University of Sana'a
Faculty of Engineering
Department: Biomedical Engineering
Title of the Program: Biomedical Engineering

Course Specification of Micro Electro-Mechanical Systems

Course Code (BE328)

I. Course Identification and General Information:

1	**Course Title:**	Micro Electro-Mechanical Systems				
2	**Course Code & Number:**	BE328				
3	**Credit hours:**	C.H				TOTAL
		Th.	Seminar	Pr	Tr.	
		2	--	2	--	3
4	**Study level/ semester at which this course is offered:**	4th Level / 2nd Semester				
5	**Pre –requisite (if any):**	BE224, BE244, BE243				
6	**Co –requisite (if any):**	None				
7	**Program (s) in which the course is offered:**	Biomedical Engineering Program				
8	**Language of teaching the course:**	English				
9	**Location of Teaching the Course:**	Faculty of Engineering				
10	**Prepared by:**	Associate Prof. Dr. Khalil Al-Hatab				
11	**Reviewed by:**	Dr. ----				
12	**Date of Approval:**					

II. Course Description:

The Microelectromechanical systems (**MEMS**) course exposes students to the foundations of microsystems and process technology involved in the design, simulation and microfabrication of MEMS devices. Major subjects covered in the course include: engineering mechanics, scaling laws for miniaturization, microfabrication techniques, material selection, microsystems design and microsystems packaging design. Through the class lectures, examples and group design projects drawn from real-word BioMEMS applications, students should have a clear idea about MEMSs, building blocks, micro-fabrication and design process of MEMSs. Modeling and simulation in the design process of MEMS is emphasized using appropriate CAD packages.

III. Course Intended learning outcomes (CILOs) of the course (maximum 8CILOs)		Referenced PILOs (Only write code number of referenced Program Intended learning outcomes)
Knowledge and Understanding: Upon successful completion of the undergraduate Biomedical Engineering Program, the graduates will be able to:		
a1	Understand the working principles of various sensors and actuators and introduce the different materials and fabrication techniques used for MEMS devices.	A2 Clarify the design principles and techniques and the engineering materials characteristics and how these are relevant to the developments and technologies in a biomedical systems context.
a2	Familiarize with concept, formula and aspects beyond materials, mechanical and electrical disciplines in context to MEMS and BioMEMS design, fabrication and applications.	A4 Understand and give examples of design methods, knowledge tools, analytical skills, measurement techniques and methodologies for innovative and creative engineering solutions applied to healthcare problems and quality of life issues.
B. Cognitive/ Intellectual Skills: Upon successful completion of the undergraduate Biomedical Engineering Program, the graduates will be able to:		
b1	Apply mathematics methods, engineering concepts, life-science basis, and modern tools professionally in modelling, analyzing, designing, and constructing of MEMS devices.	B1 Apply engineering principles; basic of life-science; mathematical theories; and modern tools professionally in modelling, analyzing, designing, and constructing physical digital systems; devices and/or processes relevant to Biomedical Engineering fields.
b2	Identify the optimal microfabrication and packaging techniques and the suitable scaling-laws for microdevices and systems.	B2 Identify, formulate and solve the complex problems related to the Biomedical Engineering fields in a creative and innovative manner by using a systematic and

		analytical thinking methods.
b3	Design MEMS devices within realistic constraints of social, political, ethical, health and safety and manufacturability.	B3 Design the biomedical systems or processes within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.
C. Professional and Practical Skills: Upon successful completion of the undergraduate Biomedical Engineering Program, the graduates will be able to:		
c1	Integrate the relevant knowledge of mathematics, life science, and engineering to the MEMS design and challenges.	C1 Apply integrally knowledge of mathematics, life science, IT, design, business context and engineering practice to solve problems and to design systems/processes relevant to Biomedical Engineering.
c2	Use appropriate practical aspects, MEMS software, materials, fabrication and packaging techniques to handle mechanical systems engineering design of microscale devices.	C3 Use computational facilities and techniques, measuring instruments, workshops and laboratory equipment to design and conduct experiments, collect, analyse and interpret data and present results in the biomedical systems practice.
D. Transferable Skills: Upon successful completion of the undergraduate Biomedical Engineering Program, the graduates will be able to:		
d1	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	D1 Lead and motivate individuals, show capability to work in stressful environments and within constraints, collaborate effectively within multidisciplinary team.
d2	Writing effective reports and design documentation and make effective presentations.	D5 Demonstrate efficient IT capabilities and communicate effectively both orally and in writing technical reports.

