



School of Science and Engineering

Office of Graduate Studies

Master of Science

Mechanical Engineering (Mechatronics)

Academic Program

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1. Introduction

Mechatronics Engineering concerns the design of computer controlled electromechanical systems. It includes robotics and automation systems, neural prosthetics, micro electro-mechanical systems (MEMS), design and implementation of smart structures, structural health monitoring, condition monitoring, and many other leading-edge technologies. Mechatronics Engineering is a multi-disciplinary program that admits graduate students from mechanical engineering, electrical engineering and computer engineering.

Graduates of the program will receive the degree of Master of Science in Mechatronics Engineering from Sharif University of Technology, International Campus on Kish Island.

2. Mechatronics program in a glance

Duration of Program (without any prerequisite courses): 2 years

Duration of Program (with 8-15 credits of prerequisite courses): 2.5 years

Course Requirements:

- i) Thesis option: 34
 - a. Compulsory: 10
 - b. Elective: 18
 - c. Thesis: 6
- ii) Course option: 34
 - a. Compulsory: 10
 - b. Elective: 24

Note: Since the program is offered in English, Master students studying in either options are required to pass 2 Credit hours “Advanced Technical English”

3. Course requirements

The program is defined in terms of two levels of courses, compulsory and elective courses. *Compulsory* courses are listed in Table 1, defined a base background for mechatronics engineering. Elective courses are given in Table 2.

Table 1: List of compulsory courses

Fundamental courses		
Course No.	Course Title	Credit hurs
53014	Advanced Engineering Mathematics	3
50621	Advanced Technical English	2
58551	Mechatronic	3
58603	Graduate seminar	2

Table 2: List of elective courses

Elective Courses		
Course No.	Course Title	Credit hours
58019	Control systems design	3
58409	Dynamic systems	3
58022	Kinematics and dynamics of robots	3
55363	Power electronics	3
58595	Nonlinear control	3
58589	Fuzzy control	3
58045	Advanced automatic control	3
58030	Smart materials and structures	3
58599	Fundamental of smart systems in modeling and control	3
58053	Continuous vibrations	3
58025	Design optimization	3
58549	Advanced robotics	3
58009	Micro Nano fluids	3
58046	Advanced dynamics	3

4. Suggested 2-years course plan

Suggested 2-years program for student choosing the course-based option (Assumed number of prerequisite courses: 9 Credits. The actual number of prerequisite courses may be different)

1 st Semester			2 nd semester		
Course No.		Credit hours	Course No.		Credit hours
53014	Adv. Eng. Math.	3	58603	Graduate Seminar	2
50621	Adv. Tech. Eng.	2		Elective course	3
	Prereq. course*	3		Prereq. course*	3
	Prereq. course*	3		Elective course	3
	Total	11		Total	11

3 rd Semester			4 th semester		
Course No.		Credit hours	Course No.		Credit hours
	Elective course	3		Elective course	3
	Elective course	3		Elective course	3
	Elective course	3		Elective course	3
	Elective course	3			
	Total	12		Total	9

Suggested 2-years program for student choosing the thesis option (Assumed number of prerequisite courses: 9 Credits. The actual number of prerequisite courses may be different)

1 st Semester			2 nd semester		
Course No.		Credit hours	Course No.		Credit hours
53014	Adv. Eng. Math.	3	58603	Graduate Seminar	2
50621	Adv. Tech. Eng.	2		Elective course	3
	Prereq. course*	3		Prereq. course*	3
	Prereq. course*	3		Elective course	3
	Total	11			11

3 rd Semester			4 th semester		
Course No.		Credit hours	Course No.		Credit hours
	Elective course	3		Elective course	3
	Elective course	3		Elective course	3
	Elective course	3		Thesis	3
	Thesis	3			
	Total	12		Total	9

***Prerequisite courses:**

Students from different disciplines are expected to have passed the following courses as part of their B.S. program. These courses either represent the prerequisite to one or more of the courses in the Mechatronics M.S. program or will be needed to have a basic understanding of the design principles and inner workings of most Mechatronic systems. These courses include:

- | | |
|---------------------------------|------------------------|
| Linear control systems | Statics |
| Electronics | Mechanics of materials |
| Logic and switching circuits | Dynamics |
| Computer language and structure | Machine design |

Any of these courses not taken as part of the students B.S. program, must be taken as a pre-requisite, during the first year in the Mechatronics M.S. program.

5. Research areas

5.1 Smart structures

- Designing smart structures including smart composites, smart surgical devices and aerospace structures.
- Designing optimized systems
- Condition monitoring systems
- Structural health monitoring
- Electromechanical systems (MEMS , NEMS)

5.2 Robotics

- Design, Modeling and control of industrial robots
- Design, Modeling and Control of Special purpose (underwater, flying, climbing,..) robots
- Robotic based rehabilitation and assistive surgery
- Biomimetics
- Micro and Nano Robotics
- Industrial Automation

5.3 Control

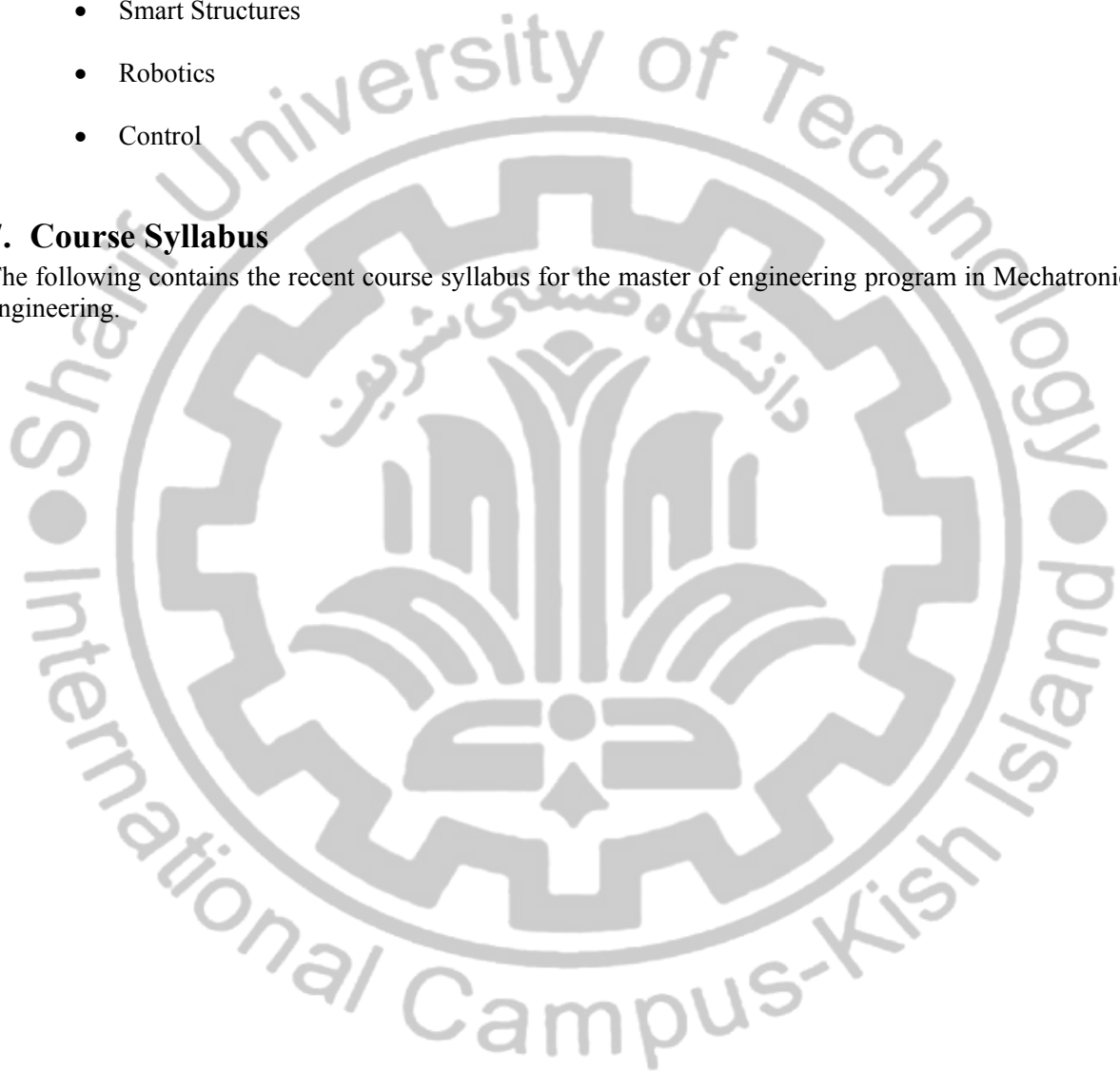
- Application of Linear , nonlinear and optimal control to Mechatronic systems
- Modeling and simulation of dynamics and Mechatronic systems
- Vehicle/ Automotive control and navigation
- Intelligent system, including fuzzy and neural networks

