Name: **Enrolment No:**	UPES

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination (ONLINE), August 2020

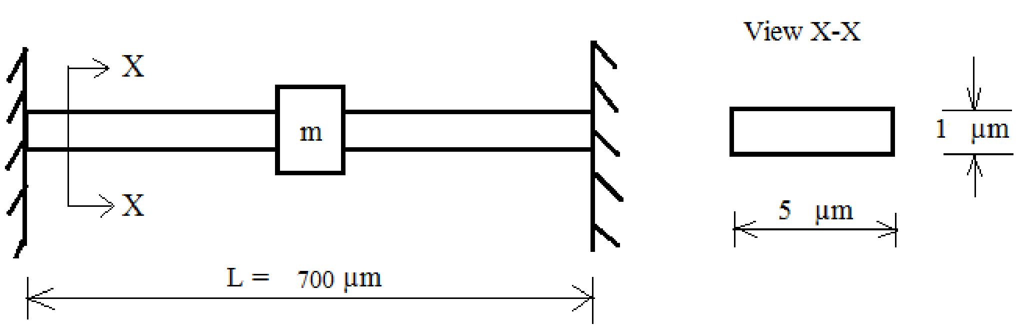
Course: MEMS (MEEL 441) **Semester: VIII**
Program: B.Tech. Mechatronics Engineering
Time: 03 hrs. **Max. Marks: 100**

Instructions:
(1) There are total 17 questions in this question paper. All the questions are compulsory.
(2) Section A contains 6 questions. Each question carries 5 marks. Total marks is 30.
(3) Section B contains 10 questions which are to be answered in not more than 20 words. You can answer in phrases. Total marks is 50.
(4) Section C contains 1 question only. There are six sub-parts: (i) to (vi). The sub-parts: (i) and (ii) are of 5 marks each, subpart (iii) is of 4 marks while sub-parts: (iv) to (vi) are of 2 marks each. The sub-parts: (iv) to (vi) are to be answered in paragraphs. Avoid using phrases while answering. Total marks is 20.
(5) Assume any missing data.

SECTION A

S. No.		Marks	CO
Q 1	Fill in the blanks using appropriate keywords. The frequently used term ______(a)______ in microelectronics means a flat macroscopic object on which microfabrication processes take place. In microsystems, this flat object serves an additional purpose: it acts as signal transducer besides supporting other transducers that convert ______(b)______ actions to ____(c) ____ outputs or vice versa. In semiconductors, this flat object is a single crystal cut into slices from a larger piece called a ____(d)_____. An example of a material from which this flat object is made is ____(e)_____. ***Keywords:*** *mechanical, wafer, quartz, iron-carbide, substrate, electrical* (Note: There are six keywords. Only five are correct.)	**5**	**CO3**
Q 2	Write True or False. a) Dimensional stability is a critical requirement for sensors and actuators with high precision.__________ b) The substrate materials used in microsystem have basically a cubic crystal lattice with a tetrahedral atomic bond. __________ c) Young's modulus of silicon is same as that of aluminium. __________	**5**	**CO3**

