AE/ME 3703 – Introduction to Control of Dynamical Systems
B-Term Fall 2013, MTRF 9:00 AM – 9:50 AM

Instructor: Dr. R. V. Cowlagi, HL 247, rvcowlagi@wpi.edu, http://www.wpi.edu/~rvcowlagi
Instructor Office Hours: Fridays 10:30 AM – 12:30 PM, otherwise by appointment via email.

Teaching Assistant: Mr. Zetian Zhang, HL 310
Tutorial Sessions: Wednesdays, 9:00 AM – 10:50 AM
TA Office Hours: Mondays, 10:30 AM – 12:30 PM

Background: A background in ordinary differential equations (MA 2051 or equivalent) is required. Familiarity with dynamics (ES 2503, PH 2201, PH 2202 or equivalent), fluid dynamics (ES3004, AE/ME 3602 or equivalent), electricity and magnetism (PH 1120 or PH 1121 or equivalent) is beneficial but not required.

Course Summary
This course introduces the mathematical modeling and control of dynamical systems in aerospace and mechanical engineering applications. Topics include: introduction to feedback control analysis and synthesis of linear dynamic systems; transient response analysis of first and second order systems (thermal, pneumatic, hydraulic, and mechanical); introduction to state-space modeling and representation of control systems; linearization of nonlinear systems; stability analysis using Routh’s criterion and Lyapunov methods; system analysis using frequency response methods; introduction to the design of controllers in time and frequency domain. The analysis and design will be accomplished with MATLAB and Simulink.

Course Objectives
By the end of this course, the students are expected to:
1. Learn to model dynamical systems in mechanical and aerospace engineering applications,
2. Learn to analyze, in time-domain and frequency-domain, the transient- and steady-state responses of linear time-invariant systems,
3. Learn fundamental concepts in feedback control system design for linear time-invariant systems,
4. Learn to use the MATLAB and Simulink software packages to analyze and design control systems.

Course Outline
• Introduction (2 lectures)
  – Overview, terminology
  – Representations of systems: block diagrams, differential equations
• Mathematical Modeling of Physical systems (4 lectures)
  – Electrical and mechanical systems; Thermal and fluid systems
• Linear Differential Equations (5 lectures)
  – Solution of linear differential equations; Steady-state and transient responses
  – State-space representations of linear systems
• The Laplace Transform (5 lectures)
  – Partial fraction expansion
  – Transfer functions; Transformations between system representations
• Transient and Steady-State Response Analysis (5 lectures)
  – First- and second-order systems
  – Routh stability criterion
  – Unit feedback systems
• Control Systems Analysis and Design by Frequency-Response (5 lectures)
  – Bode plots
  – Lead- and lag-compensation; PID control
• Overview of Modern Control Systems Design Techniques (2 lectures)
  – Pole placement
  – Linear quadratic regulators
  – Observers and Kalman filter
• Tutorial Sessions (5 sessions)
  – Introduction to programming in MATLAB
  – Introduction to control system analysis and design with Simulink
  – Root locus analysis

Recommended Textbooks
Performance Evaluation: Homeworks (35 pts), Quizzes (15 pts), Midterm exam (25 pts), Final exam (25 pts)

- Homeworks will be typically assigned on Thursdays and the completed assignments will be due on the following Tuesdays (see Figure 1). For the overall course grade, the best 5 scores of the 7 assignments will be considered.
- Four quizzes (1-2 questions, 15-30 minutes) will be administered during the Wednesday conference sessions (see Figure 1). For the overall course grade, the best 3 scores of the 4 quizzes will be considered.
- One mid-term exam and a final exam will be administered. Both exams will be held in-class.
- The following rubric will be used for grading each problem in all homeworks and exams
  - 0%: Solution missing.
  - 20%: Minimal progress made towards solution.
  - 40%: Minimal progress made towards solution and some of the work shown, but incorrect approach or incomplete answer.
  - 60%: Significant progress towards solution and all work shown, but incorrect approach or incomplete answer.
  - 80%: All work shown, correct approach, minor errors.
  - 100%: All work shown, correct approach, correct answer.

The tentative grading policy for the course is as follows:
1. The course grade for each student will be assigned based on the sum of points received by that student in each assignment (homework, midterm exam, final project/exam).
2. Let $x$ be the top score (sum of points on all assignments) in the class. A student with a score $y$ will receive Grade A if $0.9x \leq y \leq x$, Grade B if $0.7x \leq y < 0.9x$, Grade C if $0.5x \leq y < 0.7x$, or Grade NR if $y < 0.5x$.

Policies and Guidelines

- The course schedule shown in Figure 1 is tentative and subject to change.
- Students are expected to attend all class lectures and tutorial sessions. Students are encouraged to make notes in class. During the class lectures, the use of laptop computers and other mobile computing devices is strongly discouraged.
- Homework will be periodically assigned, and the students are expected to return complete homework solutions by the due dates. Late submissions will be accepted, but the homework grades will be penalized at 10% (of the original homework grade) per day, unless valid reasons are provided (such as illness or personal emergencies). For example, for a homework that was graded at 9 pts out of 10, but was turned in 2 days late, the student would be credited with $0.9 \times 0.9 = 0.81$ pts.
- Illegible and/or untidy homeworks and exams will not be graded: the students will forfeit points unless the work is entirely resubmitted. The determination of “illegibility” and “untidiness” will be based on the subjective judgment of the instructor and/or the TA.
- Cheating and plagiarism will not be tolerated. Whereas students may discuss homework assignments, they may not copy problem solutions from other students. Furthermore, students must concisely report any such discussions within the submitted homework, e.g., if John Doe and Jane Doe discuss a specific problem before writing their individual solutions, they are both expected to include a sentence such as “I discussed this problem with John / Jane”. The submitted homework must reflect a student’s own product and represent the student’s understanding of the material.
- Cheating and plagiarism on any assigned homework, exam, or project will result in forfeiture of all points associated with that assignment. Students are strongly encouraged to study the WPI policies on academic honesty, which may be found at http://www.wpi.edu/offices/policies/honesty/policy.html
- When possible, the students are required to inform the instructor of potential difficulties in advance. Most problems can be handled over email. Students should individually inform the instructor, by November 4, 2013, of any long-standing commitments (i.e. religious observances, varsity team athletic events, etc) that may affect their ability to meet the class requirements, for alternative arrangements to be considered.
- Students in need of course accommodations because of a disability should make an appointment with the instructor as soon as possible. Additionally, students are encouraged to contact the Office of Disability Services (ODS), as soon as possible to ensure that such accommodations are implemented in a timely fashion. The ODS is located at 157 West Street, (508) 831-4908, DisabilityServices@wpi.edu.