(A) Alignment Course Intended Learning Outcomes of Knowledge and Understanding to Teaching Strategies and Assessment Strategies:

Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies

a1. Understand the working principles of various sensors and actuators and introduce the different materials and fabrication techniques used for MEMS devices.	• Interactive lectures & examples, • Presentation/seminar, • Interactive class discussions, • Case studies, • Exercises and home works, • Directed self- study, • Problem based learning, • Mini/major project.	• Written tests (mid and final terms and quizzes), • Lab\Project report • Practical lab performance assessment, • Coursework activities assessment, • Home works and assignments, • Presentations.
a2. Familiarize with concept, formula and aspects beyond materials, mechanical and electrical disciplines in context to MEMS and BioMEMS design, fabrication and applications.	• Interactive lectures & examples, • Presentation/seminar, • Interactive class discussions, • Case studies, • Exercises and home works, • Directed self- study, • Problem based learning, • Mini/major project.	• Written tests (mid and final terms and quizzes), • Lab\Project report • Practical lab performance assessment, • Coursework activities assessment, • Home works and assignments, • Presentations.

(B) Alignment Course Intended Learning Outcomes of Intellectual Skills to Teaching Strategies and Assessment Strategies:		
Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
b1. Apply the mathematical methods, engineering concepts, life-science basis, and modern tools professionally in modelling, analyzing, designing,	• Interactive lectures & examples, • Presentation/seminar, • Interactive class	• Written tests (mid and final terms and quizzes), • Lab\Project report • Practical lab performance

and constructing of MEMS devices.	discussions, • Case studies, • Exercises and home works, • Directed self- study, • Problem based learning, • Mini/major project.	assessment, • Coursework activities assessment, • Home works and assignments, • Presentations.
b2. Identify the optimal microfabrication and packaging techniques and the suitable scaling-laws for microdevices and systems.	• Interactive lectures & examples, • Presentation/seminar, • Interactive class discussions, • Case studies, • Exercises and home works, • Directed self- study, • Problem based learning, • Mini/major project.	• Written tests (mid and final terms and quizzes), • Lab\Project report • Practical lab performance assessment, • Coursework activities assessment, • Home works and assignments, • Presentations.
b3. Design MEMS devices within realistic constraints of social, political, ethical, health and safety and manufacturability.	• Interactive lectures & examples, • Presentation/seminar, • Interactive class discussions, • Case studies, • Exercises and home works, • Directed self- study, • Problem based learning, • Mini/major project.	• Written tests (mid and final terms and quizzes), • Lab\Project report • Practical lab performance assessment, • Coursework activities assessment, • Home works and assignments, • Presentations.

(C) Alignment Course Intended Learning Outcomes of Professional and Practical Skills to Teaching Strategies and Assessment Strategies:		
Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
c1. Integrate the relevant knowledge	• Interactive lectures &	• Written tests (mid and final

of mathematics, life science, and engineering to the MEMS design and challenges.	examples, • Case studies, • Exercises and home works, • Computer laboratory-based sessions, • Directed self- study, • Problem based learning, • Team work (cooperative learning), • Mini/major project.	terms and quizzes), • Lab\Project report • Practical lab performance assessment, • Coursework activities assessment, • Home works and assignments, • Presentations.
c2. Use appropriate practical aspects, MEMS software, materials, fabrication and packaging techniques to handle mechanical systems engineering design of microscale devices.	• Interactive lectures & examples, • Interactive class discussions, • Case studies, • Exercises and home works, • Computer laboratory-based sessions, • Directed self- study, • Problem based learning, • Team work (cooperative learning), • Mini/major project.	• Written tests (mid and final terms and quizzes), • Lab\Project report • Practical lab performance assessment, • Coursework activities assessment, • Home works and assignments, • Presentations.

(D) Alignment Course Intended Learning Outcomes of Transferable Skills to Teaching Strategies and Assessment Strategies:

Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
d1. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	• Case studies, • Directed self- study, • Problem based learning, • Team work (cooperative	• Lab\Project report • Practical lab performance assessment, • Coursework activities

	learning), • Mini/major project.	assessment, • Presentations.
d2. Writing effective reports and make effective presentations.	• Case studies, • Directed self- study, • Problem based learning, • Team work (cooperative learning), • Mini/major project.	• Lab\Project report • Practical lab performance assessment, • Coursework activities assessment, • Presentations.

