Non-equilibrium thermodynamics
Exercise 5
Transport of heat and charge

1

a) Write the transport equations for a system with transport of heat and charge.

b) Show how Ohm's law can be derived from non-equilibrium thermodynamics. What is the relation between $L_{\phi\phi}$ and the electric conductivity?

c) Describe the Peltier effect. What is the Peltier coefficient?

d) Describe the Seebeck effect. What is the Seebeck coefficient?

2

a) Consider an electric current of 10 A/m^2 through a piece of lead. Entropy will be transported, and if the system is thermally isolated, a temperature gradient will build up. Calculate the maximum temperature gradient that arise in the metal. Use a thermal conductivity of 5 W/Km and an average temperature of 300 K. The transported entropy, $S^*_{e^-,Pb}$, is -5 J/K mol.

b) You have the same piece of lead, but it is electrically isolated, and has a heat flux of 10 W/m^2. Calculate the maximum electrical potential gradient that arise.

3

When you have junctions between two different electric conductors, this can be used to generate electric power from temperature differences or to use electric power to move thermal energy from one place to another. It can also be used to measure temperatures.

a) The device used for measuring temeperatures is called a thermocouple. A thermocouple measuring cirquit is given in figure 1. Explain how it works. Derive an equation you can use to calculate the temperature when you know T_{ref} and the properties of metal 1 and 2 and you measure the emf with the voltmeter.

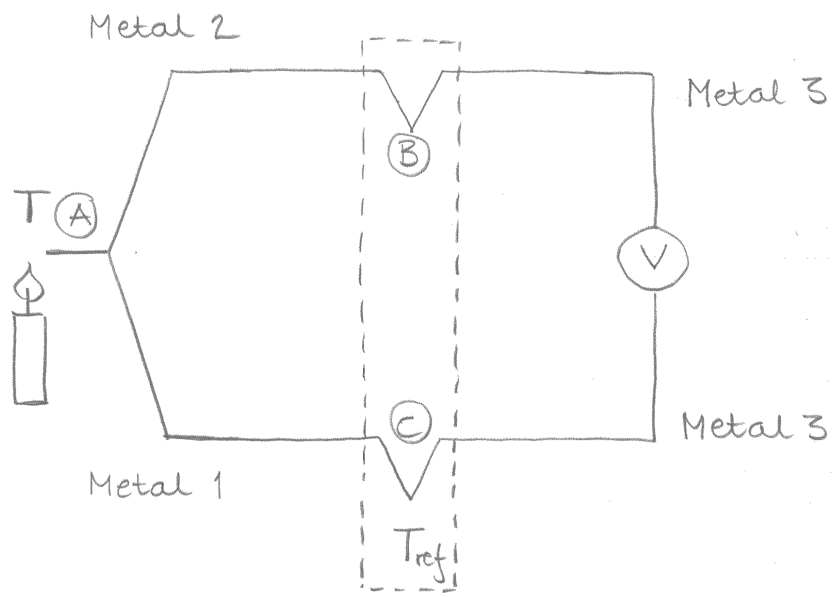

Figure 1: A thermocouple measuring cirquit. The point A is a junction between metal 1 and 2 at at temperature T, which is the temperature we want to measure. Point B and C are junctions between metal 1 and 3 and between metal 2 and 3, and they are held at a reference temperature, often in an icebath or in boiling water.

b) In the silicon industry there are high temperature heat losses, as production of silicon requires temperatures above 1800 °C. Consider a silicon casting where you have a temperature difference of 300 K available. What is the electric potential obtainable from a thermoelectric module with Seebeck coefficient $3.82 \cdot 10^{-3}$ V/K?

c) The module electric resistance is 1.8 Ω. How many modules are needed to run a fan which requires 5.9 W at 0.1 A?

d) You want to cool down a glass of water (25 cm^3) at 300 K with 5 K. How can you use a thermoelectric module to do this? The electric conductors in the module have the transported entropies 17 and -5 J/Kmol. How long will the cooling take if the current through the module is 0.84 A? Neglect the effect of the temperature gradient that evolves.