```
clc
%QS1: Defined the function (funct1.m)

%QS2: a) dy/dt=2
[t_1,y_1, time_1]=funct1(@myODE, [0 5], 0, 0.1);
time_1
```

```
time_1 = 0.0081
```

```
y_1
```

```
y_1 = 1×51
         0    0.2000    0.4000    0.6000    0.8000    1.0000    1.2000    1.4000 ···
```

```
t_1
```

```
t_1 = 1×51
         0    0.1000    0.2000    0.3000    0.4000    0.5000    0.6000    0.7000 ···
```

```
[t_2,y_2, time_2]=funct1(@myODE, [0 5], 0, 0.01);
time_2
```

```
time_2 = 7.9050e-04
```

```
y_2
```

```
y_2 = 1×501
         0    0.0200    0.0400    0.0600    0.0800    0.1000    0.1200    0.1400 ···
```

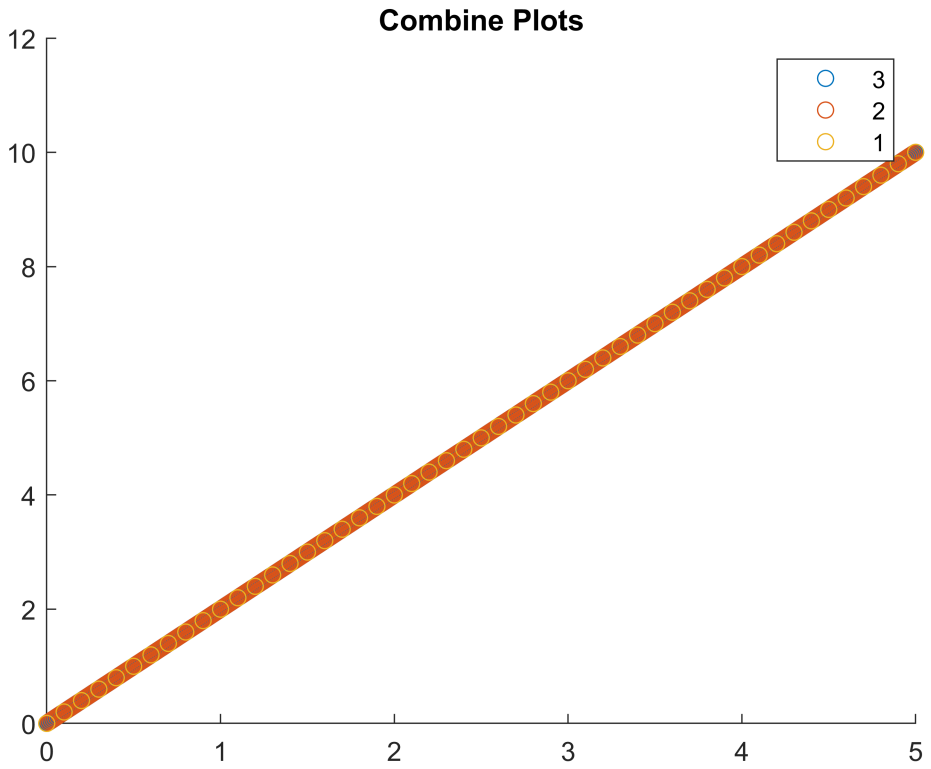
```
[t_3,y_3, time_3]=funct1(@myODE, [0 5], 0, 0.001);
time_3
```

```
time_3 = 0.0092
```

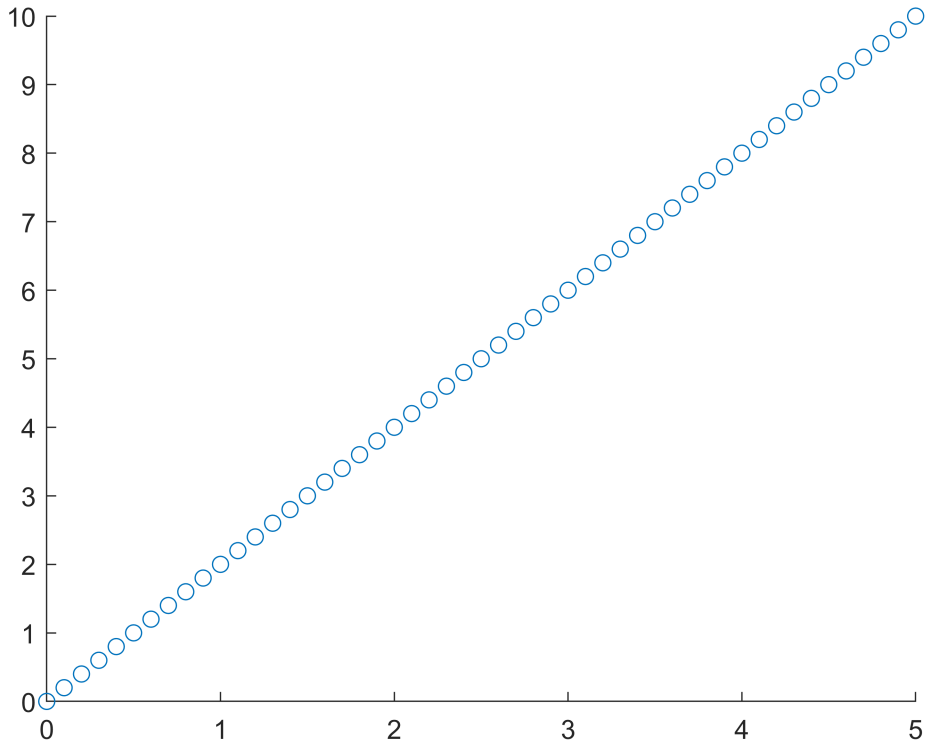
```
y_3
```

```
y_3 = 1×5001
         0    0.0020    0.0040    0.0060    0.0080    0.0100    0.0120    0.0140 ···
```

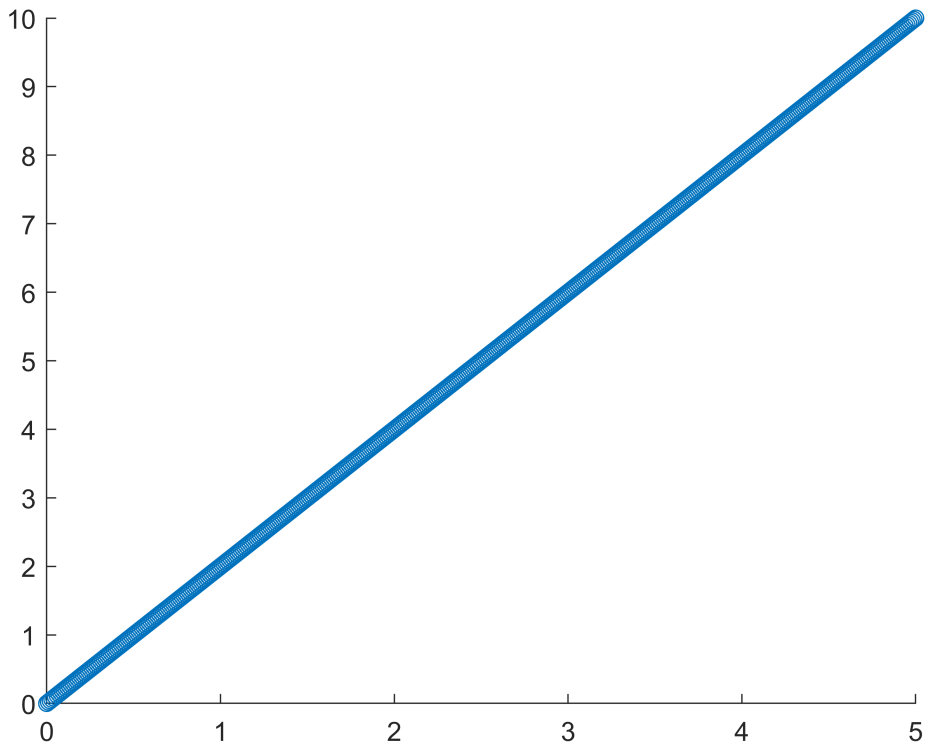
```
scatter(t_3,y_3)
hold on
scatter(t_2,y_2)
hold on
scatter(t_1,y_1)

title('Combine Plots')
legend('0.001','0.01','0.1')

hold off
```



