

FUNDAMENTALS OF NANO ELECTRONICS

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

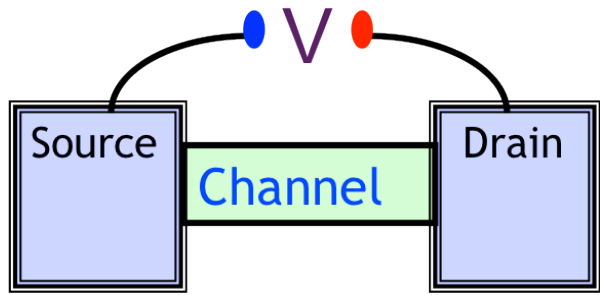
4.7. Law of Equilibrium

4.8. Shannon Entropy

4.9. Fuel Value of Information

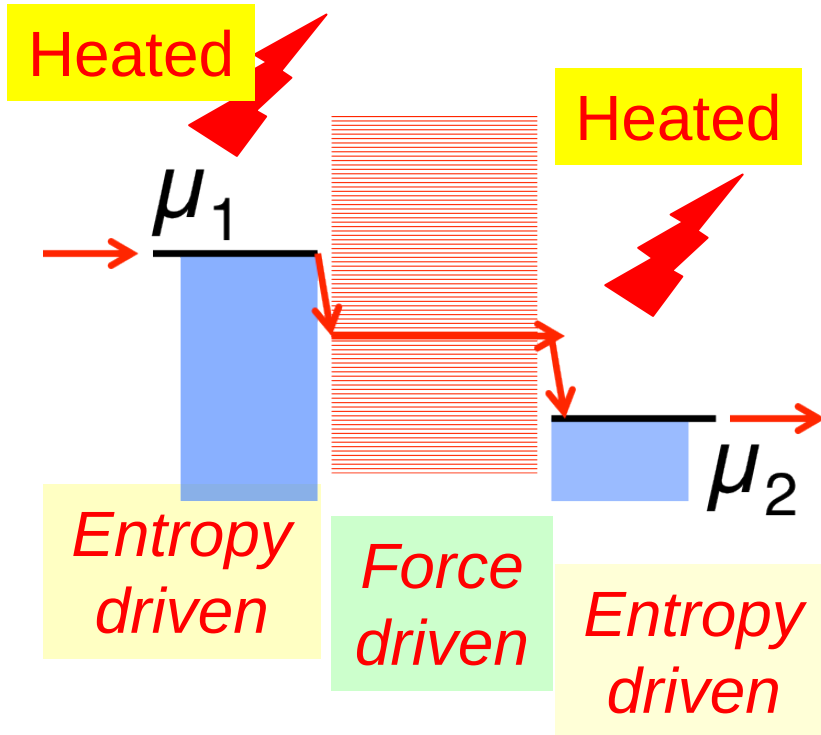
4.10. Summing up ..

4.1a Introduction

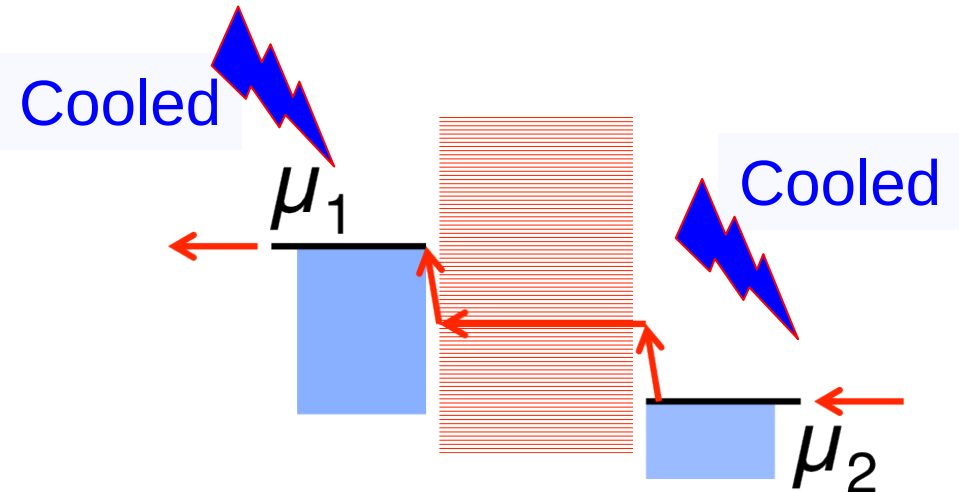
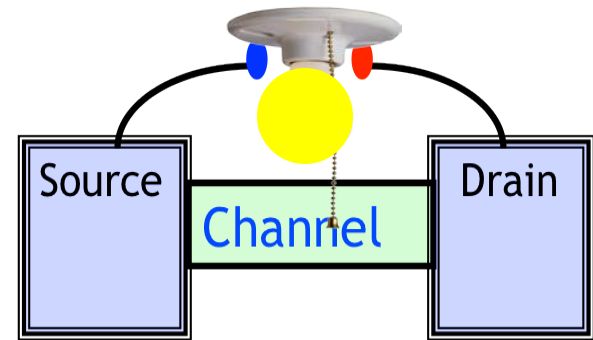


Could you reverse it?

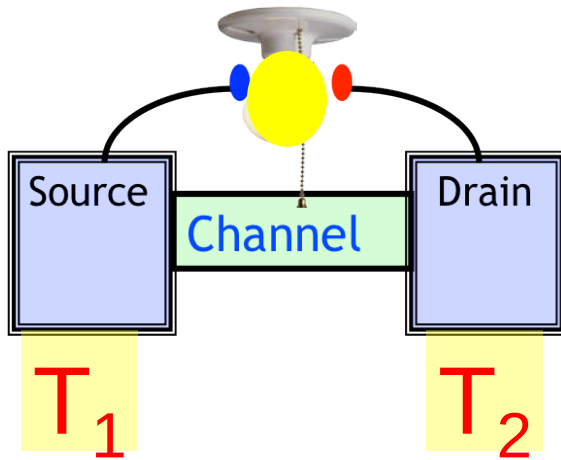
$$I = \frac{1}{q} \int_{-\infty}^{+\infty} dE G(E) (f_1(E) - f_2(E))$$



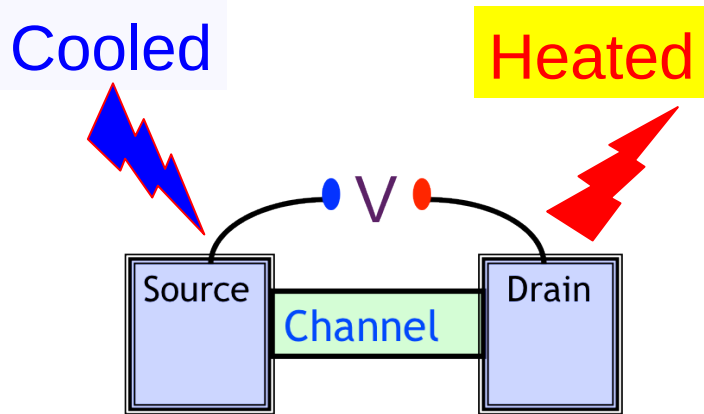
NO !!



4.2. Seebeck Effect

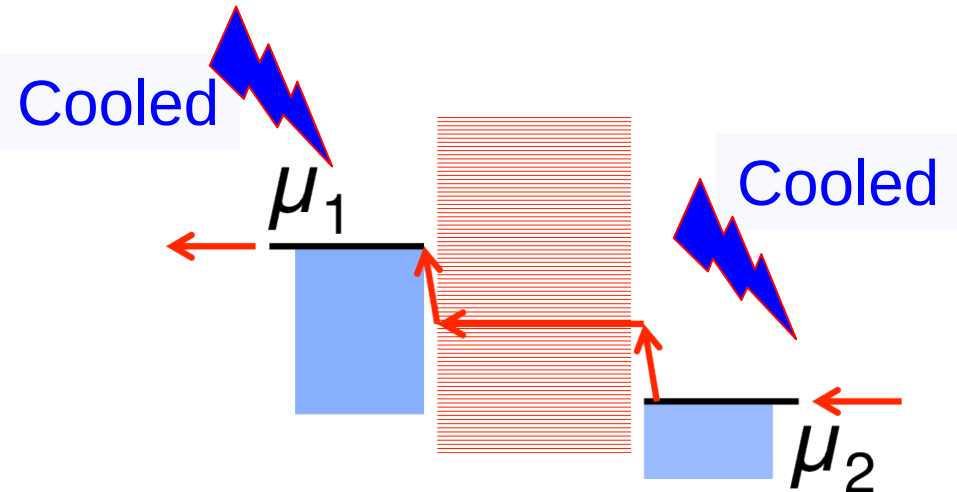
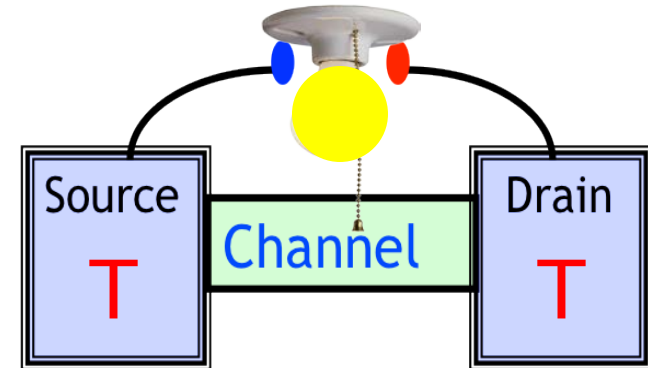


