Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2015/2016

COURSE NAME	:	MEMS AND NEMS DESIGN
COURSE CODE	:	BED 40503
PROGRAMME	:	BACHELOR OF ELECTRONIC ENGINEERING WITH HONOURS
EXAMINATION DATE	:	DECEMBER 2015 / JANUARY 2016
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTION	:	ANSWER **ALL** QUESTIONS
		DO NOT BRING OUT THIS QUESTION BOOKLET FROM THE EXAMINATION HALL

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

PART A: ANSWER ALL QUESTIONS IN THE OMR FORM

(1 mark each)

Q1 In general, a microsystem consists of

(a) one component

(b) two components

(c) three components

(d) four components

Q2 Sacrificial layers in surface micromachining are used to

(a) strengthen the microstructure

(b) be part of the structure

(c) create necessary geometric voids in the microstructure

(d) create an ohmic contact

Q3 The sensor that is used in airbag deployment systems in automobiles is

(a) pressure sensor

(b) inertia sensor

(c) thermal sensor

(d) chemical sensor

Q4 Isotropic etching is hardly desirable in microfabrication because

(a) the etching rate is too low

(b) the cost is too high

(c) the etching profile is unknown

(d) the etching trajectories is hard to control

Q5 The most favoured orientation for micromachining of silicon wafers is the

(a) <100>

(b) <110>

(c) <111>

(d) <001>

Q6 The 'damper' in a 'mass-spring' vibration system serves the purpose of including the _____ effect on the system

(a) acceleration
(b) damping ratio
(c) damping factor
(d) deceleration

Q7 The analysis that attempts to determine several or all natural frequencies of a MEMS devices is called

(a) modal analysis
(b) model analysis
(c) nodal analysis
(d) shock analysis

Q8 Which of the following software is not related to MEMS CAD?

(a) SYNOPSYS
(b) ABAQUS
(c) ANSYS
(d) COMSOL

Q9 One major advantage of using CAD in MEMS design is the capability in

(a) graphics representation of the results
(b) animation of the devices
(c) obtaining fast results
(d) fabrication of the devices

Q10 The least expensive micromanufacturing technique is

(a) surface micromachining
(b) LIGA
(c) bulk micromachining
(d) SLIGA

Q11 The *aspect ratio* of a MEMS component is defined as the ratio of

(a) the dimension of the surface to that of the height
(b) the dimension in the height to that of the width
(c) the dimension in width to that of the length
(d) the dimension in the height to those of the surface

Q12 Application of mechanical deformation to a piezoelectric crystal can result in the production of

(a) electric resistance change
(b) electric current change
(c) electric inductance change
(d) electric voltage change

Q13 An effective way to shorten the MEMS design cycle is to

(a) use computer-aided design
(b) involve more engineers
(c) use a better design method
(d) use experimental method

Q14 *Process flow* is part of MEMS

(a) manufacturing
(b) testing
(c) production
(d) design

Q15 The principle advantage of using piezoresistors is

(a) small size
(b) low cost in production
(c) high sensitivity
(d) reliability

Q16 The advantage of using MEMS capacitive methods is

(a) high temperature application
(b) simplicity
(c) easy to implement
(d) all of the above

Q17 The resonant vibration of a MEMS device made of elastic materials occurs when the frequency of the excitation force _____ any of the natural frequencies of the device.

(a) approaches
(b) equals
(c) exceeds
(d) none of the above

Q18 A vibrating beam will have its natural frequency _____ with increased of longitudinal stress in tension

(a) increased
(b) decreased
(c) unchanged
(d) none of the above

Q19 As the gap between the electrodes grows smaller, the electrostatic forces for actuation

(a) grow weaker
(b) grow stronger
(c) do not change
(d) none of the above

Q20 When dealing with crystalline materials, it often becomes necessary to specify the fundamental of crystallography in atom such as

(a) point coordinate
(b) crystallographic direction
(c) planes of atoms
(d) all of the above

Q21 Polysilicon films are used in MEMS as

(a) dielectric material
(b) substrate material
(c) electrically conducting material
(d) resist material

Q22 Piezoelectric actuation works on the principle of

(a) electric heating
(b) mechanical-electrical conversion
(c) mechanical heating
(d) electrical-mechanical conversion

Q23 Which of the following statements is true regarding the stress parameter?

