EECS 460 Fall 2025 Homework 1 Solutions
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] [TODO] Submit a file on Gradescope containing written (or LaTeX) answers
2. [31 pts] [TODO] Answer the HW1 Quiz on Canvas for the questions marked with **[Quiz]**

1.

a. i. Poles: $0, 0, -3, -10$; Zeros: -2
   ii. True
   iii. True

b. i. Poles: $-2, -2, 1$; Zeros: $0, 5$
   ii. True
   iii. True

c. i. Poles: $1, 1$; Zeros: $0, -7, -4$
   ii. False
   iii. False

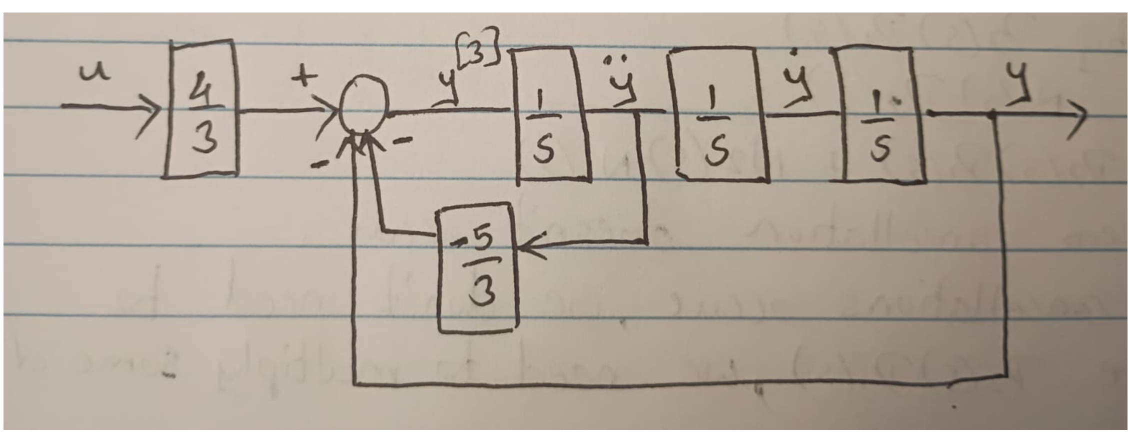
2.
(a)

