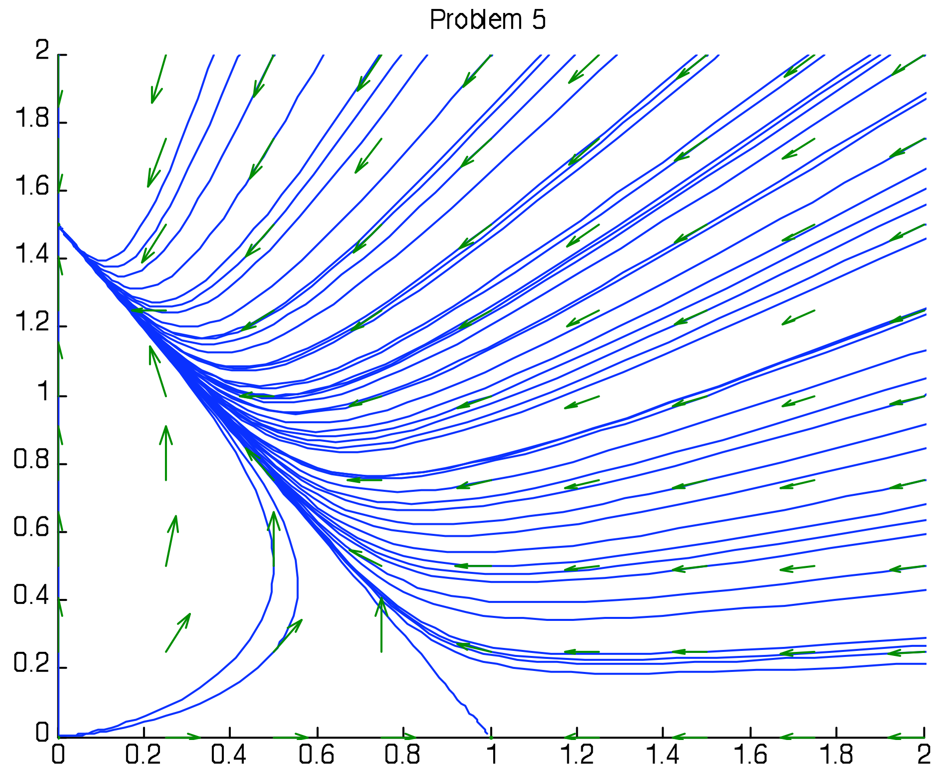
```
%Rosemond Boateng Extra Credit
%problem 5 on 9.4

syms x y
sys1 = x*(1- x - y);
sys2 = y*(1.5 - y - x);
[xc, yc] = solve(sys1, sys2, x, y);
disp ('Critical Points:'); disp ([xc yc])

warning off all
f1 = @ (t, x) [x(1)* (1 - x(1) - x(2)); x(2)* (1.5 - x(2) - x(1))];
figure; hold on
for a = -5: 0.5:2.5
   for b = 0.25: 0.25:2.5
       [t, xa] = ode45(f1, [0 10], [a b]);
       plot(xa(:,1), xa(:,2))
       [t, xa] = ode45(f1, [0 -10], [a b]);
       plot(xa(:,1), xa(:,2))
   end
end
title 'Problem 5'
axis ([0 2 0 2])
[X Y] = meshgrid (0:0.25:2, 0:0.25:2);
F1 = X.*(1- X - Y);
F2 = Y.*(1.5 - Y - X);
```

```
L= sqrt((F1/3).^2 + (F2/6).^2);
quiver(X, Y, F1./L, F2./L, 0.5);
hold off


% The critical points are:
% (0,0) is a nodal source.
% (0, 1.5) is a nodal sink
% (1,0) is a saddle point.
% This is a rabbit-squirrel competition relationship. Nither species likes
% seeing the other species nor themselves because they are competing for
% the same food supply. At (0,0), the population of both species is
% increasing and approaching (1.5,0). If either species gets above the line
% y= -1.5*x +1.5, the population of both species will decrease, then try to
% increase and approach (1.5,0).
```

Critical Points:

```
[   0,   0]
[   0, 3/2]
[   1,   0]
```



problem 6

```
syms x y
sys1 = x*(1- x + 0.5*y);
sys2 = y*(2.5 - 1.5*y + 0.25*x);
[xc, yc] = solve(sys1, sys2, x, y);
disp ('Critical Points:'); disp ([xc yc])

warning off all
f2 = @ (t, x) [x(1)* (1 - x(1) + 0.5*x(2)); x(2)* (2.5 - 1.5*x(2) + 0.25*x(1))];
figure; hold on
```

```
for a = 0.25: 0.75:2.5
    for b = 0.25: 0.25:2.5
        [t, xa] = ode45(f2, [0 10], [a b]);
        plot(xa(:,1), xa(:,2))
        [t, xa] = ode45(f2, [0 -10], [a b]);
        plot(xa(:,1), xa(:,2))
    end
end
title 'Problem 6'
axis ([0 4 0 4])
[X Y] = meshgrid (0:0.25:4, 0:0.25:4);
F1 = X.*(1- X + 0.5.*Y);
F2 = Y.*(2.5 - 1.5.*Y + 0.25.*X);
L= sqrt((F1/3).^2 + (F2/6).^2);
quiver(X, Y, F1./L, F2./L, 0.5);
hold off

% (0,0) is a nodal source.
% (0,5/3) is a saddle
% (1,0) is a also a saddle
% (2,2) is a nodal sink
```