6. Research Laboratories

- Smart Structures
- Robotics
- Control

7. Course Syllabus

The following contains the recent course syllabus for the master of engineering program in Mechatronics engineering.



Course Title : CONTROL SYSTEM DESIGN
Course Number : 58019
Field : MT
Credits : 3
Prerequisite : N.A
Prepared by : Dr. Ghaemi Osgouie

Course Objective:

To design proper systems to control motion and processes

Outlines

1. Introduction to control system Design
2. Logic operations and circuits
3. Motion control systems:
 - 3-1. Hydraulic systems
 - 3-2. Pneumatic systems
 - 3-3. Electro-Mechanical systems
4. Ladder Language and its elements
5. Process control
6. Electronic control (PLC, PC,...)

Text Book:

Class notes

References and Supplementary Readings:

1. "Pneumatic Drives: System design, modeling and control," Peter Beater, spring 2007
2. "pneumatic and hydraulics" H.L.Stewart, Adel1976
3. "Hand book of hydraulic fluid technology," Totten 2005, Marcal Dekker NY.
4. "Foundations at design Logic Design," G.Langholtz, A.Kamdel, J.L.Mott, Word Scientific2000
5. "Programmable Logic controllers," C.T.Jones,Patrick-Turner1996

Course Title : ADVANCED TECHNICAL ENGLISH
Course Number :
Field : MECHATRONICS
Credits : 3
Prerequisite :
Prepared by : Dr. A. Zabihollah

Course Objective:

1. To learn writing technical articles: Journal paper, Proposal, Report and Thesis
2. To learn technical presentations: Conference and Poster presentations
3. To practice oral presentation

Outlines

1. Why writing a paper?
2. Research Papers
3. Paper's structures: abstract, introduction, literature review

Mid-term Examination:

4. Paper's structures: evidence, methodology, conclusion, references and appendices
5. Proposal writing
6. Thesis writing
7. Oral presentation: slide preparation, opening, sequence and answer the questions

Text Book: Derek Soles, *The Academic Essay*, 2nd edition, Studymates, 2005, UK

References and Supplementary Readings:

Jean Wyrick, *Steps to Writing Well*, 10th edition, Thomson Wadsworth, 2008, USA

Course Title : VIBRATIONS OF CONTINUOUS SYSTEMS
Course Number : 58025, 53195
Field : MECHATRONICS, CIVIL
Credits : 3
Prerequisite : Engineering Mathematics, 53014
Prepared by : Dr. A. Zabihollah

Course Objective:

- To understand the vibration characteristics of continuous mechanical systems
- Further the knowledge and experience in the field of vibration analysis
- To apply the analytical and computational tools to the dynamic characteristics of continuous structures

Outlines

1. Review Vibration of discrete systems (Single DOF, Multi DOF, classical and energy methods, free and forced vibration)
2. Vibration of strings and bars
3. Vibration of beams
4. Vibration of plates and membranes
5. Boundary value and eigenvalue problems
6. Waves in elastic continua

Text Book: Rao S., S., **Vibration of Continuous systems**, John Wiley & Sons, New York, 2007

References and Supplementary Readings:

P. Hagedorn, A. DasGupta, **Vibration and Waves in Continuous Mechanical Systems**, John Wiley & Sons, Ltd, 2007

Course Title : **ADVANCED ROBOTICS**
Course Number : **58549**
Field : **MECHATRONICS**
Credits : **3**
Prerequisite : **ROBOTIC & LAB, 58864**
Prepared by : **Dr. A. Fattah**

Course Objective:

