# Lab Session 03

## 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 $x_a(t)$ and velocity $v_a(t)$ for Mass $M_1$ and position $x_b(t)$ and velocity $v_b(t)$ for Mass $M_2$ of the system with respect to time for $t = 0$ to $400$ 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*]

Case 1:

$M_2 = M_1 = 750$

$B_1 = B_2 = 20$

$K_1 = K_2 = 15$

$B_3 = 30$

$f = 300$

Case 2:

Change the value of $M_1$ from 50 to 650 with a step size of 200 and record your observation. Attach all the plots while changing values of $M_1$. Keep other parameters to be same as in *Case 1*.

Case 3:

Change the value of $M_2$ from 50 to 650 with a step size of 200 and record your observation. Attach all the plots while changing values of $M_2$. Keep other parameters to be same as in *Case 1*.

Case 4:

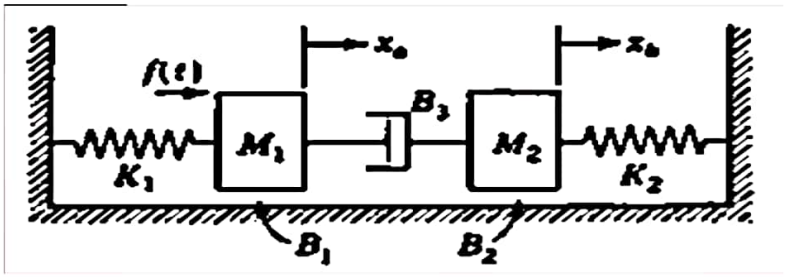
Change the value of $B_1$ from 5 to 20 with a step size of 5 and record your observation. Attach all the plots while changing values of $B_1$. Keep other parameters to be same as in *Case 1*.

Case 5:

Change the value of $B_2$ from 5 to 20 with a step size of 5 and record your observation. Attach all the plots while changing values of $B_2$. Keep other parameters to be same as in *Case 1*.

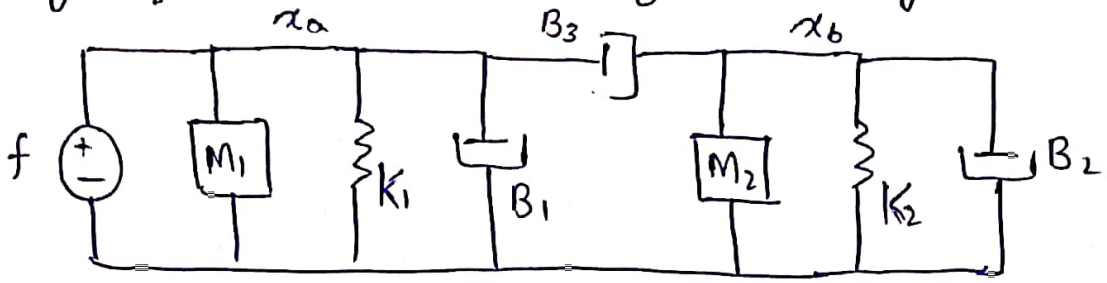
Case 6:

Change the value of $B_3$ from 10 to 30 with a step size of 10 and record your observation. Attach all the plots while changing values of $B_3$. Keep other parameters to be same as in *Case 1*.




*Write your answers below this line*

Drawing equivalent network for the system




At node $x_a$:-

$$M_1 D^2 x_a + K_1 x_a + B_1 D x_a + B_3 D x_a - B_3 D x_b = f \quad \text{— (A)}$$

At node $x_b$:-

$$B_3 D x_a - B_3 D x_b = M_2 D^2 x_b + K_2 x_b + B_2 D x_b \quad \text{— (B)}$$

State variables:-

$$x_1 = x_a \;,\; x_2 = V_a \;,\; x_3 = x_b \;,\; x_4 = V_b$$

Now,

$$x_1' = x_2 \quad \text{— (1)}$$

$$x_2' = \frac{f}{M_1} - \frac{K_1}{M_1} x_1 - \frac{B_1}{M_1} x_2 - \frac{B_3}{M_1} x_2 + \frac{B_3}{M_1} x_4 \quad \text{— (2)}$$

$$x_3' = x_4 \quad \text{— (3)}$$

$$x_4' = \frac{B_3}{M_2} x_2 - \frac{B_3}{M_2} x_4 - \frac{K_2}{M_2} x_3 - \frac{B_2}{M_2} x_4 \quad \text{— (4)}$$