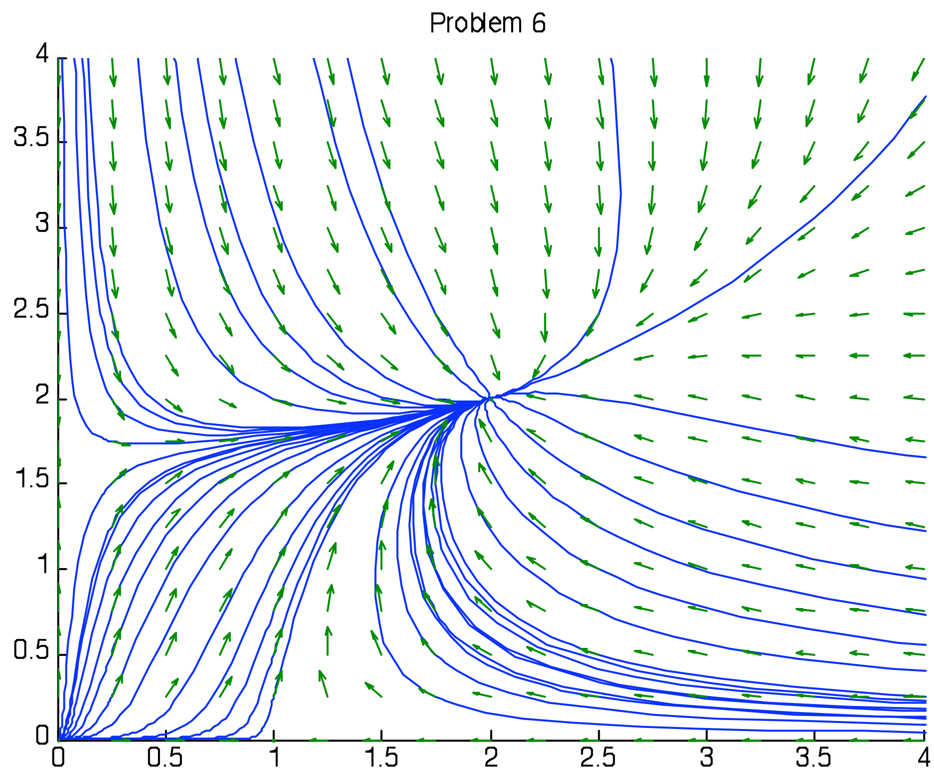
Critical Points:

[0,   0]

[0, 5/3]

[1, 0]

[2, 2]



combining prob 5 and 6 with alpha =c=0

warning off all

c = 0

syms x y

sys1 = (((1-c)*(x*(1 - x - y)))+ ((c)*(x*(1 - x + 0.5*y))));

sys2 = (((1-c)*(y*(1.5 - y - x)))+((c)*(y*(2.5 - 1.5*y + 0.25*x))));

[xc, yc] = solve(sys1, sys2, x, y);

disp ('Critical Points:'); disp ([xc yc])

```
f1 = @ (t, x) [x(1)* (1 - x(1) - x(2)); x(2)* (1.5 - x(2) - x(1))];

f2 = @ (t, x) [x(1)* (1 - x(1) + 0.5*x(2)); x(2)* (2.5 - 1.5*x(2) + 0.25*x(1))];

f3 = @ (t, x) [(((1-c)*(x(1)* (1 - x(1) - x(2))))+ (c*(x(1)* (1 - x(1) + 0.5*x(2))))); (((1-c)*(x(2)*
(1.5 - x(2) - x(1))))+((c)*(x(2)* (2.5 - 1.5*x(2) + 0.25*x(1)))))];

figure; hold on


for a = -5: 0.5:2.5

   for b = 0.25: 0.25:2.5

      [t, xa] = ode45(f3, [0 10], [a b]);

      plot(xa(:,1), xa(:,2))

      [t, xa] = ode45(f3, [0 -10], [a b]);

      plot(xa(:,1), xa(:,2))

   end

end

title 'Problem 5 and 6 with c= 0'

axis ([0 2 0 2])

[X Y] = meshgrid (0:0.25:2, 0:0.25:2);

F1 = (((1-c).*(X.* (1 - X - Y)))+ ((c).*(X.* (1 - X + 0.5.*Y))));

F2 = (((1-c).*(Y.* (1.5 - Y - X)))+((c).*(Y.* (2.5 - 1.5.*Y + 0.25.*X))));

L= sqrt((F1/3).^2 + (F2/6).^2);

quiver(X, Y, F1./L, F2./L, 0.5);

hold off


% The critical points are:
```

% (0,0) is a nodal source.

% (0, 1.5) is a nodal sink

% (1,0) is a saddle point.

