NED University of Engineering & Tech. Electrical Engineering Department

Spring Semester 2020 TE-ME / TE-EE / TE-EL

Lab Session 02

Exercise:

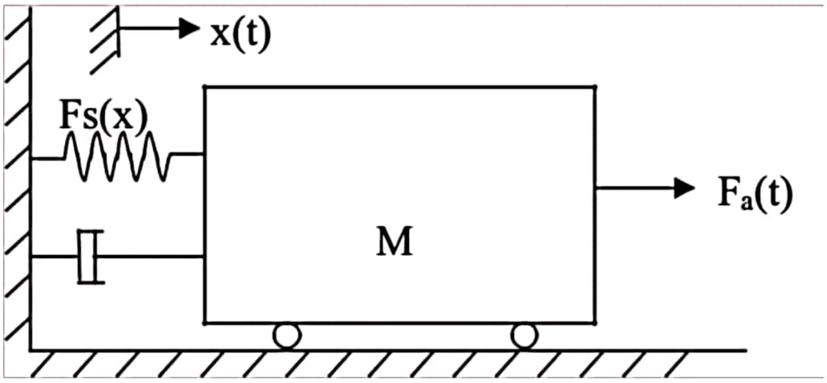
Question 1:
Obtain the state space representation for the system shown below. Solve the resulting state equations using MATLAB *ode45* function (write complete script). Plot the position *x(t)* and velocity *v(t)* of the system with respect to time for $t = 0$ to 50 sec considering the following cases and write in your words about what you observed by looking at different plots. (Attach plot under each case).
[*Use separate A4 sheets for plots and attach it with this document*]

Behavior upon changing Mass (M)			
Case 1 M = 10 B = 30 K = 15 Fa = 300	Case 2 M = 30 B = 30 K = 15 Fa = 300	Case 3 M = 50 B = 30 K = 15 Fa = 300	Case 4 M = 100 B = 30 K = 15 Fa = 300

Behavior upon changing Friction Coefficient (B)			
Case 1 M = 10 B = 5 K = 15 Fa = 300	Case 2 M = 10 B = 10 K = 15 Fa = 300	Case 3 M = 10 B = 20 K = 15 Fa = 300	Case 4 M = 10 B = 30 K = 15 Fa = 300

Behavior upon changing Stiffness (K)			
Case 1 M = 10 B = 5 K = 0.5 Fa = 300	Case 2 M = 10 B = 5 K = 5 Fa = 300	Case 3 M = 10 B = 5 K = 20 Fa = 300	Case 4 M = 10 B = 5 K = 30 Fa = 300

Behavior upon changing Applied Force (F_a)			
Case 1 M = 10 B = 5 K = 15 Fa = 50	Case 2 M = 10 B = 5 K = 15 Fa = 100	Case 3 M = 10 B = 5 K = 15 Fa = 200	Case 4 M = 10 B = 5 K = 15 Fa = 300



Write your answers below this line

Mass Spring System :-

$$M\frac{d^2x(t)}{dt^2} + B\frac{d}{dt}x(t) + Kx(t) = Fa(t)$$

State variables :-

$$x = x_1 \quad \text{and} \quad \frac{dx}{dt} = \frac{dx_1}{dt} = x_2$$

$$\frac{dx}{dt} = x_2 \quad \text{and} \quad \frac{dx_2}{dt} = -\frac{B}{M}x_2 - \frac{K}{M_1}x_1 + \frac{Fa}{M}$$

In vector form :-

$$x = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}, \quad \frac{dx}{dt} = \begin{bmatrix} \frac{dx_1}{dt} \\ \frac{dx_2}{dt} \end{bmatrix}$$

System equation → $-\frac{B}{M}x_2 - \frac{K}{M}x_1 + \frac{Fa}{M} = \frac{dx}{dt}$

Here,

M(kg), B(Ns/m), Fa(N), K(N/m)

