ME 1020 Engineering Programming with MATLAB

Chapter 5 Homework Solutions: 5.4, 5.7, 5.10, 5.14, 5.17, 5.20, 5.27, 5.31, 5.34

Problem 5.4:

4. To compute the forces in structures, sometimes we must solve equations (called transcendental equations because they have no analytical solution) similar to the following. Plot the function between $0 \leq x \leq 5$ to roughly locate the zeros of this equation:

$$x \tan x = 9$$

Then use the **fzero** function to accurately find the first three roots. Finally, use the **fplot** function to plot the function in the vicinity of each zero.

Find the first three zeros by plotting the function.

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problem5_4.m* × funprob5_4.m ×

```
function fncx = funprob5_4(x)
fncx = x.*tan(x) - 9;
end
```

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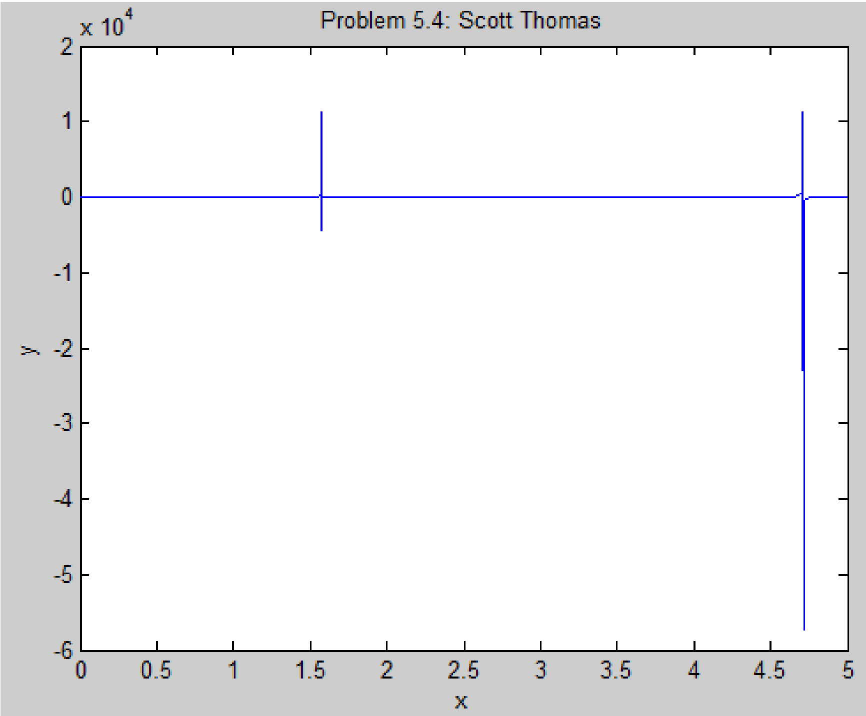
problem5_4.m × funprob5_4.m ×

```
% Problem 5.4: Scott Thomas
clear
clc
disp('Problem 5.4: Scott Thomas')

N = 10000;
x = linspace(0,5,N);
y = funprob5_4(x);
plot(x,y),xlabel('x'),ylabel('y')
title('Problem 5.4: Scott Thomas')
```



Locate the zeros by changing the limits on the y axis.

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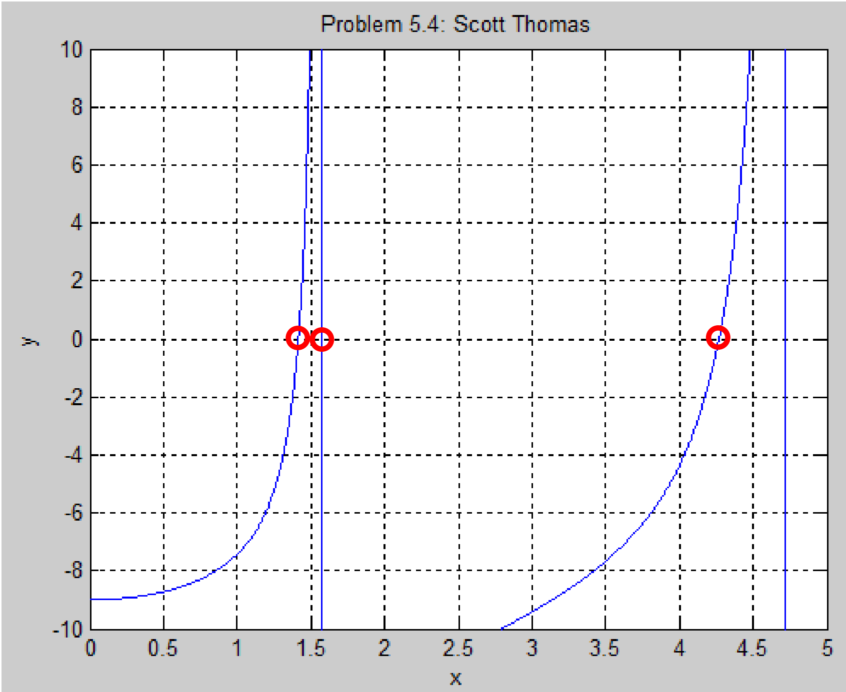
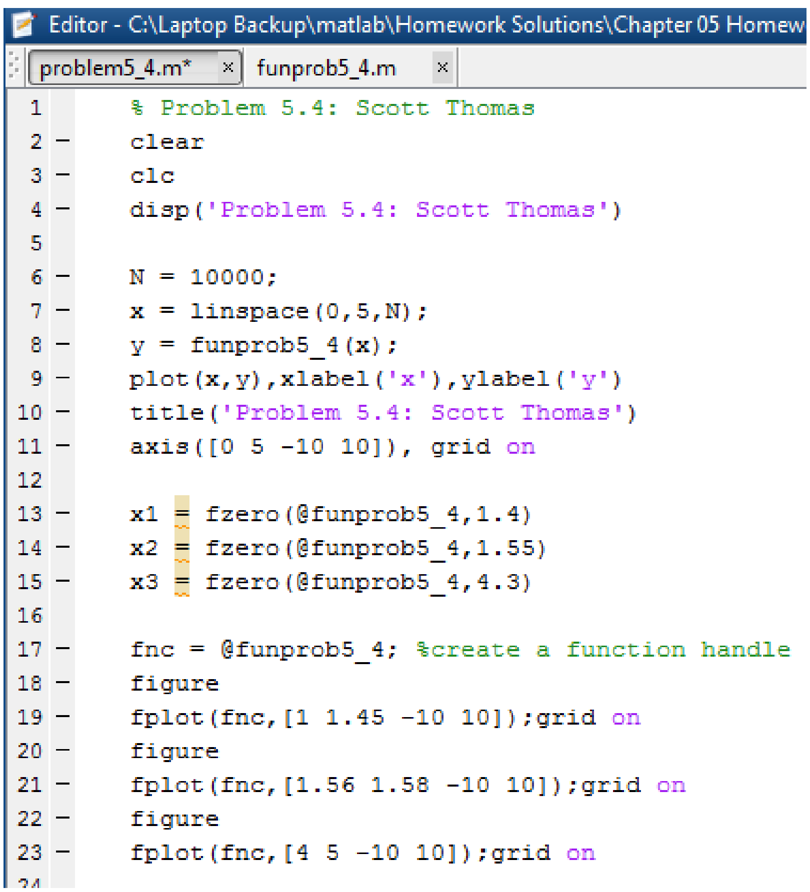
problem5_4.m | funprob5_4.m

```
% Problem 5.4: Scott Thomas
clear
clc
disp('Problem 5.4: Scott Thomas')

N = 10000;
x = linspace(0,5,N);
y = funprob5_4(x);
plot(x,y),xlabel('x'),ylabel('y')
axis([0 5 -10 10]), grid on
title('Problem 5.4: Scott Thomas')
```



