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MICRO-ELECTRO MECHANICAL SYSTEM **Course Code : 316353**

Programme Name/s : **Mechatronics**
Programme Code : **MK**
Semester : **Sixth**
Course Title : **MICRO-ELECTRO MECHANICAL SYSTEM**
Course Code : **316353**

I. RATIONALE

This course equips mechatronics diploma holders with essential MEMS knowledge and skills for industrial applications. Students will learn to identify materials, components, and packaging, alongside understanding the mechanical and electrical principles behind MEMS. The course also covers standard microfabrication processes and hands-on practice for making measurements of physical quantities using microsensors and microactuators.

II. INDUSTRY / EMPLOYER EXPECTED OUTCOME

The aim of this course is to help the students to attain the following industry identified outcome through various teaching learning experiences: Integrate Micro-Electro-Mechanical Systems (MEMS) technology into various processes and applications.

III. COURSE LEVEL LEARNING OUTCOMES (COS)

Students will be able to achieve & demonstrate the following COs on completion of course based learning

- CO1 - Identify the types of materials and components and packing processes.
- CO2 - Specify the mechanical and electrical properties and principles implied in the given MEMS.
- CO3 - Explain standard microfabrication processes.
- CO4 - Measure physical quantity using relevant microsensors and microactuators.
- CO5 - Prepare a report on the use of MEMS for a given industrial application.

IV. TEACHING-LEARNING & ASSESSMENT SCHEME

Course Code	Course Title	Abbr	Course Category/s	Learning Scheme					Credits	Assessment Scheme												
				Actual Contact Hrs./Week			SLH	NLH		Paper Duration	Theory				Based on LL & TL				Based on SL		Total Marks
															Practical						
				CL	TL	LL					FA-TH	SA-TH	Total		FA-PR		SA-PR		SLA		
											Max	Max	Max	Min	Max	Min	Max	Min	Max	Min	
316353	MICRO-ELECTRO MECHANICAL SYSTEM	MMS	DSC	3	-	4	1	8	4	3	30	70	100	40	25	10	25#	10	25	10	175

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Total IKS Hrs for Sem. : 0 Hrs
Abbreviations: CL- ClassRoom Learning , TL- Tutorial Learning, LL-Laboratory Learning, SLH-Self Learning Hours, NLH-Notional Learning Hours, FA - Formative Assessment, SA -Summative assessment, IKS - Indian Knowledge System, SLA - Self Learning Assessment
Legends: @ Internal Assessment, # External Assessment, *# On Line Examination , @$ Internal Online Examination
Note :

1. FA-TH represents average of two class tests of 30 marks each conducted during the semester.
2. If candidate is not securing minimum passing marks in FA-PR of any course then the candidate shall be declared as "Detained" in that semester.
3. If candidate is not securing minimum passing marks in SLA of any course then the candidate shall be declared as fail and will have to repeat and resubmit SLA work.
4. Notional Learning hours for the semester are (CL+LL+TL+SL)hrs.* 15 Weeks
5. 1 credit is equivalent to 30 Notional hrs.
6. * Self learning hours shall not be reflected in the Time Table.
7. * Self learning includes micro project / assignment / other activities.

V. THEORY LEARNING OUTCOMES AND ALIGNED COURSE CONTENT

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
1	TLO 1.1 Explain the importance and characteristics of MEMS in Mechatronics. TLO 1.2 List different types of elements used in MEMS. TLO 1.3 List different materials used in MEMS. TLO 1.4 List different properties of MEMS materials. TLO 1.5 Differentiate BIOMEMS, RFMEMS, and MOEMS. TLO 1.6 List the applications of MEMS.	**Unit - I Introduction to MEMS** 1.1 Introduction to MEMS: Overview and definition of MEMS, new trends of MEMS used in engineering and science, microscale systems, and intrinsic characteristics of MEMS. 1.2 Advantages & Disadvantages of MEMS. 1.3 Block diagram of MEMS: micro sensors and micro actuators, microelectronics fabrication process. 1.4 Materials for MEMS: silicon, polymers, ceramics, metals. 1.5 Packaging and integration: glass encapsulation, MEMS process integration strategies. 1.6 Definitions of BIOMEMS, RFMEMS, and MOEMS. 1.7 Applications of MEMS.	Lecture Using Chalk-Board Video Demonstrations Presentations

