6.781

Homework Set #7

26. Let $\bar{n}$ be the mean number of electrons incident in a time interval Δt. Show that the mean of the square of the deviation from the mean (i.e., the variance, σ^2) is

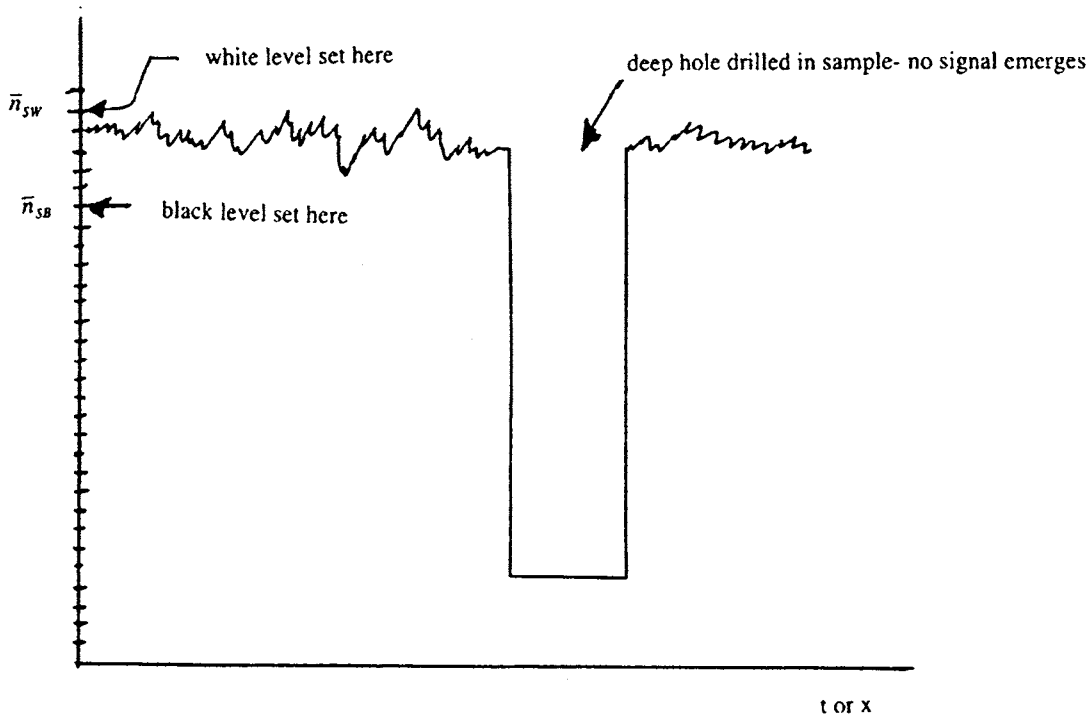
$$\sigma^2 = \bar{n}$$

and thus the root mean square (RMS) of the deviation from the mean (i.e., the standard deviation, σ) is

$$\sigma = \sqrt{\bar{n}}$$

27. If the current is 10^{-11} A, what is the mean number of electrons in a time interval of 10^{-6} sec? What is the probability that in any given time interval of 10^{-6} sec we will count 10 fewer electrons than the mean?

28. Using an SEM, an image can be formed on a CRT using any one of a wide variety of signals that result from the impingement of the incident electron beam on the sample. Suppose that we want to form an image with a signal that has a low efficiency of excitation and a large background level, as sketched below. (The sketch is to scale.)



Note that at one point on the sample a hole is drilled so that we can determine the true background level. That is, no signal can emerge from the hole. The level $\overline{n_{sw}}$ corresponds to a current at the noise bottleneck that is only 2% of the input beam current.

The SEM is a field emission type with the following specifications:

$C_s = 10$ mm

$C_c = 10$ mm

$E = 30$ keV

$\Delta E = 0.5$ eV

sample-to-collector distance = 10 mm

$B = 5 \times 10^7$ A/cm^2 Sr

We want a CRT display with 5 grays levels, 500 lines, and a probability of error in any pixel not exceeding 1%. The maximum tolerable frame time is 100 sec.

a) What spatial resolution is achievable?

b) Can you suggest some modifications that would improve the spatial resolution?

29. Read the attached article, [Yamada, S., T. Ito, K. Gouhara, and Y. Uchikawa, "Electron-Count Imaging in SEM," Scanning **13**, 165-171 (1991)].

    a. Summarize the basic idea of the paper. In particular, what is the origin of the noise that their method reduces? Give an example of a noise source that their method does not impact.

    b. In figure 4, bottom row, the caption tells us that there were on average 10.6 counts/original pixel. Assuming a Poissonian distribution of counts, if you assign "black" to <5 and "white" to >5, what is your probability of error in assigning a given color (black or white) to a pixel (using their digital counting method)?

References

Problem 29

Yamada, S., T. Ito, K. Gouhara, and Y. Uchikawa. "Electron-Count Imaging in SEM." *Scanning* 13, no. 2 (1991): 165-171.