The first three zeros are at $x_1 = 1.4$, $x_2 = 1.55$, $x_3 = 4.3$.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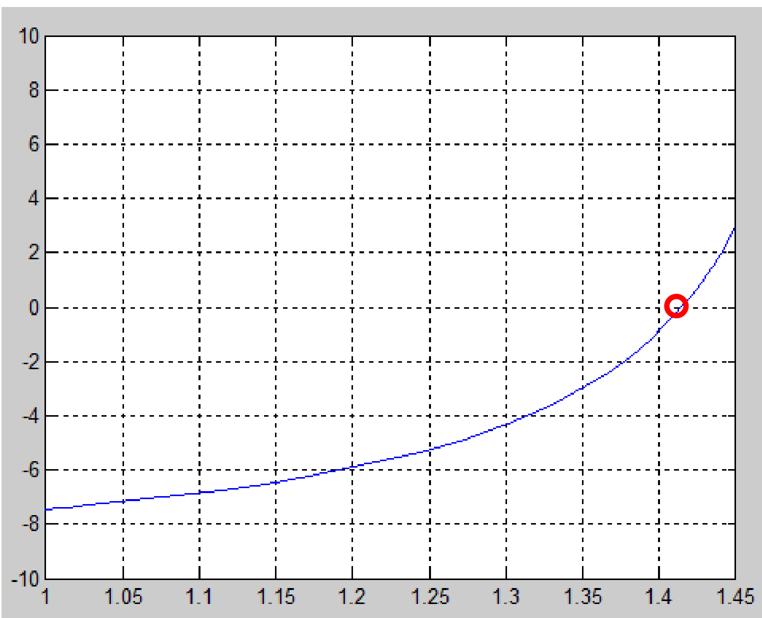
problem5_4.m* | funprob5_4.m

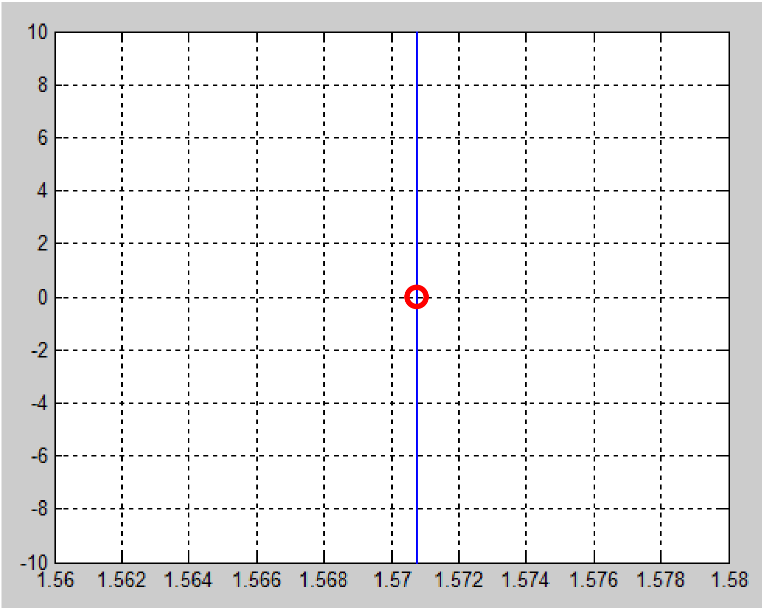
```
% Problem 5.4: Scott Thomas
clear
clc
disp('Problem 5.4: Scott Thomas')

N = 10000;
x = linspace(0,5,N);
y = funprob5_4(x);
plot(x,y),xlabel('x'),ylabel('y')
title('Problem 5.4: Scott Thomas')
axis([0 5 -10 10]), grid on

x1 = fzero(@funprob5_4,1.4)
x2 = fzero(@funprob5_4,1.55)
x3 = fzero(@funprob5_4,4.3)

fnc = @funprob5_4; %create a function handle
figure
fplot(fnc,[1 1.45 -10 10]);grid on
figure
fplot(fnc,[1.56 1.58 -10 10]);grid on
figure
fplot(fnc,[4 5 -10 10]);grid on
```

```
Problem 5.4: Scott Thomas

x1 =

    1.4149


x2 =

    1.5708


x3 =

    4.2694
```

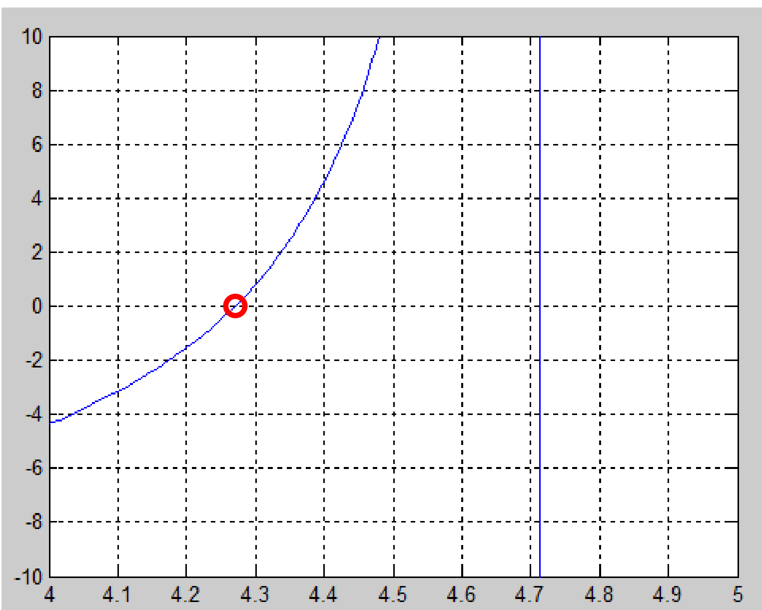
First zero:



Second zero:



Third zero:



Problem 5.7:

7. It is known that the following Leibniz series converges to the value $\pi/4$ as $n \to \infty$.

$$S(n) = \sum_{k=0}^{n} (-1)^k \frac{1}{2k+1}$$

Plot the difference between $\pi/4$ and the sum $S(n)$ versus n for $0 \leq n \leq 200$.

Problem setup: Work the summation out by hand.

$$S(0) = (-1)^0 \left(\frac{1}{2 \times 0 + 1}\right) = 1$$

$$S(1) = S(0) + (-1)^1 \left(\frac{1}{2 \times 1 + 1}\right) = 1 - \frac{1}{3} = \frac{2}{3}$$

$$S(2) = S(1) + (-1)^2 \left(\frac{1}{2 \times 2 + 1}\right) = 1 - \frac{1}{3} + \frac{1}{5} = 0.8\overline{6}$$

$$S(3) = S(2) + (-1)^3 \left(\frac{1}{2 \times 3 + 1}\right) = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} = 0.7238$$

$$S(4) = S(3) + (-1)^4 \left(\frac{1}{2 \times 4 + 1}\right) = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} = 0.8349$$

Check the program for the first five calculations:

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problem5_7.m

```
% Problem 5.7
clear
clc
disp('Problem 5.7: Scott Thomas')

sum = 0;
for k = 1:5
sum = sum + (-1)^(k-1)*(1/(2*(k-1) + 1))
end
```

Command Window

```
Problem 5.7: Scott Thomas

sum =

     1


sum =

    0.6667


sum =

    0.8667


sum =

    0.7238


sum =

    0.8349
```

Create vectors for plotting the function. Load the vectors inside the **for** loop. Use the **Debugging Tool** to check the logic flow.

