MODELING & CONTROL OF DYNAMIC SYSTEMS (1460) **FALL 2007**

UNITED STATES COAST GUARD ACADEMY
DEPARTMENT OF ENGINEERING

Course Description: The introduction to modeling mechanical systems and obtaining time-domain and Laplace-transform solutions. An emphasis is placed on understanding the fundamentals of simple, damped, and forced oscillations, transient response, and mechanical resonance. The commonality of modeling and analysis techniques is stressed, as well as the use of differential equations. Fundamentals of automatic control systems are discussed, including block diagram, root locus, Bode diagrams, as well as proportional, proportional and derivative, and proportional-integral-derivative feedback control systems. Includes incorporation of computer solutions to analyze and control linear dynamic systems.

Course Objectives: The goal of this course is to give the students a foundational understanding of the underlying physical dynamics of all systems, whether they are mechanical, electrical, fluid, etc., and then apply that understanding to modeling, simulation, and control. Students learn how to develop lumped-parameter models of real physical systems, develop the differential equations of motion for the system, linearize the differential equations of motion about an operating point, and produce the transfer function for the system. Students learn how to use various analytical and numerical techniques to optimize the performance of a controlled system.

Text: Palm, William III. System Dynamics, 1st Ed. 2005. McGraw Hill.

References: As required.

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Grading:	Homework/Quizzes	25 %	Exams (3)	40 %	Project	10%
			Final Exam	25 %		

Grades: Grades will be based on the following scale with plus/minus applied if appropriate:
A: 90-100 B: 80-89.9 C: 70-79.9

Course Structure: Lectures, reading, and homework will be integrated to promote effective use of time and development of engineering analysis and problem solving skills. You will need to be proactive, think critically, and use your time effectively. Your learning and motivation are your responsibility. If the expectations for any instruction are unclear it is your responsibility to seek clarification from the instructor. Lack of understanding of the instructions or citing of alternate standards used by other instructors or students are not valid reasons for unacceptable submittals. This course is provided at great expense to the taxpayer and shall be conducted accordingly.

Reading: Reading assignments are listed in the schedule. Students should read each section prior to lecture at a level that prepares them to participate in class. Students should go back to the text after class to develop a detailed understanding.

Lecture: It is assumed students have completed the assigned reading and will ask questions. Lecture time will generally be devoted to definitions, key concepts, and the solution of example problems. Students are expected to bring a writing instrument to class. Computers shall not be used in class without instructor approval. Proper military etiquette will be observed at all times and a lack of attention is unacceptable. Failure to respect this will result in removal from class, remediation under the conduct system, and grade reduction on applicable assignments.

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Homework: The homework problems on the course schedule are subject to change and may be weighted differently for grading. Homework shall be on the podium prior to the beginning of class on the date due. Late homework will be accepted for half credit at any time up to the start of the next scheduled exam. Homework submitted after the start of class or in the wrong format will be considered late.

Homework shall be completed in composition books with lined or blank pages. Begin each problem on a new page. Each page shall have at least ½" margins on all sides. Titles across first page must include: **"Date", "Assignment Number", "Page # / Total # of Pages"**. Subsequent pages shall include **"Page # / Total # of Pages"**. Include a detailed problem statement by identifying "**Given**" information, what you must "**Find**", your "**Audience**", appropriate sketches, and calculations with explanations and assumptions. Explanations shall include sources of information and comment on the solution. Answers must be clearly identified. Alternatively a three ring binder with green paper may be used provided all assignments are included in chronological order and no extraneous notes or papers are contained.

Your presentation of homework should focus on communicating effectively what you have done, why you have done it, and how you have done it. You are responsible for the failures of technology, so plan ahead, save early, and save often. Neatness counts. Excessive messiness or spelling and grammatical errors shall be deemed unacceptable. Any attached pages must be neatly glued or taped.

Exams and Quizzes: Formal exam dates are specified on the course schedule. The final exam is mandatory and will be given as scheduled by the registrar. Unannounced quizzes may be given.

Collaboration, Assistance, and Documentation**:** Small group collaboration with other students on homework in which each student works on and understands the solution to each problem is encouraged and permitted unless specifically instructed otherwise. All assistance or guidance, written or otherwise, from someone or something other than the student submitting it for credit must be documented on each submittal with a brief statement specifying the source and type of collaboration. The use of specific instructor solution manuals in any engineering course at CGA is specifically prohibited. Electronic and print copies of *Systems Dynamics* solution manuals are forbidden.

Achieving ME Program Outcomes: ABET has specified the following for all undergraduate engineering majors. Objectives in italics are those for which some knowledge development should occur as a result of completing this course. Those in bold indicate significant knowledge development should occur.

1. ***An ability to apply knowledge of mathematics, science and engineering***
2. An ability to design and conduct experiments as well as to analyze data
3. *An ability to design a system, component or process to meet desired needs*
4. An ability to function on multi-disciplinary teams
5. ***An ability to identify, formulate and solve engineering problems***
6. An understanding of professional and ethical responsibility
7. An ability to communicate effectively
8. The broad education necessary to understand the impact of engineering solutions in a global and societal context
9. *A recognition of the need for and an ability to engage in life-long learning*
10. A knowledge of contemporary issues
11. *An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*
12. *An ability to develop as leaders in the Coast Guard.*

Additional ABET requirements for graduates of Mechanical Engineering programs include:

1. *Knowledge of chemistry and calculus based physics with depth in at least one;*
2. ***Ability to apply advanced mathematics through multivariate calculus and differential equations;***
3. Familiarity with statistics and linear algebra;
4. The ability to work professionally in both thermal and mechanical systems areas including their design and realization.

