MAE/ECE-5320 LAB 01 SHORT FORM:
SYSTEM RESPONSES AND PID TUNING

Name:
A-num:
Collaborator: Lab01 will not need collaborator.

Section 1. Simulation with Matlab

Complete the following exercises, please show both software code and simulation results.

Please refer to the follow second order systems that has been introduced in the lecture**.**

- A standard form of the second-order system

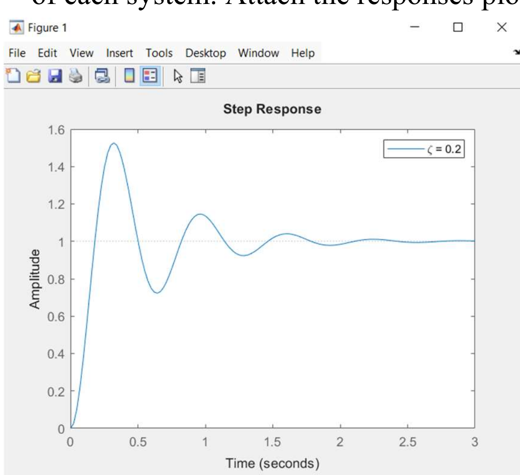
$$G(s) = \frac{\omega_n^2}{s^2 + 2\varsigma\omega_n s + \omega_n^2} \begin{cases} \varsigma : & \text{damping ratio} \\ \omega_n : & \text{undamped natural frequency} \end{cases}$$

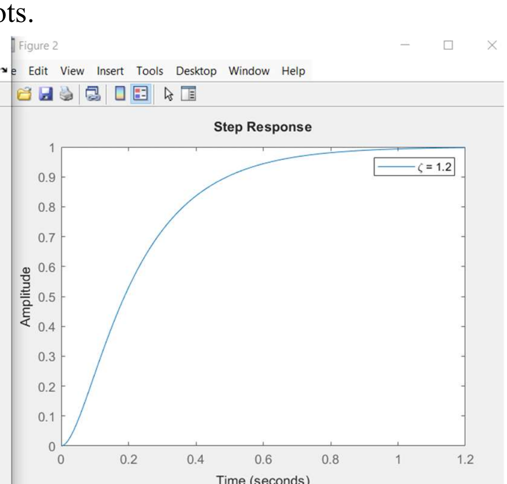
where $\omega_n = 10$ and $\varsigma = 0.2, 1.2, 1, 0$, seperately.

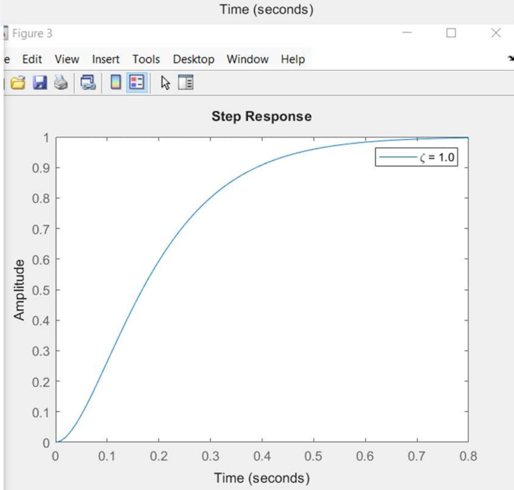
Complete the following tasks:

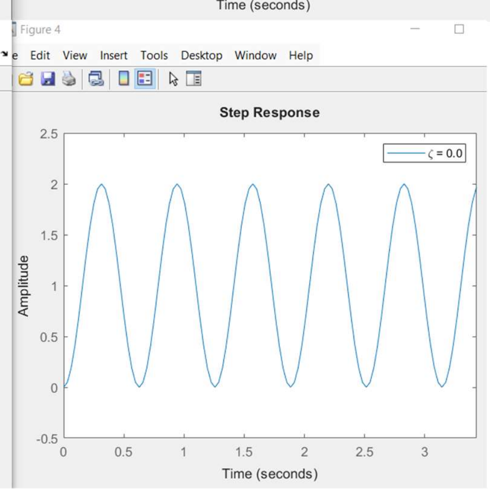
1.) What is the system category in terms of damping ratio $\varsigma = 0.2, 1.2, 1, 0$,. (<u>Undamped, overdamped, critical damped or underdamped ?</u>)
$\zeta = 0.2 \Rightarrow underdamped$, $\zeta = 1.2 \Rightarrow overdamped$, $\zeta = 1.0 \Rightarrow critically\ damped$, $\zeta = 0.0 \Rightarrow undamped$

2.) Use the command of '**linearSystemAnalyzer('step',G)**' to get the step response plot of each system. Attach the responses plots.









