Problem 1: Scaling Actuators

You are trying to decide between electrostatic and magnetic actuation.

Assumptions:
- the maximum voltage you can use for a microactuator is 100 volts.
- the ferromagnetic material has $M_s = 1.1$ Tesla $(V \cdot s / m^2)$ – the value for NiFe, a commonly used ferromagnetic material.

1-1. At which gap will the magnetostatic energy density equal the electrostatic energy density?

1-2. If you could use the maximum possible electric field instead of 100 V, at what gap will the magnetostatic energy densities be equal?

Problem 2: Chemical Safety

2-1. Use an on-line MSDS search engine to determine the NFPA ratings for health, flammability, and reactivity ratings for the following commonly used chemicals compounds. Also, indicate if any demonstrate unusual water reactivity (W) or posses oxidizing properties (OX):
- Acetone
- HF
- $H_2SO_4$
- $H_2O_2$
- KOH
- Methanol
- Silane ($SiH_4$)
- Phosphine ($PH_3$)
- Carbon Tetrafluoride ($CF_4$)

NOTE: Not all manufacturers provide this information in their MSDS, but you should be able to find one that does.
Problem 3: Cheap Masks

You want to make some masks, but do not have enough money. While printing out transparencies for a talk you are about to give, you come up with the idea of making masks with a laser printer.

3-1. Theoretically, what is the smallest feature (in micrometers) you could print with a common high-resolution laser printer (1200 dpi)?

3-2. To print 5 µm dots & spaces, what printer resolution is needed? Do such printers exist? If so, indicate the make and model.

3-3. Since laser printer toner and transparencies were not designed to be used as masks, what might be some problems that you could encounter that would make the use of a transparency mask difficult?

Problem 4: Exposure System Selection

Let’s say that you need to pattern resist using either

(a) g-line (436 nm) contact exposure tool
(b) i-line (365 nm) proximity exposure tool with a 5 µm gap between the top of the rest and the mask
(c) i-line (365 nm) projection exposure tool with an NA of 0.4

Which of these tools would you choose to print well-focused minimum size features and why for the following situations?

4-1. 1-µm–thick Resist
4-2. 10-µm–thick Resist
4-3. 100-µm–thick Resist

NOTE: Assume “minimum feature size” refers to the full line-gap period (2 · b_min). Confirm your answers by comparing the resolution of each approach.

Problem 5: Photoresist Contrast

5-1. Calculate the contrast of AZ111
5-2. Calculate the CMTF of AZ111
5-3. If you determine that the minimum exposure time to get a good exposure is 5 seconds (i.e., at the CMTF limit), what is the brightness (intensity) of your exposure tool?