MMAT 5322 – Fall 2009
Homework 2– SEM, SPM
Due Friday, Oct 2, at the start of class

Question 1

a. For an SEM beam current of 1 nA, how many electrons strike your sample per second?
b. Given a detector collection efficiency of 1 in 10^{20}, how many electrons per second are actually recorded?
c. If these electrons are focused into a spot with a 2 nm radius, what is the charge density in electrons per sec per nm^2?
d. What is the velocity of the electrons, assuming an accelerating voltage of 25 keV?
e. Given the answers to c and d, how many electrons are there at any given time in the top 2 nm of the sample at the SEM focal point?

Question 2

Fill out the following tables, indicating whether the stated resolution improves or gets worse.

	Increase Z	Decrease Eo	Increase Io
SE lateral resolution			
SE depth resolution			
BS lateral resolution			
BS depth resolution			

	Increase humidity (vacuum gets worse)
ESEM SE lateral resolution	
ESEM SE depth resolution	

Question 3

You are using contact mode AFM and need to decide which cantilever to use for your experiment. Your instrument can detect changes in lever deflection of 1 angstrom. Assume Hertzian mechanics for this question.

a. With a 40 N/m cantilever, and separately with a 0.04 N/m cantilever, what is the noise in your setpoint force (or force measurements, the answer is the same)? Use units of nN.

You may also assume a tip radius of curvature of 20 nm, a sample radius of curvature of 100 nm (e.g. the sample is covered with 100nm hemispherical nanoparticles), a sample Young's modulus of 70 GPa (glass), a tip modulus of 160 GPa (Silicon), and typical poisson ratios for both tip and sample of 0.3.

b. Assuming you apply a whopping 100 nN of force, what is the reduced modulus (in GPa), reduced radius (in nm), contact radius (in nm), and indentation depth (nm)? Note that the spring constant does not work into this part of the question.

Question 4

You are using contact mode AFM. Also, once again you may assume a tip radius of curvature of 20 nm, a sample radius of curvature of 100 nm (e.g. the sample is covered with 100nm hemispherical nanoparticles), a sample Young's modulus of 70 GPa (glass), a tip modulus of 160 GPa (Silicon), and typical poisson ratios for both tip and sample of 0.3. For part of the problem, you also need the surface energy density, 0.1 J/m^2.

a. Plot how the Force varies with the contact radius for the JKRS and Hertz mechanical models. It is strongly suggested that you use a spreadsheet to determine necessary values, as this should also help you to see how sensitive AFM is to various experimental conditions. NOTE: The suggested range for contact radii to consider is 0 to 2.5 nm.
b. Plot how the indentation varies with the contact area for the two models.
c. Finally, plot Force vs. indentation for both models (i.e. b vs a). If you try to calculate F vs indentation directly, you will have trouble due to singularities, so use contact radius as your variable from a and b above (even though this is not something you can experimentally control).
d. What is the significance of a negative indentation, and of a negative force?

Question 5

For AC-AFM:

a. Calculate the spring constant for two common commercial AFM cantilevers, each 30 microns wide by 2 microns thick, but where one is 400 um long, and the other is only 100 um long. Assume these are both made of Si so the Young's modulus is again 160 GPa, and there is a density of 2.33 g/cm^3.
b. Determine the resonant frequency for these cantilevers.
c. For the 400 micron lever **only**, how much is it's maximum deflection due to its own weight (assume this entire load is applied at the end of the lever). Given the value, does the lever mass matter? You will need Earth's gravitational acceleration to determine this.
d. If a **REPULSIVE** force gradient of just 0.002 nN/nm is experienced by the 400 um long lever, how much will its resonant frequency, phase, and amplitude change, noting the sign for each?