INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

MECHANICAL ENGINEERING

TUTORIAL QUESTION BANK

Course Name	**Design for Manufacturing MEMS and Micro Systems**
Course Code	**BCC210**
Class	M. Tech II Semester CAD/CAM
Branch	Mechanical Engineering
Year	2017 – 2018
Course Coordinator	Mr. M. Sunil Kumar, Assistant Professor.

OBJECTIVES:

Microelectromechanical systems (MEMS) is the technology of microscope devices, particularly those moving with Parts. It merges at the nano-scale into nanoelectromechanical systems (NEMS) and nanotechnology. The fabrication of MEMS evolved from the process technology in semiconductor device fabrication, i.e. the basic techniques are deposition of material layers, patterning by photolithography and etching to produce the required shapes.

S No	QUESTION BANK	Blooms Taxonomy Level	Course Outcomes
	UNIT – I **OVERVIEW AND WORKING PRICIPLES OF MEMS AND MICROSYSTEMS**		
Part - A (Short Answer Questions)			
1	Explain the differences between MEMS and Microsystems.	Remember	1
2	Why cannot microelectronics technology be adopted in the design and packing of MEMS and microsystem products.	Understand	1
3	Give three examples of the objects that you personally recognize to be of the size approximately 1 millimeter.	Remember	1
4	What are the most obvious distinction between micro system microelectronics technologies.	Understand	1
5	List out at least four distinct advantages of miniaturization of machines and devices.	Remember	1
6	What are the principal applications of microsensors, actuators and fluidics.	Understand	1
7	What are the merits and demerits of using piezoresistors as a single transducer.		1
8	Write the advantages of miniaturization.	Remember	1
9	Explain comparison between micro electronics and micro systems technologies.	Remember	1
10	Explain the advantages and disadvantages of using capacitors as signal transducer.	Remember	1
Part - B (Long Answer Questions)			
1	What do you understand by MEMS. Sketch the functional relationship between various components in a microsensor.	Remember	1
2	Explain the operation of micro pressure sensor using capacitance signal transduction.	Understand	1
3	Describe the working of silicon capacitive accelerometer. With a neat sketch.	Remember	1
4	Explain the concept miniaturization of MEMS. Distinguish between micro actuator and micro accelerometer.	Understand	1
5	Explain MEMS history and development and its application in an automobile.	Remember	1
6	Explain the concept of micro fluidics in detail. Write down fluid actuation methods. List out merits and demerits of them.	Understand	1

Part - C (Problem Solving and Critical Thinking Questions)			
1.	Design a pressure sensor with a mems microsensors suitable for an engineering application.	Remember	1
2.	Design a micro actuator with a mems micro accelerometer suitable for an engineering application.	Understand	1
3.	Describe the three principal signal transduction methods for micropressure sensors. Provide atleast one major advantage and one disadvantage of each of these methods.	Remember	1
3.	Explain how microfluidics is used extensively in biomedical precision manufacturing process and pharmaceutical industries. Write the merits and demerits of them.	Understand	1
4.	Calculate the electrostatic forces on the plate electrodes with an applied DC voltage at 70V. The geometry and dimensions of the plate electrode are shown in figure. The plate are initially misaligned by 20 percent in both length and width directions. Pyrex is used as the dielectric material, so there is no gap change with the applied voltage.	Remember	1
5.	Why are electrostatic forces used to run micro motors rather than conventional electromagnetic forces. Explain why this actuation technique is not used in macrodevices and machines.	Understand	1
6.	A parallel capacitor is made of two square plates with dimensions L=W=1000μm. Determine the normal electrostatic force if the gap between these plate id d= 2 μm. These plates are separated by static air.	Remember	1