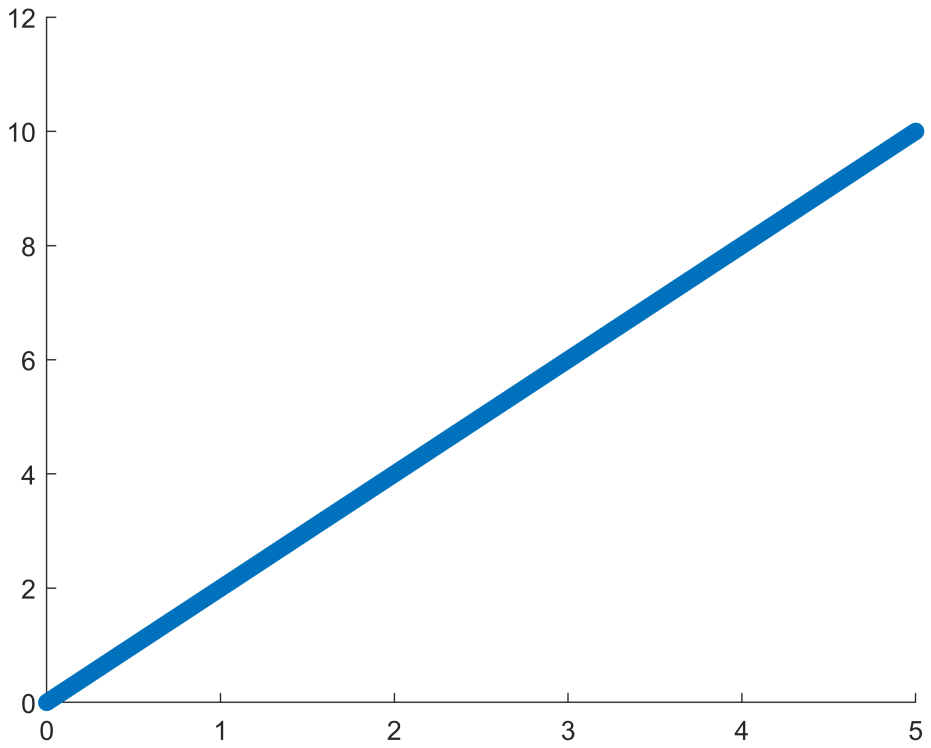

```
scatter(t_1,y_1)
```



```
scatter(t_2,y_2)
```




```
scatter(t_3,y_3)
```




```
%QS2: b) dy/dt=3*t^2

[t_1,y_1, time_1]=funct1(@myODE, [0 5], 0, 0.1);
time_1
```

```
time_1 = 0.0094
```

```
y_1
```

```
y_1 = 1×52
         0         0    0.0030    0.0150    0.0420    0.0900    0.1650    0.2730 ···
```

```
[t_2,y_2, time_2]=funct1(@myODE, [0 5], 0, 0.01);
time_2
```

```
time_2 = 0.0015
```

```
y_2
```

```
y_2 = 1×502
         0         0    0.0000    0.0000    0.0000    0.0001    0.0002    0.0003 ···
```

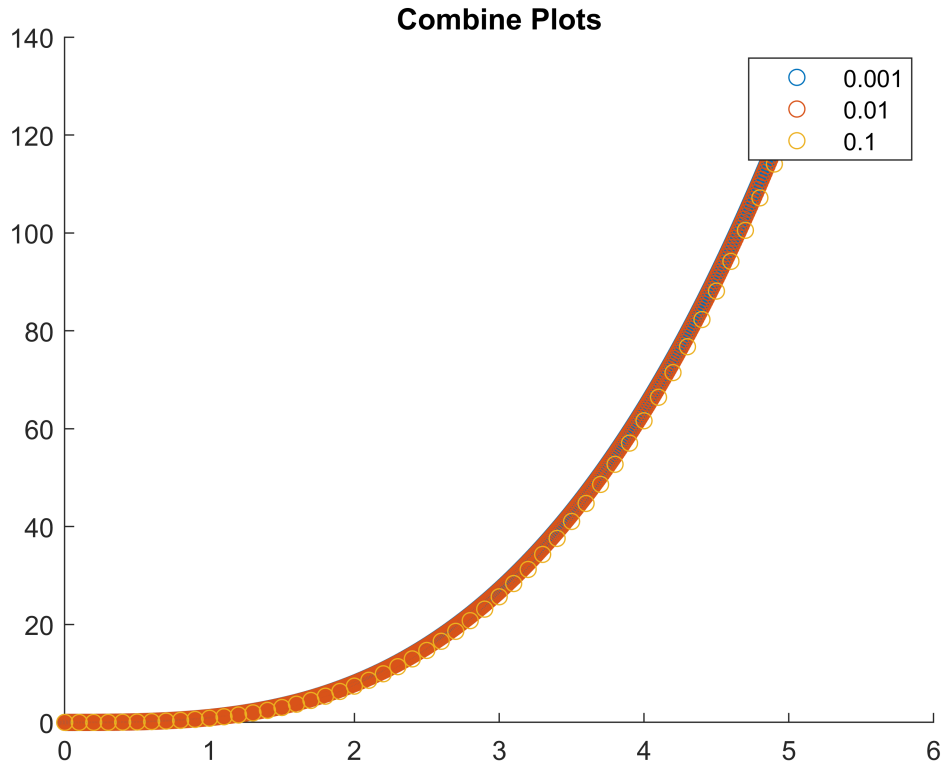
```
[t_3,y_3, time_3]=funct1(@myODE, [0 5], 0, 0.001);
time_3
```

```
time_3 = 0.0184
```

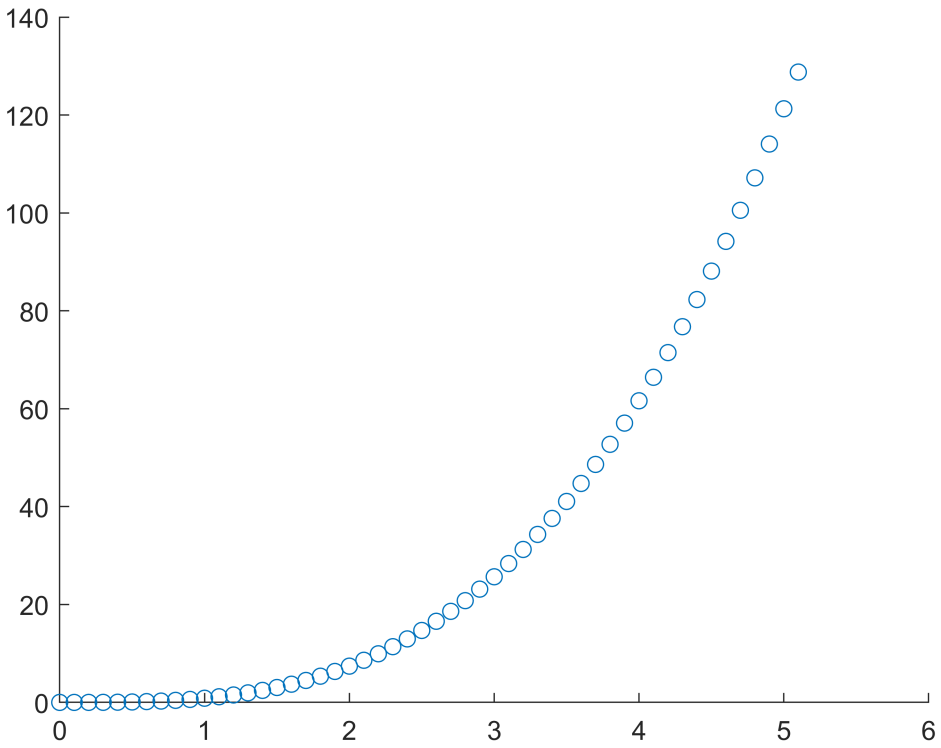
```
y_3
```

```
y_3 = 1×5001
         0         0    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000 ···
```

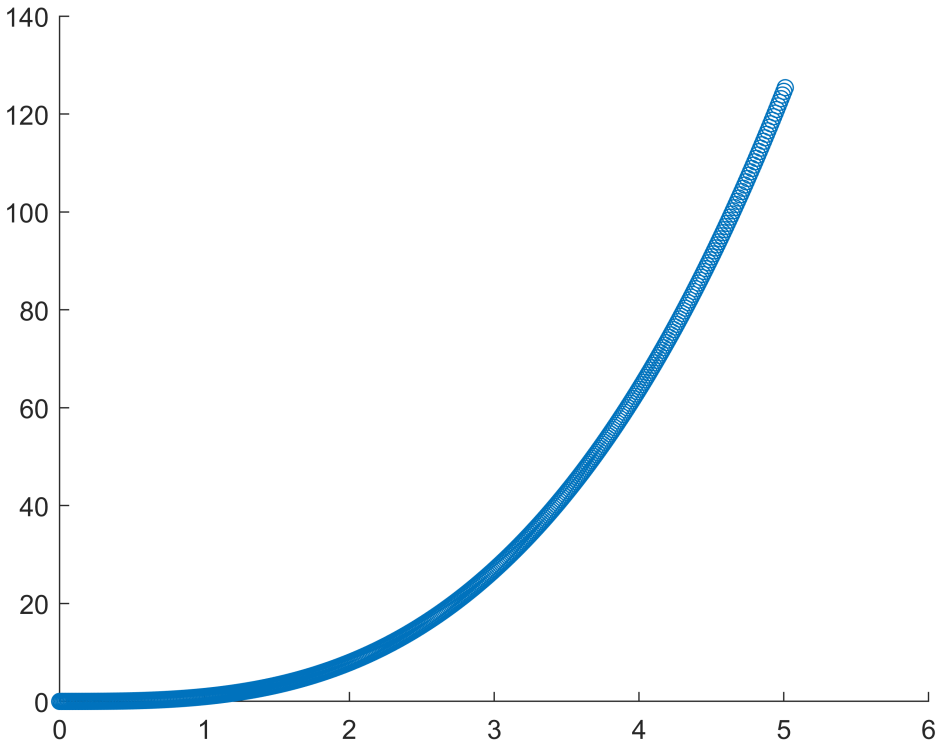
```
scatter(t_3,y_3)
hold on
scatter(t_2,y_2)
hold on
scatter(t_1,y_1)

title('Combine Plots')
legend('0.001','0.01','0.1')

hold off
```



