A) COURSE

Course Id:	Course
5703	Modeling and Simulation of Systems

Class Hours per Week	Lab hours per week	Complementary practices	Credits	Total hour course
3	1	3	7	48

B) GENERAL COURSE INFORMATION:

EE (IEA)	ME (IM)	MME (IMA)	EME (IME)	MTE (IMT)	EE (IEA)
Level:				VI	V
Course Type (Required/Elective)				Required	Required
Prerequisite Course:				Applied Mathematics	Electric Circuits A and Dynamic
CACEI Classification:				CI	CI

C) COURSE OBJECTIVE

At the end of the course, the student will be capable of:
Model mechanical, electrical, thermal, fluid, and electromechanical systems. Students will also be able to establish the dynamic model of a system by using engineering tools. Additionally, students will know simulation tools to allow them to consider the important elements to perform a correct simulation as well as an adequate interpretation of it.

D) TOPICS (CONTENTS AND METHODOLOGY)

1.- Introduction	**6 Hours**
Specific Objective:	Students will know the importance of modeling and simulation as well as main elements to a correct simulation.

1.1 Basic Definitions
- 1.1.1 Systen
- 1.1.2 Experiment
- 1.1.3 Model
- 1.1.4 Simulation

1.2 Importance of Modeling
1.3 Importance of Simulation
1.4 Types of Mathematical Models
1.5 Integrating Methods
1.6 Simulation with different integrating steps
1.7 Numerical Stability
1.8 Simulation Software (Matlab, QtOctave and SciLab)

Readings and other resources	[10, chapters 1 y 6]
Teaching Methodologies	Topics are presented by traditional and audiovisual lectures. Sometimes, professor exposes a problem, gets an analytical solution and program the reached equations in a simulation software (Matlab, QtOctave, SciLab). Other times, professor sets a problem, alumni develop an analytical answer, once this answer is feasible, professor presents a proposed solution. Finally, alumni simulate results in Matlab, QtOctave, SciLab. During de course, some sessions will take place using computers where teacher will guide alumni to simulate dynamic models previously developed. Computing sessions will not exceed 10% of total sessions.
Learning Activities	Teacher will continuously set homework involving solutions to engineering problems using computers. These solutions should contain analytical analysis and computer simulation considering integrating methods, integration step, and any other elements involved in the simulation. Professor feedback of solutions' alumni is required.

2.- Basic foundations		**9 Hours**
Specific Objective:	Students will know basic elements required to model systems.	
2.1 Coordinate Systems 2.2 Generalized Coordinates 2.3 Work and Kinetic Energy 2.4 Virtual Offsets 2.5 Virtual Work Principle 2.6 D'Alambert Principle 2.7 Inputs and Outputs of a System		
Readings and other resources	See [2]-[6].	
Teaching Methodologies	Topics are presented by traditional and audiovisual lectures. Sometimes, professor exposes a problem, gets an analytical solution and program the reached equations in a simulation software (Matlab, QtOctave, SciLab). Other times, professor sets a problem, alumni develop an analytical answer, once this answer is feasible, professor presents a proposed solution. Finally, alumni simulate results in Matlab, QtOctave, SciLab. During de course, some sessions will take place using computers where teacher will guide alumni to simulate dynamic models previously developed. Computing sessions will not exceed 30% of total sessions.	
Learning Activities	Teacher will continuously set homework involving solutions to engineering problems using computers. These solutions should contain analytical analysis and computer simulation considering integrating methods, integration step, and any other elements involved in the simulation. Professor feedback of solutions' alumni is required.	