$$3y^{(3)}(t) - 5\ddot{y}(t) + 3y(t) = 4u(t)$$

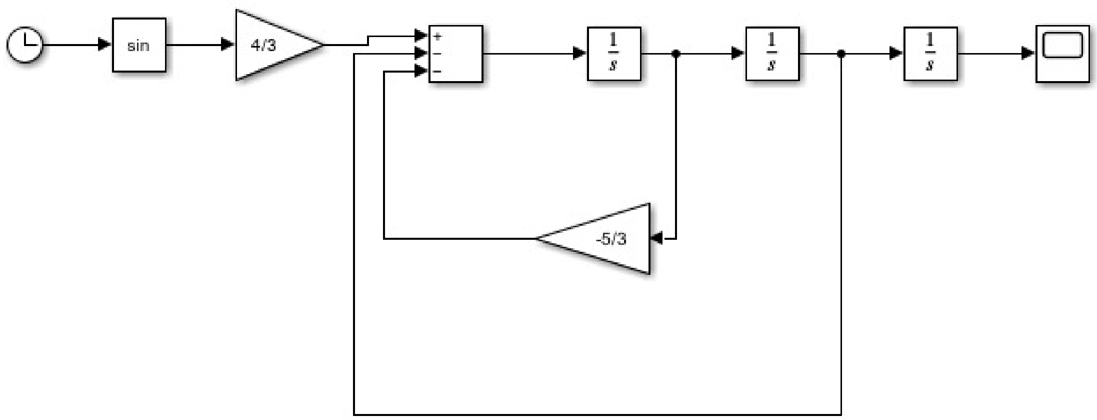
i. Transfer Function

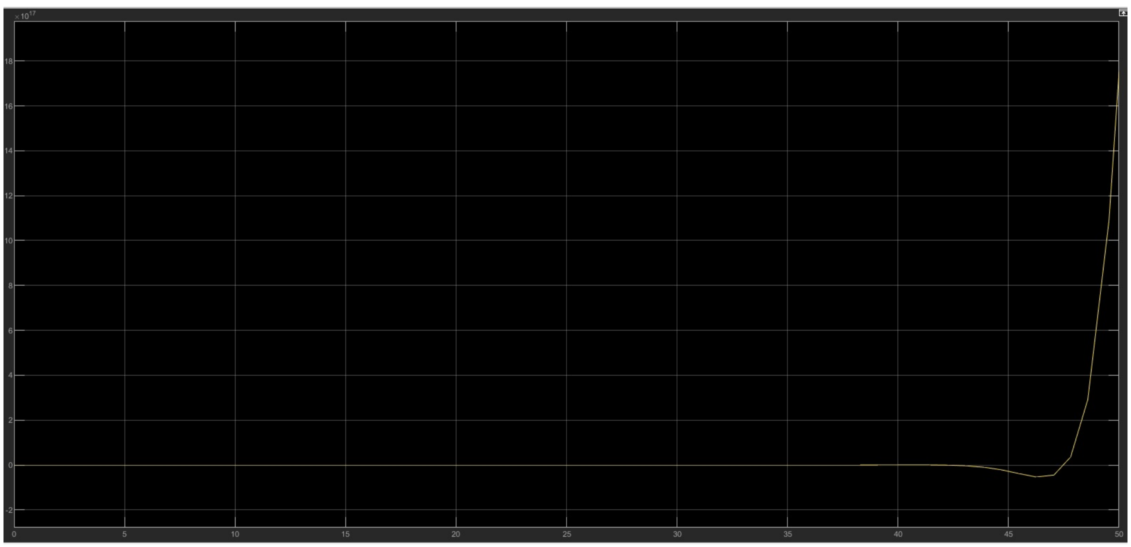
$$(3s^3 - 5s^2 + 3)Y(s) = 4U(s); \frac{Y(s)}{U(s)} = \frac{4}{3s^3 - 5s^2 + 3}$$