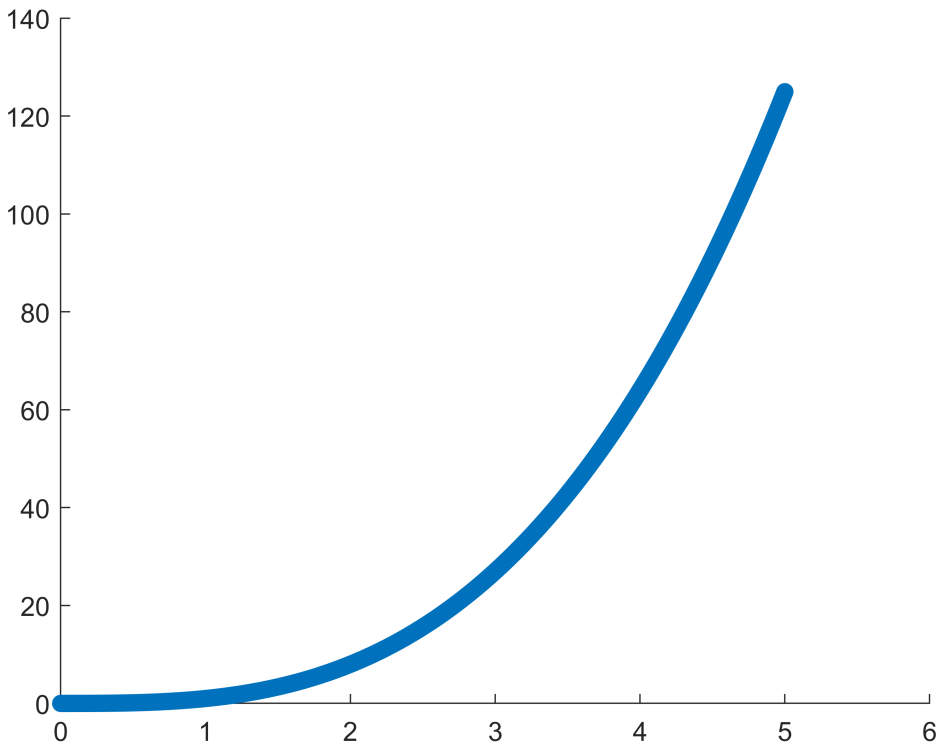

```
scatter(t_1,y_1)
```




```
scatter(t_2,y_2)
```



```
scatter(t_3,y_3)
```




```
tic
dist_1=norm(y_1-t_1.^3)
```

```
dist_1 = 12.6628
```

```
toc
```

```
Elapsed time is 0.017718 seconds.
```

```
tic
dist_2=norm(y_2-t_2.^3)
```

```
dist_2 = 3.7750
```

```
toc
```

```
Elapsed time is 0.017854 seconds.
```

```
tic
dist_3=norm(y_3-t_3.^3)
```

```
dist_3 = 1.1861
```

```
toc
```

```
Elapsed time is 0.009693 seconds.
```

```
% with the increase in h value the accuracy of function reduces, error function increases, the
```

```
% number of datapoints reduces, and the computational time increases
```

```
%QS3: defined the function (funct2.m)

%QS4:
[t_1,y_1, time_1]=funct2(@myODE, [0 5], 0, 0.1);
time_1
```

```
time_1 = 0.0043
```

```
y_1
```

```
y_1 = 1×52
         0    0.0010    0.0080    0.0270    0.0640    0.1250    0.2160    0.3430 ···
```

```
[t_2,y_2, time_2]=funct2(@myODE, [0 5], 0, 0.01);
time_2
```

```
time_2 = 0.0053
```

```
y_2
```

```
y_2 = 1×502
         0    0.0000    0.0000    0.0000    0.0001    0.0001    0.0002    0.0003 ···
```

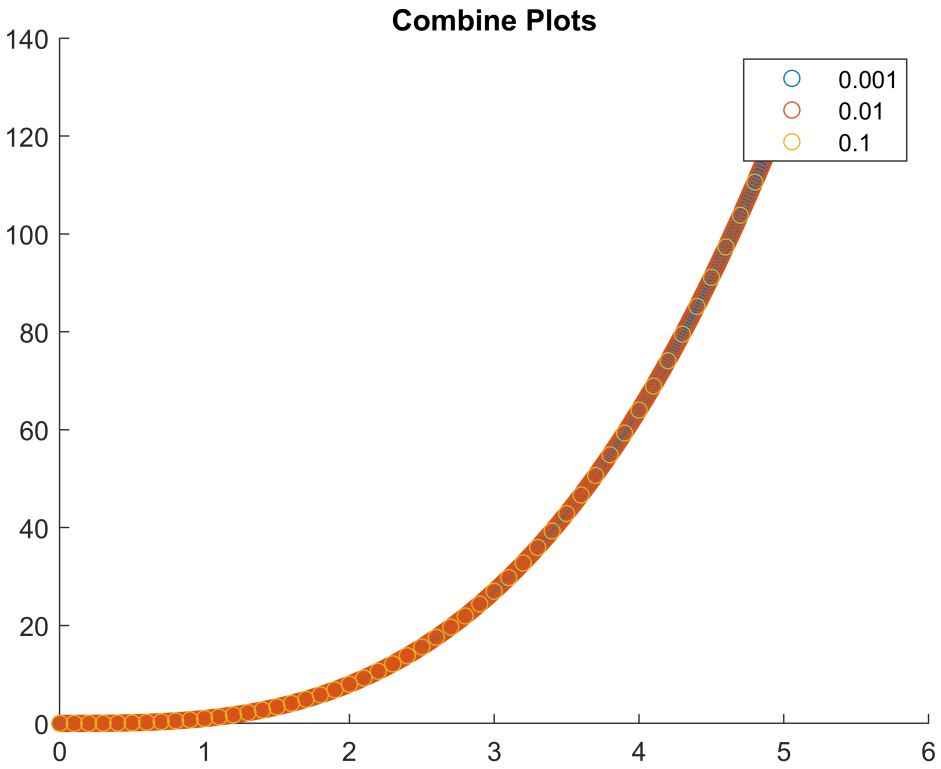
```
[t_3,y_3, time_3]=funct2(@myODE, [0 5], 0, 0.001);
time_3
```

```
time_3 = 0.0497
```

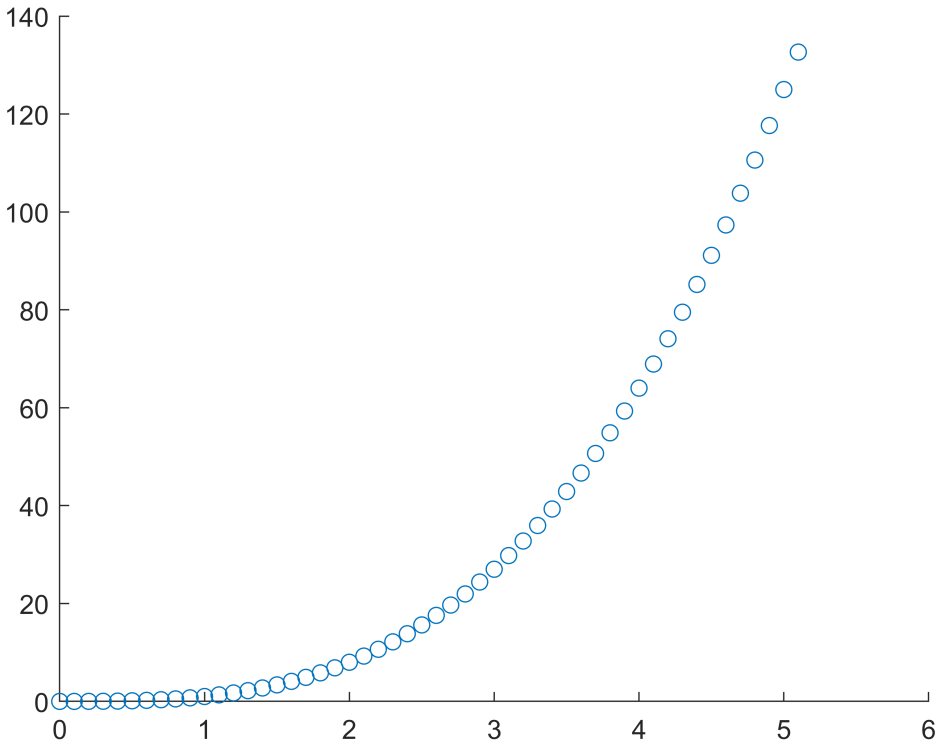
```
y_3
```

```
y_3 = 1×5001
         0    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000 ···
```

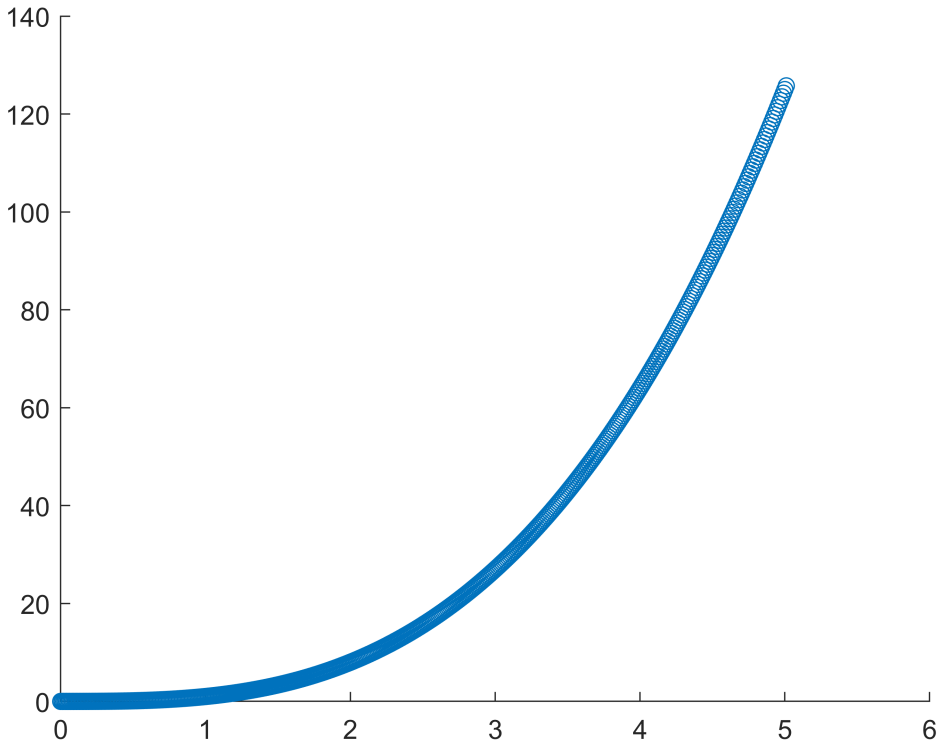
```
scatter(t_3,y_3)
hold on
scatter(t_2,y_2)
hold on
scatter(t_1,y_1)

title('Combine Plots')
legend('0.001','0.01','0.1')

hold off
```