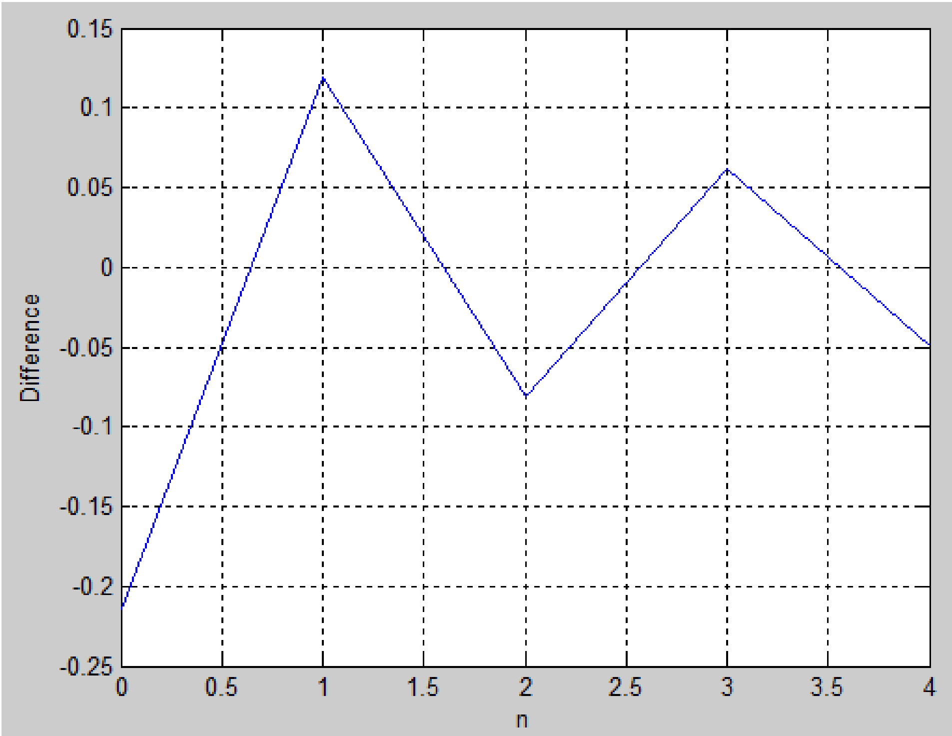
Editor - C:\Laptop Backup\matlab\Homework Solutions\Chapter 05 Homework\problem5_7.m

problem5_7.m*

```
% Problem 5.7
clear
clc
disp('Problem 5.7: Scott Thomas')

sum = 0; % Initialize the sum variable to zero
for k = 1:5
sum = sum + (-1)^(k-1)*(1/(2*(k-1) + 1));
x(k) = k - 1;
y(k) = sum;
end
x
y
diff = pi/4 - y
plot(x,diff), xlabel('n'), ylabel('Difference'),grid on
```

Command Window

```
Problem 5.7: Scott Thomas

x =

     0     1     2     3     4


y =

    1.0000    0.6667    0.8667    0.7238    0.8349


diff =

   -0.2146    0.1187   -0.0813    0.0616   -0.0495
```

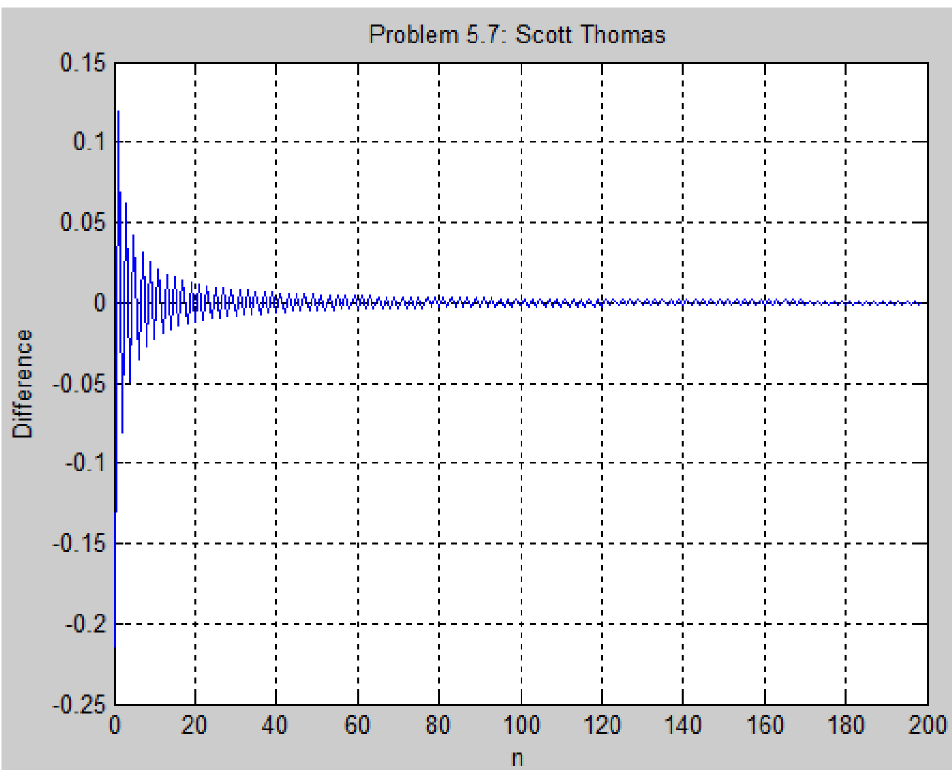

0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
Difference
0
0.5
1
1.5
2
2.5
3
3.5
4
n

Now that the program has been checked for a small number of calculations, suppress output from all of the vectors and change the number of elements to 200.

Editor - C:\Laptop Backup\matlab\Homework Solutions\Chapter 05 Homework\problem5_7.m

problem5_7.m*

```
% Problem 5.7
clear
clc
disp('Problem 5.7: Scott Thomas')

sum = 0; % Initialize the sum variable to zero
for k = 1:200
sum = sum + (-1)^(k-1)*(1/(2*(k-1) + 1));
x(k) = k - 1;
y(k) = sum;
end
x;
y;
diff = pi/4 - y;
plot(x,diff), xlabel('n'), ylabel('Difference'),grid on
title('Problem 5.7: Scott Thomas')
```



Problem 5.10:

10. Many applications use the following "small angle" approximation for the sine to obtain a simpler model that is easy to understand and analyze. This approximate states that $\sin x \approx x$, where x must be in radians. Investigate the accuracy of this approximation by creating three plots. For the first, plot $\sin x$ versus x for $0 \leq x \leq 1$. For the second plot the approximation error $\sin x - x$ versus x for $0 \leq x \leq 1$. For the third plot the relative error $[\sin(x) - x]/\sin(x)$ versus x for $0 \leq x \leq 1$. How small must x be for the approximation to be accurate within 5 percent? Use the relative error for this calculation.