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3.) Then fill the chart below about the setting time, rise time, overshoot for $\varsigma = 0.2$

Damping ratio	Setting Time	Rise Time	Overshoot
0.2	**1.96 s**	**0.121 s**	**0.5265 = 52.65%**

Hint: An example of code is shown below:

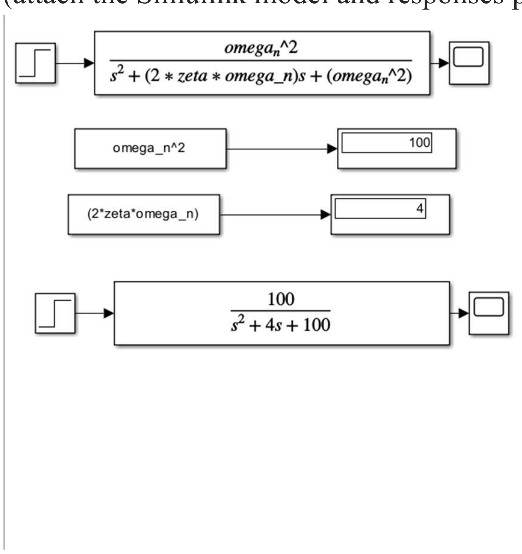
```
% Step response for 2nd order system
w_n = 10;
zeta = 0.2; %underdamped system

s = tf('s');
G1 = w_n^2/(s^2 + 2*zeta*w_n*s + w_n^2);
linearSystemAnalyzer('step',G1)
axis([0 3 0 2])
```

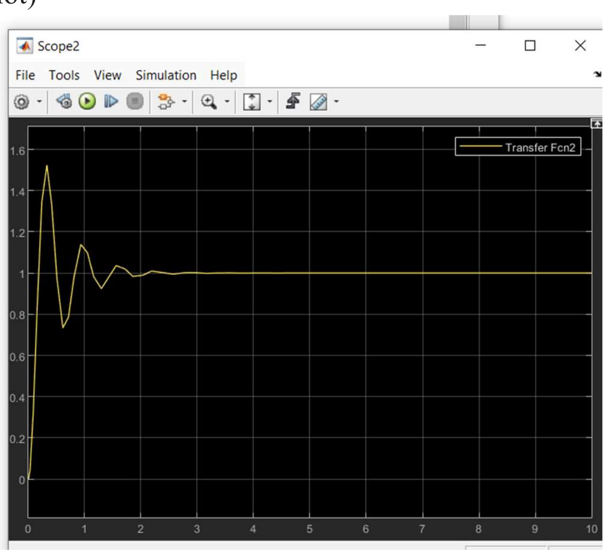
Figure 2. Code Example for Exercise 1.3.1

Section 2. Simulation with Simulink

Complete the following exercise (show both Simulink diagram and simulation result)

Please use $\omega_n = 10, \varsigma = 0.2$ for the 2nd order system defined in Section 1 to construct a Simulink model and simulate the system step response in Simulink.
(attach the Simulink model and responses plot)





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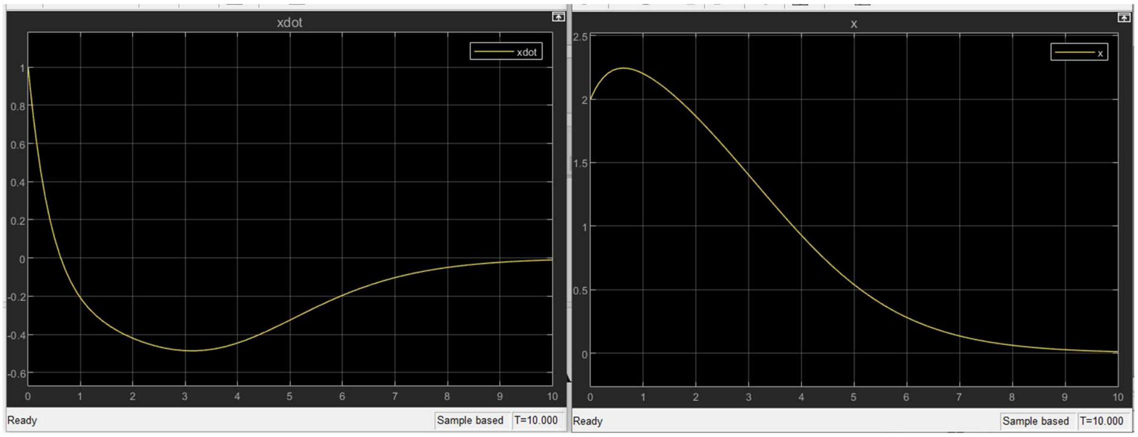
Section 3. Simulate a nonlinear model in Simulink

