1)

- Describe how you proceed in order to wet-etch a 25 μm thick silicon diaphragm in a single crystal silicon wafer of thickness 400 μm (surface is 100 plane, primary flat in <110> direction).
- Show how you calculate the dimensions of the mask opening resulting in a square diaphragm with side lengths 500 μm. For etching you use etchants TMAH or KOH.
- For the etch process, which material would you choose to protect the silicon outside the mask opening?
- Draw a sketch of the cross-section of the diaphragm in the wafer. Define the crystal planes in the drawing.

2)

- Describe the RIE (reactive ion etching) dry etch process. Describe the wall angle of a typical RIE-etched channel.

3)

- Describe silicon-glass anodic bonding.
- Give one example of a silicon-glass micro-element with or without an etched cavity in the glass.
- Draw a typical cross-section of an etched glass-cavity. Draw the protecting mask (gold mask) and the width and depth of the etched cavity for isotropic glass etch.

4)

- Describe the main characteristics of surface micromachining and bulk micromachining. Give micro-element examples.

5)

- Describe the meaning of Young’s modulus and the Poisson ratio in Hooke’s law. Draw the stress-strain curve for silicon. What are the mechanical/elastic advantages using silicon compared to e.g. a metal?

6)

- Describe the capillary rise of a wetting liquid in a vertical capillary tube. Define the wetting angle. Which forces act on the water column?

7)

- The linear beam equation describes the bending and stresses in a beam for small deflections (say less than 10% of it's thickness).
- Define the constants/variables of this equation. How do you proceed (boundary conditions etc.) to obtain the deflection for a beam that is clamped in one end, and has a uniform force (e.g. from acceleration) over the beam?

$$\frac{d^4 w}{dx^4} = q / EI$$

8)

- Draw a beam that is fixed at one end.
- Describe the stresses on a surface x=constant (i.e. stresses in a cross-section) of a beam bending due to e.g. a point force at the end of the beam.
- Where do you find the maximum stress?

9)

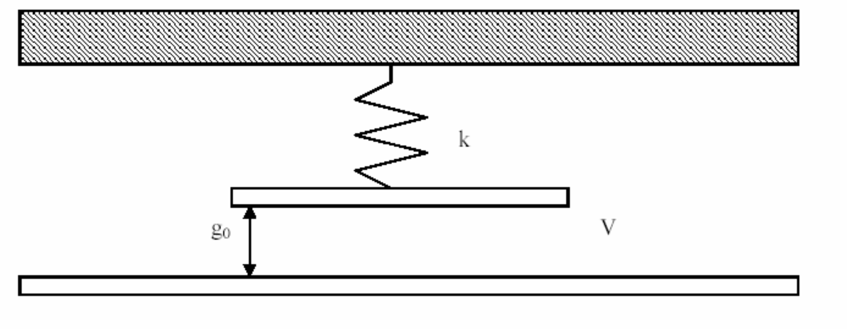
- If you were to place one piezoresistor on this beam, where would you place it for maximum sensitivity and what would be the change in resistance with stress for this piezoresistor, gauge factor ($\Delta R/R$)?

10)

- The capacitance of a conducting beam (e.g. length 80 μm, width 10 μm, thickness 0.5 μm), placed 2 μm above an infinite electrode, can be found approximately using the parallel plate definition. Why is this capacitance different (larger or smaller?) from that found by the Coventor program?

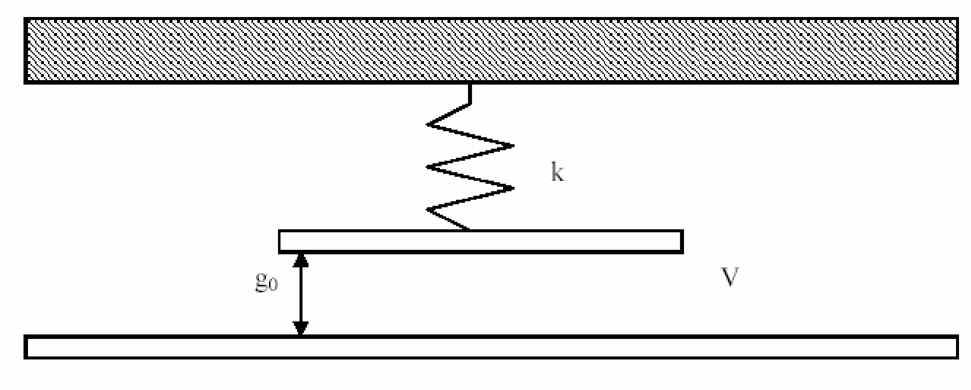
11)

- Consider a conducting plate that is suspended by a linear elastic spring. A small voltage (below pull-in voltage) is applied between the plate and an infinite electrode.
- Describe the forces that act on the plate and the position of the plate when the electric field is applied (disregard the fringing electrostatic field).