Outlines

1. Kinematics, dynamics and design of parallel manipulators(4 weeks)
 - Introduction to parallel manipulators
 - Kinematics of parallel manipulators
 - Dynamics of parallel manipulators
2. Manipulator performance evaluation and optimization(3weeks)
 - rigid body mechanics
 - screw Jacobian matrix
 - kinematic performances indices
 - isotropic design of serial manipulators
3. Kinetic calibration and dynamic calibration(load and inertia estimation) of robotic mechanical system(2.5weeks)
 - Kinematic calibration
 - load inertia parameter estimation
 - link inertia parameter estimation
4. Control of serial manipulators(2.5weeks)
 - Linear control
 - Nonlinear control
5. Novel actuator design (2weeks)

Text Book: J. Angeles, Fundamental of Robotic Mechanical System, Spriger, 1997.

References and Supplementary Readings:

1. J. Pierre-Merlet, Parallel Robots, Kluwer Academic Publishers, 2000
2. Asada H., and Slotine J.J., Robot Analysis and control, Wiley Interscience, 1986
3. Caring, J.J., Introduction to Robotics: Mechanics and control, Addison Weesley, 1989.
4. Nakamura, Y., Advanced Robotics: Redundancy and Optimization, Addison Wesley , 1991

Course Title : FINITE ELEMENT METHOD
Course Number : 58025, 53195
Field : MECHATRONICS, CIVIL
Credits : 3
Prerequisite : Engineering Mathematics, 53014
Prepared by : Dr. A. Zabihollah

Course Objective:

This course should lead to a sound understanding of the fundamentals underlying the theoretical aspects of the *Finite Element Method*, and of the way the basic concepts are employed in the analysis of engineering problems. The ability of the students to apply the concepts involved in this field will be developed and it will be enhanced through adequate training in the solution of representative simple problems.

Outlines

1. Concept of the Finite Element Method.
System Stiffness Equation, Shape functions, Element matrices, Weighted Residual Methods
2. 1-D Structural Problems
Truss and beams (Euler- Bernoulli and Timishenko beam element)
3. 2-D Structural Problems: Plates
4. Triangular and Quadrilateral elements
5. Natural Coordinates and Isoparametric Formulation

Text Book: J.N. Reddy, *An Introduction to Finite Element Methods*, McGraw-Hill, 2000

References and Supplementary Readings:

1. Robert D. Cook, *Finite Element Modeling for Stress Analysis*, John Wiley & Sons, Inc., 1995
2. O.C. Zienkiewicz, R.L.Taylor, *Finite Element Method, 5th edition*, Butterworth-heinemann, 2000, Spain

Course Title : FUZZY SYSTEMS AND CONTROL
Course Number : 58589
Field : MECHATRONICS
Credits : 3
Prerequisite : NA
Prepared by : Dr. A. A. Khayat

Course Objective:

To understand the concept of *Fuzzy Logic*, *Fuzzy Systems* and *Fuzzy Controllers* fully and completely. To introduce the fundamental concepts and principles in the general field of fuzzy theory, that are useful in fuzzy systems and fuzzy control. To study the operations inside the fuzzy systems and to design fuzzy systems and fuzzy controllers.

Outlines

- Why Fuzzy Systems? The uncertain and inexact nature of the real world.
- Fuzzy Sets and Basic Operations on Fuzzy Sets.
- Fuzzy Relations and the Extension Principle.
- Fuzzy Sets and Fuzzy Multi-valued Logic vs. Crisp Sets and Classical Two-valued Logic.
- Fuzzy Membership Functions, Fuzzy Numbers, and Fuzzy Arithmetic.
- Basic Concepts and Techniques for Fuzzy Information Processing.
- Fuzzy Inference Principles, Fuzzy Decision Making, and Approximate Reasoning.
- Linguistic Variables and Fuzzy IF-THEN Rules; and Establishment of Fuzzy Rule Base.
- Static Fuzzy Modeling; and Dynamic Fuzzy Modeling.
- Basic Fuzzy Control Principles; Set-Point Tracking.
- Open-Loop and Closed-Loop Fuzzy Control Systems.
- Fuzzy PID Controllers: Design Methods and Applications.
- Computational Verb Controllers.

Text Book: Li-Xin Wang, *A Course in Fuzzy Systems and Control*, Prentice Hall, 1997.

