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

4.1. Introduction

4.2. Seebeck Coefficient

4.3. Heat Current

4.4. One-level Device

4.5. Second Law

4.6. Entropy

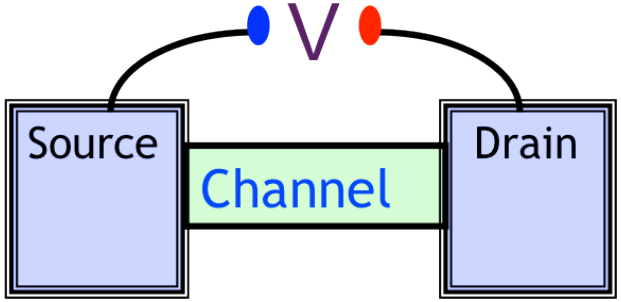
4.7. Law of Equilibrium

4.8. Shannon Entropy

4.9. Fuel Value of Information

4.10. Summing up ..

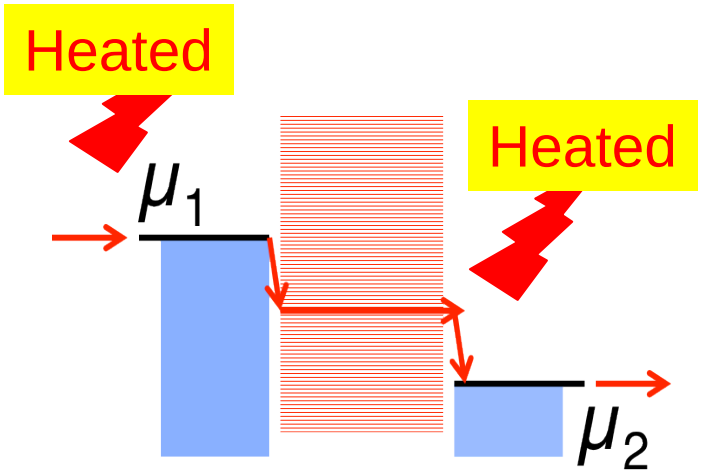
4.10a Summing up



4.2, 4.3, 4.4 Thermoelectricity

➢ Obtain standard results for thermoelectric coefficients

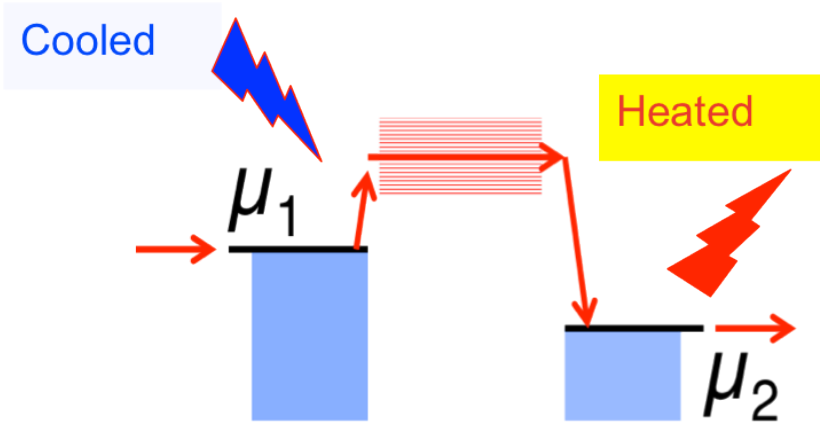
$$I = \frac{1}{q}\int_{-\infty}^{+\infty} dE\, G(E)\left(f_1(E) - f_2(E)\right)$$



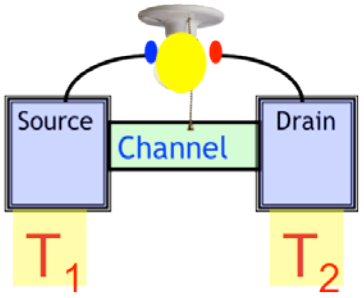
Entropy driven | *Force driven* | *Entropy driven*