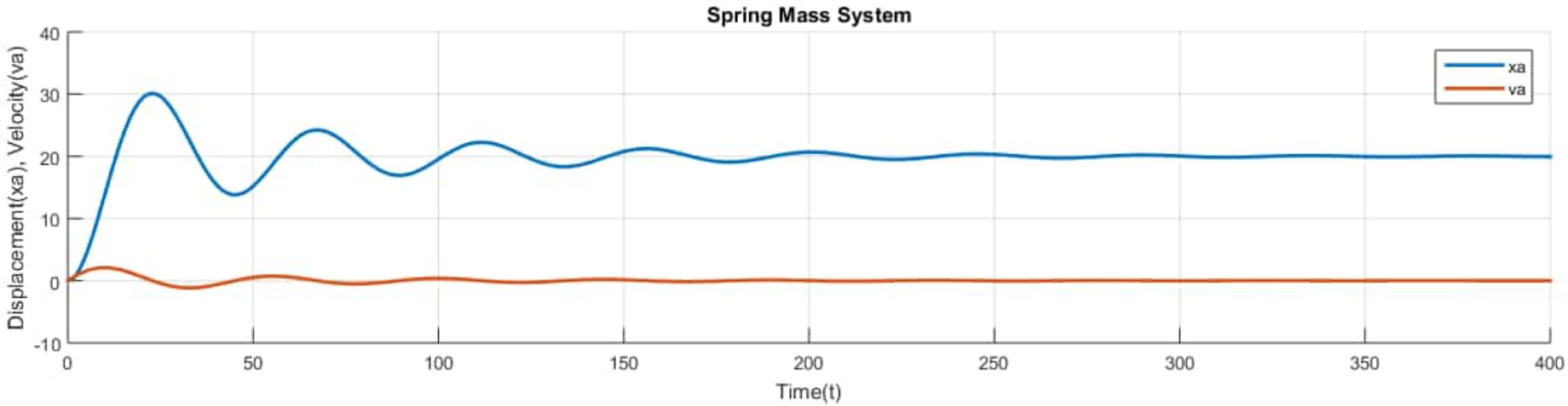
# PROGRAM SCRIPT:-

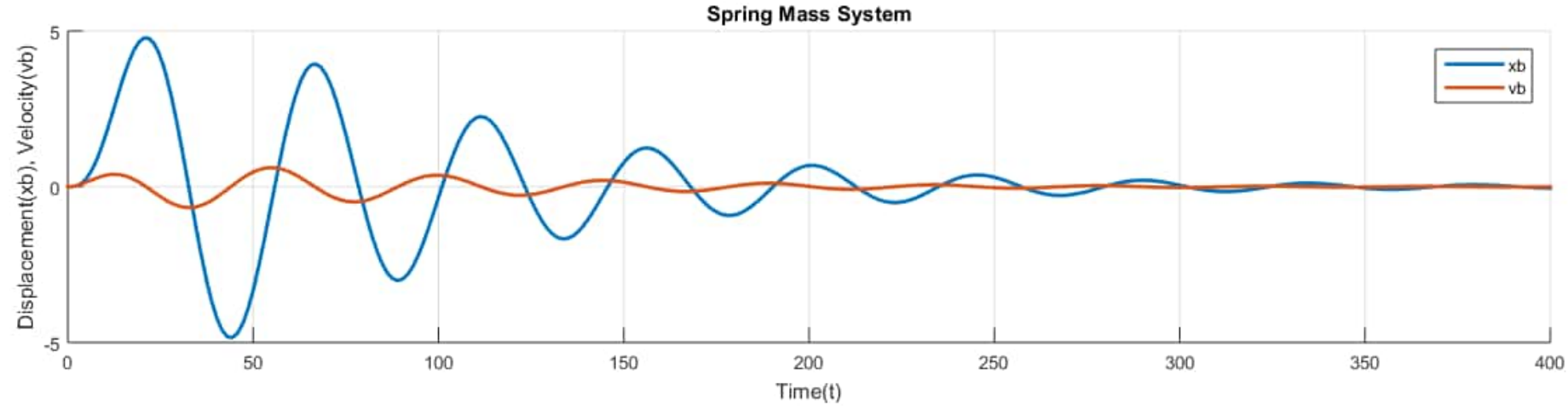
```
1- clear, close, clc
2- % SAME MASSES (M1=M2), DAMPERS (B1=B2), SPRINGS (K1=K2)
3- figure; [t,x]=ode45('case1-sameMassesDampersValues',[0 400],[0;0;0;0]);
4- subplot(2,1,1); hold on;
5- plot(t,x(:,1),t,x(:,2),'LineWidth',2);
6- xlabel('Time(t)'); ylabel('Displacement(xa), Velocity(va)');
7- title('Spring Mass System');
8- legend('xa','va');
9- grid; hold off;
10- subplot(2,1,2); hold on;
11- plot(t,x(:,3),t,x(:,4),'LineWidth',2);
12- xlabel('Time(t)'); ylabel('Displacement(xb), Velocity(vb)');
13- title('Spring Mass System');
14- legend('xb','(vb)');
15- grid; hold off;
```

