FUNDAMENTALS OF NANOELECTRONICS

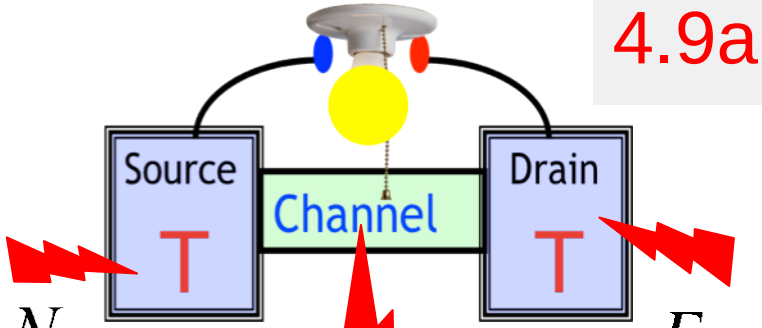
Basic Concepts

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

Heat & Electricity:
Second Law & Information

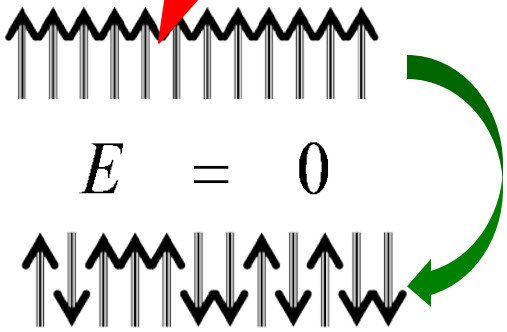
4.1. Introduction
4.2. Seebeck Coefficient
4.3. Heat Current
4.4. One-level Device
4.5. Second Law
4.6. Entropy
4.7. Law of Equilibrium
4.8. Shannon Entropy
4.9. Fuel Value of Information
4.10. Summing up ..

4.9a Fuel value of information



$E_1 - \mu_1 N_1$ $E_2 - \mu_2 N_2$

$S = 0$ $E = 0$ $S = nk\ell n2$



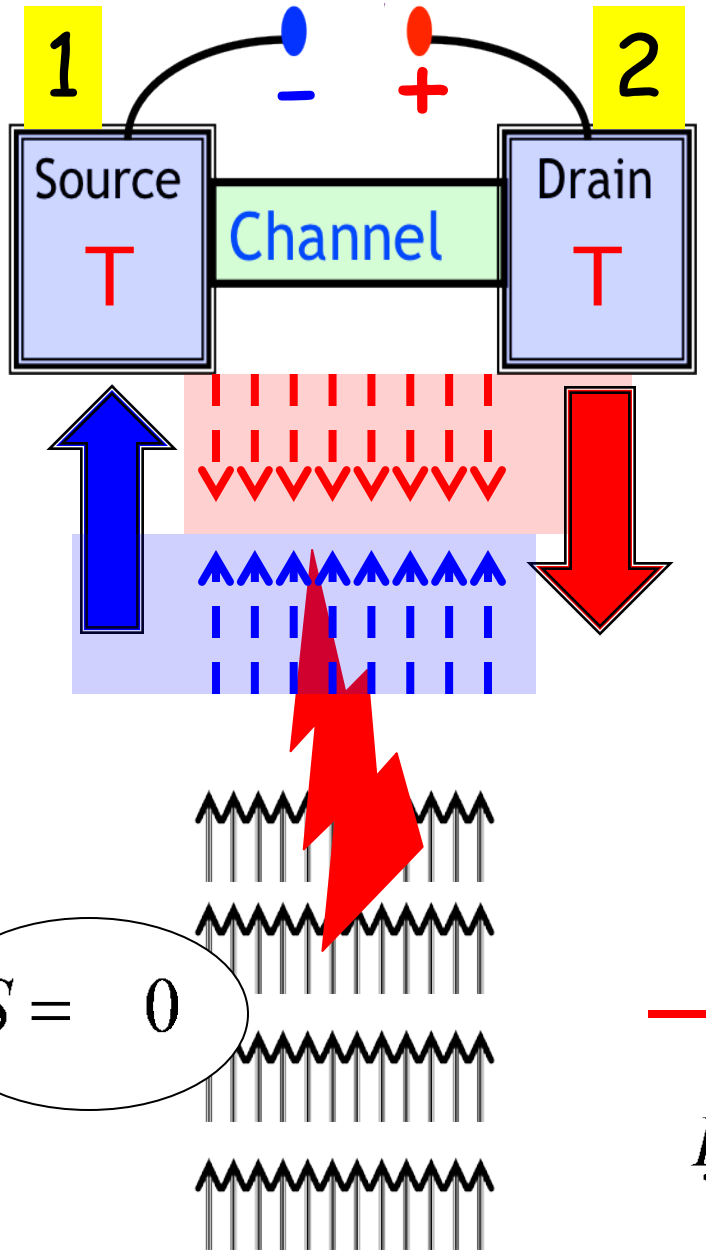
But how do we make such a device?