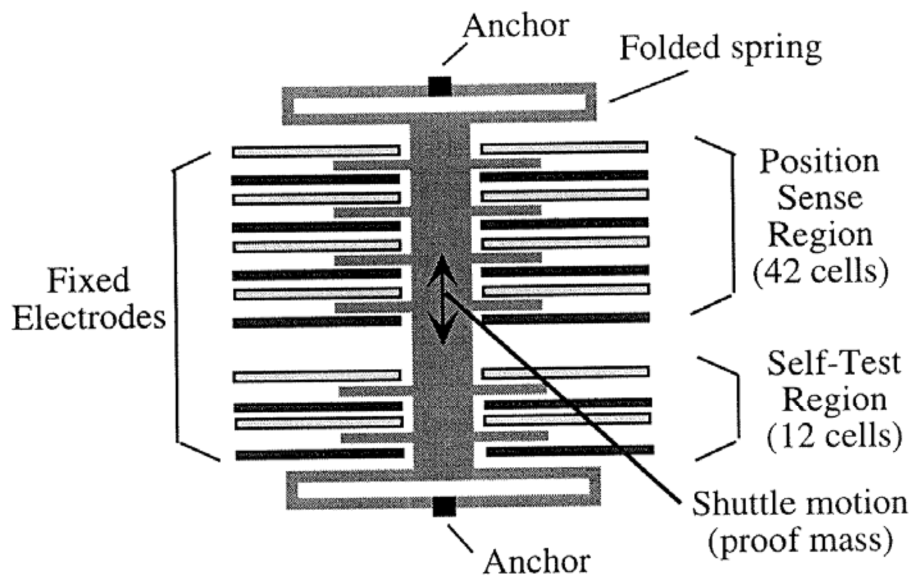
12)

- Explain the pull-in effect for the plate, spring, electrode system in the figure.
- In terms of the mechanical and electrostatic forces acting on the plate, what is the pull-in voltage/displacement of the plate?
- Describe hysteresis when the voltage between the plate and the electrode is increased above the pull-in voltage and then decreased. You may add a thin dielectric layer in the figure.



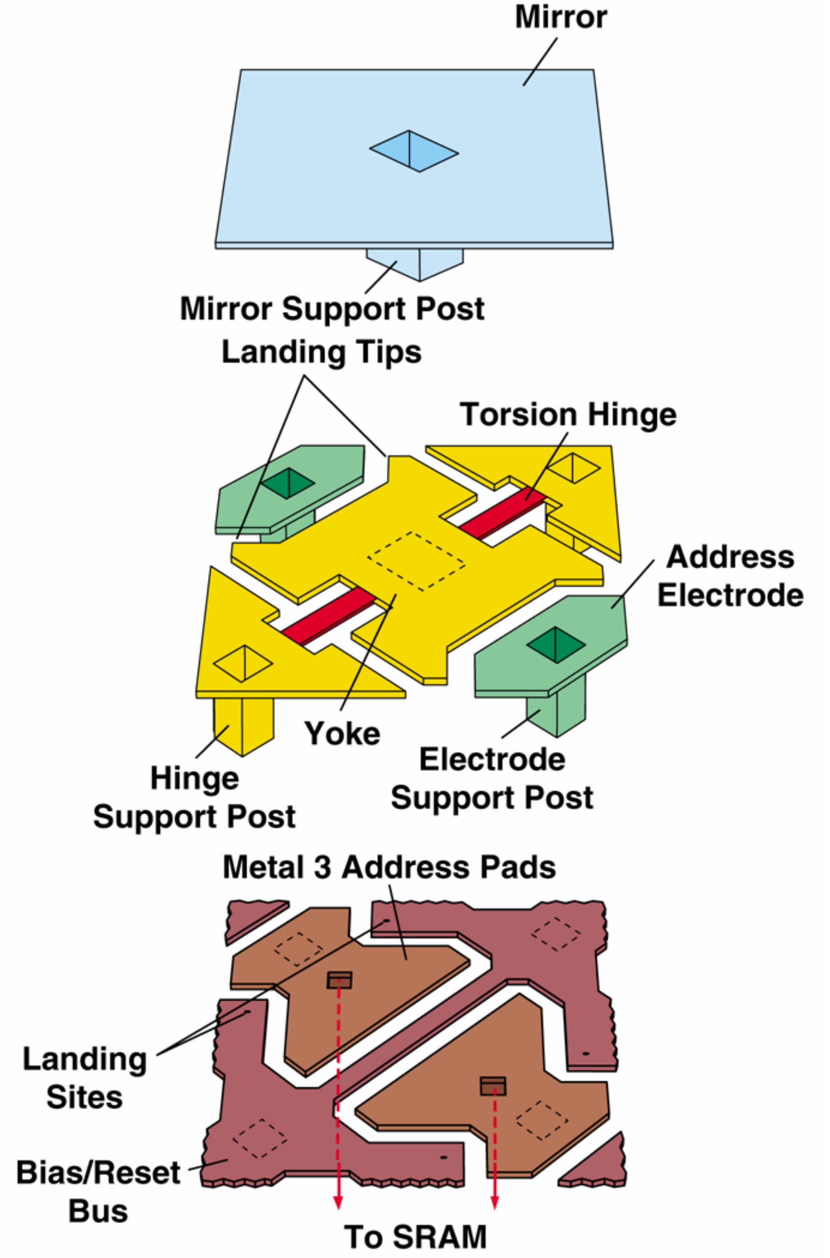
13)

- Describe the functioning of a capacitive surface-machined comb-accelerometer
- Which parts constitute the three electrodes of the differential capacitor?
- Which inertial/elastic/electrostatic forces act on the proof mass?
- What is self-test?



14)

- Describe the functioning of the DLP pixel sketched
- Consider pure torsion, and a linear angular displacement with torsional force, explain roughly how the electrostatic forces change with the tilt angle (no equations).



15)

- Describe the flow profile of pressure driven flow through a narrow pipe and the flow profile of an electro-osmotically driven flow through a pipe. If you want to perform electrophoresis for separation of molecules from size and charge in the pipe, and later optical detection of molecules of a specific size/charge, which type of flow would you prefer?

16) Explain the PCR amplification process in three steps