IV. Course Content:

A – Theoretical Aspect:

Order	Units/Topics List	Learning Outcomes	Sub Topics List	Number of Weeks	contact hours
1	**Overview of MEMS and Microsystems**	**a1,a2,b1, b3,c1**	– Overview of Course – The History of MEMS Development – MEMS and Microsystems – The Intrinsic Characteristics of MEMS – MEMS & Microsystem Products – Evolution of Microfabrication – Microsystems &Microelectronics – The Multidisciplinary Nature of Microsystem Design and Manufacture – Applications of Microsystems	**1**	**2**
2	**Working Principles of Microsystems**	**a1,a2,b1, b3,c1**	– Introduction – Electrostatic Sensing and Actuation – Thermal Sensing and Actuation – Piezoelectric Sensing and Actuation – Magnetic Actuation	**2**	**4**

3	**Engineering Science for Microsystem Design and Fabrication**	**a1,a2,b1, b3,c1**	– Introduction – Atomic Structure of Matter – Ions and Ionization – Molecular Theory of Matter – Doping of Semiconductors – The Diffusion Process – Plasma Physics – Electrochemistry – Electrolysis	**1**	**2**
4	**Engineering Mechanics for Microsystems Design**	**a1,a2,b1, b3,c1**	– Static Bending of Thin plate – Mechanical Vibration – Thermomechanics – Thin-Film Mechanics – Overview of Finite Element Stress Analysis	**1**	**2**
5	**Thermofluid Engineering and Microsystems Design**	**a1,a2,b1, b3,c1**	– Overview of the Basics of Fluid Mechanics in Macro- and Mesoscale – Laminar Fluid Flow in Circular Conduits – Incompressible Fluid Flow	**1**	**2**
6	**Scaling Laws in Miniaturization**	**a1,a2,b1, b2, b3,c1**	– Introduction to Scaling – Scaling in Geometry – Scaling in Rigid-Body Dynamics – Scaling in Electrostatic Forces – Scaling in Electromagnetic Forces – Scaling in Electricity – Scaling in Fluid Mechanics – Scaling in Heat Transfer	**1**	**2**
7	**Mid-Term Theoretical Exam**	**a1,a2,b1, b2, b3,c1**	– All Preceding Lectures	**1**	**2**
8	**Materials for MEMS and Microsystems**	**a1,a2,b1, b3,c1**	– Substrates and Wafer – Active Substrate Materials – Silicon as a Substrate Material – Silicon Compound – Silicon Piezoresistors	**1**	**2**

			– Polymers		
9	**Microsystems Fabrication Processes**	**a1,a2,b1, b2, b3,c1**	– Introduction – Photolithography – Ion Implantation – Diffusion – Oxidation – Chemical Vapor Deposition – Physical Vapor Deposition-Sputtering – Deposition by Epitaxy – Etching	**2**	**4**
10	**Overview of Micromanufacturing**	**a1,a2,b1, b2, b3,c1**	– Bulk Micromanufacturing – Surface Micromachining – The LIGA Process	**2**	**4**
11	**Microsystems Design**	**a1,a2,b1, b2, b3,c1, c2**	– Design Considerations – Process Design – Mechanical Design – Design of Silicon Die for a Micropressure Sensor – Design of a Microfluidic Network Systems – Computer-Aided Design (CAD)	**1**	**2**
12	**Microsystem Packaging**	**a1,a2,b1, b2, b3,c1**	– Overview of Mechanical Packaging of Microelectronics – Microsystem Packaging – Interfaces in Microsystem Packaging – Essential Packaging Technologies – Three-Dimensional Packaging – Assembly of Microsystems – Selection of Packaging Materials – Reliability in MEMS Packaging – Testing for Reliability	**1**	**2**
13	**Final Theoretical Exam**	**a1,a2,b1, b2, b3,c1**	– All Preceding Lectures	**1**	**2**
Number of Weeks /and Units Per Semester				**16**	**32**

