Initial Displacement	3.00 in		Initial Displacement	3.00 in
Natural Frequency ω	6.28 rad/s		Natural Frequency ω	6.28 rad/s
Damping ratio ζ	0.10		Damping ratio ζ	0.20
Damped Frequency ω_D	6.25		Damped Frequency ω_D	6.16

Time t, s	y, in		Time t, s	y, in
0	3.00		0	3.00
0.1	2.45		0.1	2.47
0.2	1.09		0.2	1.23
0.3	-0.51		0.3	-0.16
0.4	-1.73		0.4	-1.18
0.5	-2.19		0.5	-1.58
0.6	-1.81		0.6	-1.35
0.7	-0.82		0.7	-0.72
0.8	0.34		0.8	0.01
0.9	1.25		0.9	0.58
1	1.59		1	0.82
1.1	1.33		1.1	0.74
1.2	0.62		1.2	0.42
1.3	-0.23		1.3	0.03
1.4	-0.90		1.4	-0.28
1.5	-1.16		1.5	-0.43
1.6	-0.98		1.6	-0.40
1.7	-0.47		1.7	-0.24
1.8	0.15		1.8	-0.04
1.9	0.64		1.9	0.13
2	0.85		2	0.22
2.1	0.72		2.1	0.22
2.2	0.35		2.2	0.14
2.3	-0.10		2.3	0.03
2.4	-0.46		2.4	-0.06
2.5	-0.62		2.5	-0.11
2.6	-0.53		2.6	-0.12
2.7	-0.26		2.7	-0.08
2.8	0.07		2.8	-0.02
2.9	0.33		2.9	0.03
3	0.45		3	0.06
3.1	0.39		3.1	0.06
3.2	0.20		3.2	0.04
3.3	-0.04		3.3	0.01
3.4	-0.24		3.4	-0.01
3.5	-0.33		3.5	-0.03
3.6	-0.29		3.6	-0.03
3.7	-0.15		3.7	-0.02
3.8	0.03		3.8	-0.01
3.9	0.17		3.9	0.01
4	0.24		4	0.02
4.1	0.21		4.1	0.02
4.2	0.11		4.2	0.01
4.3	-0.02		4.3	0.01
4.4	-0.12		4.4	0.00
4.5	-0.17		4.5	-0.01
4.6	-0.16		4.6	-0.01
4.7	-0.08		4.7	-0.01
4.8	0.01		4.8	0.00
4.9	0.09		4.9	0.00
5	0.13		5	0.00