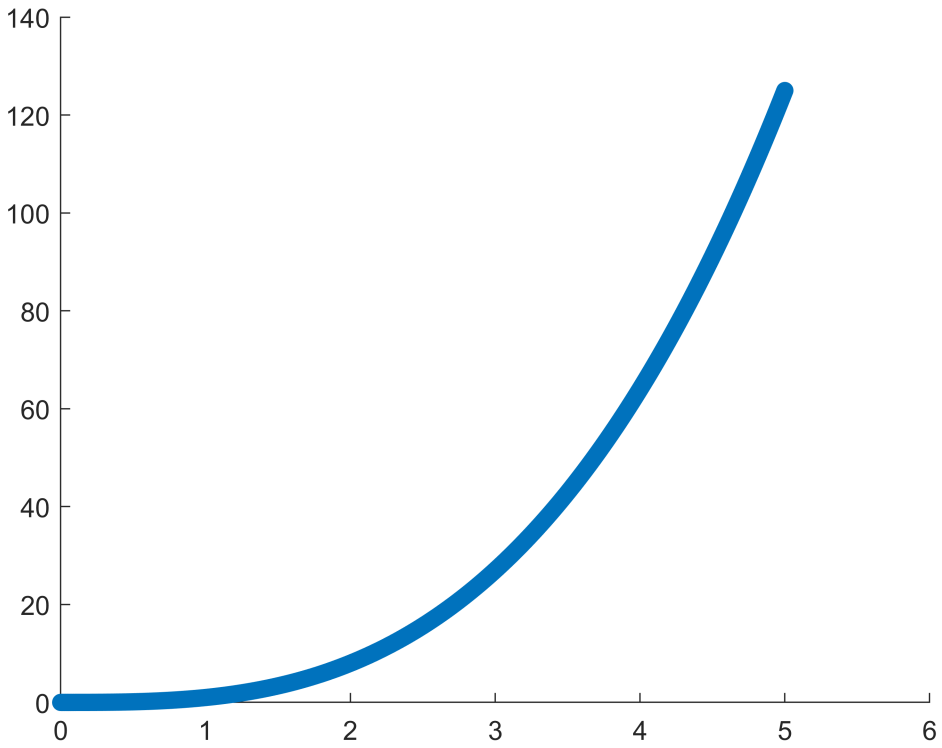

```
scatter(t_1,y_1)
```



```
scatter(t_2,y_2)
```




```
scatter(t_3,y_3)
```




```
tic
dist_1=norm(y_1-t_1.^3)
```

```
dist_1 = 3.9074e-13
```

```
toc
```

```
Elapsed time is 0.011848 seconds.
```

```
tic
dist_2=norm(y_2-t_2.^3)
```

```
dist_2 = 2.0548e-11
```

```
toc
```

```
Elapsed time is 0.009676 seconds.
```

```
tic
dist_3=norm(y_3-t_3.^3)
```

```
dist_3 = 2.6125e-10
```

```
toc
```

```
Elapsed time is 0.007808 seconds.
```

```
% with the RK4 method it provoides higher accuracy, very low value of error
% however higher time of
```

```
% computation wrt Euler method
```

```
%QS5: Pendulum

g = 9.8;
L = 2;
time = [0,20];
f = @(t,y) funct3(t,y,g,L);
[t,y] = ode45(f,time,[2 0]);

[t1,y1, time1] = funct1(f,time_span,[2 0],0.1);
time1
```

```
time1 = 0.0024
```

```
[t2,y2, time_1] = funct1(f,time_span,[2 0],0.01);
time_1
```

```
time_1 = 0.0099
```

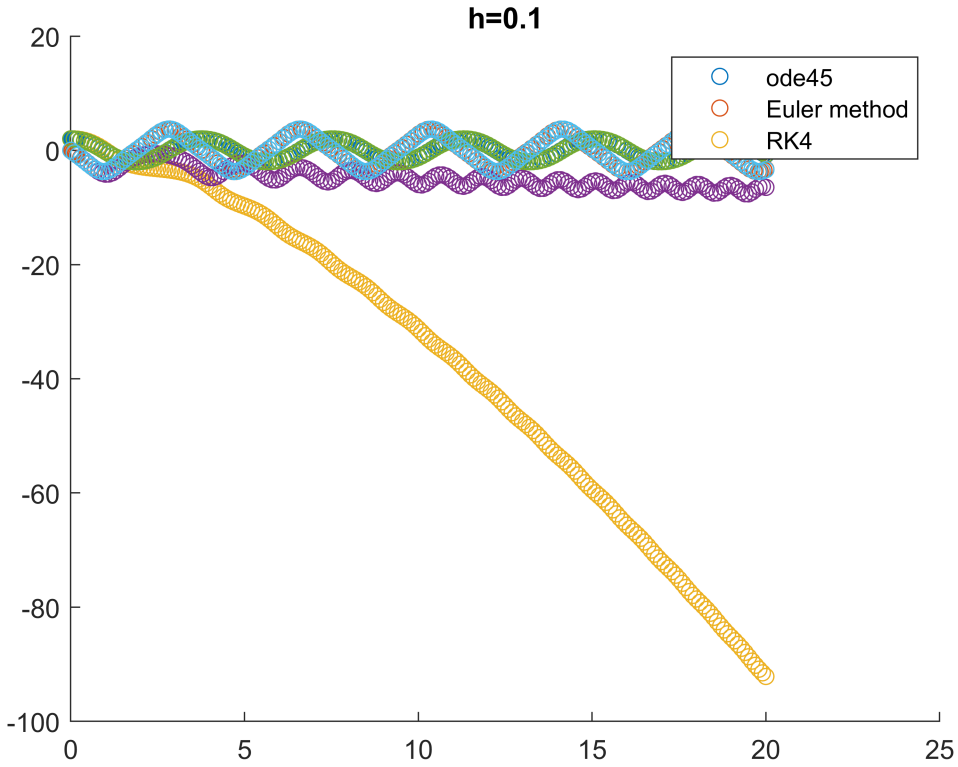
```
[t3,y3, time2] = funct2(f,time_span,[2 0],0.1);
time2
```

```
time2 = 0.0019
```

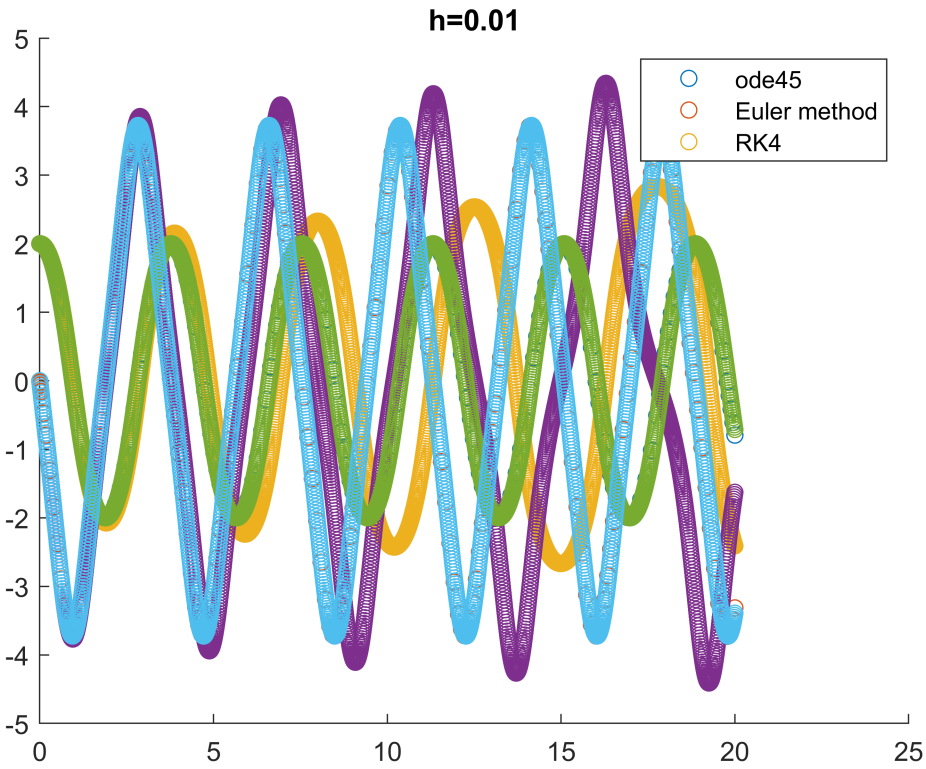
```
[t4,y4, time_2] = funct2(f,time_span,[2 0],0.01);
time_2
```

```
time_2 = 0.0148
```