ii. Block Diagram

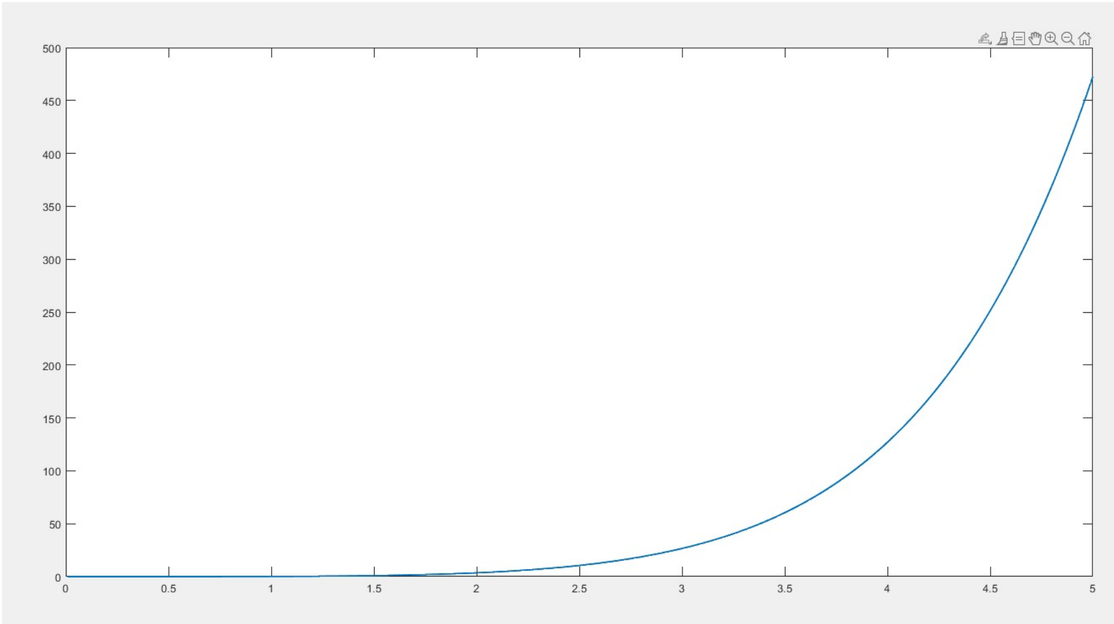


iii. Simulink Model





iv. Observation: The output blows up to infinity.



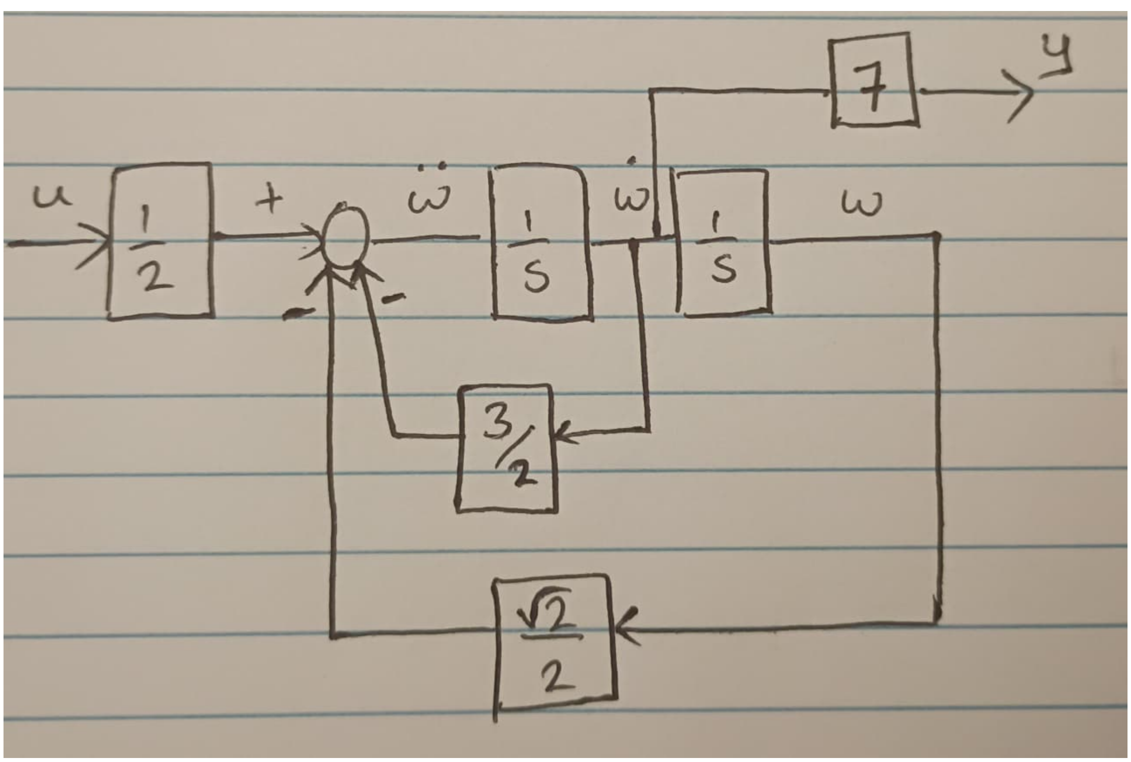
(b)