% This is a rabbit-squirrel competition relationship. Nither species likes

% seeing the other species nor themselves because they are competing for

% the same food supply. At (0,0), the population of both species is

% increasing and approaching (1.5,0). If either species gets above the line

% y= -1.5*x +1.5, the population of both species will decrease, then try to

% increase and approach (1.5,0).

c =

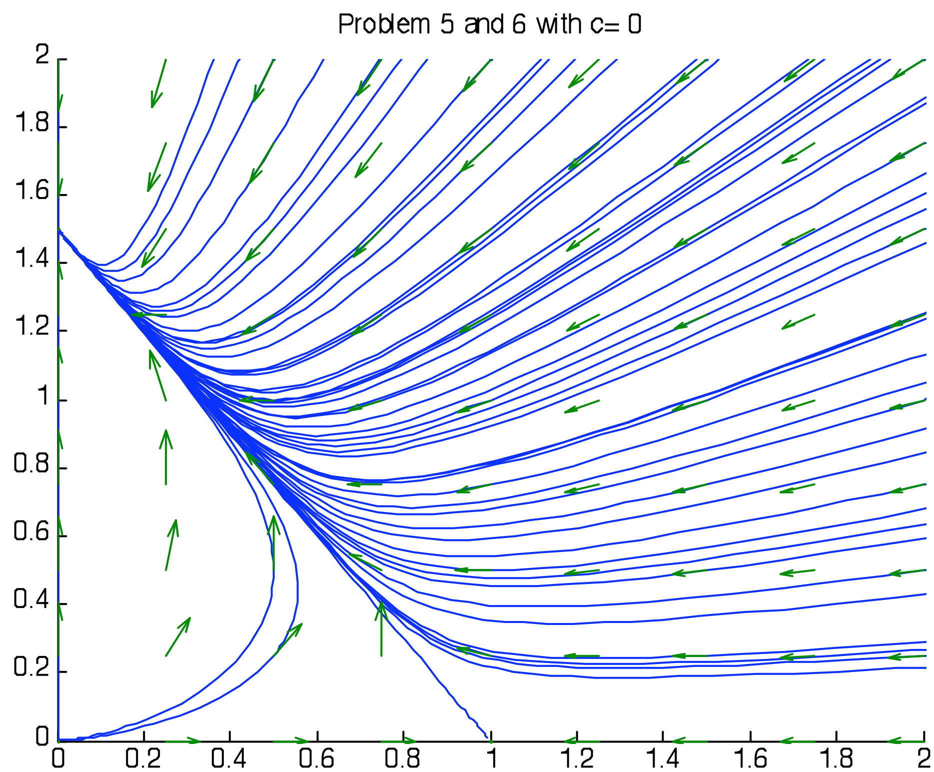
    0

Critical Points:

[0,   0]

[0, 3/2]

[1,   0]



combining prob 5 and 6 with alpha =c=1/6

```
warning off all

c = 1/6

syms x y

sys1 = (((1-c)*(x*(1 - x - y)))+ ((c)*(x*(1 - x + 0.5*y))));

sys2 = (((1-c)*(y*(1.5 - y - x)))+((c)*(y*(2.5 - 1.5*y + 0.25*x))));

[xc, yc] = solve(sys1, sys2, x, y);

disp ('Critical Points:'); disp ([xc yc])


f1 = @ (t, x) [x(1)* (1 - x(1) - x(2)); x(2)* (1.5 - x(2) - x(1))];
```

```
f2 = @ (t, x) [x(1)* (1 - x(1) + 0.5*x(2)); x(2)* (2.5 - 1.5*x(2) + 0.25*x(1))];

f3 = @ (t, x) [(((1-c)*(x(1)* (1 - x(1) - x(2))))+ (c*(x(1)* (1 - x(1) + 0.5*x(2))))); (((1-c)*(x(2)* (1.5 - x(2) - x(1))))+((c)*(x(2)* (2.5 - 1.5*x(2) + 0.25*x(1)))))];

figure; hold on


for a = -0.25: 0.75:2

   for b = -0.25: 0.25:2

       [t, xa] = ode45(f3, [-5 10], [a b]);

       plot(xa(:,1), xa(:,2))

       [t, xa] = ode45(f3, [-5 -10], [a b]);

       plot(xa(:,1), xa(:,2))

   end

end

title 'Problem 5 and 6 with c= 1/6'

axis ([-0.5 2 0 2])

[X Y] = meshgrid (-0.5:0.25:2, 0:0.25:2);

F1 = (((1-c).*(X.* (1 - X - Y)))+ ((c).*(X.* (1 - X + 0.5.*Y))));

F2 = (((1-c).*(Y.* (1.5 - Y - X)))+((c).*(Y.* (2.5 - 1.5.*Y + 0.25.*X))));

L= sqrt((F1/3).^2 + (F2/6).^2);

quiver(X, Y, F1./L, F2./L, 0.5);

hold off


% The critical points are:

% (0,0) is a nodal source.

% (0, 20/13) is a nodal sink
```