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Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
2	TLO 2.1 Explain various electrical concepts implied by MEMS. TLO 2.2 Explain various mechanical concepts implied by MEMS. TLO 2.3 Calculate resistivity of the semiconductor	**Unit - II Electrical & Mechanical properties and principles of MEMS.** 2.1 Electrical concepts of materials (silicon, polymers, ceramics, metals) related to MEMS: semiconductor materials. 2.2 Calculate charge carrier concentration, conductivity, and resistivity of the semiconductor (only simple numerical based on above). 2.3 Mechanical concepts of materials related to MEMS: Crystal planes and orientation, Internal force analysis, mechanical properties of silicon and related thin films. 2.4 Surface preparation, microhardness testing of materials/metals, microscopic study of materials for microstructure and hardness, Effect of surface finish on MEMS fabrication.	Lecture Using Chalk-Board Video Demonstrations Presentations
3	TLO 3.1 Define micromachining. TLO 3.2 Explain surface micromachining processes. TLO 3.3 Explain micromachining processes. TLO 3.4 Explain bulk micromachining. TLO 3.5 Explain etching processes. TLO 3.6 Explain thin film deposition methods.	**Unit - III MEMS fabrication processes** 3.1 Micromachining – Definition, needs types. 3.2 Surface micromachining: Sacrificial layer processes – steps, MEMS accelerometer, humidity microsensor, micromotors advantages and disadvantages, examples. 3.3 Bulk micromachining: – Advantages and disadvantages, examples (micro nozzle). 3.4 Etching: dry etching, plasma etching, wet etching - principle and processes. 3.5 High Aspect-Ratio Processes: LIGA process, Deep Reactive Ion Etching (DRIE). 3.6 Thin film deposition: Chemical Vapor Deposition (CVD), Physical Vapor Deposition (PVD), evaporation, and sputtering.	Lecture Using Chalk-Board Video Demonstrations Presentations
4	TLO 4.1 Explain the construction of different Micro-sensors. TLO 4.2 Explain the operation of different Micro-sensors. TLO 4.3 Explain the construction of different Micro-actuators. TLO 4.4 Explain the operation of different Micro-actuators.	**Unit - IV Micro sensors and Micro actuators.** 4.1 Electrostatic sensor, the principle of parallel plate capacitors and its applications. 4.2 Thermal sensor: Fundamentals of thermal transfer, thermal bimorph principle. 4.3 Piezoresistive sensor: Materials, piezo resistivity, Piezoelectric sensor: Materials and Piezoelectric effect. 4.4 Actuation using thermal forces, Actuation using shape memory alloys. 4.5 Actuation using piezoelectric crystals. 4.6 Electrostatic actuation. 4.7 Actuation using electrostatic forces (Comb drive actuators), micromotors and micropumps.	Lecture Using Chalk-Board Video Demonstrations Presentations

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Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
5	TLO 5.1 Collect the specification, data sheets, and block diagram of given MEMS applications.	**Unit - V Applications of MEMS.** 5.1 Applications of MEMS - (a) Automobile deployment - Airbag, navigation, tyre pressure, (b) Medical field – Microneedle, blood pressure sensor, micropump,(c) Manufacturing industries – Pressure, humidity, level, temperature, (d) Consumer products – Washing machines, printers.	Lecture Using Chalk-Board Video Demonstrations Presentations

VI. LABORATORY LEARNING OUTCOME AND ALIGNED PRACTICAL / TUTORIAL EXPERIENCES.

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 1.1 Identify the different MEME devices.	1	*Understand the different MEMS devices.	2	CO1
LLO 2.1 Microscopic study of specimen material	2	*Microscopic analysis of Specimen materials.	2	CO2
LLO 3.1 Check the resistivity of given materials. LLO 3.2 Suggest suitable materials for the given MEMS application.	3	*Measure the electrical resistivity of given MEMS materials.	2	CO2
LLO 4.1 Check the Ra value of given materials. LLO 4.2 Suggest suitable materials for the given MEMS application.	4	*Microscopic analysis for surface finish of different materials.	2	CO2
LLO 5.1 Study of surface finish using a microscope.	5	*Microscopic analysis for surface finish of different materials.	2	CO2
LLO 6.1 Test the surface hardness of MEMS material before application.	6	*Microhardness testing of MEMS materials/metals before application.	2	CO2
LLO 7.1 Test the surface hardness of MEMS material after application	7	*Microhardness testing of MEMS materials/metals after application.	2	CO2
LLO 8.1 Select the microsensors for pressure measurement. LLO 8.2 Measure pressure using microsensors.	8	Pressure measurement using microsensors.	4	CO3
LLO 9.1 Select the microsensors for speed measurement. LLO 9.2 Measure speed using microsensors.	9	Speed measurement using microsensors.	4	CO3
LLO 10.1 Select the microsensors for temperature measurement. LLO 10.2 Measure temperature using microsensors.	10	*Temperature measurement using microsensors.	4	CO3

