1. Calculate the intersection angle of all members of the \{111\} family of equivalent planes with a (110) silicon wafer.

2. Fold up (or just look at) a copy of the ever-popular fold-up crystal (http://www-bsac.eecs.berkeley.edu/~pister/crystal.pdf)
   a. Approximately how many hours does it take to grow a 1 um thick thermal oxide at 1100C under “wet” and “dry” conditions? (note: you’ll have to extrapolate the curves a bit for one or both of these, and one of them is going to give a really long time)
   b. Approximately how many hours does it take to grow a 0.1um oxide at 1000 C under wet and dry conditions?
   c. Two silicon resistors are identical in shape and both are doped with 1e14 atoms/cc, one with boron, one with phosphorous. Which one has a lower resistance? Roughly how much lower?
   d. Roughly what percentage of the atoms in a crystal are dopants when silicon is doped to a resistivity of 1m\(\Omega\)cm? How does this resistivity compare to the resistivity of aluminum?

3. In the following figure, assuming that the cantilever pointing out of the page is oriented in the [110] direction on a (001) wafer, label each flat etch face in the image. (image source: https://cmi.epfl.ch/etch/PladeKOH.php)

4. In Figure 3 and Table VI of “What is the Young’s modulus of silicon?” [4]
   a. How much does the spring constant of a beam vary as the orientation of the axis of the beam rotates 45 degrees on a (100) wafer?
   b. How does the stiffness of a beam change if the temperature increases by 100C?
c. What is the torsional spring constant in axial twisting of a 1mm long, 2um wide beam in 25um SOIMUMPS?

5. In reference [1],
   a. In the paragraph below Figure 2 it explains why the pressure rises during the etch. Based on that explanation, approximately what fraction of the XeF2 gas is consumed in the etch shown in Figure 2?
   b. Compare the lateral etch rate of bulk silicon and polysilicon thin films (figures 6 and 11) with 60 second pulses and 120 second pulses. (n.b. check the number of pulses used in each etch). Are they both linear in the length of the pulse? Are the rates the same?
   c. In figure 8, which structures etched fastest in the first two pulses, the 50um, 200um, or 800um square openings? What about after 12 pulses? What might account for the difference, and the shape of the etch front of the 800um aperture after 12 pulses?

6. In reference [2],
   a. From Figure 5, what is the highest etch rate that they measured in the “smooth etched surface region”? Roughly what is the mixture of acids that gives that etch rate?
   b. Same question, but for the lowest etch rate in that region.
   c. At the overall highest etch rate that they measured, how long would it take to etch a 500um thick bare silicon wafer (both sides exposed to the etch).

7. In reference [3], rectangular apertures aligned with the flat of a (100) wafer, or 45 degrees to the flat, are etched in KOH (they also did NaOH etching, but you can ignore that for this problem).
   a. In Figure 2, what is the direction of the aperture alignment (either <100> or <110>)? What is the resulting sidewall angle and plane?
   b. In Figure 3, what is the direction of the aperture alignment? What are the resulting sidewall angles and corresponding planes? What process variable determines plane emerges?
   c. In Figure 5, cross-sections AA and BB are on the wafer with the standard CMOS orientation and flat. Other than ~54 degrees, what other sidewall angles are possible, what combination of mask layout and processing is necessary to get them, and what crystal planes define them?

8. [247A] Flip through at least one MEMS journal or conference proceedings from cover to cover (the library has journals, the bsac conference room 402 Cory has journals and conference proceedings and is open during the day, the internet will work too). Find at least two papers where either:
   a. the design or structure could have been built in a standard process but wasn’t
   b. some aspect of the paper could be extended, refined, clarified, or otherwise improved by designing and testing structures in a standard process