Response of Spring-Mass-Damper System

d, mm	F, N
1	102
2	156
3	230
4	317
5	400
6	452
7	530
8	611
9	670
10	739

Spring test

y = 72.285x + 23.133
R² = 0.9983
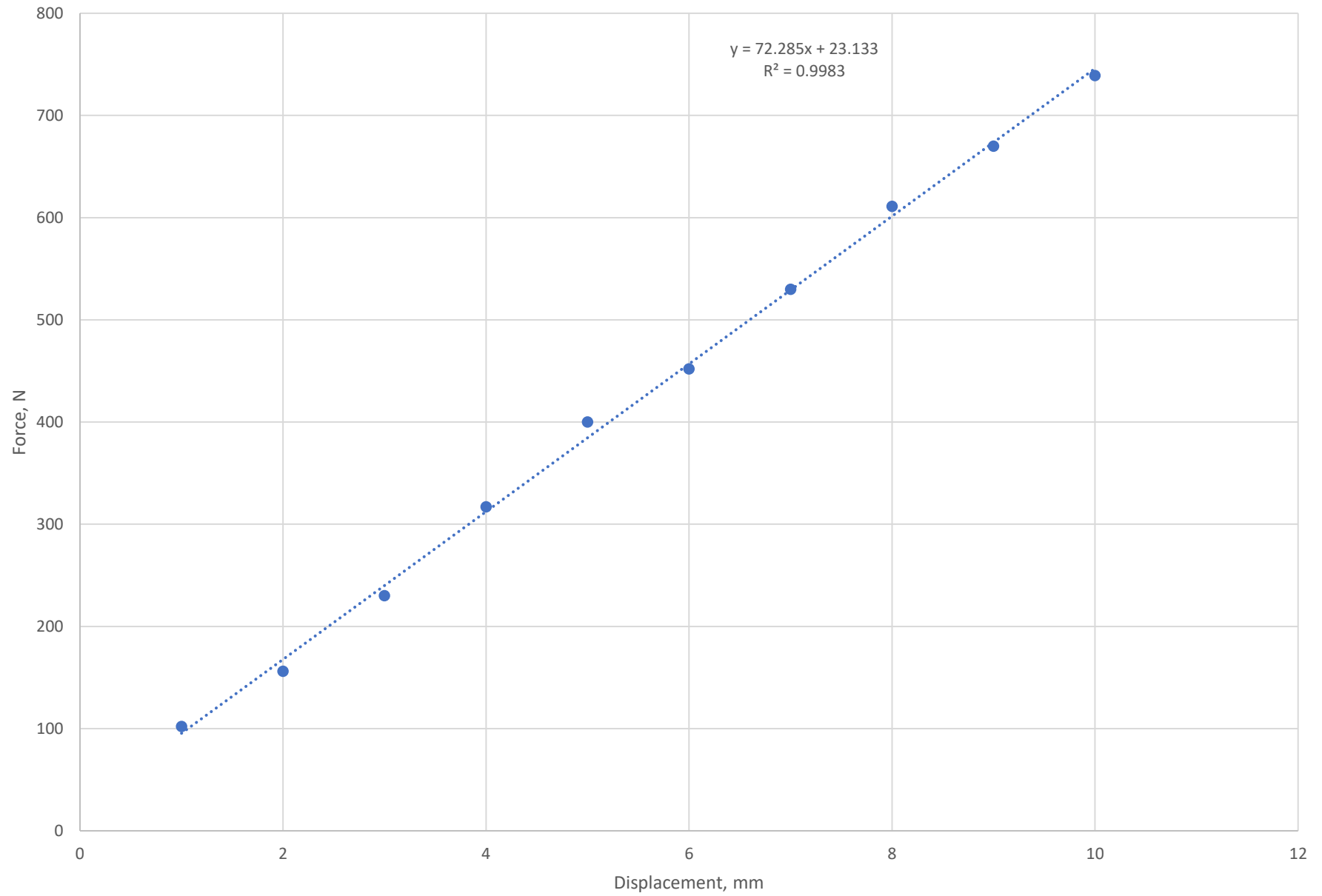
Time, minutes	Temperature, F	Delta T, Degrees F
0	200	123
1	192	115
2	185	108
3	179	102
4	174	97
5	169	92
10	151	74
15	138	61
20	126	49
25	117	40
30	106	29
60	84	7

