

Charles Griebell

Homework 19

OK to post

PREAMBLE:

```
> read `C:/Users/cgrie/Dynam Models Bio/Homeworks/HW19/M19.txt` ;
  Help19() ;
  SIRSDemo(N,IN,gamma,nu,h,A),e.g. SIRSDemo(100,20,1, 1,0.01, 10); EquPts(F,var), StEquPts(F, (1)
    var) , IsStable(M), RandNice(var,K)
```

#Problem 1

Carefully read the Maple code for procedure

```
SIRSDemo(N,IN, gamma,nu,h,A)
```

and run it for the following parameter values (with h=0.01)

Population = 1000 people

Initial infected people = 200 people

No dead people (or removed people) at t=0 (the start)

```
> SIRSDemo(1000,200,gamma,nu,0.01,A) ;
This is a numerical demonstration of the R0 phenomenon in the SIRS model using discretization with
  mesh size=, 0.01, and letting it run until time t=, A
    with population size, 1000, and fixed parameters nu=, v, and gamma=, γ
    where we change beta from 0.2*nu/N to 4*nu/N
Recall that the epidemic will persist if beta exceeds nu/N, that in this case is,  $\frac{v}{1000}$ 
We start with , 200, infected individuals, 0 removed and hence, 800, susceptible
We will show what happens once time is close to, A
beta is,  $\frac{1}{10}$ , times the threshold value
Error, (in Orb2) final value in for loop must be numeric or character
|C:/Users/cgrie/Dynam Models Bio/Homeworks/HW19/M19.txt:198|
```

```
> #at time t=10 (In SIRSDemo, let A=10) ,
  #SIRSDemo(1000,200,gamma,nu,0.01,10) ;
  #Let nu =1, gamma = 3
```

**SIRSdemo(1000,200,3,1,0.01,10);**

*This is a numerical demonstration of the R0 phenomenon in the SIRS model using discretization with mesh size=, 0.01, and letting it run until time t=, 10*

*with population size, 1000, and fixed parameters nu=, 1, and gamma=, 3*

*where we change beta from 0.2\*nu/N to 4\*nu/N*

*Recall that the epidemic will persist if beta exceeds nu/N, that in this case is,  $\frac{1}{1000}$*

*We start with , 200, infected individuals, 0 removed and hence, 800, susceptible*

*We will show what happens once time is close to, 10*

*beta is,  $\frac{1}{10}$ , times the threshold value*

*the long-term behavior is*

*[[9.98, [998.9666995, 0.9909989667]], [9.99, [998.9666995, 0.9909989667]], [10.00, [998.9666995, 0.9909989667]], [10.01, [998.9666995, 0.9909989667]]]*

*beta is,  $\frac{3}{10}$ , times the threshold value*

*the long-term behavior is*

*[[9.98, [996.7009881, 2.978970309]], [9.99, [996.7009881, 2.978970309]], [10.00, [996.7009881, 2.978970309]], [10.01, [996.7009881, 2.978970309]]]*

*beta is,  $\frac{1}{2}$ , times the threshold value*

*the long-term behavior is*

*[[9.98, [994.1715221, 4.974854288]], [9.99, [994.1715221, 4.974854288]], [10.00, [994.1715221, 4.974854288]], [10.01, [994.1715221, 4.974854288]]]*

*beta is,  $\frac{7}{10}$ , times the threshold value*

*the long-term behavior is*

*[[9.98, [991.3807432, 6.978577656]], [9.99, [991.3807432, 6.978577656]], [10.00, [991.3807432, 6.978577656]], [10.01, [991.3807432, 6.978577656]]]*

*beta is,  $\frac{9}{10}$ , times the threshold value*

*the long-term behavior is*

*[[9.98, [988.3315033, 8.990054852]], [9.99, [988.3315033, 8.990054852]], [10.00, [988.3315033, 8.990054852]], [10.01, [988.3315033, 8.990054852]]]*

*beta is,  $\frac{11}{10}$ , times the threshold value*

*the long-term behavior is*

*[[9.98, [985.0270559, 11.00918827]], [9.99, [985.0270559, 11.00918827]], [10.00, [985.0270559, 11.00918827]], [10.01, [985.0270559, 11.00918827]]]*

*beta is,  $\frac{13}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [981.4710448, 13.03586861]], [9.99, [981.4710448, 13.03586861]], [10.00, [981.4710448, 13.03586861]], [10.01, [981.4710448, 13.03586861]]]

