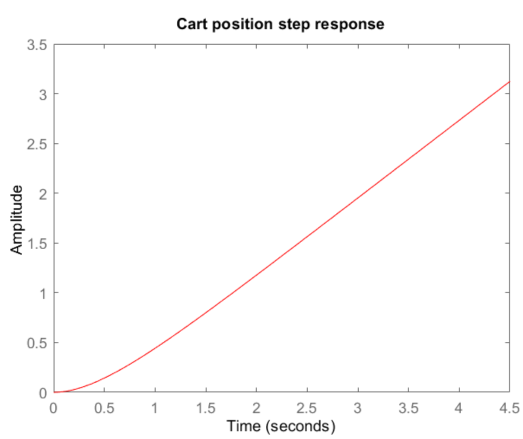
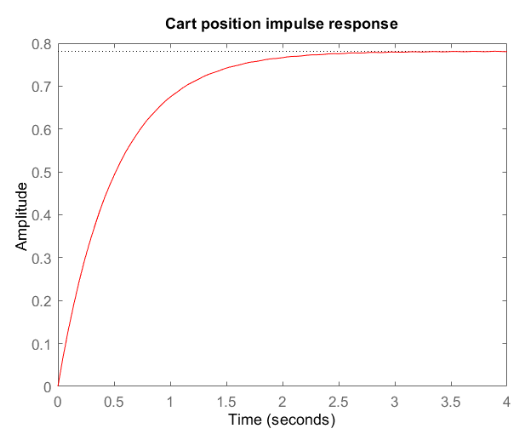
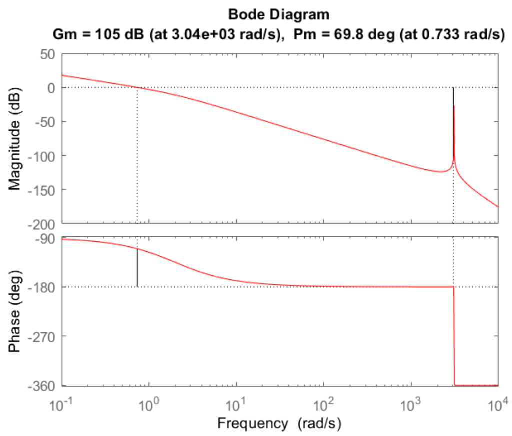
```
close all
clear all

% Assignment belt variable values
m=20;    % Mass of the sled [kg]
M=m;
a=1;     % m/s2
b=40;    % Sled friction coefficient [N/(m/s)] (Friction force of the sled = b*(sled
speed))
k=1e6 % Spring constant of the belt [N/m]

% Uncomment if these are needed.
% bs=40
% br=0.5


% Motor variable values
T_N=2.0;   % Nominal torque of the motor [Nm]
rpmN=2400; % Nominal speed of the motor [rpm]
J=0.0028;  % JSUURI (Comment out the J below if you want to test the system with a
bigger J value.)
J=1.08e-4; % Inertia of the motor [kgm^2]

r=0.032; % Radius of the pulley [m]

% T/r=F
% Js=J/gr^2
% Js=J; % no gear J

%%  state space

% For system given in EX. work
% No roller friction, mass friction exists , no damping of belt

% States:
%   x1:rotorAngle
%   x2:rotor angular frequency
%   x3:position of cart
%   x4:velocity of cart

% Notice that one state less would do , we have difference k(r*theta-x)
% leading to states e.g. x1=r*theta-x, x2=r*d(theta)/dt, and x3=dx/dt
% first we take these as separate states, no harm done but sometimes
% diffuculties in analysis with matlab, simulation goes well, and gives
% reliable background for analysis.
% See model page 38, Lecture1_mechmodels.pdf, Week3 in Moodle.


A = [      0       1        0        0;
     -(k*r^2)/J   0     (k*r)/J     0;
           0       0        0        1;
       (k*r)/M    0      -k/M     -b/M];

B = [ 0;
```