Cooling Experiment

$y = 0.0392x^2 - 4.1534x + 193.04$
$R^2 = 0.9916$

Temperature, Degrees F

Time Seconds

Cooling Experiment

$y = 8E\text{-}05x^4 - 0.0085x^3 + 0.3323x^2 - 7.4449x + 199.16$
$R^2 = 0.9998$

Temperature, Degrees F

Time Seconds

Cooling Experiment

$y = 182.97e^{-0.015x}$
$R^2 = 0.9438$

Temperature, Degrees F

Time Seconds

Delta T, Degrees F

140

y = 120.19e^{-0.047x}

$$y = 120.19e^{-0.047x}$$
$$R^2 = 0.9972$$
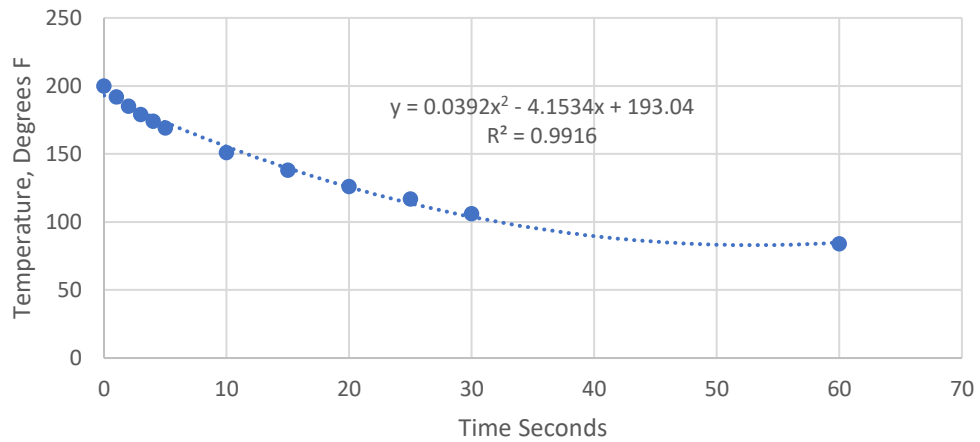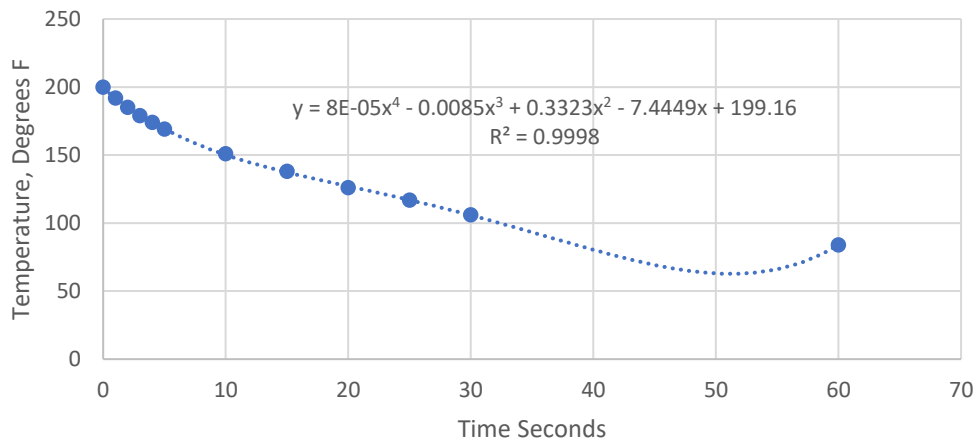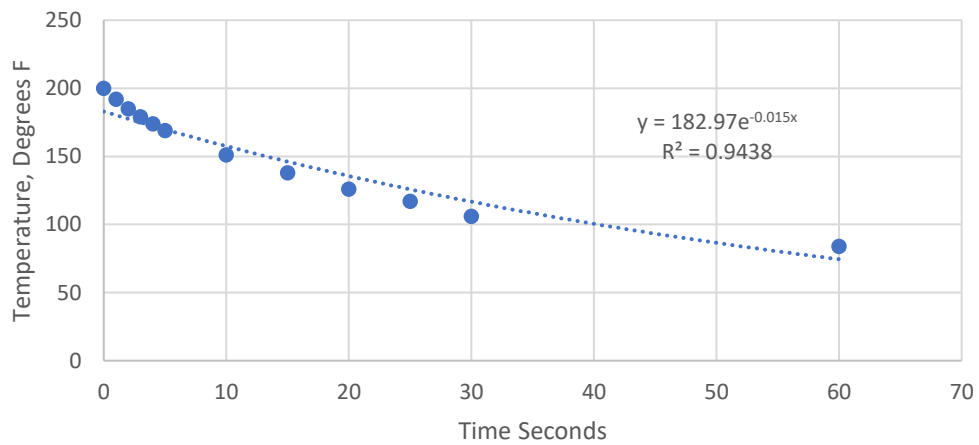
● Delta T, Degrees F   ⋯⋯ Expon. (Delta T, Degrees F)
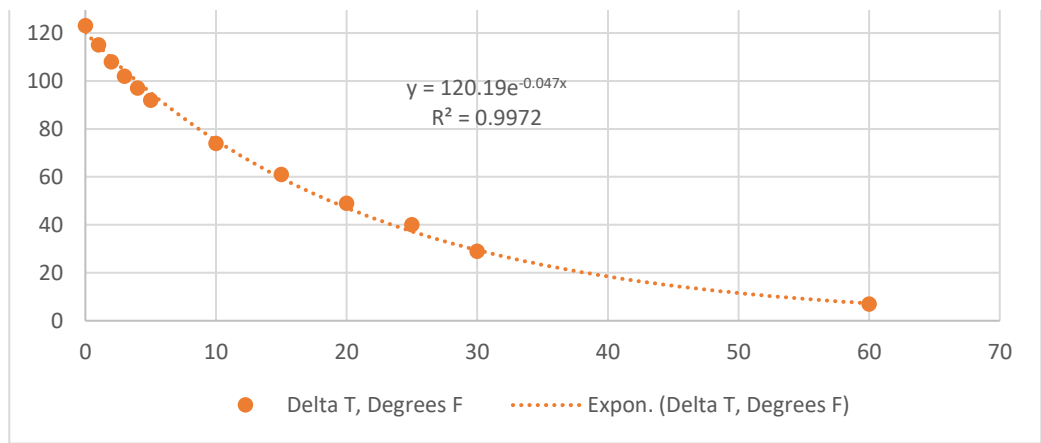
Previous Year	Current Year
$16.00	$16.80
$6.40	$9.25
$3.75	$3.80
$2.20	$2.20
$1.25	$1.45
$14.00	$16.00