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Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 11.1 Select the microactuator for Mechanical motion measurement. LLO 11.2 Measure mechanical motion using a microactuator.	11	*Mechanical motion measurement. using microactuator – piezoelectric.	4	CO3
LLO 12.1 Select the microactuator for mechanical motion measurement. LLO 12.2 Measure mechanical motion using a microactuator.	12	Mechanical motion measurement. using microactuator – magnetic.	4	CO3
LLO 13.1 Select the microactuator for Mechanical motion measurement. LLO 13.2 Measure Mechanical motion using a microactuator.	13	Mechanical motion measurement. using microactuator – electrostatics.	4	CO3
LLO 14.1 Observe the operation of Surface micromachining. LLO 14.2 Interpret the fabrication process.	14	*Demonstration of surface micromachining. Part - I	2	CO4
LLO 15.1 Observe the operation of Surface micromachining. LLO 15.2 Interpret the fabrication process.	15	Demonstration of surface micromachining. Part - II	2	CO4
LLO 16.1 Observe the operation of bulk micromachining. LLO 16.2 Interpret the fabrication process.	16	Demonstration of bulk micromachining. Part - I	2	CO4
LLO 17.1 Observe the operation of bulk micromachining. LLO 17.2 Interpret the fabrication process.	17	Demonstration of bulk micromachining. Part - II	2	CO4
LLO 18.1 Search information on the use of MEMS in automobile industries by market survey. LLO 18.2 Prepare a report on the same	18	*Case study on the use of MEMS in Automobile industries. (Specifications, data sheets, block diagram, etc.)- Airbag, navigation, tyre pressure (Any one).	4	CO5
LLO 19.1 Search information on the use of MEMS in the medical field by market survey. LLO 19.2 Prepare a report on the same.	19	*Case study on the use of MEMS in the Medical field. (Specifications, data sheets, block diagram, etc.) Medical field – Microneedle, blood pressure sensor, micropump (Any one).	4	CO5
LLO 20.1 Search information on the use of MEMS in manufacturing industries by market survey. LLO 20.2 Prepare a report on the same.	20	Case study on the use of MEMS in Manufacturing industries. (Specifications, data sheets, block diagram, etc.) - Pressure, humidity, level, temperature (Any one).	4	CO5

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Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 21.1 Search information on the use of MEMS in consumer products by market survey. LLO 21.2 Prepare a report on the same.	21	Case study on the use of MEMS in Consumer products. (Specifications, data sheets, block diagram, etc.)- Washing machines, printers (Any one).	4	CO5

Note : Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

VII. SUGGESTED MICRO PROJECT / ASSIGNMENT/ ACTIVITIES FOR SPECIFIC LEARNING / SKILLS DEVELOPMENT (SELF LEARNING)

Assignment

- Any other relevant assignment given by subject teacher.
- Prepare a detailed report on MEMS application.
- Numerical on the resistivity and conductivity of MEMS materials.
- Collect the information of various microactuators and microsensors used in industries
- Compare the parameters of different semiconductors used in MEMS.
- Collect information about materials used for MEMS with specifications and compare them.

Note :

- Above is just a suggestive list of microprojects and assignments; faculty must prepare their own bank of microprojects, assignments, and activities in a similar way.
- The faculty must allocate judicial mix of tasks, considering the weaknesses and / strengths of the student in acquiring the desired skills.
- If a microproject is assigned, it is expected to be completed as a group activity.
- SLA marks shall be awarded as per the continuous assessment record.
- For courses with no SLA component the list of suggestive microprojects / assignments/ activities are optional, faculty may encourage students to perform these tasks for enhanced learning experiences.
- If the course does not have associated SLA component, above suggestive listings is applicable to Tutorials and maybe considered for FA-PR evaluations.

