The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

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Study Programme	:	Bachelor of Technology Honours in Engineering
Name of the Examination	:	Final Examination
Course Code and Title	:	**DMX6306 Micro/ Nano Electro Mechanical Systems**
Academic Year	:	2020/21
Date	:	30th January 2022
Time	:	1400 hours -1700 hours
Duration	:	**3 hours**

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (08)** questions in **Four (04)** pages.
3. Answer any **Five (05)** questions.
4. Answer for each question should commence from a new page.
5. This is a Closed Book Test (**CBT**).
6. Answers should be in clear handwriting.
7. Do not use Red colour pen.

Question 01 – *(20 Marks)*

(a) A cylindrical silicon rod is pulled on both ends with a force of 10 mN. The rod is 1 mm long and in diameter. Find the stress and strain in the longitudinal direction of the rod.

[06 marks]

(b) Fixed-guided springs are often used to support rigid plates and facilitate their translation. Often, a plate is supported by two or more such beams as shown in, (Figure Q01a and Figure Q01b). In these cases, one end of the beam is fixed, with all degrees of freedom limited. Another end of the spring can move in the vertical direction, but no angular displacement is allowed because it is connected to the stiff translational plate, which remains parallel to the substrate under allowable plate movement as shown in (Figure Q01c). Find the expression of the force constant associated with the plate.

[14 marks]

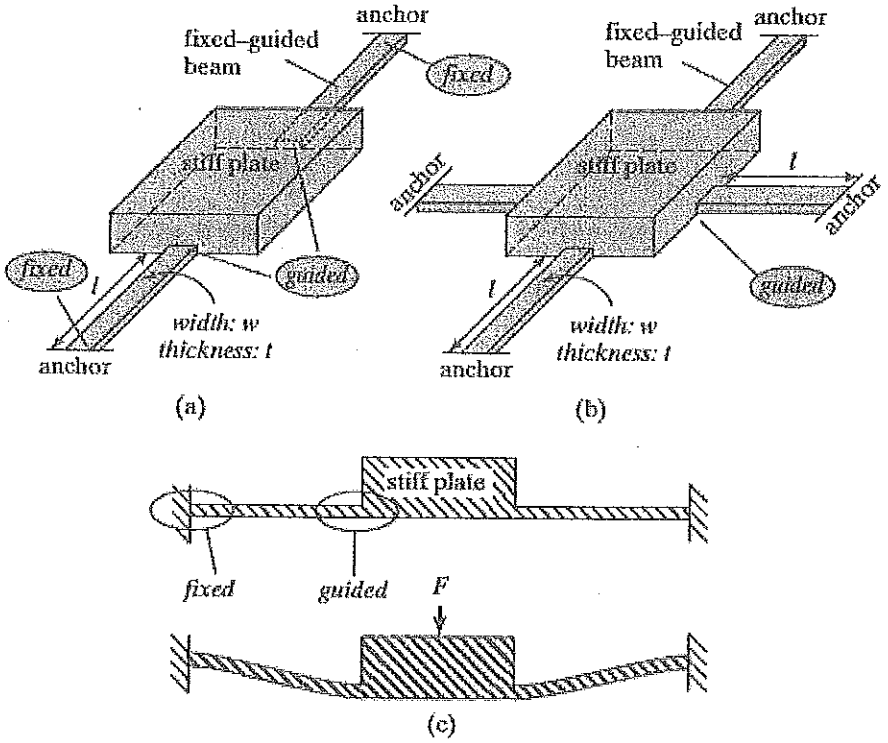

Figure Q01: Commonly encountered plate support configurations.

