ME 41100 System Dynamics and Control

Dr. B. Wang

Homework 1

Note: This homework reviews the course information and policies and reinforces the introductory feedback and modeling concepts from Lectures 1 and 2. Scan your answers, append them to this signed homework file, and submit the complete document to Brightspace as a single PDF.

Class information:

- The class website is: https://bwang-ccny.github.io/ME41100.html
- The main textbooks for the course will be:
  - G. F. Franklin, J. D. Powell, A. Emami-Naeini, *Feedback Control of Dynamic Systems*, Pearson.
    (The most up-to-date edition of this book is the 8th edition. Previous editions should, for the most part, be fine, as the material will not be substantially different.)
  - K. Ogata, *System Dynamics*, 4th ed., Pearson Prentice Hall.
- Office hours: Mon/Wed 1:00 PM - 2:00 PM, Steinman 247

I, ______________, understand and will follow the following policies of this course.

- **Policy on Lateness and Absence.** Students are expected to attend every class session of each course in which they are enrolled and to be on time. A WU grade will be assigned to a student by the instructor for excessive absence. Students should note that **an instructor may treat lateness as equivalent to absence**. **No distinction is made between excused and unexcused absences.** The number of hours absent may not exceed twice the number of contact hours the course meets per week.
- **Grading Policy.** The grade will be assigned roughly according to the following percentages: Weekly homework: 15%, Lab reports: 15%, Midterms: 30%, Final exam: 40%. **No late homework will be accepted.** If answers are not accompanied by satisfactory explanations (e.g., all intermediate steps, clearly readable handwriting), no credit will be given.
- **Exam Policy.** Exams will be **closed books** and **closed notes**. No phone or laptop is allowed to be used in the exams. During exams, you will be allowed to use **one** reference sheet. Reference sheet must be on a Letter-size paper. Both sides may be used, and the reference sheet must be **hand-written**.

- **Academic Integrity.** All students are subject to the university's academic integrity policies. Academic dishonesty will **not** be tolerated in any form. The lecturer will strongly adhere to the CUNY Policy on Academic Integrity, should the need arise. Instances of academic dishonesty include, but are not limited to
  - Copying solutions from other students during homework or during exams.
  - Solutions from previous years: It is forbidden to look at or copy solutions for homework from previous years.
- **Copyright Policy.** All course materials (class lectures and discussions, handouts, examinations, web materials) and the intellectual content of the course itself are protected by United States Federal Copyright Law. Students (and all other persons) are forbidden from recording lectures or discussions and from distributing or selling lecture notes and all other course materials without the prior written permission of the instructor. Students are permitted to make notes solely for their own private educational use. Exceptions to accommodate students with disabilities may be granted with appropriate documentation.

Lecture 1: What Is Control and Why Do We Need Feedback?

Reading: Read Chapter 1 of *Feedback Systems: An Introduction for Scientists and Engineers*, then answer Problems 1–5 below.

Problem 1. Identify one feedback system you used today. What are its reference, measured output, sensor, actuator, plant, and principal disturbance?

Problem 2. Under what conditions can feedback reduce the effect of a disturbance that was not explicitly included in the controller design?

Problem 3. Why does feeding the measured output back not automatically guarantee improved performance or stability?

Problem 4. In the mass–spring–damper example, what happens if $b = 0$? How does the feedback gain K affect the natural frequency, and can proportional feedback alone make the motion decay?

Problem 5. When might a simple approximate model be more useful for control design than a highly detailed model?

Lecture 2: Modeling Dynamic Systems for Control

Reading: Read Chapter 3 of *Feedback Systems: An Introduction for Scientists and Engineers*, then answer Problems 6–10 below.

Problem 6. A rotational inertia J is connected to ground through a torsional spring of stiffness k_θ and a viscous rotational damper with coefficient b_θ. An applied torque $\tau(t)$ acts on the inertia. Draw the free-body diagram and derive the governing differential equation for the angular displacement $\theta(t)$.

Problem 7. The mass–spring–damper plant is modeled by

$$m\ddot{q}(t) + b\dot{q}(t) + kq(t) = u(t) + d(t).$$

Suppose that velocity rather than position is measured. Write the output equation and state whether changing the measured output changes the governing differential equation of the plant.

Problem 8. Classify each model as linear or nonlinear and as time invariant or time varying:

(a) $m\ddot{x} + b\dot{x} + kx = u$;

(b) $m\ddot{x} + b\dot{x} + kx^3 = u$;

(c) $m\ddot{x} + b(t)\dot{x} + kx = u$;

(d) $J\ddot{\theta} + b_\theta\dot{\theta} + mgl\sin\theta = \tau$.

Problem 9. Convert the second-order equation

$$m\ddot{q} + b\dot{q} + kq = u$$

into two first-order equations using $x_1 = q$ and $x_2 = \dot{q}$.

Problem 10. Give one example of a physical effect that you might intentionally neglect when building a control model. Explain what engineering objective or operating condition would justify neglecting it.