VIII. LABORATORY EQUIPMENT / INSTRUMENTS / TOOLS / SOFTWARE REQUIRED

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number
1	Various microsensors and microactuators.	1,8,9,10,11,12,13
2	Experimental setup of temperature measurement using related microsensors.	10
3	Experimental setup of a piezoelectric microactuator for mechanical motion measurement.	11
4	Experimental setup of a magnetic microactuator for mechanical motion measurement.	12
5	Experimental setup of an electrostatic microactuator for mechanical motion measurement.	13

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Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number
6	Experimental setup of surface roughness tester for surface evaluation.	2,4,5,6,7
7	Experimental setup to measure the resistivity of the given materials.	3
8	Experimental setup of surface hardness testing using microhardness tester.	5
9	Microscope for microstructure analysis.	6
10	Experimental setup of pressure measurement using related microsensors.	8
11	Experimental setup of speed measurement using related microsensors.	9

IX. SUGGESTED WEIGHTAGE TO LEARNING EFFORTS & ASSESSMENT PURPOSE (Specification Table)

Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
1	I	Introduction to MEMS	CO1	6	2	4	4	10
2	II	Electrical & Mechanical properties and principles of MEMS.	CO2	10	2	6	6	14
3	III	MEMS fabrication processes	CO3	12	4	6	8	18
4	IV	Micro sensors and Micro actuators.	CO4	12	4	6	8	18
5	V	Applications of MEMS.	CO5	5	2	2	6	10
Grand Total				**45**	**14**	**24**	**32**	**70**

X. ASSESSMENT METHODOLOGIES/TOOLS

Formative assessment (Assessment for Learning)

- Formative assessment (Assessment for Learning)
- Two-unit tests of 30 marks and average of two-unit tests.
- For laboratory learning 25 Marks
- For Self-Learning 25 Marks

Summative Assessment (Assessment of Learning)

- End semester assessment of 25 marks for laboratory learning.
- End semester assessment of 70 marks.

XI. SUGGESTED COS - POS MATRIX FORM

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)		
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2	PSO-3
CO1	3	2	2	1	2	1	2			

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CO2	3	1	2	2	2	2	3			
CO3	3	2	2	2	2	2	1			
CO4	3	3	3	3	2	2	2			
CO5	3	3	2	2	2	2	3			

Legends :- High:03, Medium:02,Low:01, No Mapping: -
*PSOs are to be formulated at institute level

XII. SUGGESTED LEARNING MATERIALS / BOOKS

Sr.No	Author	Title	Publisher with ISBN Number
1	Dilip kumar Bhattacharya , Brajesh Kumar Kaushik	Microelectromechanical Systems	CENGAGE Publication, New Delhi,2014, ISBN-10. 9788131525883
2	Tai Ran Hsu	MEMS & Micro systems Design and Manufacture	TMH, New Delhi, 2002, ISBN-10. 007048709X
3	Chang Liu	Foundation of MEMS	Pearson education Inc., 2006 ISBN-10. 0132497360
4	Stephen D Senturia	Microsystem design	Springer Publication, 2000. ISBN-10. 0792372468
5	Hans H. Gatzen, Volker Saile, JurgLeuthold	Micro and Nano Fabrication: Tools and Processes	Springer Publication, 2015. ISBN-13. 978-3662508268
6	Marc J. Madou	Fundamentals of Microfabrication and Nanotechnology	3rd Edition, 2011, CRC Press. ISBN 9780849331800
7	M.D. Singh, J.G. Joshi	Mechatronics	Prentice Learning Pvt. Limited New Delhi, 2006. ISBN 9788120329867

XIII . LEARNING WEBSITES & PORTALS

Sr.No	Link / Portal	Description
1	https://www.youtube.com/watch?v=O5qTDrZIPeI	Fundamentals of MEMS
2	https://www.youtube.com/watch?v=GaGQrP0D6Zw	Materials for MEMS
3	https://www.youtube.com/watch?v=m8kXG5ZERYI	Applications of MEMS
4	https://www.youtube.com/watch?v=jQF4_hO_2qw	Types of MEMS, MEMS process integrations
5	https://www.youtube.com/watch?v=1qDfxPW02Pw	Calculation of charge carrier concentration
6	https://www.youtube.com/watch?v=STs55uv389Y	Flexural beam bending
7	https://www.youtube.com/watch?v=lHXZkamSMWw	Surface micromachining, Bulk micromachining
8	https://www.youtube.com/watch?v=9UOiSxFB6aA	Electrostatics sensors
9	https://www.youtube.com/watch?v=_iMHP-gaABk	Piezo electric actuators
10	https://www.mdpi.com/2072-666X/13/5/654	Different case studies in MEMS

Note :

- Teachers are requested to check the creative common license status/financial implications of the suggested online educational resources before use by the students