Cost Components for Product ABC
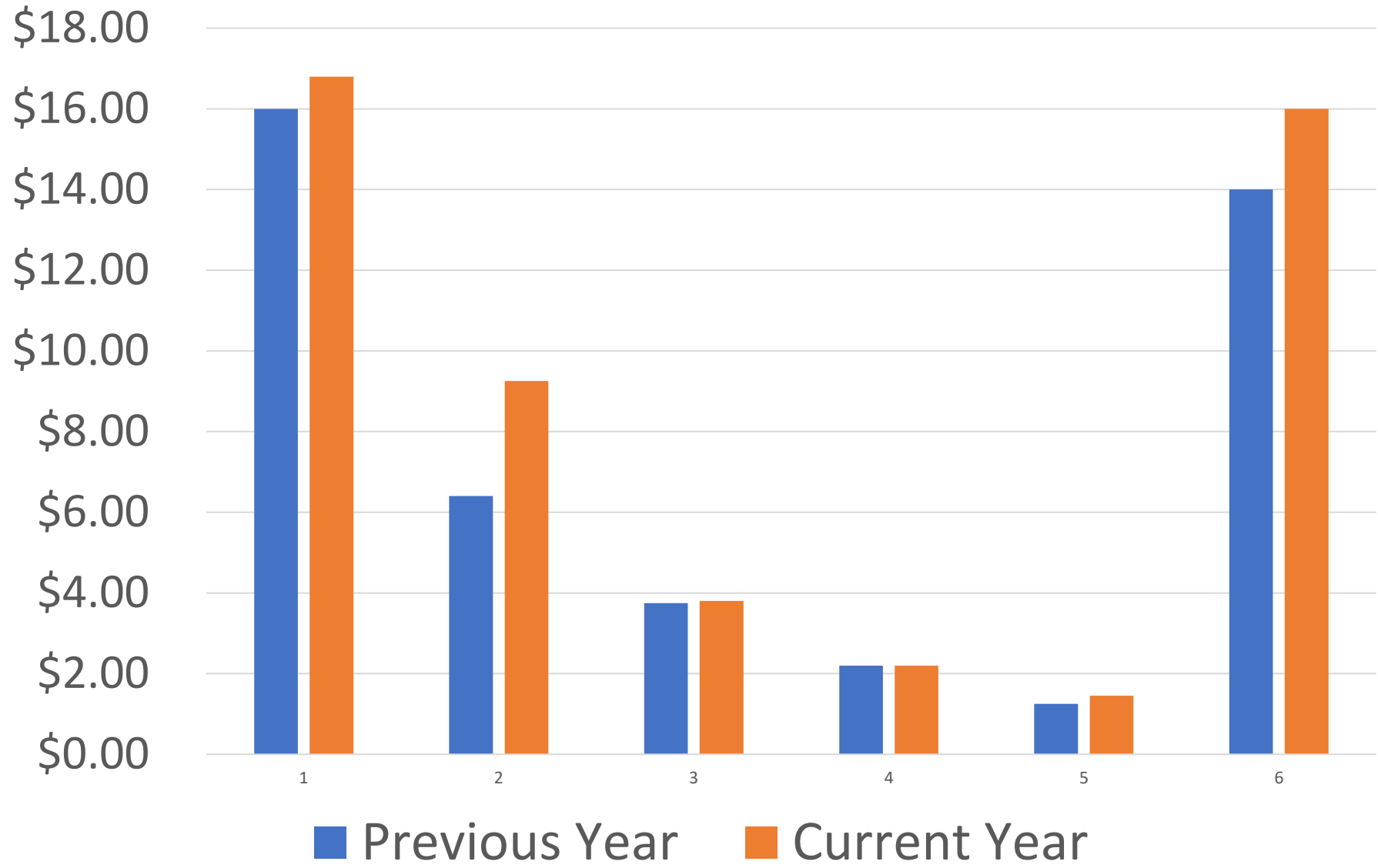
Table of Contents

