10.551 Systems Engineering Spring 2019

Course Syllabus and Schedule

Course Description

The course introduces students to process systems engineering and its application in chemical engineering practice. Emphasis is placed on developing skills in problem formulation, system design, use of analytical tools, and group dynamics. The topics include systems analysis, process simulation software (Aspen Plus), experimental design, applied optimization, and data analytics. Applications of these tools will be illustrated with a series of case studies involving steady-state and dynamic process simulation, product and process design, and control system design. Some case studies will be undertaken as group projects. One of the primary motivations for this course is to prepare students with important skills that will be useful at the MIT practice school stations.

Instructors

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Teaching Assistants

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Meeting Times

Tuesdays and Thursdays, 9:30 am to 11:00 am, Room 4-231

Office Hours

TA hours and electronic classroom sessions will be announced in class and on the Stellar site.

Consultations at other times can be made by appointment with the instructors or the TAs. We all want to make ourselves as accessible as possible to help you, but the responsibility lies with you to contact us either during regular hours or by appointment.

Reading Materials

Comprehensive notes and background articles will be posted on the Stellar site. Students will be expected to read this material, and homework assignments will test material not covered in class

Course Web Page

Electronic versions of the class material will be posted on the 10.551 stellar site (http://stellar.mit.edu/S/course/10/sp19/10.551/).

Prerequisites

Students should have taken undergraduate courses in chemical engineering and 10.34, or have permission of the instructor. Students should be familiar with and prepared to use email, and have some experience with at least one programming language such as MATLAB®. Students are also recommended to review your notes on linear algebra and statistics, which will be used extensively in the course.

Grading

Systems engineering can only be learned by solving practical problems. The assignments will be of two types:

(1) Homework problem sets to test understanding of the material presented in class and in the handouts, with each student required to do his/her own work and able to discuss the solution.

(2) Projects carried out in small groups to develop collaborative problem-solving skills and gain experience with group dynamics, with group membership announced with each assignment and each group member required to contribute equally to the solution and write-up.

The group projects take the place of midterm and final examinations.

<u>In individual and group assignments, reference to model and/or student solutions from previous years is strictly prohibited. Failure to abide by this rule will lead to an F grade.</u>

Grade Breakdown

Problem Sets (individual effort):	45%
Projects (group effort):	45%
Class participation (individual effort):	10%

Course Schedule

Class	Date	Topic	Due Date
1	5 Feb	Part 1: **Introduction to Systems Engineering** • Systems and their origin • Systems engineering with examples	
2	7 Feb	Part 2: **Foundations of Systems Engineering** • Scope and formulation of engineering problems • Goals, objectives, specifications, and constraints • Types of models, hierarchical decomposition of systems • Types of problems: forward solution and inversion of models	
3	12 Feb	Part 3: **Structural Analysis of Systems** • Graphs and digraphs: representation of systems • Partitioning and precedence ordering of systems • Structural analysis of modeling equations • Structural controllability and observability of systems • Applications to engineering problems	
4	14 Feb	Part 3: **Structural Analysis of Systems** (Continued)	PS 1
	19 Feb	(MONDAY SCHEDULE OF CLASSES – **NO CLASS**)	
5	21 Feb	Part 3: **Structural Analysis of Systems** (Continued)	
6	26 Feb	Part 4: **Steady-state Analysis of Systems** • Formulating steady-state models and simulations • Degrees of freedom and design specifications • The sequential-modular strategy • The equation-oriented strategy • Applications to engineering problems	
7	28 Feb	Part 4: **Steady-state Analysis of Systems** (Continued)	PS 2
8	5 Mar	Part 4: **Steady-state Analysis of Systems** (Continued)	
9	7 Mar	Part 5: **Systems Optimization: Formulation & Software** • Basic concepts and definitions • Linear programming • Unconstrained nonlinear optimization • Nonlinear programming • Combinatorial optimization • Applications to engineering problems	
10	12 Mar	Part 5: **Systems Optimization** (Continued)	
11	14 Mar	Part 5: **Systems Optimization** (Continued)	Project 1

12	19 Mar	Part 6: **Simulation of Dynamic Systems** • Introductory concepts: ODEs/ DAEs, stability • Model formulations, index analysis, consistent initialization • High-index DAEs • Modeling and simulation of hybrid discrete/continuous systems	
13	21 Mar	Part 6: **Simulation of Dynamic Systems** (Continued)	
	26, 28 Mar	(SPRING VACATION – **NO CLASS**)	
14	2 Apr	Part 6: **Simulation of Dynamic Systems** (Continued)	
15	4 Apr	Part 7: **Process Control** • Introduction, analysis, filtering • Feedback, control structures, plant-wide control • Batch optimal control and introduction to model predictive control	PS 3
16	9 Apr	Part 7: **Process Control** (Continued)	
17	11 Apr	Part 7: **Process Control** (Continued)	
	16 Apr	(PATRIOT'S DAY – **NO CLASS**)	
18	18 Apr	Part 7: **Process Control** (Continued)	Project 2
19	23 Apr	Part 7: **Process Control** (Continued)	
20	25 Apr	Part 7: **Process Control** (Continued)	
21	30 Apr	Part 8: **Process Data Analytics** • Statistical and model-based iterative experimental design • Linear and nonlinear regression (aka parameter estimation) • Uncertainty quantification • Statistical process control (aka fault detection) • Chemometrics for sensor calibration • Fault detection and diagnosis and data mining	
22	2 May	Part 8: **Process Data Analytics** (Continued)	Project 3
23	7 May	Part 8: **Process Data Analytics** (Continued)	
24	9 May	Part 8: **Process Data Analytics** (Continued)	
25	14 May	Part 8: **Process Data Analytics** (Continued)	
26	16 May	Part 8: **Process Data Analytics** (Continued)	PS 4