% (1,0) is a also a saddle

% (-16/47,84/47) is also saddle

% It's still a rabbit-squirrel competition relationship but both species

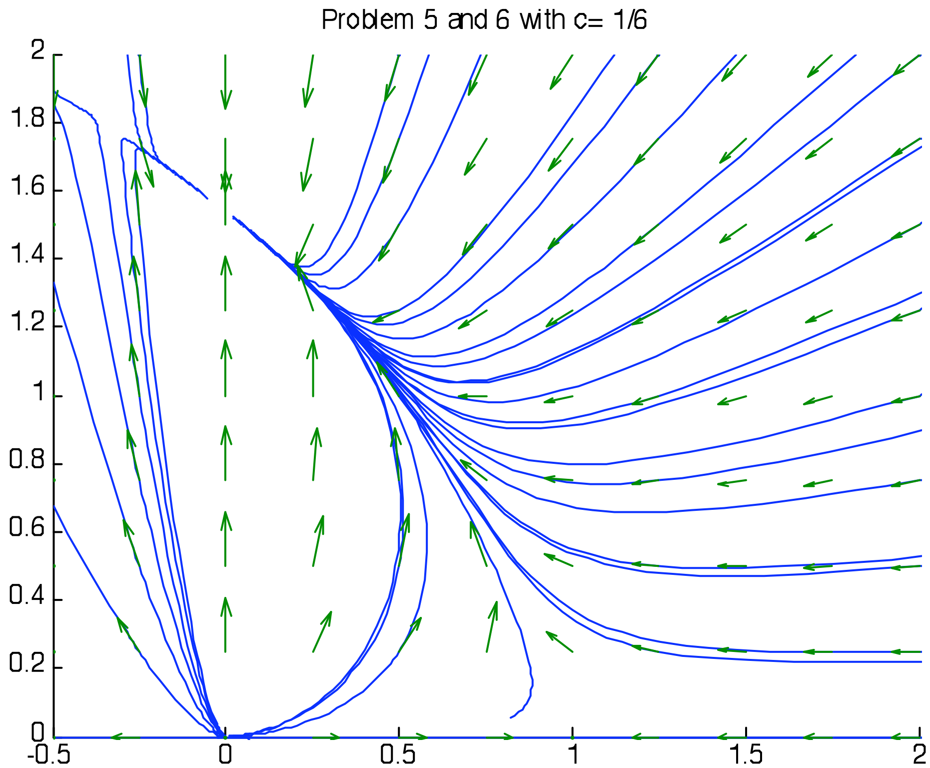
% increase from (0,0) until they get close to the curve going from 1.54 to

% approximately 1, then they approach the point (0, 1.54). One of the

% species has started to evolve causing the line when c=0 to change into a

% curve.

```
c =

    0.1667

Critical Points:
[      0,      0]
[      0,  20/13]
[      1,      0]
[ -16/47,  84/47]
```



combining prob 5 and 6 with alpha =c=1/3

```
warning off all

c = 1/3

syms x y

sys1 = (((1-c)*(x*(1 - x - y)))+ ((c)*(x*(1 - x + 0.5*y))));

sys2 = (((1-c)*(y*(1.5 - y - x)))+((c)*(y*(2.5 - 1.5*y + 0.25*x))));

[xc, yc] = solve(sys1, sys2, x, y);

disp ('Critical Points:'); disp ([xc yc])


f1 = @ (t, x) [x(1)* (1 - x(1) - x(2)); x(2)* (1.5 - x(2) - x(1))];
```

```
f2 = @ (t, x) [x(1)* (1 - x(1) + 0.5*x(2)); x(2)* (2.5 - 1.5*x(2) + 0.25*x(1))];

f3 = @ (t, x) [(((1-c)*(x(1)* (1 - x(1) - x(2))))+ (c*(x(1)* (1 - x(1) + 0.5*x(2))))); (((1-c)*(x(2)* (1.5 - x(2) - x(1))))+((c)*(x(2)* (2.5 - 1.5*x(2) + 0.25*x(1)))))];

figure; hold on


for a = 0.25: 0.75:2.5

   for b = 0.25: 0.25:3

      [t, xa] = ode45(f3, [0 10], [a b]);

      plot(xa(:,1), xa(:,2))

      [t, xa] = ode45(f3, [0 -10], [a b]);

      plot(xa(:,1), xa(:,2))

   end

end

title 'Problem 5 and 6 with c= 1/3'

axis ([0 2 0 2])

[X Y] = meshgrid (0:0.1:2, 0:0.25:2);

F1 = (((1-c).*(X.* (1 - X - Y)))+ ((c).*(X.* (1 - X + 0.5.*Y))));

F2 = (((1-c).*(Y.* (1.5 - Y - X)))+((c).*(Y.* (2.5 - 1.5.*Y + 0.25.*X))));

L= sqrt((F1/3).^2 + (F2/6).^2);

quiver(X, Y, F1./L, F2./L, 0.5);

hold off


% The critical points are:

% (0,0) is a nodal source

% (0,11/7) is a saddle
```

% (1,0) is a also a saddle

% (2/7, 10/7) is a nodal sink

% It's still a rabbit-squirrel competition relationship. One of the species

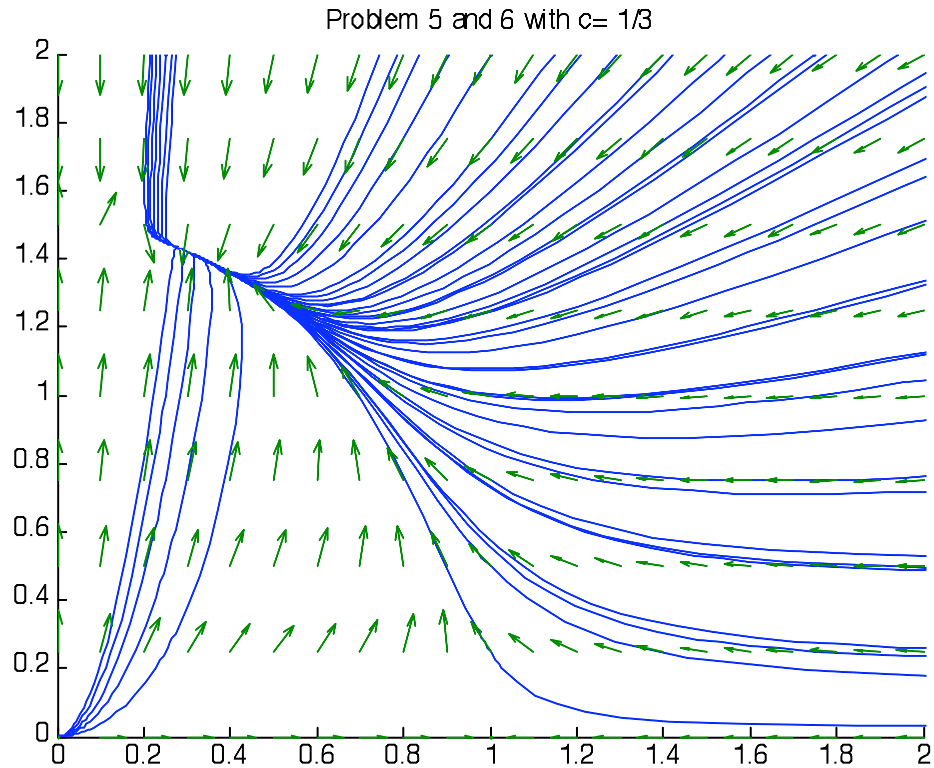
% has evolved some more causing the curve to widen at the base. Both