4.3. Peltier Effect

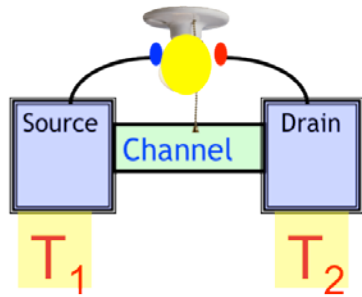


4.1b Introduction

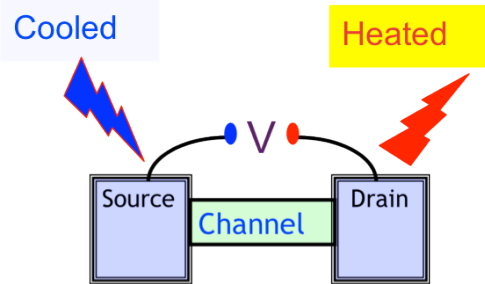
NO !!



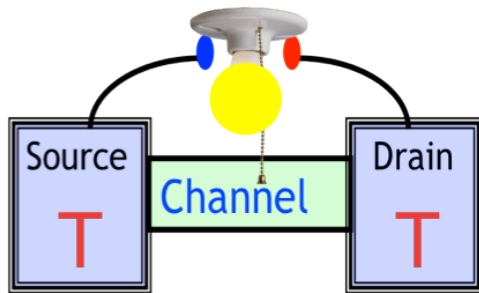
4.2. Seebeck Effect



4.3. Peltier Effect



NO !!

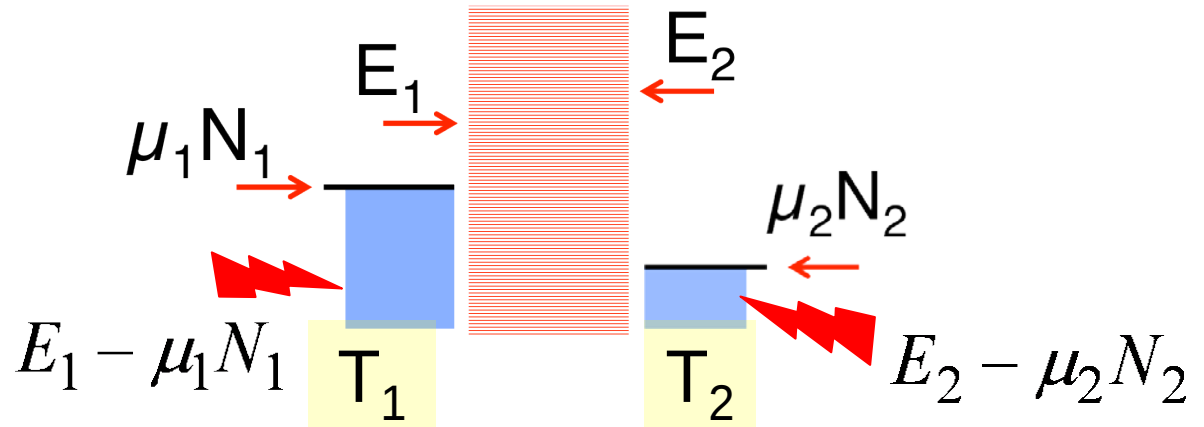


$$N_1 + N_2 = 0$$

4.1c Introduction

First Law

$$E_1 + E_2 = 0$$



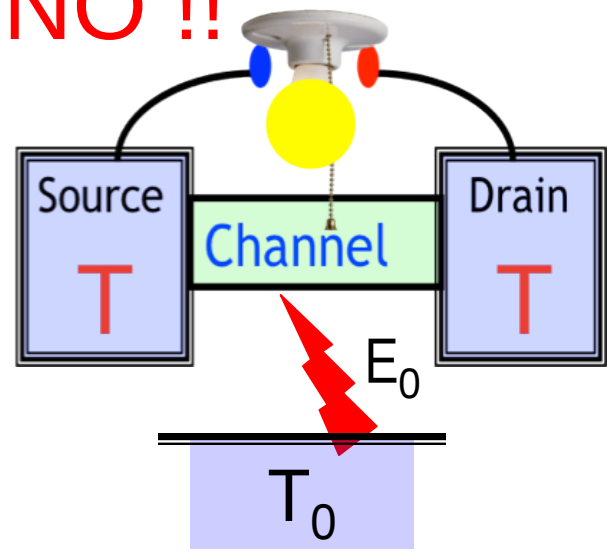
$$I = \frac{1}{q} \int_{-\infty}^{+\infty} dE G(E) (f_1(E) - f_2(E))$$

ensures

4.5. Second Law

$$\frac{E_1 - \mu_1 N_1}{T_1} + \frac{E_2 - \mu_2 N_2}{T_2} \leq 0$$

NO !!



