Objectives and General Information

Fall 2002

ME 360 *Modeling, Analysis and Control of Dynamic Systems*

<objectives.ps, pdf>

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Revised 8/30/02

Course Motivation and Purpose:

In an effort to continue to produce competitive products, industry has been forced to shorten the design life cycle while simultaneously producing higher performance products.. This has resulted in the increased utilization of cross-functional design teams to perform true systems design. Part of the systems design process includes the use of models that allows what-if? design engineering. The use of models has both been fueled by and fueled an explosion of computer tools for manipulating analyzing models and the data they produce. These computer based techniques demand skills from engineers in the area of modeling. The purpose of this course is to provide engineering undergraduate students with these fundamental modeling skills. More specifically, to provide information and tools to help students develop skills for creating mathematical models of physical, multi-media systems which can be effectively solved on a digital computer for purposes of control system design, performance evaluation, design sensitivity studies, model-based monitoring, etc..

Course Idea and Methods:

The idea behind this course is to use a unified approach to abstracting real mechanical, fluid, and electrical systems into proper models in graphical and state equation form to meet engineering design and control system objectives. The emphasis is not on the mechanics of deriving equations but rather on understanding how the engineering task defines the modeling objectives which in turn determines what modeling assumptions are appropriate. A variety of modeling graph languages exist (e.g., bond graphs, linear graphs, block diagrams) that can represent the models of the multi-energy domain systems. Regardless of the representation used, models are checked for consistency with basic energy conservation and power continuity laws. System analysis tools are used to determine the correctness of the modeling assumptions. If bond graphs are used, cauality can also be used to determine the correctness of the modeling assumptions. System analysis techniques include: free and forced response, model solutions, eigenvalues and eigenvectors, s-plane analysis and frequency response methods. In addition, numerical integration techniques, linearization, system representation techniques are presented. Several project like problem sets are required to reinforce the theoretical concepts presented in the lecture. Most of the projects require computer simulation and thus a complete array of modeling skills will be developed in this course. The key exception to this, of course, is that no skills with regard to the design of experiments needed to determine model parameters or to perform model validation studies are developed.

Instructors:

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Grading:	Problem Sets and Projects[1]	30 %
	Exam #1	15 %
	Exam #2	15 %
	Final Exam	40 %

Grading Policy: ALL MATERIALS ARE DUE AT TIME AND DATE INDICATED ON EACH PROBLEM SET. THE MATERIALS ARE TO BE TURNED INTO 2250 GGB TO Melanie Panyard. Late materials will not be accepted. If you are going to be away, it is your responsibility to turn your work in before you leave. If you wish to mail, fax etc the material to me you must first get permission to do so. ,You are also responsible for late, lost, illegible or other disruptions in getting your problems sets turned in on time. Do not depend on the ME Dept. staff without making specific agreed to requests. Include my name, and the GSI's name, course name, number and **section**. Please keep abreast with the schedule.

Policy on Homework Preparation

All problem sets (homework assignments) are to be completed on your own. You **are** allowed to consult with other students in the current class during the conceptualization of a problem **but** all written work, whether in scrap or final form, are to be generated by you working alone. You are not allowed to sit together and work out the details of the problems with anyone. You are not allowed to discuss the problem set with previous class members, nor anyone else who has significant knowledge of the details of the problem set. Nor should you compare your written solutions, whether in scrap paper form, or your final work product, to other students (and vice versa). You are also not allowed to possess, look at, use, or in anyway derive advantage from the existence of solutions prepared in prior years, whether these solutions were former students' work product or copies of solutions that had been made available by me. Violation of this policy is grounds for me to initiate an action that would be filed with the Dean's office and would come before the College of Engineering's Honor Council. If you have any questions about this policy, PLEASE do not hesitate to contact me.

Exams:

Un-excused absence from an examination will result in a grade of zero for that exam.

Regrade Policy:

If you have a question about the grading of your problem set (ps), please attach a note by stapling a full 81/2 by 11 inch piece of paper to your ps with your name, date and a description of which problem(s) you have a concern about the grading and why. Please be as specific as possible. Submit this to **Melanie Panyard**, in 2250 ggb. Say its is for the ME360 Regrading Folder.
The grader periodically checks for documents in this folder, replies to the questions submitted and returns the regraded problem set to the same folders used for returning problem sets (i.e., the envelopes in the reception area of 2250). If you are unsatisfied with the grader's response, then you will need to come to me during my office hours.

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[1] There will be approximately 9 problem sets and three projects. The weighting of these are not all equal. In general, the first couple of problem sets and first projects carry less weight than the others. In general, assignments that require the most complex and time consuming work are weighted the most.

Finally, in order to make everything flow smoothly, I ask that all regrade requests be make NO LATER THAN TWO (2) WEEKS after the problem set is returned. Regrade requests made after this period will not be honored.

Classroom Etiquette

- Please do not engage in any activities during class that might interfere with your classmates. This includes such things as reading the newspaper, coming late to class, leaving class early, etc…
- Please carry out all materials that you bring to class. This is particularly true for newspapers, coffee cups, snack food wrappers.