% species increase from (0,0) and approach (2/7, 10/7). If any of the

% species get above the curve, their population will decrease then increase

% and approach (2/7, 10/7).

```
c =

    0.3333

Critical Points:
[   0,    0]
[   0, 11/7]
[   1,    0]
[ 2/7, 10/7]
```



combining prob 5 and 6 with alpha =c=1/2

```
warning off all

c = 1/2

syms x y

sys1 = (((1-c)*(x*(1 - x - y)))+ ((c)*(x*(1 - x + 0.5*y))));

sys2 = (((1-c)*(y*(1.5 - y - x)))+((c)*(y*(2.5 - 1.5*y + 0.25*x))));

[xc, yc] = solve(sys1, sys2, x, y);

disp ('Critical Points:'); disp ([xc yc])


f1 = @ (t, x) [x(1)* (1 - x(1) - x(2)); x(2)* (1.5 - x(2) - x(1))];
```

```
f2 = @ (t, x) [x(1)* (1 - x(1) + 0.5*x(2)); x(2)* (2.5 - 1.5*x(2) + 0.25*x(1))];

f3 = @ (t, x) [(((1-c)*(x(1)* (1 - x(1) - x(2))))+ (c*(x(1)* (1 - x(1) + 0.5*x(2))))); (((1-c)*(x(2)*
(1.5 - x(2) - x(1))))+((c)*(x(2)* (2.5 - 1.5*x(2) + 0.25*x(1)))))];

figure; hold on


for a = 0.25: 0.75:3

   for b = 0.25: 0.25:3

      [t, xa] = ode45(f3, [0 10], [a b]);

      plot(xa(:,1), xa(:,2))

      [t, xa] = ode45(f3, [0 -10], [a b]);

      plot(xa(:,1), xa(:,2))

   end

end

title 'Problem 5 and 6 with c= 1/2'

axis ([0 2 0 2])

[X Y] = meshgrid (0:0.2:2, 0:0.25:2);

F1 = (((1-c).*(X.* (1 - X - Y)))+ ((c).*(X.* (1 - X + 0.5.*Y))));

F2 = (((1-c).*(Y.* (1.5 - Y - X)))+((c).*(Y.* (2.5 - 1.5.*Y + 0.25.*X))));

L= sqrt((F1/3).^2 + (F2/6).^2);

quiver(X, Y, F1./L, F2./L, 0.5);

hold off


% The critical points are:

% (0,0) is a nodal source.

% (0, 8/5) is a saddle
```

% (1,0) is a also a saddle

% (24/37, 52/37) is a nodal sink

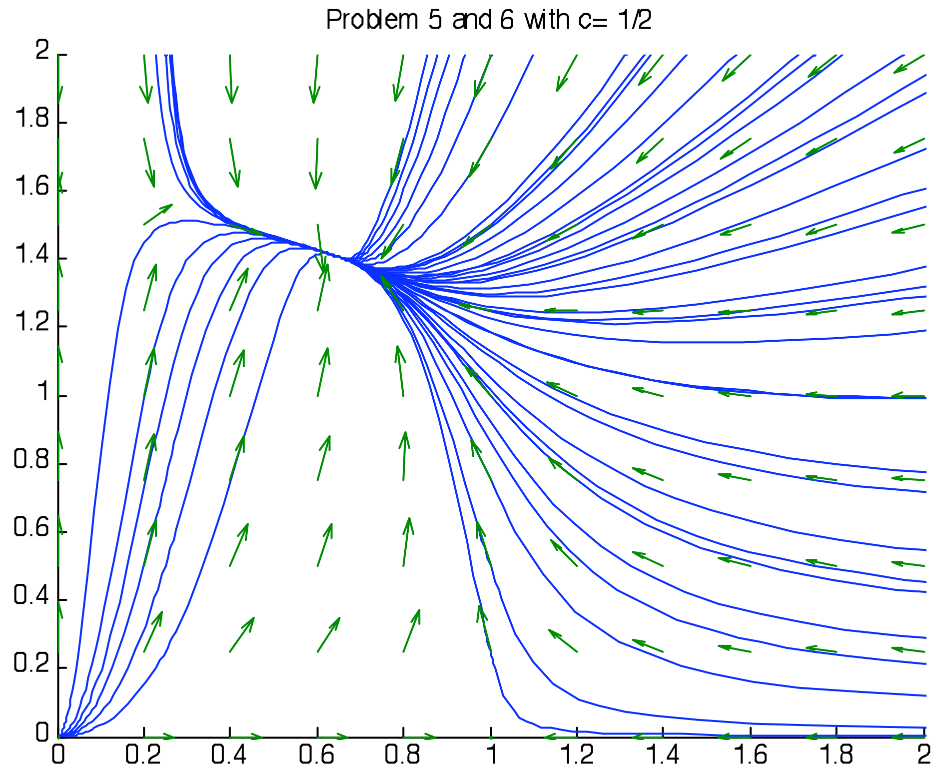
% One of the species has evolved more than the other one causing the curve

