PHY 312
Final Exam

Due May 17th , 2010 at 5 PM

You may use any reference sources but cannot consult with other people.

Problem 1 (25 pts)*:* Electronics – Current to voltage converter

Design a circuit using an operational amplifier that generates an output voltage proportional to the input current.

Two circuits for two different input current ranges are desired. One is for current range of 0.1 to 100 nA and another for current range of 0.01 to 10 mA.

For each of the two input current ranges specify the best operational amplifier chip and other elements to provide most accurate and noise-free output. You can use amplifiers from Analog, listed at http://www.analog.com/en/amplifiers-and-comparators/operational-amplifiers-op-amps/products/index.html

Calculate the output noise spectral density (in $V/Hz^{1/2}$) and the systematic error in the measurement of the current for each of the two circuits.

Problem 2 (20 pts)*:* Data analysis

You have been asked to calibrate a solenoidal coil for generating magnetic field. Your recorded data of electric current (in A) vs. magnetic field (in G) are contained in a file Fielddata.dat. From these data calculate the calibration constant C for the coil (in G/A) and estimate the statistical and systematic error in the calibration. Report your result in the form $C \pm \sigma_{stat} \pm \sigma_{syst}$. Describe the procedure that you used to obtain these estimates.

Problem 3: General knowledge

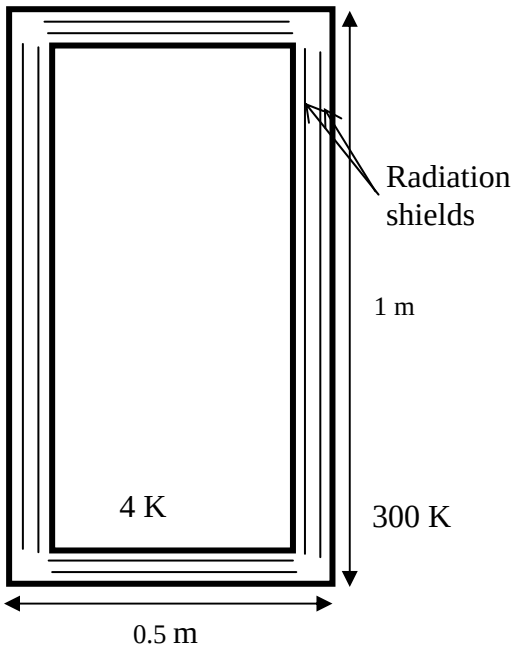
a) (10 pts) In many nuclear magnetic resonance experiments the longitudinal spin relaxation time T_1 is often much longer than the transverse spin relaxation time T_2. In some cases people on purpose try to reduce the longitudinal relaxation time. Why is this beneficial?

b) (15 pts) A laser generates a Gaussian beam at 1064 nm. The waist of the Gaussian beam is located at the front of the laser and its w parameter (where the intensity drops to $1/e^2$ of the maximum) is equal to 0.3 mm. The laser is used to form a dipole trap for atoms, using the atomic polarizability potential $U=-\alpha E^2/2$. It is desired to focus the laser beam to a spot size with w =5 μm inside a vacuum chamber. The closest lens must be

located outside the vacuum chamber, 20 cm away from the focal spot. Design a system of lenses necessary to achieve this. Specify the focal length and the position of each lens.

c) (15 pts) Consider the heat loss in a cryostat consisting of two cylinders with evacuated space in between containing two aluminum radiation shields, as shown in the figure. The cryostat is 1 meter high, 0.5 meter in diameter. The radiation shields have emissivity of 0.1 on both surfaces. Assume that the inner and outer cylinders of the cryostat have emissivity of 1. The inner space is filled with liquid helium at 4 K.

Estimate the heat loss power of the cryostat. Using the heat of vaporization of liquid helium, estimate how long the helium will last. How is it possible to achieve much longer hold time for LHe in a dewar?



d) (15 pts) While hiking through a desert you have come across a mysterious (possibly alien!) gun that seems to emit a beam of high energy particles. Using items a hiker is likely to carry (including Particle Physics Booklet) determine the nature of the particles emitted by the gun. In particular, try to estimate the energy and the rest mass of the particles, whether they are electrically charged or uncharged, and whether they interact strongly with hadrons.