$$2\ddot{y}(t) + 3\dot{y}(t) + \sqrt{2}\,y(t) = 7\dot{u}(t)$$

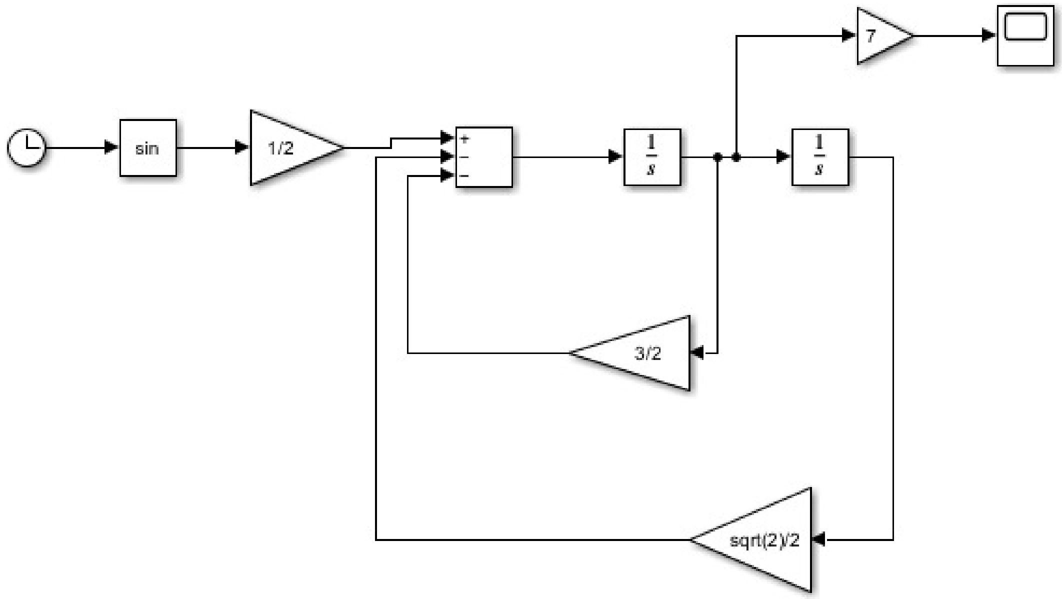
i. Transfer Function

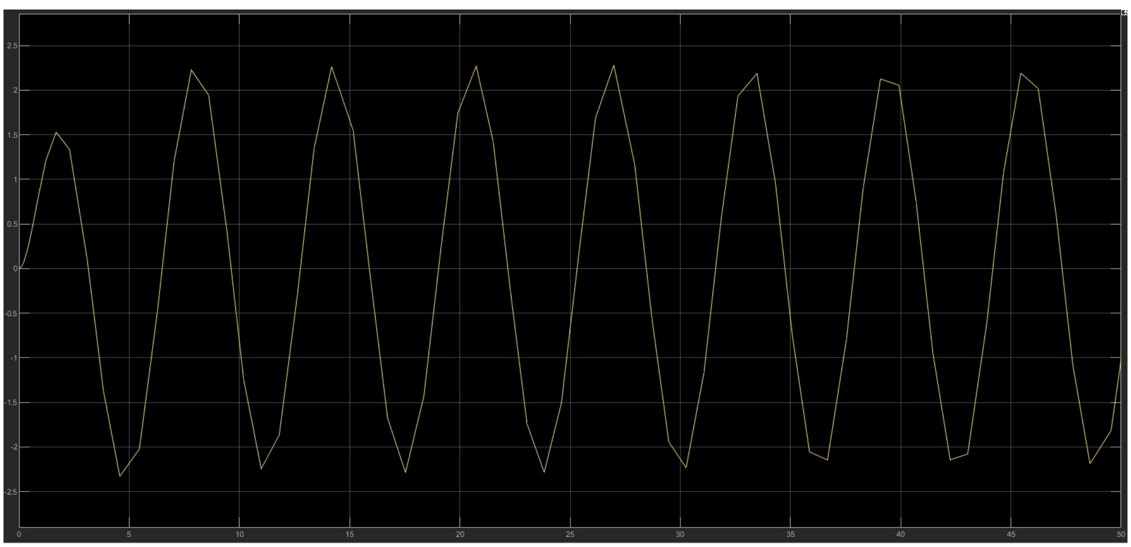
$$(2s^2 + 3s + \sqrt{2})Y(s) = 7sU(s); \frac{Y(s)}{U(s)} = \frac{7s}{2s^2 + 3s + \sqrt{2}}$$