% from c= 1/3 to widen more at the base. The more evolved species increases

% from (0,0)at a faster rate but their growth is limited because they

% eventually approach (24/37, 52/37) just like the other species.

```
c =

    0.5000

Critical Points:
[     0,     0]
[     0,   8/5]
[     1,     0]
[ 24/37, 52/37]
```



combining prob 5 and 6 with alpha =c=4/6

```
warning off all

c= 4/6

syms x y

sys1 = (((1-c)*(x*(1 - x - y)))+ ((c)*(x*(1 - x + 0.5*y))));

sys2 = (((1-c)*(y*(1.5 - y - x)))+((c)*(y*(2.5 - 1.5*y + 0.25*x))));

[xc, yc] = solve(sys1, sys2, x, y);

disp ('Critical Points:'); disp ([xc yc])


f1 = @ (t, x) [x(1)* (1 - x(1) - x(2)); x(2)* (1.5 - x(2) - x(1))];
```

```
f2 = @ (t, x) [x(1)* (1 - x(1) + 0.5*x(2)); x(2)* (2.5 - 1.5*x(2) + 0.25*x(1))];

f3 = @ (t, x) [(((1-c)*(x(1)* (1 - x(1) - x(2))))+ (c*(x(1)* (1 - x(1) + 0.5*x(2))))); (((1-c)*(x(2)* (1.5 - x(2) - x(1))))+((c)*(x(2)* (2.5 - 1.5*x(2) + 0.25*x(1)))))];

figure; hold on


for a = 0.25: 0.75:3

   for b = 0.25: 0.25:3

      [t, xa] = ode45(f3, [0 10], [a b]);

      plot(xa(:,1), xa(:,2))

      [t, xa] = ode45(f3, [0 -10], [a b]);

      plot(xa(:,1), xa(:,2))

   end

end

title 'Problem 5 and 6 with c= 4/6'

axis ([0 2 0 2])

[X Y] = meshgrid (0:0.2:2, 0:0.25:2);

F1 = (((1-c).*(X.* (1 - X - Y)))+ ((c).*(X.* (1 - X + 0.5.*Y))));

F2 = (((1-c).*(Y.* (1.5 - Y - X)))+((c).*(Y.* (2.5 - 1.5.*Y + 0.25.*X))));

L= sqrt((F1/3).^2 + (F2/6).^2);

quiver(X, Y, F1./L, F2./L, 0.5);

hold off


% The critical points are:

% (0,0) is a nodal source.

% (0,13/8) is a saddle
```

% (1,0) is a also a saddle

% (1,1.5) is a nodal sink

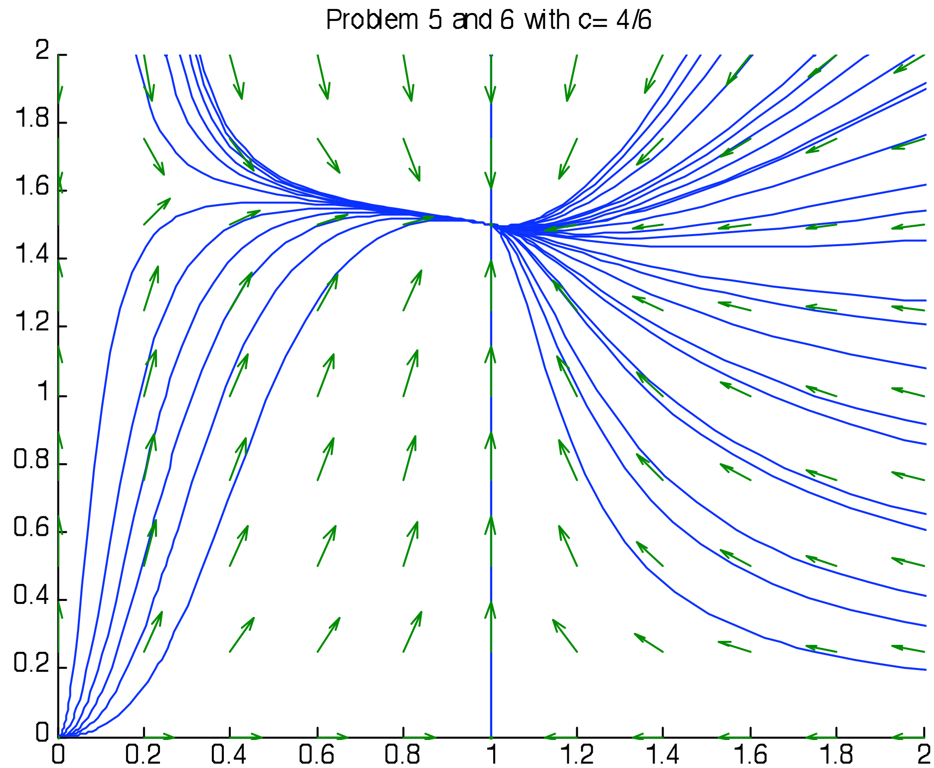
% Both species have evolevd a lot. They are getting close to a mutually

% benefiting relationship. They increase from (0,0) and approach (1,1.5).