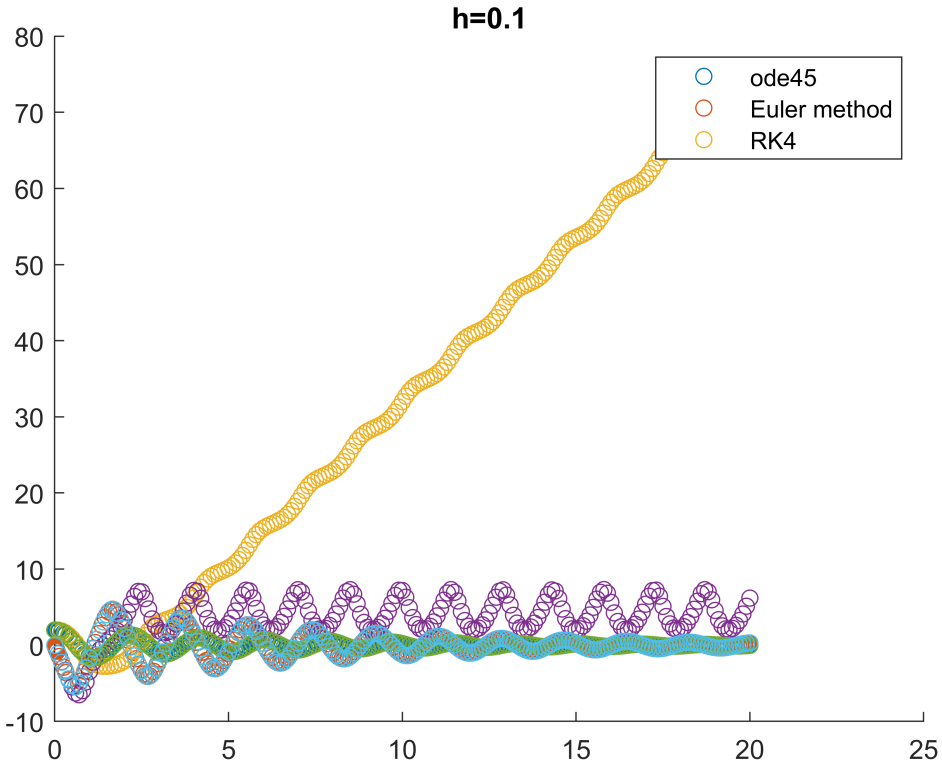
```
scatter(t,y)
hold on
scatter(t1,y1)
hold on
scatter(t3,y3)

title('h=0.1')
legend('ode45','Euler method','RK4')

hold off
```



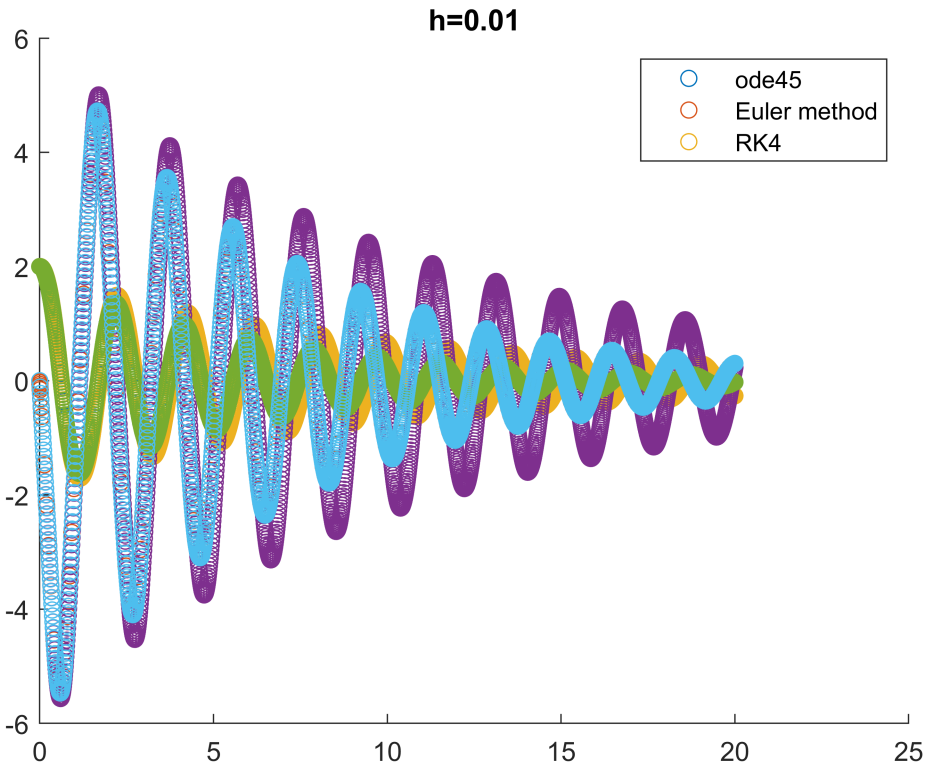

```
scatter(t,y)
hold on
scatter(t2,y2)
hold on
scatter(t4,y4)
title('h=0.01')
legend('ode45','Euler method','RK4')

hold off
```



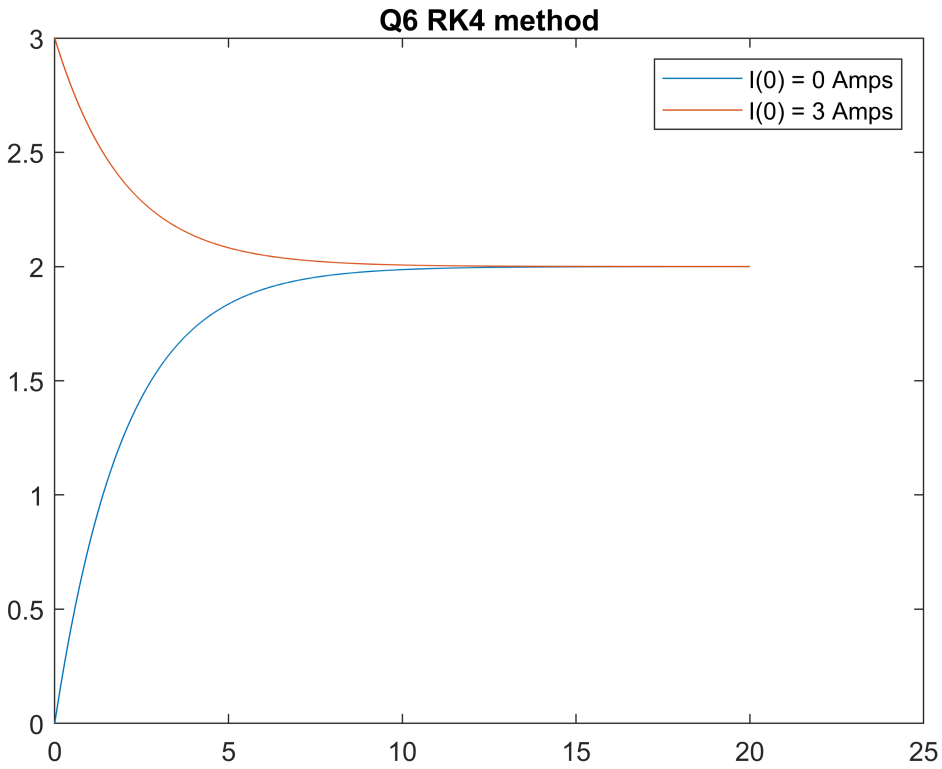

```
m=1;
b=0.3;
time = [0,20];
f = @(t,y) funct4(t,y,g,L,m,b);
[t,y] = ode45(f,time_span,[2 0]);

[t1,y1,time1] = funct1(f,time_span,[2 0],0.1);
[t2,y2,time_1] = funct1(f,time_span,[2 0],0.01);
[t3,y3,time2] = funct2(f,time_span,[2 0],0.1);
[t4,y4,time_2] = funct2(f,time_span,[2 0],0.01);

scatter(t,y)
hold on
scatter(t1,y1)
hold on
scatter(t3,y3)

title('h=0.1')
legend('ode45','Euler method','RK4')

hold off
```




```
scatter(t,y)
hold on
scatter(t2,y2)
hold on
scatter(t4,y4)
title('h=0.01')
legend('ode45','Euler method','RK4')

hold off
```




```
%% Q6

time_span = [0 20];
R = 0.5;
L = 1;
f = @(t,y) (1-y*R)/L;
[t_1,y_1] = funct2(f,time_span,0,0.001);
[t_2,y_2] = funct2(f,time_span,3,0.001);

figure
plot(t_1,y_1,t_2,y_2);
legend("I(0) = 0 Amps","I(0) = 3 Amps")
title('Q6 RK4 method')
```