*beta is,  $\frac{3}{2}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [977.6674922, 15.06997519]], [9.99, [977.6674922, 15.06997519]], [10.00, [977.6674922, 15.06997519]], [10.01, [977.6674922, 15.06997519]]]

*beta is,  $\frac{17}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [973.6207848, 17.11137641]], [9.99, [973.6207848, 17.11137641]], [10.00, [973.6207848, 17.11137641]], [10.01, [973.6207848, 17.11137641]]]

*beta is,  $\frac{19}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [969.3356593, 19.15993017]], [9.99, [969.3356593, 19.15993017]], [10.00, [969.3356593, 19.15993017]], [10.01, [969.3356593, 19.15993017]]]

*beta is,  $\frac{21}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [964.8171858, 21.21548438]], [9.99, [964.8171858, 21.21548438]], [10.00, [964.8171858, 21.21548438]], [10.01, [964.8171858, 21.21548438]]]

*beta is,  $\frac{23}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [960.0707508, 23.27787743]], [9.99, [960.0707508, 23.27787743]], [10.00, [960.0707508, 23.27787743]], [10.01, [960.0707508, 23.27787743]]]

*beta is,  $\frac{5}{2}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [955.1020392, 25.34693877]], [9.99, [955.1020392, 25.34693877]], [10.00, [955.1020392, 25.34693877]], [10.01, [955.1020392, 25.34693877]]]

*beta is,  $\frac{27}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [949.9170149, 27.42248950]], [9.99, [949.9170149, 27.42248950]], [10.00,

[949.9170149, 27.42248950]], [10.01, [949.9170149, 27.42248950]]]

*beta is,  $\frac{29}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [944.5219011, 29.50434292]], [9.99, [944.5219011, 29.50434292]], [10.00, [944.5219011, 29.50434292]], [10.01, [944.5219011, 29.50434292]]]

*beta is,  $\frac{31}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [938.9231598, 31.59230516]], [9.99, [938.9231598, 31.59230516]], [10.00, [938.9231598, 31.59230516]], [10.01, [938.9231598, 31.59230516]]]

*beta is,  $\frac{33}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [933.1274712, 33.68617582]], [9.99, [933.1274712, 33.68617582]], [10.00, [933.1274712, 33.68617582]], [10.01, [933.1274712, 33.68617582]]]

*beta is,  $\frac{7}{2}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [927.1417118, 35.78574860]], [9.99, [927.1417118, 35.78574860]], [10.00, [927.1417118, 35.78574860]], [10.01, [927.1417118, 35.78574860]]]

*beta is,  $\frac{37}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [920.9729335, 37.89081195]], [9.99, [920.9729335, 37.89081195]], [10.00, [920.9729335, 37.89081195]], [10.01, [920.9729335, 37.89081195]]]

*beta is,  $\frac{39}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [914.6283415, 40.00114971]], [9.99, [914.6283415, 40.00114971]], [10.00, [914.6283415, 40.00114971]], [10.01, [914.6283415, 40.00114971]]]

(2)

1000 - (914.6283415 + 40.00114971) people have died

```
> #LEt nu=2, gamma =3  
SIRSdemo(1000,200,3,2,0.01,10);
```

*This is a numerical demonstration of the R0 phenomenon in the SIRS model using discretization with mesh size=, 0.01, and letting it run until time t=, 10*

*with population size, 1000, and fixed parameters nu=, 2, and gamma=, 3*

*where we change beta from 0.2\*nu/N to 4\*nu/N*

Recall that the epidemic will persist if beta exceeds  $\nu/N$ , that in this case is,  $\frac{1}{500}$

We start with , 200, infected individuals, 0 removed and hence, 800, susceptible

We will show what happens once time is close to, 10

beta is,  $\frac{1}{10}$ , times the threshold value

the long-term behavior is

[[9.98, [998.9334028, 0.9819978668]], [9.99, [998.9334028, 0.9819978668]], [10.00, [998.9334028, 0.9819978668]], [10.01, [998.9334028, 0.9819978668]]]

beta is,  $\frac{3}{10}$ , times the threshold value

the long-term behavior is

[[9.98, [996.4021571, 2.957935239]], [9.99, [996.4021571, 2.957935239]], [10.00, [996.4021571, 2.957935239]], [10.01, [996.4021571, 2.957935239]]]