$$I = G_0\ \Delta V + G_S\ \Delta T$$

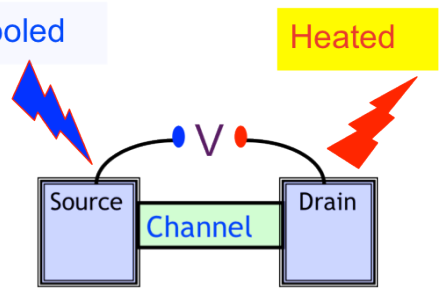
$$I_Q = G_P\ \Delta V + G_Q\ \Delta T$$



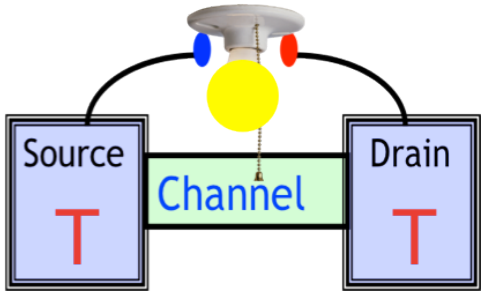
4.2. Seebeck Effect



4.3. Peltier Effect



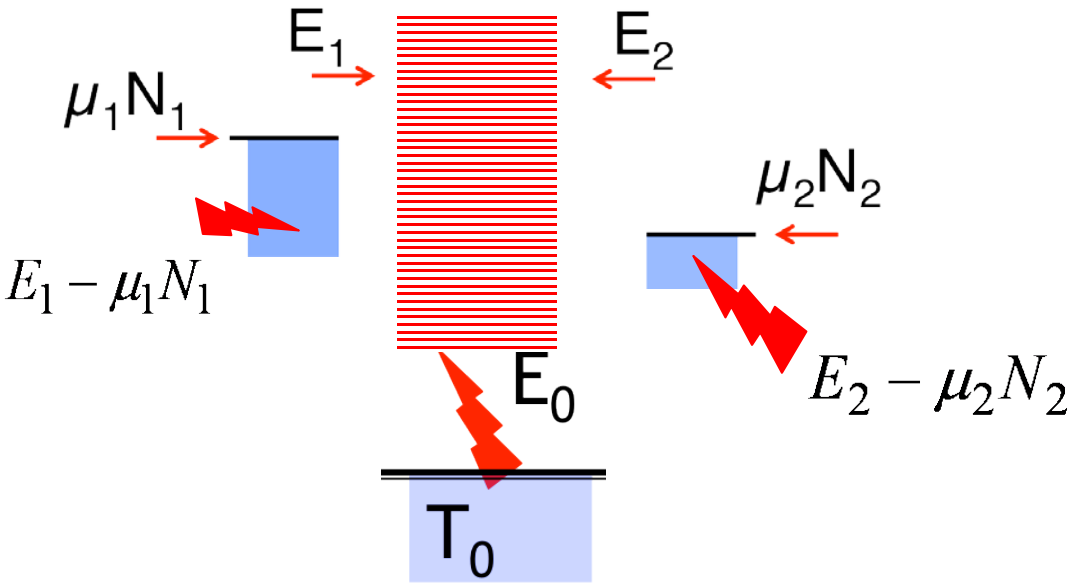
NO !!



4.5 Second Law

4.10b Summing up

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



4.10c Summing up

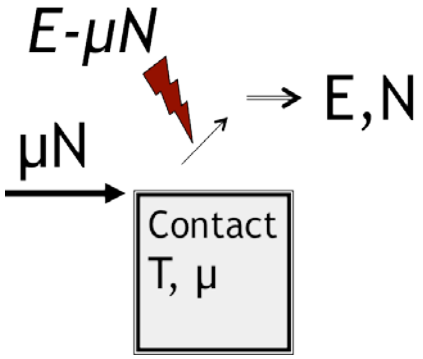
4.5 Second Law

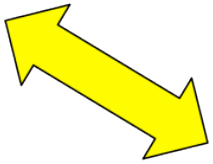
$$\frac{E_1 - \mu_1 N_1}{T_1} + \frac{E_2 - \mu_2 N_2}{T_1} + \frac{E_0}{T_0} \leq 0$$