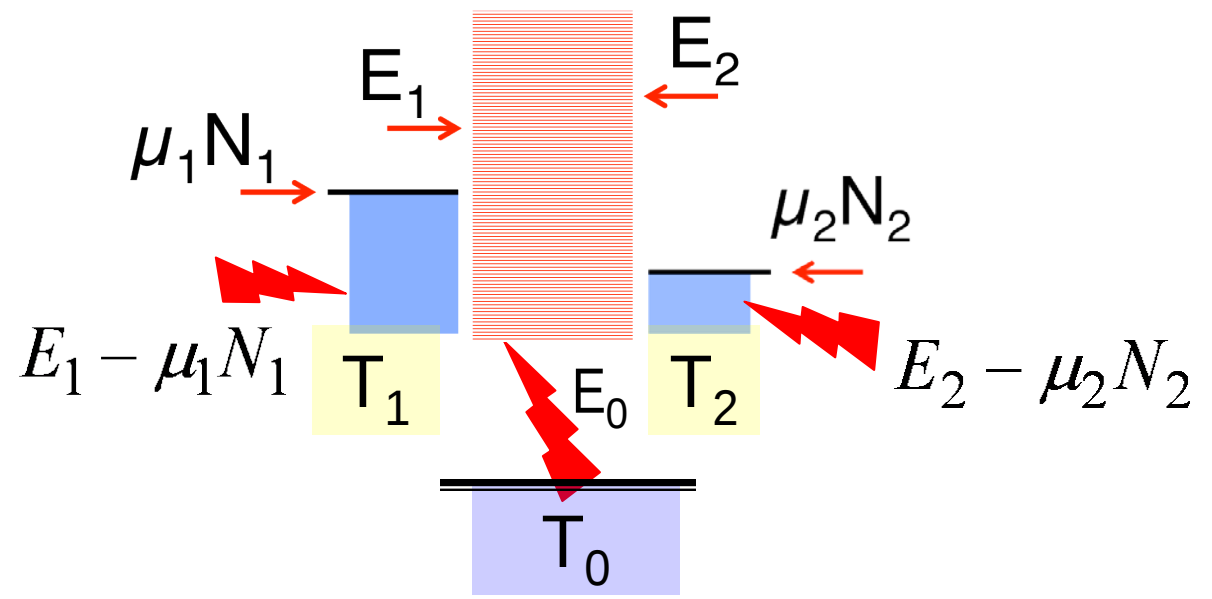
$$N_1 + N_2 = 0$$

4.1d Introduction

First Law

$$E_0 + E_1 + E_2 = 0$$

4.6. Entropy
4.7. Law of Equilibrium

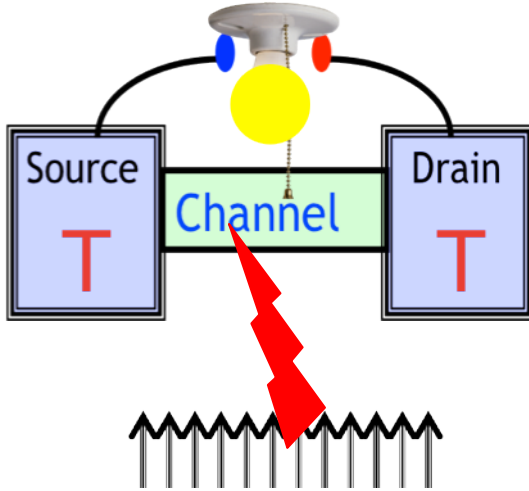


4.5. Second Law

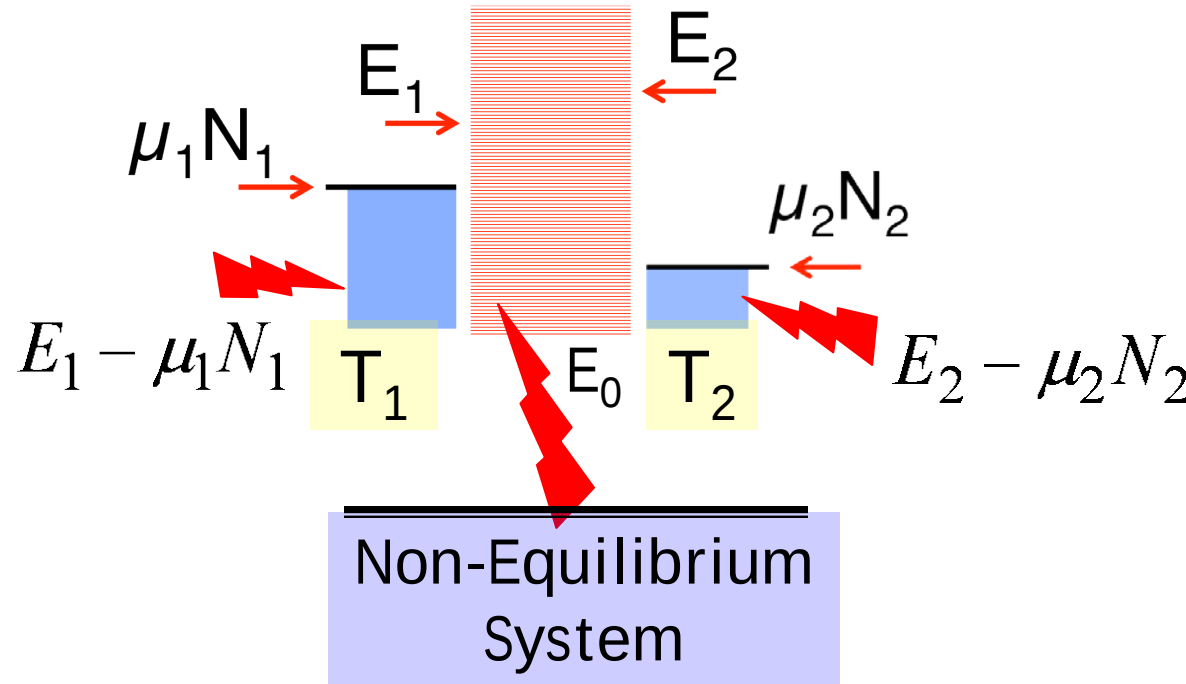
$$-\Delta S_0$$

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

4.1e Introduction



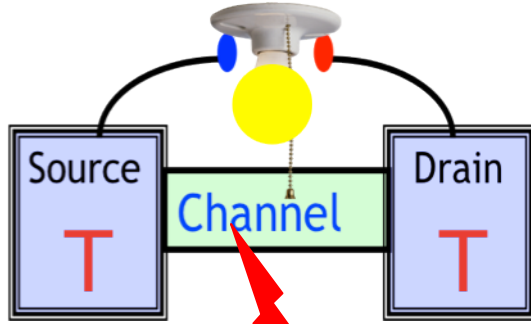
Equilibrium



Second Law

$$-\Delta S_0 + \frac{E_1 - \mu_1 N_1}{T_1} + \frac{E_2 - \mu_2 N_2}{T_1} \leq 0$$

