Exam Mesoscopic Physics 8-7-2015 9:00-12:00 5115.0017

Write each answer and your name and study number on a separate sheet. Indicate for every answer how it is obtained! There are 5 questions. Total 100pts

1) (total 15pts) Consider a ring made out of a diffusive conductor. It has two contacts. A perpendicular magnetic field produces a magnetic flux through the ring.

a) Describe and draw two types of electron interference paths, which can be affected by the Aharonov-Bohm effect (5pts).

b) Indicate how the conductance of the ring can be modulated by the magnetic flux, and what the periodicities are (h/e or h/2e) (5pts).

c) What are the conditions for the temperature to observe these effects? (5pts).

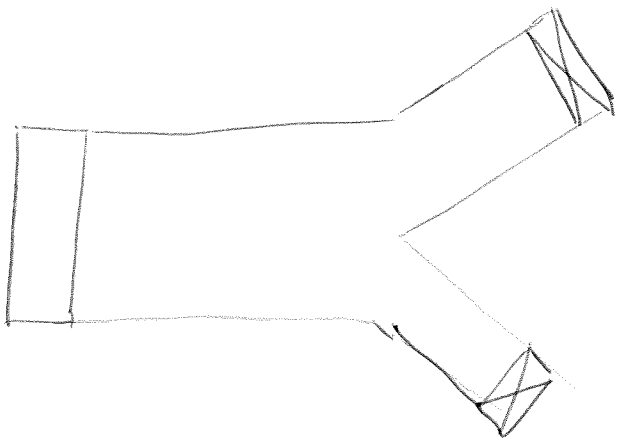
2) (total 18pts) Consider a quantum point contact (QPC)

a) Describe/draw how it can be made, by using a two-dimensional electron gas, and a split top gate (8pts).

b) Indicate what the conditions are to observe quantized conductance steps (5pts).

c) Describe how the accuracy of the quantization depends on the shape of the quantum point contact. Consider the following situations: long/short channel, abrupt/smooth channel (5pts).

3) (total 27pts) Consider a two dimensional electron gas below. The mean free path is much larger than the diameter, and the reflection from the boundaries is specular. The three contacts are ideal reservoirs, and are connected to the 2DEG by N channels (for B=0)



a) Describe how the Landauer-Buttiker formalism is applied for each of the three contacts. Write down the equations of the currents in each of the contacts in terms of reflection and transmission coefficients, the number of channels N, and the electrochemical potentials of the contacts 1, 2, and 3 (5pts).

b) Give an estimate for all reflection and transmission coefficients for B=0 (5pts).

c) Derive an expression for the measured voltage in terms of the transmission and reflection coefficients (5pts)

Consider now large magnetic fields, such that the 2DEG is in the quantum Hall regime with two occupied landau levels. The corresponding circlotron motion is anti-clockwise.

d) Draw the edge channels and their transport directions for this case (3 pts).

e) Calculate the voltage between contact 1 and 2 (3pts).

f) The direction of the current I is reversed. Does this change the voltage, and how (or why not)? (3pts)

g) The direction of the magnetic field is reversed. Does this change the voltage between contacts 1 and 2, and how (or why not)? (3pts)

4) (total 22pts) Consider a Josephson junction (JJ), which is formed by a tunnel barrier in between two superconductors, with critical temperature Tc.

a) Give the two basic equations for the supercurrent through a JJ, and the voltage across a JJ. Indicate what the parameters in these equations mean (4 pts).

b) One of these equations is exact, and can be used as a basis of a metrological standard. Which one is it? Indicate why (4pts).

c) Sketch the critical current as a function of temperature (4pts).

Consider a superconducting quantum interference device (SQUID). It consists of a superconducting ring with two Josephson junctions with the same critical current Ic.

d) Describe the basic operation of a SQUID. Show that the critical current of the SQUID is a periodic function of the magnetic flux through the SQUID ring (5pts).

e) Consider now the situation that the critical currents of the JJs are not equal. Assume that Ic1=2*Ic2. Describe how it would change the operation of the SQUID (5pts).

5) (total 18pts) Consider a single electron transistor. (SET)

a) Describe the operation of a SET. Make a drawing of the electrodes. Indicate the distribution of the charges for the following cases:

1) Zero gate voltage
2) A gate voltage which induces half an electron charge on the central island (6 pts).

b) Give three conditions needed for the SET to operate properly (4pts).

c) Explain for the situations 1) and 2) is the SET is the ON or OFF state. Explain why (4pts)

d) A SET can be used as sensitive electrometer to measure (changes) in the charge present close to the central island. Assume that the SET can measure for 1 second. Can you give an indication of the smallest (change in) charge which can be detected? (4pts)