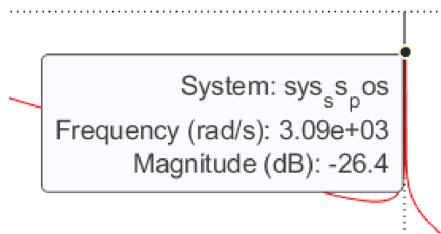
```
      1/J;
       0;
       0];

C=[ 0 0 1 0;
    0 0 0 1;
    0 1 0 0 ];

D=[0;0;0];

sys_ss=ss(A,B,C,D);

eig(A)
% figure(1);
% step(sys_ss) % Draws step responses in subplots of the same figure.

%% cart position

C_pos=[0 0 1 0];step(sys_ss)
D_pos=[0];
sys_ss_pos=ss(A,B,C_pos,D_pos);

figure(2);
step(sys_ss_pos,'r')
title('Cart position step response')
xlim([0 4.5]) % Same xlim as with speed

figure(3);
impulse(sys_ss_pos,'r')
title('Cart position impulse response')

figure(4);
margin(sys_ss_pos,'r')
```





Cart position step response, impulse response:

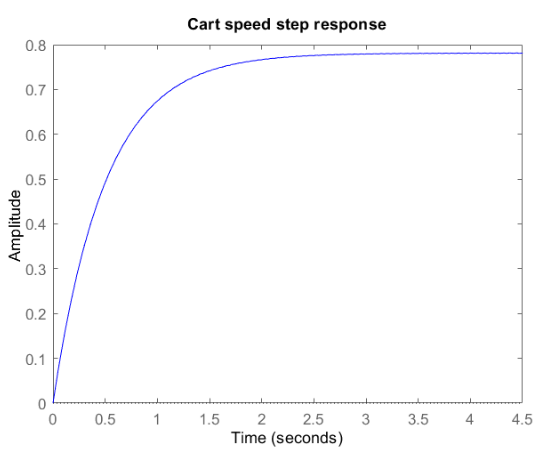


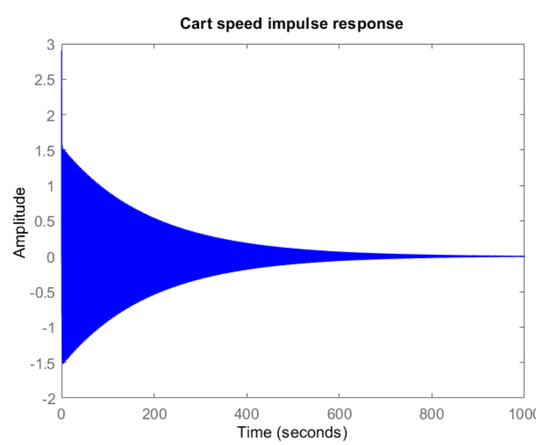


Cart position Bode diagram:

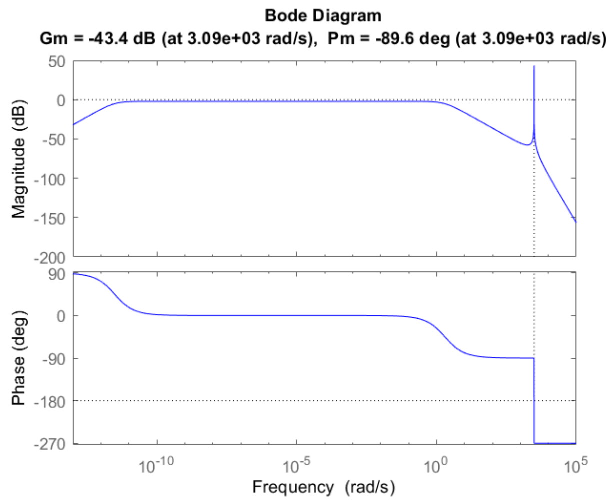
- Resonance is at 3090 rad/s

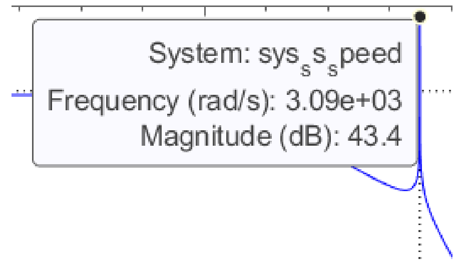
```
%% cart speed

C_speed=[0 0 0 1];
D_speed=[0];
sys_ss_speed=ss(A,B,C_speed,D_speed);

figure(5);
step(sys_ss_speed,'b')
title('Cart speed step response')
xlim([0 4.5])

figure(6);
impulse(sys_ss_speed,'b')
title('Cart speed impulse response')

figure(7);
margin(sys_ss_speed,'b')
```





Cart speed step response, impulse response:





Cart velocity Bode diagram:§

Decreasing value of friction coefficient **b**:

- Cart position, step response: Amplitude increases.
- Cart position, impulse response: Amplitude increases and settling time increases.
- Cart position, Bode Diagram: Gain Margin increases, Phase Margin decreases.
- Cart speed, step response: Amplitude increases and settling time increases.
- Cart speed, impulse response: Amplitude stays the same but reaches zero much slower.
- Cart velocity, Bode Diagram: Gain Margin decreases, Phase Margin stays the same.

