Homework Assignment #5
Due by online submission Wednesday 9/30/2015 (Thursday at 9am)

1. You have built a comb-drive resonator similar to the one shown in Figure 1 of reference [1] using POLY1 in the polyMUMPs process. Beams are 2um wide and 300um long. Combs use 2um line and space, and each have 50 moving fingers (100 gaps). Young’s modulus is 150GPa. Assume that the total effective mass of the structure, and the area for damping calculations, is equivalent to a plate that is 100x100um$^2$.
   a. Calculate the spring constant of the folded suspension.
   b. Calculate the resonant frequency
   c. Calculate the damping coefficient and the Q factor for the device operated in air at STP.
   d. Estimate the output current with a 1um zero to peak displacement at 1kHz if a constant bias of 10V is applied to the sense pads.

2. How would the following process-related changes affect the resonant frequency?
   a. beams increase in width by 10%
   b. Young’s modulus increases by 10%

3. If you make six resonators which are identical except for the width of the beams, which vary from 2, to 2.5um in 0.1um increments, how could you use experimentally-measured resonant frequencies to estimate the Young’s modulus and the actual beam width?

4. How do the spring constant, mass, damping coefficient, electrostatic drive force, resonant frequency, quality factor, DC deflection, and resonant deflection of a comb-drive resonator change if you scale every dimension by a factor S?

5. Same question, but just for stretching the structure only in the Z direction by $S_Z$ (like going from polyMUMPS to SOIMUMPS)

6. Calculate the DC deflection of the resonator in problem 1 due to a 1.5 V signal applied to one comb drive (pad3 in Figure 1) with the structure grounded (pad2).

7. Calculate 1Hz deflection (zero to peak) with a 1.5V 1Hz sine wave applied to one comb drive with the structure at 15V DC.

8. Calculate the amplitude and phase of the three terms (DC, $f_r$, $2f_r$) describing the deflection due to a 1.5 V sine wave at the resonant frequency applied to one comb drive with 15 V DC applied to the structure.