ii. Block Diagram

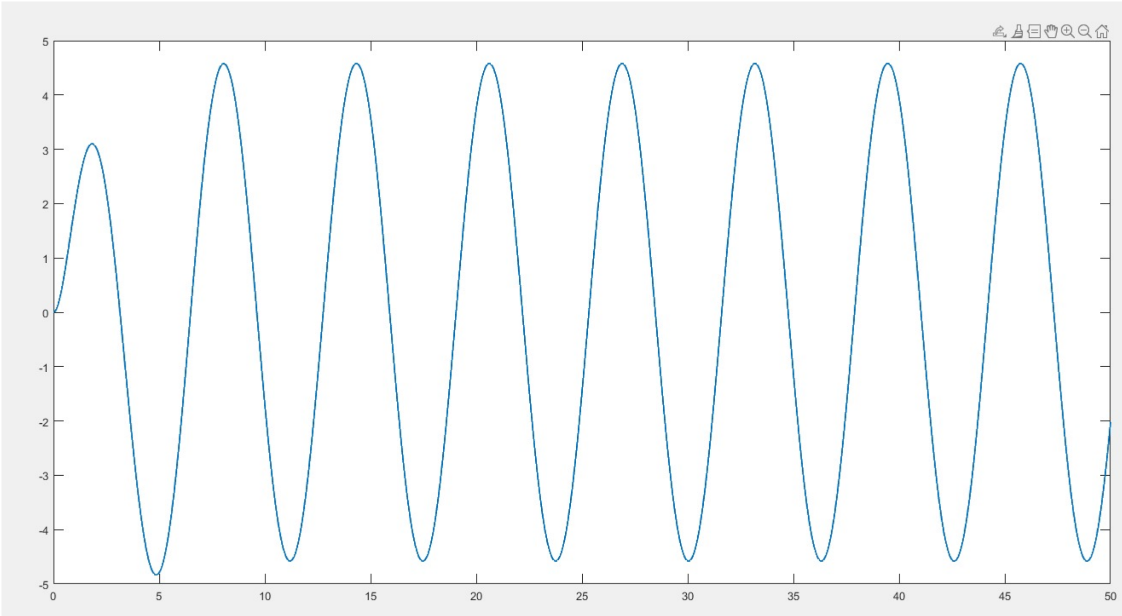


iii. Simulink Model





iv. Observation:The output is a signal that has the same frequency but a different magnitude than the input



3.

a. False

b. True

Reason:

$$G(s) = \frac{G_1(s)}{1 + G_1(s)G_2(s)} \quad \text{where } G_1(s) = \frac{N_1(s)}{D_1(s)},\ G_2(s) = \frac{N_2(s)}{D_2(s)}$$

$$G(s) = \frac{\frac{N_1(s)}{D_1(s)}}{1 + \frac{N_1(s)}{D_1(s)}\frac{N_2(s)}{D_2(s)}}$$

To make numerator and denominator polynomials, multiply both by $D_1(s)D_2(s)$. Poles: $D_1(s)D_2(s) + N_1(s)N_2(s) = 0$ Zeros: $N_1(s)D_2(s) = 0$

4.

a. No. For $G_1(s) = \frac{N_1(s)}{D_1(s)}$, $G_2(s) = \frac{N_2(s)}{D_2(s)}$:

In Series:

$$G(s) = G_1(s)G_2(s) = \frac{N_1(s)N_2(s)}{D_1(s)D_2(s)}$$

In Parallel:

$$G(s) = G_1(s) + G_2(s) = \frac{N_1(s)}{D_1(s)} + \frac{N_2(s)}{D_2(s)}$$

Poles of $G(s)$ must come from $D_1(s)D_2(s)$. Since neither $G_1(s)$ nor $G_2(s)$ has a pole at 2, it is not possible.

b. Yes. For $G_1(s) = \frac{1}{s+1}$, $G_2(s) = \frac{1}{s-5}$:

$$G_1(s) + G_2(s) = \frac{2s-4}{(s-5)(s+1)}$$

which has a zero at $s = 2$.

