3. Thermoelectric transport and heating

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11 punten

Consider an electrical conductor, which has a temperature difference ΔT and a voltage difference ΔV.

1. Start with a temperature difference equal to zero ($\Delta T = 0$) and presume that the electrical current I is determined by Ohm's Law: $I = \Delta V R^{-1}$, with R the resistance of the conductor. Use the first law of Thermodynamics, $dU = dQ + \mu dN = TdS + \mu dN$ (where dU : change of energy, dQ the heat, μ : the chemical potential, dN : the change of particles T the temperature and dS the change of entropy), to show that the total heat, produced by the electric current per time unit, is given by:

$$\frac{dQ}{dt} = \frac{\Delta V^2}{R} \tag{3.1}$$

2. Let us now discuss the situation $\Delta V = 0$, $\Delta T = 0$. Now we find an electric current I, as well as an heat wave I_Q through the conductor. Presume that:

$$I = \frac{\Delta V}{R} - \frac{S\Delta T}{R} \tag{3.2}$$

and

$$I_Q = \frac{P\Delta V}{R} - \kappa^{'}\Delta T \tag{3.3}$$

Here S is the so called Seebeck coefficient and P the Peltier coefficient. Furthermore $\kappa^{'}$ is the thermal conductivity at $\Delta V = 0$. Use the First Law to show that:

$$\frac{dQ}{dt} = \frac{\kappa^{'}\Delta T^2}{T} + \frac{\Delta V^2}{R} - \frac{P\Delta V\Delta T}{RT} - \frac{S\Delta V\Delta T}{R} \tag{3.4}$$

3. Use the Second Law of Thermodynamics to show that the transport coefficients must satisfy: $\kappa^{'}R \geq PS$