PROGRAM SCRIPT :-

```
clear, clc, close
[t,x] = ode45('changing_mass', [0 50], [0;0]);
[t1,x1] = ode45('changing_mass1', [0 50], [0;0]);
[t2,x2] = ode45('changing-mass2, [0 50], [0;0]);
[t3, x3] = ode45('changing-mass3, [0 50], [0;0]);
figure
subplot(2,1,1), hold on
plot(t,x(:,1),'color',[0.8500,0.3250,0.0980],'LineWidth',2);
plot(t1,x1(:,1),'color',[0.4940,0.1840,0.5560],'LineWidth',2);
plot(t2,x2(:,1),'color',[1,0,0],'LineWidth',2);
plot(t3,x3(:,1),'color',[0.75,0,0.75],'LineWidth',2);
xlabel('Time(t)'); ylabel('Displacement(x)');
title('Mass Spring Damper System');
legend('M = 10','M= 30','M= 50', 'M=100');
grid;
subplot(2,1,2), hold on
plot(t,x(:,2),'color',[0.8500,0.3250,0.0980],'LineWidth',2];
plot(t1,x1(:,2),'color',[0.4940,0.1840,0.5560];'LineWidth',2);
plot(t2,x2(:,2),'color',[1,0,0],'LineWidth',2);
plot(t3,x3(:,2),'color',[0.75,0,0.75],'LineWidth',2);
xlabel('Time(t)'); ylabel('velocity(v)');
title('Mass Spring Damper System');
legend('M=10','M=30','M=50','M=100');
grid;
hold off.
```

FUNCTION SCRIPT :-

changing_mass.m :-

```
% Case 1
function dxdt = changing_mass(t,x)
  M= 10;
  B = 30;
  K = 15;
  Fa = 300;
  dxdt = zeros(2,1);
  dxdt(1,1) = x(2);
  dxdt(2,1) = - B/M*x(2) - K/M*x(1) + Fa/M;
end
```

changing_mass1.m :-

```
% Case 2
function dxdt1 = changing_mass1(t1,x1)
  M= 30;
  B= 30;
  K= 15;
  Fa = 300;
  dxdt1 = zeros(2,1);
  dxdt1(1,1) = x1(2);
  dxdt1(2,1) = - B/M*x1(2) - K/M*x1(1) + Fa/M;
end
```

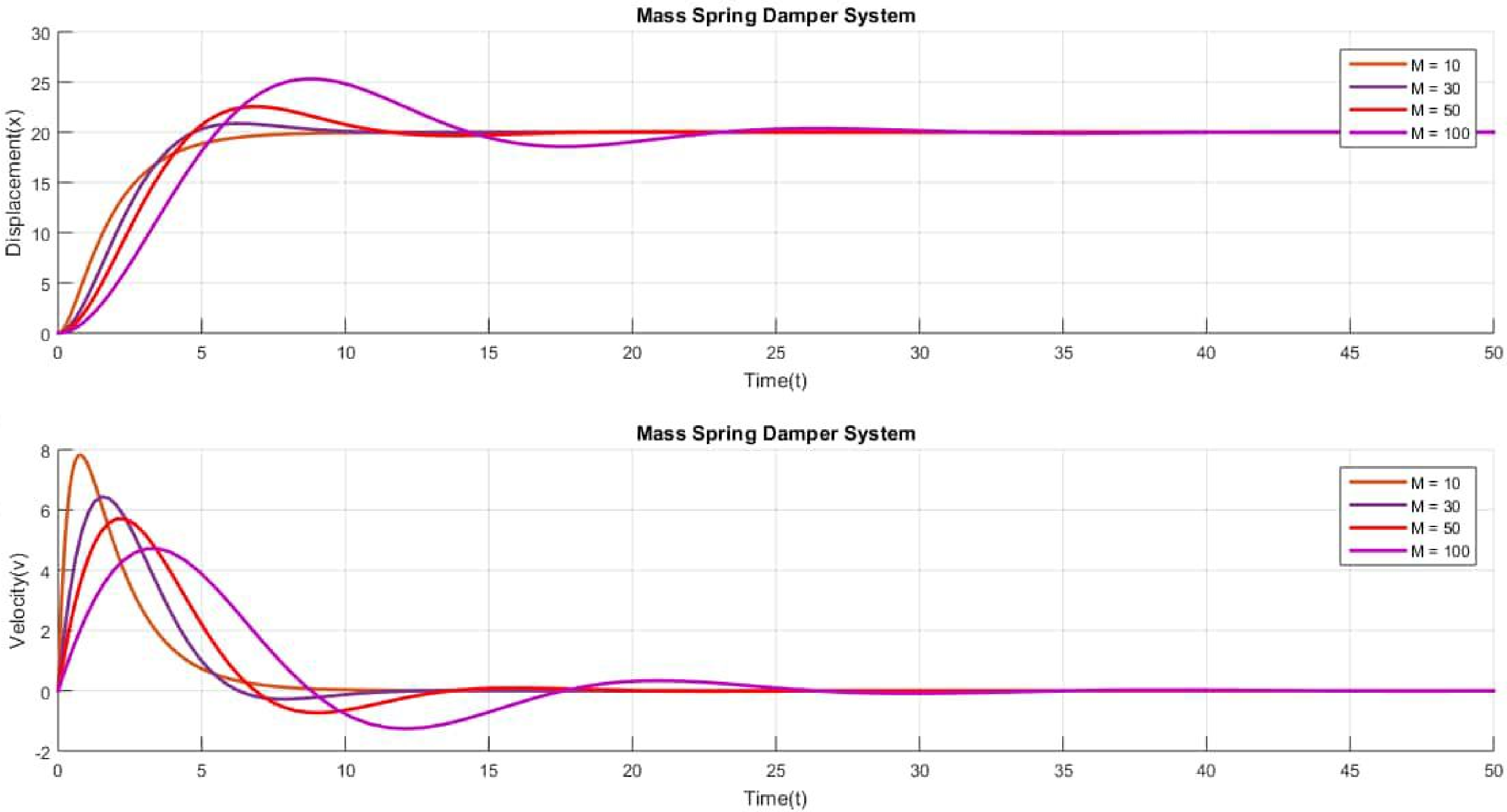
changing_mass2.m :-

```
% Case 3
function dxdt2 = changing_mass2(t2,x2)
M= 50;
B = 30;
K = 15;
Fa = 300;
dxdt2 = zeros (2, 1);
dxdt2 (1,1) = x2(2);
dxdt2 (2 , 1) = -B/M* x2(2) - K/M*x2(1)+ Fa/M;
end
```