	d) There is a greater flexibility in design and manufacture with gallium arsenide than with other substrate materials. __________ e) Polymers are widely used for electromagnetic interference (EMI) and radio-frequency interference (RFI) shielding in microsystems. __________		
Q 3	Fill in the blanks using appropriate keywords. LB films are good candidate materials for exhibiting ___(a)____, ____(b)_____, and ____(c)______ properties. LB films may also be produced with controlled optical properties such as _____(d)______ and _____(e)______. They are thus ideal materials for microsensors and optoelectronic devices. ***Keywords:*** *refractive index, magnetic, thermal shielding, heat generating, antireflectivity, piezoelectric* (Note: There are six keywords. Only five are correct.)	**5**	**CO3**
Q 4	Answer the following. a) Three planes of silicon crystals are of particular importance in micromachining. These are: __________________ b) In micromachining, the ______________ orientation is the favoured orientation. c) The term LIGA is an acronym for ______________________________. d) The substrate used in the LIGA process is often called the ___________. e) Sacrificial components in surface micromachining are usually made up of ________.	**5**	**CO4**
Q 5	Write True or False. a) Surface-micromachined devices are typically made up of three types of components. _______________ b) The major advantage of bulk micromanufacturing is that it facilitates virtually unlimited aspect ratio of the microstructure geometry. ________________ c) LIGA process is the best of the three manufacturing processes for mass production. ___________________ d) Selectivity ratio of a material is defined as the ratio of the etching rate of material to the etching rate of silicon. ____________ e) Dry etching of silicon substrates, such as by plasma, typically is faster and cleaner than wet etching. ____________	**5**	**CO4**
Q 6	Write down one advantage and one disadvantage for each of the three micromanufacturing techniques.	**5**	**CO4**
SECTION B (Answer in not more than 20 words. Use phrases while answering.)			

Q 7	Recognize your major criterion in selecting materials for the masks used in etching, e.g., in etching silicon substrate with moderate depth and also for deeper etching?	**5**	**CO4**
Q 8	Differentiate between LIGA and SLIGA.	**5**	**CO4**
Q 9	Differentiate between isotropic etching and anisotropic etching.	**5**	**CO4**
Q 10	Differentiate between plasma etching and DRIE.	**5**	**CO4**
Q 11	Describe the procedure(s) for production of silicon dioxide. Give very brief description.	**5**	**CO3**
Q 12	State the mathematical relationships used in design of piezoelectric transducers in unidirectional loading situations. (You may use text instead of symbols.)	**5**	**CO3**
Q 13	Discuss the major technical issues involved in the application of MEMS in biomedicine.	**5**	**CO2**
Q 14	Describe the concept of 'lab-on-chip'. Mention the typical features of an intelligent microsystem.	**5**	**CO1**
Q 15	Describe the various types of microactuation processes.	**5**	**CO2**
Q 16	Discuss the advantages and applications of polymers.	**5**	**CO3**
	SECTION C		
Q 17	A microdevice component, 4 gram in mass, is attached to a fine strip made of silicon at the middle of the device, as illustrated in Figure 1. Both the mass and the strip-spring (fixed at both ends) are made of silicon. The arrangement is to be used in a microaccelerometer deployed in airbags of a car which comes to rest from its initial velocity of 72 km/h in 0.5 second. Take Young's modulus of Si, E = 190,000MPa. Length of strip-spring, L = 700 µm, width of strip-spring, b = 5 µm and thickness of strip-spring, d = 1 µm.  Figure 1: Figure for Q 17 Consider the following. i. The equation of motion of the mass in Fig. 1 can be written as: $$m\frac{d^2x(t)}{dt^2} + k_{eq}x(t) = 0$$	**20**	**CO5**

where, m = proof mass attached at the end of microdevice, k_{eq} = equivalent stiffness of the strip-spring, $x(t)$ = displacement of mass 'm' at any time 't' from its mean position.

Find the value of k_{eq} and natural angular frequency, ω. Mention the formulae used by you in evaluating these two values.

ii. If the solution for the differential equation described in part (i) is given as:

$$x(t) = C\sin(\omega t + \phi)$$

Determine the values of coefficient C and phase angle ϕ and hence find out the absolute displacement, $x(t)$ of mass 'm' from its neutral equilibrium position. Mention the boundary conditions used by you for finding out the values of C and ϕ.

iii. If the maximum relative movement of proof mass is represented by the following formula:

$$Z = -\frac{a_{base}}{\omega^2}$$

where, a_{base} is the maximum acceleration of proof mass; find out the maximum restoring force felt by the proof mass.

iv. Name the method that can be used for manufacturing the microdevice with the least cost. Discuss the significant aspects of this method.

v. Which materials can be used as a mask for the manufacturing process.

vi. Discuss some wet etchants that can be used during the process.