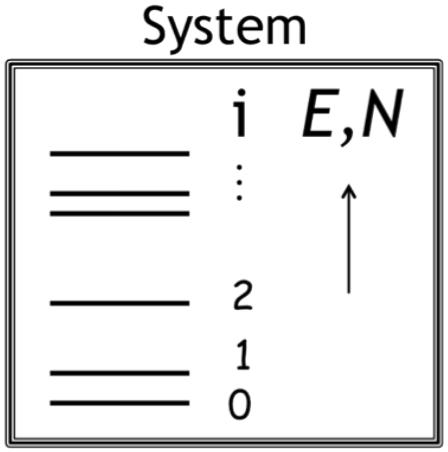
4.6 Entropy

4.7 Law of Equilibrium

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



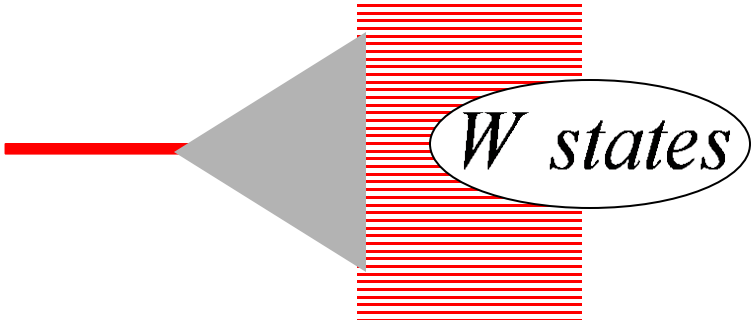




$$\frac{P(E,N)}{P_r(E,N)} = \exp\left(-\frac{E - \mu N}{kT}\right)$$

4.10d Summing up

System | Contact

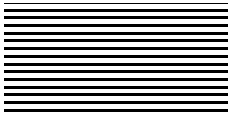


4.6 Entropy

$$\frac{S}{k} = \ell n\, W$$

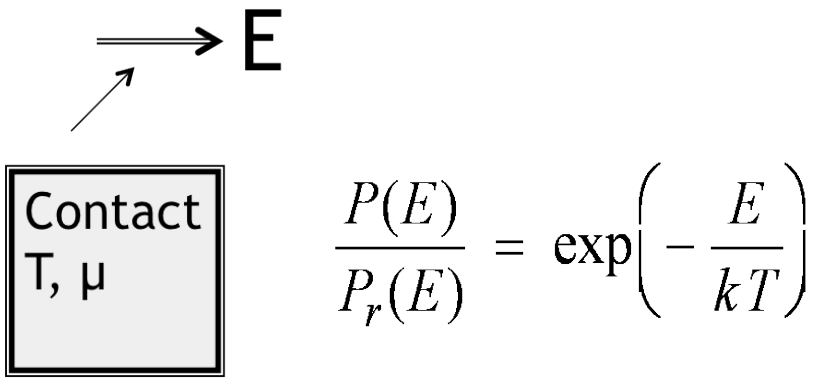
4.8 Shannon Entropy

$$\frac{S}{k} = -\sum_i \tilde{p}_i \ell n\, \tilde{p}_i$$



$$\{E_i, N_i, \tilde{p}_i\}$$

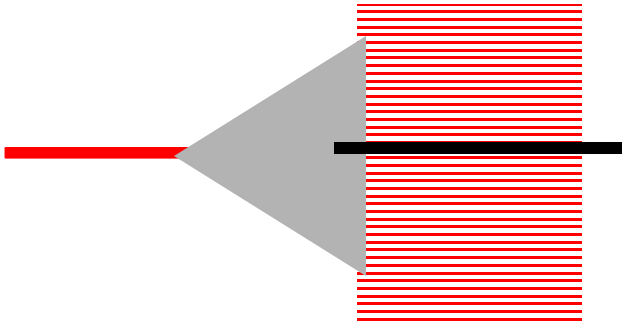
Why is it harder to take than to give



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

System

Contact



$$S = nk\ell n2$$

$$S = 0$$