Example 5.3

```matlab
% SMD.m: Plots displacement of under damped spring-mass-damper system

% Inputs:
y0 = 3.0; % initial displacement, inches
dr = 0.10; % damping ratio
fr = 2*pi; % natural frequency, radians/second
T = 5.0; % total time to be plotted, seconds
N = 100; % number of time intervals to be plotted

% Calculate damped frequency, radians/second
fd = fr*sqrt(1-dr^2);

% Calculate time interval for displacement calculations
tinc = T/N;

for i = 1:N+1
    t(i) = (i-1)*tinc;
    c = cos(fd*t(i));
    s = sin(fd*t(i));
    e = exp(-dr*fr*t(i));
    y(i) = (y0*c + y0*dr*fr/fd*s)*e;
end
figure
plot(t,y,'LineWidth',3,'Color','Red')
grid on
title('Response of Spring-Mass-Damper System','FontSize',20)
xlabel('Time, seconds','FontSize',16)
ylabel('Displacement, inches','FontSize',16)
```
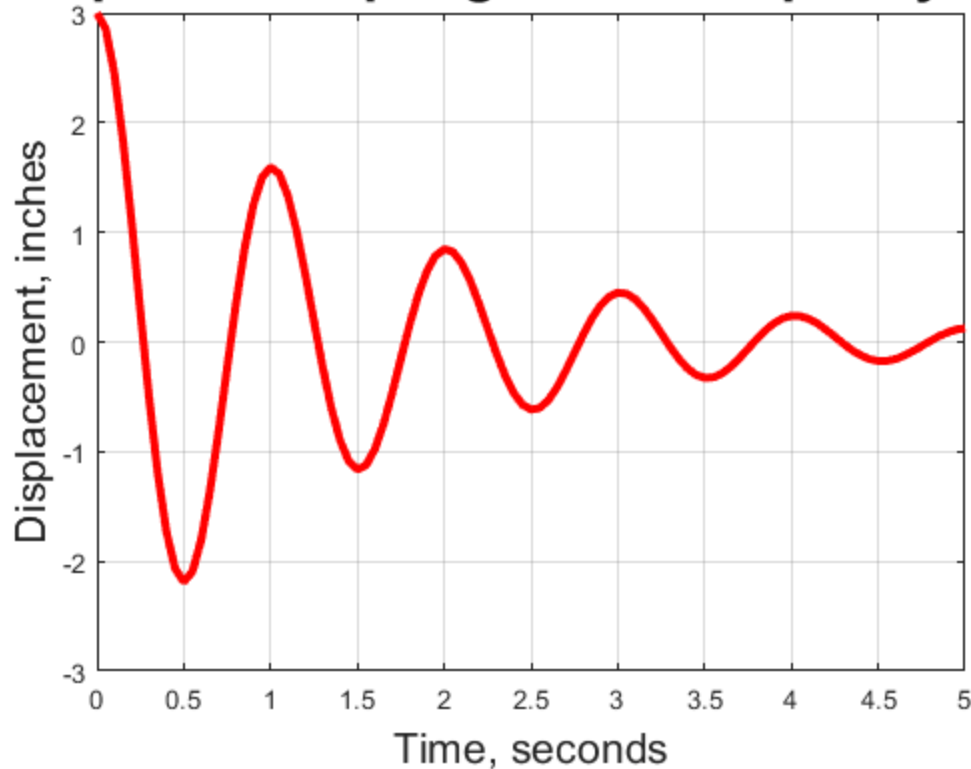
Response of Spring-Mass-Damper System

