PHY2405 HW4

March 7, 2024

1) When searching through the drawers in the lab you find a silicon detector. Of course, the data sheet is nowhere to be found, but apparently the detector was designed for charged particle tracking, so you have good reason to expect that it is less than a mm thick and is configured so that it can be reverse biased and used as a tracking plane.

   (a) How can you determine the correct polarity of the bias voltage?

   (b) You have a source of 1 MeV electrons. How can you determine the depletion voltage and the thickness of the detector?

   (c) Assume that the detector is 300 mm thick with a depletion voltage of 120 V. What is the resistivity of the material?

   (d) You've measured the diameter of the detector to be 20 mm. What is the capacitance at 0, 30, 60 and 120V?

   (e) What are the collection times for electrons and holes when the detector is operated at 30, 60 and 120 V?

2) Consider a colliding beam vertex detector consisting of two approximately massless silicon strip detectors concentric with the beampipe, at distances of 2.5 cm and 5 cm from the beamline, respectively. Assume that the strips are oriented parallel to the beamline, and achieve a resolution of 5 μm in the azimuthal (ϕ) direction. The inner layer of this detector sits just outside of a cylidrical aluminum beampipe of 1 mm thickness and 2.5 cm radius.

   (a) For cylindrical coordinates with the z-axis lying along the beamline, estimate the impact parameter resolution in the $r - \phi$ plane for a charged pion of infinite momentum, where the impact parameter is the distance of closest approach of the extrapolated vertex detector track to the beamline.

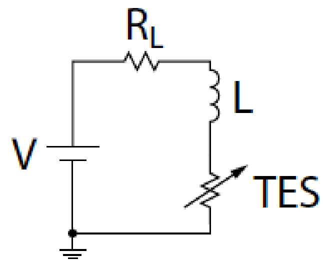
   (b) Also estimate the $r - \phi$ impact parameter resolution for a charged pion of momentum $p = 0.5$ GeV/c exiting the beampipe perpendicular to the beamline, assuming that the rest of the detector (the central tracker) allows the curvature of this particle through the magnetic field to be measured with perfect precision.

   NB: Yes, this problem covers some of the smae ground as the Mark-II tracker problem from PS3. But this is back to the simpler case (only two measurements) and spells out the momentum of the track you should consider better. I hope it won't take to long and will allow you to consolidate what did (or didn't) learn from the previous track extrapolation problem. Don't over think this one.

3) Consider a Transition Edge Sensor detector, operated in a circuit whose Thevenin's equivalence circuit is below. $\alpha = \frac{T_0}{R_0}\frac{\partial R}{\partial T}$ is positive, and $\beta = \frac{I_0}{R_0}\frac{\partial R}{\partial I} = 0$.

   (a) What is the condition that this TES can be operated stably?

   (b) For a TES with parameters in the table below, what is the expected resolution? What's roughly the useful bandwidth of this TES?



C	1.92	pJ/K
G	200	pW/K
R	10	mΩ
R_L	1	mΩ
T	75	mK
T_b	50	mK
α	90	
n	3.2	

4) Derive the critical radius of a bubble chamber by minimizing the total Gibbs free energy (G) of the system, given the chemical potentials of the liquid and vapour phase of the material (μ_l,μ_g). For a pure system, $G = N\mu$ where N is the number of molecules, μ is its chemical potential. When a boundary between two phases form, there's an extra Gibbs free energy $G = A\sigma$ associated, where A is the surface area and σ is its tension.

5) For a Ge(Li) detector, assuming perfect electronics, what's its energy resolution for the γ from ^{137}Cs? Assume the typical characteristics of a Ge(Li) detector which you might need to look up. How does this relate to the energy threshold of this detector?