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Tentative Schedule updated 20 SEP 07

			LECTURE TITLE	**Reading (Due)**	**HW (Assigned)**	**HW (Due)**
1	Th "M	8/23	Course Intro;	Chpt 1	1: HW1	
2	M	8/27	Intro/Review Mechanical System Modeling – D'Alembert, Gen'l Planar Motion	2.1 – 2.2	2: HW2	
3	W	8/29	Review Mechanical Modeling – Translational & Rotating Systems	2.3 – 2.4	3: 2.28	1, 2
4	F	8/31	Review Model Solution Methods – Classical Approach	3.1-3.2	4: 3.1, 3.3a, 3.4a	
		9/3	**LABOR DAY**			
5	T "M"	9/4	Review Model Solution Methods – Laplace Transforms	3.3	5: HW5	
6	W	9/5	Review Model Solution Methods – Transfer Functions	3.4, 3.5	6: HW6	3, 4
7	F	9/7	Review Mechanical Modeling – Spring & Damping Elements	4.1, 4.4	7: 4.3, 4.5	
8	M	9/10	Review Mechanical Modeling – Spring Mass Damper Systems	4.2, 4.5	8: 4.35d	
9	W	9/12	**Exercises 1**		9: 4.40	5, 6, 7
10	F	9/14	Review Mechanical Modeling – Spring Mass Damper Systems 2		10: 4.48	
11	M	9/17	TBD		11: SKIP	
12	W	9/19	**Exam 1**		12: SKIP	8, 9, 10
13	F	9/21	Review Other System Modeling – Fluid, Thermal, & Electrical	6.2, 7.6	13: 6.5	
14	M	9/24	Mechanical Modeling – Alt Equn Formulation - Block Diagrams	5.1	14: 5.1, 5.5	
15	W	9/26	Mechanical Modeling – Alt Equn Formulation - State Variable Equations	5.2	15: 5.8, 5.9, 5.13	13, 14
16	F	9/28	Model Solution Methods – Matlab applications	2.5, 3.8-3.9, 4.6	16: 2.34, 4.51	
17	M	10/1	Model Solution Methods - Simulink applications	5.5-5.6	17: 5.35, 5.48	
18	W	10/3	Model Solution Analysis - Time domain– step & ramp response - 1st order systems	8.1	18: 8.1, 8.10, 8.14	15, 16
19	F	10/5	Model Solution Analysis - Time domain– step & ramp response - 2cd order sys	8.2	19: 8.16, 8.17a, 8.32	
		10/8	**COLUMBUS DAY**			
20	W	10/09	Model Solution Analysis - Time domain– Step response - a closer look	8.3	20: 8.36	17, 18, 19
21	F	10/12	**Exercises 2** {Parents Weekend}		21: SKIP	
22	M	10/15	Model Solution Analysis - Time domain – Impulse response - a closer look	8.4	22: 8.44	
23	W	10/17	Model Solution Analysis - Time domain – Matlab & Simulink applications	8.7-8.9	23: 8.70	20, 22
	F	10/19	Model Solution Analysis - Time domain – sinusoidal response, a closer look		24: SKIP	
24	M	10/22	Model Solution Analysis - Freq domain – sinusoidal response of 1st order systems	9.1	25: 9.5	

25	W	10/24	Model Solution Analysis - Freq domain – sinusoidal response of higher order systems	9.2	26: 9.17	23
26	F	10/26	**Faculty In Service Day**			
27	M	10/29	Model Solution Analysis - Freq domain – additional examples	9.3	27: 9.22	
28	W	10/31	**Exam 2**		28: SKIP	25, 26, 27
29	F	11/2	Model Solution Analysis - Freq domain – Filtering properties of systems	9.4	29: 9.37	
30	M	11/5	Model Solution Analysis - Freq domain – Matlab applications	9.6-9.7	30: 9.44	
31	W	11/7	**Exercises 3**		31: SKIP	29, 30
32	F	11/9	Control Systems - Intro	10.1-10.2	32: 10.1, 10.2	
	M	11/12	**VETERAN'S DAY**			
33	T "F"	11/13	Control Systems – Modeling	10.3	33: 10.6	
34	W	11/14	Control Systems – PID Algorithm	10.4	34: 10.8	32, 33
35	F	11/16	Control Systems – Analysis	10.5	35: 10.14	
36	M	11/19	Control System – Performance	10.6 – 10.8	36: 10.20	
	W	11/21	**THANKSGIVING LEAVE**			
	F	11/23	**THANKSGIVING LEAVE**			
37	M	11/26	Control System – Matlab & Simulink applications	10.9 -10.10	37: TBD	
38	W	11/28	Control System Design – Root Locus Plot	11.1	38: TBD	34, 35, 36
39	F	11/30	Control System Design – Series Compensation		39: TBD	
40	M	12/3	Control System Design – Root Locus Plot		40: TBD	
41	W	12/5	Project		41: SKIP	37, 38, 39, 40
42	F	12/7	Project		42: SKIP	
43	M	12/10	Project		43: SKIP	
44	W	12/12	Project		44: SKIP	Project
	Th	12/13	**STUDY & CONFERENCE DAY**			

- Not all assignments are listed. Students are responsible for recording changes.
- Instructor will not field homework questions on the day the assignment is due.