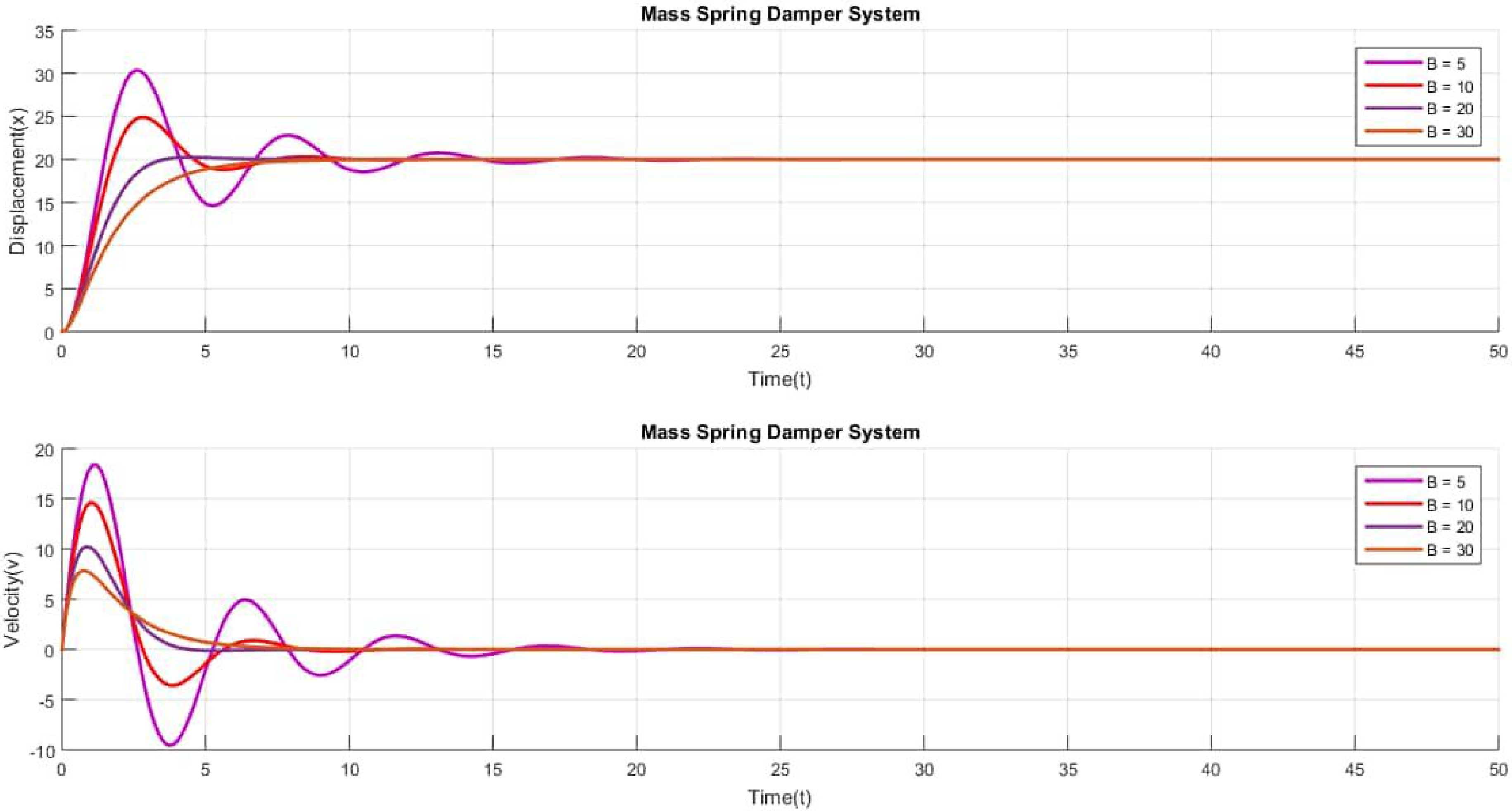
changing_mass3.m :-

```
% Case 4
function dxdt3 = changing_mass 3 (t3, x3)
M = 100;
B = 30;
K = 15;
Fa = 300;
dxdt 3 = zeros (2, 1);
dxdt3 (1;1) = x3(2);
dxdt3 (2, 1) = - B/M*x3(2) - K/M*x3 (1)+Fa/M;
end
```