References and Supplementary Readings:

5. Guanrong Chen and Trung T. Pham, *Introduction to Fuzzy Sets, Fuzzy Logic and Fuzzy Control Systems*, CRC Press, 2001.
6. Hao Ying, *Fuzzy Control and Modeling: Analytical Foundations and Applications*, John Wiley, 2000.

Course Title : MECHATRONICS
Course Number : 58551
Field : MECHATRONICS
Credits : 3
Prerequisite : N.A
Prepared by : Dr. Vosoughi

Course Objective:

Outlines

1. Solenoids, DC and Stepper motors types, selection guide
2. Linear Drive of DC motors
3. PWM Drives for DC motors
4. Stepper motor Drives
5. Piezoelectric Actuators(Characteristics/Modeling)
6. Piezoelectric Actuator Drive
7. Finite state Machines
8. Programmable Logic Controllers

Other possible topics:

1. Digital Control Systems
2. Kalman Filtering / Estimation – sensor fusion
3. Dynamics Systems Modeling: Lagrangian or Bondgraph
4. Mobile Robotic Systems (Design and Kinematics)
5. Mobile Robotic Sensor Systems
6. Mechatronic Design / Control Case studie

Text Book:

References and Supplementary Readings:

Course Title : NEURAL NETWORKS
Course Number : 58072
Field : MECHATRONICS
Credits : 3
Prerequisite : Automatic Control (58416)
Prepared by : Dr. A. A. Khayyat

Course Objective:

This course examines the organization of neural networks. Topics will include the basic architecture of neural networks; the organization of feed-forward networks, recurrent networks, and competitive networks; and learning and performance issues. The emphasis in the course will be divided between the theory of neural networks and computational issues as the training and testing of neural networks.

Outlines

- What is a Neural Network?
- Network Organization and Processing
- Activation Functions
- Linear Units / Linear Associator / Associative Memory Network
- Threshold Units / Perceptrons
- Training a Neural Network (Learning)
- Function Mapping vs. Pattern Classification
- Back Propagation Network
- Delta Learning via Gradient Descent Training
- Speed of Learning, Competitive Networks
- Competitive Learning, Self Organizing Map
- Counter Propagation Networks
- Learning Vector Quantization
- Recurrent Networks
- Associative Network
- Hopfield Network
- Evaluation of System Performance
- Hierarchical Networks
- Radial Basis Function Networks
- Probabilistic Neural Networks
- Functional Link Networks
- Neural Network Controllers

References and Supplementary Readings:

1. Simon Haykin, Neural Networks
2. شبکه های عصبی – دکتر محمد باقر منهاج

Course Title : **NONLINEAR CONTROL**
Course Number : **58595**
Field : **MECHATRONICS**
Credits : **3**
Prerequisite : **Modern Control (58045)**
Prepared by : **Dr. A. A. Khayyat**

Course Objective:

When engineers analyze and design nonlinear dynamical systems in any engineering disciplines, they need to absorb and digest a wide range of nonlinear analysis tools. In this course, some of these tools are introduced. In particular, tools for stability analysis of nonlinear systems are presented, with an emphasis on Liapunov's method. Special attention is given to the stability of feedback systems. Finally, nonlinear feedback control tools are introduced, including linearization, gain scheduling, exact feedback linearization, Liapunov redesign, backstepping, sliding mode control, and adaptive control

Outlines

- Linearization: Classical and State Vector Methods.
- Autonomous and Nonautonomous Systems.
- Phase-Plane Analysis (Topological Approach).
- Poincare's Theory and Indices of Poincare.
- Limit Cycles and Stability.
- Liapunov Stability Analysis (Liapunov's Direct and Indirect Methods).
Time-Invariant Systems, Time-Varying Systems
- Describing Function Analysis of Nonlinear Control Systems.
- Input/Output Properties
I/O Stability, Stability of Feedback Interconnections (The Small Gain Theorem).
Passivity and Passive Interconnections
- Feedback Linearization
Input – State Linearization, Input – Output Linearization
- Liapunov-Based Control Design Techniques.
BackStepping
Sliding Mode Control
Adaptive Control

Text Book: Khalil K. H., *Nonlinear Systems*, 3rd edition, Prentice Hall, 2002.