Question 02 - *(20 Marks)*

(a) Derive a scaling law for the ratio of surface area and the volume of a cube and discuss the consequences for MEMS design. *[06 marks]*

(b) Explain the importance of Reynolds number with respect to scaling of the fluidic system. *[04 marks]*

(c) Given a cube of dimension, d, on a side and density, ρ_c, floating in a liquid of surface tension, σ.

i. Calculate the cube dimension, d at which surface tension force is greater than the cube weight. *[05 marks]*

ii. The cube is made of silicon ($\rho_c = 2300$ kg/m^3) and the liquid is water ($\sigma = 0.072$ N/M). What is the cube dimension from part (a)? *[05 marks]*

Question 03 - *(20 Marks)*

(a) Explain the two types of substrate materials used in MEMS materials. *[05 marks]*

(b) A thin piezoelectric crystal film of (Lead Zirconate Titanate) PZT is used to transduce the signal in a microaccelerometer with a cantilever beam made of silicon. The accelerometer is designed for maximum acceleration/deceleration of ***10g***. The PZT transducer is located at the support base of the cantilever beam where the maximum strain exists during the bending of the beam, as illustrated in Figure 03. Determine the electrical voltage output from the PZT film at the maximum acceleration/deceleration of ***10g***. *[15 marks]*

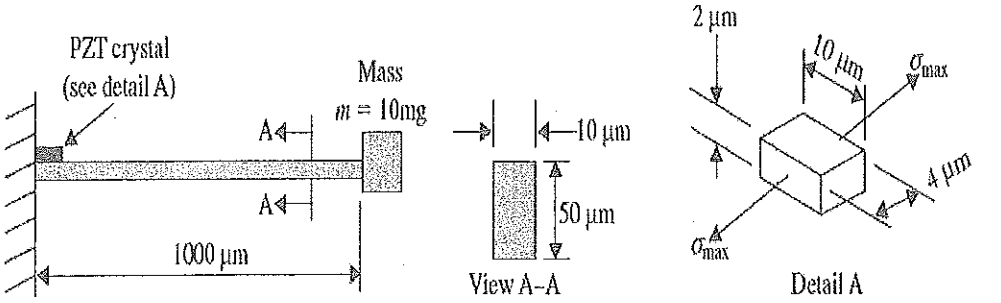

Figure. Q03: Piezoelectric transducer in a beam-accelerometer.

Question 04 - *(20 Marks)*

(a) i) Why is silicon a desirable work material in microsystem technology? *[02 marks]*
ii) What is the difference between bulk micromachining and surface micromachining? *[02 marks]*

(b) i) Describe the importance and advantages of LIGA. *[05 marks]*
ii) Explain the differences between stereolithography and micro stereolithography. *[04 marks]*

(c) The MEMS devices are applicable to macroscale machine elements, such as spur gears, hinges, and beams. Which of the following machine elements can or cannot be applied to MEMS, and why? *[07 marks]*

- ball bearings
- bevel gears
- worm gears
- cams
- helical springs
- rivets
- bolts

Question 05 - *(20 Marks)*

Explain the operation principles of the following actuations in MEMS systems.

- Electrothermal Actuation
- Piezoelectric Actuation
- Electromagnetic Actuation
- Electrostatic Actuation *[4 X 05 marks]*

Question 06 - *(20 Marks)*

(a) Identify some of the present and future products associated with NEMS systems. *[05 marks]*

(b) Explain, why biology is so closely associated with nanoscience and nanotechnology. *[05 marks]*

(c) i) What are the two basic categories of approaches used in nanofabrication? *[05 marks]*

ii) Briefly explain the lithography techniques used in nanofabrication. *[05 marks]*

Question 07 - *(20 Marks)*

(a) i) What are the NEMS attributes? *[03 marks]*

ii) Briefly explain three of them. *[05 marks]*

(b) i) State the types of NEMS based materials. *[04 marks]*

ii) Identify the significance of NEMS based materials. *[03 marks]*

(c) Briefly explain the applications of Carbon Nanotubes and Carbon Fullerenes. *[05 marks]*

Question 08 - *(20 Marks)*

(a) Explain the two types of vapor deposition techniques. *[05 marks]*

(b) i) What is self-assembly in nanofabrication? *[03 marks]*

ii) How is nano-imprint lithography different from micro-imprint lithography? *[04 marks]*

(c) i) What are the types of actuation methods of NEMS systems? *[03 marks]*

ii) Briefly explain three of them. *[05 marks]*