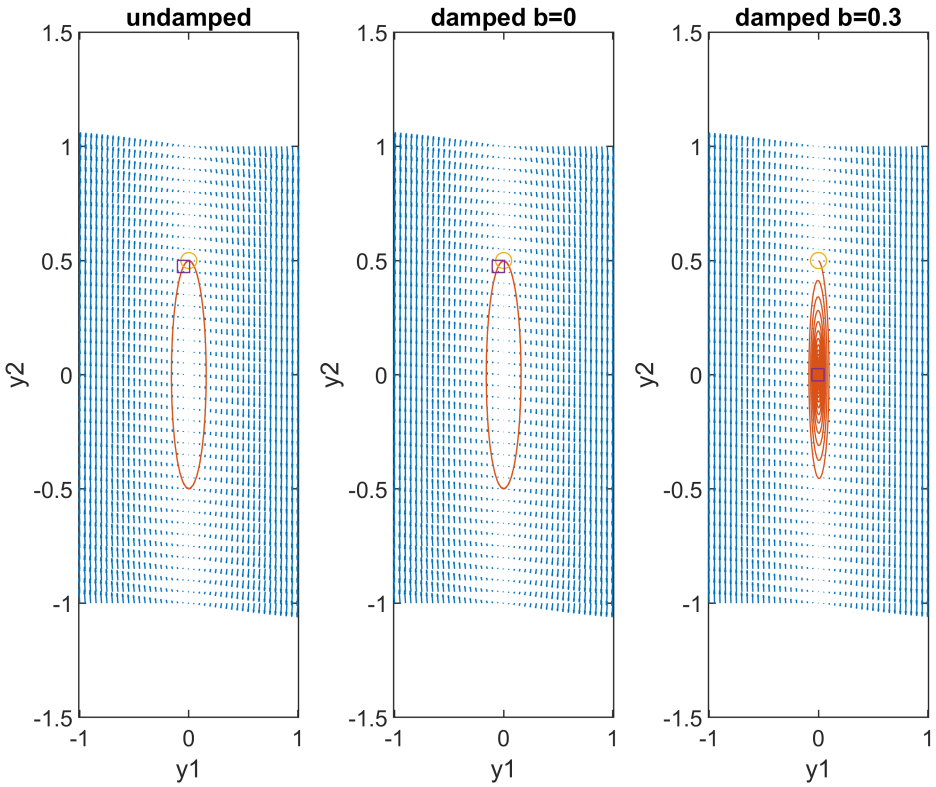

```
%results same are theoretical
```

```
%% Q7

y1 = -1:0.05:1;
y2 = -1:0.05:1;

[Y1 Y2] = meshgrid(y1,y2);
y1dot = Y2;
y2dot = -(g/L)*sin(Y1);

subplot(1,3,1);
quiver(Y1,Y2,y1dot,y2dot);
title("undamped");
xlabel("y1");
ylabel("y2");
hold on

f = @(t,y) funct3(t,y,g,L);
[t, y] = ode45(f,[0,20],[0,0.5]);
end_idx = size(y)
```

```
end_idx = 1×2
   337     2
```

```
plot(y(:,1),y(:,2));
plot(y(1,1),y(1,2),'o',y(end,1),y(end,2),'s');
```

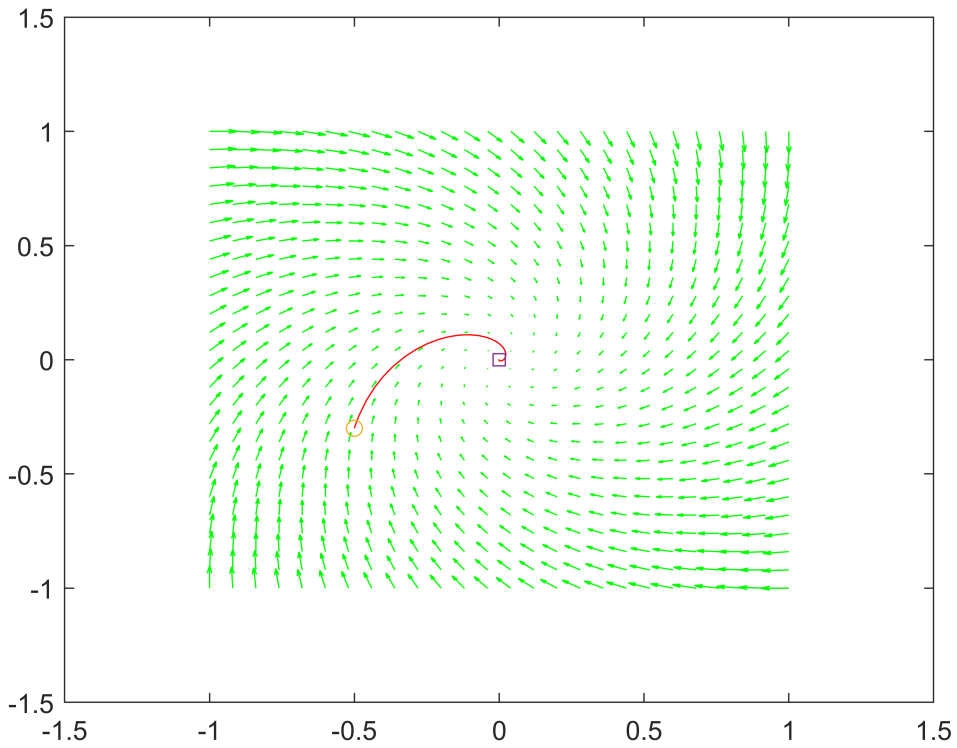
```
hold off

m=1;
b=0;
y1dot_2 = Y2;
y2dot_2 = -((b/m)*Y2 + ((m*g)/(L*(m-2*b)))*sin(Y1));

subplot(1,3,2);
quiver(Y1,Y2,y1dot_2,y2dot_2);
title("damped b=0");
xlabel("y1");
ylabel("y2");
hold on

f = @(t,y) funct4(t,y,g,L,m,b);
[t, y] = ode45(f,[0,20],[0,0.5]);

plot(y(:,1),y(:,2));
plot(y(1,1),y(1,2),'o',y(end,1),y(end,2),'s');
hold off

b= 0.3;
y1dot_2 = Y2;
y2dot_2 = -((b/m)*Y2 + ((m*g)/(L*(m-2*b)))*sin(Y1));

subplot(1,3,3);
quiver(Y1,Y2,y1dot_2,y2dot_2);
title("damped b=0.3");
xlabel("y1");
ylabel("y2");
hold on

f = @(t,y) funct4(t,y,g,L,m,b);
[t, y] = ode45(f,[0,20],[0,0.5]);

plot(y(:,1),y(:,2));
plot(y(1,1),y(1,2),'o',y(end,1),y(end,2),'s');
hold off
```



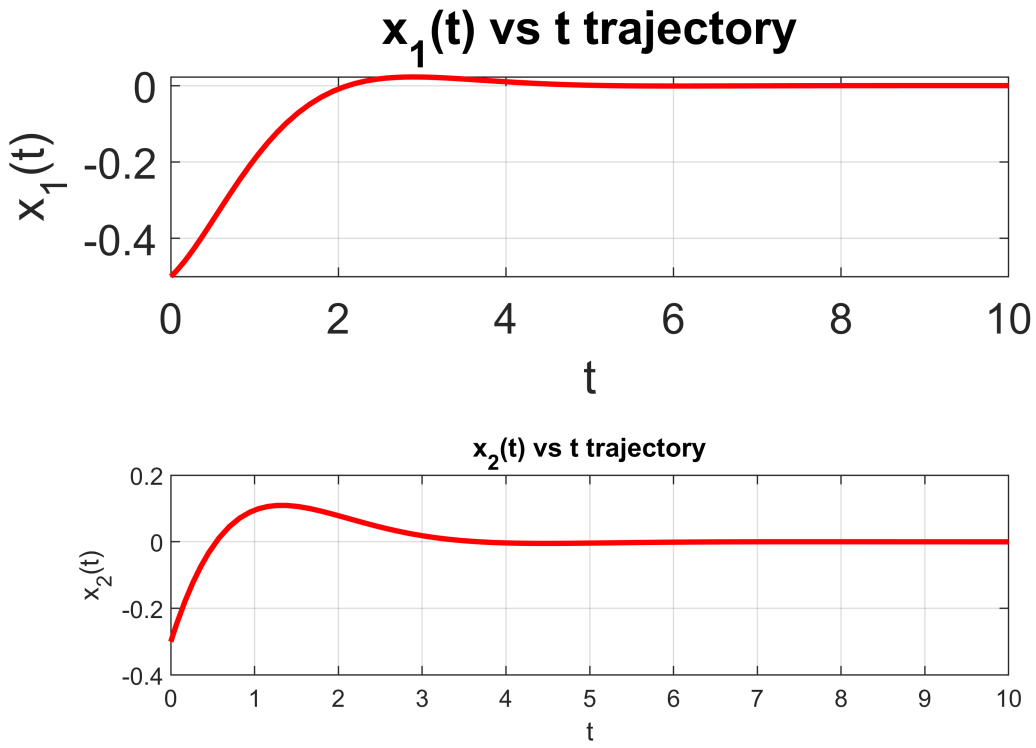

```
%% Q8

% (a)

range = -1:0.08:1;
A = [-1,1;-1,-1];

eig1 = eig(A);
eig1
```

```
eig1 = 2×1 complex
  -1.0000 + 1.0000i
  -1.0000 - 1.0000i
```

```


[X1,X2] = meshgrid(range,range);

X1dot = A(1,1)*X1 + A(1,2)*X2;
X2dot = A(2,1)*X1 + A(2,2)*X2;
[t,x] = ode45(@(t,x) A*x,[0,10],[-0.5,-0.3]);

figure
quiver(X1,X2,X1dot,X2dot,'g')
hold on
plot(x(:,1),x(:,2),'r');
plot(x(1,1),x(1,2),'o',x(end,1),x(end,2),'s');
hold off
```



