ME 450-1: Modeling of Dynamic Systems
Course Syllabus – Fall 2008, Section 1

Instructor:	Dr. Sean Brennan E-mail: sbrennan@psu.edu Office: 318 Leonhard Building Standard office hours: (no appt necessary, but a "heads-up" is nice). Wednesdays: 1:00 pm – 3:00 pm Conflict hours: (only by appointment) Monday or Friday: 2-3:30 pm, first-come, first-serve.
TA's:	Willie Streeter and Zheqian Zhang E-mails: wcs149@psu.edu; zxz133@psu.edu Offices and Hours of availability: TBD
Class Schedule:	MWF, 10:10A - 11:00P, 102 LEONHARD
Prerequisites:	ME 54, ME 82. Most students will take ME450 in their 7th semester
Optional Text:	*Dynamic Modeling and Control of Engineering Systems* by J. L. Shearer, B. T., Kulakowski, and J. F. Gardner, Sec. Ed., Prentice Hall 1997.
Required Software:	MATLAB, Student Edition (~$100)
References:	System Theory: *Analog and Digital Signal Processing, Second Ed.* Ashok Ambaradar. 1999, *System Dynamics* by K. Ogata, Third Ed., Prentice Hall 1998. Differential Equations: *Elementary Differential Equations and Boundary Value Problems* by W. E. Boyce and R. C. DiPrima, Sixth Ed., John Wiley & Sons 1997; *Differential Equations* by Paul Blanchard, Robert L. Devaney, and Glen R. Hall, 1998. Control Theory: *Feedback Control of Dynamic Systems* by G. F. Franklin, J. D. Powell and A. Emami-Naeini, any edition, Prentice Hall; *Modern Control Theory* by W. L. Brogan, 3rd ed., Prentice Hall 1990.

Grading Option I: An initial grade based on 500 total points will be assigned after the third exam. If the student is satisfied with this grade, then the Final Exam is not required.

3 exams	= 300 points
homework	= 120 points
final project	= 30 points
quizzes+muddiest points	= 50 points
Total	**500 points**

Grading Option II: If the student is not satisfied with their Option 1 grade, a final exam (comprehensive) may be taken. In this case, the grade will be based on 650 total points. The percentage score required to achieve each grade will be identical to that of Option I.

option 1 points	= 500 points
final exam	= 150 points
Total	**650 points**

As a philosophy, homework is graded especially hard, and exams are graded slightly easier. Both are of similar difficulty. Quizzes will be given on random dates. No make-ups of quizzes are allowed without prior permission. In accordance with the policy of this University, all students are encouraged to attend every class period. While the lecture content will nominally follow the syllabus, some rescheduling may occur depending on how students are absorbing content.

Course Description

The primary objective of the course is to give the students the skills and knowledge required so they can mathematically model and apply simple controls to engineering systems. These include mechanical, electrical, thermal, and fluid systems. The emphasis is on the processes of energy storage and dissipation that are common for the different kinds of engineering systems. Students will learn how to identify the inherent dynamic characteristics of systems: system order, transient response characteristics, linearity, etc. While modern techniques for mathematical modeling and computer simulation of engineering systems are presented, the importance of *critical and intuitive understanding* the physical processes taking place in dynamic systems is stressed throughout the course material. Approximately one third of the course is devoted to the basic methods for analysis and design of natural and human-made feedback systems. The main content will be restricted to linear-time-invariant (LTI) systems; however, linearization around nominal operating points will be taught as a method to study nonlinear systems. The role of feedback in automatic control systems is discussed in the context of natural negative feedback that is present in all physical, biological, economic, social, and other types of processes as well as human-designed feedback systems.

Course Objectives

Upon completion of the course, students should be able to:

1. Recognize energy storing elements in an engineering system and distinguish appropriate state variables.
2. Write ODE's which describe the dynamic behavior of lumped parameter systems including mechanical, fluid, thermal and electrical elements.
3. Analytically solve linear ODE's for response to initial conditions, external disturbances, and known forcing functions.
4. Evaluate stability of linear-time-invariant systems.
5. Evaluate system performance in terms of "time constant" for first-order LTIs and "damping ratio" and "natural frequency" for second-order LTI systems. Students should understand how to approximate behavior of high-order LTI systems with low-order models as well as a steady-state response.
6. Analyze nonlinear systems by local linearization around nominal operating points.
7. Draw block diagrams for LTI systems from the system equations and vice versa: write system equations from block diagrams.
8. Understand the basic concepts of feedback control, the objectives and functions of proportional (P), integral (I), and derivative (D) feedback controls. Design PID feedback controllers for simple linear systems.
9. Sketch bode and root-locus plots and use these sketches to analyze system stability and expected performance.
10. Use Matlab/Simulink as a tool to study system stability and performance both in time and frequency domain.
11. Apply system knowledge to contemporary systems and the surrounding world.

Some messages from previous students:
"It was fun to learn how so many real world applications can apply to so much we are taught as engineers. It reaffirms for me that I am where I want to be for my profession and I thank you for that." - End of semester quote from the Fall 2007 class

Academic Integrity: Academic integrity is the pursuit of scholarly activity in an open, honest and responsible manner. The University's Code of Conduct states that all students should act with personal integrity, respect other students' dignity, rights and property, and help create and maintain an environment in which all can succeed through the fruits of their efforts. Academic integrity includes a commitment not to engage in or tolerate acts of falsification, misrepresentation or deception. Such acts of dishonesty violate the fundamental ethical principles of the University community and compromise the worth of work completed by others. The academic integrity web site for the College of Engineering is at http://www.engr.psu.edu/www/ug/acad_int/students/default.htm (there's an underline in acad_int).

Specific to this class:

1. Group work: Students are encouraged to study in groups, and teach each other concepts, but homework and projects must be completed individually. While it is understood that students may work together in the preliminary stages of individual homework assignments (concept development), it is also understood that the final work handed in reflects individual efforts (numerical answers and answer approach should be unique). **MY criteria for working too closely: if I can spot that two (or more) people are working together solely by comparing their solutions, then in my interpretation, cheating has occurred! If you wish to work with someone but have questions whether a boundary has been crossed by working together, be sure to document who you work with as a statement at the end of the assignment!** For example: "I used the software model obtained from Brain E. Acc to do problem 4 because I couldn't find why mine wasn't working." You might get some points counted off still, but at least it isn't cheating.
2. Due dates: homework problems will usually be due at least a week after the initial assignment. Assignments will almost always be given on a Monday, and be due on the following Friday **before class starts**. Due to the large number of students in the class, **no credit will be given for late submissions**. Penalties are waived for special circumstances with an appropriate written excuse, as long as the student contacts the professor and their TA 24 hours in advance. Again, students who give advance notice (more than a day), will always be given consideration, even in cases where students are in an "assignment overload" situation.
3. Some examples of academically dishonest behavior:
   - Intentionally disrupting class, for example calling (or receiving calls) on a cell phone, walking in front of the class after lecture has started, etc.
   - Glancing at other peoples exams during a testing situation
   - Publicly releasing old/new class solutions, old exams, or lecture notes without prior written authorization of the professor.
   - Discussing exam content or difficulty with a student who must still take the exam.
4. Cheating: If a student is suspected of cheating, standard university policy applies. The situation will be discussed in private with the student and significant grade

sanctions will be imposed of **a minimum 20% off the assignment grade for the first warning, one class letter grade for second warning and written note added into the student's permanent file. Three warnings will result in automatic failure** from the class.

5. Gross Violations of Academic Integrity: If an individual encourages and facilitates academic dishonesty with multiple other students, this may be considered grounds for immediately applying an XF grade.

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Course Syllabus – Fall 2008

Class #	Date	Topics	Assignments
1	Monday, August 25	Missed class… Brennan out	
2	Wednesday, August 27	Syllabus and Concept Inventory	HW #1 Assigned
3	Friday, August 29	System Types	
Skip	Monday, September 01	Translational Mechanical Systems	HW #2 Assigned
4	Wednesday, September 03	**Labor Day – No Class**	
5	Friday, September 05	Rotational Systems and Coupling	HW #1 Due Solutions
6	Monday, September 08	Linearization	
7	Wednesday, September 10	Laplace Transforms	HW #3 Assigned
8	Friday, September 12	Laplace Transforms (continued…)	
9	Monday, September 15	IO Models	HW #2 Due Solutions
10	Wednesday, September 17	Partial Fractions again (if needed)	HW #4 Assigned
11	Friday, September 19	System Transfer Function	
12	Monday, September 22	Final Value Theorem	HW #3 Due Solutions
13	Wednesday, September 24	Final Value Theorem applications	
EXAM 1	TBD	Content: Lectures 1 - 12	
14	Friday, September 26	Numerical Methods / Simulations	HW #5 Assigned
15	Monday, September 29	Simulation Block Diagrams/Simulink	
16	Wednesday, October 01	First Order Systems	HW #4 Due Solutions
17	Friday, October 03	Second-Order Models	HW #6 Assigned
18	Monday, October 06	Third and Higher-Order Models Movies: -	
19	Wednesday, October 08	(review)	HW #5 Due Solutions
20	Friday, October 10	State-Space Models (see Lesson 16)	HW #7 Assigned
21	Monday, October 13	State-Space Models (see Lesson 16)	
22	Wednesday, October 15	Lectures 1 through 10	Examples of Exam1 Fa03 Solutions Sp05 Solutions
23	Friday, October 17	Dimensional Analysis (skip if behind)	HW #6 Due Solutions
24	Monday, October 20	Frequency Response Movies:	HW #8 Assigned
25	Wednesday, October 22	Frequency Response	

26	Friday, October 24	Electrical Systems: Circuit Laws	HW #7 Due Solutions
27	Monday, October 27	Electrical Systems: Circuit Laws	HW #9 Assigned
28	Wednesday, October 29	Electrical Systems: Examples	
29	Friday, October 31	Electrical Systems: Examples	HW #8 Due Solutions
30	Monday, November 03	Time Varying Capacitors/Inductors Movies: -	
31	Wednesday, November 05	Hydraulic Systems	
32	Friday, November 07	Hydraulic Systems	
33	Monday, November 10	Hydraulic Systems	
34	Wednesday, November 12		
35	Friday, November 14	Lectures 11 through 23	Examples of Exam2 Fa03 Solutions Sp05 Solutions
36	Monday, November 17	Hydraulic Systems	HW #9 Due Solutions
37	Wednesday, November 19	Hydraulic Systems	HW #10 Assigned
38	Friday, November 21	Pneumatic Systems	
Thanksgiving	Monday, November 24	Thermal Systems	HW #11 Assigned
Thanksgiving	Wednesday, November 26	Mixed Systems – Electric Motors Movies: - -	HW #10 Due Solutions
Thanksgiving	Friday, November 28	More Electric Motors	Final Project Assigned
39	Monday, December 01	Mixed Systems – Hydraulic Movies: -	
40	Wednesday, December 03	Mixed Examples/ Feedback Systems Movies: - -	
41	Friday, December 05	Control Systems Movies: -	
42	Monday, December 08		
43	Wednesday, December 10		HW #11 Due Solutions
44	Friday, December 12		
FINAL / Exam 3	TBD	Exam 3: Lectures 24 through 40 Final: comprehensive	Examples of Exam3 Fa03 Solutions Sp05 Solutions

Past Project Ideas:

(items with a * indicate that further work could be done for future projects)

2007 projects:

- Modeling the fill/empty of shopping carts in the parking lot of a grocery store using tank model and time-varying Qin, Qout describing functions. Data was taken from a local grocery store and fit with logistics curves. (*)
- Determining the transfer function of a cartridge-style printer sitting on top of a rickety shelf using frequency response methods.
- For a pile of boxes staked on top of a rolling cart, model the system dynamics resulting from someone standing on the cart trying to pull the top box off the stack.
- Model the world's energy consumption (a sister problem to modeling oil supply).
- Modeling the buoyancy force causing air to rise in a chimney, or oscillate in a Rijke's tube (*).
- Modeling the "flush" dynamics of a toilet using fluid modeling (*)
- Modeling the slap-shot: using a flexible stick approximation to determine how the "slap" speeds up the puck (*)
- Modeling the second-order flex response of a snowboard, and how active damper systems in a snowboard dampen out sinusoidal inputs at steady-state
- Determining the amount of time someone who falls through a frozen lake has to survive before freezing to death
- Modeling the dynamics of a candle burning from both ends and balanced about its midpoint (*)
- Modeling the electromechanical system related to a car lock-opening device.
- Modeling why a heavily loaded vehicle has a harsher ride than a lightly loaded vehicle
- Modeling an open-close motor mechanism
- Modeling the dynamics of the eyeball during tracking motion
- Determining the frequency response of "ghost blinds" that mysteriously oscillate in cold weather
- Modeling bounce of a person in a seat
- Modeling cruise control system oscillation and feedback controller design (*)
- Determining the input-output dynamics of a jug of water sliding across a desk
- Determining the coupling dynamics of a snow-making machine (*)
- Determining energy conversion efficiency of a faucet-powered turbine system
- Predict how long a rose will bloom assuming a first-order model (*)
- Modeling the suspension dynamics of a Chevy Camero
- Modeling the fill dynamics of a toilet, specifically calculating time you would have to find a plunger in the case of a clogged system!
- Modeling a hydroelectric dam (again)
- Modeling the dynamics of a rubber-band car!
- Using a wind-turbine generator to power a beer keg pump
- Analyzing and experimenting on the high-speed stability of turning vehicles to predict speed at which vehicles become unstable if tires are under-inflated.
- Determining the transfer function of a suspension system by using a sinusoidal road excitation

- Modeling Santa falling down a chimney using impulse-response methods
- Development of a simple, low-order model capable of predicting the cyclical ice-age cycles. The model required extensive research into the global emissivity changes due to Antarctic ice cover as well as modeling the precipitation rates as a function of global temperature. The result is a nonlinear feedback loop on the water cycle that produces a stable cycle with a period of approximately 120 thousand years, with 100 thousand years of ice and 20 thousand years of warmth. The model also suggests that global warming may accelerate the onset of the next ice age. (**)
- Determining which of several wine glasses is the most expensive by examining resonance phenomena, then predicting resonance as a function of thickness by linearizing the nonlinear stiffness equations.
- Modeling the performance of steam-powered centrifugal machine guns (*)
- Calculating how many pumps of a keg will cause particular beverages to flow
- Model the air brakes on a tractor-trailer system (*)
- Analysis of the open/close pneumatic actuators for a building ventilation system
- Modeling a gutter system as cascaded tank systems (*)
- Analyze the filling of a pool with a leaky drain
- Optimize the design of a wind turbine
- Develop a model that demonstrates the momentum transfer that causes the cat to always land on its feet. Then, using this model and experiments with actual cats, estimate the physical fitness of fat cats by dropping upside down (above a bed) at lower and lower heights to find the one at which the cat will not land on its feet. Show using simulations that the lowest height requires the most torque and therefore the highest fitness.