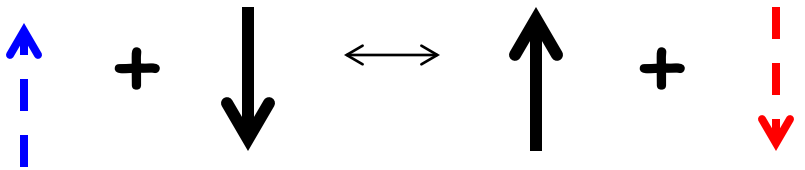
$$(E_1 - \mu_1 N_1) + (E_2 - \mu_2 N_2) \leq T\Delta S = nkT\,\ell n2$$

Second Law

$$\frac{E_1 - \mu_1 N_1}{T} + \frac{E_2 - \mu_2 N_2}{T} - \Delta S \leq 0$$

4.9b Fuel value of information





$$u + D \leftrightarrow U + d$$

$$n_D \times \qquad n_U \times$$

$$I \sim f_u(1-f_d) - f_d(1-f_u)$$

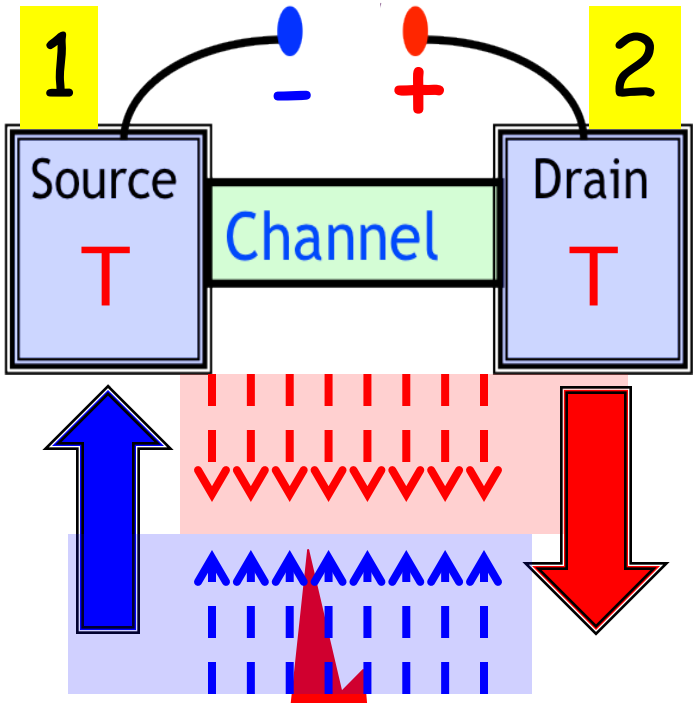
$$\sim f_1(1-f_2)\,n_D - f_2(1-f_1)\,n_U$$

If $n_D = n_U$,

$$I \sim f_1(1-f_2) - f_2(1-f_1)$$

$$\sim f_1 - f_2$$

4.9c Fuel value of information



$$I \sim \; f_1(1-f_2)\,n_D \; - \; f_2(1-f_1)\,n_U$$

$$If\ I=0, \qquad \frac{1-f_1}{f_1}\,n_U \;=\; \frac{1-f_2}{f_2}\,n_D$$

$$\exp\left(\frac{E-\mu_1}{kT}\right) n_U \;=\; \exp\left(\frac{E-\mu_2}{kT}\right) n_D$$

$$\exp\left(\frac{\mu_1-\mu_2}{kT}\right) \;=\; \frac{n_U}{n_D} \;=\; \frac{P_U}{P_D}$$

$S = 0$

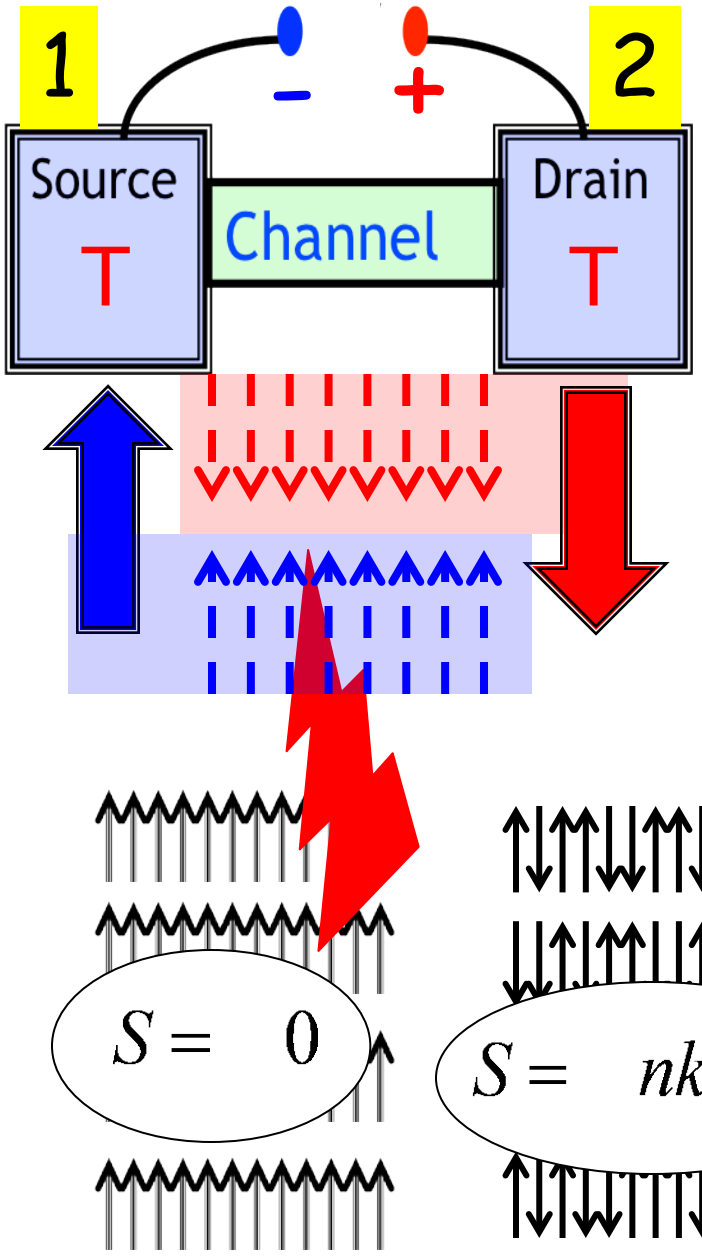
$$f = \frac{1}{1+e^x}$$

$$\rightarrow \quad \frac{1-f}{f} = e^x$$

$$\mu_1 - \mu_2 \;=\; kT\,\ell n\frac{P_U}{P_D}$$

$$n_U = nP_U\,,\; n_D = nP_D$$

4.9d Fuel value of information



$$\mu_1 - \mu_2 = kT\,\ell n\frac{P_U}{P_D}$$

$$E = -\int_{Initial}^{Final} dn_U\,(\mu_1 - \mu_2)$$

$$= -nkT\int_{Initial}^{Final} dP_U\,(\ell n\,P_U - \ell n\,P_D)$$

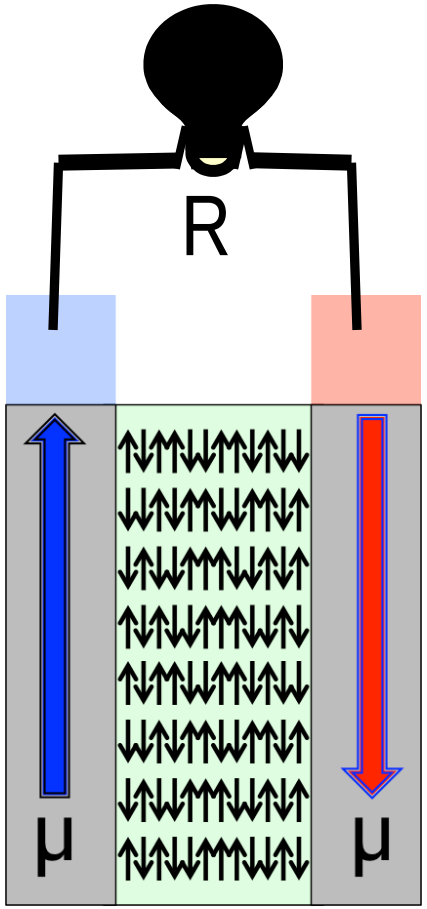
$$= T\int_{Initial}^{Final} dS$$