UNIT-II
ENGINEERING SCIENCE FOR MICROSYSTEM DESIGN AND FABRICATION

Part – A (Short Answer Questions)			
1	Explain about the concept of atomic numbers.	Remember	2
2	Explain the group number in period table.	Understand	2
3	Describe how ions are produced in an electrolysis process.	Remember	2
4	Describe the role of quantum physics in the design of MEMS and microsystems.	Understand	2
5	Explain the process of ionization.	Remember	2
6	What is the desirable level of electric resistivity to make a semiconductor electrically conducting.	Understand	2
7	Explain the process of doping of semiconductors.	Remember	2
8	Explain the process of electrochemistry.	Understand	2
9	Write a short note on plasma physics.	Remember	2
10	Explain the process of diffusion process.	Understand	2
Part - B (Long Answer Questions)			
1	Discuss the role of electrochemistry in micro fabrications write the merits and demerits.	Remember	2
2	Explain why atomic structure of matter is considered as a decisive factor in microsystem.	Understand	2
3	Explain the diffusion process and discuss how electric resistivity of silicon versus doses of dopant, develop a relationship between them.	Remember	2
4	Determine the optimum temperatures of silicon substrates for which doping of arsenic, phosphorous and boron are to be carried out by diffusion process.	Understand	2
5	Discuss how ions are produced in an electrolysis process. With a neat sketch.	Remember	2
6	Describe the role of quantum physics in the design of MEMS and micosystem.	Understand	1
7	Explain the capillary effect in microfluid flow and why conventional mechanical pumping cannot move fluid in small channels with capillary effect.	Remember	2
8	Determine the time required to dope boron into the silicon substrate so that the resistivity of the doped silicon at the depth of 2 μm is 10^{-3} Ω-cm.	Understand	2
9	What is the desirable level of electrical resistivity to make a semiconductor electrically conducting.	Understand	2

10	Explain the concept of plasma physics and discuss about plasma generator.	Understand	2
Part – C (Problem Solving and Critical Thinking)			
1	Phosphorus is to be doped into silicon wafer substrate by a diffusion process. The substrate is heated at 1000°C for 30 minutes in the presence of the dopant with the depth x = 0.075μm beneath the substrate surface.	Remember	2
2	Explain the plasma physics in detail and discuss how plasma generator works with a neat sketch.	Understand	2
3	Explain the concept of quantum physics, how vander waal's forces and critical atomic effect that can affect the engineering design of microsystem is the means of transportation of energy.	Remember	2
4	Determine the time required to dope born into the silicon substrate so that the resistivity of the doped silicon at the depth of 2 μm is 10^{-3} Ω-cm.	Understand	2
5	Describe the role of quantum physics in the design of MEMS and microsystem.	Remember	2
UNIT-III **ENGINEERING SCIENCE FOR MICROSYSTEMS DESIGN AND FABRICATION**			
Part - A (Short Answer Questions)			
1	Explain static bending of thin plates.	Remember	3
2	Explain about bending of circular plate with edge fixed.	Understand	3
3	Explain how mechanical vibration is the basis for microaccelerometer.	Remember	3
4	When does fracture mechanics occur.	Understand	3
5	Why thin-film mechanics is used in microfabrication.	Remember	3
6	Explain the FEM principle in MEMS and microsystem.	Understand	3
7	Summarize the applications of FEM in the field of MEMS	Remember	3
Part – B (Long Answer Questions)			
1.	Discuss the static bending theory applied to microsystem. Deduce the bending moment and bending stresses equations.	Remember	4
2.	A square silicon diaphragm with 532-μmedge length is subjected to the same pressure loading of p= 20 Mpa. The diaphragm has same thickness 13.887μm. All material properties are identical. Determine the maximum stress and deflection in the diaphragm under the applied pressure The silicon diaphragm has a Young's modulus E= 190,000 Mpa and Poisson's ratio =0.25.	Understand	4
3.	Determine the amplitude and frequency of a10-mg mass suspended from a spring with a spring constant k= 6x 10^{-5} N/m. The vibration of the mass is initiated by a small "pull" of the mass downwards by an amount δ_{st} =5 μm.	Remember	4
4.	Determine the amplitude and frequency of a10-mg mass suspended from a spring with a spring constant k= 6x 10^{-5} N/m. The vibration of the mass is initiated by a small "pull" of the mass downwards by an amount δ_{st} =5 μm. For a balanced mass spring system with spring constants K_1=K_2.	Understand	4
Part - C (Problem Solving and Critical Thinking Questions)			
1.	Determine the minimum thickness of the circular diaphragm of a micro pressure sensor made of silicon. The diaphragm has a diameter of 600μm and its edge is rigidly fixed to the silicon die. The diaphragm is designed to withstand a pressure of 20 Mpa without exceeding the plastic yield strength of 7000 Mpa. The silicon diaphragm has a Young's modulus E= 190,000 Mpa and Poisson's ratio =0.25.	Understand	4
2.	Discuss the static bending applied to microsystems.	Understand	4
UNIT IV **THERMO FLUID ENGINEERING AND MICROSYSTEM**			
Part - A (Short Answer Questions)			
1	Find the height of water, h, rising in small tube. The tube has a	Understand	4