5.

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

i. Equilibrium Point: $\dot{y} = 0$, $\bar{y} = 1$.

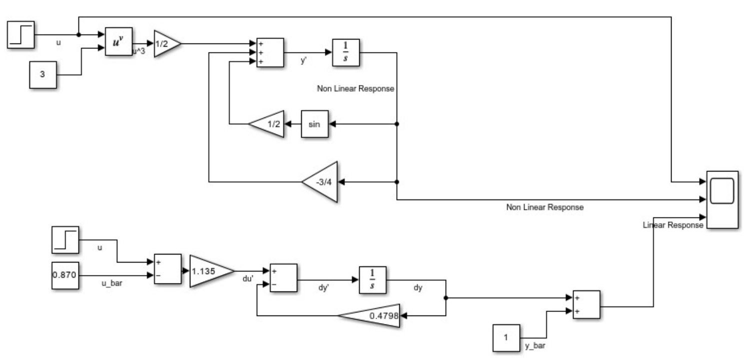
$$2(0) + 1.5(1) - \sin(1) - \bar{u}^3 = 0 \quad \Rightarrow \quad \bar{u} = (1.5 - \sin(1))^{\frac{1}{3}} \approx 0.870$$

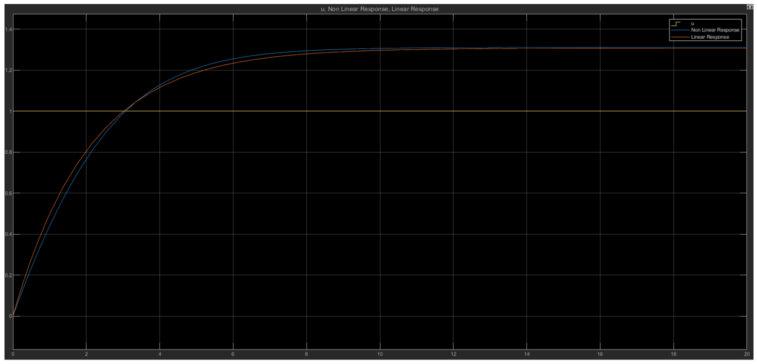
ODE Form and Linearization:

$$\begin{aligned}
\dot{y} &= f(y,u) = -\tfrac{3}{4}y + \tfrac{1}{2}\sin(y) + \tfrac{1}{2}u^3 \\
\frac{\partial f}{\partial y} &= -\tfrac{3}{4} + \tfrac{1}{2}\cos(y) \\
\left.\frac{\partial f}{\partial y}\right|_{(\bar{y},\bar{u})} &= -\tfrac{3}{4} + \tfrac{1}{2}\cos(1) \\
\frac{\partial f}{\partial u} &= \tfrac{3}{2}u^2 \\
\left.\frac{\partial f}{\partial u}\right|_{(\bar{y},\bar{u})} &= \tfrac{3}{2}\left(1.5 - \sin(1)\right)^{\frac{2}{3}}
\end{aligned}$$

$$\delta\dot{y} = \left(-\tfrac{3}{4} + \tfrac{1}{2}\cos(1)\right)\delta y + \tfrac{3}{2}\left(1.5 - \sin(1)\right)^{\frac{2}{3}}\delta u \approx -0.4798\delta y + 1.1354\delta u$$

ii.





6. There are many correct answers. One example set is:

a. Sensors: muscle spindle, eyes, proprioceptor

b. Reference: desired arm position (from the brain)

c. Disturbances: object placed on the arm, external push, wind force

d. Controller:

e. Block Diagram