B - Practical Aspect: (if any)				
Order	Tasks/ Experiments	Number of Weeks	contact hours	Learning Outcomes
1	**Lab 1:** Introduction to MEMS Pro (L-Edit)	1	2	b2, b3, c1, c2, d1, d2
2	**Lab 2:** Design of MEMS 3D Model Using L-Edit	1	2	b2, b3, c1, c2, d1, d2
3	**Lab 3:** Introduction to MEMS Pro (S-Edit)	1	2	b2, b3, c1, c2, d1, d2
4	**Lab 4:** Design of Piezoresistive Sensor using S-Edit	1	2	b2, b3, c1, c2, d1, d2
5	**BioMEMS Case Study-1**	1	2	a1,a2, b1, b2, b3, c1, c2, d1, d2
6	**BioMEMS Case Study-2**	1	2	a1,a2, b1, b2, b3, c1, c2, d1, d2
7	**Mid-Term Practical Exam**	1	2	b2, b3, c1, c2, d1, d2
8	**Lab 5 :** Introduction to Samcef Field	1	2	b2, b3, c1, c2, d1, d2
9	**Lab 6:** Analysis of RF Switch using Samcef Field	1	2	b2, b3, c1, c2, d1, d2
10	**Mini Project**	1	2	b2, b3, c1, c2, d1, d2
11	**Lab 7:** Analysis of Thermal Actuator using Samcef Field	1	2	b2, b3, c1, c2, d1, d2
12	**BioMEMS Case Study- 3**	1	2	a1,a2, b1, b2, b3, c1, c2, d1, d2
13	**BioMEMS Case Study-4**	1	2	a1,a2, b1, b2, b3, c1, c2, d1, d2
14	**Mini Project (continue)**	1	2	a1,a2, b1, b2, b3, c1,

				c2, d1, d2
15	Final Practical Exam & Mini Project Revised	1	2	a1,a2, b1, b2, b3, c1, c2, d1, d2
Number of Weeks /and Units Per Semester		15	30	

C. Tutorial Aspect:				
No.	Tutorial	Number of Weeks	Contact Hours	Learning Outcomes (CILOs)
1	None	----	----	----
Number of Weeks /and Units Per Semester		0	0	

V. Teaching Strategies of the Course:

- Interactive lectures & examples,
- Presentation/seminar,
- Interactive class discussions,
- Case studies,
- Computer laboratory-based sessions,
- Exercises and home works,
- Directed self- study,
- Problem based learning,
- Team work (cooperative learning),
- Mini/major project.

VI. Assessment Methods of the Course:

- Written tests (mid and final terms and quizzes),
- Lab\Project report

VI. Assessment Methods of the Course:

- Practical lab performance assessment,
- Coursework activities assessment,
- Home works and assignments,
- Presentations.

VII. Assignments:

No	Assignments	Aligned CILOs(symbols)	Week Due	Mark
1	Homework (10 sets)	**a1,a2,b1, b2, b3,c1**	3 to 13	10
Total				10

VIII. Schedule of Assessment Tasks for Students During the Semester:

No.	Assessment Method	Week Due	Mark	Proportion of Final Assessment	Aligned Course Learning Outcomes
1	Assignments	3-13	10	6.7%	**a1,a2,b1, b2, b3,c1**
2	Quizzes	6, 12	10	6.7%	**a1,a2,b1, b2, b3,c1**
3	Midterm Theoretical Exam	8	20	12.3%	**a1,a2,b1, b2, b3,c1**
4	Midterm Practical Exam	7	20	12.3%	**b2, b3, c1, c2, d1, d2**
5	Final Practical Exam & a course-project evaluation	15	30	20%	**a1,a2, b1, b2, b3, c1, c2, d1, d2**
6	Final Theoretical Exam	16	60	40%	**a1,a2,b1, b2, b3,c1**
Total			150	100%	

IX. Learning Resources:

1- Required Textbook(s) (maximum two).

1. Hsu, Tai-Ran, 2008, **MEMS and Microsystems Design, Manufacture, and Nanoscale Engineering**, 2nd Edition,, Hoboken, New Jersey, John Wiley & Sons, Inc.
2. Chang Liu, 2012, **Foundations of MEMS**, 2nd Edition, New Jersey, USA, Pearson Education Inc.

2- Essential References.