3.1 Attach the responses of x and $\dot{x}$ from the scope. And answer the question: is this nonlinear system a stable system or unstable system ?



The system is stable

3.2 Try to linearize the nonlinear system at the operating point x=0, run the simulation for linear system and compare the x response with nonlinear system in the same scope.

- Step 1: identify the system model's input $r(t)$ and ouput $y(t)$
  With initial conditions $\dot{r}_0 = 0, \dot{y}_0 = 0, \ddot{r}_0 = 0, \dddot{r}_0 = 0$

- Step 2: express model in the form $f(r, \dot{r}, \dots, y, \dot{y}, \dots) = 0$

- Step 3: define equilibrium operation point r_0, y_0 and set all derivatives to zeros at the equilibrium points

- Step 4: perform Taylor expansion about (r_0, y_0) and only retain 1st order derivative

- Step 5: change variables to derivatives
  $(\tilde{r} = r - r_0, \dot{\tilde{r}} = \dot{r} - \dot{r}_0, \dots, \tilde{y} = y - y_0, \dot{\tilde{y}} = \dot{y} - \dot{y}_0)$

Given:

$$f(x, \dot{x}) = \ddot{x} = -(2\dot{x} + \sin(x))$$

$$f(x, \dot{x}) \approx f(x_0, \dot{x}_0) + \frac{\partial f}{\partial x}_{|x_0, \dot{x}_0} \cdot (x - x_0) + \frac{\partial f}{\partial \dot{x}}_{|x_0, \dot{x}_0} \cdot (\dot{x} - \dot{x}_0)$$

$$x_0 = 0 \rightarrow \dot{x}_0 = 0$$

$$f' = \frac{d\ddot{x}}{dx} = -0 + -\cos(x) = -\cos(x)$$

$$f'(0,0) = -\cos(0) = -1$$

$$f'' = \frac{d\ddot{x}}{d\dot{x}} = -2 + 0 = -2$$

$$f''(0,0) = -2$$

$$\begin{aligned} f(x, \dot{x}) &\approx [-(2 \cdot (0) + \sin(0))] + [-1] \cdot \big(x - (0)\big) + [-2] \cdot \big(\dot{x} - (0)\big) \\ &\approx [0] + [-x] + [-2\dot{x}] \\ &\approx -(2\dot{x} + x) \end{aligned}$$