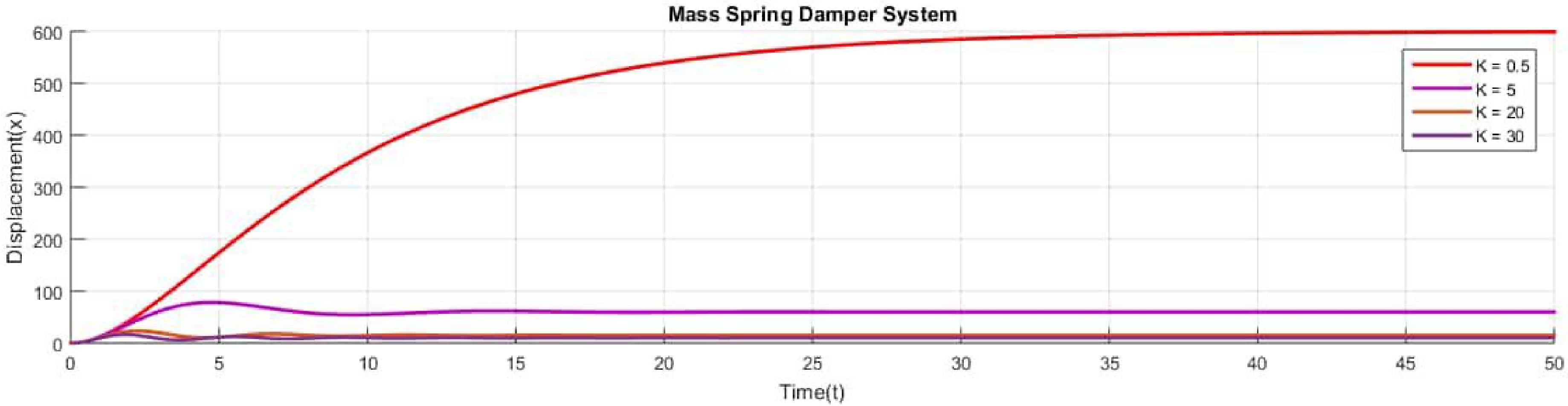
Varying Mass

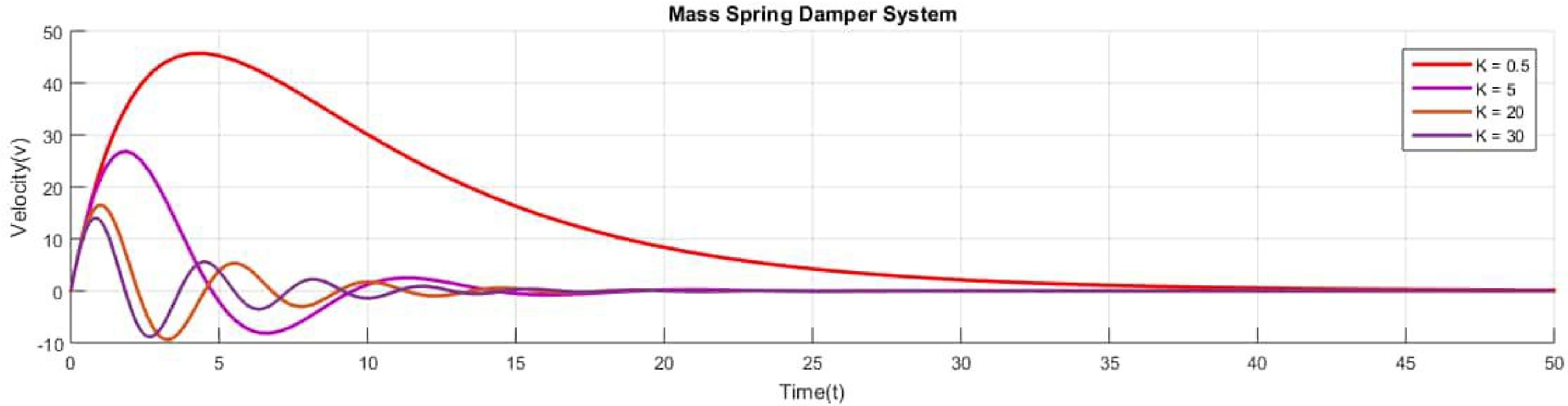


Varying Friction Coefficient

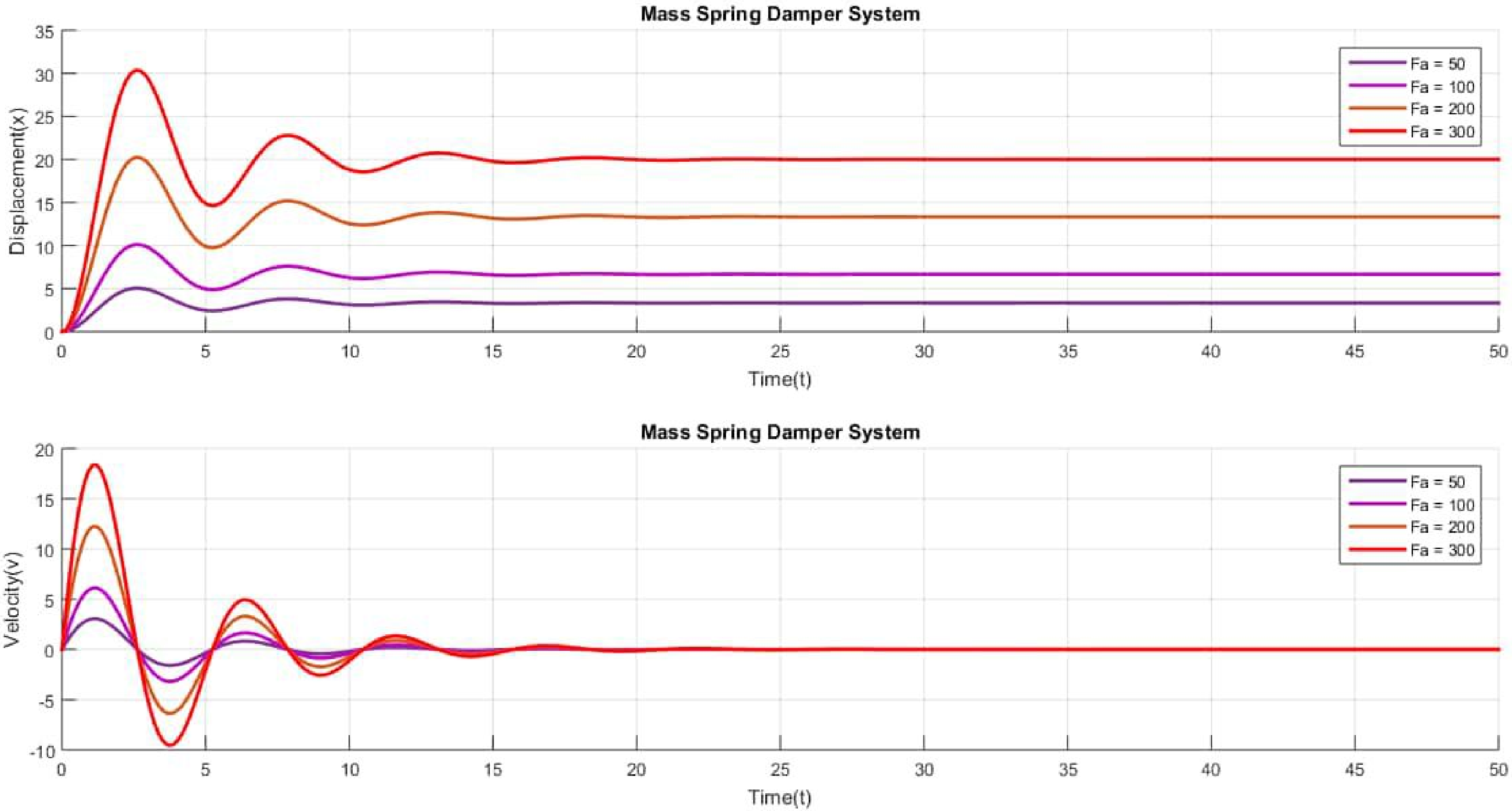


Varying Stiffness





Varying Applied Force



Observations:-

1/ **Behavior upon Changing Mass:-**

If other parameters are kept constant so increase in value of mass gives more oscillations and shows underdamped response. Overdamped response acheived at low value of mass.

2/ **Behavior upon Changing Friction Coefficient:-**

If other parameters are kept constant so increase the value of friction coefficient gives stability in system & overdamped response. System gives more oscillations at low value of friction coefficient.

3/ **Behavior upon Changing Stiffness:-**

If other parameters are kept constant so increase the value of stiffness, rise time decreases and system acheived stability soon as compare to lower stiffness value.

4/ **Behavior upon Changing Applied Force:-**

If other parameters are kept constant so increase the value of forces causes more oscillations and stability time also increases. Stability of system acheived at low value of force.

NOTE:- All responses have exponential decay whether the changing in values but stability is acheived after some time.