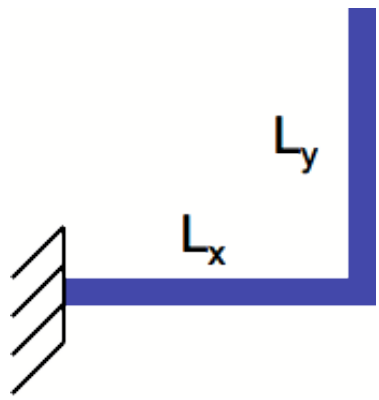
EE 245 / NEEM 6441: Introduction to MEMS Design
Homework 2

Beams and Electrostatics

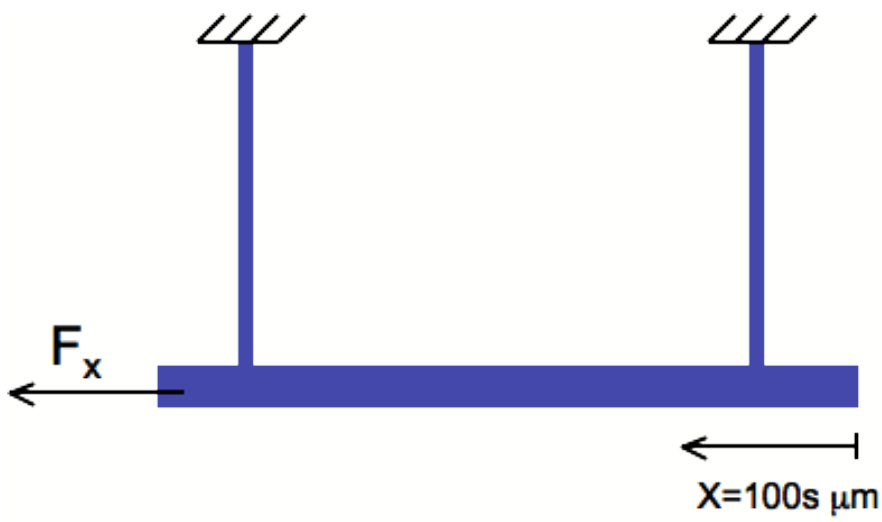
1. You are designing a suspension using two constant-cross-section beams. One beam is anchored to the substrate and has length L_x, and the other is attached to the end of the first beam at a 90º angle with length L_y.



   Design the beam lengths (L_x,L_y) so that when you apply a force along the x-axis and measure the x deflection, you get the same result as when you apply a force along the y-axis and measure the y deflection (i.e. make $k_x = k_y$). What is the ratio L_x/L_y?

   Hint: Write down the compliance matrix for the whole suspension and make the diagonals equal.

2. Your buddy at Stanford is designing a suspension for an actuator with long travel (several 100 μm). Here's what he came up with:



Is this a good idea? If not, propose a simple suspension to fix this problem (no numbers required – just general suspension layout).

3. Assuming a DRIE aspect ratio of R, a minimum feature size λ, a material density of ρ, and a maximum voltage V:

    a. Calculate the force per unit area of an idea gap-closing actuator array (use zero-deflection force and not the force after pull-in). Make some assumptions on magical gap stops that will prevent the actuator from shorting out.

    b. Calculate the force output per kilogram, assuming a film thickness t. Will microrobots with gap closing electrostatic actuators be able to lift themselves without massive gearing or levers?

    c. What is the optimum value for t, assuming we want to make minimum sized gaps and the maximum aspect ratio possible in our beams?

    d. Calculate the maximum work done per cycle of the actuator against a constant force load?

    e. Calculate the electrical energy input per cycle, assuming that some smart control circuit limits the total charge on the capacitor plates to twice the charge applied initially to the actuator (the zero-deflection charge).

    f. What is the actuator's energy efficiency (energy out for energy in)?

4. (Bonus) Check your solution to the first problem in SUGAR.