SPA 3609 Tutorial 4, Questions for formative feedback

1. A silicon strip sensor 0.5 mm thick and 10×10 mm^2 area is lightly doped n type such that $n_0 = 10^{13}$ cm^{-3}. One 5 MeV alpha particle deposits all its energy in this sensor underneath a single 0.1 mm wide strip. Calculate the thermal equilibrium concentration of holes and then the concentration of electrons and holes in the region under the strip just after the alpha particle has interacted with the sensor. [Mean ionisation energy for Si is 3.6 eV]

$n_0 p_0 = n_i^2$ thus $p_0 = 10^7$ cm^{-3}

Calculate volume of silicon under the strip = 1.0×0.05×0.01 cm^3, thus $p_0 = 5\times10^4$. An alpha of 5 MeV deposits 1.4 million e/h pairs thus the non-equilibrium hole concentration is dominated by the contribution from the alpha particle ionisation signal. For the electrons, $n_0 = 5\times10^{10}$ which is essentially unchanged by the ionisation signal. [Subscript 0 used to imply thermal equilibrium concentration]

2. In Q1 assume that the e/h pairs are produced at the silicon just under the strip (very highly ionising particles). Calculate how long will it takes to collect the signal electrons if they drift towards the substrate (opposite side) if the sensor reverse bias is 50V [You may assume that $\mu_e = 1400$ cm^2/Vs]

Electric field is 100/0.05 V/cm = 2 kV/cm, velocity is the product of mobility and electric field (until you approach saturation velocity) so $v_e = 2.8\times10^6$ cm/s and thus the total time taken is 18 ns for 0.05 cm thickness.

3. In Q1 assume that pitch (centre-to-centre repeat distance) of the strips is 0.12 mm and that we are recording a uniform beam of 1 GeV muons passing vertically through the whole area of the sensor. If we have an electronic readout which only returns the spatial location of the strip with the largest signal (binary readout) calculate the sensor resolution at right angles to the direction of the strips.

This is a classic statistical problem of calculating the variance of a uniform distribution (1 GeV muons will essentially not scatter). Thus the variance is $(0.12)^2/12$ and the resolution $\sigma = 0.035$ mm.

$$\sigma^2 = \frac{\int_{-\frac{p}{2}}^{\frac{p}{2}} (x_r - x_m)^2 D(x_r)\, dx_r}{\int_{-\frac{p}{2}}^{\frac{p}{2}} D(x_r)\, dx_r} = \frac{p^2}{12}$$

D(x) =1 uniform distribution of tracks

X_m=0 pixel centre