ME 253 – Linear Systems Theory

Catalog Description:
Mathematical modeling of dynamic systems, linearization of nonlinear behavior, Laplace domain representation of dynamics, transfer functions, block diagram algebra, signal flow graphs, Mason’s rule, transient analysis of system response, convolution integral, Duhamel's integral, Green’s function, stability of linear systems, Routh-Hurwitz method, root locus, frequency response, Bode and polar representations, introduction to feedback systems.

Prerequisites:
♦ CE 212 – Applied Mechanics
♦ MATH 211Q – Elementary Differential Equations

Texts:

Course Objectives:
This course is designed to expose students to the properties of linear systems and the use of various modeling tools. Laplace transformation representations of dynamic systems and MATLAB-Simulink programming packages are used. Linear system stability is discussed using Routh stability criterion and Root locus techniques. Frequency response concept is addressed.

Topics:
♦ Ordinary differential equations
♦ Laplace domain representation of dynamics
♦ Mathematical modeling of dynamic systems
♦ Block diagram algebra
♦ Time domain analysis of system response
♦ Stability of linear systems
♦ Frequency domain analysis

Design Projects:
Not applicable

Computer Use:
Various simulation and modeling software (such as MATLAB, Simulink and Maple) are available for use by the students. In addition to analytical software, students are required to use available word processing software to complete homework projects.

Evaluation Methods:
Homework = 10%
Quiz = 20%
Midterm Exam = 30%
Final Exam = 40%

Contribution to Professional Component:
This course builds upon the fundamentals of statics, dynamics and differential equations. The course provides the necessary building blocks for Measurement Techniques (ME 260W) and the Senior Design capstone course (ME 272P/273P).

Relationship of Course Objectives to Program Educational Objectives:
As a junior level course in Mechanical Engineering, ME 253 emphasizes abilities and skills leading to the fulfillment of Program Educational Objective #1: “our alumni practice mechanical engineering by designing systems and solving problems using mathematical, scientific and engineering principles and tools,” and Program Educational Objective #3: “our alumni continue to expand their professional and personal skills and engage in life-long learning.”

Relationship of Course Objectives to ABET 3a-k:

a)  an ability to apply knowledge of mathematics, science, and engineering:
   In this course students start with the linear ordinary differential equation solutions, Laplace transformations, and transfer function representations of dynamics, and continue with the broader understanding of dynamic responses. Using programming tools such as MATLAB and Simulink, students gain expertise in debugging numerical outcomes using engineering insight and mathematical functions.

b)  an ability to design and conduct experiments, as well as analyze and interpret data:
   Through the use of modeling and simulation tools students are exposed to design alternatives and corresponding system response. Students learn to draw conclusions based on the response properties obtained.

c)  an ability to design a system, component, or process to meet desired needs:
   Students are required to complete an open-ended design project using modeling, simulation and animation tools.

d)  an ability to function on multi-disciplinary teams: not applicable

e)  an ability to identify, formulate, and solve engineering problems:
   Students gain an understanding that every linear system can be broken into first and second order dynamics, and that these are the building blocks of more complex systems. Students learn how to assess the systems response to a set of conventional driving functions (such as step, impulse, ramp and sine functions). Based on this, students can troubleshoot and interpret the simulation results obtained through MATLAB/Simulink.

f)  an understanding of professional and ethical responsibility: not applicable

g)  an ability to communicate effectively: not applicable

h)  the broad education necessary to understand the impact of engineering solutions in a global and societal context: not applicable

i)  a recognition of the need for, and an ability to engage in life-long learning:
   The need for life-long learning is reinforced by exposure to new developments in modeling and simulation tools, as emphasized by the changing popularity of the various commercial packages.

j)  a knowledge of contemporary issues: not applicable

k)  an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice:
   Students learn to work with the underlying analytical tools which give them greater decision making abilities. Advanced modeling and simulation tools, such as MATLAB/Simulink are used in this course.

Relationship of Course Objectives to Course Outcomes:

1)  Students will be able to apply Laplace transforms in linear system modeling.
2)  Students will be able to solve ordinary differential equations (ODE) using Laplace transformations.
3)  Students will be able to model mechanical dynamic systems.
4)  Students will be able to model hydraulic dynamic systems.
5)  Students will be able to model thermal dynamic systems.
6)  Students will assess the fundamental characteristics of first order systems.
7)  Students will assess the fundamental characteristics of second order systems.
8)  Students will assess the fundamental characteristics of higher order systems.
9)  Students will be able to model systems using MATLAB/Simulink tools.
10) Students will be able to perform parametric analysis of system properties using MATLAB.
11) Students will be able to examine the output signatures of a linear system in response to a step input.
12) Students will be able to examine the output signatures of a linear system in response to an impulse input.
13) Students will be able to form transfer functions to represent input-output relations for dynamic systems.
14) Students will be informed about the connection between the system behavior and characteristic root distribution.
15) Students will be able to extract the root distribution of the linear systems using Routh-Hurwitz method.
16) Students will know how to assess the frequency response of a linear system.

Approval Block:
Prepared by: J. Tang and N. Olgac, Sept. 15, 2005
Reviewed by: K. Kazerounian, Oct. 12, 2005
Revised by:
C&C Approval: October 21, 2005
Dept. Head Approval: