2017

MECH 350: Introduction to Dynamics and Controls of Engineering Systems—A Peer Review of Teaching Project Benchmark Portfolio

Benjamin S. Terry

University of Nebraska-Lincoln, bterry2@unl.edu

Follow this and additional works at: http://digitalcommons.unl.edu/prtunl

Part of the Higher Education Commons, Higher Education and Teaching Commons, and the Mechanical Engineering Commons


http://digitalcommons.unl.edu/prtunl/88

This Portfolio is brought to you for free and open access by the Peer Review of Teaching Project at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in UNL Faculty Course Portfolios by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.
MECH 350: Introduction to Dynamics and Controls of Engineering Systems—A Peer Review of Teaching Project Portfolio

Benjamin S. Terry

University of Nebraska-Lincoln, bterry2@unl.edu
Abstract

There are two purposes of this portfolio. The first purpose is to outline and explain my approach to teaching this classic and fundamental course. I highlight in detail the purpose and curricula, the desired outcomes, and the goals and objectives. I also describe how the course activities and my teaching methodology support the course objectives. The second purpose of this portfolio is to describe a simple course modification—the introduction of a recitation session—and to test in a preliminary way the effect of this change on students’ attitudes towards the examples worked out in class. The results show that in the Spring 2017 semester, the students expressed higher favorable opinions (19.3%) regarding the examples worked out in class and during the recitation session than any other semester. On the other hand, students expressed the second highest unfavorable opinion (12.3%) regarding examples. No improvement is seen in students’ attitudes of how well new concepts and examples are explained.

Keywords: Undergraduate teaching, curriculum, dynamics and controls, engineering systems, recitation.
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5</td>
<td>Planned changes for future MECH 350 instruction</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>Summary</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>Citations</td>
<td>17</td>
</tr>
<tr>
<td>7</td>
<td>Appendices</td>
<td>18</td>
</tr>
<tr>
<td>7.1</td>
<td>Syllabus</td>
<td>18</td>
</tr>
<tr>
<td>7.2</td>
<td>Example of Introductory Material</td>
<td>22</td>
</tr>
<tr>
<td>7.3</td>
<td>Example of a Reading Quiz</td>
<td>23</td>
</tr>
<tr>
<td>7.4</td>
<td>Example of Notes</td>
<td>24</td>
</tr>
<tr>
<td>7.5</td>
<td>Example of Homework Assignment</td>
<td>28</td>
</tr>
<tr>
<td>7.5.1</td>
<td>Assignment</td>
<td>28</td>
</tr>
<tr>
<td>7.5.2</td>
<td>Assignment output</td>
<td>30</td>
</tr>
<tr>
<td>7.6</td>
<td>Example of Course Project</td>
<td>40</td>
</tr>
<tr>
<td>7.6.1</td>
<td>Project</td>
<td>40</td>
</tr>
<tr>
<td>7.6.2</td>
<td>Project output</td>
<td>46</td>
</tr>
<tr>
<td>7.7</td>
<td>Example of an Exam Question</td>
<td>47</td>
</tr>
<tr>
<td>7.8</td>
<td>Complete course evaluations from Spring 2017</td>
<td>50</td>
</tr>
</tbody>
</table>
1 Introduction and objectives of course portfolio

There are two purposes of this portfolio. The first is to outline and explain my approach to teaching the classic and fundamental course of Dynamics and Control of Engineering Systems (see Appendix 7.1 for course syllabus). I highlight in detail the purpose and curricula, the desired outcomes, and the goals and objectives of the course. I also describe how the course activities and my teaching methodology support the course objectives. The second purpose of this portfolio is to describe a simple course modification—the introduction of a recitation session—and to test in a preliminary way the effect of this change on students’ attitudes towards the examples worked out in class. The motivation behind adding the recitation session is from written feedback from the students from five previous semesters. The single change to the course explored in this portfolio (the addition of a recitation session) is one small step toward achieving my overall lofty goal of students scoring 90% or better on the final exam.

2 Reflections on the course syllabus

In this section I provide a description of the course, the goals and objectives of the course, and how these goals and objectives are reflected in the daily course structure.

2.1 Description of the Course

**UNL Course Description:** Unified treatment of the dynamics and control of engineering systems. Emphasis on physical aspects, formulation of mathematical models, application of various mathematical methods, and interpretation of results in terms of the synthesis and analysis of real systems.

**Detailed Course Description:** This course presents methodology for modeling and analyzing a variety of dynamic systems, irrespective of their physical origin. Although it focuses on systems that mechanical engineers typically encounter in practice, the approach and methodology can be applied to any system that is amenable to modeling via first principles that result in differential equations. It includes detailed modeling of mechanical, thermal, fluid, electrical, and electro-mechanical systems. Models are developed in the form of input-output differential equations, state-variable equations, transfer functions and block diagrams. The differential equations are solved analytically using the Laplace-transform method. MATLAB and Simulink are also used to achieve solutions via computer.

2.1.1 Purpose of the course

The purpose of this course is to provide an introductory treatment of certain types of dynamic systems that are typically encountered by mechanical engineers. The course also provides a foundation for subsequent courses in dynamics, vibration, circuits, electronics, chemical process control, linear systems, feedback systems, nuclear reactor control, and biocontrol systems.

2.1.2 Curricula

The course is required for Mechanical and Materials Engineering (MME) students and the department recommends students take this course in their junior year. The student should have knowledge of differential and integral calculus and basic college physics. It is also recommended that students take concurrently (or have taken) differential equations. Specifically, the prerequisites for the course are MECH 373 (engineering dynamics), ELEC 211 (elements of electrical engineering), and MATH 314 (linear algebra). The course (or its equivalent) is also a core requirement for the Minor in Robotics Engineering, which is generally pursued by those in the engineering disciplines.
2.1.3 Students
Historically, the course roughly consists of two-thirds of those in their junior year and the remaining who are seniors and ambitious sophomores. Students outside the MME department infrequently enroll in this course because of the large number of MME prerequisites.

2.1.4 The course and the broader curriculum
This course is considered foundational in that it is a prerequisite for nearly all of the senior-level curriculum (MECH 380, MECH 444, MECH 445, MECH 446, MECH 450, MECH 453, MECH 455, MECH 457, and MECH 483).

2.2 Goals and objectives of the course
The course is based on the classic text “Modeling and Analysis of Dynamic Systems” by Close and Frederick. The scope and detail of this text are appropriate for a very rigorous single-semester course and are grouped into four primary topic areas:

1) Modeling of mechanical and electrical systems.
2) Analytical solutions for linear systems and linearizing nonlinear system models.
3) Modeling other types of systems.
4) Block diagrams, feedback systems, and design tools.

The following details are the specific goals of the course in terms of knowledge, abilities, understanding, retention, perspectives and attitudes.

2.2.1 Knowledge
At the termination of the course, the student should be able to:

1) Given a description of a dynamic system, construct a simplified version using idealized elements and define a suitable set of variables.
2) Use the appropriate element and interconnection laws to obtain a mathematical model generally consisting of ordinary differential equations.
3) If the model is nonlinear, determine the equilibrium conditions and, where appropriate, obtain a linearized model in terms of incremental variables.
4) Arrange the equations that make up the model in a form suitable for solution, and use them to construct and simplify block diagrams.
5) For a first-order system, solve directly for the time-domain response without transforming the functions of time into functions of other variables.
6) For a model of up to fourth order, use the Laplace transform to find the complete time response, determine the transfer function and its poles and zeros, analyze stability, etc.
7) Find from the transformed expression the steady-state response to a constant sinusoidal input without requiring a general solution.
8) Use Matlab to:
   o Obtain the response of a system to initial stored energy and to arbitrary inputs.
   o Study the influence of changing system parameters on the system response, and predict the response.
   o Create root-locus plots, bode diagrams, etc. as aids in analyzing and designing feedback systems.
9) Use the C programming language to program an Arduino microcontroller to control an electrical or electromechanical device.

2.2.2 Abilities, understanding
Students should be efficient, confident, and accurate in applying the knowledge of 2.2.1. Here efficiency is defined as the ability to quickly recall from memory (or possibly with the aid of a few pages of notes) the correct “first principles” that are needed to solve a particular problem related to dynamics and controls. In other words, students should not rely on rote memorization of derivations that can otherwise be obtained from understanding fundamental theory. Students should be able to apply the theory and concepts of the course to problems that are related (but not identical) to homework and examples.

2.2.3 Retention
The course material builds upon itself like a brick wall. The foundation concepts are built first and then subsequent topics are layered thereon. Because of this, it is necessary that material taught at the beginning of the course be retained throughout the course. The fundamental approach of building a differential equation from the first principles governing a physical system is an indispensable engineering tool that should be impressed on the student to a sufficient degree during this course that it remains with the student throughout his or her career. The detailed methodology for solving the equations may fade without continual practice, but the detail should be able to be recovered and refreshed with a brief review.

2.2.4 Perspectives and attitudes
Although students enter the course with knowledge of foundational physics, most students have no previous experience with the concept of forming mathematical models of dynamic systems. Thus, there is a prime opportunity to positively impact student perceptions of this field. However, because the material is new and conceptually very difficult, attitudes toward the material tend to be polarized after taking the course. There would be much value in discovering a way to improve overall attitudes without jeopardizing the rigor of the course.

2.2.5 The field and the larger society
The topic of dynamics and controls is found not only in every engineering discipline, but has been successfully applied to economics, biology, sociology, astronomy, and virtually every field that explores interactions between dynamic entities. Many of the principles and methods learned in this course can be directly applied to those fields once the governing first principles of those systems are known. Helping students understand the broad application of this course may be one way to improve attitudes.

2.2.6 Justification for goals
Dynamics and controls provides a foundation of fundamental material for much of a mechanical engineering student’s future progress in the discipline. The core concepts listed in items 1-7 of section 2.2.1 (knowledge) are universally agreed upon as necessary curriculum for all mechanical engineers and students must know this material do pass the “Fundamentals in Engineering” (FE) exam. Some type of computer-aided solver and programming language is necessary to quickly and efficiently solve the homework problems. Items 8 and 9 of section 2.2.1 specify Matlab and Arduino C as the computer tools to do this. These two software programs are modern and widely used in industry and academia for
solving dynamics- and controls-related problems but other options are certainly valid (such as Mathematica®, Microsoft Excel®, and other freeware options).

2.3 Goals reflected in daily course structure
The daily course structure consists of three components:

1) Motivational introduction
2) Example-based lecture
3) Closed-book, closed-notes, open-neighbor quiz

The motivational introduction is a 2- to 3-minute explanation of how the material that will be covered in class is relevant in the context of real-world problems. I usually show a picture, video, or some non-text material that captures the students’ attention and helps them immediately engage from the start of class. See Appendix 7.2 for an example of the motivational introduction material. Another purpose of the motivational material is to improve perspectives and attitudes toward the course material.

Following the introduction, I deliver a traditional lecture from notes that are distributed to the students before class. The students can either transcribe the lecture notes, annotate the previously distributed notes, or passively listen without taking notes. At the midway point through the class I offer a quiz for extra credit that takes about 7 minutes (5 minutes to perform the quiz and 2 minutes for discussion). The correct answers are displayed immediately after the students turn in the quiz so they have instant feedback. Students are encouraged to work in groups on the quiz and discussion and talking are encouraged during this time. The purposes of the quizzes are to break the lecture into two, roughly 20-minute segments so that attention does not wane toward the latter part of lecture. It also provides students with immediate feedback regarding the quality of their study and preparation for class.

Although the students seem to enjoy this format for class, it is unknown if it leads to improved outcomes in terms of retention and performance.

3 Description of course activities
This section contains descriptions of the teaching methods and use of classroom time, course activities outside of class, the course materials and supplies that are needed, and the course choices with respect to the broader curriculum.

3.1 Teaching methods and classroom time
Classroom time consists of three 50-minute lecture sessions, and one 50-minute recitation session (about 3.3 hours total).

The lecture sessions will consist of the following format:

- Motivational introduction (3 minutes)
- Lecture covering new material (20 minutes).
- iClicker quiz that is closed book, closed notes, but “open neighbor”, meaning students can discuss the solutions to the quiz in small groups (5 minutes).
- Quiz discussion in which the correct answers to the quiz are presented and students can discuss the solutions with their neighbor or ask me for clarification (5 minutes).
• Lecture covering new material (17 minutes).

The recitation sessions will be dedicated to working out problems in detail. I will rely on students to suggest problems to work through on-the-fly. The recitation sessions end when students have no more questions or when 50 minutes has expired.

I also encourage students to receive extra help during office hours and I rarely turn a student away even if they stop by outside of the prescribed hours.

In addition to the above in class activities, three in-class exams will also be offered.

3.1.1 How the motivational introduction facilitates course goals
The motivational introduction is a 2- to 3-minute explanation of how the material that will be covered in class is relevant in the context of real-world problems a mechanical engineer may encounter. The purpose of this introduction is to help shape the students’ perspectives and attitudes in a positive way and to help them understand the role of control systems engineering in society. Because the concepts can be abstract and conceptually difficult to understand, my hope is that the real-world examples will provide them with motivation to overcome these difficulties. See Appendix 7.2 for an example of a motivational introduction.

3.1.2 How the lecture covering new material facilitates course goals
It is impossible to cover all of the course material in lecture, thus the lecture time will be spent explaining the most difficult concepts. The lecture is accompanied by detailed notes that summarize the very dense text for the course. The notes are provided online in PDF and Microsoft OneNote format prior to class so students have the choice of annotating the notes, transcribing the notes from scratch (and then using the online notes as supplemental material), or passively listening. My observations have been that this suits the majority of learning styles. The OneNote format appears to be especially popular with students who take notes on a tablet PC. Unlike PDFs, notes in the OneNote format are very easily modified. I also use lecture time to demonstrate concepts with live examples and hardware and occasionally show videos. See Appendix 7.4 for an example of the notes.

3.1.3 How the iClicker quizzes and following discussion facilitate course goals
One of the goals of this course is that all students achieve mastery of the material. Talking about ideas and problems has been shown to enhance student learning [1]. The format I have adopted for quizzes (open-neighbor, closed-book) strongly encourages the students to discuss the concepts with their classmates. The post-quiz discussion further enables talking about the lecture concepts and ideas. This format also increases the kinds of personal communications that are needed for students to internally organize, process, and retain ideas [2]. Furthermore, students take ownership of their learning rather than relying solely on the teacher’s authority when they share their rationale for choosing a particular answer with their neighbor [3]. See Appendix 7.3 for an example of a reading quiz.

3.2 Course activities outside of class
There are three primary activities the students participate in outside of class:

• Reading and studying the course text.
• Solving short, focused problems (homework).
• Solving a longer, multi-faceted problem (course project).
3.2.1 The purpose of the outside-class activities
The purpose of the outside class activities is primarily two-fold. The problems and concepts on the FE exam will be similar to the homework problems, so the reading and the homework problems are designed to help the students achieve mastery of the subject such that they can succeed on the FE exam. The purpose of the course project is to provide students with a problem that will be similar to something they may experience in industry post-graduation, thus illustrating the relevance of the subject and enhancing their interest.

3.2.2 Learning goals of the outside-class activities
The learning goals of the outside class activities are as follows.

- Reading and studying the course text: All students understand 90% or more of the course text.
- Solving short, focused problems (homework): All students are proficient and efficient in solving 90% or more of the homework problems. See Appendix 7.5 for an example of homework.
- Solving a longer, multi-faceted problem (course project): All students demonstrate mastery of solving an industry-related controls problem. See Appendix 7.6 for an example of a project.

3.3 Course materials and supplies
The following materials and supplies are required for this course:

2) i>Clicker2
3) Arduino UNO Rev.3
4) Miscellaneous (inexpensive) electronic circuit board components.
5) Matlab software.
6) Course notes provided online in PDF and MS OneNote format.

3.3.1 Rational for using the course materials and supplies
The course text by Close and Frederick provides superior treatment of the material to prepare students for the FE exam. It is also concisely written in clear language and the rigor and scope of the examples is appropriate for upperclassmen. Furthermore, I wanted a single, standalone text that the students could solely rely upon as a single source for all the course material. The course material is drawn 100% from the text so the students are not dependent on the lecture or class notes.

The iClicker facilitates efficient administration of quizzes and provides real-time feedback during the lecture regarding understanding. Difficult concepts can be reexamined in class in real-time, if needed.

Students implement a physical controller using an Arduino Uno board and electromechanical components for the course project, which allows them to apply theoretical concepts. The miscellaneous and inexpensive electronic circuit board components are needed to implement the controller. The choice of the Arduino Uno was made due to the wide availability of open-source code and message boards. UNL also produces and sells a generic, very low cost version of the Arduino Uno through the EE
shop in the Engineering College. This gives the students a convenient and low-cost avenue for implementing their projects.

The course text uses Matlab software for solving some examples and in the homework. It is also widely used in industry, so gaining proficiency with this tool is valuable to the students.

The course notes are available to the students prior to class in MS OneNote and PDF format and are verbatim what is presented during the lecture. The rational for making these notes available is that it gives students the option of transcribing from scratch, annotating as desired, or simply passively listening, depending on their individual learning style.

3.3.2 Expected use of the course materials
The use of the course text, lecture notes, and the iClicker are designed to give the students maximum flexibility in their approach to learning, thus they may choose a learning style that is appropriate to strengths. In other words, the text and notes stand on their own, which makes lecture is optional. It is entirely possible that a student may do well in the course by using:

- Just the course text
- The course text and lecture notes
- The course text, lecture notes, and attending lecture
- The course text, lecture notes, attending lecture, and the iClicker
- (other permutations of the above)

Because lecture attendance is optional and iClicker quizzes are extra credit, there is no explicit penalty for NOT using one or more of the above course materials. The Arduino Uno, the miscellaneous electrical components, and the Matlab Software are all required in order to complete the course project and homework, which are graded.

3.4 Course choices and the broader curriculum
Knowledge of dynamics and control is fundamental in mechanical engineering. It is also an advanced undergraduate course and builds upon knowledge of dynamic system analysis and solving differential equations. The material covered in this course gives students a new way to predict and analyze dynamic systems. The concepts taught are applicable to a huge domain considering that the entire universe is a dynamic system composed of dynamic subsystems. Thus, the material covered in this course fundamentally changes the way engineers look at virtually everything around them. The theory and practice covered in this course enables one to predict the behavior of a simple set of dynamic systems and gives students an appreciation for what it might take to predict the behavior of more complex systems.

This course is typically taken curing the sixth semester of an MME undergraduate’s career and is a prerequisite for nine courses that the student can take during the seventh and eighth semesters. These courses are: MECH 380, MECH 444, MECH 445, MECH 446, MECH 450, MECH 453, MECH 455, MECH 457, MECH 483 (Required courses are bolded). As can be seen, this course provides important fundamental knowledge required for many upper-level undergraduate courses.

The course also has the reputation of being somewhat of a gatekeeper in that some students find it the most difficult course in the MME curriculum. Because of this, about 15% of students drop or fail this
course the first time they take it. This pushes the course downstream into their final semesters in the program and creates a high-risk environment for those students in that many take the course for the second or third time in their final semesters. Taking the course so late in the program limits elective options and raises the unfortunate prospect of a student being unable to obtain his or her degree.

These factors demonstrate the necessity of teaching the material well and providing students with the best possible opportunity of success.

4 Analysis of student learning via detailed solutions to system dynamics and control problems

An important teaching method in engineering is the demonstration of problem solving by working through in detail the solutions to homework- and exam-style problems. For this course, the purpose of the problem solving process is to apply the first principles that undergird system dynamics and control to concrete, real-world problems. The textbook uses this method as well, and a typical chapter will demonstrate several problem solutions in detail. Engineering students are accustomed to seeing a range of difficulty in the problems worked out in class by the instructor and they have an almost insatiable appetite for this process because they are asked to perform in this way on homework and exams.

For the instructor, time spent working through an example problem is time NOT spent teaching new material. Of course, the new material must also be thoroughly covered or the student will not be able to follow the derivations or detailed solutions of the example problem. Thus, the instructor must strike a balance between working on example problems and introducing new material.

4.1 Benchmark performance data

The students are asked in their course evaluations to provide specific information regarding things that help and hinder learning. They are asked (amongst other things):

1) What are 1 or 2 specific things that helped you learn in this class?
2) What are 1 or 2 specific things that caused a problem with your learning in this class?
3) Please provide 1 or 2 practical suggestions on ways to help improve student learning in this course.

Typical favorable and unfavorable responses to the above questions are, respectively:

“The examples in class help to learn the material.”

“Most of the examples given were the simplest example possible and usually did not help when doing the homework. It would help if some examples were taken from the end of the chapter like the homework”

A common request throughout the five semesters I taught this course was to work through more examples and especially more difficult examples. Table 1 summarizes the number of favorable and unfavorable responses to the above questions.

Students are also asked to rate, on a scale of 1 to 5, the statement “New concepts and examples are clearly explained at a level students can comprehend.” The survey uses a Likert scale where 1 is “Strongly disagree” and 5 is “Strongly agree.” In my experience, the students interpret the term
“examples” in this statement to mean working through the detailed solution to a homework- or exam-style problem. Table 1 also provides the mean Likert score for each semester I have taught this course.

Table 1. Summary of example-related student feedback.

<table>
<thead>
<tr>
<th>Semester</th>
<th>Enrolled</th>
<th>Percent that expressed favorable opinion of examples</th>
<th>Percent that expressed an unfavorable opinion of examples</th>
<th>Likert Score mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 13</td>
<td>42</td>
<td>14.3%</td>
<td>11.9%</td>
<td>4.27±0.81</td>
</tr>
<tr>
<td>Spring 13</td>
<td>54</td>
<td>11.1%</td>
<td>7.4%</td>
<td>3.96±1.1</td>
</tr>
<tr>
<td>Spring 14</td>
<td>56</td>
<td>17.9%</td>
<td>10.7%</td>
<td>4.04±0.67</td>
</tr>
<tr>
<td>Spring 15</td>
<td>60</td>
<td>13.3%</td>
<td>6.7%</td>
<td>4.29±0.66</td>
</tr>
<tr>
<td>Spring 16</td>
<td>68</td>
<td>8.8%</td>
<td>14.7%</td>
<td>4.05±1.01</td>
</tr>
</tbody>
</table>

4.2 Objective and hypothesis

The objective of Section 4 is to improve learning by providing detailed solutions to more examples and especially more difficult examples. In order to not displace teaching new material, students were required to attend a recitation for an additional hour each week. Thus, the class met Monday, Wednesday, and Friday from 8:30 AM to 9:20 AM for lecture, but then met again Wednesday afternoon from 3:30 PM to 4:20 PM for recitation. I personally taught this recitation session and the time was spent exclusively working out homework- and exam-style problems in detail. I also created a discussion board on which students could recommended specific problems to work on.

The hypotheses of this objective is that the additional recitation session which was dedicated to working through examples increases the favorable and decrease the unfavorable opinions of examples. Additionally, I hypothesize that the mean Likert score to the statement “New concepts and examples are clearly explained at a level students can comprehend” will be increased due to the addition of a recitation section.

4.3 Preliminary results

A problem that occurred with the new recitation session early on in the semester was that students did not suggest problems on the discussion board. I tried to address this problem by encouraging students to post suggestions and by cancelling recitation the first few weeks due to lack of suggestions. Finally, though, after three weeks of still no discussion board suggestions, I told students that I would choose the problems and that we would have recitation weekly regardless of whether or not they posted suggestions. Once I made this change, a few students began posting suggestions. Thus, I held recitation weekly for the remaining 12 weeks of the semester.

The results from the single semester implementation of the recitation session are shown in Table 2.

Table 2. Results from Spring 2017 semester.

<table>
<thead>
<tr>
<th>Semester</th>
<th>Enrolled</th>
<th>Percent that expressed favorable opinion of examples</th>
<th>Percent that expressed an unfavorable opinion of examples</th>
<th>Likert Score mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 2017</td>
<td>69</td>
<td>19.3%</td>
<td>12.3%</td>
<td>3.96±0.82</td>
</tr>
</tbody>
</table>
Figure 1 and Figure 2 show, in graphical form, students’ attitudes towards examples used in class for the Spring 2017 semester compared to previous semesters. No statistical analyses were performed on the results.

Figure 1. Comparison by semester of the percentage of students that had favorable and unfavorable opinions of the examples that were worked out during class (in semesters prior to Spring 2017) or during class and recitation during the Spring 2017 semester.

Figure 2. Comparison by semester of the students’ attitudes toward the explanation of new concepts and examples. A score of 1 indicates a student strongly disagrees, whereas a score of 5 indicates a student strongly agrees.
The results show that in the Spring 2017 semester, the students expressed higher favorable opinion (19.3%) regarding examples than any other semester. On the other hand, students expressed the second highest unfavorable opinion (12.3%) regarding examples. The Spring 2016 semester was the only semester with a higher unfavorable opinion (14.7%). No improvement is seen in students’ opinions of how well new concepts and examples are explained.

The performance of students was not analyzed and compared with the performance from previous semesters because of significant confounding variables, the main one being the different cohorts of students.

The full student evaluation results from Spring 2017 semester can be found in Appendix 7.8.

4.4 Discussion and conclusions
Although more students expressed favorable opinions of examples during the Spring 2017 semester than any other semester, this improvement is only slightly more than the next best semester (Spring 2014, 17.9%) and overall the gains seem to be incremental (19.3% in Spring 2017 compared to the overall mean of 14.1%). Furthermore, the extra recitation session appears to have no impact on unfavorable opinion of examples, which may confirm my suspicion that students have an insatiable appetite to see examples worked out in class. Although recitation was focused on working through the details of homework problems, it appears to have had no effect on students’ opinions of how well new concepts and examples are explained. This may suggest that to make further gains in the area of explanations of new concepts, I should examine the methodology and the quality of the instruction perhaps rather than the quantity. Overall, I do not see evidence that the additional recitation session is desired by the students nor particularly useful.

4.5 Planned changes for future MECH 350 instruction
It is difficult to draw too many conclusions from the implementation of a new teaching tool in a single semester due to other factors that come with a cohort of students. Thus, my plan is to go forward with the additional recitation session for at least two more semesters and then reevaluate and statistically analyze differences in attitudes.

In addition, a method for directly evaluating the effect of the additional recitation session on student performance should be investigated. To do this, the overall grade performance of a control group that does not attend recitation should be compared to an experimental group, which does attend recitation. These two groups should be randomly chosen from the same cohort and taught in the same class in order to minimize introducing other factors that may contribute to differences in performance. How this is to be done is not obvious to me, but I believe it is a necessary step because self-reporting on psychometric tests is not necessarily an accurate method for objectively measuring learning benefit. Such an approach of having only some students in a class attend recitation is fraught with problems, though, because students are keenly tuned to unfair and unequitable arrangements.

5 Summary
This portfolio accomplished two aims. Firstly, it outlined and explained my approach to teaching MECH 350, Dynamics and Control of Engineering Systems. I highlighted in detail the purpose and curricula of the course, the desired outcomes, and the goals and objectives. I also describe how the course activities and my teaching methodology support the course objectives. Secondly, I described a simple course
modification—the introduction of a recitation session—and tested in a preliminary way the effect of this change on students’ attitudes towards the examples worked out in class. The results of this modification show that in the Spring 2017 semester, the students expressed higher favorable opinions (19.3%) regarding the examples worked out in class and during the recitation session than any other semester. On the other hand, students expressed the second highest unfavorable opinion (12.3%) regarding examples. No improvement is seen in students’ attitudes of how well new concepts and examples are explained. It is difficult to draw too many conclusions from the implementation of a new teaching tool in a single semester due to other factors that come with a cohort of students. Thus, my plan is to go forward with the additional recitation session for at least two more semesters and then reevaluate and statistically analyze differences in attitudes.
6 Citations


7 Appendix

7.1 Syllabus

**MECH 350 Introduction to Dynamics and Control of Engineering Systems**

**General Information:**
Lecture Time: MWF 8:30AM-9:20AM
Recitation Time: W 3:30-4:20 PM
Lecture Location: Othmer Hall 106
Recitation Location: Othmer Hall 106
Instructor: Benjamin Terry, NH317.4B, 472.7595, bterry2@unl.edu
Office Hours: W 4:30-5:30 PM, (or by apt.)
Class Website: [http://my.unl.edu](http://my.unl.edu) (Blackboard)

**Catalog Description:**
(3 credit hours) Preq: ENGM 373; ELEC 211; MATH 314 or parallel.

**Supplies:**
Required items:
2) i>Clicker2 is required for extra credit reading quizzes that will occur during class.
3) MECH 350 electronics kit which is available in the EE shop ([eeshop.unl.edu](http://eeshop.unl.edu)). ~$20. The kit contains a “generic” Arduino Uno microcontroller. You can also get the kit with an authentic Arduino Uno for ~$30. Either kit works.

**Objectives:**
At the termination of the course, the student should be able to¹:
1) Given a description of a dynamic system, construct a simplified version using idealized elements and define a suitable set of variables.
2) Use the appropriate element and interconnection laws to obtain a mathematical model generally consisting of ordinary differential equations.
3) If the model is nonlinear, determine the equilibrium conditions and, where appropriate, obtain a linearized model in terms of incremental variables.
4) Arrange the equations that make up the model in a form suitable for solution, and use them to construct and simplify block diagrams.
5) For a first-order system, solve directly for the time-domain response without transforming the functions of time into functions of other variables.
6) For a model of up to fourth order, use the Laplace transform to find the complete time response, determine the transfer function and its poles and zeros, analyze stability, etc.
7) Find from the transformed expression the steady-state response to a constant sinusoidal input without requiring a general solution.
8) Use Matlab to:
   - Obtain the response of a system to initial stored energy and to arbitrary inputs.

¹This course will follow the text very closely; therefore, the given objectives are a summary of pages 12 and 13 of the text.
- Study the influence of changing system parameters on the system response, and predict the response.
- Create root-locus plots, bode diagrams, etc. as aids in analyzing and designing feedback systems.

9) Use the C programming language to program an Arduino microcontroller to control an electromechanical device.

Topics:
1. Modeling of mechanical and electrical systems.
2. Analytical solutions for linear systems and linearizing nonlinear models.
3. Modeling other types of systems
4. Block diagrams, feedback systems, and design tools.

Evaluation:
1. 3 Exams (2 one hour exams and one two-hour final)
2. Approximately 14 homework assignments
3. Arduino project

Exams: Three exams will be given. Each exam will cover all material presented/assigned to date. One 8.5" x 11" piece of paper containing notes will be allowed during the first exam, two during the second, and three during the third. In general, no make-up exams will be given. A cumulative grade of D+ or lower on the exams will be your final grade in the course. Most of the exam problems will be modified versions of the homework.

Homework: Homework must be neat and organized. Homework is due at midnight on the date posted in the class schedule. If you can't do the homework on your own, you won't do well on exams. You are required to submit your homework electronically via Blackboard as a PDF file using a phone, personal scanner, or the copy machine located in the MME administrative office (W342 NH). The copier code for this course is 90209 and is only to be used for scanning (not printing or copying). Enter the copy code for the “Dept. ID”. There is no passcode. It is your responsibility to ensure the scanned version is legible. Note that only PDF format will be accepted—submittals in other file formats will not be graded. The grader will randomly choose one homework problem to grade in detail and will check to make sure all problems were attempted.

Arduino Project: A single course project will be due in stages throughout the semester according to the course schedule. Details on this project will be given at a later date.

Extra credit reading quizzes: You are strongly encouraged to read and study the entire textbook throughout this course. Hopefully, you will get to know this book well enough that it will become part of your personal engineering library. Extra credit reading quizzes will be given every class period via iClickers. To successfully complete the quizzes you will need to have thoroughly read the assigned material prior to class. You must register a personal i>Clicker 2 prior to class in order to take the quiz.

Recitation: The recitation session will be used to work through homework (or other) problems of students’ choosing. Recitation is held every Wednesday. Only suggestions submitted the prior Thursday through Monday will be considered. If no suggestions have been submitted during the previous period (Thursday through Monday), there will be no recitation session. Problems from the homework that are due at some future time will not be considered. Submit suggestions via
the Discussion Board on Blackboard entitled, “Forum: Problems for the Recitation session”.

**Check the discussion board on Tuesday to know if recitation will be held on Wednesday.**

**Schedule:** Exam dates, reading quiz chapters, and homework due dates are located in the Excel document `me350_schedule_s17.xlsx` located on Blackboard in the “Course Documents” folder. Note that this schedule may change, which will be indicated by a new revision number at the end of the filename, e.g. `me350_schedule_s17_v2.xlsx`

**Grading:**
Extra credit reading quizzes are in-class work and will **not** be distributed outside of class; therefore if you miss class you miss the opportunity to earn extra credit. If you would like to discuss any grade, you must do so within one week of when the work was returned.

Homework assignments, the project, and exams are scored based on the standard point scale (0 to 100%). Your final grade is calculated based on the following weighting and grade scale:

<table>
<thead>
<tr>
<th>Table 3. Grade weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exam 1</td>
</tr>
<tr>
<td>Exam 2</td>
</tr>
<tr>
<td>Final</td>
</tr>
<tr>
<td>Homework</td>
</tr>
<tr>
<td>Project</td>
</tr>
<tr>
<td>Reading quizzes (extra credit)</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4. Grade scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>A+</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>A-</td>
</tr>
<tr>
<td>B+</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>B-</td>
</tr>
<tr>
<td>C+</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>C-</td>
</tr>
<tr>
<td>D+</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>D-</td>
</tr>
<tr>
<td>F</td>
</tr>
</tbody>
</table>

**Late work, missed class, and missed exams:**

**No late work is accepted.** If you have to miss an exam (UNL sponsored event, funeral, illness, etc.), you need to send me an e-mail ahead of time. If I agree you had a valid reason for missing the exam, I reserve the right to require documentation before allowing you to take a make-up.
Make-up exams will be given prior to the exam date. There will be no option for making up extra credit reading quizzes.

The most common request by students for accepting late work is that the upload to Blackboard was slower than expected and thus it was uploaded just a minute or two late. To be fair to everyone in the class, I do not make individual exceptions (unless otherwise stated in the syllabus, e.g. for illness or other university excused situations). That said, I totally understand that the Blackboard system has a certain failure rate (albeit very, very small in my experience), that sometimes students (and professors) forget things, etc. To that end, I have provided a mechanism (the reading quizzes) to compensate for occasional mess ups. You can very easily earn back all the points from a missed homework or project step by doing well on the reading quizzes. The true value in doing the homework is that you will learn the material and do well on the exams, where the bulk of points are. In summary, my opinion is that you should not feel frustrated if you get a zero on a homework assignment or two or three or a project step because of a snafu. Study the material prior to coming to class, do great on the reading quizzes, and that will more than compensate for an occasional glitch. As a failsafe, you can also discipline yourself to upload homework and projects a day before they are due.
7.2 Example of Introductory Material

Below is a still frame from a video of a mountain biker that illustrates the dynamic motion of the rear suspension of the bike as it travels down a hill. I show this video in class before the lecture in which we create the modeling equations for mountain bike and rider.
7.3 Example of a Reading Quiz

1) The techniques learned in this course can be applied to which of the following systems (check all that apply)?
   a. Mechanical
   b. Electrical
   c. Thermal
   d. Fluidic
   e. Sociological
   f. Physiological
   g. Economic
   h. Transportation

2) (Y/N) A teenager is quietly doing homework in his room. His mother is downstairs texting a friend. They are not interacting in any way. Are the mother and son together by classified as a system?
   a. Y
   b. N

3) What two important factors need to be considered when deciding how comprehensive to make the model of a system?
   a. The objectives of the modeling
   b. System linearity
   c. The availability of resources (like computing power)
   d. Interacting elements

4) This course primarily focuses on which of the following systems?
   a. Distributed
   b. Lumped
   c. Continuous
   d. Discrete-time
   e. Hybrid
   f. Nonquantized
   g. Quantized
   h. Fixed
   i. Time-varying
   j. Linear
   k. Nonlinear

5) Which of the following differential equations is/are nonlinear?
   a. \( \frac{d u}{d x} + u^2 = 0 \)
   b. \( \frac{d^2 \theta}{d t^2} + \theta = 0 \)
   c. \( \frac{d^2 \theta}{d t^2} + \sin(\theta) = 0 \)
   d. \( \frac{d^2 \theta}{d t^2} + \pi - \theta = 0 \)
Chapter 1, Introduction

Dynamics & control of Engineering systems.

Outline
- Course description
- Syllabus
- System dynamics
- System control

Course description
By the end of this course you should be able to:
- Develop a math model of many physical systems.
- Solve the math model
- Analyze the math model
- Develop a simple controller for the physical system
- Know the basics of Matlab and Arduino C

Syllabus
- Read it
- Daily reading quizzes
- Homework
  - Do it as we learn it
  - Scan & submit PDF to BB
- Project
- Exams

System Dynamics

System: Two or more elements connected by a cause and effect relationship.

EX:

Generic System

For the purpose of predicting the future behavior of the system.
**System Classification**

All mathematical models are simplifications of the real systems. Systems are classified according to the manner in which they are simplified.

- **Lumped vs. Distributed**: E.g., Amazon is modeled above as a single element (lumped). Alternatively, every employee and cause & effect between employers could also be modeled.

- **Fixed vs. Time Varying**: E.g., tax law changes periodically, but modeling tax law as fixed is an approximation that makes math simpler.

**Pop Quiz**: What’s the danger in creating a fixed economic model and then using that model to predict the economy very far into the future?

- **Non-linear vs. Linear**

Ex: Balancebot motor element model

Motor torque

- Linear model
- Operating point
- Non-linear model
- Quantized vs. non-quantized

- Discrete vs. continuous

Most relevant mechanical engineering systems

- Translational mechanical
- Rotational mechanical
- Thermal
- Fluid
- Electrical
- Combinations of the above

System dynamics: How the system responds to an input.

Note: we will define systems as
We use modeling and analysis of systems to predict the system dynamics.

Conversely, we can measure system dynamics to give us insight into the system model.

Ex of the design process using system dynamics:

- Elon Musk
- Math model, design, analysis
- Simulation of system
- Model refinement
- First prototype
- Measure actual input & output
- Model refinement, redesign, analysis, retest...
System control

Once you have defined the system, you can design and build a controller.

\[ EY: \text{Desired velocity, } W_i \rightarrow \text{Controller} \]
\[ \text{Torque, } \tau \rightarrow \text{System velocity, } W_o \]

Actuating signal \((W_i - W_o)\)

7.5 Example of Homework Assignment

7.5.1 Assignment

*2.27. The input for the system shown in Figure P2.27 is the displacement \(x_1(t)\). Draw the free-body diagrams for the mass \(M\) and for the massless point \(A\). Write the differential equations describing the system.

*2.26. In the mechanical system shown in Figure P2.26, the spring forces are zero when \(x_1 = x_2 = x_3 = 0\). Let the base be stationary so that \(x_3(t) = 0\) for all values of \(t\). Draw free-body diagrams and write a pair of coupled differential equations that govern the motion when the only input is \(f_2(t)\).
2.8. Repeat Problem 2.7 for the system shown in Figure P2.8.

![Figure P2.8](image)

2.1. For the system shown in Figure P2.1, the springs are undeflected when $x_1 = x_2 = 0$. The input is $f(t)$. Draw free-body diagrams and write the modeling equations.

![Figure P2.1](image)
7.5.2 Assignment output

For the system shown, the springs are undeflected when $x_1 = x_2 = 0$. The input is $f_{a1}(t)$. Draw free-body diagrams and write the resulting equations.

i) $FBDs$

ii) Equations

\[ f_{k1} = k_1 (0 + x_1) = k_1 x_1 \]

\[ f_{b1} = f_{b1}(0 + x_1) = B_1 x_1 \]

\[ f_{m1} = m_1 \left( \frac{d^2 x_1}{dt^2} \right) = m_1 \ddot{x}_1 \]

\[ f_{k2} = k_2 (-x_1 + x_2) = k_2 (x_2 - x_1) \]

\[ f_{m2} = m_2 \left( \frac{d^2 x_2}{dt^2} \right) = m_2 \ddot{x}_2 \]

\[ f_{b2} = f_{b2}(0 - x_2) = -B_2 x_2 \]

\[ \text{current} \]
(2) iii) cont

Equation for $m_1$:

$$f_1 + f_2 + f_3 = 0$$

$$k_1x_1 + k_2(x_2 - x_1) - m_1 \ddot{x}_1 + f_{act}$$

$$f_{act} = k_1x_1 + k_2(x_2 - x_1) + m_1 \ddot{x}_1$$

Equation for $m_2$:

$$f_2 + f_{act} = 0$$

$$k_2(x_2 - x_1) + m_2 \ddot{x}_2 = -B_2 \dot{x}_2$$

$$\therefore k_2(x_2 - x_1) = -B_2 \dot{x}_2 - m_2 \ddot{x}_2$$

2.6 Spring forces $= 0$ when $x_1 = x_2 = x_3 = 0$

$x_5 = 0$ for all $t$ values. Draw FBDs and more.

[Diagram]

i) TMS Diagram

*if $M_2$ doesn't move, treat it like ground.*
(ii) FBDs

(iii) Equations
\[ f_{x1} = m_1 (0 + x_1) = k_1 x_1 \]
\[ f_{B1} = B_1 (0 + \dot{x}_1) = B_1 \dot{x}_1 \]
\[ f_{m1} = m_1 \left( \frac{d\dot{x}_1}{dt} \right) = \ddot{m}_1 (\dot{x}_1) = m_1 (\ddot{x}_1) \]
\[ f_{x2} = k_2 (x_2 - x_1) \]
\[ f_{m2} = m_2 \left( \frac{d\dot{x}_2}{dt} \right) = \ddot{m}_2 (\dot{x}_2) = m_2 (\ddot{x}_2) \]
\[ f_{B2} = B_2 (0 - \dot{x}_2) = -B_2 \dot{x}_2 \]

(iv) Combine into diff. eqs
\[ f_{m1} + f_{x1} + f_{B1} = f_{x2} + f_{m2} + f_{B2} = \]
\[ m_1 \ddot{x}_1 + k_1 x_1 + B_1 \dot{x}_1 = \]
\[ k_2 (x_2 - x_1) + \text{slack} \]
\[ \therefore \text{slack} = m_2 \ddot{x}_2 + k_1 x_1 + B_1 \dot{x}_1 + k_2 (x_2 - x_1) \]
2.6 IV can’t

\[ F_{m_2} + k_2 \ddot{x}_2 = f_{B2} \rightarrow m_2 \dddot{x}_2 + k_2(x_2 - x_1) = -B_2x_2 \]

[Diagram showing \( M_2 \) and \( M_1 \) with springs and forces labeled]

2.8 Springs are undeflected when \( x_1 = x_2 = 0 \). The input is \( x_2(t) \), the displacement of the left edge of \( M_2 \). Write the governing motion of \( M_1 \) and \( M_2 \). Expression for force \( f_{B2} \) 1. sense to the right must be applied to \( M_2 \) to achieve displacement \( x_2(t) \).

i) TMS Diagram

[Diagram showing the TMS diagram with forces and displacement labeled]

ii) FBDS

[Diagram showing the FBDS with forces and displacement labeled]

iii) Equations

\[ f_{k_2} = k_2(-x_2 + 0) = -k_2x_2 \]

\[ f_{m_2} = m_2 \frac{d^2x_2}{dt^2} = m_2 \dddot{x}_2 \]

[Continued on next page]
(B) ii) + iii) cont

\[ f_B = B (\ddot{x}_2 + \dot{x}_1) = B (x_1' - \dot{x}_2) \]

\[ f_{m_1} = m_1 (\frac{d\dot{x}_1}{dt}) = m_1 \ddot{x}_1 \]

\[ f_{x_1} = k_1 (-x_1 + 0) \]

iv) Combine into diff. eq.'s

\[ m_2 \dddot{x}_2 = f_B + f_{x_2} + f_2 \rightarrow m_2 \dddot{x}_2 = B (x_1' - \dot{x}_2) + (-k_2 x_2) + f_2 \]

\[ f_2 = m_2 \dddot{x}_2 + k_2 x_2 + B (\dot{x}_2' - \dot{x}_1) \]

\[ f_{m_1} + f_2 - f_{x_1} \rightarrow m_1 \dddot{x}_1 + B (x_1' - \dot{x}_2) = -k_1 x_1 \]

\[ \therefore m_1 \dddot{x}_1 + B (x_1' - \dot{x}_2) + k_1 x_1 = 0 \]
2.19. The system shown has a nonlinear spring that obeys the expression $F_k = x^3$.

a) Write the differential equation describing the system in terms of the displacement $x$.

b) Let $x = x_0 + z$ where $x_0$ is const. displacement caused by the gravitational force when the system is in static equilibrium. Rewrite the diff. eq. in terms of the variable $z$, cancelling the gravitational term.

![Diagram]

i) TMS Diagram

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$

$F_k = x^3$
2.19. ii) and iii) cont.

\[ f_m = m\left(\frac{dv}{dt}\right) = m\ddot{x} \]

iv) Combine into diff. eqs:

\[ f_x + f_B + f_m = mg + f(t) \rightarrow x^3 + B\dot{x} + m\ddot{x} = mg + f(t) \]

v) Cancel gravitational term

\[ x = x_0 + z \]

\[ \dot{x} = \dot{z} \]

\[ \ddot{x} = \ddot{z} \]

\[ (x_0 + z)^3 + B\ddot{z} + m\ddot{z} = mg + f(t) \]

\[ (x_0^3 + 3x_0^2z + 3x_0z^2 + 3z^3) + B\ddot{z} + m\ddot{z} = mg + f(t) \]

\[ x_0^3 + 3x_0^2z + 3x_0z^2 + z^3 + B\ddot{z} + m\ddot{z} = mg + f(t) \]

\[ 3z^2 + 3z^2x_0 + z^3 + B\ddot{z} + m\ddot{z} = f(t) \]

Because the spring is nonlinear, when the mg term is deleted, the equation changes to include the terms \( 3z^2 + 3z^2x_0 \) that weren't in the original equation. This is unlike the example shown in the text.
The pulley shown is ideal. Draw the FBDs and write the modeling equations.

1) FBDs

\[ f_B = B(\ddot{x}_2 - \ddot{x}_1) \]

2) FBDs and Equations

\[ f_E = -f_m \]
\[ f_m = M_1 \dddot{x}_1 \]
\[ f_B = B(\dddot{x}_2 - \dddot{x}_1) \]

3) Combine into differential equations

\[ f_B + f_m + f_\text{alt} = 0 \]
\[ k(x_1) + m_1 \dddot{x}_1 + f_\text{alt} = B(\dddot{x}_2 - \dddot{x}_1) \]
\[ f_B + f_m = m_2 g \]
\[ B(\dddot{x}_2 - \dddot{x}_1) + m_2 \dddot{x}_2 = m_2 g \]
Input for the system is displacement $x_3(t)$. Draw the FBDs for the mass $M$ and the massless point $A$. Write the diff. eqs. for the system.

i) TMS Diagram

ii) FBDs + iii) Equations

\[
\begin{align*}
    f_{k1} &= k_1(x_1 + \Delta) \\
    f_m &= m\ddot{x}_1 \\
    f_{k2} &= k_2(x_2 - \dot{x}_1) \\
    f_{k1} &= B_1(\dot{x}_1 + \Delta) \\
    f_{k2} &= k_2(x_2 - \dot{x}_1) \\
    f_{k3} &= f_{k2} + f_{k2} \\
    f_{k3} &= k_3(x_3 - x_2)
\end{align*}
\]
v) Combine into diff eqs.

\[ f_m + f_kx_1 + f \dot{x}_1 = f_{B_2} + f_kz \]

\[ m \ddot{x}_1 + k_1 \dot{x}_1 + B_1 \dot{x}_1 = B_2 (x_2 - \dot{x}_1) + k_2 (x_2 - \dot{x}_1) \]

\[ f(t) = f_k \Rightarrow f_{B_2} + f_kz \]

\[ f(t) = B_2 (x_2 - \dot{x}_1) + k_2 (x_2 - \dot{x}_1) \Rightarrow f(t) = k_3 (x_3 - x_2) \]
7.6 Example of Course Project

7.6.1 Project

**Final Project Step**

Throughout this class we have learned how to create models of dynamic systems and we’ve seen how those models can be represented by a transfer function, say $G(s)$:

\[
U(s) \xrightarrow{G(s)} C(s)
\]

Where:

\[
G(s) = \frac{C(s)}{U(s)}
\]

We’ve also learned how to predict the output of the system given a particular input and set of initial conditions. Later in the class we will introduce you to the concepts of control system design where we compare a desired reference point (R) to the output (C) of a dynamic control system and then control the system based on that comparison using a controller ($G_c$). This is the typical strategy of closed-loop feedback control and it is represented in block diagram form as:

\[
R(s) \xrightarrow{G_c(s)} C(s)
\]

Feedback control has existed for many years, even before modern electronics. Following is a purely mechanical feedback control system that regulates steam flow from a boiler through a turbine (created by James Watt in 1788). In this system (Figure 1), the reference signal R is the desired shaft velocity. The actual shaft velocity is the output C. The controller ($G_c$) is the centrifugal governor, and dynamic system (G) is the boiler and steam engine.
A modern example of a feedback control system implementation is a robotic manipulator created at John Hopkins Applied Physics Laboratory for shoulder-level double amputees. In this system (Figure 2), $R$ is the desired position of the manipulator. The signal $R$ is sent by the amputee’s brain. The actual position is $C$ and is measured by feedback sensors on the manipulator, $G$ is a transfer function model of the manipulator, and $G_c$ is the controller that translates the error ($R - C$) into voltage input to the manipulator motors.

Figure 2. Leslie Baugh, shoulder-level double amputee controlling two 4 DOF manipulators created at the John Hopkins Applied Physics Laboratory.

The following schematics illustrate other miscellaneous examples of control systems:
Figure 4. Flight control system. (http://circuitecellar.com/ce-blog/mcu-based-experimental-glider-with-gps-receiver/)

Figure 5. Self-acting temperature control. Note that this system is a purely mechanical control system, similar to the governor system in Figure 1. (Spirax Sarco, 2016, http://www.spiraxsarco.com/Resources/Pages/Steam-Engineering-Tutorials/control-hardware-sa-actuation/self-acting-temperature-controls.aspx)
With the exception of the purely mechanical controllers like the fluid flowrate controller governor (Figure 1) and the temperature control (Figure 5), these systems all implement the control scheme, $G_c$, on a microcontroller, such as the Arduino Uno that you have been using.

The purpose of the final project step is to design a control system (on paper), similar to figures 1, 3-6, above and to build, and test your own Arduino-based controller ($G_c$). Note that you do NOT need to build the entire feedback control system, nor do you need to actively control your system, although you may certainly do this if you wish. At a minimum, you need
to implement (on a microcontroller) the controller \( G_c \), the reference input (R), and the output (C), highlighted in green below.

![Diagram](image)

Figure 7. The portion of the control system that must be physically implemented and demonstrated in your project is highlighted in green. Note: you do not need to control \( G(s) \).

Following are the requirements of your custom project:

1. Sketch the physical control system. Your sketch will be similar to figures 1, 3-6. Identify on your sketch the reference input (R), the output (C), the dynamic system you are controlling (G), and the controller (G_c).
2. Your system must sense some physical property which is the output of a dynamic system. This is C. You may NOT use a button or motion sensor to sense the physical property.
3. The microcontroller must calculate the difference between the reference signal and the output \( e = C - R \).
4. The microcontroller must perform some mathematical operation on the error signal and generate an output based on that operation. This is the controller output (the output of \( G_c \)). Examples of outputs are analog or digital voltages that drive an LED, speaker, or digital multimeter. Other examples of outputs include the Serial Monitor in the Arduino software, etc.

Create a 3 minute (or less) video demonstrating your system and describing the code. Upload three files:

1. The sketch of the complete control system (similar to figures 1, 3-6) in pdf format.
2. A video of the microcontroller generating the \( G_c \) output based on a reference signal, R. You must also briefly explain your code in the video.
3. The microcontroller code (the .ino file or equivalent if you are using some other type of controller, e.g. a .c file).

Videos posted to BB must be in one of the following formats.

- .mp4
- .wmv
- .mov
- Link to a YouTube video.

Videos posted in other formats, broken (or inaccessible, i.e. private) YouTube links, and corrupted video files will receive 0 points. Double and triple check your video file after posting. Unless you are posting to YouTube, do not exceed 50MB video size!

The rubric for the project grade is based on:

1. Your sketch. Does it clearly represent a feedback control system? Are R, C, e, G_c, and G all identified on the sketch? Is it in PDF format? (15 points)
2. A demonstration of your custom system correctly processing the reference signal, output, and \( G_c \) output. (20 points)
3. The correctness of your code and your understanding of the code. (20 points)
4. The total length of the video is less than 3 minutes and the size is less than 50MB unless it is posted on YouTube, then there is no minimum size constraint, but it still must be less than 3 minutes. (5 points)
7.6.2 Project output

Dynamic System: Motor Temperature against Ambient Air Temperature

Sketch

Dynamic System:

Motor (Dynamic System) Fan (controller)

Air Intake

Ambient Air Temperature

Controller

Motor Temp.

Temp Differential

Fan Speed

Final Project Step

Redacted
Example of an Exam Question

University of Nebraska-Lincoln
Department of Mechanical Engineering

MECH 350
Introduction to Dynamic Systems and Control

FINAL EXAM
5/2/17

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible Points</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>3 (optional problem)</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>4 (optional problem)</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100-35</td>
<td>76</td>
</tr>
</tbody>
</table>

Instructions:
Do problems 1 and 2. Choose either problem 3 or problem 4. Place a giant X over the problem you do not want graded. If it is unclear which problem you chose, I will grade problem 3 by default.

Three 8.5x11 sheets of notes are allowed. Calculators are allowed.

**DRAW A BOX AROUND YOUR FINAL ANSWER**

Read all instructions carefully. Be sure to answer the question that is asked. Be clear. **Circle or box your answers.** Show all work. Write your name on each page. Make sure you have 12 pages total.

Stay Calm. Good luck.
Problem 1 (cont.)

c) Solve for the steady-state error in \( \theta_0 \) that is due to a unit step input, \( \theta_i(t) \). (6 pts)

\[
E_{ys} = r_{ys}(t) - y_{ys}(t) \bigg| \mathcal{L}\{ \theta_i(t) = u(t) \} = \frac{1}{s}
\]

\[
Y = \frac{15Kc}{s(s+2.5)+15Kc} \cdot \frac{1}{s} = \frac{15Kc}{s^2+2.5s+15Kc} \cdot \frac{1}{s}
\]

\[
y_{ss} = \lim_{s \to 0} s \left[ \frac{1}{s} \cdot \frac{15Kc}{s^2+2.5s+15Kc} \right] = \frac{1}{Kc}
\]

\[
e_{ys} = 1 - \frac{1}{Kc} = \frac{Kc-1}{Kc}
\]

\[\checkmark\] +6


d) Solve for the steady-state error in \( \theta_0 \) that is due to a unit step disturbance torque, \( r_0(t) \). (7 pts)

\[
E_{ys} = r_{ys}(t) - y_{ys}(t) \bigg| \mathcal{L}\{ r_0(t) = u(t) \} = \frac{1}{s}
\]

\[
Y = \frac{15}{s(s+2.5)+15Kc} \cdot \frac{1}{s} = \frac{15}{s^2+2.5s+15Kc} \cdot \frac{1}{s}
\]

\[
y_{ss} = \lim_{s \to 0} s \left[ \frac{1}{s} \cdot \frac{15}{s^2+2.5s+15Kc} \right] = \frac{1}{Kc}
\]

\[
e_{ys} = \frac{2}{Kc} - \frac{1}{Kc} = \frac{Kc-1}{Kc}
\]

\[\checkmark\] +5
Problem 1 (cont.)

(g) Determine the locations of all the closed-loop poles for this value of $k_c$ (10 pts)

$$P(s) = s^2 + 2.5s + 6.25$$

$$-2.5 \pm \sqrt{2.5^2 - 4(1)(6.25)}$$

$$\frac{2}{2}$$

$$-1.25 + 2.165j$$

$$-1.25 - 2.165j$$

Problem 4 (cont.)

$$\dot{\theta} = \omega$$

$$\ddot{\omega} = \frac{1}{J}[-k\theta - B\dot{\theta} + i^2\alpha]$$

$$\frac{di}{dt} = \frac{1}{L}[(R + \alpha\omega)i + e^{i\alpha t}]$$
7.8  Complete course evaluations from Spring 2017

Individual Course Report - MECH350 Sec. 150

MECH350 Section 150: DYNAMICS & CONTROL

Semester:'16-'17: Spring Semester
Survey Trigger: Spring 2017
Instructor: Benjamin S. Terry
Students: 69
Respondents: 57
82.6%

Download raw response data (CSV/Excel)

Evaluation of Course and Instructor

**Base Questions item 4**

<table>
<thead>
<tr>
<th></th>
<th>Freshman</th>
<th>Sophomore</th>
<th>Junior</th>
<th>Senior</th>
<th>Graduate Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. My year in college is:</td>
<td>0</td>
<td>0</td>
<td>38</td>
<td>16</td>
<td>3</td>
</tr>
</tbody>
</table>

**Base Questions item 5**

<table>
<thead>
<tr>
<th></th>
<th>4.0 to 3.5</th>
<th>3.5 to 3.0</th>
<th>3.0 to 2.5</th>
<th>2.5 to 2.0</th>
<th>Below 2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. My overall grade point average is:</td>
<td>29</td>
<td>17</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Base Questions item 6**

<table>
<thead>
<tr>
<th></th>
<th>More than 18 hours</th>
<th>15 to 17 hours</th>
<th>12 to 14 hours</th>
<th>9 to 11 hours</th>
<th>Less than 9 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. I am enrolled for the following number of credit hours this semester:</td>
<td>6</td>
<td>33</td>
<td>15</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

**Base Questions item 7**

<table>
<thead>
<tr>
<th></th>
<th>More than 40 hours</th>
<th>30 to 40 hours</th>
<th>20 to 30 hours</th>
<th>10 to 20 hours</th>
<th>Less than 10 hours</th>
</tr>
</thead>
</table>
4. I currently work the following number of hours per week at a job:

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>2</th>
<th>10</th>
<th>17</th>
<th>28</th>
</tr>
</thead>
</table>

**Base Questions item 8**

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. This course is my major field of study:</td>
<td>53</td>
<td>4</td>
</tr>
</tbody>
</table>

**Base Questions item 10**

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Disagree (1)</th>
<th>Disagree (2)</th>
<th>Indifferent (3)</th>
<th>Agree (4)</th>
<th>Strongly Agree (5)</th>
<th>N/A ()</th>
<th>mean</th>
<th>mode</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. I see myself as a motivated student in this course.</td>
<td>1</td>
<td>6</td>
<td>4</td>
<td>28</td>
<td>18</td>
<td>0</td>
<td>3.98</td>
<td>4</td>
<td>0.99</td>
</tr>
<tr>
<td>7. I was academically prepared to take this course.</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>34</td>
<td>13</td>
<td>0</td>
<td>3.91</td>
<td>4</td>
<td>0.95</td>
</tr>
<tr>
<td>8. I was challenged to think in this course.</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>18</td>
<td>35</td>
<td>0</td>
<td>4.53</td>
<td>5</td>
<td>0.68</td>
</tr>
<tr>
<td>9. My course grade will be a fair representation of my learning.</td>
<td>5</td>
<td>11</td>
<td>11</td>
<td>24</td>
<td>6</td>
<td>0</td>
<td>3.26</td>
<td>4</td>
<td>1.16</td>
</tr>
<tr>
<td>10. I treated the instructor fairly and respectfully.</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>26</td>
<td>28</td>
<td>0</td>
<td>4.44</td>
<td>5</td>
<td>0.60</td>
</tr>
</tbody>
</table>

**Question Set Statistics**

|                          | 4.02 | 4   | 1.00 |

**Base Questions item 12**

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Disagree (1)</th>
<th>Disagree (2)</th>
<th>Indifferent (3)</th>
<th>Agree (4)</th>
<th>Strongly Agree (5)</th>
<th>N/A ()</th>
<th>mean</th>
<th>mode</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Before taking this course, my interest in this subject was very high.</td>
<td>2</td>
<td>8</td>
<td>16</td>
<td>24</td>
<td>7</td>
<td>0</td>
<td>3.46</td>
<td>4</td>
<td>1.00</td>
</tr>
<tr>
<td>12. I understand the objectives of this course.</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>39</td>
<td>10</td>
<td>0</td>
<td>4.00</td>
<td>4</td>
<td>0.65</td>
</tr>
<tr>
<td>13. The organization of the course topics is reasonable and logical.</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>37</td>
<td>12</td>
<td>0</td>
<td>4.02</td>
<td>4</td>
<td>0.72</td>
</tr>
<tr>
<td>14. The pace at which course topics are covered is reasonable.</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>31</td>
<td>9</td>
<td>0</td>
<td>3.60</td>
<td>4</td>
<td>1.12</td>
</tr>
<tr>
<td>15. This course helped me improve my rational thinking.</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>30</td>
<td>19</td>
<td>0</td>
<td>4.12</td>
<td>4</td>
<td>0.85</td>
</tr>
</tbody>
</table>
### Base Questions item 14

<table>
<thead>
<tr>
<th>Strongly Disagree (1)</th>
<th>Disagree (2)</th>
<th>Indifferent (3)</th>
<th>Agree (4)</th>
<th>Strongly Agree (5)</th>
<th>N/A (O)</th>
<th>mean</th>
<th>mode</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>17. The textbook, workbook, and/or lesson notes help me understand course material.</td>
<td>2</td>
<td>7</td>
<td>4</td>
<td>35</td>
<td>9</td>
<td>0</td>
<td>3.74</td>
<td>4</td>
</tr>
<tr>
<td>18. The method (or methods) of presenting information in class enhances my learning.</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>28</td>
<td>16</td>
<td>0</td>
<td>3.86</td>
<td>4</td>
</tr>
<tr>
<td>19. The coursework helps me understand and apply the subject matter.</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>37</td>
<td>10</td>
<td>0</td>
<td>3.86</td>
<td>4</td>
</tr>
<tr>
<td>20. The amount of coursework is reasonable for what I am expected to learn.</td>
<td>2</td>
<td>8</td>
<td>7</td>
<td>30</td>
<td>10</td>
<td>0</td>
<td>3.67</td>
<td>4</td>
</tr>
<tr>
<td>21. Testing methods fairly measure my understanding of the course material.</td>
<td>10</td>
<td>17</td>
<td>13</td>
<td>15</td>
<td>2</td>
<td>0</td>
<td>2.68</td>
<td>2</td>
</tr>
</tbody>
</table>