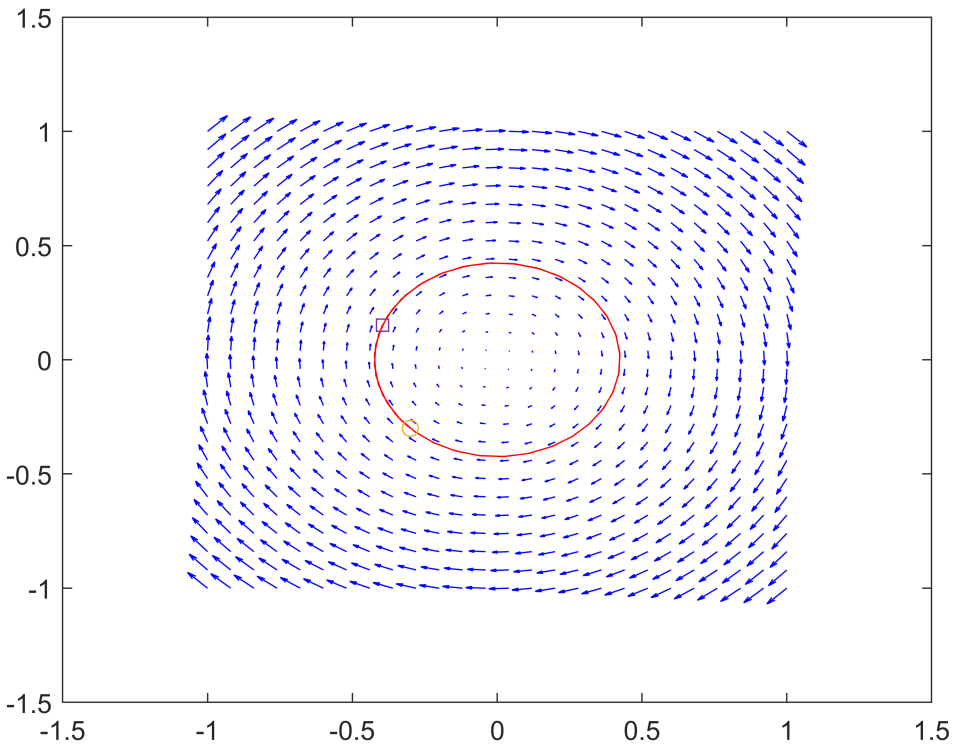

```
figure
%x1(t) vs t plot
subplot(2,1,1)
plot(t,x(:,1),"LineWidth",2,"Color","r");
grid on
title("x_1(t) vs t trajectory");
ylabel("x_1(t)");
xlabel("t");
set(gca,'Fontsize',16);
%x2(t) vs t plot
subplot(2,1,2)
plot(t,x(:,2),"LineWidth",2,"Color","r");
grid on
title("x_2(t) vs t trajectory");
ylabel("x_2(t)");
xlabel("t");
```



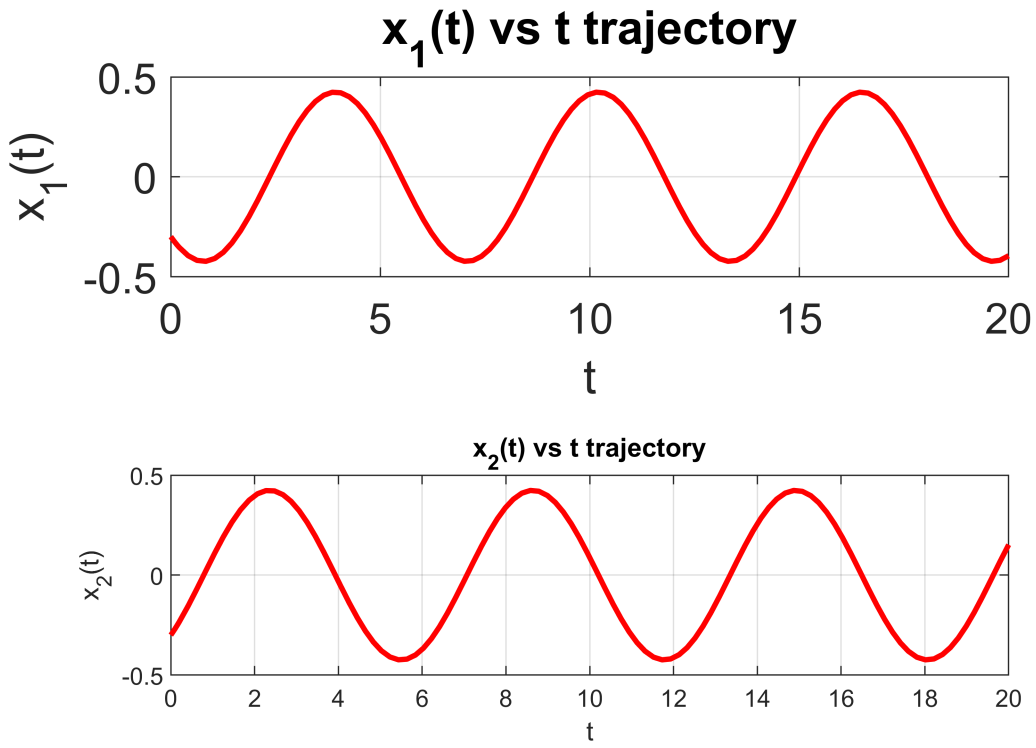

```
% (b)
range = -1:0.08:1;
A = [0,1;-1,0];
eig2 = eig(A);
eig2
```

```
eig2 = 2×1 complex
   0.0000 + 1.0000i
   0.0000 - 1.0000i
```

```
[X1,X2] = meshgrid(range,range);

X1dot = A(1,1)*X1 + A(1,2)*X2;
X2dot = A(2,1)*X1 + A(2,2)*X2;
[t,x] = ode45(@(t,x) A*x,[0,20],[-0.3,-0.3]);

figure
quiver(X1,X2,X1dot,X2dot,'b')
hold on
plot(x(:,1),x(:,2),'r');
plot(x(1,1),x(1,2),'o',x(end,1),x(end,2),'s');
hold off
```




```
figure
%x1(t) vs t plot
subplot(2,1,1)
plot(t,x(:,1),"LineWidth",2,"Color","r");
grid on
title("x_1(t) vs t trajectory");
ylabel("x_1(t)");
xlabel("t");
set(gca,'Fontsize',16);
%x2(t) vs t plot
subplot(2,1,2)
plot(t,x(:,2),"LineWidth",2,"Color","r");
grid on
title("x_2(t) vs t trajectory");
ylabel("x_2(t)");
xlabel("t");
```

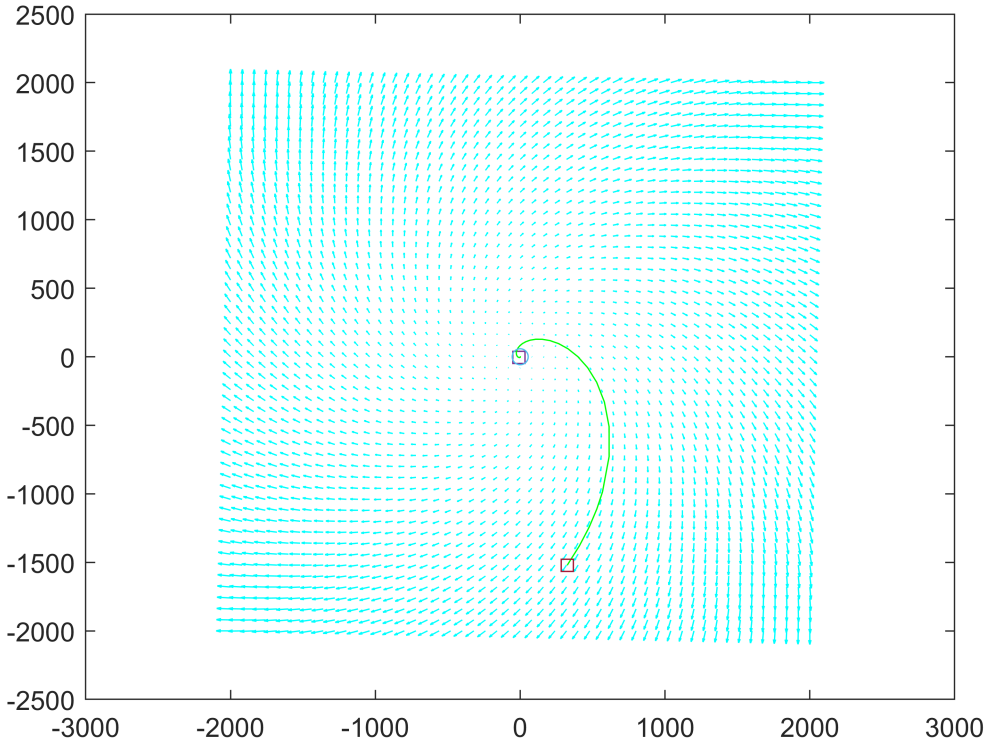



```
% (c)
range = -2000:80:2000;
A = [1,1;-1,1];
eig3 = eig(A);
eig3
```