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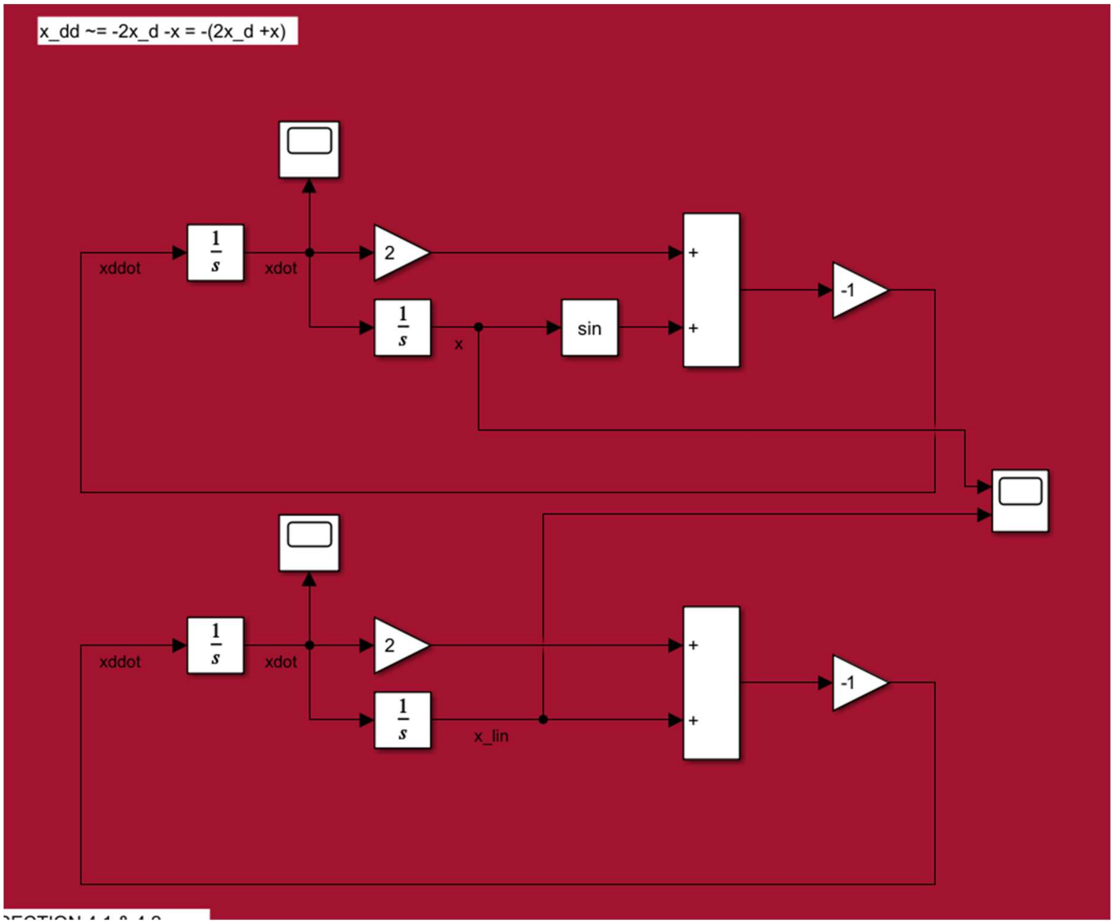

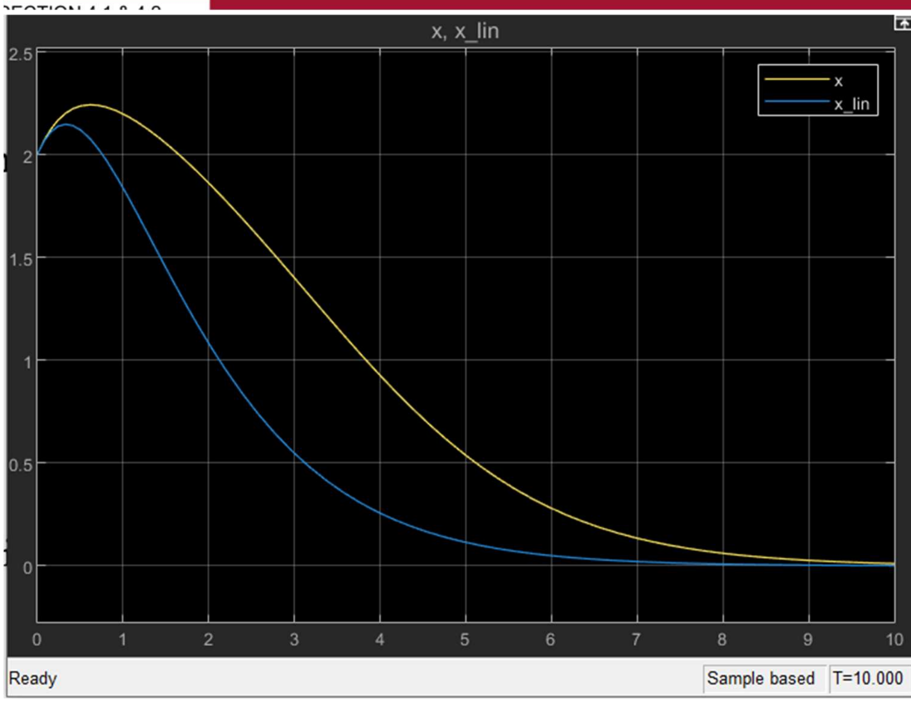

both the nonlinear and linear response converge to the same value, but while in transience, the nonlinear response is larger in magnitude.