4.1f Introduction



4.9 Fuel Value of Information

Can extract energy $NkT \ln 2$ without violating Second law

$S_0 = 0$



$$\Delta S_0 = Nk \ln 2$$

Equilibrium



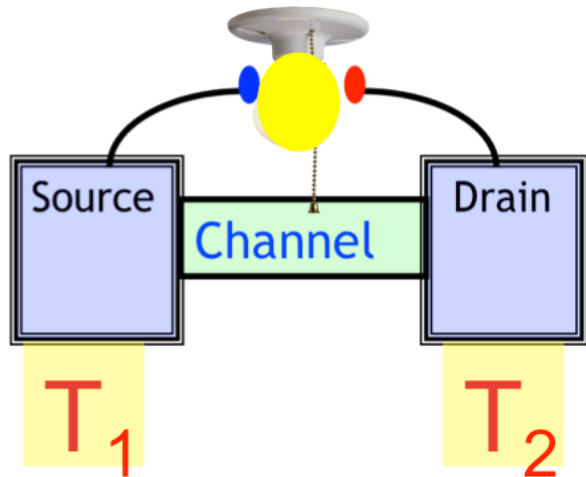
Erasure requires energy $NkT \ln 2$

Landauer's Principle

Second Law

$$-\Delta S_0 + \frac{E_1 - \mu_1 N_1}{T_1} + \frac{E_2 - \mu_2 N_2}{T_1} \leq 0$$

4.2. Seebeck Effect



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 ..