Example 5.4

```matlab
% SMD.m: Plots displacement of under damped spring-mass-damper system

% Inputs:
y0 = 3.0; % initial displacement, inches
dr = 0.10; % damping ratio
fr = 2*pi; % natural frequency, radians/second
T = 5.0; % total time to be plotted, seconds
N = 100; % number of time intervals to be plotted

% Calculate damped frequency, radians/second
fd = fr*sqrt(1-dr^2);

% Calculate time interval for displacement calculations
tinc = T/N;

for i = 1:N+1
    t(i) = (i-1)*tinc;
    c = cos(fd*t(i));
    s = sin(fd*t(i));
    e = exp(-dr*fr*t(i));
    y(i) = (y0*c + y0*dr*fr/fd*s)*e;
end
figure
```

```matlab
plot(t,y,'LineWidth',3,'Color','Red')
grid on
title('Response of Spring-Mass-Damper System','FontSize',20)
xlabel('Time, seconds','FontSize',16)
ylabel('Displacement, inches','FontSize',16)

% Compute and plot displacements for a different damping ratio

dr2 = 0.20; % new damping ratio

% Calculate new damped frequency fd
fd2 = fr*sqrt(1-dr2^2);

for i = 1:N+1
    c = cos(fd2*t(i));
    s = sin(fd2*t(i));
    e = exp(-dr2*fr*t(i));
    y2(i) = (y0*c + y0*dr2*fr/fd2*s)*e;
end
hold on
plot(t,y2,'LineWidth',3,'LineStyle',':','Color','Blue')
legend('Damping Ratio = 0.1','Damping Ratio = 0.2')
```
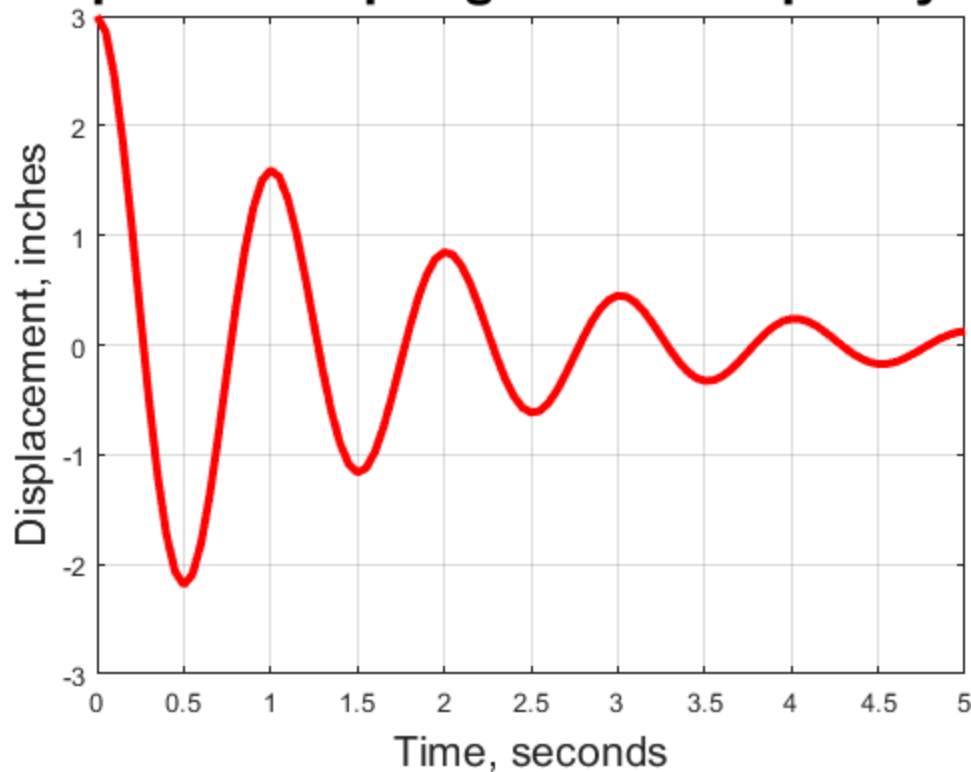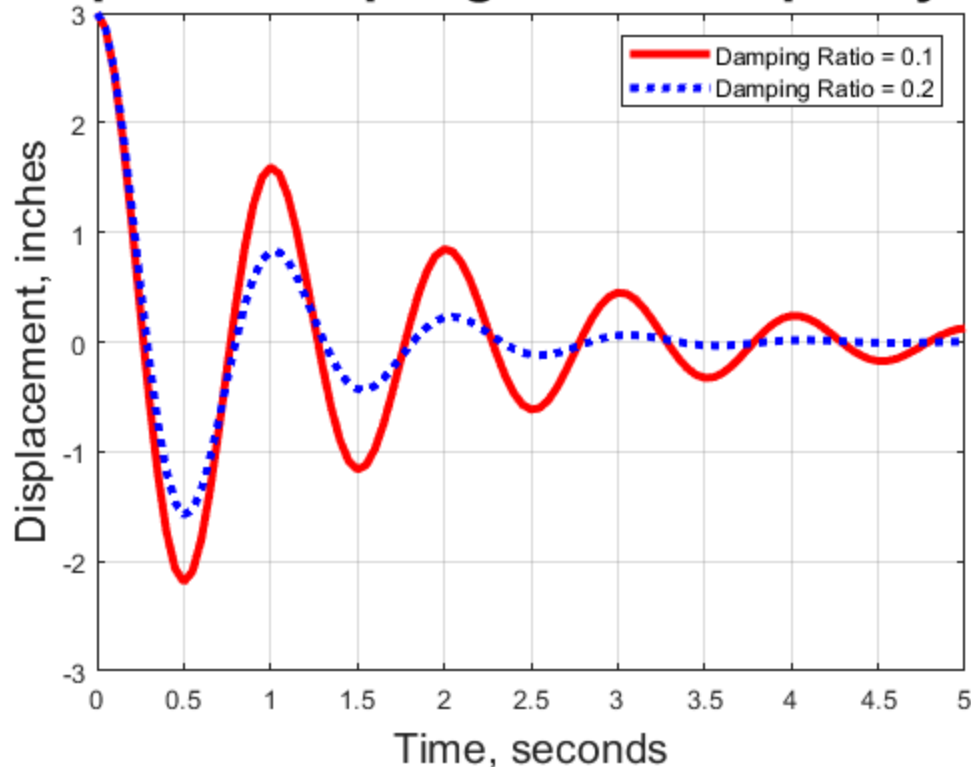
Response of Spring-Mass-Damper System