beta is,  $\frac{1}{2}$ , times the threshold value

the long-term behavior is

[[9.98, [993.3444243, 4.949667221]], [9.99, [993.3444243, 4.949667221]], [10.00, [993.3444243, 4.949667221]], [10.01, [993.3444243, 4.949667221]]]

beta is,  $\frac{7}{10}$ , times the threshold value

the long-term behavior is

[[9.98, [989.7667603, 6.956997143]], [9.99, [989.7667603, 6.956997143]], [10.00, [989.7667603, 6.956997143]], [10.01, [989.7667603, 6.956997143]]]

beta is,  $\frac{9}{10}$ , times the threshold value

the long-term behavior is

[[9.98, [985.6773407, 8.979679729]], [9.99, [985.6773407, 8.979679729]], [10.00, [985.6773407, 8.979679729]], [10.01, [985.6773407, 8.979679729]]]

beta is,  $\frac{11}{10}$ , times the threshold value

the long-term behavior is

[[9.98, [981.0859054, 11.01742279]], [9.99, [981.0859054, 11.01742279]], [10.00, [981.0859054, 11.01742279]], [10.01, [981.0859054, 11.01742279]]]

beta is,  $\frac{13}{10}$ , times the threshold value

the long-term behavior is

[[9.98, [976.0036901, 13.06988925]], [9.99, [976.0036901, 13.06988925]], [10.00, [976.0036901, 13.06988925]], [10.01, [976.0036901, 13.06988925]]]

*beta is,  $\frac{3}{2}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [970.4433482, 15.13669951]], [9.99, [970.4433482, 15.13669951]], [10.00, [970.4433482, 15.13669951]], [10.01, [970.4433482, 15.13669951]]]

*beta is,  $\frac{17}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [964.4188616, 17.21743410]], [9.99, [964.4188616, 17.21743410]], [10.00, [964.4188616, 17.21743410]], [10.01, [964.4188616, 17.21743410]]]

*beta is,  $\frac{19}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [957.9454447, 19.31163661]], [9.99, [957.9454447, 19.31163661]], [10.00, [957.9454447, 19.31163661]], [10.01, [957.9454447, 19.31163661]]]

*beta is,  $\frac{21}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [951.0394389, 21.41881679]], [9.99, [951.0394389, 21.41881679]], [10.00, [951.0394389, 21.41881679]], [10.01, [951.0394389, 21.41881679]]]

*beta is,  $\frac{23}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [943.7182031, 23.53845386]], [9.99, [943.7182031, 23.53845386]], [10.00, [943.7182031, 23.53845386]], [10.01, [943.7182031, 23.53845386]]]

*beta is,  $\frac{5}{2}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [935.9999984, 25.67000000]], [9.99, [935.9999984, 25.67000000]], [10.00, [935.9999984, 25.67000000]], [10.01, [935.9999984, 25.67000000]]]

*beta is,  $\frac{27}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [927.9038703, 27.81288384]], [9.99, [927.9038703, 27.81288384]], [10.00, [927.9038703, 27.81288384]], [10.01, [927.9038703, 27.81288384]]]

*beta is,  $\frac{29}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [919.4495282, 29.96651411]], [9.99, [919.4495282, 29.96651411]], [10.00, [919.4495282, 29.96651411]]]

[919.4495282, 29.96651411]], [10.01, [919.4495282, 29.96651411]]]

*beta is,  $\frac{31}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [910.6572255, 32.13028319]], [9.99, [910.6572255, 32.13028319]], [10.00, [910.6572255, 32.13028319]], [10.01, [910.6572255, 32.13028319]]]

*beta is,  $\frac{33}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [901.5476397, 34.30357076]], [9.99, [901.5476397, 34.30357076]], [10.00, [901.5476397, 34.30357076]], [10.01, [901.5476397, 34.30357076]]]

*beta is,  $\frac{7}{2}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [892.1417551, 36.48574730]], [9.99, [892.1417551, 36.48574730]], [10.00, [892.1417551, 36.48574730]], [10.01, [892.1417551, 36.48574730]]]

*beta is,  $\frac{37}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [882.4607475, 38.67617753]], [9.99, [882.4607475, 38.67617753]], [10.00, [882.4607475, 38.67617753]], [10.01, [882.4607475, 38.67617753]]]