**Question Set Statistics**

<table>
<thead>
<tr>
<th>mean</th>
<th>mode</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.56</td>
<td>4</td>
<td>1.13</td>
</tr>
</tbody>
</table>

### Base Questions item 16

<table>
<thead>
<tr>
<th>Strongly Disagree (1)</th>
<th>Disagree (2)</th>
<th>Indifferent (3)</th>
<th>Agree (4)</th>
<th>Strongly Agree (5)</th>
<th>N/A (O)</th>
<th>mean</th>
<th>mode</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>22. The instructor is prepared for the class and is concerned about his or her preparation.</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>23</td>
<td>27</td>
<td>0</td>
<td>4.28</td>
<td>5</td>
</tr>
<tr>
<td>23. The instructor makes good use of class time.</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>30</td>
<td>22</td>
<td>0</td>
<td>4.25</td>
<td>4</td>
</tr>
<tr>
<td>24. The instructor is enthusiastic and interested in teaching this course.</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>24</td>
<td>29</td>
<td>0</td>
<td>4.40</td>
<td>5</td>
</tr>
<tr>
<td>25. The instructor treats students in a professional manner.</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>25</td>
<td>28</td>
<td>0</td>
<td>4.42</td>
<td>5</td>
</tr>
</tbody>
</table>

**file:///C:/Users/Benjamin%20Terry/Box%20Sync/Working/Teaching/MECH%20350%202017%20Spring/Results/Individual%20Course%20Report%20-%20... 3/13**
<table>
<thead>
<tr>
<th>26. New concepts and examples are clearly explained at a level students can comprehend.</th>
<th>0</th>
<th>4</th>
<th>8</th>
<th>31</th>
<th>14</th>
<th>0</th>
<th>3.96</th>
<th>4</th>
<th>0.82</th>
</tr>
</thead>
<tbody>
<tr>
<td>27. The instructor motivated me to understand and apply course concepts.</td>
<td>0</td>
<td>6</td>
<td>11</td>
<td>29</td>
<td>11</td>
<td>0</td>
<td>3.79</td>
<td>4</td>
<td>0.88</td>
</tr>
<tr>
<td>28. The instructor provides useful feedback on how I am doing in the course.</td>
<td>1</td>
<td>4</td>
<td>9</td>
<td>32</td>
<td>11</td>
<td>0</td>
<td>3.84</td>
<td>4</td>
<td>0.88</td>
</tr>
<tr>
<td>29. The instructor is accessible for help outside of the classroom.</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>28</td>
<td>16</td>
<td>1</td>
<td>3.93</td>
<td>4</td>
<td>1.01</td>
</tr>
</tbody>
</table>

**Question Set Statistics**

<table>
<thead>
<tr>
<th>Strongly Disagree (1)</th>
<th>Disagree (2)</th>
<th>Indifferent (3)</th>
<th>Agree (4)</th>
<th>Strongly Agree (5)</th>
<th>N/A (0)</th>
<th>mean</th>
<th>mode</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>30. The classroom physical environment (e.g. temperature, lighting, acoustics) is comfortable for learning.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>36</td>
<td>18</td>
<td>0</td>
<td>4.21</td>
<td>4</td>
</tr>
<tr>
<td>31. The classroom is free from outside distractions.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>35</td>
<td>19</td>
<td>0</td>
<td>4.26</td>
<td>4</td>
</tr>
<tr>
<td>32. The classroom design and furnishings do not interfere with my learning.</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>33</td>
<td>17</td>
<td>0</td>
<td>4.14</td>
<td>4</td>
</tr>
<tr>
<td>33. The classroom has adequate instructional equipment and technology.</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>36</td>
<td>19</td>
<td>0</td>
<td>4.30</td>
<td>4</td>
</tr>
</tbody>
</table>

**Question Set Statistics**

<table>
<thead>
<tr>
<th>mean</th>
<th>mode</th>
<th>Std. Dev.</th>
</tr>
</thead>
</table>

**Base Questions item 18**

**Base Questions item 20**

34. What are 1 or 2 specific things that helped you learn in this class?

- The class notes and the book were the greatest tools for learning in this course.
- I like that he re writes the notes with us so he doesn’t go too fast
- Having the notes online as well as being modified in class as needed.
- I liked how you used onenote for the notes. It was easy to keep up and see on the projector.
- Examples in class
• Being able to go over the exams in depth with the professor during office hours is really nice. It really helps me learn from the mistakes I made. Recitation is super helpful, but I wish we could do more than one problem. The problems in this class just take too long.

• The note style was good as well as homework.

• Examples used in class and the involvement with clicker questions.

• I like how we would go through examples together.

• Working through examples in class.

• The printed out notes helped me understand the lecture a lot better. Also, the clicker quizzes help you think about what you just learned in lecture.

• Lecture notes

• The annotated notes are helpful.

• Extra help with the teacher and

• Examples in the notes

• examples and recitation

• The homework was very helpful and the follow along notes were very helpful as well

• Examples in class Recitation

• I believe reading the chapters along with attending lecture is essential to understanding the material. Also, Chegg was helpful when I was stuck on a problem, as the solutions posted on blackboard were not complete.

• Read the book. Saw the professor for any issues. Downloaded the class notes for use in class.

• The clicker questions

• Office hours

• Arduino project.

• I liked how Dr. Terry makes the notes available before class, and then re-writes them on his surface as he goes through new material. This way, I can follow along easily. This is a great way for me to learn.

• Homework, Office hours (I liked that Dr. Terry had them in Othmer)

• When he brought real world examples into class to compare it to what we are learning that day.

• Professor is always enthusiastic and seems genuinely interested in how well the students are learning.

• Providing the homework solutions, as well as having the lecture notes online to better follow along with.

• The homework was tough but helped for the exams
Lectures are well-organized and Dr. Terry is often available outside of class. He's good about answering questions and generally explains topics well.

Pro: Terry always inspires me and help me to move forward. I really appreciated it.

The TA really helped me understand the material more clearly.

THE EXAMS SHOULD NOT BE HARDER THAN THE HOMEWORK, IT'S EITHER THE SAME LEVEL OF DIFFICULTY OR LOWER SINCE THE STUDENT HAVE MORE TIME AND NO STRESS WHEN DOING HOMEWORK.

-Dr. Terry working through example problems (on the few occasions he didn’t explain the concept incorrectly) - The Arduino project was very challenging, but interesting.

Recitations offered valuable time outside of class to practice the material and get specific answers on questions. Office hours were extremely productive and Dr. Terry was always open to taking questions.

Class notes, homework problems and then looking over solutions afterwards.

1. The clear notes and examples from the lectures during class were very helpful. I doubt I could have made it through the class with only the textbooks. 2. The homework and provided solutions helped me learn the concepts. 3. The recitations were very helpful in helping to learn the more difficult topics and to ask any specific questions we had.

na

class notes / book

The Printed notes were helpful

I liked that the notes were posted before the lecture so I could focus more on comprehending and learning and not scrambling to write down words.

Dr. Terry had great lectures, and I was always confident that if I needed help, I could ask him a question or two after class.

I thought the teacher was interactive and accommodating. He was helpful and encouraged questions. The material covered in class seemed to be straightforward and taught in a way that students could understand for an undergraduate level.

I liked the detailed examples and accessible notes on blackboard.

the Arduino projects the class notes

The quizzes, examples, homework, recitation and the textbook helps

The lecture notes posted are very helpful. It makes me understand further and can learn it beforehand. Additionally, this give me a chance to view it and ask questions if needed.

Base Questions item 21

35. What are 1 or 2 specific things that caused a problem with your learning in this class?
The pace at which the course was taught and the amount of material covered made it difficult to learn everything.

Second test was clearly way too hard for a lot of us which means it wasn't explained well enough, homework is very long

I felt it was taught at a very quick pace and there was not very much time for material to really sink in.

The material became much more difficult after the first test. And when you skipped over steps in lecture it made the homework difficult. I know you did this to save time, but it was detrimental.

Poor handwriting and mistakes on lecture notes

The projects and homework often have nothing to do with what will be on the exams. Professor doesn't know how to answer questions in class, he doesn't know reasoning/information when put on the spot. Also, I went to office hours for help with a class project and he wasn't familiar with the assignment when he was the one that assigned it and I had spent over 5 hours working on it and he didn't even know what the assignment was asking.

Homework grading. I understand that there are lots of students in the course, and grading 6 problems per student each week is a lot of work. I just don't think grading 1 out of 6 problems per week is satisfactory. I have to go over the entire homework assignments again (before an exam) to make sure I have them correct.

Some material was presented at too fast of a pace.

Dr. Terry struggled to explain some of the more complicated topics. Also, his wording on exams confused me and he won't explain what he is looking for if you ask him during the exam. I'm usually an A student and I've dedicated the largest amount of my studying to this course and I'm still only able to get a B on his exams.

Didn't always show all the steps to get the final answer when doing examples.

The class got a bit dry from time to time. The theory can become overwhelming.

The pace is a little too fast

I got in a habit of looking on the internet for homework solutions. Some non-book problems mixed in for the homework would have been helpful.

A lot of information to try and grasp

Teacher unwilling to do reviews for exams

fast pace, my head is still spinning but I learned a lot.

lighting in the classroom is quite dim in some parts if you are not directly under the lighting

The merger of using MATLAB and trying to show how to actually code and make Simulink models wasn't discussed completely due to a lack of time, which made for a long five hours of trying to get a model to work

Sometimes Prof. Terry's handwriting was difficult to decipher, although he was often asked to correct it.

I got nothing.
The exams do not reflect my learning. Very limited office hours.

Recitation was very hit and miss, sometimes it would just be one or two examples that were similar to already assigned homework problems.

Difficult tests!

The class was offered at 8:30 am. This time caused me to zone out easily sometimes.

he needs to do better reviews for the tests

Exams aren't quite the same as the homework (for exam 1, problem 1 broke up the different parts which was harder for me to understand/ less intuitive than the way I did it on the homeworks; For exam 2, the problems seemed oddly worded and made it hard to understand what they were asking for)

There is a very large amount of material to cover

Dr. Terry just wrote down what he had on his notes posted to blackboard for every class. Little to no extra explanation was given to help understand the new material. Additionally, the assigned homework was always too long and time consuming which made it difficult to work out and learn without getting really stressed out and tired.

There is way too much material in my opinion. There's so much that it's hard to keep up. My folder was full of lecture notes halfway through the semester. Homework is also exceedingly long.

The objective of certain subject matters were not clear.

-De. Terry often told us how to solve a problem, but then realizes a few minutes later that he told us how to do a critical step in the opposite way that we are supposed to do it. He rarely goes back through the problem to show us the right way, just tells us to think of it the opposite way. This is VERY frustrating and VERY difficult to figure out how to understand the material. If the professor runs into a lot of problems with it, it is tough to understand how students can.