Example 5.4 Function displace & displace2 section

```
out = displace(2)
out2 = displace2(3,.1,2*pi,2)

figure
fplot(@(t)displace2(3,.1,2*pi,t),[0 5])
hold on
fplot(@(t)displace2(3,.2,2*pi,t),[0 5])


out =

    0.8467


out2 =

    0.8467

Warning: Function behaves unexpectedly on array inputs. To improve
 performance,
properly vectorize your function to return an output with the same size and
shape as the input arguments.
```
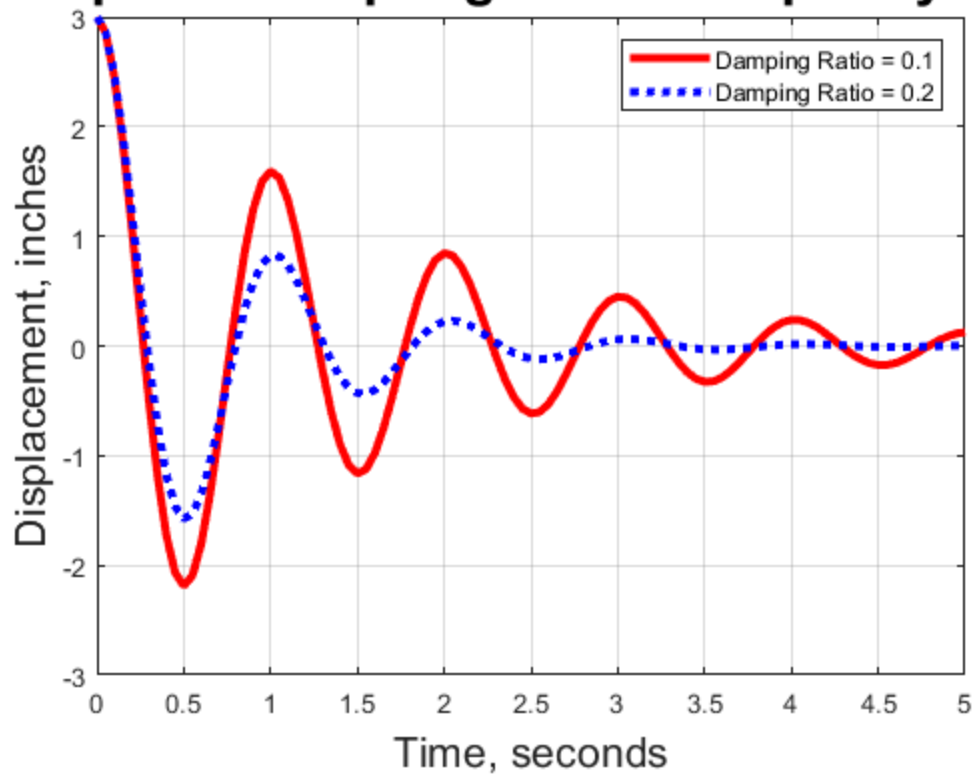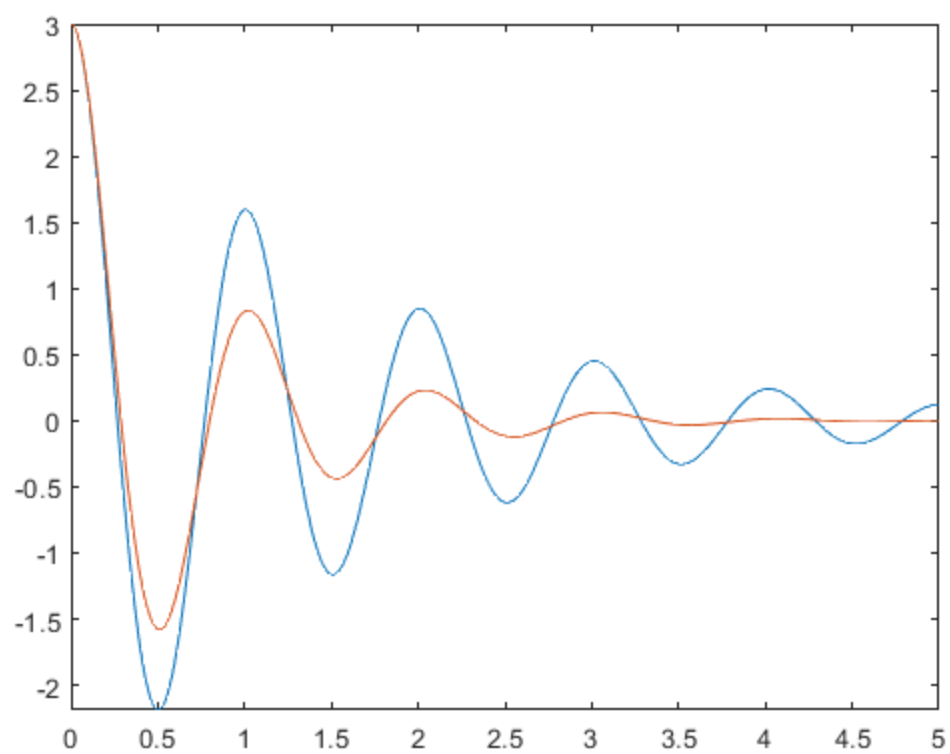
Warning: Function behaves unexpectedly on array inputs. To improve
 performance,
properly vectorize your function to return an output with the same size and
shape as the input arguments.

Response of Spring-Mass-Damper System

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