1. Stephen D Senturia,2002, **Microsystem Design**, New York, Kluwer Academic Publishers.
2. Werner Karl Schomburg, 2015, **Introduction to Microsystem Design**, 2nd Edition, RWTH Aachen University, Springer.
3. Thomas M.Adams and Richard A.Layton, 2012, **Introduction MEMS, Fabrication and Application**, Springer.
4. Wanjun Wang, Stephen A.Soper, 2007, **BioMEMS: Technologies and Applications**, New York, CRC Press.
5. Julian w. Gardner, Vijay K. Varadan, Osama O. Awadelkarim, 2002, **Micro Sensors MEMS and Smart Devices**, USA, John Wiley and Son.
6. Marc J. Madou, 2002, **Fundamentals of Microfabrication: the Science of Miniaturization**, USA, CRC Press.
7. Nadim Maluf, Kirt Williams. 2004, **An introduction to Microelectromechanical Systems Engineering**, 2nd Edition, Artech House Inc.
8. Nitaigour Premchand Mahalik, 2007, **MEMS**, New Delhi, Tata McGraw Hill Publishing Company.

3- Electronic Materials and Web Sites *etc.*

Websites:

1. http://www.people.cornell.edu/pages/akt1/memsmain.html
2. http://www.mosis.com
3. http://www.memsrus.com/CIMSmain2ie.html
4. http://www.d arpa.mil
5. http://mems.isi.edu

Journals:

1. Journals with a primary focus in MEMS areas:
2. Journal of Microelectromechanical Systems (JMEMS)
3. Journal of Micromechanics and Microengineering

	4. Microsystem Technologies: Sensors, Actuators, Systems Integration 5. Journal of Smart Materials and Structures 6. Sensors and Actuators A (Physical) 7. Sensors and Actuators B (Chemical) 8. Sensors and Actuators C (Material) 9. IEEE Electron Device Letters 10. Journal of Electrochemical Society 11. Journal of Vacuum Society 12. Proceedings of SPIE – International Society for Optical Engineering 13. Journal of Analytical Chemistry

X. Course Policies:

1	**Class Attendance:** A student should attend not less than 75 % of total hours of the subject; otherwise he/she will not be able to take the exam and will be considered as exam failure. If the student is absent due to illness, he/she should bring a proof statement from university Clinic. If the absent is more than 25% of a course total contact hours, student will be required to retake the entire course again.
2	**Tardy:** For late in attending the class, the student will be initially notified. If he repeated lateness in attending class, he/she will be considered as absent.
3	**Exam Attendance/Punctuality:** A student should attend the exam on time. He/she is permitted to attend an exam half one hour from exam beginning, after that he/she will not be permitted to take the exam and he/she will be considered as absent in exam
4	**Assignments & Projects**: In general one assignment is given to the students after each chapter; the student has to submit all the assignments for checking on time, mostly one week after given the assignment.
5	**Cheating**: For cheating in exam, a student will be considered as fail. In case the cheating is repeated three

	times during his/her study the student will be disengaged from the Faculty.
6	**Plagiarism**: Plagiarism is the attending of a student the exam of a course instead of another student. If the examination committee proofed a plagiarism of a student, he/she will be disengaged from the Faculty. The final disengagement of the student from the Faculty should be confirmed from the Student Council Affair of the university or according to the university roles.
7	**Other policies**: - Mobile phones are not allowed to use during a class lecture. It must be closed; **otherwise** the student will be asked to leave the lecture room. - Mobile phones are not allowed in class during the examination. - Lecture notes and assignments might be given directly to students using soft or hard copy.

Template for Course Plan (Syllabus)