References and Supplementary Readings:

2. Sastry S., *Nonlinear Systems: Analysis, Stability, and Control*, Springer, 1999.
3. J.J.E. Slotine and W. Li, *Applied Nonlinear Control*, Prentice Hall, 1991.

Course Title : DESIGN OPTIMIZATION
Course Number : 58025, 53195
Field : MECHATRONICS, CIVIL
Credits : 3
Prerequisite : Engineering Mathematics, 53014
Prepared by : Dr. A. Zabihollah

Course Objective:

To understand optimization algorithms, to apply formal optimization techniques for optimal design, and to understand the commercial tools for design optimization.

Outlines

6. Introduction of design optimization, conventional versus optimal design, review of mathematical background (notations and concepts)
7. Formulating the problem, design variables, cost functions, constraint functions, and typical problems
8. Graphical problems, feasible region, infeasible region, solving graphical problem using MATLAB
9. Optimum design concepts, local and global minima/maxima, gradients, Hessian matrix Taylor expansion, single variable function, Taylor expansion, multivariable functions, Quadratic forms, optimality criteria, unconstraint optimal problems
10. Constraint optimal problems, Lagrange multipliers, KKT conditions
11. Linear programming methods
12. Unconstraint design optimization
13. Constraint design optimization
14. Optimization using MATLAB

Text Book: Jasbir S. Arora, *Introduction to Design Optimization*, 2nd edition, 2004

References and Supplementary Readings:

4. Venkataraman, *Applied Optimization with MATLAB Programming*, 2003

Course Title : SMART MATERIALS AND STRUCTURES
Course Number : 58030
Field : MECHATRONICS
Credits : 3
Prerequisite : NA
Prepared by : Dr. A. Zabihollah

Course Objective:

To understand the concepts of multifunctional elements, fundamental and applications of smart materials in smart structures, and to design smart structures for civil, automobile, aerospace and biomedical applications.

Outlines

1. The basic concepts of smartness, historical review and the fields of application.
2. The basics of multifunctional materials for smart structures; microscopic, macroscopic.
3. Signal processing for smart structures: fundamental
4. Sensors: measurement, piezoelectric, PVDF, PZT, LVDT, fiber optic, etc.
5. Actuator techniques: piezoelectric, electrostrictive, electrorheological fluids, magnetorheological fluids, shape memory alloys, etc.
6. Controllers for smart structures, linear and nonlinear systems.
7. Structural health /condition monitoring.
8. Shape control, position control, and vibration suppression.
9. Smart composite (damage/delamination detection, vibration control)
10. Applications of smart structures in aerospace systems (smart skin, detection and control of unpredicted loads), automobile (self-diagnostics), civil engineering (vibration damping), biomechanics (artificial muscles, sense of touch, force sensing etc).

Text Book: Donald J. Leo, *Engineering Analysis of Smart Material Systems*, John Wiley & Sons, Inc., 2007.

References and Supplementary Readings:

1. Hartmut Janocha, *Adaptronics and Smart Structures: Basics, Materials, Design and Applications*, Springer-Verlag Berlin Heidelberg, 2007.
2. B. Bandyopadhyay, T.C. Manjunath, M. Umamathy, *Modeling, Control and Implementation of Smart Structures*, Springer Berlin Heidelberg New York, 2007.
- 3 A.V. Srinivasan, *Smart Structures: Analysis and Design*, Cambridge University Press, Cambridge; New York, 2001.

Course Title : GRADUATE SEMINAR
Course Number : 58040
Field : MECHATRONICS
Credits : 2
Prerequisite : 2nd semester standing
Prepared by : S. Orangi

Course Objective:

To prepare students to present a full seminar.
Guide students through selection of good primary journal articles suitable for a seminar presentation.
Guide students through proper presentation of data for a seminar.
Help students develop a good speaking style suitable for a broad scientific audience