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problem5_10.m

```
% Problem 5.10
clear
clc
disp('Problem 5.10: Scott Thomas')

x = 0:0.01:1;
y1 = sin(x);
y2 = sin(x) - x;
y3 = (sin(x) - x)./sin(x);

subplot(3,1,1)
plot(x,y1,x,x), ylabel('sin(x) and x'),grid on
title('Problem 5.10: Scott Thomas')
legend('sin(x)','x','Location','Best')
subplot(3,1,2)
plot(x,y2), ylabel('sin(x) - x'),grid on
subplot(3,1,3)
plot(x,y3), xlabel('x (Radians)'), ylabel('(sin(x) - x)/sin(x)'),grid on

dx1 = 0.0001;
x1 = 0;
y4 = 0;
while y4 < 0.05
    x1 = x1 + dx1;
    y4 = abs((sin(x1) - x1)/sin(x1));
 end
x1
y4
```

Command Window

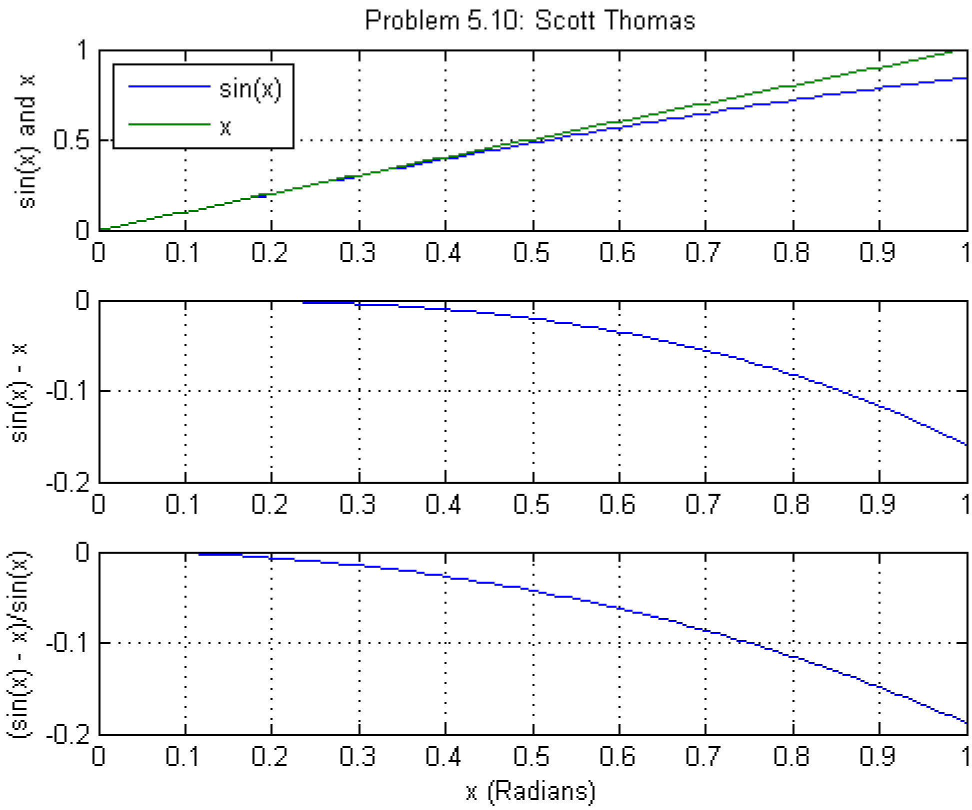
```
Problem 5.10: Scott Thomas

x1 =

    0.5385


y4 =

    0.0500
```


Problem 5.10: Scott Thomas
sin(x) and x
sin(x)
x
sin(x) - x
(sin(x) - x)/sin(x)
x (Radians)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
-0.1
-0.2

Problem 5.14:

14. The function $y(t) = 1 - e^{-bt}$, where t is time and $b > 0$, describes many processes, such as the height of liquid in a tank as it is being filled and the temperature of an object being heated. Investigate the effect of the parameter b on $y(t)$. To do this, plot y versus t for $0 \le t \le 10$ seconds and $b = 0.01, 0.05, 0.1, 0.5, 1.0, 5.0$ and 10.0 on the same plot. How long will it take for $y(t)$ to reach 98 percent of its steady-state value when $b = 0.5$?

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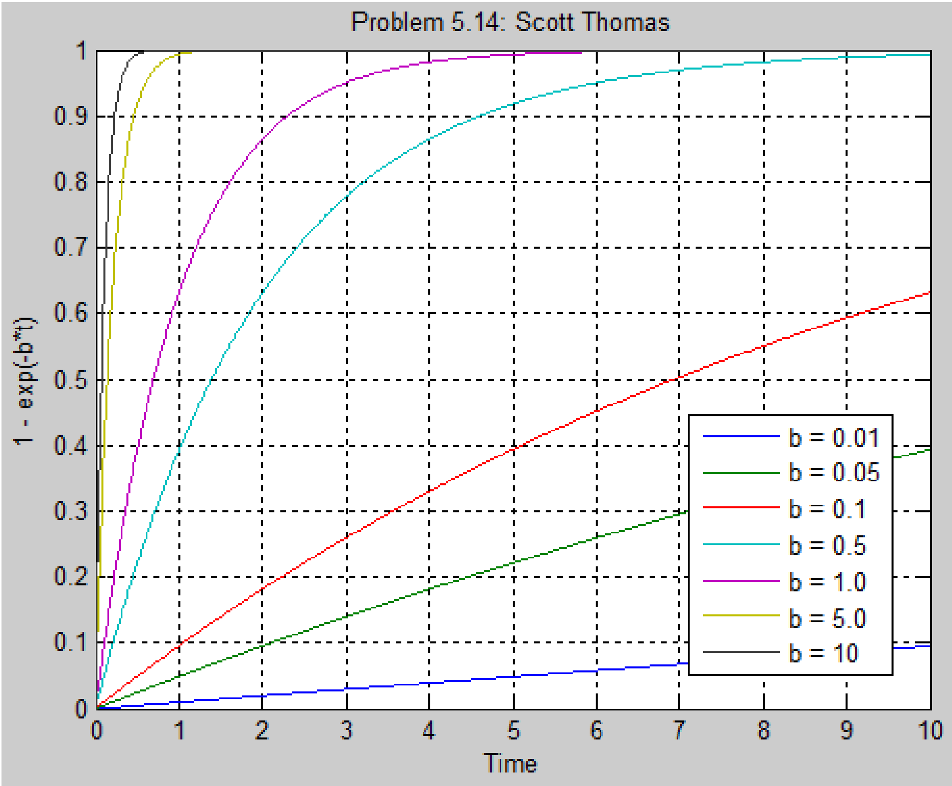
problem5_14.m

```
% Problem 5.14
clear
clc
disp('Problem 5.14: Scott Thomas')

N = 1000;
t = linspace(0,10,N);
b = [0.01 0.05 0.1 0.5 1.0 5.0 10.0];
Levels = length(b);

for L = 1:Levels
    for k = 1:N
    y(L,k) = 1 - exp(-b(L)*t(k));
    end
end

plot(t, y(1,:), t, y(2,:), t, y(3,:), t, y(4,:), t, y(5,:), t, y(6,:), t, y(7,:))
xlabel('Time'),grid on, ylabel('1 - exp(-b*t)')
title('Problem 5.14: Scott Thomas')
legend('b = 0.01','b = 0.05','b = 0.1','b = 0.5','b = 1.0','b = 5.0','b = 10','Location','Best')

t98 = 0;
b98 = 0.5;
y98 = 1 - exp(-b98*t98);
dt = 0.00001;
while y98 < 0.98
t98 = t98 + dt;
y98 = 1 - exp(-b98*t98);
end

t98
```