N/A

Sometimes homework took over 6 hours to complete if you factor in reading the textbook as well. I am all for practicing problems however, time became an issue so I would hurry through occasionally.

1. The professor is very busy, which I understand, but his availability outside of class was limited at times. I had conflicts with his office hours so I couldn't always go then. 2. I had trouble on exams because the problems, though the same topics as the homework, were structured differently. Often for the homework, we would solve the problem straight through. For the exams, there were often multiple steps with ambiguous instructions. This was difficult to prepare for and hard to adjust to during an exam.

na

na

The printed notes were nice but when use a bunch of different colors and continuously modify a single diagram the notes become extremely difficult to follow when you are looking over them after class.

MATLAB solutions should be covered a little more thoroughly for how useful they are in real world applications. Also the content on Tests was very different from the format of problems we had seen in class and homework.
Not sure if anyone else has noticed this, but Othmer 106 seems to have more bugs (physical, lives ones, not technical) on average than other lecture halls.

The test questions were nothing like what was taught in class. They may have been like the homework problems, but I did not study the questions of the homework problems for tests 1 and 2. I did study the material. I knew how to do the work, but was confused by the way the questions were worded. Therefore I do not think the grade I received, especially on test two, is anything like what I should have received.

NA

The terminology used in the homework does not match the wording used on the test. Which makes it hard to determine what the professor is actually looking for. I do not like the structure and organization of the book.

sometimes not sure what the question is asking for

Exam 1 and Exam 2 are vastly different that it feels like different instructors were preparing the questions.

Base Questions item 22

36. Please provide 1 or 2 practical suggestions on ways to help improve student learning in this course.

Based off of the vast material that is covered, it would be very beneficial to have review sheets before exams that cover the main points that you think we should know for the exam in the form of problems.

Maybe use real world examples more often to gives us a visual of what we are solving because sometimes you can get lost in the numbers and the words of like transfer functions and things like that when to be honest i couldn't actually tell you what a transfer function is in the real world i can only show you the equation for how to find it

For testing purposes it would be nice to have some sort of a practice exam that is written at the level of difficulty in which we should be prepared for the actual exam.

Don't spend as much time on the transnational mechanical systems as you do. That portion of the class was easy, and now we have to rush through the much more difficult topics.

Better handwriting and more formal lecture slides

Don't say that your tests will be like the homework unless they are actually going to be like the homework. This professor's tests are also a bit too long. Other than that, this professor is always enthusiastic about teaching the material, even at 8:30am.

Less material and more examples.

Spend some time reviewing material before an exam and use examples worded in the way you would word a question on the exam.

Provide full worked through examples on blackboard of examples that were skimmed over in class.

This class can be very very interesting I would highly recommend adding more real life examples, the boston dynamics robot in particular is really interesting. That kind of stuff helps tremendously to get through the dry theory material.
• Slow down
• Assign some original problems for homework.
• A required every week recitation with a T.A to help go over each week’s lessons
• Test seemed to stray away from book and notes
• Recitation was helpful
• maybe provide example problem videos that go in depth showing how to solve a problem
• Dedicate more than the last five minutes to teach a little more on the coding/block diagram modeling for Simulink
• I believe the second exam could have been more clear. The problems were quite different from what we learned in class and practiced in the homework. The first test was a much better representation of the material. Also, I believe that little to no material should be taught on the dead week, which should be dedicated to review and studying. However, I understand that the material listed in the outline would be difficult to rearrange when cut a week short.
• Read the book. There are additional examples in the book that really help with extra applications and in depth explanation. It is also very well written, you can understand it pretty well, and I am not much of a text book reader.
• clearly list and label the steps to the method being used, then after the example is through go back and reiterate and label again the process being used. I know I am supposed to memorize methods of problems solving but sometimes it is hard to follow. Also, I spent much more time learning state variable form and neglected input/output form little did I know we’d use the latter almost exclusively. I would like to know what I should prioritize learning.
• Focus tests on NOTES material instead of homework problems!
• Provide exam study guides
• review for the tests
• Exams closer to the wording of homeworks (more for understanding the problem).
• While the projects are very interesting to do, it felt like they were detached from the class. Possibly try to tie the projects more into what we are learning
• Dr. Terry never provided a practice exam or even a review before a test. When asked whether he could even work out some applicable examples in recitation he responded by saying, just work out every homework problem I’ve ever assigned and you should be okay for the test. In the world of engineering, there is simply not enough time to do that and he simply did not want to put any effort into making a simple review.
• Cut out topics that are unimportant or cover less of the textbook.
• Use a newer version of the book.
• -PAY ATTENTION TO WHAT YOU TELL US! Stop thinking about your research, your kids, your wife, etc.. It shows that you aren't focused on class because you make so many CRITICAL mistakes. If you explain things the right way we will actually understand the material. -Provide more comments on
what to expect for exams. Exams are unreasonably difficult and asked very differently than what we work on in class from homework problems.

- Offer more flexible office hours and find a way to encourage greater recitation attendance.
- Maybe have the set be 1 or 2 problems shorter, but then add suggested problems alongside.
- Provide practice or sample exams for students to look at and practice. This would help students perform better and be less stressed for exams.
- na
- na

DONT USE Multiple colors for notes, nobody brings a bunch of different color pens to class. The grade % breakdown for the class is overly weighted on the two midterm exams 25% of your class grade for a 50 min exam is absolutely ridiculous. Increase the weight of the homework by 5% and make the project a group project and increase the weight 5%.

- I think the tests were designed to breakdown problems and make them simpler but for me this made the whole problem more confusing. On the first test for example I understand the process of getting SV equations and even solving them but when it was broke down into such small steps it made it hard to understand what was being asked for. I think the tests should be formatted a lot more like the homework problems and it doesn't mean they have to be easier, just less confusing.

- The tests were not as much like the homework as I would have hoped, which is fine. I just think it was not accurate to say they were just like the homework when the methods were slightly different (first test was fine, what I'm referring to is the linearization problem on the second exam. The homework was always the linearization of a whole system, and the test was just one element law. This confused me for a few minutes)

- If you are going to ask questions on the tests that are difficult to understand, maybe you should use similar wording in your lectures so that students will know what to expect, or maybe put out some previous exams that students may look at to realize how impossibly hard to understand the questions will be.
- NA
- look into using a different book.
- be more specific on the questions asked.
- Give a sample exam to the students since your exam are so unpredictable that students have no idea on what to expect (such as type of question). Include a video of lecture if we use MATLAB. A number of homework question are using it and students do not have an idea on how to use Simulink.

Base Questions item 23

37. Other comments that you would like to make:

- Overall, I enjoyed this course and would like to take other course to better my understanding in this area of engineering.
hes a nice guy, cancels office hours way too much at the most inconvenient times. Test this week? office hours will be cancelled

I feel that the professor is a very good instructor and really cares about the material and his students.

I hate this class, but that is of no fault of the professor. The professor is very open, helpful, and understanding. I can tell that he cares about his students and that makes me very happy.

I didn't do great grade wise in the class but I did learn and understand the concepts just did not perform well on the exams. Seemed to get the stuff down that didn't show up on the test. Exam content was stuff I did not have down pat.

Dr. Terry focuses on stuffing in as much material as possible, but I think that compromises our understanding because we don't have days to review and he has limited accessibility outside of class.

The tests are fair I would say but in particular the first test was structured very poorly in my opinion. I would of appreciated some more freedom to do the problem how we had been doing them in the homework. If you would have forced us to do the homework like that I would of understood the rigid structure a little bit more.

The Arduino projects are pointless. The only one useful is the last one.

Very knowledgeable and enthusiastic teacher.

None

The first exam was very fair, and then the method of testing changed. I think that my actual understanding doesn't reflect in my test scores. Trying to work out problems similar to homework was okay, but not having a definitive final answer to compare to did not help.

Prof. Terry is very dedicated to this topic, with plenty of robots and relevant examples for control systems. This is an interesting, yet challenging class that will make you rethink many different engineering problems.

Terry is a pretty great professor. He is always willing to answer questions and make additional office hours when he can. Really approachable.

I actually enjoyed the beginning of the class with transnational mechanical systems. But then ELEC happened... I do not enjoy electrical engineering or its wizardry. From after the first exam it essentially felt like ELEC part 2. I do not enjoy robotics and plan to stay far away from this field of study.

Very intelligent professor.

I believed that the exams were too difficult (minus the first one). Make sure they are the right difficulty. We are learning this for the first time, we aren't experts.

Great professor, great class, genuinely enjoyed it.

N/A

Recitation is at an awful time.

Tests were also an area where Dr. Terry struggled. On our second midterm, the average was a 54% and he thought that he had made an easy test. I scored below the curve because I was overwhelmed with
this test and I was not able to answer questions with a clear mind. Dr. Terry did not account for his
horrible test and made no effort to help out his class to fix what we didn't know.

- For hearing that Terry is a "good professor" from other students, I had moderate expectations for him.
Unfortunately, he corrupted my expectations by teaching us very poorly and being so unavailable. It is
clear that he is not cut out for teaching; research is what is on his mind. He is better than To and Szyd
and Bai Cui, but I am still disappointed in his teaching capabilities.

- Dr. Terry is a fantastic professor that clearly cares about quality of his instruction.

- The tests were not anything over my ability, however, I felt slightly misguided because I was told if I
could do the homework, then the tests wouldn't be a problem. I did not feel the homework was parallel
to the tests. I don't think either the homework or test was wrong, but maybe the message on how to
prepare for the tests. I found the best way to prepare was to go through your lecture notes since much of
the test is based on how well you know the concepts.

- Professor Terry is very nice and helpful. I enjoyed having him as a professor.

- n/a

- Thought the instructor was enthusiastic about the subject

- When you don’t give a review and tell students to focus on knowing how to do the hw and then word
the test problems that are not anything like the hw that’s a problem. Also for the second exam throwing
questions that are absolutely nothing like the hw, and later I found out that the questions were the same
as a previous exam you gave, meaning some people having access to that material before the exam
makes that exam the worst possible measure of comprehension of material that you could possible
judge.

- I enjoyed Dr. Terry teaching this semester, he is very calm and understanding of our struggles with the
material and overall did a nice job of teaching the content.

- Dr. Terry is easily in the top 3 professors I’ve ever had. He is always willing to answer questions and
makes his lectures understandable for everyone. He tries to make sure everyone (not the majority,
EVERYONE) understands before moving on. That has saved me several times. Keep doing what you're
doing!

- I enjoy the teacher's teaching style and his enthusiasm in the course.

- n/a