# 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 Electromechanical Systems** |
| Academic Year | : 2021/22 |
| Date | : 12th February 2023 |
| Time | : 0930 hours -1230 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.

*[08 marks]*

(b) A suspended beam shown in the Figure Q01 diagram below is under a force of $F$ ($F = 10\mu N$). Find the vertical displacement at the end of the beam, assuming the flexural bending of the cantilever beam is negligible. The dimensions of the beam are $L = 40\mu m$, $l = 200\mu m$, and $w = 5\mu m$, $t = 2\mu m$. The beam material's Young's Modulus of is $E = 150GPa$. The Poisson's ratio of the beam material is **0.3**.
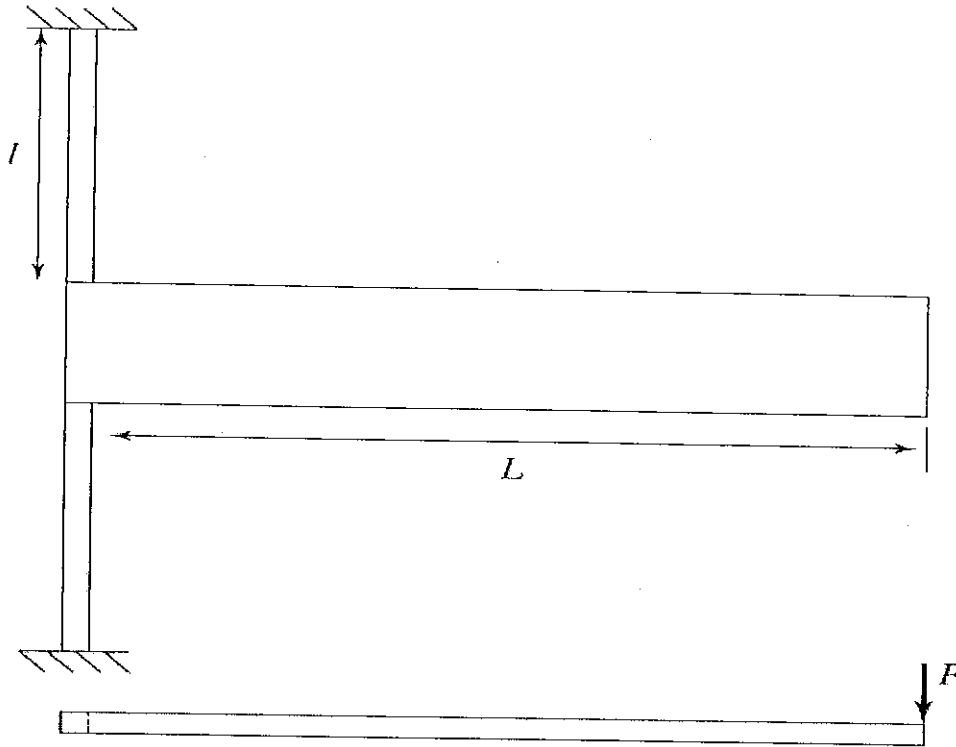
*[12 marks]*



Figure Q01: A torsional supported cantilever

## 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 the Reynolds number with respect to the scaling of the fluidic system.

*[04 marks]*

(c) Given a cube of dimension, **d**, on a side and density, $\rho_c$, floating in a liquid of surface tension, $\sigma$.

   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) Briefly explain the two types of substrate materials used in MEMS materials. *[06 marks]*

(b) i) In the context of using piezo resistivity to sense strain, what are the advantages/disadvantages of using silicon vs. silicon nitride for pressure sensor diaphragms? How does residual stress affect the sensitivity? *[08 marks]*

ii) Describe five methods you could implement to prevent stiction between surface micromachined components. *[06 marks]*

## Question 04 - *(20 Marks)*

(a) i) Why is silicon a desirable work material in microsystem technology? *[02 marks]*

ii) Differentiate between bulk micromachining and surface micromachining. *[05 marks]*

iii) Explain the importance and advantages of LIGA. *[05 marks]*

(b) The Discuss the general compatibility between three sacrificial materials (CVD oxide, photoresist and metal) and three structural materials (CVD polysilicon, CVD silicon nitride, metal). How many pairs are viable structural-sacrificial material combinations in a two-layer process? *[08 marks]*

## Question 05 - *(20 Marks)*

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

- Electrothermal Actuation
- Piezoelectric Actuation
- Electromagnetic Actuation
- Shape Memory 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]*