References

Course Text:
"Engineering System Dyanmics: A Unified Graph-Centered Approach" Forbes T. Brown (Lehigh University, Pennsylvania) August 2001, Marcel Dekker, ISBN 0-8247-0616-1. The price should be about $85.

A good supplemental text (not required):
Rosenberg and Karnopp, Introduction to Physical System Dynamics, 1983 McGraw Hill.
Karnopp, Rosenberg and Margolis, System Dynamics: Modeling and Simulation of Mechatronic Systems, 3rd Edition, Wiley-Interscience, 2000. Used copies should be available.

Course Software:
20SIM from Control Lab Products, Matlab from Mathworks

Additional References: Most are available at the North Engineering Library.

Antsaklis, P. J. and A. N. Michel, Linear Systems, McGraw-Hill, 1997.
Cannon, Robert, Dynamic Physical Systems, McGraw Hill 1967.
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Chapman, Bahill, and Wymore, Engineering Modeling and Design, CRC 1992.
Chen, C.-T., Linear System Theory and Design, 2nd edition, , Holt, Rinehart and Winston, 1984.
Close and Frederick Modeling and Analysis of Dynamic Systems,. Houghton-Miflin,
Dorny, Nelson Understanding Dynamic Systems: Approaches to Modeling Analysis and Design, Prentice Hall, 1993.
Kailath, Thomas, Linear Systems, Prentice Hall, 1980
Karnopp and Rosenberg, Analysis and Simulation of Multiports
Karnopp and Rosenberg, System Dynamics: A Unified Approach, Wiley, 1975
Karnopp, Margolis and Rosenberg, System Dynamics: A Unified Approach, 2nd Ed., Wiley, 1990
Ogata, Katsuhiko System Dynamics Prentice Hall, 1992.
Rosenberg and Karnopp, Introduction to Physical System Dynamics, McGraw Hill, 1983
Rowell, D. and Wormley, D.N. System Dynamics: An Introduction, Prentice Hall, 1997.
Schultz and Melsa, State Functions and Linear Control Systems, McGraw Hill, 1967
Shearer and Kulakowski, Dynamic Modeling and Control of Engineering Systems, MacMillan, 1990.
Shearer, Murphy and Richardson, Introduction to System Dynamics, Addison and Wesley, 1971
Smith, Introduction to Dynamic Systems Modeling for Design, Prentice Hall, 1994.
Takahashi, Rabins & Auslander, Introducing Systems and Control, Addison & Wesley, 1972
Wellstead, Introduction to Physical System Modeling, 1979?

COURSE OBJECTIVES

See (http://www.engin.umich.edu/dept/meam/ASO/undergrad/courses/CourseObjs.html)
(numbers shown in brackets are links to department educational outcomes)

1.To teach students elementary tools of modeling of mechanical, electrical, fluid, and thermofluid systems [1, 5,11].
2.To teach a basic understanding of behavior of first- and second-order linear time-invariant differential equations [1, 12, 13].
3.To teach basic concepts of Laplace transforms, transfer functions, and frequency response analysis [12].
4.To introduce the concept of stability and the use of feedback control to actively control system behavior [1, 3, 5].
5.To provide examples of real-world systems to which modeling and analysis tools are applied (e.g., automotive shock absorber) for the purpose of design [11].
6.To introduce an appreciation for decision-making skills needed to devise models that adequately represent relevant behaviors yet remain simple [1, 5].
7. To teach basic concepts in numerical integration and computer simulation of mathematical models.

COURSE OUTCOMES*

(numbers shown in brackets are links to course objectives)

1.Given a description of a real-world system, make educated decisions about how to model it in terms of idealized, lumped elements [1, 5, 6,7].
2.Given a simple system containing some combination of mechanical, electrical, and/or thermofluid elements, write a differential equation describing its input/output behavior [1].
3.Given a first- or second-order LTI differential equation, predict its step response or free response [2].
4.Given a LTI differential equation and a sinusoidal input, predict the gain and phase of the steady-state output as a function of input frequency [3].
5.Given certain desired performance characteristics for a system (such as maximum overshoot due to a step input), translate specifications into design parameters (such as the dimensions of a coil spring) necessary to provide those characteristics [4, 5, 7].
6.Given a physical description of a system and a graphical representation of its time-domain response (step, frequency, etc.), estimate system parameters (i.e. friction or damping coefficient, spring constant) [3, 4, 5].
7.Given a LTI differential equation and an arbitrary input composed of steps, ramps, and other simple functions, set up the solution using Laplace transforms [3].
8.Describe basic applications of proportional and derivative feedback in control systems to improve performance or stability [4].
9.Given a system composed of mixed mechanical/electrical/thermofluid components, write the transfer function describing input-output behavior [1, 3].
10.Given a system with given performance, describe (qualitatively) how behavior can be improved according to specifications such as overshoot and settling time, using some combination of parameter tuning and feedback control [2, 4, 5, 7].
11.Describe how changes in parameter values will affect damping ratio and natural frequency for a system, and how these characteristics are manifested in the system's behavior [2, 3, 7].
12.Implement a mathematical model into commercial simulation software, and excersize the model to make engineering assessments. [2, 5, 6, 7].