	diameter of 1 mm.		
2.	Determine the pressure required to overcome the surface tension of water in a small tube of 0.5 mm inside diameter. Assume that the water is at 20°C.	Understand	4
3.	Explain how fluid mechanics is involved in macro and mesoscales.	Remember	4
4.	Explain concept of viscosity of fluids in mems.	Understand	4
5.	Summarize basic equations in continuum fluid dynamics.	Remember	4
6.	Explain the concept of incompressible fluid flow in microconduit.	Understand	4
7.	Determine the pressure required to overcome the surface tension of water in a small tube of 0.02 mm inside diameter. Assume that the water is at 10°C.	Remember	4
8.	Explain the overview of heat conduction in solids in a micrometer scale.	Understand	4
9.	Explain the design consideration for a micro system design.	Understand	4
10.	Explain the schematic design steps followed in silicon die for a micro pressure sensor	Understand	4
Part – B (Long Answer Questions)			
1	Derive equations for calculation of pressure drop in a micro conduit of circular cross section under laminar flow condition taking into account frictional and surface tension forces.	Remember	4
2.	How do you achieve linear and rotary motion required in micro motors using electrostatic forces. Explain with suitable line diagram.	Understand	4
3.	Discuss the functioning of micro pressure sensors with different means of signal transduction with their relative merits	Remember	4
4.	Estimate the thermal conductivity of silicon films of 0.2 μm thick.	Understand	4
5.	Estimate the flow rate of a nitrogen gas in a section of minute tube 30 nm in diameter x 50 nm long. A pressure difference of 0.5 Pa is applied to drive the flow. The flow is conducted at room temperature, 20°C.	Remember	4
6.	A noncompressible fluid is used in a microfluidic system. It flows through a tube with a diameter 1 mm at a rate of 1 microliter per minute. A reducer is used to connect this tube this tube to the micro conduits in the fluidic system. The reducer has an outer diameter of 20μm. Determine the velocity of the fluid at the inlet and outlet of the reducer.	Understand	4
Part - C (Problem Solving and Critical Thinking Questions)			
1.	Estimate the ratio of airflow in the section of small tube 10μm in diameter and 1cm in length. Assume that a pressure difference of 5 Pa is maintained between the inlet and outlet of the tube section. The airflow takes places at room temperature.	Remember	4
2.	Estimate the pressure drop in a minute stream of alchol through a section of a tapered tube 10 cm length. The inlet velocity is 600μ m/s. The mass density of alchol is 789.6 kg/m^3. The tube is inclined 30° from horizontal plane. Using Hagen-Poiseuille equation.	Understand	4
3	Summarize the steps involved in Design of a silicon die for pressure design for microsystem design with a neat sketch.	Remember	4
4	Explain ion implantation in detail with a neat sketch. List out merits.	Understand	4
5	List out and explain the design consideration of micro system.	Remember	4
UNIT V MATERIAL FOR MEMS, MICROSYSTEM AND THEIR FABRICATION			
Part - A (Short Answer Questions)			
1	Why silicon is used as a substrate material.	Remember	5

2	List out different materials used for MEMS.	Understand	5
3	Write short notes on substrate and wafers.	Remember	5
4	Explain about ion implantation.	Understand	5
5	Write short notes on bulk micro manufacturing.	Remember	5
6	Explain briefly LIGA process.	Understand	5
7	Explain the various mechanical properties of Galium arsenide.	Understand	5
8	Explain the various mechanical properties of Quartz.	Understand	5
Part – B (Long Answer Questions)			
1	Explain the key process involved in photolithography with necessary sketches.	Remember	5
2	Explain the various steps involved in the fabrication of a cantilever structure by surface machining.	Understand	5
3	Write a short note on the following: a. Isotropic etching. b. Dry etching. c. LIGA process.	Remember	5
4	Explain physical vapor deposition with a neat sketch.	Understand	5
5	Explain the various steps involved in the fabrication of bulk micro manufacturing.	Understand	5
Part - C (Problem Solving and Critical Thinking Questions)			
1	Explain different process steps involved in the fabrication of micro system. With a neat sketch.	Remember	5
2	What are the different material used in MEMS fabrication process and explain each one with their properties and application.	Understand	5
3	Discuss in detail the surface machining technique.	Remember	5
4	Explain the working of surface micro machining with neat sketches and compare with bulk micro machining.	Understand	5
5	Suggest atleast one of the properties and applications of the following MEMS materials silicon, silicon nitride, poly silicon, conductive polymer.	Remember	5

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