3.- Basic principles of electrical system modeling	**5 Hours**
Specific Objective:	Students will model electrical systems.
3.1 Kirchhoff Laws 3.2 RLC Circuits with single input/output (SISO) 3.3 RLC Circuits with multiple inputs/outputs (MIMO) 3.4 Operational Amplifier (OpAmp) 3.4.1 The Ideal Operational Amplifier 3.4.2 Settings of OpAmp 3.4.3 Systems with OpAmp 3.5 Electrical Systems Simulation	
Readings and other resources	[1]-[2], [7] y [9]
Teaching Methodologies	Topics are presented by traditional and audiovisual lectures. Sometimes, professor exposes a problem, gets an analytical solution and program the reached equations in a simulation software (Matlab, QtOctave, SciLab). Other times, professor sets a problem, alumni develop an analytical answer, once this answer is feasible, professor presents a proposed solution. Finally, alumni simulate results in Matlab, QtOctave, SciLab. During de course, some sessions will take place using computers where teacher will guide alumni to simulate dynamic models previously developed. Computing sessions will not exceed 30% of total sessions.
Learning Activities	Teacher will continuously set homework involving solutions to engineering problems using computers. These solutions should contain analytical analysis and computer simulation considering integrating methods, integration step, and any other elements involved in the simulation. Professor feedback of solutions' alumni is required.

4.- Basic principles of mechanical system modeling	**5 Hours**
Specific Objective:	Students will model mechanical systems.
4.1 Newton Laws 4.2 Rotational Mechanical Systems: Case SISO and MIMO 4.3 Translational Mechanical Systems: Case SISO and MIMO 4.3 Inverted Pendulum 4.4 Mechanical Systems Simulation	
Readings and other resources	[1]-[2], [7] y [9]
Teaching Methodologies	Topics are presented by traditional and audiovisual lectures. Sometimes, professor exposes a problem, gets an analytical solution and program the reached equations in a simulation software (Matlab, QtOctave, SciLab). Other times, professor sets a problem, alumni develop an analytical answer, once this answer is feasible, professor presents a proposed solution. Finally, alumni simulate results in Matlab, QtOctave, SciLab. During de course, some sessions will take place using computers where teacher will guide alumni to simulate dynamic models previously developed. Computing sessions will not exceed 30% of total sessions.
Learning Activities	Teacher will continuously set homework involving solutions to engineering problems using computers. These solutions should contain analytical analysis and computer simulation considering integrating methods, integration step, and any other elements involved in the simulation. Professor feedback of solutions' alumni is required.

<table>
<tr><td colspan="2">5.- Basic principles of electromechanical systems modeling</td><td>3 Hours</td></tr>
<tr><td>Specific Objective:</td><td colspan="2">Students will model electromechanical systems.</td></tr>
<tr><td colspan="3">5.1 Basic Principles of DC Motors
5.2 Permanent Magnet DC Motors
5.3 Torque-Speed Curves of a DC Motor
5.4 Torque-Speed Curves of an Amplifier/DC Motor System
5.5 Electromechanical Systems Simulation</td></tr>
<tr><td>Readings and other resources</td><td colspan="2">[1]-[2], [7] y [9]</td></tr>
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<tr><td>Learning Activities</td><td colspan="2">Teacher will continuously set homework involving solutions to engineering problems using computers. These solutions should contain analytical analysis and computer simulation considering integrating methods, integration step, and any other elements involved in the simulation. Professor feedback of solutions' alumni is required.</td></tr>
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<table>
<tr><td colspan="2">6.- Basic principles of fluid and thermal system modeling</td><td>5 Hours</td></tr>
<tr><td>Specific Objective:</td><td colspan="2">Students will model hydraulic and thermal systems.</td></tr>
<tr><td colspan="3">6.1 Liquid Level System
6.2 Pneumatic Systems
6.3 Hydraulic Systems
6.4 Thermal Systems
6.5 Fluid and Thermal Systems Simulation</td></tr>
<tr><td>Readings and other resources</td><td colspan="2">[1]-[2], [7] y [9].</td></tr>
<tr><td>Teaching Methodologies</td><td colspan="2">Topics are presented by traditional and audiovisual lectures. Sometimes, professor exposes a problem, gets an analytical solution and program the reached equations in a simulation software (Matlab, QtOctave, SciLab). Other times, professor sets a problem, alumni develop an analytical answer, once this answer is feasible, professor presents a proposed solution. Finally, alumni simulate results in Matlab, QtOctave, SciLab.
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7.- Euler-Lagrange modeling of mechanical systems		**8 Hours**
Specific Objective:	Students Will model mechanical systems.	
7.1 The Lagrangian 7.2 Hamilton's Principle 7.3 Energy Functions for Translational Mechanical Elements 7.4 Energy Functions for Rotational Mechanical Elements 7.5 Lagrangian Equation for Conservative Mechanical Systems 7.6 Euler's Dynamics Equations 7.7 Euler's Dynamic Equations for a Two-Link Planar Robot Arm		
Readings and other resources	[2]-[6]	
Teaching Methodologies	Topics are presented by traditional and audiovisual lectures. Sometimes, professor exposes a problem, gets an analytical solution and program the reached equations in a simulation software (Matlab, QtOctave, SciLab). Other times, professor sets a problem, alumni develop an analytical answer, once this answer is feasible, professor presents a proposed solution. Finally, alumni simulate results in Matlab, QtOctave, SciLab. During de course, some sessions will take place using computers where teacher will guide alumni to simulate dynamic models previously developed. Computing sessions will not exceed 30% of total sessions.	
Learning Activities	Teacher will continuously set homework involving solutions to engineering problems using computers. These solutions should contain analytical analysis and computer simulation considering integrating methods, integration step, and any other elements involved in the simulation. Professor feedback of solutions' alumni is required.	