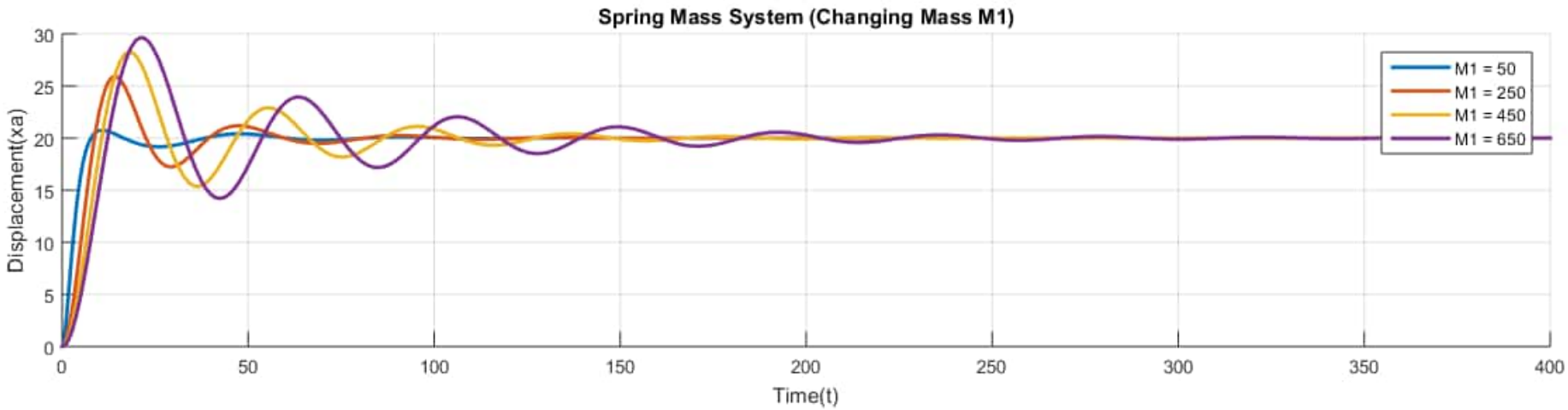
## FUNCTION SCRIPT:-

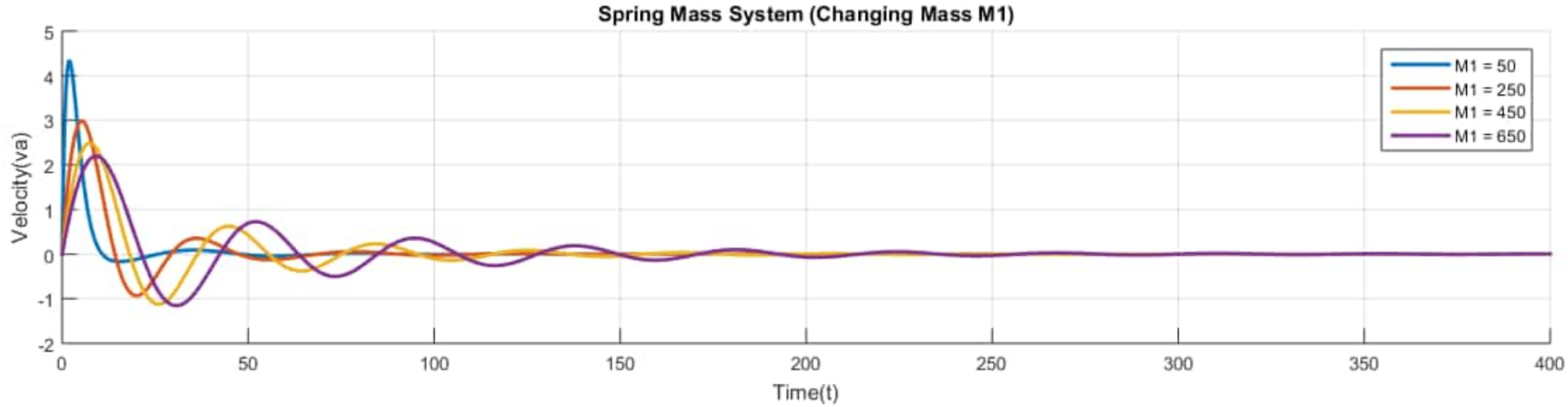
### case1_sameMassesDampersValues.m:-

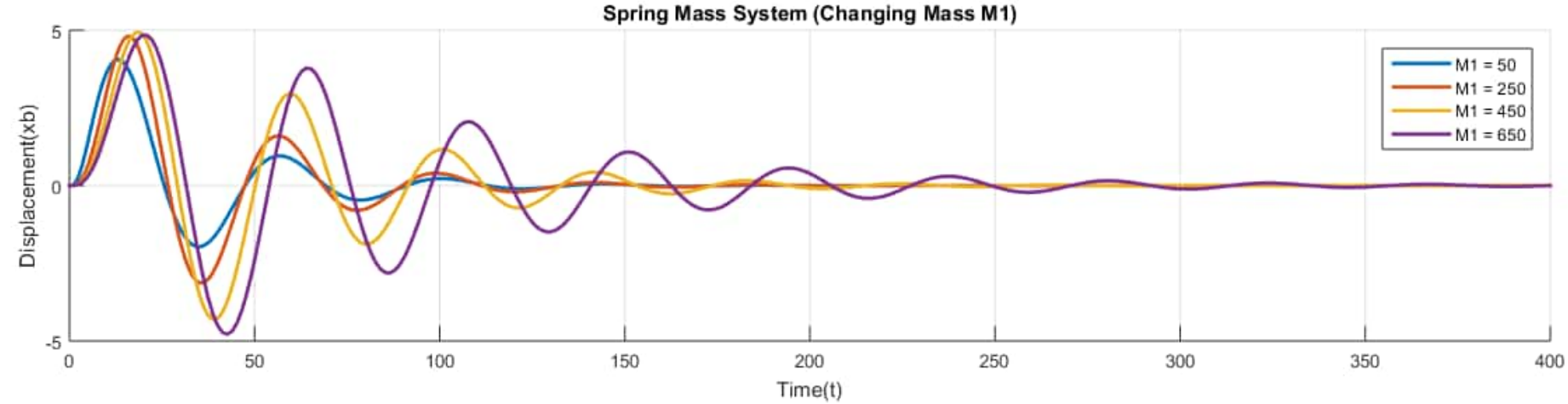
```
function dxdt = case1_sameMassesDampersValues(t,x)
M1 = 750; M2 = 750;
B1 = 20 ; B2 = 20;
K1 = 15 ; K2 = 15;
B3 = 30; f = 300;
dxdt(1,1) = x(2);
dxdt(2,1) = f/M1 - K1*x(1)/M1 - B1*x(2)/M1 - B3*x(2)/M1 + B3*x(4)/M1;
dxdt(3,1) = x(4);
dxdt(4,1) = B3*x(2)/M2 - B3*x(4)/M2 - K2*x(3)/M2 - B2*x(4)/M2;
end
```

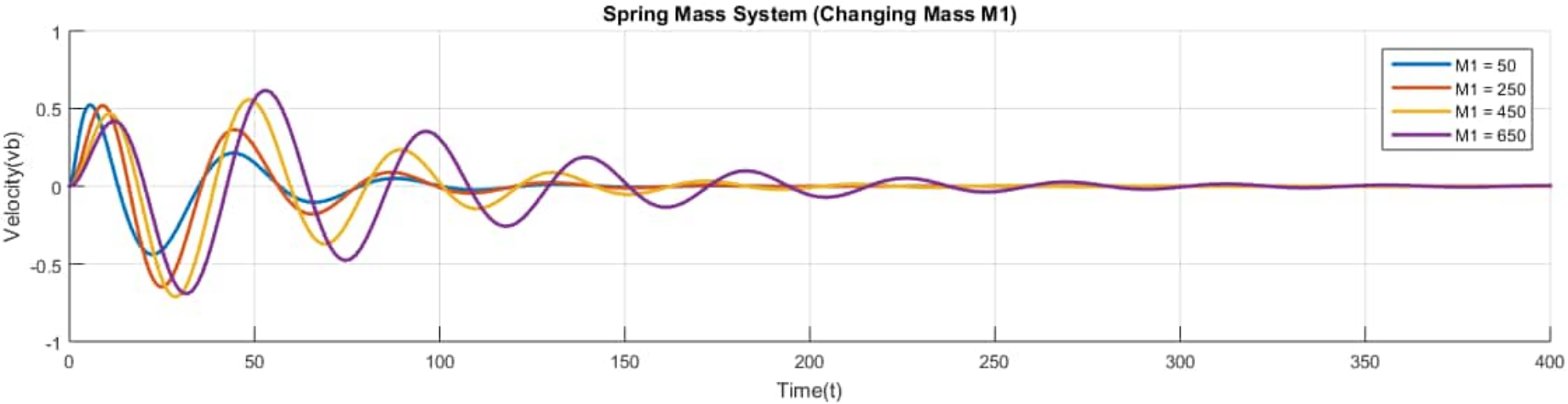

Spring Mass System
Displacement(xa), Velocity(va)
Time(t)
xa
va
40
30
20
10
0
-10
0
50
100
150
200
250
300
350
400

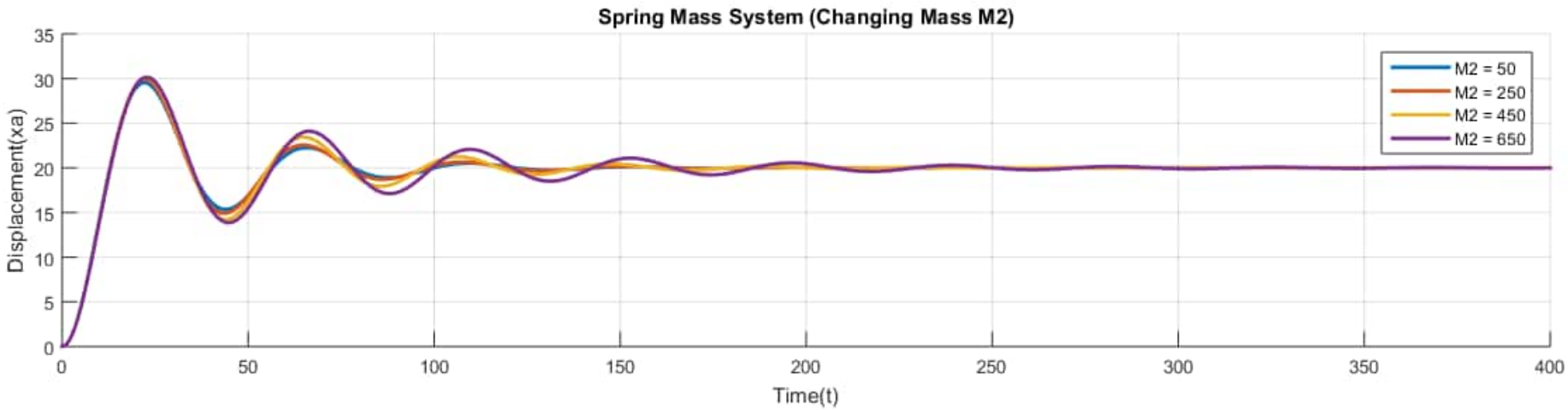

Spring Mass System
Displacement(xb), Velocity(vb)
Time(t)
xb
vb
5
0
-5
0
50
100
150
200
250
300
350
400

