ER/EM 341 CONTROL ENGINEERING
IES Abroad Madrid

DESCRIPTION:
This course is presented as a first course of control engineering for engineering students. This course is in general terms is described as classical feedback control of dynamics systems; and is organized in four parts. The first part will cover the mathematical modeling of linear time invariant (LTI) dynamics systems, by using ordinary differential equations (ODE's). This part will allow to the student integrate different physical systems, as mechanical, hydraulic, electrical or thermal into the mathematical framework of dynamical systems. The second part will cover the analysis of the dynamical system in the complex plane using the concept of transfer function. Into this framework we will analyze stability. Next, study the effects of feedback loops over the response of the systems and how is possible control by using the technique of root-locus. The third part analyzes the dynamical system studying the frequency response via the Bode plots and develops control tools to achieve a specific time response. Finally the student will integrate in a project associated with a relevant engineering problem the previous stages from the modeling, the parameter estimation, and the control techniques. At the end of the course, the students will have acquired an advanced knowledge on how to tackle the control of dynamics systems from the modeling to the control using classical techniques.

CREDITS: 4 credits

CONTACT HOURS: 60 hours

LANGUAGE OF INSTRUCTION: English

PREREQUISITES: Physics. Mathematics (Complex variable). Some previous knowledge of Matlab programing.

ADDITIONAL COST: None

METHOD OF PRESENTATION:
The different lessons will develop in backboard, explaining the theoretical concepts needed to understand each of the module, and combined with explanations for the simulations of the results with numerical simulations. After each module is completed, several problems will be solved and selected lab projects will be proposed, in order to reinforce all the concepts. Weekly assignments will also be proposed, in which students will put in practice everything learnt in the course.

REQUIRED WORK AND FORM OF ASSESSMENT:
- Final exam - 30%
- Project (individual project)- 30%
- Homework assignments - 30%
- Participation - 10%

Course components
2 weekly sessions of 2 hours each where theory and practice will take place in each session. The instructor will present the theory and cover examples.
- **Final exam** will be comprehensive and include a multiple choice section and an exercise section.
- **Midterm exam** will cover the content of sessions 1-10. The exam consist of Worked-out exercises and multiple choice questions.
- **Homework assignments:** Different readings, problem solving and lab projects that will be assigned weekly. The completion of the assignment (reading and writing) should take 3-4 hours. No late homework will be accepted. Each written assignment must include results and conclusions. Students are invited to work together on the assignments, but each student must complete and hand-on his/her own assignment.

- **Participation:** This includes the interaction of the student in the classroom, the ability to answer questions made by the instructor, engagement with the course material, keeping up week-to-week and the general interest shown in the course. Some of the in-class assignments will use tools such us Kahoot verifying understanding of concepts.

- **Project:** The Individual Project is a learning experience that enables the student to carry out research and bring together many of the concepts learned over the semester.
 In the first part of the course the student learned the concepts of modeling of dynamics systems, the different techniques for feedback control systems based on root locus, frequency response. All these were considered in an isolated manner.
The integrative project will deal with the study of cases to consider the control engineering problems with an step-by-step design approach. In this way the student can learn a useful starting point to deal with real world problems, consider meaningful checkpoints during the process that will help to create a whole picture.
Addressing from the conceptualization of the problem, the modeling, the estimation of the associated model parameters, the actuators and the sensor. Discuss the role of perturbation to address the sensitivity to variations in the model parameters along the lifetime. For instance the inertia moment of a satellite change with reduction of the fuels.
The proposed projects cover:

  Design for Satellite Attitude Control.
  Lateral and longitudinal airplane control.
  The Segway as an Inverted pendulum.
  Control if fuel-air ratio for automotive engine.
  Quadrotor Drone control.
  Thermal control for wafer manufacturing

LEARNING OUTCOMES:
By the end of the course, students will be able to:

- The use of systems thinking to solve complex engineering problems integrating multiphysics layers studied in previous courses.
- A systematic understanding of the key aspects and concepts of their branch of engineering in control engineering.
- A coherent knowledge of their branch of engineering including some at the forefront of the branch in control engineering.
- The ability to apply their knowledge and understanding of control engineering to identify, formulate and solve engineering problems using established methods.
- The ability to combine theory and practice to solve control engineering problems.
- An understanding of applicable techniques and methods in control engineering, and of their limitations.

ATTENDANCE POLICY:
Attendance is mandatory for IES Abroad Madrid classes. Please read our attendance policy posted in Moodle and in IES Abroad Madrid Student Handbook.

