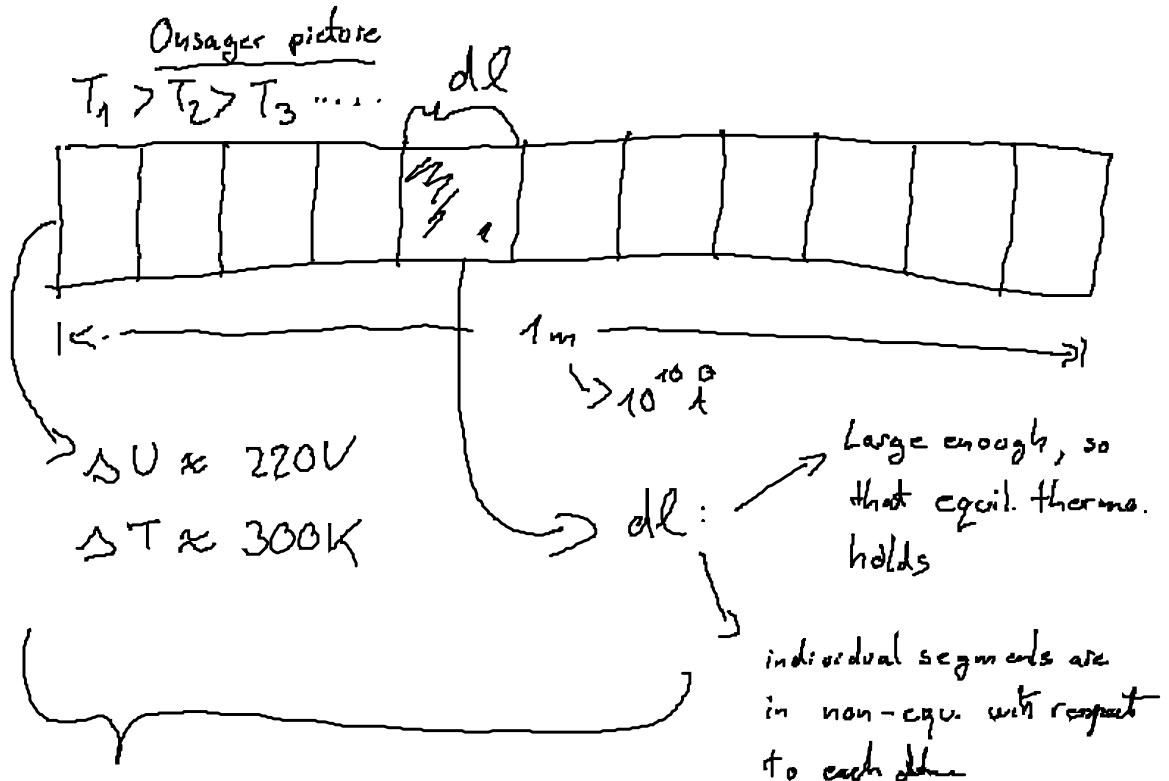


→ Chap 9: TRANSPORT

→ Non-Equilibrium Thermodyn. & Statistical Mechanics



$$\begin{aligned} \vec{j}_e &= -\sigma \nabla U \quad \dots \text{Ohm's law} \\ \vec{j}_h &= -\kappa \nabla T \quad \dots \text{Fourier's law} \end{aligned} \left. \vphantom{\begin{aligned} \vec{j}_e \\ \vec{j}_h \end{aligned}} \right\} \text{linear response}$$

⇒ Lasers: ⇒ non-linear optics

⇒ $\left. \begin{array}{l} \sigma \dots \text{elec. conductivity} \\ \kappa \dots \text{thermal conductivity} \end{array} \right\} = f(T, \rho, \text{crystal structure, compo.})$

→ Macroscopic Effects: $\nabla U, \nabla T$

→ Microscopic Response: \mathbb{H} , \mathbb{G}

Definition of transport coefficients: Onsager Coefficients

⇒ electrons $\begin{cases} \text{charge} \rightarrow \vec{j}_c \\ \text{Energy} \rightarrow \vec{j}_h \end{cases}$ ← phonons

$$\vec{j}_c = L^{11} \left(-\nabla U - \frac{\nabla \mu}{e} \right) + L^{12} (-\nabla T)$$

$$\vec{j}_h = L^{21} \left(-\nabla U - \frac{\nabla \mu}{e} \right) + L^{22} (-\nabla T)$$

$$\rightarrow L^{21} = T \cdot L^{12}$$

$$G = L^{11} \quad \dots \quad \nabla T = 0 \quad \rightarrow \text{closed thermal circuit}$$

$$R = L^{22} - \frac{L^{21} L^{12}}{L^{11}} = L^{22} - T \frac{(L^{12})^2}{L^{11}}$$

→ open electrical circuit.

$$\left(-\nabla U - \frac{\nabla \mu}{e} \right) = \frac{L^{12}}{L^{11}} \nabla T = S \nabla T$$

→ Seebeck coefficient:

“Temperature is converted into voltage”

⇒ convert unused heat into useful voltage

η ... efficiency

$$\eta = \eta_{\text{CARNOT}} (zT)$$

$$zT = \frac{S^2 \sigma}{\kappa_{\text{el}} + \kappa_{\text{ph}}}$$