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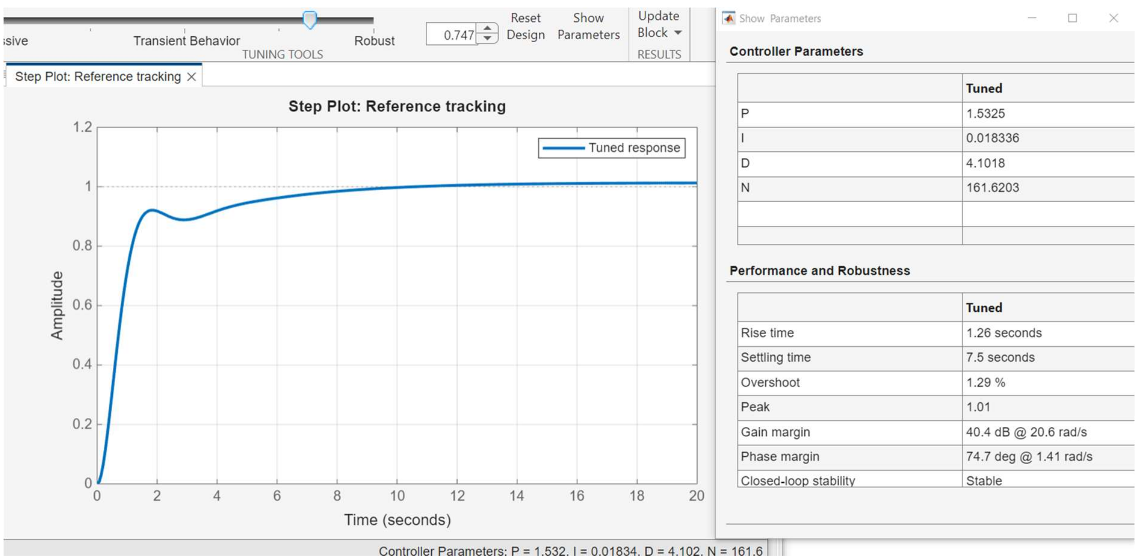
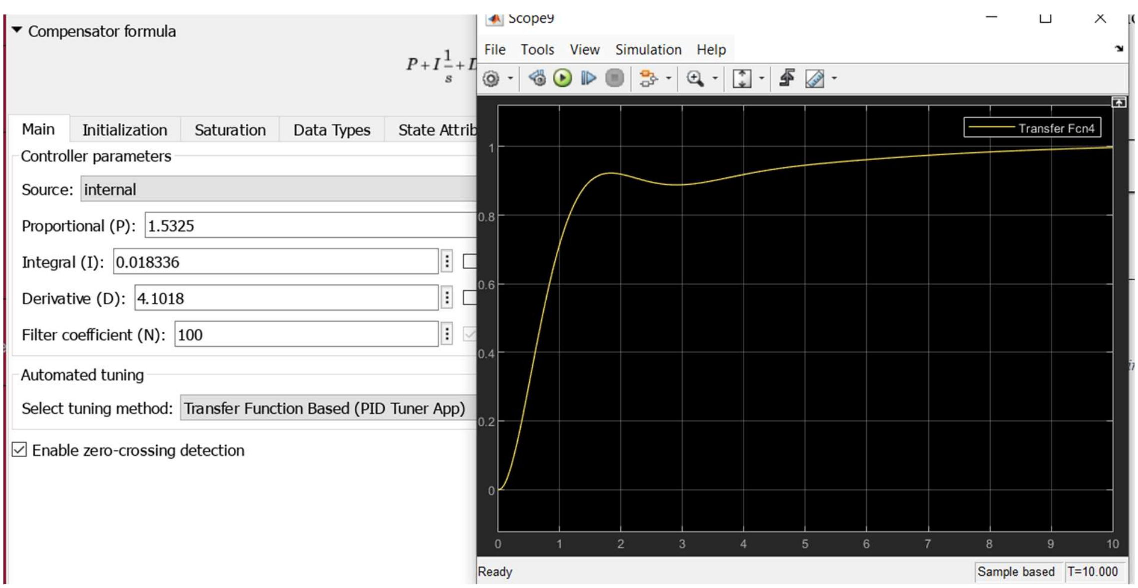
Section 4. PID Controller Tuning

Complete following exercise (show both code/model and results)

1. Build up the Simulink model for the system in Figure 12 of Lab01 handout, and use "pidTuner" to tune the PID controller such that the closed-loop system output satisfies: **rise time < 2 second, overshoot < 5%**

(attach PID Tuner block and 'show parameter' window)





What are the PID's
https://www.mathworks.com/videos/understanding-pid-control-part-1-what-is-pid-control--1527089264373.html