SUPERCONDUCTIVITY AND LOW TEMPERATURE PHYSICS
EXERCISES

1. The two fluid model is central in describing superfluid phenomena. During the laboratory exercise you will study a number of effects in superfluid helium. Pick one of these, describe it, describe the two-fluid model and interpret the effect within that model. 1-2 pages are sufficient.

2. Compare properties of superfluid helium and superconductors. One example: Quantized vortices appear in superfluid ^{4}He in rotation for a frequency $f > f_{crit}$. Similarly, quantized fluxons appear in a typeII superconductor for $H > H_{c1}$. Show that the circulation and the magnetic flux are quantized and discuss under which conditions the phenomena occur. Suggest different ways of measuring vortices and fluxes. What results are obtained? Try to make a somewhat general discussion.

3. The superconducting Josephson effects and their applications.
   Which are the Josephson equations and what do they mean? What is behind the Josephson coupling?
   The magnetic field response and the ac response can be used in applications such as very sensitive magnetometers (SQUIDs) or in high frequency devices/high speed logics. Your task is to treat the magnetic and high frequency electromagnetic responses and describe two corresponding devices of your choice:

- principle (physics behind the application)
- circuit design or other experimental arrangement
- examples of results (e.g., sensitivities), uses, and prospects for the future.

4. The Ginzburg-Landau equations describing the superconducting order close to the transition is said to be a phenomenological theory, while the Bardeen-Cooper-Schrieffer (BCS) one is a microscopic theory. Compare the two theories. What are the assumptions and approximations that are made for the two? What are the strengths and weaknesses of the two models? What are their uses?

5. Tunneling is a powerful method to study properties of a superconductor. Describe, with the aid of words and diagrams:
   a) what tunneling is,
   b) how to determine the superconducting energy gap and the density of (quasi-particle) states for excitations out of the superconducting ground state,
   c) how it is possible to characterize other types of excitations, like the phonon spectrum for a strongly coupled superconductor,
   Your description should include a discussion of the effect (principles) and a suggestion of how to perform the experiment.

6. ^{3}He and high T_c superconductors.

Both ^{3}He and high T_c superconductors can be fundamentally different from the "low T_c superconductors" described by the BCS theory. This may be valid for both the symmetry of the wave function, describing the superconducting order, and the interaction leading to pairing.

Describe (shortly) the main properties of the two phenomena with an emphasis on those properties that indicate that a simple singlet BCS pairing is not sufficient to describe the states. Describe how the attractive interactions may differ from those of "ordinary" superconductors.

7. Thermometry in the interval 1-10mK, 20-50mK, 50mK-1K, 1-4K, 4-20K, 20-77K, 77-300K (pick one of the intervals according to below)

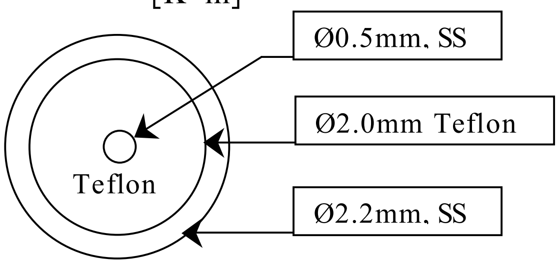
You want to perform a low temperature experiment measuring some temperature dependent property or demonstrating an effect that appeals to you and which depends on temperature. Describe (shortly) what you want to measure, what is the interesting temperature dependence, which is the temperature interval of greatest interest?
Suggest a thermometer for the interval that you have chosen.

- Motivate the choice.
- Principle of operation (physical property)
- Advantages and disadvantages with the thermometer
- Sensitivity
- Instruments and methods of measurements
- Calibration
- Thermal equilibrium, response and other relevant points

8. Cryogenic technology - thermal isolation

A stainless steel (SS) coaxial cable with Teflon isolation is mounted in a dilution refrigerator, it is heat sunk at the Still (0.7K) and at the mixing chamber, which is at 50mK. The coax is 20 cm long and has a cross-section as shown in the figure below. The heat conductivity for stainless steel is

$\kappa = 0.15 \cdot T \left[\frac{\text{W}}{\text{K} \cdot \text{m}}\right]$, and for teflon $\kappa = 0.003 \cdot T^2 \left[\frac{\text{W}}{\text{K} \cdot \text{m}}\right]$



a) Calculate the power with which the coax heats the mixing chamber.
b) How much worse would it be if the coax was not heat sunk at the Still, but was mounted directly between the IVC (4.2K) and the mixing chamber but twice as long.