Instrumentation Problem Sheet 3

(1) A thermistor with a temperature coefficient α is to be used for temperature measurement in a simple series circuit with a load resistor R_L, operated from a stable power supply providing a voltage V. The voltage to be measured is the value across the thermistor, V_0. Show that the sensitivity $dV_0/dT = VR_LR\alpha(R+R_L)^{-2}$

At the operating temperature the thermistor has a resistance of 1kΩ and a temperature coefficient α = 4%/K. The power dissipated in the thermistor at V = 10V must be kept below 1mW to minimise heating and ensure the measurements are reliable. What value of R_L should be used and what is the resulting sensitivity? Would it be advisable to increase R_L above the minimum value, say by a factor 10, to be more conservative about possible heating?

(2) The condition for Cerenkov radiation to be emitted can be derived using Huygen's principle by requiring that the wavefronts of rays emitted at different points along the path of a charged particle are always in phase. Using the fact that a wavefront is a sphere surrounding the point of emission and that wavefronts in phase must have a common tangent, derive the condition

$$\cos\theta = 1/\beta n$$

n= refractive index, $\beta = v/c$, v = particle speed.

(3) The AD590 temperature transducer is a two terminal IC which produces an output current of 1µA/K from –55°C to +150°C and it specified to be accurate to ±0.5K. How would you set it up so that it produces an output of 1mV/K? What requirements would you put on the selection of any resistors used in your circuit to ensure sufficient accuracy? If you needed to read out °C instead of K, can you suggest how it could be done?

(4) A 12 stage photomultiplier is to operate with average signals of 10 photoelectrons, which are expected at a rate of 1MHz. The tube voltage is 2400V to achieve a gain of 5×10^7. What is the peak current signal assuming a pulse duration at the PM tube output of 10ns? Compare this with the average signal current flowing in the tube. Assuming equal resistors for each stage of the divider chain, what value would you suggest for each?

(5) Estimate the signal transit time in a photomultiplier tube of 12 stages, assuming a voltage of 200V is applied between each dynode, which are separated by a distance of 1mm.

(6) Sketch the distribution of electric field magnitude as a function of position between anode and cathode in

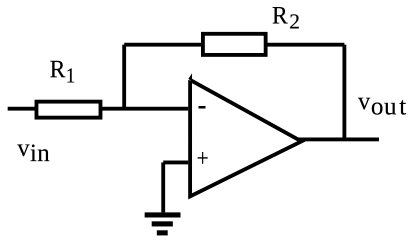
(i) a parallel plate gas chamber (flat plates with a voltage applied between them)

(ii) a cylindrical proportional wire chamber

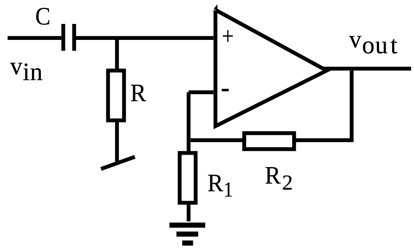
(iii) a silicon diode detector, when it is (a) partly depleted ($V < V_D$), (b) fully depleted ($V = V_D$), (c) over-depleted ($V > V_D$),

(7) In a gas detector the average number of ionisations per cm produced by a high energy particle is N. What thickness of gas should be used to ensure a detection efficiency of 99%? (Remember this is a random process)

(8) An inverting amplifier has $R_1 = 10k\Omega$ and $R_2 = 1M\Omega$. What is the gain of the circuit if the op-amp has infinite open loop gain? What is the closed loop input impedance?



(9) What is the function of the amplifier configuration in the figure? Assuming an ideal op-amp, for $R = 100k\Omega$, $R_1 = 2.2k\Omega$, $R_2 = 47k\Omega$ and $C_{in} = 0.1\mu f$, what is the voltage gain of the circuit in the high frequency limit, and at 10Hz? If the amplifier has a pole of 80kHz, make a rough sketch of the magnitude term of its Bode plot.



(10) Find the output from the op-amp circuit illustrated. How could you convert it to an averaging circuit?