10.551 **SYSTEMS ENGINEERING** **Spring 2014**

COURSE SYLLABUS AND SCHEDULE

February 4, 2014

Course Description

The course has been designed to introduce students to the elements of systems engineering and its application in chemical engineering practice. Emphasis is placed on developing skills in problem formulation, system synthesis, use of analytical tools, and group dynamics. Some of the topics that will be presented include the structural analysis of systems, sequential-modular and equation-oriented process simulation software (Aspen Plus, Jacobian), mathematical systems and control theory, optimization theory and algorithms, and modeling from data and experimental design. Applications of these tools will be illustrated with a series of case studies involving steady-state and dynamic process simulation, control system synthesis, new product and process design, plant-wide diagnostics and planning, and formulation and decomposition of large-scale problems. Some of these 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, 8:30 am to 10:00 am, Room 66-110

Office Hours

TA hours and electronic classroom sessions will be announced in class and on the 10.551 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 Material

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 most of the class material will also be posted on the 10.551 stellar site at: <http://stellar.mit.edu/S/course/10/sp14/10.551/index.html>

Prerequisites

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

Grading

Systems engineering can really only be learned by solving practical problems. There will be two types of assignments. One will be homework problem sets designed to test the student's understanding of the material presented in class and in the handouts. For these problem sets, each student must do his/her own work and be able to discuss the solution. The second type of assignments will involve projects that are carried out in small groups (group membership will be announced with the assignment). The purpose of these projects is to develop collaborative problem-solving skills and give students experience with group dynamics. Each member of the group is required to contribute equally to the solution and write-up of the project. The group projects take the place of midterm and final examinations.

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.

Grade Breakdown

Homeworks (individual effort):	45%
Projects (group effort):	40%
Class participation (individual effort):	15%

Course Schedule

Class	Date	Topic	Work Due
1	4 Feb	Part 1: **Introduction to Systems Engineering** • Systems and their origin • Examples of problems and methods	
2	6 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	11 Feb	Part 2: **Foundations of Systems Engineering** (Continued)	
4	13 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	HW 1
	18 Feb	(MONDAY SCHEDULE OF CLASSES – **NO CLASS**)	
5	20 Feb	Part 3: **Structural Analysis of Systems** (Continued)	
6	25 Feb	Part 4: **Steady State Analysis of Systems** • Formulating steady-state models and simulations • Degrees of freedom and design specification • The Sequential-Modular Strategy • The Equation-Oriented Strategy • Applications to engineering problems	HW 2
7	27 Feb	Part 4: **Steady State Analysis of Systems** (Continued)	
8	4 Mar	Part 4: **Steady State Analysis of Systems** (Continued)	
9	6 Mar	Part 5: **Optimization of Systems: Theory and Algorithms** • Basic concepts and definitions • Linear programming • Unconstrained nonlinear optimization • Nonlinear programming • Combinatorial optimization • Applications to engineering problems	

10	11 Mar	Part 5: **Optimization of Systems** (Continued)	Project 1
11	13 Mar	Part 5: **Optimization of Systems** (Continued)	
12	18 Mar	Part 5: **Optimization of Systems** (Continued)	HW 3
13	20 Mar	Part 5: **Optimization of Systems** (Continued)	
	25,27 Mar	(SPRING VACATION – **NO CLASS**)	
14	1 Apr	Part 6: **Simulation of Dynamic Systems** • Basic concepts: Systems described by ODEs and DAEs • Formulating dynamic simulations; consistent initialization • Modeling-simulation of hybrid discrete/continuous systems • Applications to engineering systems	
15	3 Apr	Part 6: **Simulation of Dynamic Systems** (Continued)	Project 2
16	8 Apr	Part 6: **Simulation of Dynamic Systems** (Continued)	
17	10 Apr	Part 6: **Simulation of Dynamic Systems** (Continued)	
18	15 Apr	Part 7: **Process Control** • Linear systems • Feedback and control structures • Control structure selection • Statistical process control • Model-based control systems • Model predictive control	HW 4
19	17 Apr	Part 7: **Process Control** (Continued)	
	22 Apr	(PATRIOT'S DAY – **NO CLASS**)	
20	24 Apr	Part 7: **Process Control** (Continued)	Project 3
21	29 Apr	Part 7: **Process Control** (Continued)	
22	1 May	Part 7: **Process Control** (Continued)	
23	6 May	Part 8: **Creating Models from Data** • Types of models created from data • Linear and nonlinear regression • Uncertainty quantification • Experimental design • State-space identification • Chemometrics	

- Time series analysis
- Data archiving

24	8 May	Part 8: **Creating Models from Data** (Continued)	Project 4
25	13 May	Part 8: **Creating Models from Data** (Continued)	
26	15 May	Part 8: **Creating Models from Data** (Continued)	HW 5