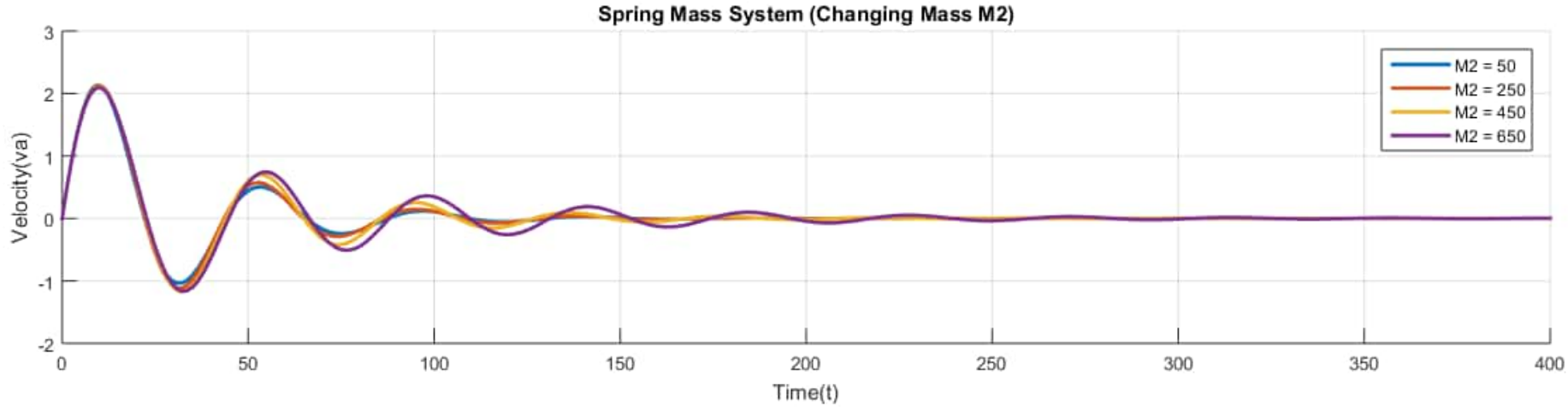

Spring Mass System (Changing Mass M1)
Displacement(xa)
Time(t)
M1 = 50
M1 = 250
M1 = 450
M1 = 650
0
5
10
15
20
25
30
0
50
100
150
200
250
300
350
400

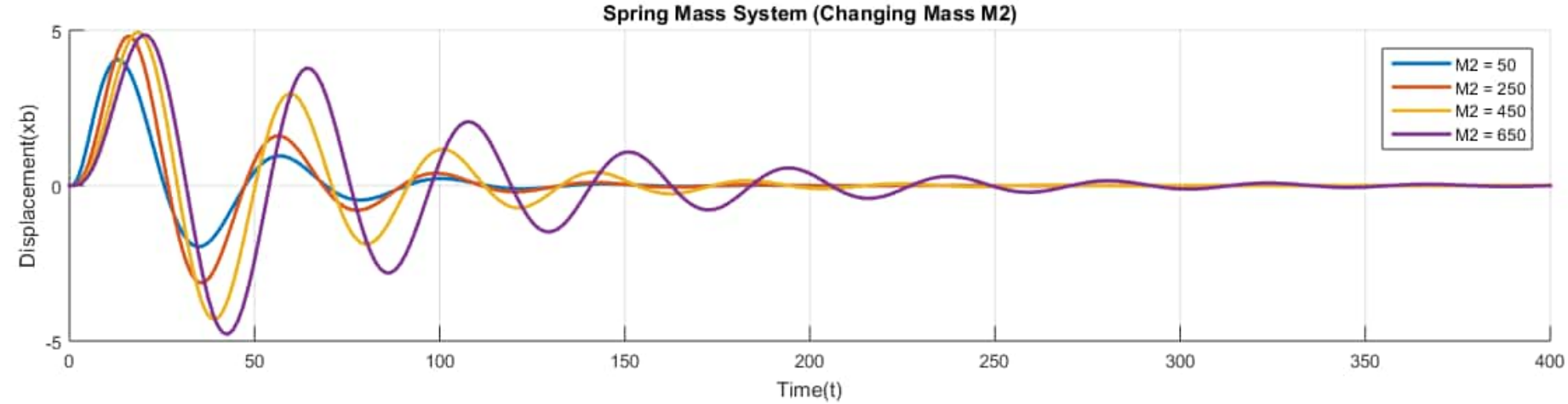

Spring Mass System (Changing Mass M1)
Velocity(va)
Time(t)
M1 = 50
M1 = 250
M1 = 450
M1 = 650
-2
-1
0
1
2
3
4
5
0
50
100
150
200
250
300
350
400

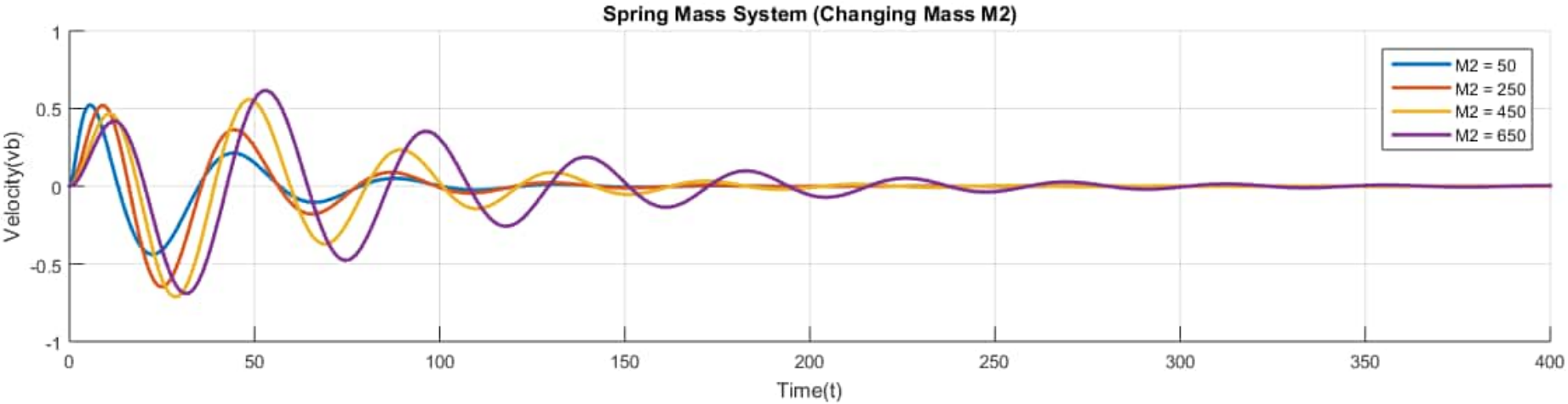

Spring Mass System (Changing Mass M1)
Displacement(xb)
Time(t)
M1 = 50
M1 = 250
M1 = 450
M1 = 650
5
0
-5
0
50
100
150
200
250
300
350
400