Micro Electro-Mechanical Systems
BE328

<table>
<tr><th colspan="6">I. Course Identification and General Information:</th></tr>
<tr><td>1</td><td>Course Title:</td><td colspan="4">Micro Electro-Mechanical Systems</td></tr>
<tr><td>2</td><td>Course Code & Number:</td><td colspan="4">BE328</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Credit Hours:</td><td rowspan="2">Credit Hours</td><td colspan="2">Theory Hours</td><td rowspan="2">Lab. Hours</td></tr>
<tr><td>Lecture</td><td>Exercise</td></tr>
<tr><td>3</td><td>2</td><td>--</td><td>2</td></tr>
<tr><td>4</td><td>Study Level/ Semester at which this Course is offered:</td><td colspan="4">4th Level / 2nd Semester</td></tr>
<tr><td>5</td><td>Pre –Requisite (if any):</td><td colspan="4">BE224, BE244, BE243</td></tr>
<tr><td>6</td><td>Co –Requisite (if any):</td><td colspan="4">None</td></tr>
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<tr><td>8</td><td>Language of Teaching the Course:</td><td colspan="4">English</td></tr>
<tr><td>9</td><td>Location of Teaching the Course:</td><td colspan="4">Faculty of Engineering</td></tr>
<tr><td>10</td><td>Prepared by:</td><td colspan="4">Associate Prof. Dr. Khalil Al-Hatab</td></tr>
<tr><td>11</td><td>Reviewed by:</td><td colspan="4">Dr. ----</td></tr>
<tr><td>12</td><td>Date of Approval:</td><td colspan="4"></td></tr>
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II. Course Description:

The Microelectromechanical systems (**MEMS**) course exposes students to the foundations of microsystems and process technology involved in the design, simulation and microfabrication of

MEMS devices. Major subjects covered in the course include: engineering mechanics, scaling laws for miniaturization, microfabrication techniques, material selection, microsystems design and microsystems packaging design. Through the class lectures, examples and group design projects drawn from real-word BioMEMS applications, students should have a clear idea about MEMSs, building blocks, micro-fabrication and design process of MEMSs. Modeling and simulation in the design process of MEMS is emphasized using appropriate CAD packages.

III. Course Intended Learning Outcomes (CILOs): (مخرجات تعلم المقرر)

A. Knowledge and Understanding: Upon successful completion of the course, students will be able to:	
a1	Understand the working principles of various sensors and actuators and introduce the different materials and fabrication techniques used for MEMS devices.
a2	Familiarize with concept, formula and aspects beyond materials, mechanical and electrical disciplines in context to MEMS and BioMEMS design, fabrication and applications.
B. Intellectual Skills: Upon successful completion of the course, students will be able to:	
b1	Apply the mathematical methods, engineering concepts, life-science basis, and modern tools professionally in modelling, analyzing, designing, and constructing of MEMS devices.
b2	Identify the optimal microfabrication and packaging techniques and the suitable scaling-laws for microdevices and systems.
b3	Design MEMS devices within realistic constraints of social, political, ethical, health and safety and manufacturability.
C. Professional and Practical Skills: Upon successful completion of the course, students will be able to:	
c1	Integrate the relevant knowledge of mathematics, life science, and engineering to the MEMS design and challenges.
c2	Use appropriate practical aspects, MEMS software, materials, fabrication and packaging techniques to handle mechanical systems engineering design of microscale devices.
D. Transferable Skills: Upon successful completion of the course, students will be able to:	
d1	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
d2	Writing effective reports and make effective presentations.

IV. Course Contents:

A. Theoretical Aspect:

No.	Units/Topics List	Sub Topics List	Number of Weeks	Contact Hours
1	**Overview of MEMS and Microsystems**	– Overview of Course – The History of MEMS Development – MEMS and Microsystems – The Intrinsic Characteristics of MEMS – MEMS & Microsystem Products – Evolution of Microfabrication – Microsystems &Microelectronics – The Multidisciplinary Nature of Microsystem Design and Manufacture – Applications of Microsystems	1	2
2	**Working Principles of Microsystems**	– Introduction – Electrostatic Sensing and Actuation – Thermal Sensing and Actuation – Piezoelectric Sensing and Actuation – Magnetic Actuation	2	4
3	**Engineering Science for Microsystem Design and Fabrication**	– Introduction – Atomic Structure of Matter – Ions and Ionization – Molecular Theory of Matter – Doping of Semiconductors – The Diffusion Process – Plasma Physics – Electrochemistry – Electrolysis	1	2
4	**Engineering Mechanics for Microsystems Design**	– Static Bending of Thin plate – Mechanical Vibration – Thermomechanics – Thin-Film Mechanics – Overview of Finite Element Stress Analysis	1	2
5	**Thermofluid Engineering and Microsystems Design**	– Overview of the Basics of Fluid Mechanics in Macro- and Mesoscale – Laminar Fluid Flow in Circular Conduits – Incompressible Fluid Flow	1	2
6	**Scaling Laws in Miniaturization**	– Introduction to Scaling – Scaling in Geometry – Scaling in Rigid-Body Dynamics	1	2