% Both species also cannot keep increasing if they increase too much they

% decrease and approach (1, 1.5)

```
c =

    0.6667

Critical Points:
[    0,    0]
[    0, 13/8]
[    1,    0]
[    1,  3/2]
```



combining prob 5 and 6 with alpha =c=5/6

```
warning off all

c = 5/6

syms x y

sys1 = (((1-c)*(x*(1 - x - y)))+ ((c)*(x*(1 - x + 0.5*y))));

sys2 = (((1-c)*(y*(1.5 - y - x)))+((c)*(y*(2.5 - 1.5*y + 0.25*x))));

[xc, yc] = solve(sys1, sys2, x, y);

disp ('Critical Points:'); disp ([xc yc])


f1 = @ (t, x) [x(1)* (1 - x(1) - x(2)); x(2)* (1.5 - x(2) - x(1))];
```

```
f2 = @ (t, x) [x(1)* (1 - x(1) + 0.5*x(2)); x(2)* (2.5 - 1.5*x(2) + 0.25*x(1))];

f3 = @ (t, x) [(((1-c)*(x(1)* (1 - x(1) - x(2))))+ (c*(x(1)* (1 - x(1) + 0.5*x(2))))); (((1-c)*(x(2)*
(1.5 - x(2) - x(1))))+((c)*(x(2)* (2.5 - 1.5*x(2) + 0.25*x(1)))))];

figure; hold on


for a = 0.25: 0.75:3

    for b = 0.25: 0.25:3

        [t, xa] = ode45(f3, [0 10], [a b]);

        plot(xa(:,1), xa(:,2))

        [t, xa] = ode45(f3, [0 -10], [a b]);

        plot(xa(:,1), xa(:,2))

    end

end

title 'Problem 5 and 6 with c= 5/6'

axis ([0 2.5 0 2.5])

[X Y] = meshgrid (0:0.25:2.5, 0:0.5:2.5);

F1 = (((1-c).*(X.* (1 - X - Y)))+ ((c).*(X.* (1 - X + 0.5.*Y))));

F2 = (((1-c).*(Y.* (1.5 - Y - X)))+((c).*(Y.* (2.5 - 1.5.*Y + 0.25.*X))));

L= sqrt((F1/3).^2 + (F2/6).^2);

quiver(X, Y, F1./L, F2./L, 0.5);

hold off


% The critical points are:

% (0,0) is a nodal source.

% (0, 28/17) is a saddle
```

% (1,0) is a also a saddle

% (64/45, 76/45) is a nodal sink

% The relationship is evolving into a mutually benefiting one. They both

% increase from (0,0).Both species have evolved to a point of almost

% tollerating one another without competing for resources. However, they

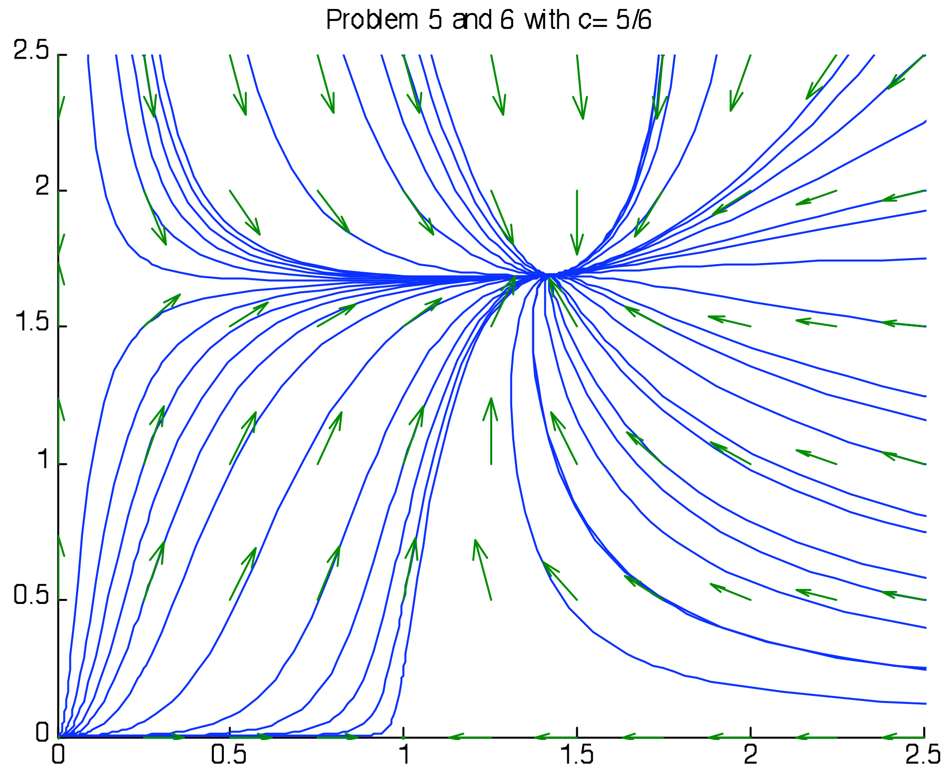
% always grow or decrease to approach (64/45, 76/45).