*beta is,  $\frac{39}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [872.5258747, 40.87422371]], [9.99, [872.5258747, 40.87422371]], [10.00, [872.5258747, 40.87422371]], [10.01, [872.5258747, 40.87422371]]]

(3)

# here,  $1000 - (872.5258747 + 40.87422371)$  have died

```
> #LEt nu = 3, gamma = 7  
SIRSdemo(1000,200,7,3,0.01,10);
```

*This is a numerical demonstration of the  $R_0$  phenomenon in the SIRS model using discretization with mesh size=, 0.01, and letting it run until time t=, 10*

*with population size, 1000, and fixed parameters nu=, 3, and gamma=, 7*

*where we change beta from  $0.2 \cdot \text{nu}/N$  to  $4 \cdot \text{nu}/N$*

*Recall that the epidemic will persist if beta exceeds  $\text{nu}/N$ , that in this case is,  $\frac{3}{1000}$*

*We start with , 200, infected individuals, 0 removed and hence, 800, susceptible*

*We will show what happens once time is close to, 10*

*beta is,  $\frac{1}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [998.9571869, 0.9729968716]], [9.99, [998.9571869, 0.9729968716]], [10.00, [998.9571869, 0.9729968716]], [10.01, [998.9571869, 0.9729968716]]]

*beta is,  $\frac{3}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [996.6155905, 2.936908621]], [9.99, [996.6155905, 2.936908621]], [10.00, [996.6155905, 2.936908621]], [10.01, [996.6155905, 2.936908621]]]

*beta is,  $\frac{1}{2}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [993.9350689, 4.924545130]], [9.99, [993.9350689, 4.924545130]], [10.00, [993.9350689, 4.924545130]], [10.01, [993.9350689, 4.924545130]]]

*beta is,  $\frac{7}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [990.9190693, 6.935665103]], [9.99, [990.9190693, 6.935665103]], [10.00, [990.9190693, 6.935665103]], [10.01, [990.9190693, 6.935665103]]]

*beta is,  $\frac{9}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [987.5717147, 8.969979927]], [9.99, [987.5717147, 8.969979927]], [10.00, [987.5717147, 8.969979927]], [10.01, [987.5717147, 8.969979927]]]

*beta is,  $\frac{11}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [983.8977865, 11.02715490]], [9.99, [983.8977865, 11.02715490]], [10.00, [983.8977865, 11.02715490]], [10.01, [983.8977865, 11.02715490]]]

*beta is,  $\frac{13}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [979.9027040, 13.10681067]], [9.99, [979.9027040, 13.10681067]], [10.00, [979.9027040, 13.10681067]], [10.01, [979.9027040, 13.10681067]]]

*beta is,  $\frac{3}{2}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [975.5925002, 15.20852494]], [9.99, [975.5925002, 15.20852494]], [10.00, [975.5925002, 15.20852494]], [10.01, [975.5925002, 15.20852494]]]



*beta is,  $\frac{17}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [970.9737953, 17.33183428]], [9.99, [970.9737953, 17.33183428]], [10.00, [970.9737953, 17.33183428]], [10.01, [970.9737953, 17.33183428]]]

*beta is,  $\frac{19}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [966.0537675, 19.47623623]], [9.99, [966.0537675, 19.47623623]], [10.00, [966.0537675, 19.47623623]], [10.01, [966.0537675, 19.47623623]]]

*beta is,  $\frac{21}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [960.8401210, 21.64119148]], [9.99, [960.8401210, 21.64119148]], [10.00, [960.8401210, 21.64119148]], [10.01, [960.8401210, 21.64119148]]]

*beta is,  $\frac{23}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [955.3410529, 23.82612625]], [9.99, [955.3410529, 23.82612625]], [10.00, [955.3410529, 23.82612625]], [10.01, [955.3410529, 23.82612625]]]

*beta is,  $\frac{5}{2}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [949.5652167, 26.03043478]], [9.99, [949.5652167, 26.03043478]], [10.00, [949.5652167, 26.03043478]], [10.01, [949.5652167, 26.03043478]]]

*beta is,  $\frac{27}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [943.5216861, 28.25348193]], [9.99, [943.5216861, 28.25348193]], [10.00, [943.5216861, 28.25348193]], [10.01, [943.5216861, 28.25348193]]]

*beta is,  $\frac{29}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [937.2199158, 30.49460585]], [9.99, [937.2199158, 30.49460585]], [10.00, [937.2199158, 30.49460585]], [10.01, [937.2199158, 30.49460585]]]