(a) Shear stress is the ratio of deformation to length

(b) Tensile stress as in the case of pushing along the rod

(c) Normal stress is the stress acts in a direction perpendicular to cross section

(d) Compressive stress as in the case of pulling along the rod

Q24 To achieve maximal sensitivity of a MEMS pressure sensor, one would maximize the

(a) stress

(b) strain

(c) shear modulus

(d) deformation in the diaphragm

Q25 A Wheatstone bridge is use to measure

(a) electric current

(b) electric voltage

(c) electric resistance

(d) electric inductance

Q26 Which of the following is a meshing type used in the CoventorWare ?

(a) Manhanttan bricks

(b) Mapped bricks

(c) surface

(d) all of the above

Q27 The principal theory used in MEMS accelerometer design is

(a) plate bending

(b) mechanical vibration

(c) strength of materials

(d) natural frequency

Q28 The deflection of the square membrane in MEMS pressure sensor is measured by

(a) mechanical means

(b) optical means

(c) magnetic means

(d) electrical means

Q29 The signal transduction methods for MEMS pressure sensors is

(a) piezoresistors

(b) capacitors

(c) resonant vibrating beams

(d) all of the above

Q30 The market value of microsystems in intimately related to

(a) volume demand

(b) special features

(c) performance of the products

(d) size of the products

PART B: ANSWER ALL QUESTIONS

Q31 (a) Define and differentiate these terminologies of microsensor and microactuator.

(4 marks)

(b) MEMS design process basically involves of modeling, simulation and experiment. Describe the importance of these processes.

(8 marks)

(c) **Figure Q31(c)** shows the suspension of an electrostatic comb-drive microactuator. Except for the darkly-shaded region marked as fixed, the rest of the structure is free to move above the substrate separated by a gap. Obtain the linear stifness, k of the spring structure in the y-direction for the microactuator. Given E = 150GPA, L = 200 μm, w = 5 μm and out-of-plane t = 3 μm.

(8 marks)

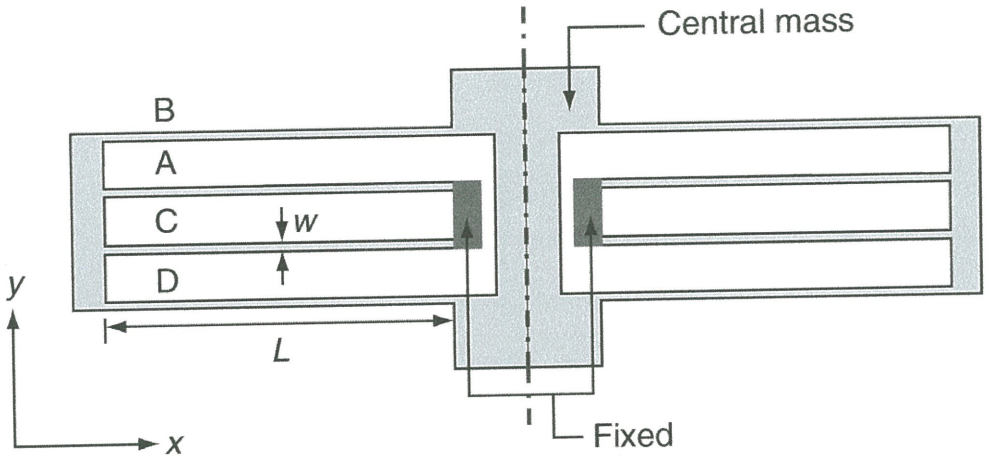

FIGURE Q31(c)

Q32 The understanding of MEMS system dynamics is crucial for predicting performance characteristics of sensors and actuators. The system can be simplified into a mass-spring-damper system subjected to time varying input, dynamic input and sinusoidal input signals.

(a) Categorize the damping factor, ξ and explain why it is an important parameter to determine the transient response of a MEMS system dynamics.

(10 marks)

(b) By the aid of a diagram, define the coutte flow damping between two plates, and compute the damping coefficent of an accelerometer in which the mass area is 20000 μm^2 with a gap of 1 μm air between the mass and substrate, and viscosity of 2×10^{-5} Pas.

(5 marks)

Q33 An elastic fixed-free microbeam is designed with length of 1200 μm, width 8 μm, thickness 4 μm and Young's modulus of 150 Gpa.

(a) Compute the magnitude of maximum stress for the loading force, F which gives out-of-plane movement to the microbeam.

(3 marks)

(b) A stiff plate of 5 mg is attached to the free-end of the microbeam. Calculate the natural frequency of the mass-spring system in Hz.

(3 marks)

(c) Another fixed-free microbeam with the same dimension is attached to the stiff plate as illustrated in **Figure Q33(c)**.