Outline

1. **Paper Summary:** Guidelines will be presented for preparing a paper summary.
 - a. Each student will submit one paper summary according to guidelines provided. The selected article must be from **peer-reviewed** scientific publications.
2. **Slide preparation:** An overview of techniques for creating slides suitable for technical presentation will be given.
 - a. **Data Slides:** Each student will prepare two slides that demonstrate their ability to present scientific information using Microsoft Office PowerPoint.
3. **Presentations:** develop necessary skills to effectively communicate with a broad audience, discuss techniques for presenting technical data, and rules and etiquettes that must be observed:
 - a. **Introduction.** Each student will prepare and present an eight to ten-minute seminar presentation that is an overview of the introductory material needed to provide adequate background for their research topic.
 - b. **Methods and Results.** Each student will prepare and present an eight to ten-minute presentation of the methods and research from the primary references that were submitted as part of the topic selection. Each presentation must included and integrate data from **two** peer-reviewed research articles.
 - c. **Discussion, Conclusions and Acknowledgments.** Each student will prepare and present an eight-ten-minute presentation that discusses the results presented and provides overall conclusions about the research articles reviewed in the results presentations.
 - d. **Full Seminar.** Each student will submit their revised set of PowerPoint slides to be used for their presentation. Students will give a 20-min seminar presentation
4. **Attendance.** Each student is required to attend all seminars.

Text Book: None

References and Supplementary Readings: None

Course Title : SYSTEM DYNAMICS
Course Number : 58049
Field : MECHATRONICS
Credits : 3
Prerequisite : NA
Prepared by : Dr. Ali Selk Ghafari

Course Objective:

The objective of this course is to introduce Bondgraph method to model and simulate the dynamics of a variety of energy domains such as mechanical, electrical, magnetic, hydraulic and thermofluidix systems. The topics include introduction to power and energy variables, constitutive modeling of multi-port energy elements, transducers, transformers, gyrators, power flow, causality, derivation and simulation of state space equations.

Outlines

5. multi-port systems and bond-graph
6. basic component of bond-graph
7. system models
8. state-space equations
9. multi-port fields and junctions
10. mechanical systems with nonlinear geometry
11. distributed parameter systems (optional)
12. magnetic circuits and devices
13. thermo-fluid systems (optional)

Text Book:

System Dynamics: Modeling and Simulation of Mechatronic Systems. Dean C. Karnopp, Donald L. Margolis, and Ronald C. Rosenberg. 4th Edition. John Wiley, 2005.

References and Supplementary Readings:

- 1- Bond graph methodology: development and analysis of multidisciplinary dynamic system model. Wolfgang Borutzk, Springer, 2010.
- 2- Engineering system dynamics: A unified graph-centered approach. Forbes T. Brown, Second Edition, Taylor and Francis, 2007.

Course Title	: MICROELECTROMECHANICAL SYSTEMS (MEMS)
Course Number	: 3
Field	: MECHATRONICS
Credits	: 3
Prerequisite	: Fundamentals of Machine Design, Electrical and Electronics Eng.
Prepared by	: Dr. A. Zabihollah

Course Objective:

To provide students with the necessary fundamental knowledge and experience in the design, manufacture, and packaging of Microsystems.

Outlines

1. Overview of MEMS and Microsystems.
2. Working Principles of Microsystems: Microsensors (optical, pressure, thermal), and Microactuators.
3. Engineering Mechanics for Microsystems Design:
 - a. Mechanical Vibration
 - b. Micro accelerometers
 - c. Resonant microsensors
 - d. Thin-film mechanics
 - e. Overview of finite element
4. Scaling Laws in Miniaturization:
 - a. Scaling in geometry
 - b. Scaling in electrostatic forces
 - c. Scaling in electricity
5. Materials for MEMS: silicon, piezoelectric, polymers.
6. Microfabrication processes: photolithography, ion implantation, diffusion, etching, etc.
7. Overview of Micromanufacturing: bulk micromanufacturing, surface micromanufacturing.
8. Microsystem Design
 - a. Design consideration
 - b. Process design
 - c. Mechanical design: dynamic design, thermomechanical loading and stress analysis.
 - d. Mechanical design using finite element
9. Microsystem Packaging: overview of mechanical packaging, assembly of Microsystems.

Text Book:

Tai-Ran Hsu, MEMS & Microsystems: Design and Manufacture, Tata McGraw-Hill Publishing Company, New Delhi, 2006

References and Supplementary Readings:

1. Stephen D Senturia, Microsystem Design
2. Gregory T. A. Micromachined Transducer Sourcebook