Physics 198, Spring Semester 1999 Helmuth Spieler
Introduction to Radiation Detectors and Electronics

Problem Set 10: Due on Tuesday, 13-Apr-99 at begin of lecture.
Discussion on Wednesday, 14-Apr-99 at 12 – 1 PM in 347 LeConte.
Office hours: Mondays, 3 – 4 PM in 420 LeConte

1. Traps in semiconductor materials are often characterized by a lifetime τ. A packet of charge subject to trapping will decay with time as

$$Q(t) = Q_0 e^{-t/\tau}$$

   a) In an electric field E the charge will drift. What is the charge remaining after drifting a distance x?

   b) The parameter $\mu E \tau$ is the trapping (or recombination) length L. In a detector with depletion width d, what is the induced signal charge as a function of d and L? Consider only the carrier type subject to trapping/recombination.

   c) If $d >> L$, what is the induced signal charge? How thick must the detector be for the induced charge to be 95% of the deposited charge?

2. A Si detector diode with 1 cm^2 area has a reverse bias current of 1 nA at a temperature of 20 °C.

   a) Under forward bias, how much voltage is required to obtain a current of 1 mA?

   b) On the same wafer there is a second identical diode, except that its diameter is 100 μm. How large is its reverse bias current?

   c) How much forward bias voltage on the small diode is required for a current of 1 mA? How much voltage is required after cooling the diode to –20 °C?

3. A radiation damaged detector has a reverse bias current of 1 μA at 100 μm depletion width. The operating temperature is 20 °C.

   a) The detector is still partially depleted after quadrupling the bias voltage. How large is the reverse bias current?

   b) What is the detector current when the temperature is decreased from 20 °C to –10 °C?

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4. A spectroscopy system using a Si diode at room temperature (20 °C) exhibits an equivalent noise charge of 200 eV at the optimum shaping time of 1 μs.

   a) How large are the noise contributions (in eV) due to current and voltage noise?

   b) Assuming that the current noise is dominated by the reverse bias current of the detector, what is the total noise when the detector is cooled to liquid nitrogen temperature?

   c) If the detector is cooled to –20 °C, what is the optimum shaping time? Assume $F_i = F_v = 1$. What is the corresponding noise level?