CONTENT:

Week	Content	Assignments
Week 1	**Session 1: ntroduction to Control Engineering.** Definition of dynamics systems and its stability. Feedback loops. **Session 2:** Descriptions in general terms of the Control Engineering approach.	Read Ch 1 of Franklin et al. “Feedback Control of dynamics systems”. Assignments: Answer review questions Chapter 1
Week 2	**Modeling and Analysis of Dynamics Systems (I).** **Session 3**: Modeling Mechanical systems. **Session 4:** Linear Time Invariant Systems (LTI)	Read Ch 2 and practical exercises of Franklin et al. “Feedback Control of dynamics systems”. Assignments: Simulate Ex 2.2-4 with Matlab. P 2.1, P2.2, P2.8

Week 3	**Modeling and Analysis of Dynamics Systems (II).** **Session** 5: Summary Laplace transform. Dynamic response: **Session** 6: First and second order systems and its time response. Thinking the systems in the complex	Read Ch 3 and practical exercises of Franklin et al. “Feedback Control of dynamics systems”. P 3.2, P 37, P3.9, P 3.32, P 3. 34
Week 4	**Modeling and Analysis of Dynamics Systems (III).** **Session** 7: Modeling Electromechanical systems: RLC nets, electronic circuits. **Session** 8: DC-motors, servo-mechanisms.	Read chapters 2 and practical exercises of Franklin et al. “Feedback Control of dynamics systems”. Simulate with Matlab. Ex 2.10, 2.13, 2.14, 2.15 Solve the problems: 2.20, 2.21, 2.23
Week 5	**Modelling and Analysis of Dynamics Sytems (IV)** **Session** 9: Modeling of Thermofluid systems. Linearization of nonlinear systems. **Session 10:** Feedback loop response. Review for Midterm exam	Read chapters 2 and practical exercises of Franklin et al. “Feedback Control of dynamics systems”. Simulate Ex 2.17, 2.28, 2.19, 2.21 with Matlab. Solve the problems: 2.24, 2.25, 2.27 Do Review exercises
Week 6	Session **11: MIDTERM EXAM** Session **12: Root locus (I):** Introduction to the analysis of the systems in the complex plane (poles - zeros) Time-Domain Specifications.	Read sections 3.4 of Franklin et al. “Feedback Control of dynamics systems”. Simulate Ex 3. 25-28 with Matlab. Solve the problems: 3. 28, 3.32, 3.34, 3.38
Week 7	**Root locus (II):** **Session** 13&14: Analysis of example of PID feedback control systems	Read chapters 5.1 – 5.3 Franklin et al. “Feedback Control of dynamics systems”. Discuss and simulate Ex 5.1-5.3,5.6
Week 8	**Root locus (III).** **Session** 15: Design by dynamics compensation: **Session** 16: Lead and Lag compensators	Read chapters 5.4 – 5.5 of Franklin et al. “Feedback Control of dynamics systems” Discuss and simulate Ex 5.11-5.13. Solve Problem 5.35 and 5.36
Week 9	**Frequency response.** **Session** 17: Frequency response of dynamics system **Session** 18: Bode plots: Magnitude and Phase.	Read chapters 6 of Franklin et al. “Feedback Control of dynamics systems” Solve Problem 6.3 from (a) to (i)

Week 10	**Frequency response: Design Method (II).** **Session** 19: Design by dynamics compensation (filters): Lead and Lag compensators. **Session** 20: Theoretical concepts.	Read chapters 6 and practical exercises of Franklin et al. "Feedback Control of dynamics systems". Discuss and simulate Ex 6.2, 6.4-6.6
Week 11	**Session** 21: Summary to integrate the concepts developed in the course. **Session** 22: Presentation of the projects	Chapter 10: Control systems design, principles and case studies
Week 12	**Integration Projects (I)** **Session** 23&24: Development of integrative project of each student linking from the modeling, estimation of the physical parameters and compensation technique by root-locus and frequency response.	Chapter 10: Control systems design, principles and case studies Develop Matlab scripts to simulate the presented project.
Week 13	**Integration Projects (II)** **Session** 25&26: Development of integrative project of each student linking from the modeling, estimation of the physical parameters and compensation technique by root-locus and frequency response.	Chapter 10: Control systems design, principles and case studies Develop Matlab scripts to simulate the presented project.
Week 14	**Integration Projects (III)** **Session** 27&28: Development of integrative project of each student linking from the modeling, estimation of the physical parameters and compensation technique by root-locus and frequency response.	Chapter 10: Control systems design, principles and case studies Develop Matlab scripts to simulate the presented project..
Week 15	**Session** 29: Final review of the course **Session** 30: FINAL EXAM	

REQUIRED READINGS:

- Frankling, Powell, Emami-Naemi."Feedback Control of Dynamics Systems", 8th edition. Pearson Education Global Edition - 2020

RECOMMENDED READINGS:

- Katsuhiko Ogata "Modern Control Engineering", 5th edition. Prentice Hall.