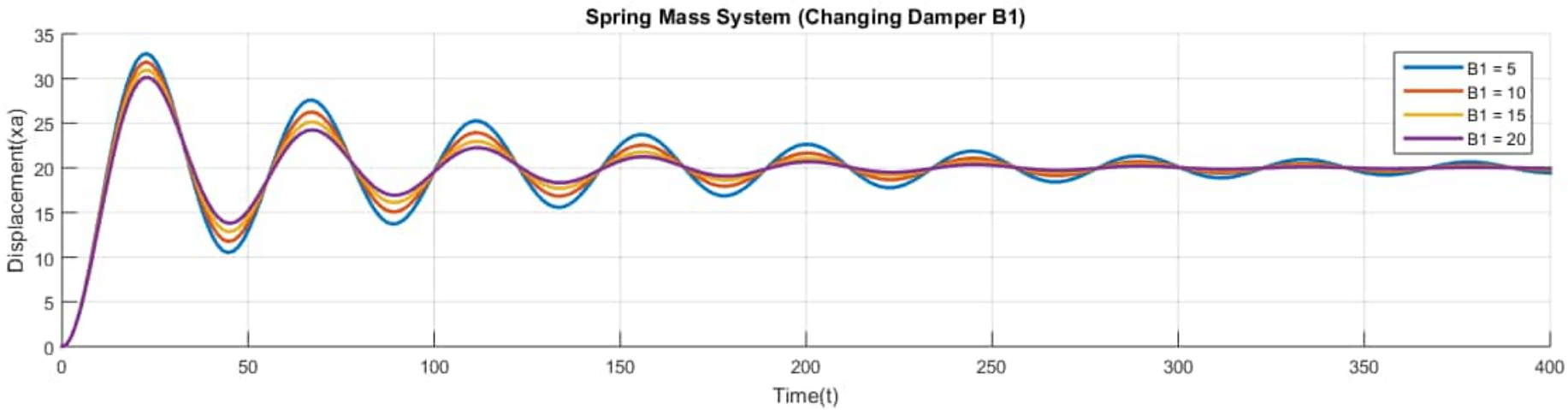

Spring Mass System (Changing Mass M1)
Velocity(vb)
Time(t)
M1 = 50
M1 = 250
M1 = 450
M1 = 650
1
0.5
0
-0.5
-1
0
50
100
150
200
250
300
350
400

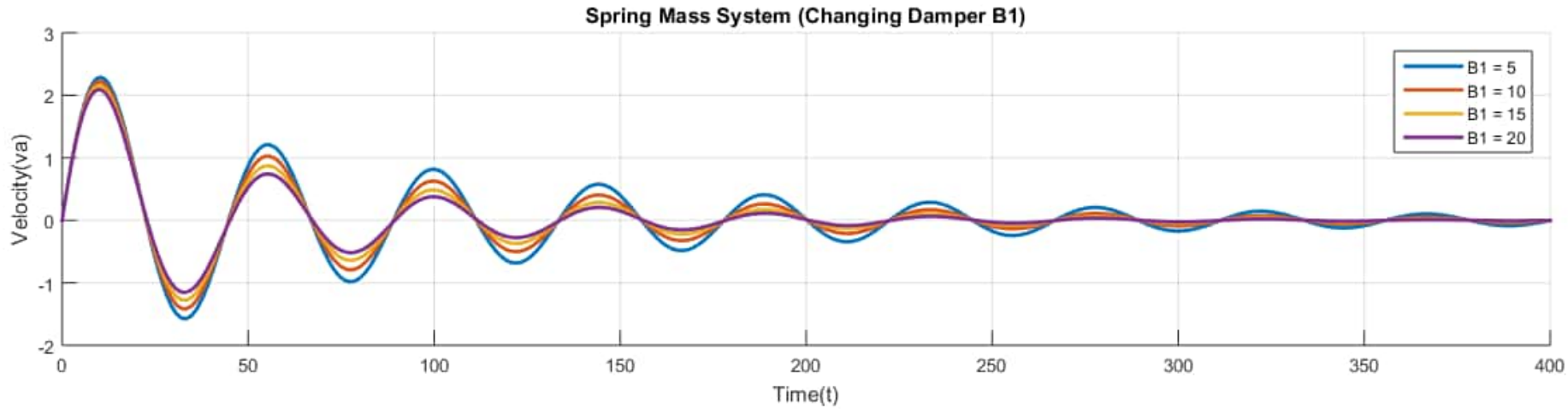

Spring Mass System (Changing Mass M2)
Displacement(xa)
Time(t)
M2 = 50
M2 = 250
M2 = 450
M2 = 650
0
5
10
15
20
25
30
35
0
50
100
150
200
250
300
350
400

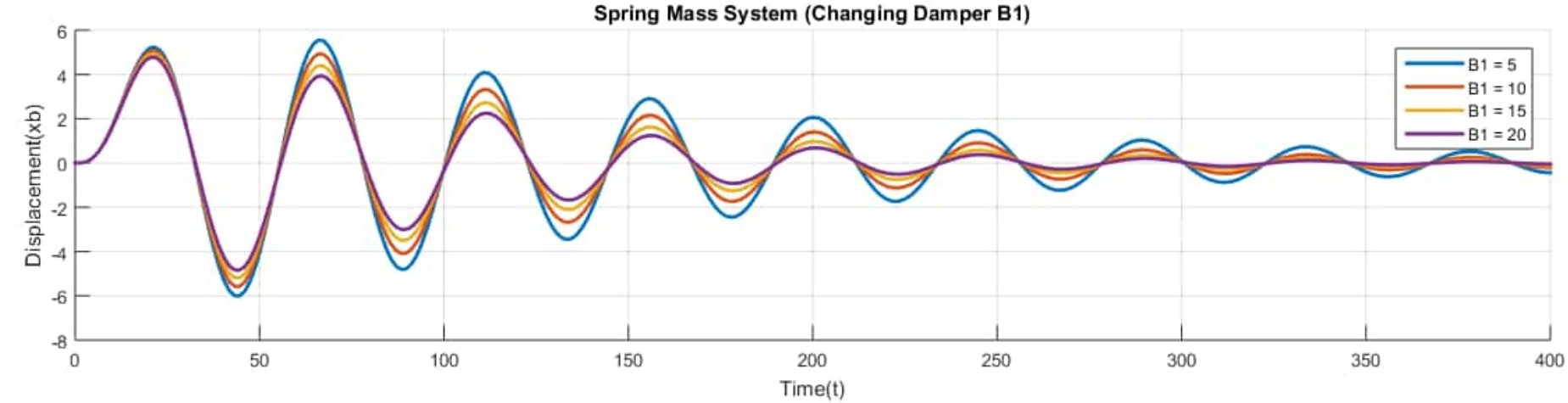

Spring Mass System (Changing Mass M2)
Velocity(va)
Time(t)
M2 = 50
M2 = 250
M2 = 450
M2 = 650
-2
-1
0
1
2
3
0
50
100
150
200
250
300
350
400

