Midterm Exam

- This is 3 hours open book exam.
- State and justify clearly any assumptions you make.

Problem 1

In this problem, you are to design a single axis micro-mirror capable of a maximum rotation of 5 degree. The mirror, made of Aluminum, is $200\mu m \times 200\mu m$ and its thickness is H. The mirror is electrostatically actuated where a voltage V is applied between a fixed electrode (of length 200 μm and width W_e) on the substrate and the mirror. The minimum dimension you are allowed to use is 2 μm. In answering the following questions, you are to select the dimensions of the beams L, W, t, thickness of mirror H, gap h, and electrode width W_e, and offset X_e. The desired switching speed is 1 ms, i.e. the time the mirror takes to undergo the 5 degree rotation is at most 1 ms. For Aluminum, $\nu = 0.33$, $E = 69$ GPa and the yield strength is 95 MPa.

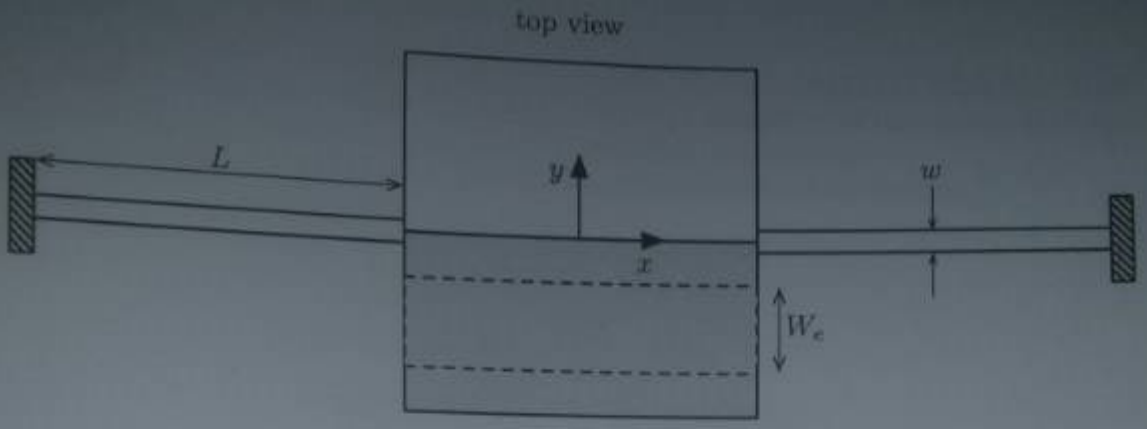
(a) What are the conditions under which static analysis is sufficient?

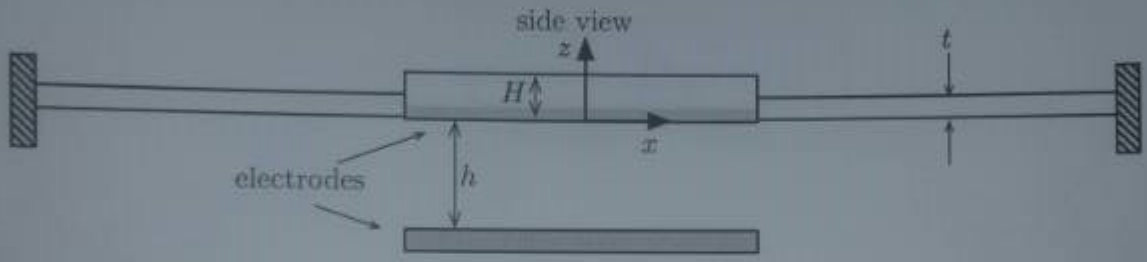
(b) What is the electrostatic energy needed to deflect the mirror? How can you minimize this energy?

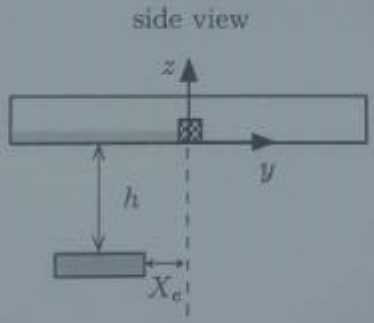
(c) How would you go about choosing the beam length L, width W, and thickness t.

(d) How can you maximize the switching speed?

(e) Assuming a damping force of the form $b\dot{\theta}$, what should the value of the damping coefficient,b, to get a fast yet stable response (no overshoot)? How do you envision such a damping force could come about?







Problem 2

In discussing the capacitive sensing of acceleration, we used a voltage source connected to one of the capacitor plates, while the other is connected to the input of an OP-AMP. While investigating this possibility in class, we came upon the possibility of sensing the deflection speed of the capacitor plate, rather than its position. Explain this effect and come up with possible application for its use.

Problem 3

In old inkjet printers, ink droplets were dispensed by thermal actuation. When the switch is closed, current flows through the resistor. The heat dissipated by the resistor goes into expanding the vapor bubble, which in turn pushes ink droplet out.

(a) What are the thermal challenges for successful operation of the device?

(b) How would you go about solving them?