)}{P_r(E)} = \exp\left(-\frac{E}{kT}\right)$$

$$-\Delta S_0 \quad -\Delta S_1 \quad -\Delta S_2 \quad \leq \quad 0$$

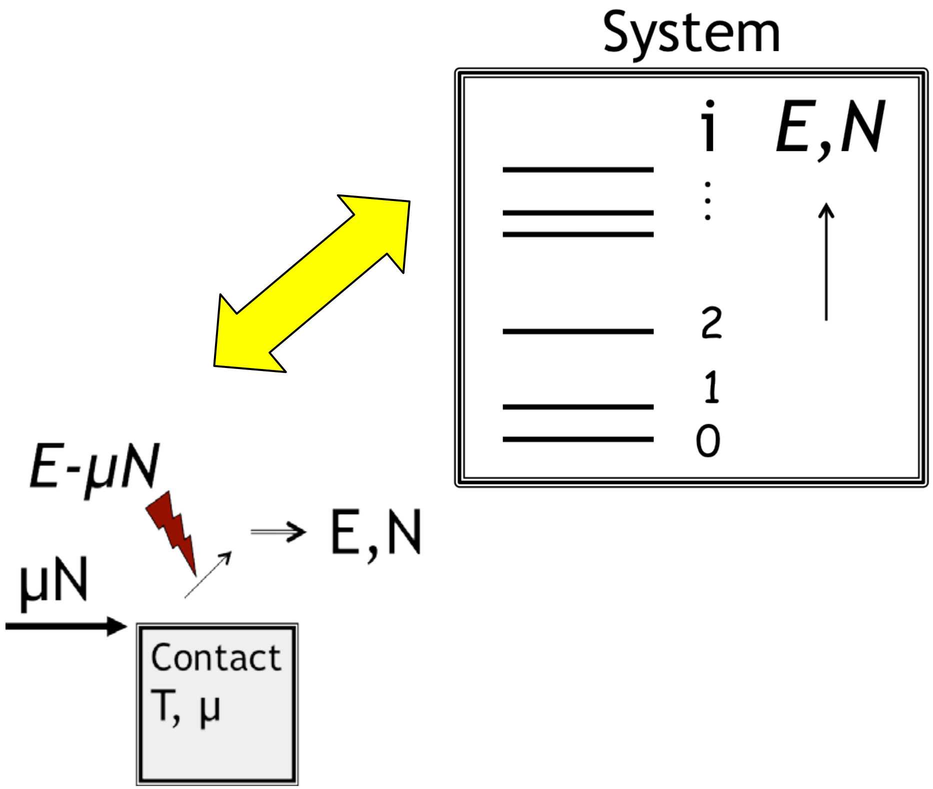
$$S = k \, \ell n W$$

$$\Delta S \geq 0$$

$$\Delta S = \frac{\Delta E}{T} \longleftarrow \left(\frac{dS}{dE}\right)_{E=E_0} = \frac{1}{T}$$

Law of Equilibrium

$$p_i = \frac{1}{Z} e^{-(E_i - \mu N_i)/kT}$$



$$\frac{P(E,N)}{P_r(E,N)} = \exp\left(-\frac{E-\mu N}{kT}\right)$$

Coming up next ..