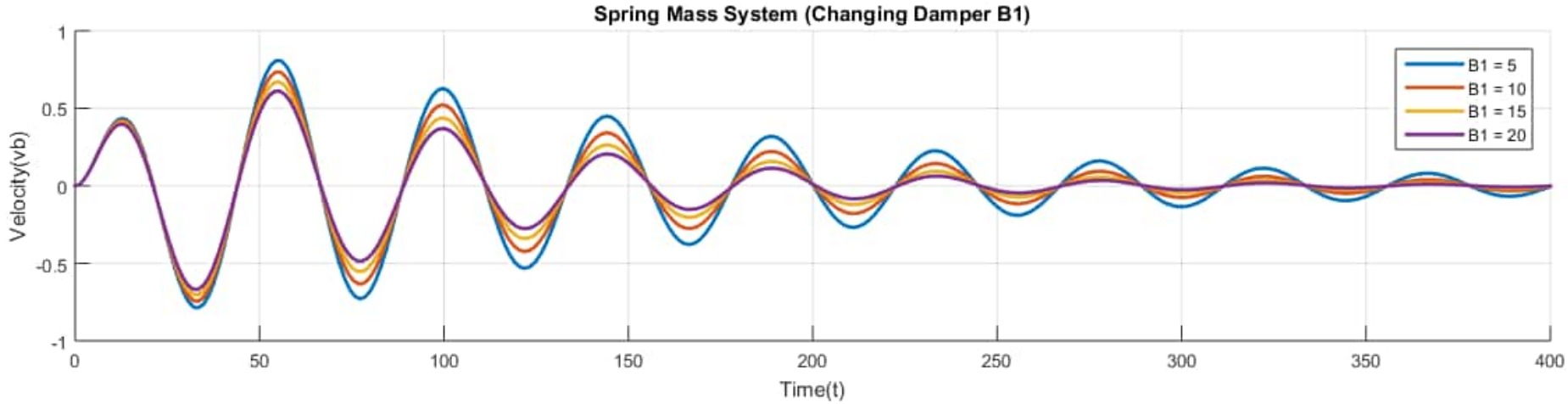

Spring Mass System (Changing Mass M2)
Displacement(xb)
Time(t)
M2 = 50
M2 = 250
M2 = 450
M2 = 650
5
0
-5
0
50
100
150
200
250
300
350
400

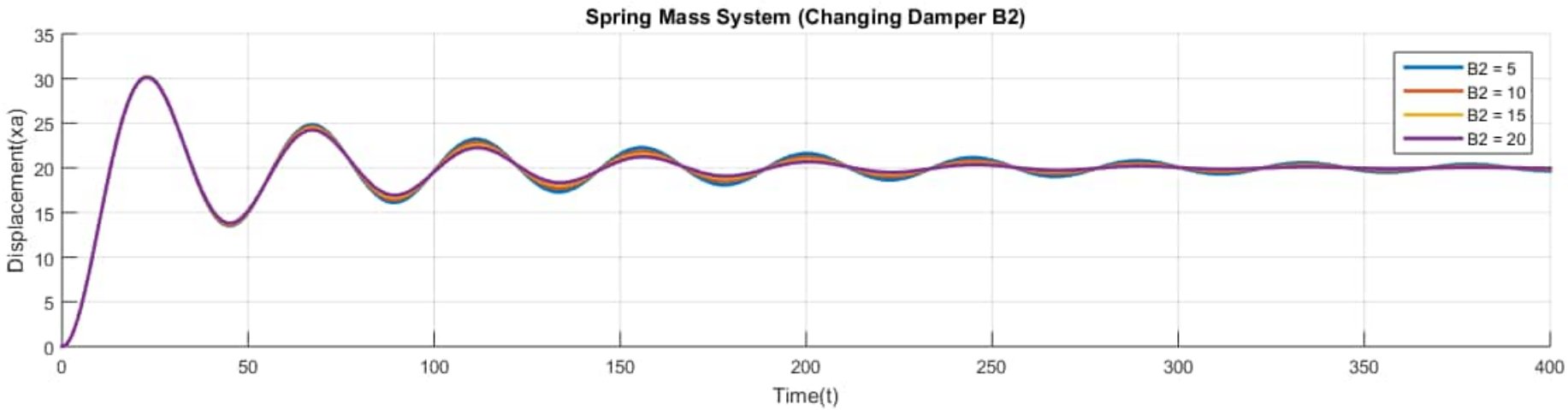

Spring Mass System (Changing Mass M2)
Velocity(vb)
Time(t)
M2 = 50
M2 = 250
M2 = 450
M2 = 650
1
0.5
0
-0.5
-1
0
50
100
150
200
250
300
350
400

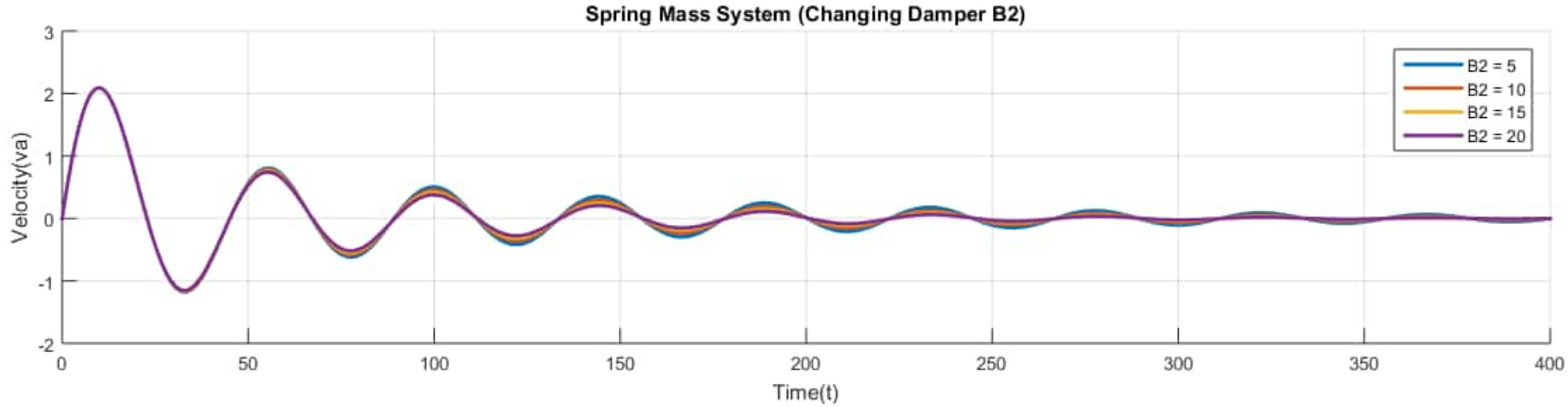

Spring Mass System (Changing Damper B1)
Displacement(xa)
Time(t)
B1 = 5
B1 = 10
B1 = 15
B1 = 20
0
5
10
15
20
25
30
35
0
50
100
150
200
250
300
350
400

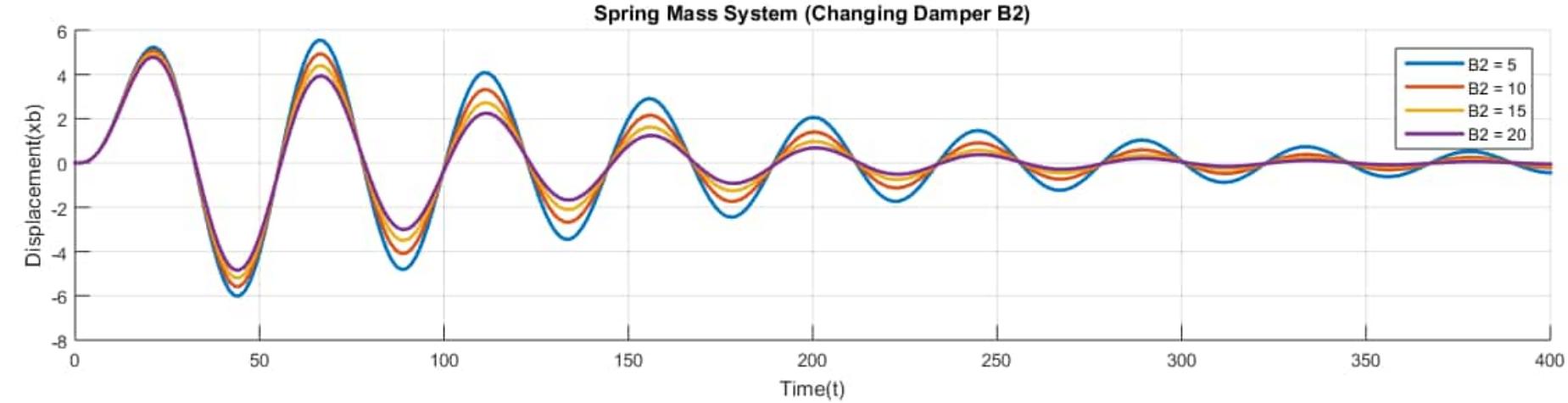

Spring Mass System (Changing Damper B1)
Velocity(va)
Time(t)
B1 = 5
B1 = 10
B1 = 15
B1 = 20
-2
-1
0
1
2
3
0
50
100
150
200
250
300
350
400