Command Window

```
Problem 5.14: Scott Thomas

t98 =

    7.8240
```



Problem 5.14: Scott Thomas
1 - exp(-b*t)
Time
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1
2
3
4
5
6
7
8
9
10
b = 0.01
b = 0.05
b = 0.1
b = 0.5
b = 1.0
b = 5.0
b = 10

Problem 5.17:

17.* The height $h(t)$ and horizontal distance $x(t)$ traveled by a ball thrown at an angle A with a speed v are given by

$$h(t) = vt \sin A - \frac{1}{2}gt^2$$

$$x(t) = vt \cos A$$

At Earth's surface the acceleration due to gravity is $g = 9.81 \text{ m/s}^2$.

a. Suppose the ball is thrown with a velocity $v = 10$ m/s at an angle of 35°. Use MATLAB to compute how high the ball will go, how far it will go, and how long it will take to hit the ground.

b. Use the values of v and A given in part a to plot the ball's *trajectory;* that is, plot h versus x for positive values of h.

c. Plot the trajectories for $v = 10$ m/s corresponding to five values of the angle A: 20°, 30°, 45°, 60°, and 70°.

d. Plot the trajectories for $A = 45°$ corresponding to five values of the initial velocity v: 10, 12, 14, 16, and 18 m/s.

Parts a and b:

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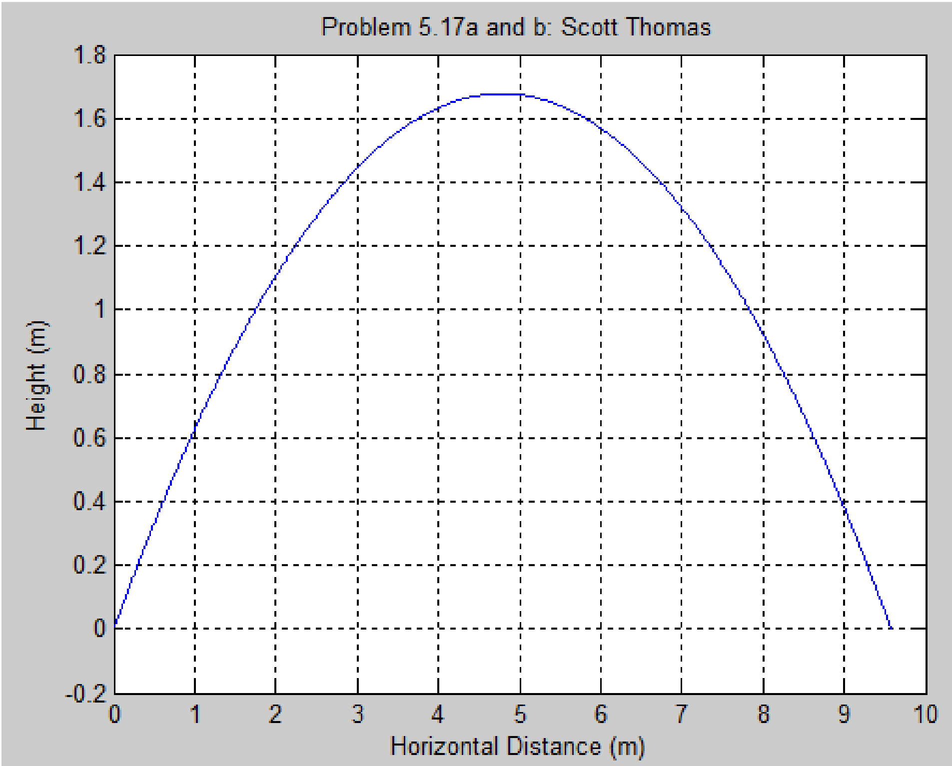
problem5_17ab.m × problem5_17a.m ×

```
% Problem 5.17
clear
clc
disp('Problem 5.17: Scott Thomas')
disp('Parts a and b: ')
g = 9.81;% m/s
v = 10;% m/s
ADeg = 35;% degrees
ARad = ADeg*pi/180;% radians

dt = 0.001;% seconds
t = 0;
h = 0;
k = 1;
while h >= 0
t = t + dt;
h = v*t*sin(ARad) - 0.5*g*t.^2;% m
x = v*t*cos(ARad);% m
tplot(k) = t;
hplot(k) = h;
xplot(k) = x;
k = k + 1;
end

maximum_height = max(hplot)
maximum_distance = max(xplot)
maximum_time = max(tplot)

figure
plot(xplot, hplot), xlabel('Horizontal Distance (m)')
grid on, ylabel('Height (m)')
title('Problem 5.17a and b: Scott Thomas')
```

Command Window

```
Problem 5.17: Scott Thomas
Parts a and b:

maximum_height =

    1.6768


maximum_distance =

    9.5841


maximum_time =

    1.1700
```


Problem 5.17a and b: Scott Thomas
Height (m)
Horizontal Distance (m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
1
2
3
4
5
6
7
8
9
10

Part c:

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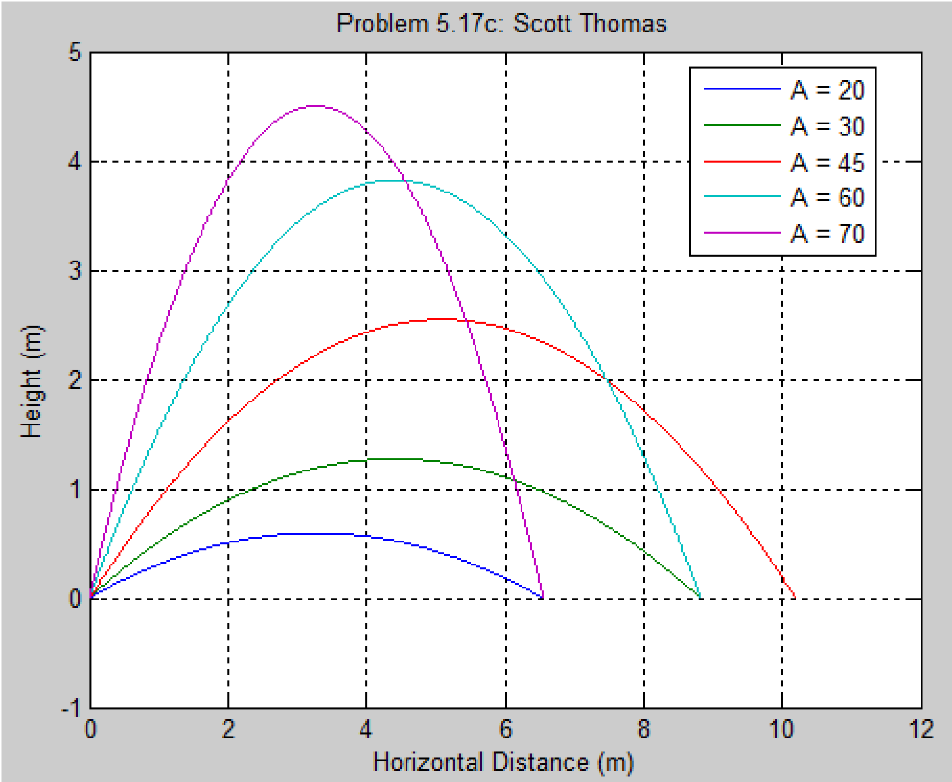
problem5_17c.m*

```
% Problem 5.17c
clear,clc
disp('Problem 5.17c: Scott Thomas')
g = 9.81;% m/s
v = 10;% m/s
ADeg = [20, 30, 45, 60, 70];% degrees
ARad = ADeg*pi/180;% radians
dt = 0.001;% seconds
for m = 1:5
    t = 0;
    h = 0;
    k = 1;
     while h >= 0
         h = v*t*sin(ARad(m)) - 0.5*g*t.^2 ;% m
         x = v*t*cos(ARad(m));% m
         hplot(m,k) = h;
         xplot(m,k) = x;
         t = t + dt;
         k = k + 1;
     end
end
% Find the nonzero values of x and h
[~,~,xplot1] = find(xplot(1,:));
[~,~,hplot1] = find(hplot(1,:));
[~,~,xplot2] = find(xplot(2,:));
[~,~,hplot2] = find(hplot(2,:));
[~,~,xplot3] = find(xplot(3,:));
[~,~,hplot3] = find(hplot(3,:));
[~,~,xplot4] = find(xplot(4,:));
[~,~,hplot4] = find(hplot(4,:));
[~,~,xplot5] = find(xplot(5,:));
[~,~,hplot5] = find(hplot(5,:));
plot(xplot1, hplot1, xplot2, hplot2, xplot3, hplot3,...
    xplot4, hplot4,xplot5, hplot5)
xlabel('Horizontal Distance (m)')
grid on, ylabel('Height (m)')
title('Problem 5.17c: Scott Thomas')
legend('A = 20', 'A = 30', 'A = 45', 'A = 60', 'A = 70',...
    'Location','Best')
```


Problem 5.17c: Scott Thomas
A = 20
A = 30
A = 45
A = 60
A = 70
Height (m)
Horizontal Distance (m)
5
4
3
2
1
0
-1
0
2
4
6
8
10
12

Part d:

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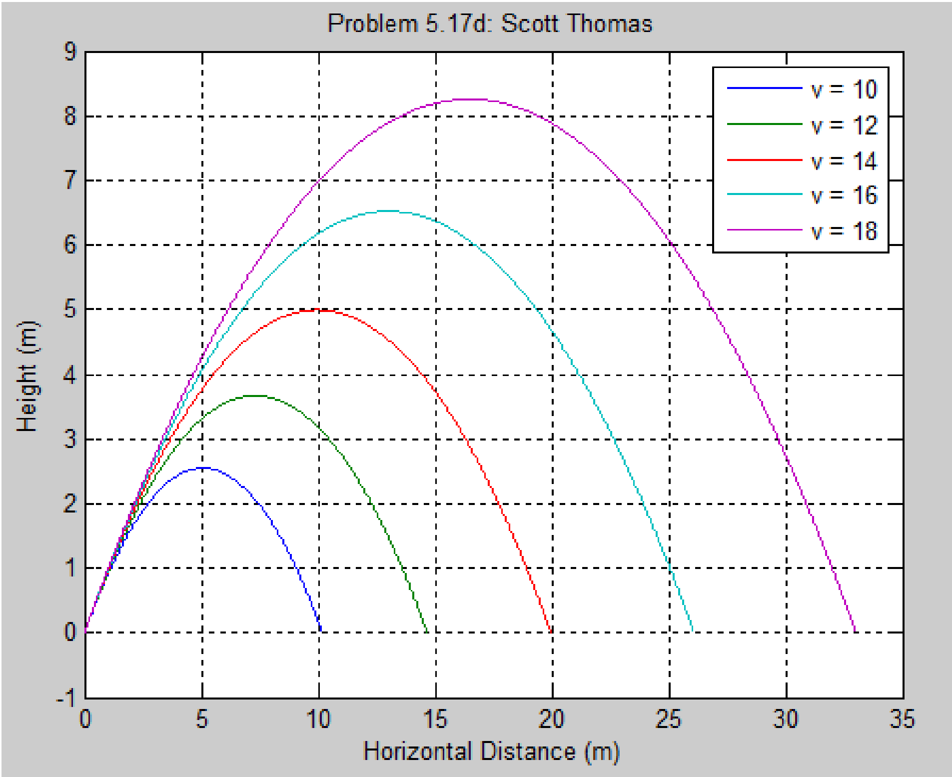
problem5_17d.m

```matlab
% Problem 5.17d
clear
clc
disp('Problem 5.17d: Scott Thomas')
g = 9.81;% m/s
v = 10:2:18;% m/s
ADeg = 45;% degrees
ARad = ADeg*pi/180;% radians
dt = 0.001;% seconds
for m = 1:5
    t = 0;
    h = 0;
    k = 1;
     while h >= 0
        h = v(m)*t*sin(ARad) - 0.5*g*t.^2 ;% m
        x = v(m)*t*cos(ARad);% m
        hplot(m,k) = h;
        xplot(m,k) = x;
        t = t + dt;
        k = k + 1;
     end
end
% Find the nonzero values of x and h
[~,~,xplot1] = find(xplot(1,:));
[~,~,hplot1] = find(hplot(1,:));
[~,~,xplot2] = find(xplot(2,:));
[~,~,hplot2] = find(hplot(2,:));
[~,~,xplot3] = find(xplot(3,:));
[~,~,hplot3] = find(hplot(3,:));
[~,~,xplot4] = find(xplot(4,:));
[~,~,hplot4] = find(hplot(4,:));
[~,~,xplot5] = find(xplot(5,:));
[~,~,hplot5] = find(hplot(5,:));
plot(xplot1, hplot1, xplot2, hplot2, xplot3, hplot3,...
    xplot4, hplot4,xplot5, hplot5)
xlabel('Horizontal Distance (m)')
grid on, ylabel('Height (m)')
title('Problem 5.17d: Scott Thomas')
legend('v = 10', 'v = 12', 'v = 14', 'v = 16', 'v = 18',...
    'Location','Best')
```


Problem 5.17d: Scott Thomas
Height (m)
Horizontal Distance (m)
v = 10
v = 12
v = 14
v = 16
v = 18
9
8
7
6
5
4
3
2
1
0
-1
0
5
10
15
20
25
30
35

Problem 5.20:

When a constant voltage was applied to a certain motor initially at rest, its rotational speed $s(t)$ versus time was measured. The data appear in the following table:

Time (sec)	1	2	3	4	5	6	7	8	10
Speed (rpm)	1210	1866	2301	2564	2724	2881	2879	2915	3010

Plot the rotational speed versus time using open red circles. Then plot the following function on the same graph:

$$s(t) = b(1 - e^{-ct}); \qquad b = 3010, \qquad c = 0.1{:}\,0.1{:}\,0.6$$

What value of c provides the best fit to the data?