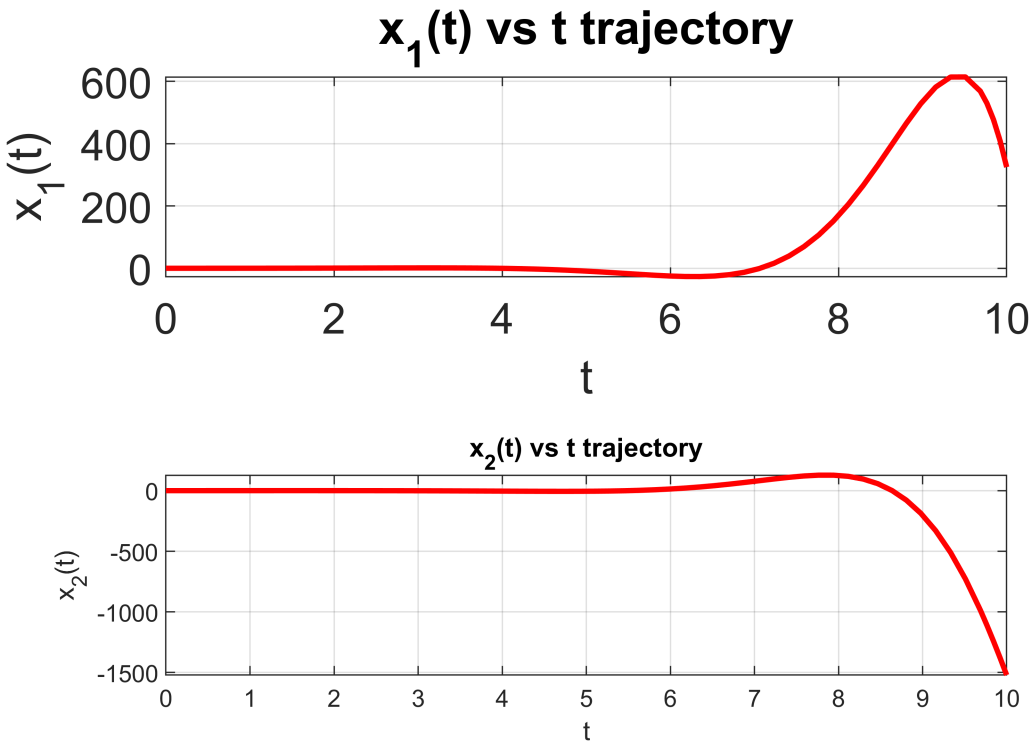
```
eig3 = 2×1 complex
   1.0000 + 1.0000i
   1.0000 - 1.0000i
```

```
[X1,X2] = meshgrid(range,range);

X1dot = A(1,1)*X1 + A(1,2)*X2;
X2dot = A(2,1)*X1 + A(2,2)*X2;

figure
quiver(X1,X2,X1dot,X2dot,'c')

hold on
[t,x] = ode45(@(t,x) A*x,[0,5],[-0.05,0.05]);
plot(x(:,1),x(:,2),'r');
plot(x(1,1),x(1,2),'o',x(end,1),x(end,2),'s');
[t,x] = ode45(@(t,x) A*x,[0,10],[-0.05,0.05]);
plot(x(:,1),x(:,2),'g');
plot(x(1,1),x(1,2),'o',x(end,1),x(end,2),'s');
```

```
hold off
```




```
figure
%x1(t) vs t plot
subplot(2,1,1)
plot(t,x(:,1),"LineWidth",2,"Color","r");
grid on
title("x_1(t) vs t trajectory");
ylabel("x_1(t)");
xlabel("t");
set(gca,'Fontsize',16);
%x2(t) vs t plot
subplot(2,1,2)
plot(t,x(:,2),"LineWidth",2,"Color","r");
grid on
title("x_2(t) vs t trajectory");
ylabel("x_2(t)");
xlabel("t");
```

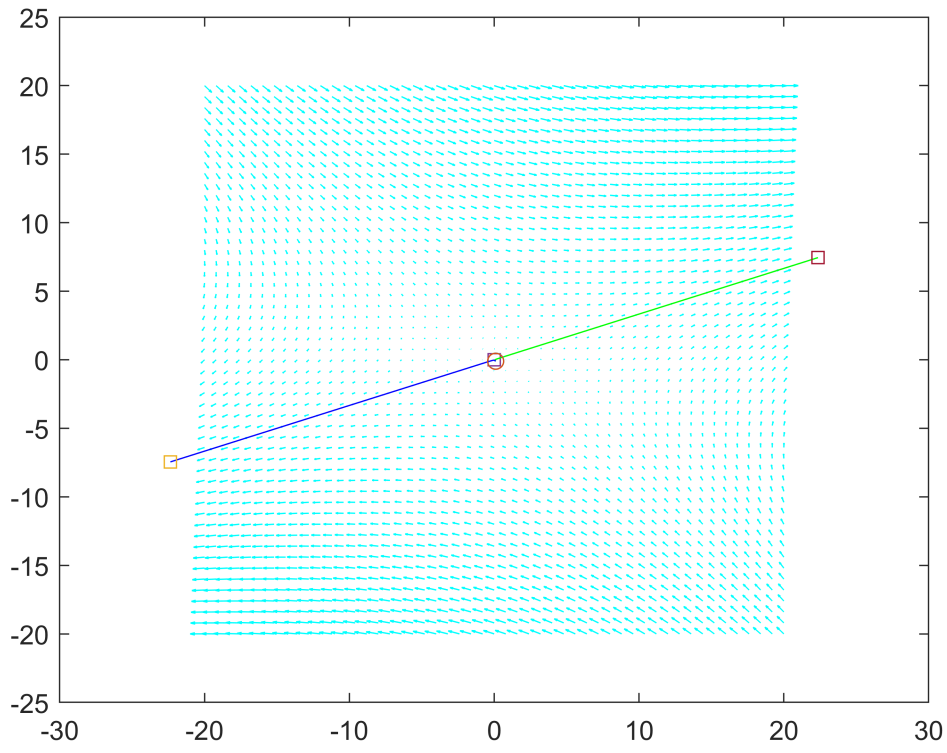



```
% (d)
range = -20:0.8:20;
A = [1,3;1,-1];
eig4 = eig(A);
eig4
```

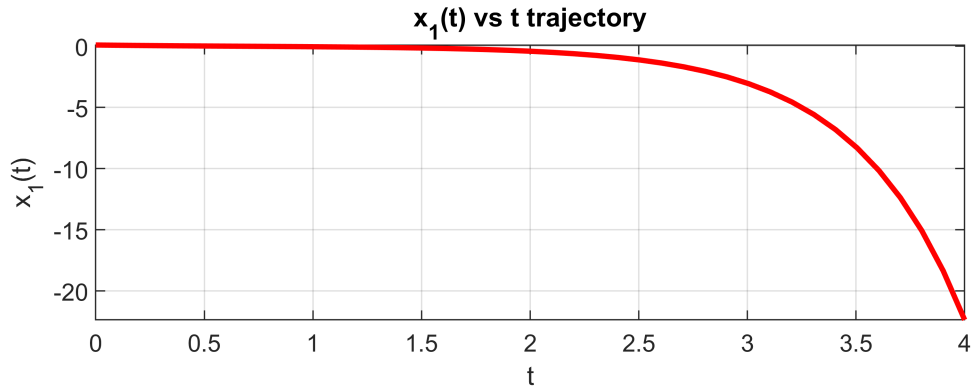
```
eig4 = 2×1
     2
    -2
```

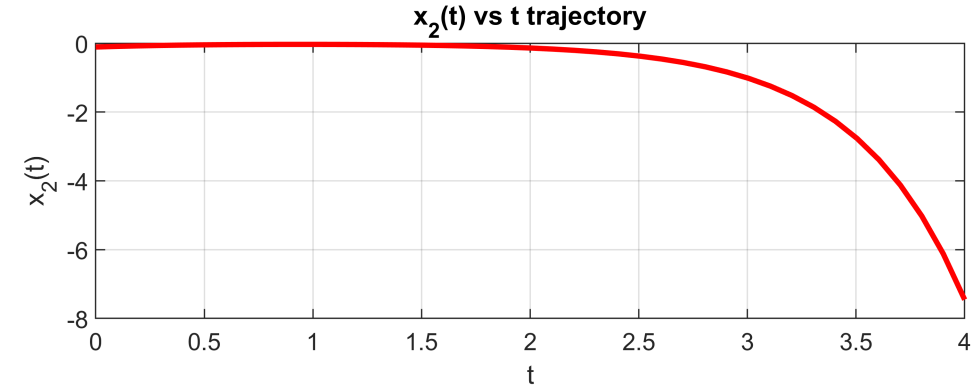
```
[X1,X2] = meshgrid(range,range);

X1dot = A(1,1)*X1 + A(1,2)*X2;
X2dot = A(2,1)*X1 + A(2,2)*X2;

figure
quiver(X1,X2,X1dot,X2dot,'c')

hold on
[t,x] = ode45(@(t,x) A*x,[0,10],[0.1,-0.1]);
plot(x(:,1),x(:,2),'r');
plot(x(1,1),x(1,2),'o',x(end,1),x(end,2),'s');
[t,x] = ode45(@(t,x) A*x,[0,4],[0.11,-0.1]);
plot(x(:,1),x(:,2),'g');
plot(x(1,1),x(1,2),'o',x(end,1),x(end,2),'s');
[t,x] = ode45(@(t,x) A*x,[0,4],[0.1,-0.11]);
```

```
plot(x(:,1),x(:,2),'b');
plot(x(1,1),x(1,2),'o',x(end,1),x(end,2),'s');
hold off
```




```
figure
%x1(t) vs t plot
subplot(2,1,1)
plot(t,x(:,1),"LineWidth",2,"Color","r");
grid on
title("x_1(t) vs t trajectory");
ylabel("x_1(t)");
xlabel("t");
%x2(t) vs t plot
subplot(2,1,2)
plot(t,x(:,2),"LineWidth",2,"Color","r");
grid on
title("x_2(t) vs t trajectory");
ylabel("x_2(t)");
xlabel("t");
```






```
%Real eigenvalues provide direction in space andcomplex generated the
%circular motion
%in first equation, complex eigen with negative part generates damping spiral
%in second equation, complex eigen with 0 real part generates periodic
%motion
%in third equation, complex eigen with positive part generates amplifying spiral
%in fourth equation, negative real eigen generates towards origin vector
```