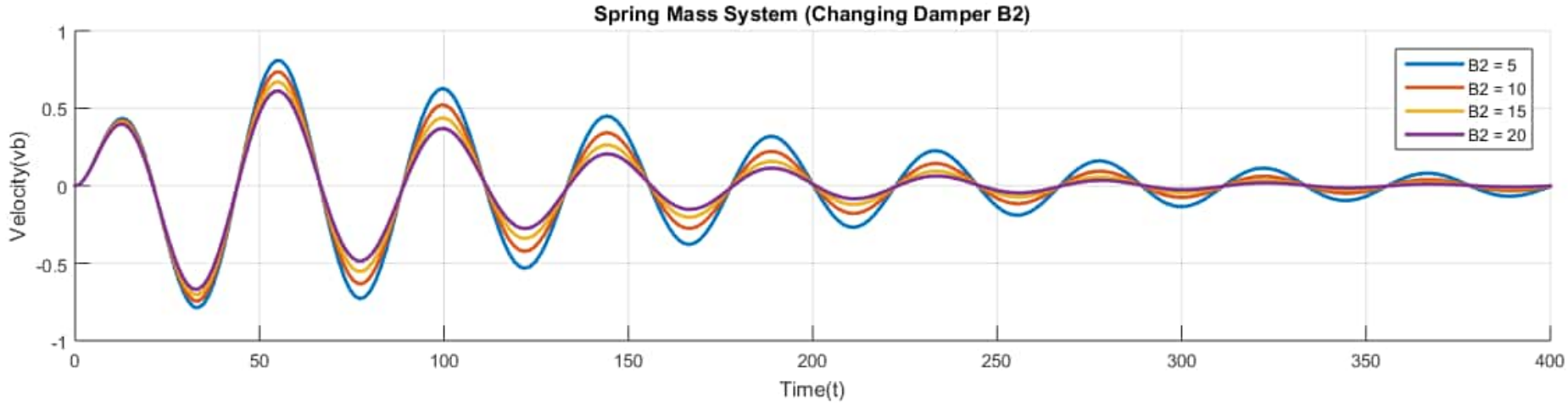

Spring Mass System (Changing Damper B1)
Displacement(xb)
Time(t)
B1 = 5
B1 = 10
B1 = 15
B1 = 20
6
4
2
0
-2
-4
-6
-8
0
50
100
150
200
250
300
350
400

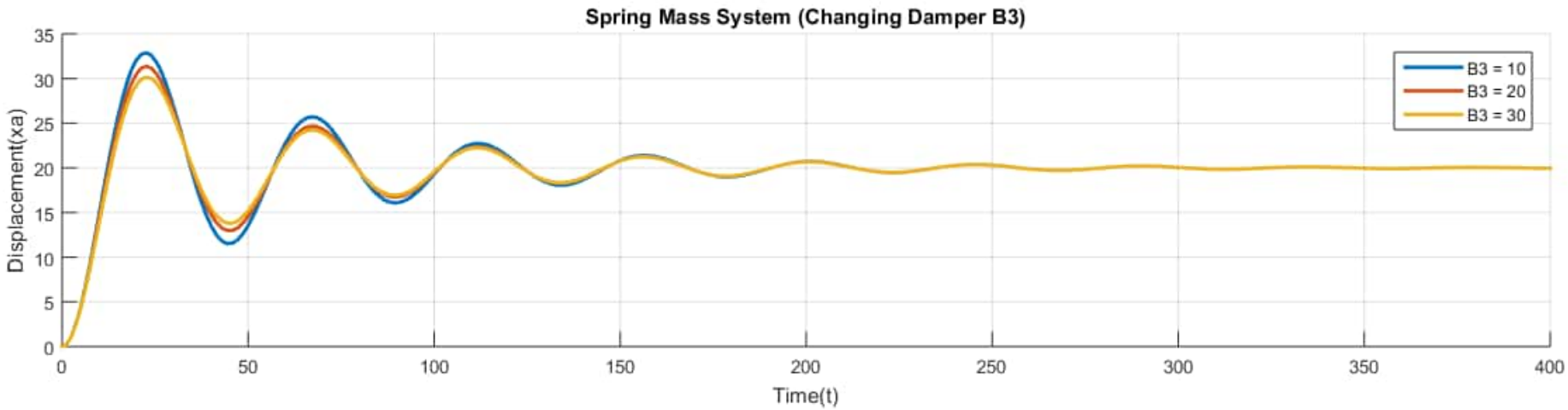

Spring Mass System (Changing Damper B1)
Velocity(vb)
Time(t)
B1 = 5
B1 = 10
B1 = 15
B1 = 20
1
0.5
0
-0.5
-1
0
50
100
150
200
250
300
350
400

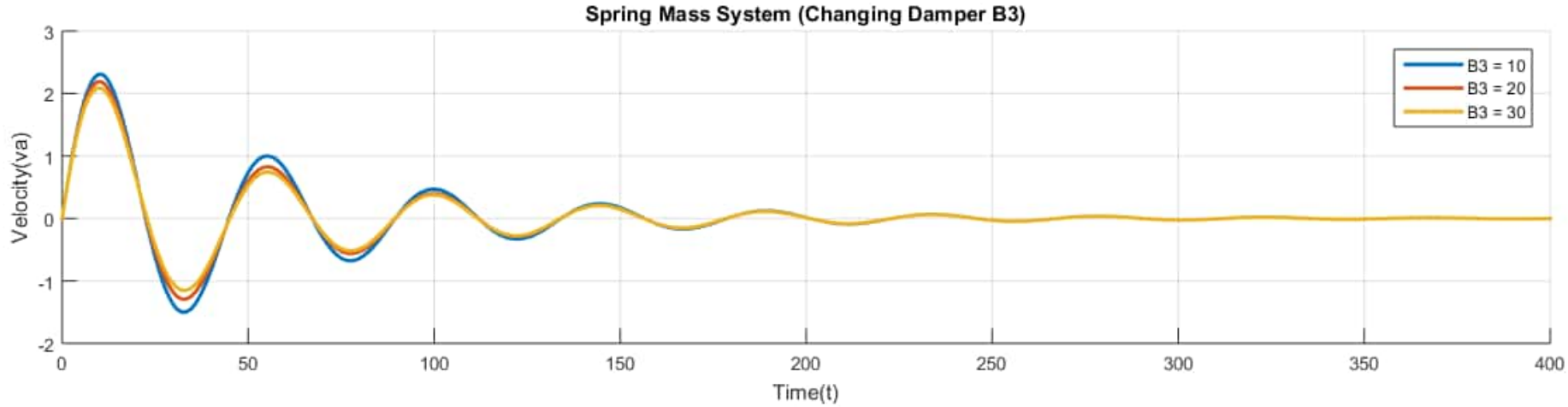

Spring Mass System (Changing Damper B2)
Displacement(xa)
Time(t)
B2 = 5
B2 = 10
B2 = 15
B2 = 20
0
5
10
15
20
25
30
35
0
50
100
150
200
250
300
350
400