8.- Euler-Lagrange Modeling of Electrical Systems		**7 Hours**
Specific Objective:	Students will model electrical systems.	
8.1 Expressions of Lagrange's Equations for Electrical Circuits 8.2 Establishment of Generalized Forces 8.3 Euler's Dynamic Equations for Electrical Systems 8.4 Analogy of Mechanical and Electrical Systems		
Readings and other resources	[2]-[6]	
Teaching Methodologies	Topics are presented by traditional and audiovisual lectures. Sometimes, professor exposes a problem, gets an analytical solution and program the reached equations in a simulation software (Matlab, QtOctave, SciLab). Other times, professor sets a problem, alumni develop an analytical answer, once this answer is feasible, professor presents a proposed solution. Finally, alumni simulate results in Matlab, QtOctave, SciLab. During de course, some sessions will take place using computers where teacher will guide alumni to simulate dynamic models previously developed. Computing sessions will not exceed 30% of total sessions.	

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E) TEACHING AND LEARNING METHODOLOGIES

a) Traditional exposition of each topic by the professor, using materials such as blackboard.
b) Reading of scientific and divulgation articles.
c) Research work by the students.
d) Exposition of projects by the student.
e) Use of updated software.

F) EVALUATION CRITERIA:

Elaboration and/or presentation of:	**Schedule**	**Topics**	**Weighting**
1st. Term Exam: 90% Homework: 10% Total: 100%	Session 16 At the end of unit II	Units I y II	30%
2nd. Term Exam: 90% Homework: 10% Total: 100%	Session 32 At the end of unit III	Units III-VI	40%
3rd. Term Exam: 90% Homework: 10% Total: 100%	Session 48 At the end of unit IV	UnitsVII and VIII	30%
Total			100 %
Extraordinary Exam	According to schedule	100% Exam	100% Of topics
Title Exam	According to schedule	100% Exam	100% Of topics
Regularization Exam	According to schedule	100% Exam	100% Of topics

G) BIBLIOGRAPHY AND ELECTRONIC RESOURCES

Main Books:

1. Ogata, K. “Ingeniería de Control Moderna”. 5a Edición. McGraw-Hill. 2010.
2. Ogata, K. “Dinámica de Sistemas”. Prentice-Hall. 1987.
3. Fernández Rañada, A., “Dinámica Clásica”, Alianza Editorial, 1994.
4. Wells, D.A. “Lagrangian Dynamics”, 2a Edición, McGraw-Hill. 1967.
5. Hamill, P. “A Student's Guide to Lagrangians and Hamiltonians”, Cambridge University Press, 2014.
6. Strauch D.“Classical Mechanics: An Introduction”, Springer, 2009.
7. Kuo B.C. “Sistemas de Control Automático”, 7a Edición, Prentice-Hall, 1996
8. Dorf R. C., Bishop R. H. “Sistemas de control moderno”, 10a Edición, Pearson Educación, 2005
9. Palm III W. J. “System Dynamics”, 3a Edición, McGraw-Hill Science/Engineering/Math, 2013.
10. Won Y. Yang, Wenwu Cao, Tae S. Chung, John Morris, Applied numerical methods using MATLAB, Wiley-Interscience, 2005