c =

    0.8333

Critical Points:

```
[     0,     0]
[     0, 28/17]
[     1,     0]
[ 64/45, 76/45]
```

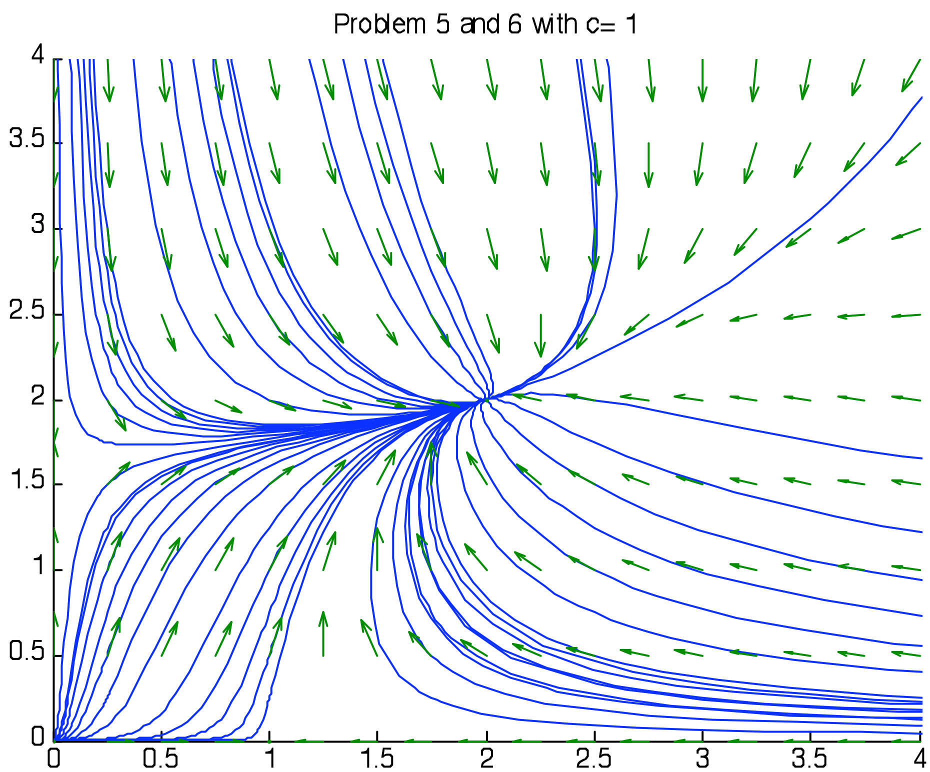


combining prob 5 and 6 with alpha =c= 1

```
warning off all

c = 1

syms x y

sys1 = (((1-c)*(x*(1 - x - y)))+ ((c)*(x*(1 - x + 0.5*y))));

sys2 = (((1-c)*(y*(1.5 - y - x)))+((c)*(y*(2.5 - 1.5*y + 0.25*x))));

[xc, yc] = solve(sys1, sys2, x, y);

disp ('Critical Points:'); disp ([xc yc])


f1 = @ (t, x) [x(1)* (1 - x(1) - x(2)); x(2)* (1.5 - x(2) - x(1))];
```

```
f2 = @ (t, x) [x(1)* (1 - x(1) + 0.5*x(2)); x(2)* (2.5 - 1.5*x(2) + 0.25*x(1))];

f3 = @ (t, x) [(((1-c)*(x(1)* (1 - x(1) - x(2))))+ (c*(x(1)* (1 - x(1) + 0.5*x(2))))); (((1-c)*(x(2)*
(1.5 - x(2) - x(1))))+((c)*(x(2)* (2.5 - 1.5*x(2) + 0.25*x(1)))))];

figure; hold on


for a = 0.25: 0.75:3

    for b = 0.25: 0.25:3

        [t, xa] = ode45(f3, [0 10], [a b]);

        plot(xa(:,1), xa(:,2))

        [t, xa] = ode45(f3, [0 -10], [a b]);

        plot(xa(:,1), xa(:,2))

    end

end

title 'Problem 5 and 6 with c= 1'

axis ([0 4 0 4])

[X Y] = meshgrid (0:0.25:4, 0:0.5:4);

F1 = (((1-c).*(X.* (1 - X - Y)))+ ((c).*(X.* (1 - X + 0.5.*Y))));

F2 = (((1-c).*(Y.* (1.5 - Y - X)))+((c).*(Y.* (2.5 - 1.5.*Y + 0.25.*X))));

L= sqrt((F1/3).^2 + (F2/6).^2);

quiver(X, Y, F1./L, F2./L, 0.5);

hold off


% The critical points are:

% (0,0) is a nodal source.

% (0,5/3) is a saddle
```

```
% (1,0) is a also a saddle
% (2,2) is a nodal sink
% The relationship between the species has evolved into a mutually
% beneficial one but there is still competition between individual species.
% An example of this is the trees in a forest and underground bacteria
% relationship. The trees compete for sunlight while the bacteria compete
% for food and shelter among themselves. They both benefit because the
% bacteria gets shelter and the trees can use waste produced by the
% bacteria. The graph is now an attracting cw sprial sink approaching (2,2)
% because there is still internal competition between the individual
% species.

c =

     1

Critical Points:
[   0,   0]
[   0, 5/3]
[   1,   0]
[   2,   2]
```



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