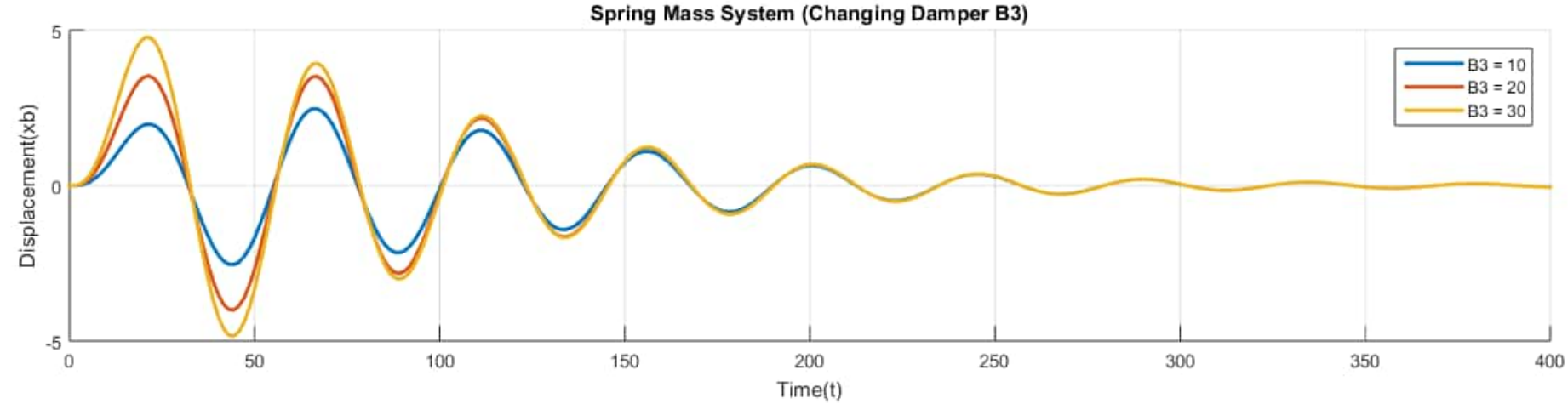

Spring Mass System (Changing Damper B2)
Velocity(va)
Time(t)
B2 = 5
B2 = 10
B2 = 15
B2 = 20
-2
-1
0
1
2
3
0
50
100
150
200
250
300
350
400

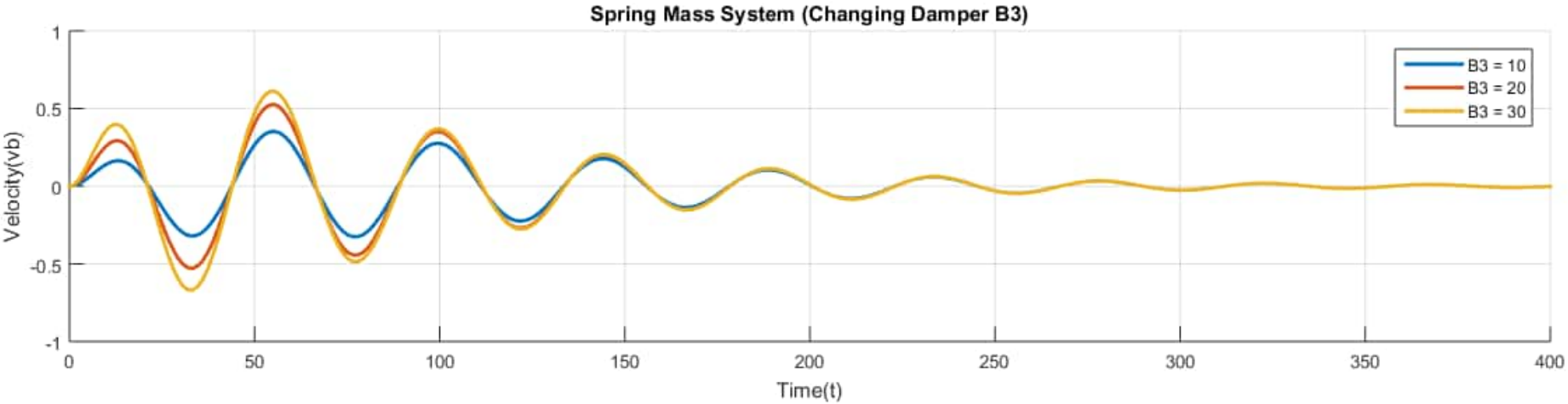

Spring Mass System (Changing Damper B2)
Displacement(xb)
Time(t)
B2 = 5
B2 = 10
B2 = 15
B2 = 20
6
4
2
0
-2
-4
-6
-8
0
50
100
150
200
250
300
350
400


Spring Mass System (Changing Damper B2)
Velocity(vb)
Time(t)
B2 = 5
B2 = 10
B2 = 15
B2 = 20
1
0.5
0
-0.5
-1
0
50
100
150
200
250
300
350
400


Spring Mass System (Changing Damper B3)
Displacement(xa)
Time(t)
B3 = 10
B3 = 20
B3 = 30
0
5
10
15
20
25
30
35
0
50
100
150
200
250
300
350
400


Spring Mass System (Changing Damper B3)
Velocity(va)
Time(t)
B3 = 10
B3 = 20
B3 = 30
-2
-1
0
1
2
3
0
50
100
150
200
250
300
350
400


Spring Mass System (Changing Damper B3)
Displacement(xb)
Time(t)
B3 = 10
B3 = 20
B3 = 30
5
0
-5
0
50
100
150
200
250
300
350
400


Spring Mass System (Changing Damper B3)
Velocity(vb)
Time(t)
B3 = 10
B3 = 20
B3 = 30
1
0.5
0
-0.5
-1
0
50
100
150
200
250
300
350
400

# OBSERVATIONS:-

## Changing Masses ($M_1$, $M_2$):-

By changing values of masses, amplitudes of oscillations also changes.

* For $M_1$ and $M_2$ increasing the value of masses also increase in amplitudes of oscillation causing unstability.
* Lower the value of masses gives more stable system.

## Changing Dampers ($B_1$, $B_2$, $B_3$):-

By changing values of dampers, amplitudes of oscillations also change.

* For $B_1$ and $B_2$ increasing the value of dampers, decrease in amplitudes of oscillation as a result system is more stable.
* For $B_3$ system acheives stability when the values increases.