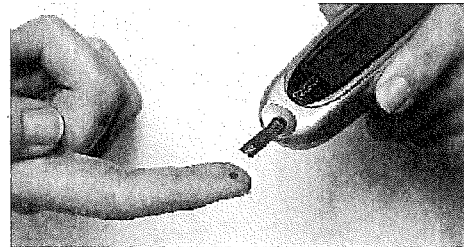


The following ten questions are qualitative and examine your basic knowledge of MEMS and BioMEMS, they all have short answers. If needed, you can draw a schematic to explain your answers.

- 1) The most commercially successful biosensor is the blood glucose sensors (glucose strips, shown below), manufactured and sold in several hundred million units each year, what is the transduction mechanism? Is it optical or electrical? If electrical, specify what kind (amperometric, potentiometric, gravimetric, Wheatstone bridge, etc.)?? if optical, specify what kind (absorption, reflection, fluorescent, etc.)(5 points)



- 2) What is the most successful consumer MEMS sensor that you encounter and use in everyday life these days? (5 points)
- 3) Which of the following wet silicon etchants have the least p++ etch stop selectivity, EDP, KOH, or TMAH? (5 points)

- 4) What is the main advantage of TMAH as a silicon etchant in particular for post-CMOS MEMS technologies? **(5 points)**

- 5) Name two methods used to deposit silicon dioxide on a silicon wafer assuming you can only tolerate a maximum temperature of 500 °C? **(5 points)**

- 6) Miller indices are a set of numbers that identify in a silicon wafer **(5 points)**

- 7) Name one advantage and one disadvantage of resonant sensors (sensors which are based on a resonating mechanical structure such as a beam) **(5 points)**

- 8) Name two common actuation methods for soft robotics. These are rubbery structures made of PDMS or other elastomers that deflect or stretch several hundred % compared to their original size. **(5 points)**

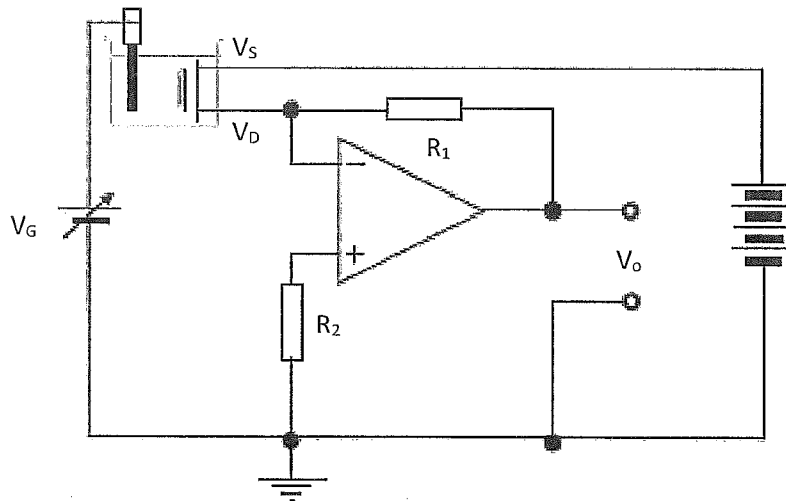
9) Name two drawbacks of using environmentally sensitive hydrogel as smart material in biomedical microsystems. (5 points)

10) Name two methods used in bio-printing 2 or 3D structures? How can you get nutrient and remove waste products from cells in these constructs? (5 points)

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11) Ion Sensitive Field Effect Transistors (ISFET or ISEFET) were invented in the early 70s but technical difficulties prevented their commercial success until very recently when they have become available as pH sensors.

- a- Draw a cross section of an ISEFET pH sensor in the solution and mark all the components, regions etc. Explain how it works, i.e. how a change in a solution pH translated into an electrical output? Assume a two electrode sensing system (working and reference electrode) (5 Points).
- b- Name two problems that prevented the successful launch of the ISEFET until recently (5 Points).
- c- What is the maximum theoretical pH sensitivity ($\Delta V/\Delta \text{pH}$) of the ISEFET (HINT: remember Nernst) (5 Points).
- d- Circuit below shows a possible interface circuit for ISEFET in which a constant V_{GS} is applied to the device, explain how it works, what is the expression for V_o ? (5 Points).

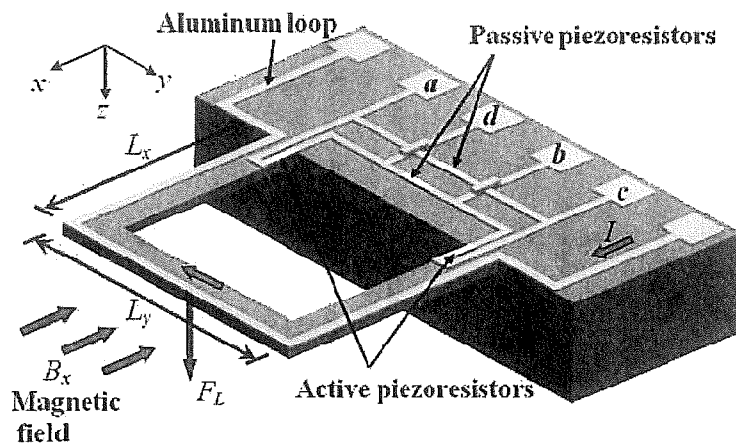


- 12) Superparamagnetic nanoparticles are used in nanobiotechnology for hyperthermia, cell separation, MRI contrast agent, and sensing applications.
- a- Explain what do we mean by superparamagnetic and how that is differentiated by just paramagnetic material that you learned in basic physics and EM courses? **(5 Points)**
 - b- Draw the B-H curves for paramagnetic, ferromagnetic, and superparamagnetic materials **(5 Points)**
 - c- Sometimes magnetic microparticles are better suited for bio-applications, these can be anywhere between 1-100 μm . Explain two methods used to make these considering that superparamagnetic ones are much smaller (10-20 nm) and are made using a bottom-up approach? Draw the cross section of each particle showing the position of magnetic material. **(5 points)**

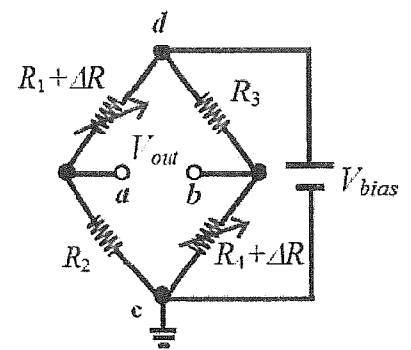
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13) Figure below shows a resonant MEMS magnetic sensor,

- a- Explain how it works (5 points)
- b- Find the expression V_{out}/V_{bias} assuming the shown half bridge (you can assume $R_1=R_2=R_3=R_4=R$). (5 Points)
- c- Propose a process to fabricate the device. Hint: Assume you can use a silicon on insulator (SOI) wafer and have access to a deep reactive ion etch (DRIE) system in the lab. You don't need to specify details, just show the main steps in cross sections. (5 Points)



(a)



(b)

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