Increasing value of friction coefficient **b**:

- Cart position, step response: No change.
- Cart position, impulse response: Amplitude decreases and settling time decreases.
- Cart position, Bode Diagram: Gain Margin decreases, Phase Margin increases.
- Cart speed, step response: Amplitude decreases and settling time decreases.
- Cart speed, impulse response: Amplitude stays the same but reaches zero much faster.

- Cart velocity, Bode Diagram: Gain Margin increases, Phase Margin stays the same.

Decreasing value of spring constant **k**:

- Cart position, step response: Amplitude
- Cart position, impulse response: Amplitude is the same and settling time decreases. Response has more ripple effects.
- Cart position, Bode Diagram: Gain Margin decreases, Phase Margin stays the same. Frequency of GM decreases. Frequency of PM stays the same.
- Cart speed, step response: Amplitude and settling time stays the same. Response has more ripple.
- Cart speed, impulse response: No noticeable changes.
- Cart velocity, Bode Diagram: Gain Margin and Phase Margin stays the same. Frequency decreases.

Increasing value of spring constant **k**:

- Cart position, step response: No noticeable changes.
- Cart position, impulse response: No noticeable changes.
- Cart position, Bode Diagram: Gain Margin increases, Phase Margin is the same. Freq of GM increased.
- Cart speed, step response: No noticeable changes.
- Cart speed, impulse response: No noticeable changes.
- Cart velocity, Bode Diagram: Gain Margin and Phase Margin stays the same. Frequency increases.

The spring constant in a Cartesian linear tooth belt robot affects the stiffness and elasticity of the system. Changing the spring constant will affect the robot's response to external forces and its ability to maintain its position.

If you increase the spring constant, the robot will become stiffer, meaning it will require more force to deform the system. This may result in a faster response to changes in external forces, but it may also make the system more sensitive to small changes.

On the other hand, decreasing the spring constant will make the robot more elastic, meaning it will deform more easily in response to external forces. This may result in a slower response to changes in external forces, but it may also make the system less sensitive to small changes.

In summary, changing the spring constant in a Cartesian linear tooth belt robot will affect its stiffness, elasticity, and response to external forces. The appropriate spring constant will depend on the specific application and requirements of the robot.

The friction coefficient in a Cartesian linear tooth belt robot affects the amount of force required to move the robot along its axis. Changing the friction coefficient will affect the robot's speed, accuracy, and energy consumption.
If you decrease the friction coefficient, the robot will require less force to move along its axis, resulting in higher speeds and smoother motion. This may result in improved accuracy and reduced energy consumption, but it may also make the system more susceptible to overshooting its target position.
On the other hand, increasing the friction coefficient will increase the force required to move the robot along its axis, resulting in slower speeds and less smooth motion. This may result in reduced accuracy and increased energy consumption, but it may also make the system more stable and less likely to overshoot its target position.
In summary, changing the friction coefficient in a Cartesian linear tooth belt robot will affect its speed, accuracy, energy consumption, and stability. The appropriate friction coefficient will depend on the specific application and requirements of the robot.

Yes, changing the coefficient of friction between the linear tooth belt and its corresponding pulleys can affect the rising time of a Cartesian linear tooth belt robot.

The rising time of the robot is affected by a number of factors including the motor performance, the mechanical design of the robot, and the friction between the moving components. In the case of a linear tooth belt robot, the friction between the belt and pulleys can have a significant impact on the rising time.

If the coefficient of friction between the belt and pulleys is increased, the resistance to motion will also increase. This increased resistance will make it harder for the motor to move the belt, resulting in slower rising times. On the other hand, if the coefficient of friction is decreased, the resistance to motion will decrease, making it easier for the motor to move the belt and resulting in faster rising times.

It is important to note that changing the coefficient of friction will also affect other aspects of the robot's performance, such as accuracy, repeatability, and overall system stability. Therefore, any changes to the friction coefficient should be carefully considered and tested to ensure that they do not have any unintended consequences on the system's performance.