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problem5_20.m

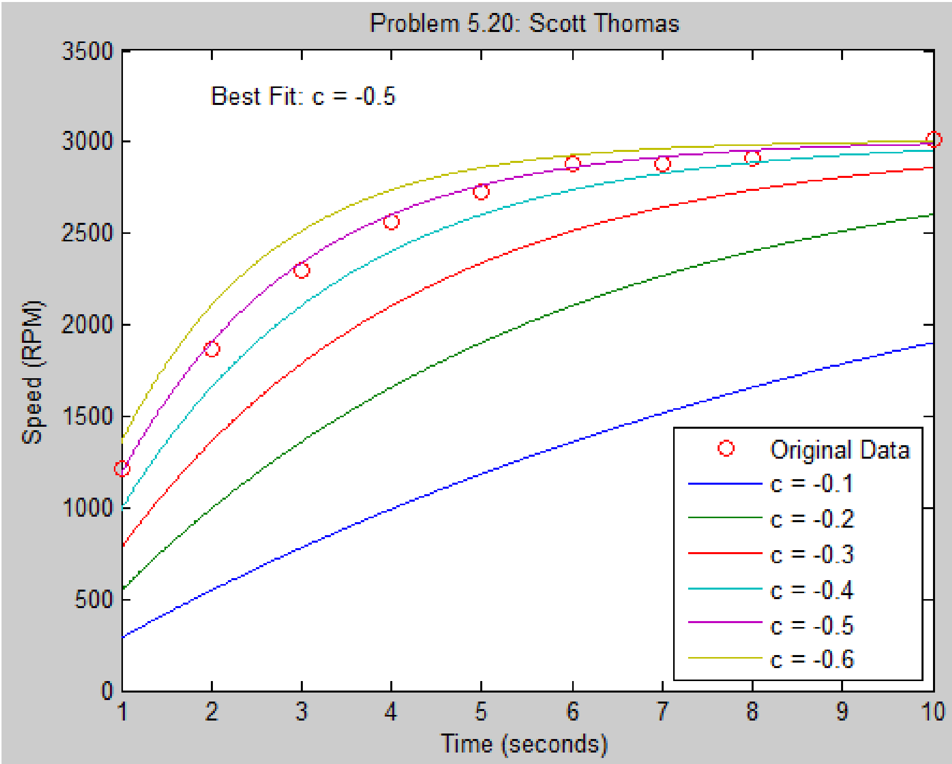
```
% Problem 5.20
clear
clc
disp('Problem 5.20: Scott Thomas')

t = [1 2 3 4 5 6 7 8 10];
s = [1210 1866 2301 2564 2724 2881 2879 2915 3010];

N = 1000;
tt = linspace(1,10,N);
b = 3010;
c = 0.1:0.1:0.6;

for k = 1:length(c)
    for m = 1:N
    ss(k,m) = b*(1 - exp(-c(k).*tt(m)));
    end
end

plot(t, s, 'ro', tt,ss(1,:), tt,ss(2,:), tt,ss(3,:), tt,ss(4,:),...
    tt,ss(5,:), tt,ss(6,:))
xlabel('Time (seconds)'), xlabel('Time (seconds)'), ylabel('Speed (RPM)')
legend('Original Data','c = -0.1','c = -0.2','c = -0.3','c = -0.4',...
    'c = -0.5','c = -0.6','Location','SouthEast')
title('Problem 5.20: Scott Thomas')
text(2, 3250,'Best Fit: c = -0.5')
```


Problem 5.20: Scott Thomas
Best Fit: c = -0.5
Speed (RPM)
Time (seconds)
0
500
1000
1500
2000
2500
3000
3500
1
2
3
4
5
6
7
8
9
10
Original Data
c = -0.1
c = -0.2
c = -0.3
c = -0.4
c = -0.5
c = -0.6

Problem 5.27:

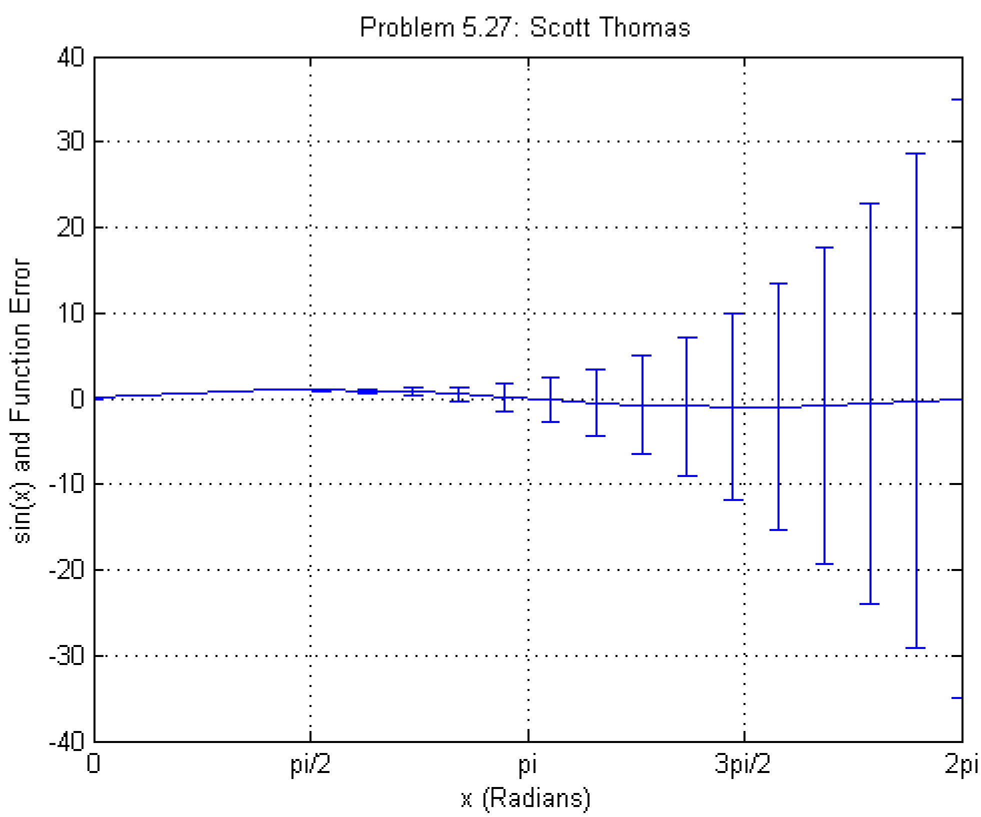
27. An approximation to the function sin x is $\sin x \approx x - x^3/6$. Plot the sin x function and 20 evenly spaced error bars representing the error in the approximation.

```
% Problem 5.27
clear
clc
disp('Problem 5.27: Scott Thomas')

N = 20;
x = linspace(0,2*pi,N);
y1 = sin(x);
y2 = x - x.^3/6;
error = abs(y1 - y2);% Relative Error

errorbar(x,y1, error)
ylabel('sin(x) and Function Error'), xlabel('x (Radians)')
title('Problem 5.27: Scott Thomas')
set(gca,'XTick',0:pi/2:2*pi)
set(gca,'XTickLabel',{'0','pi/2','pi','3pi/2','2pi'})
grid on
axis([0 2*pi -40 40])
```

```
Problem 5.27: Scott Thomas
```



Problem 5.31:

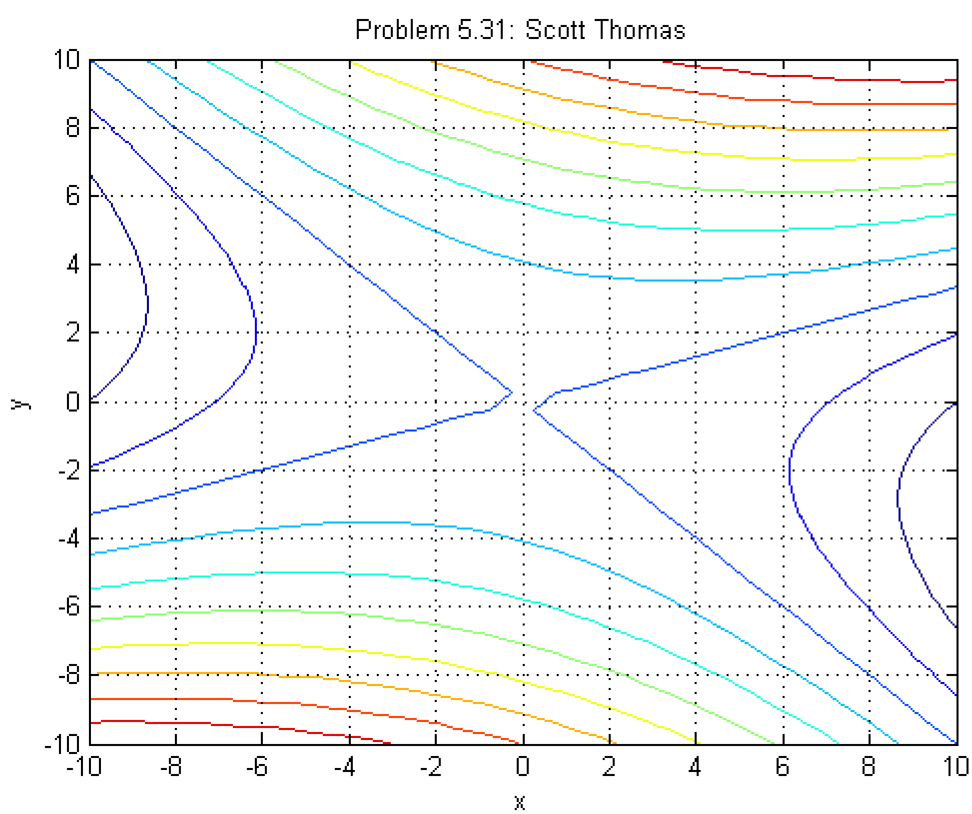
31. Obtain the surface and contour plots for the function $z = -x^2 + 2xy + 3y^2$. This surface has the shape of a saddle. At its saddlepoint at $x = y = 0$, the surface has zero slope, but this point does not correspond to either a minimum or a maximum. What type of contour lines corresponds to a saddlepoint?

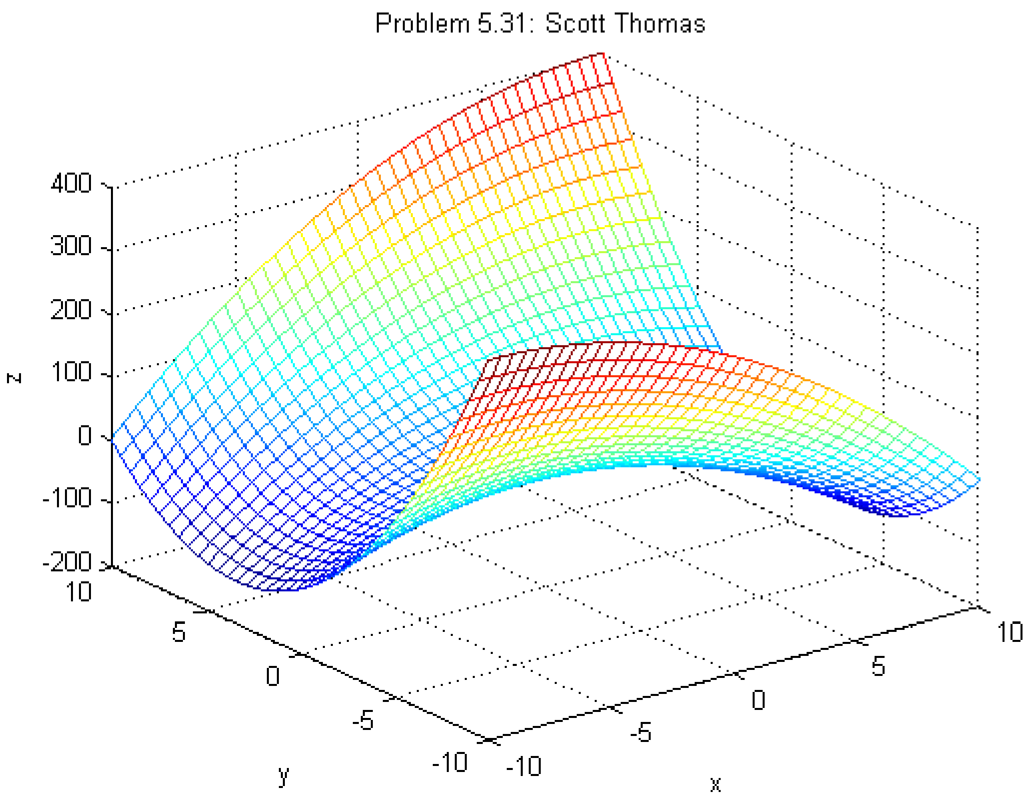
```
% Problem 5.31
clear
clc
disp('Problem 5.31: Scott Thomas')

N = 40;
x = linspace(-10,10,N);
y = linspace(-10,10,N);
[X,Y] = meshgrid(x,y);
Z = -X.^2 + 2*X.*Y + 3*Y.^2;

%mesh(X,Y,Z)
contour(X,Y,Z)
ylabel('y'), xlabel('x'), zlabel('z')
title('Problem 5.31: Scott Thomas')
grid on
```

```
Problem 5.31: Scott Thomas
```




Problem 5.31: Scott Thomas
400
300
200
100
0
-100
-200
z
10
5
0
-5
-10
y
-10
-5
0
5
10
x

Problem 5.34:

34. The following function describes oscillations in some mechanical structures and electric circuits.

$$z(t) = e^{-t/\tau} \sin(\omega t + \phi)$$

In this function t is time, and ω is the oscillation frequency in radians per unit time. The oscillations have a period of $2\pi/\omega$, and their amplitudes decay in time at a rate determined by τ, which is called the *time constant.* The smaller τ is, the faster the oscillations die out.

Suppose that $\phi = 0$, $\omega = 2$, and τ can have values in the range $0.5 \leq \tau \leq 10$ sec. Then the preceding equation becomes

$$z(t) = e^{-t/\tau} \sin(2t)$$

Obtain a surface plot and a contour plot of this function to help visualize the effect of τ for $0 \leq t \leq 15$ sec. Let the x variable be time t and the y variable be τ.

```
% Problem 5.34
clear
clc
disp('Problem 5.34: Scott Thomas')

N = 60;
t = linspace(0,15,N);
tau = linspace(0.5,10,N);
[X,Y] = meshgrid(t,tau);
z = exp(-(X./Y)).*sin(2*X);
%mesh(X,Y,z)
contour(X,Y,z)
ylabel('\tau (seconds)'), xlabel('t (seconds)'), zlabel('z')
title('Problem 5.34: Scott Thomas')
grid on
```

Problem 5.34: Scott Thomas