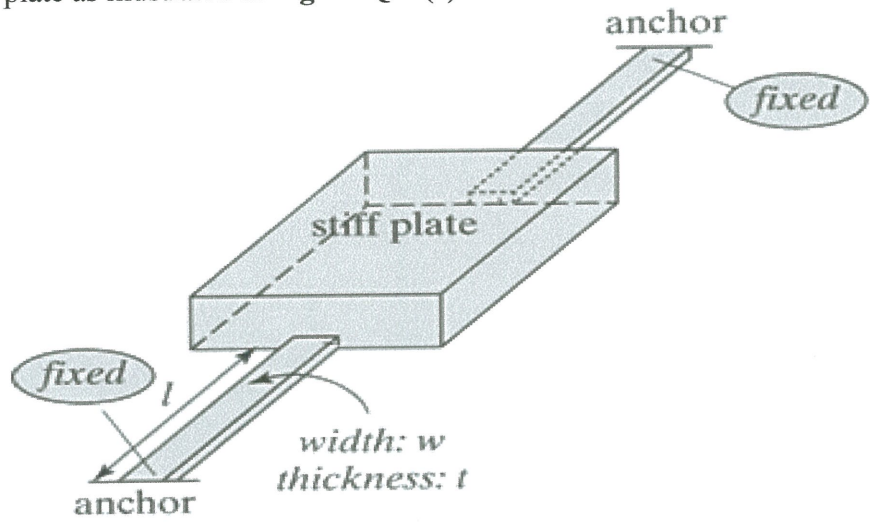

FIGURE Q33(c)

(i) Plot for g-force vs displacement for the mass-spring system for out-of-plane movement. Calculate for at least three points.

(6 marks)

(ii) Calculate the effective spring constant of the system for in-plane movement.

(3 marks)

Q34 A parallel plate capacitor is suspended by four cantilever beams, shown by **Figure Q34**. The lower electrode is connected to a voltage supply of value V = 2V, while the suspended plate is grounded. The gap between the lower electrode and the plate is g_0 = 1.0 μm.

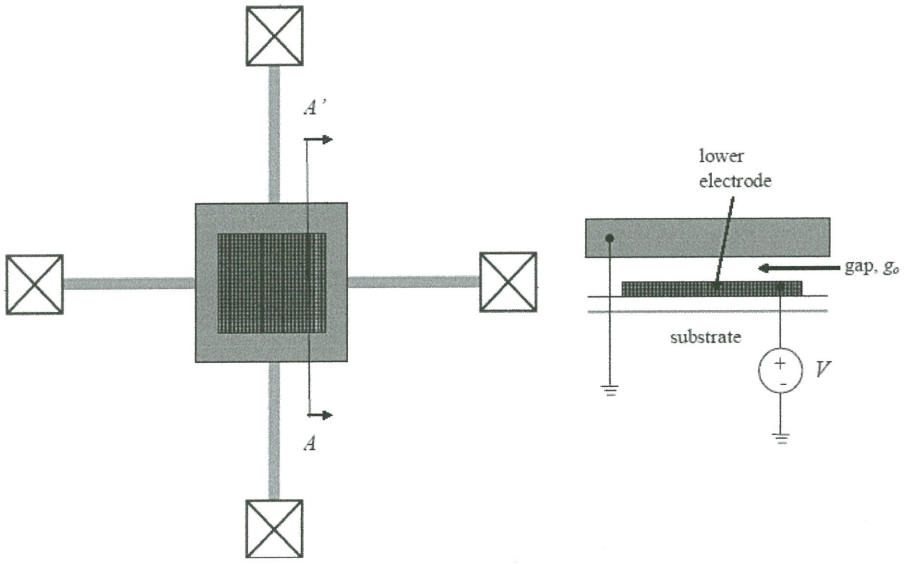

FIGURE Q34

(a) The condition of pull-in or snap-in will occur due to the electrostatic actuation. By using an appropiate diagram, explain on pull-in effect of this parallel-plate capacitive actuators.

(5 marks)

(b) Find the area A of the lower electrode in μm^2 such that the electrostatic force on the plate is 100 nN. Use $\varepsilon = 8.85 \times 10^{-12}$.

(5 marks)

(c) The four support beams are each 500 μm long, 0.3 μm thickness and 5 μm wide. If the area, A of the lower electrode is equal to 1x1 mm^2, predict the distance between the two plates under a bias voltage of 0.3 V.

(10 marks)

- END OF QUESTION –