EECS 460 Fall 2025 Homework 1
Coverage: Concepts up to and including Lecture 3
Assigned: Friday September 5
Due: Friday September 12 at 5:00pm
Total pts: 100

1. [69 pts] Submit a file on Gradescope containing written (or LaTeX) answers
2. [31 pts] Answer the HW1 Quiz on Canvas for the questions marked with **[Quiz]**

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1. For each of the following transfer functions $G(s)$

   i. [9 pts: 3 pts per TF] List all the poles and zeros
   ii. [3 pts: 1 pt per TF] Is $G(s)$ causal? **[Quiz]**
   iii. [3 pts: 1 pt per TF] Is $G(s)$ strictly proper? **[Quiz]**

   (a) $$G(s) = \frac{10(s+2)}{s^2(s+3)(s+10)}$$
   (b) $$G(s) = \frac{2s(s+5)}{(s+2)(s^2+3s+2)}$$
   (c) $$G(s) = \frac{5s(s+7)(s+4)}{s^2-2s+1}$$

2. For each of the following ordinary differential equations (ODEs)

   i. [6 pts: 3 pts per ODE] Write the corresponding transfer function **[Quiz]**
   ii. [12 pts: 6 pts per ODE] Draw block diagrams for the system that only contain integrator, gain, and summation blocks
   iii. [8 pts: 4 pts per ODE] Construct the system in Simulink using integrator, gain, and summation blocks. Let the initial condition be zero; simulate the system's response to the input $u(t) = \sin(t)$. Submit a plot of $y(t)$ and $u(t)$ vs. t; label which is which.
   iv. [8 pts: 4 pts per ODE] Use the `lsim` function in MATLAB to simulate the system's response to the input $u(t) = 2\sin(t)$, with initial condition zero. Submit a plot of $y(t)$ and $u(t)$ vs. t; label which is which.
   v. [4 pts: 2 pts per ODE] Comment (1-2 sentences) on the system's response, and how the Simulink and MATLAB simulations compare to one another.

   (a) $$3y^{[3]}(t) - 5\ddot{y}(t) + 3y(t) = 4u(t)$$
   (b) $$2\ddot{y}(t) + 3\dot{y}(t) + \sqrt{2}y(t) = 7\dot{u}(t)$$

   Note: $y^{[3]}(t) := \frac{d^3y}{dt^3}$.

3. Consider transfer functions $G_1(s)$ and $G_2(s)$ in a negative feedback interconnection, as shown in Fig. 1. Let $G(s) = \frac{Y(s)}{U(s)}$. Assume that no pole-zero cancellations occur in G_1, G_2, or G.

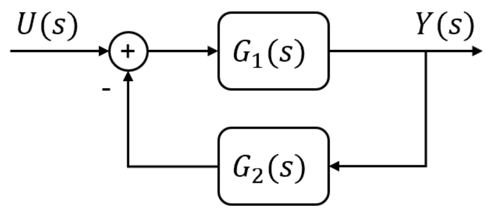

Figure 1: Negative feedback interconnection of $G_1(s)$ and $G_2(s)$

(a) [4 pts] True or false: every pole of $G_1(s)$ is a zero of $G(s)$ **[Quiz]**

(b) [4 pts] True or false: every pole of $G_2(s)$ is a zero of $G(s)$ **[Quiz]**

(c) [4 pts] Let $G_1(s) = \frac{s+1}{s+2}$, and let $G_2(s) = \frac{s+3}{s+4}$. What is $G(s)$?

4. You are given two transfer functions $G_1(s)$ and $G_2(s)$. Neither function has a pole at 2; neither function has a zero at 2. Let $G(s)$ be the overall transfer function resulting from either a series or parallel interconnection of $G_1(s)$ and $G_2(s)$.

   (a) [5 pts: 3 for quiz + 2 for justification] Is it possible that $G(s)$ has a pole at 2? If yes, give an example. If no, why not? **[Quiz]**

   (b) [5 pts: 3 for quiz + 2 for justification] Is it possible that $G(s)$ has a zero at 2? If yes, give an example. If no, why not? **[Quiz]**

5. Consider the first-order nonlinear system

   $$2\dot{y} + 1.5y - \sin(y) - u^3 = 0$$

   (a) [12 pts: 5 for quiz + 7 for work shown] Linearize this system about $\bar{y} = 1$. **[Quiz]**

   (b) [8 pts] Let the initial condition be zero. Simulate the nonlinear system's response to a step input, then simulate the linearized system's response to a step input. Plot $y(t)$ for the linear and nonlinear systems on the same axes and label which is which. **Hint:** One way to do the nonlinear simulation is to follow similar steps as Lecture 2: first, draw a chain of integrators for y, then use the nonlinear ODE to relate u, y, and $\dot{y}$. You may find the Math Operations library in Simulink to be useful.

6. Consider your arm (the bones, tendons, and muscle) as the plant, and consider your nervous system (nerves, spine, brain) as the controller. Your muscles receive "control input" from nerves.

   (a) [1 pt] Give an example of a sensor that provides information about the plant to the controller.

   (b) [1 pt] Give an example of a reference signal. Where does it come from?

   (c) [1 pt] Give an example of a disturbance on the system.

   (d) [2 pts] Draw a block diagram depicting this closed-loop control system (similar to the car cruise control example from Lecture 1). Label your blocks and your signals.

   Note: the purpose of this question is to help you interpret an everyday system as a feedback control system, not to test your knowledge of biology. There are multiple correct answers.