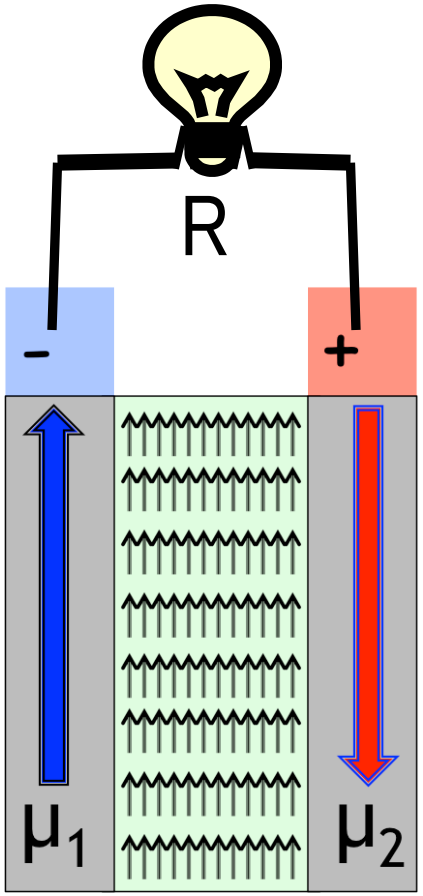
4.8 Shannon Entropy

$$S = -k\sum_i \tilde{p}_i \ell n\, \tilde{p}_i$$

$$H = -\sum_i \tilde{p}_i \ell n\, \tilde{p}_i$$

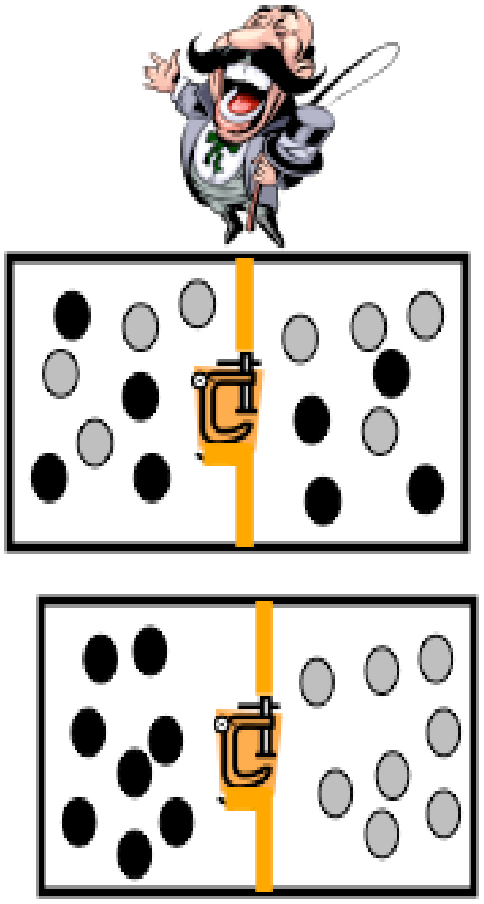
Information Content

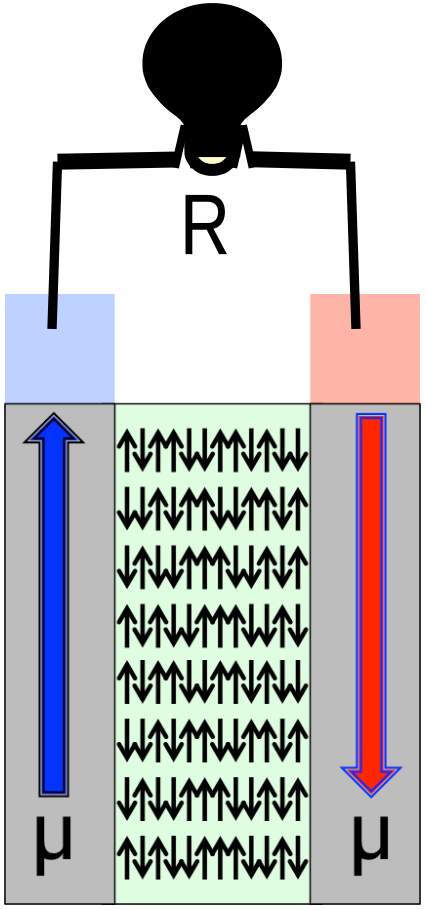
" Info-battery "



$$S = 0$$

Maxwell's Demon

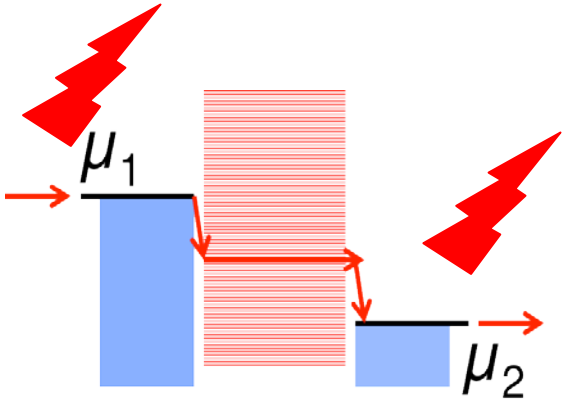




$$S = nk\ell n2$$

Basic Concepts: Semiclassical Models

1. The New Perspective
2. Energy Band Model
3. What and Where is the Voltage?
4. Heat & Electricity: Second Law & Information



Entropy driven | *Force driven* | *Entropy driven*

Coming up next ..

“ Epilogue “

Quantum Models

5. Schrodinger Equation
6. Contact-ing Schrodinger
7. NEGF Method
8. Spin Transport