NATIONAL TECHNOLOGICAL UNIVERSITY
IC 792CA Fall 2001
Introduction to MEMS
(UC Berkeley EECS 245)

Homework Assignment #4 (Due Oct. 11th)

Problem 1: Strength of Silicon

a) If you want to make a solid thread of silicon that will hold up your body weight how large must the cross-sectional area be?
b) If the thread is round, what is the diameter?
c) What is the longest thread of this cross-sectional area that could be made from a 1 cm^2 chip that is 0.5 mm thick?
d) From 1 liter?

Problem 2: Beam Deflection

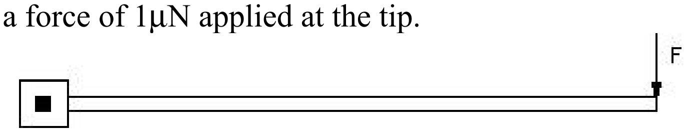
In this problem you will calculate the deflection of a beam under its own weight. Assume that the beam is a rectangular solid with length L, width b, and thickness a. Assume that it is made of a uniform isotropic material of density ρ, and Young's modulus E.

a) Calculate M(x), the bending moment as a function of position along the beam.
b) Calculate y(x), the deflection as a function of position.
c) Calculate y(L), the deflection of the tip of the beam.
d) Compare the answer above to the lumped-element answer, in which it is assumed all of the mass of the beam was at the tip. By what factor does this overestimate the deflection?
e) How long can I make a 2μm square cross section beam before the tip sags more than 2μm due to its own weight?

Problem 3: Beam Deflection using SUGAR

Use SUGAR to perform the following simulations. You may assume a Young's modulus of 10^{11}Pa.

a) Find the tip deflection and rotation of a 100x2x2 μm polysilicon beam (as shown below) due to a force of 1μN applied at the tip.



b) Find the frequency of the first resonant mode of the beam above, and send in a printout of the mode shape.

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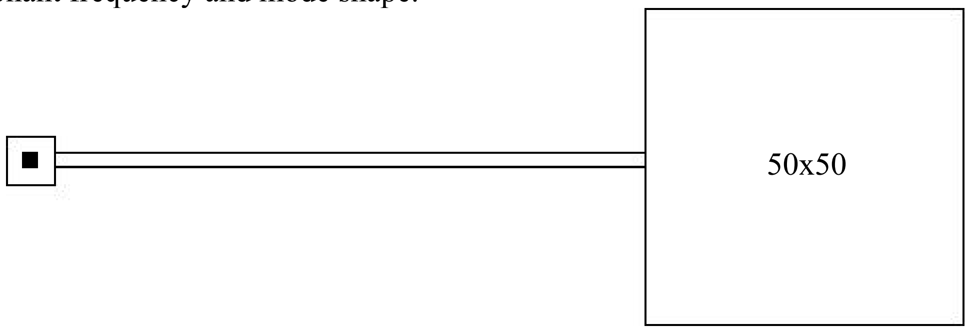
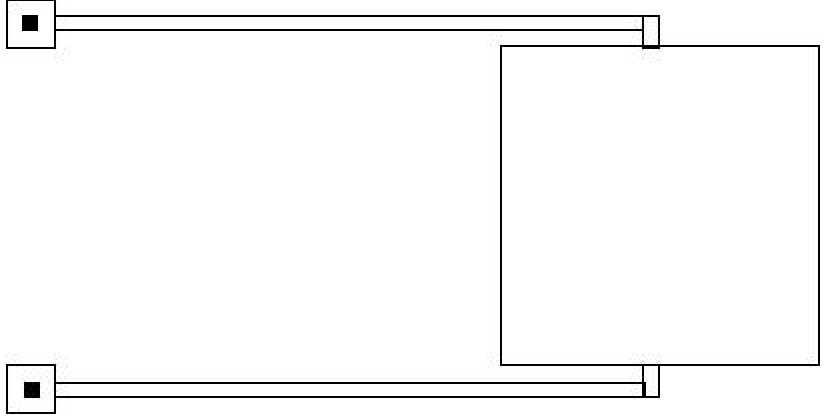
c) Add a 50x50 μm beam at the tip of the beam (as shown below), and find the new resonant frequency and mode shape.



d) Add another thin beam supporting the wide beam (as shown below) and find the new resonant frequency and mode shape. (Note: SUGAR joins beams at the center of their endpoints, so things may look a little funny as drawn. Just because two things overlap in SUGAR does not mean that they are connected. In the figure below, I've put in two little beams to make the attachment between the springs and the mass easier to see in SUGAR. You can use them or not, at your discretion.)



Problem 4: Spring System of Resonator

Design the following structure in your CAD tool of choice according to MUMPS design rules. The structure is half of the spring system of a comb-drive resonator. The structure is made from the POLY1 layer. (Print-outs of the design are fine for the HW but emailing me CIF files are preferred) Assume a film thickness of 2μm, a density of 2.3 g/cm^{-3}, and a stiffness of 10^{11}Pa.

a) Calculate the spring constant of the support assuming that the end beam is perfectly stiff (mostly true if W is large).
b) Calculate the mass of the dog bone, and the mass of the whole structure assuming W=20μm.
c) Calculate the resonant frequency using the above masses and spring constant.
d) Use SUGAR to calculate the spring constant of the support structure when W is 2, 4, and 20μm. (Note: you will need to break up the dog bone into sections so you will have enough nodes and in the proper location to attach the spring beams)

e) Use SUGAR to calculate the resonant frequency and mode shape when W is 2, 4, and 20μm.

f) Comment on your results. What method do you trust? What trends do you see as W changes?