PHYS-E055102, Low Temperature Physics, Exercise 7 DL 02.11.2022

---

1. Read the paper about thermotry of a Josephson junction coupled to a resonator (Click this or in MyCourses)
   a) Explain the working principles of the thermometer.
   b) What is limiting the temperature range at the lower end?
   c) Explain the concept of noise equivalent temperature NET.

2. What is the voltage sensitivity of a voltmeter necessary to read a $1\,\mathrm{M}\Omega$ resistor at $1\,\mathrm{K}$ with a resolution of $1\,\mathrm{mK}$ if the measurement band width is $1\,\mathrm{Hz}$ or $1\,\mathrm{MHz}$? How much capacitance is tolerated in the measurement leads?

3. How large is the operating temperature of copper-island Coulomb blockade thermometer (CBT) with a volume of $100 \times 100 \times 10\,\mu\mathrm{m}^3$ mounted at the mixing chamber of a dilution refrigerator with base temperature $T_0 = 0.01\,\mathrm{K}$ when you excite the thermometer with $P = 1\,\mathrm{nW}$? You can use $\Sigma = 2 \cdot 10^9\,\mathrm{Wm}^{-3}\mathrm{K}^{-5}$ for the electron-phonon coupling constant of copper.

4. When is the self-heating of a thermometer limited by Kapitza resistance?

5. ^{3}He is pre-cooled on the way from the still to the mixing chamber (MC) by exchanging heat with the diluted phase flowing from the mixing chamber to the still. Figure 1 shows the schematic system. The temperature of ^{3}He entering the MC is T_{ex} and the temperature of the diluted phase leaving the mixing chamber is T_{mc}. Initially, the ^{3}He rich phase has temperature T_{st}. Show that T_{ex} is given by

$$T_{\mathrm{ex}}^2 = 11 \frac{\dot{n}_3 r_k}{A} \mathrm{J/(mol\ K^2)},$$

with r_k the prefactor of the Kapitza resistance $R_K(T) = r_k \cdot T^{-3}$ and area A of the heat exchanger. It can be assumed that the initial temperature of the Helium entering the mixing chamber is higher than the temperature of the diluted phase. Further, you can assume that $T_{\mathrm{ex}} \ll T_{\mathrm{st}}$.

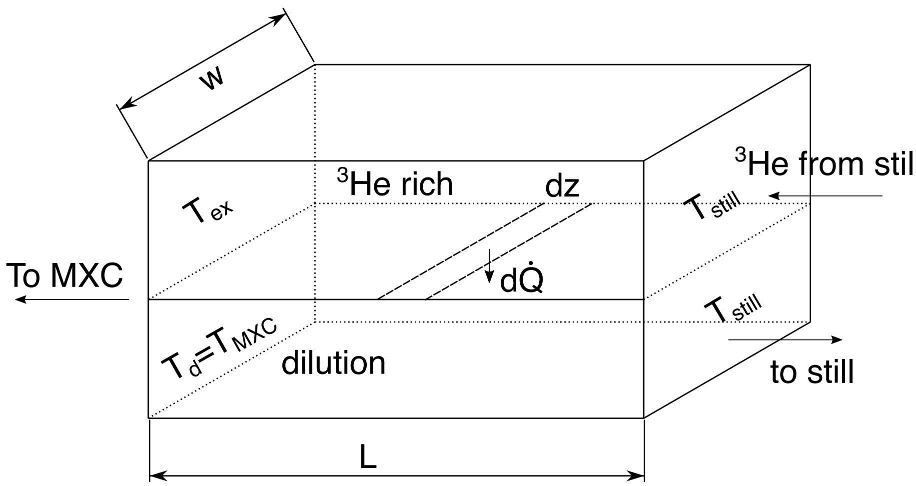

Figure 1: Schematic heat exchanger with pure ^{3}He phase on top and diluted phase on the bottom. Within an interface area $w\mathrm{d}z$ the heat flow $\mathrm{d}\dot{Q}$ is transferred.