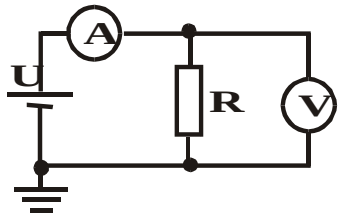
Measurement Methods in Physics I
Additional exercise
21.10.2016

The exercise must be returned by 18.11.2016 23:59. They can be returned either to Axi Holmström's mailbox or by e-mail to axi.holmstrom@helsinki.fi. The mailbox is located in the C-wing of the 2nd floor in Physicum, in the end towards the lobby next to room C204a. Note, the corridor in question can only be accessed during weekdays during 8-16.

Each task is worth three (3) points.

1. You have a normal icosahedral dice that you suspect is weighted. You throw the dice 500 times and write down the results. Fourteen of the throws give you the number 20. Does this result support the conclusion that the dice is weighted? Is the deviation from the expected value outside the 95% confidence limit (two sigma)?

2. The following circuit is used to measure the resistance R.



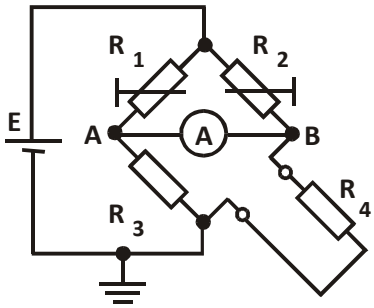
The voltage source is a chemical battery with a specified terminal voltage U. A voltmeter V is used to read out voltage U_R and the ammeter for the current I.

a) What are the systematic errors if R is determined in this manner?
b) Does the value of R affect the magnitude of the systematic errors?
c) The measurement is repeated 100 times with the same components and R is averaged. How does this affect the error bounds of the measurement?
d) You take 100 resistors R from an unopened factory package and you perform one measurement with each resistor. How does this affect the error bounds of resistance R?

3. a) How big can the rms-value of the noise be, if a voltage signal, which fluctuates between 10 mV and 100 mV, is measured and the desired SNR is 45 dB?
b) If the noise in a) is Johnson noise, in what temperature should the measurement be performed if the system under investigation can be modelled as a 500 kΩ resistor and the measured bandwidth is 1 MHz?
c) You are transmitting a voltage signal, which fluctuates between 0 V and 1 V, from one device to another. The analog transmission and reception adds a noise to the signal with an rms-value of 0.5 mV. You can avoid the noise by transferring the signal digitally. You have four different A/D-

converters at your disposal, whose resolutions are 8, 10, 12, and 16 bits, respectively. According to the data sheets each has a conversion precision of 2×LSB. Which A/D-converter has the smallest resolution with which the uncertainty of the signal diminishes compared to the analog transmission?

4. A Wheatstone bridge is used to measure unknown resistors. The resistance R_4 is determined by adjusting the resistances R_1 and R_2 until the bridge is in balance, i.e. no current flows between A and B.



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a) What is the value of R_4 as a function of the other resistances, when the bridge is in balance?
b) Consider a general situation, when the bridge might not be in balance. The ammeter is replaced with a voltmeter, whose internal resistance is so large that the current flowing through it can be approximated to zero in calculations. What is the voltage between points A and B?

5. a) Why does a multimeter functioning as a voltmeter have a high input impedance?
b) What is the functioning principle of a dual slope converter?
c) What is the difference between a common cheap multimeter and a so called true rms–meter?

6. Below is a picture of a normal non-inverting amplifier circuit. Derive the amplification of the circuit and calculate error bounds for the amplification using propagation of error, when R1 = 1 kΩ ± 1 %, and R2 = 100 Ω ± 1 %. How would the output voltage, amplification, and the error bounds change if R1 = 10 kΩ ± 1 % and R2 = 1 kΩ ± 1 %?