IV. Course Contents:

A. Theoretical Aspect:

No.	Units/Topics List	Sub Topics List	Number of Weeks	Contact Hours
		– Scaling in Electrostatic Forces – Scaling in Electromagnetic Forces – Scaling in Electricity – Scaling in Fluid Mechanics – Scaling in Heat Transfer		
7	**Mid-Term Theoretical Exam**	– All Preceding Lectures	1	2
8	**Materials for MEMS and Microsystems**	– Substrates and Wafer – Active Substrate Materials – Silicon as a Substrate Material – Silicon Compound – Silicon Piezoresistors – Polymers	1	2
9	**Microsystems Fabrication Processes**	– Introduction – Photolithography – Ion Implantation – Diffusion – Oxidation – Chemical Vapor Deposition – Physical Vapor Deposition-Sputtering – Deposition by Epitaxy – Etching	2	4
10	**Overview of Micromanufacturing**	– Bulk Micromanufacturing – Surface Micromachining – The LIGA Process	2	4
11	**Microsystems Design**	– Design Considerations – Process Design – Mechanical Design – Design of Silicon Die for a Micropressure Sensor – Design of a Microfluidic Network Systems – Computer-Aided Design (CAD)	1	2
12	**Microsystem Packaging**	– Overview of Mechanical Packaging of Microelectronics – Microsystem Packaging – Interfaces in Microsystem Packaging – Essential Packaging Technologies	1	2

IV. Course Contents:

A. Theoretical Aspect:

No.	Units/Topics List	Sub Topics List	Number of Weeks	Contact Hours
		– Three-Dimensional Packaging – Assembly of Microsystems – Selection of Packaging Materials – Reliability in MEMS Packaging – Testing for Reliability		
13	**Final Theoretical Exam**	– All Preceding Lectures	**1**	**2**
Number of Weeks /and Units Per Semester			**16**	**32**

B. Case Studies and Practical Aspect:

No.	Tasks/ Experiments	Number of Weeks	Contact Hours
1	**Lab 1:** Introduction to MEMS Pro (L-Edit)	1	2
2	**Lab 2:** Design of MEMS 3D Model Using L-Edit	1	2
3	**Lab 3:** Introduction to MEMS Pro (S-Edit)	1	2
4	**Lab 4:** Design of Piezoresistive Sensor using S-Edit	1	2
5	**BioMEMS Case Study-1**	1	2
6	**BioMEMS Case Study-2**	1	2
7	**Mid-Term Practical Exam**	1	2
8	**Lab 5 :** Introduction to Samcef Field	1	2
9	**Lab 6:** Analysis of RF Switch using Samcef Field (part1)	1	2
10	**Mini Project**	1	2

B. Case Studies and Practical Aspect:			
No.	**Tasks/ Experiments**	**Number of Weeks**	**Contact Hours**
11	**Lab 7:** Analysis of Thermal Actuator using Samcef Field	1	2
12	**BioMEMS Case Study-3**	1	2
13	**BioMEMS Case Study-4**	1	2
14	**Mini Project (continue)**	1	2
15	**Final Practical Exam & Mini Project Revised**	1	2
	Number of Weeks /and Units Per Semester	**15**	**30**

C. Tutorial Aspect:			
No.	**Tutorial**	**Number of Weeks**	**Contact Hours**
1	**None**	----	----
	Number of Weeks /and Units Per Semester		

V. Teaching Strategies of the Course:

- Interactive lectures & examples,
- Presentation/seminar,
- Interactive class discussions,
- Case studies,
- Computer laboratory-based sessions,
- Exercises and home works,
- Directed self- study,
- Problem based learning,
- Team work (cooperative learning),
- Mini/major project.

VI. Assessment Methods of the Course:

- Written tests (mid and final terms and quizzes),
- Lab\Project report
- Practical lab performance assessment,
- Coursework activities assessment,
- Home works and assignments,
- Presentations.