$$S = -nk\left(P_U \ell n\,P_U + P_D \ell n\,P_D\right)$$

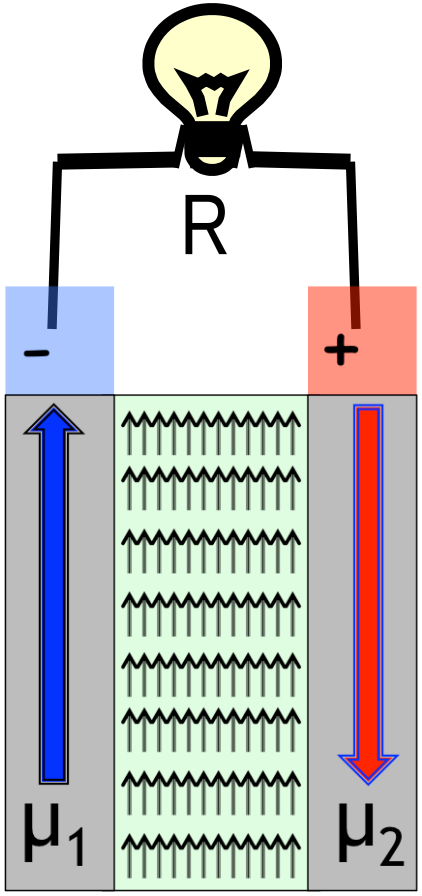
$$dS = -nk\left(\begin{matrix} dP_U \ell n\,P_U + dP_U \\ +dP_D \ell n\,P_D + dP_D \end{matrix}\right)$$

4.9e Fuel value of information

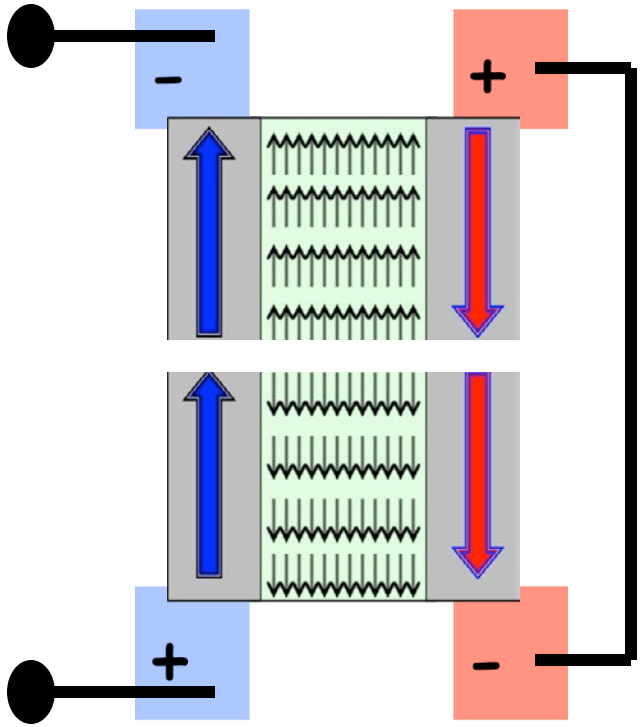
" Info-battery "

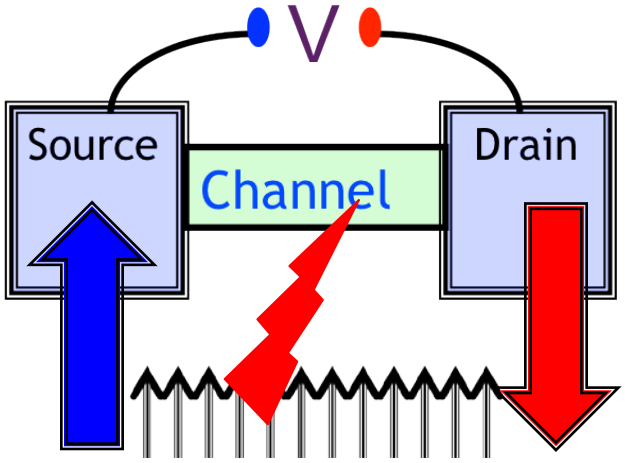


$$S = nk\ell n2$$



$$S = 0$$





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

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

Coming up next ..