*** Please put your answer for each question on a separate sheet ***

6.781
HOMEWORK SET #4 (POSTPONED PROBLEM)

17. Read the two attached articles, one by Batson et al., the other by Crewe.
(a) draw a simple sketch illustrating the method by which contrast is obtained in their schemes. Label the sketch clearly to indicate the direction of incoming and outgoing electrons in the sample, and the electrons that are collected to form the image. The sketch need not include details of the electron column such as lens locations.

(b) How does the Batson paper achieve superior resolution relative to the Crewe paper? Considering the 30+-years that have elapsed between the two papers, what technological realities have changed to make this improvement possible? Can you identify any remaining obstacles that prevent the Batson technique from becoming broadly available and useful (hint: what about the contrast mechanism—would it work for all materials and sample types)?

(c) What is the image contrast (Emax – Emin)/(Emax + Emin) for two objects separated by the demonstrated FWHM of the beam for each paper? How far need the objects be separated for this contrast to be 1/2?

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HOMEWORK SET #5

18. Given a beam diameter of 50 nm at the sample. If we want to display 1000 lines on a CRT (that measures 10 cm x 10 cm), what is the maximum "meaningful" magnification (i.e., the magnification above which further magnification is empty or meaningless in the sense that no new information is contained in the picture)?

19. Make a log-log plot of d_o, d_s, d_c, and d_f and versus α for C_s = 1 cm (typical SEM), C_c = 1 cm, and B = 10^6 A/cm^2 steradian (typical of LaB_6). Let i = 10^{-10}, 10^{-11}, and 10^{-12} amp, E = 25 keV, and ΔE = 2.5 eV. Make a neat plot and label curves.

20. Make a log-log plot of d_o, d_s, d_c, and d_f versus α for an SEM with a field emission (FE) source. Let C_s = 1 cm, C_c = 1 cm, B = 10^8 A/cm^2 ster (FE source), ΔE= 0.5 eV (FE source), and E = 25 KeV.

Determine the approximate minimum beam diameter at a beam current of 10^{-11} amp. What value of α does this correspond to?

21. In class we said,

$$d^2_{tot} = d^2_0 + d^2_s + d^2_c + d^2_f$$

Show that the convolution of two Gaussian distributions characterized by standard deviations σ_1 and σ_2 is a Gaussian distribution with standard deviation σ_3, where

$$\sigma^2_3 = \sigma^2_1 + \sigma^2_2$$

22. Consider a SEM being operated at 30 frames/sec with 1000 lines per field.

(a) What is the time interval per pixel, t_p?

(b) What is the transit time, t, for an electron with energy 10 eV, in going from the sample to a collector located 3 cm away?

(c) At what electron energy would the transit time equal the time interval per pixel?

$$t_t = t_p$$

References

Problem 17

Crewe, A. V., J. Wall, and J. Langmore. "Visibility of Single Atoms." *Science, New Series* 168, no. 3937 (June 12, 1970: 1338-1340.

Batson, P. E., N. Dellby, and O. L. Krivanek. "Sub-Angstrom Resolution Using Aberration Corrected Electron Optics." *Nature* 418 (August 8, 2002): 617-620.

Batson, P. E., N. Dellby, and O. L. Krivanek. "Corrigendum: Sub-Angstrom Resolution Using Aberration Corrected Electron Optics." *Nature* 419 (September 5, 2002): 94.