VII. Assignments:

No.	Assignments	Week Due	Mark
1	**Homework (10 sets)**	3-13	10
Total			

VIII. Schedule of Assessment Tasks for Students During the Semester:

No.	Assessment Method	Week Due	Mark	Proportion of Final Assessment
1	Assignments	3-13	10	6.7%
2	Quizzes	6, 12	10	6.7%
3	Midterm Theoretical Exam	8	20	12.3%
4	Midterm Practical Exam	7	20	12.3%
5	Final Practical Exam & a course-project evaluation	15	30	20%
6	Final Theoretical Exam	16	60	40%
Total			**150**	**100%**

IX. Learning Resources:

1- Required Textbook(s) (maximum two):

1. Hsu, Tai-Ran, 2008, **MEMS and Microsystems Design, Manufacture, and Nanoscale Engineering**, 2nd Edition,, Hoboken, New Jersey, John Wiley & Sons, Inc.
2. Chang Liu, 2012, **Foundations of MEMS**, 2nd Edition, New Jersey, USA, Pearson Education Inc.

2- Essential References:

1. Stephen D Senturia,2002, **Microsystem Design**, New York, Kluwer Academic Publishers.
2. Werner Karl Schomburg, 2015, **Introduction to Microsystem Design**, 2nd Edition, RWTH Aachen University, Springer.
3. Thomas M.Adams and Richard A.Layton, 2012, **Introduction MEMS, Fabrication and Application**, Springer.
4. Wanjun Wang, Stephen A.Soper, 2007, **BioMEMS: Technologies and Applications**, New York, CRC Press.
5. Julian w. Gardner, Vijay K. Varadan, Osama O. Awadelkarim, 2002, **Micro Sensors MEMS and Smart Devices**, USA, John Wiley and Son.
6. Marc J. Madou, 2002, **Fundamentals of Microfabrication: the Science of Miniaturization**, USA, CRC Press.
7. Nadim Maluf, Kirt Williams. 2004, **An introduction to Microelectromechanical Systems Engineering**, 2nd Edition, Artech House Inc.
8. Nitaigour Premchand Mahalik, 2007, **MEMS**, New Delhi, Tata McGraw Hill Publishing Company.

3- Electronic Materials and Web Sites etc.:

Websites:

1. http://www.people.cornell.edu/pages/akt1/memsmain.html
2. http://www.mosis.com
3. http://www.memsrus.com/CIMSmain2ie.html
4. http://www.d arpa.mil
5. http://mems.isi.edu

Journals:

1. Journals with a primary focus in MEMS areas:
2. Journal of Microelectromechanical Systems (JMEMS)
3. Journal of Micromechanics and Microengineering
4. Microsystem Technologies: Sensors, Actuators, Systems Integration

IX. Learning Resources:

5. Journal of Smart Materials and Structures
6. Sensors and Actuators A (Physical)
7. Sensors and Actuators B (Chemical)
8. Sensors and Actuators C (Material)
9. IEEE Electron Device Letters
10. Journal of Electrochemical Society
11. Journal of Vacuum Society
12. Proceedings of SPIE – International Society for Optical Engineering
13. Journal of Analytical Chemistry

X. Course Policies:

1	**Class Attendance:** A student should attend not less than 75 % of total hours of the subject; otherwise he/she will not be able to take the exam and will be considered as exam failure. If the student is absent due to illness, he/she should bring a proof statement from university Clinic. If the absent is more than 25% of a course total contact hours, student will be required to retake the entire course again.
2	**Tardy:** For late in attending the class, the student will be initially notified. If he repeated lateness in attending class, he/she will be considered as absent.
3	**Exam Attendance/Punctuality:** A student should attend the exam on time. He/she is permitted to attend an exam half one hour from exam beginning, after that he/she will not be permitted to take the exam and he/she will be considered as absent in exam
4	**Assignments & Projects**: In general one assignment is given to the students after each chapter; the student has to submit all the assignments for checking on time, mostly one week after given the assignment.
5	**Cheating**:

	For cheating in exam, a student will be considered as fail. In case the cheating is repeated three times during his/her study the student will be disengaged from the Faculty.
6	**Plagiarism**: Plagiarism is the attending of a student the exam of a course instead of another student. If the examination committee proofed a plagiarism of a student, he/she will be disengaged from the Faculty. The final disengagement of the student from the Faculty should be confirmed from the Student Council Affair of the university or according to the university roles.
7	**Other policies**: - Mobile phones are not allowed to use during a class lecture. It must be closed; **otherwise** the student will be asked to leave the lecture room. - Mobile phones are not allowed in class during the examination. - Lecture notes and assignments might be given directly to students using soft or hard copy.