*beta is,  $\frac{31}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [930.6697029, 32.75312075]], [9.99, [930.6697029, 32.75312075]], [10.00,

[930.6697029, 32.75312075]], [10.01, [930.6697029, 32.75312075]]]

*beta is,  $\frac{33}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [923.8811464, 35.02831970]], [9.99, [923.8811464, 35.02831970]], [10.00, [923.8811464, 35.02831970]], [10.01, [923.8811464, 35.02831970]]]

*beta is,  $\frac{7}{2}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [916.8646074, 37.31947743]], [9.99, [916.8646074, 37.31947743]], [10.00, [916.8646074, 37.31947743]], [10.01, [916.8646074, 37.31947743]]]

*beta is,  $\frac{37}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [909.6306685, 39.62585316]], [9.99, [909.6306685, 39.62585316]], [10.00, [909.6306685, 39.62585316]], [10.01, [909.6306685, 39.62585316]]]

*beta is,  $\frac{39}{10}$ , times the threshold value*

*the long-term behavior is*

[[9.98, [902.1900937, 41.94669340]], [9.99, [902.1900937, 41.94669340]], [10.00, [902.1900937, 41.94669340]], [10.01, [902.1900937, 41.94669340]]]

(4)

# here, 1000 - 902.1900937 + 41.94669340 people died

#PROBLEM 2

Using RandNice([x,y],8) 3 times, (call it F) each time.

```
> F1 := RandNice([x,y],8);  
F2 := RandNice([x,y],8);  
F3 := RandNice([x,y],8);  
F1 := [(1 - 2x - 4y) (5 - 3x - 4y), (8 - x - 7y) (8 - x - y)]  
F2 := [(2 - 2x - 3y) (4 - 7x - 5y), (8 - x - 6y) (4 - x - 7y)]  
F3 := [(2 - x - 5y) (1 - x - 4y), (3 - 5x - 7y) (4 - 6x - 4y)]
```

(5)

For each of them find the following:

(i) The set of equilibrium points

```
> print(`Equilibrium points for F1`);  
e1 := EquPts(F1,[x,y]);  
print(`Equilibrium points for F2`);  
e2 := EquPts(F2,[x,y]);  
print(`Equilibrium points for F3`);  
e3 := EquPts(F3,[x,y]);
```

$$\begin{aligned}
 & \text{Equilibrium points for } F1 \\
 e1 & := \left\{ [27, -19], \left[ -\frac{5}{2}, \frac{3}{2} \right], \left[ \frac{3}{17}, \frac{19}{17} \right], \left[ \frac{31}{2}, -\frac{15}{2} \right] \right\} \\
 & \text{Equilibrium points for } F2 \\
 e2 & := \left\{ \left[ -\frac{16}{37}, \frac{52}{37} \right], \left[ -\frac{4}{3}, \frac{14}{9} \right], \left[ \frac{2}{11}, \frac{6}{11} \right] \right\} \\
 & \text{Equilibrium points for } F3 \\
 e3 & := \left\{ \left[ \frac{1}{18}, \frac{7}{18} \right], \left[ \frac{3}{5}, \frac{1}{10} \right], \left[ \frac{5}{13}, \frac{2}{13} \right], \left[ \frac{6}{13}, \frac{4}{13} \right] \right\}
 \end{aligned} \tag{6}$$

(ii) The set of stable equilibrium points

```

> print(`Stable Equilibrium points for F1`);
s1:= StEquPts(F1,[x,y]);
print(`Stable Equilibrium points for F2`);
s2:= StEquPts(F2,[x,y]);
print(`Stable Equilibrium points for F3`);
s3:= StEquPts(F3,[x,y]);

```

$$\begin{aligned}
 & \text{Stable Equilibrium points for } F1 \\
 s1 & := \left\{ \left[ -\frac{5}{2}, \frac{3}{2} \right], \left[ \frac{31}{2}, -\frac{15}{2} \right] \right\} \\
 & \text{Stable Equilibrium points for } F2 \\
 s2 & := \emptyset \\
 & \text{Stable Equilibrium points for } F3 \\
 s3 & := \left\{ \left[ \frac{1}{18}, \frac{7}{18} \right] \right\}
 \end{aligned} \tag{7}$$

(iii) Using `Dis2(F,x,y,pt+[0.1,0.1],0.01,10)` ;

confirm numerically that for **pt** in the stable set it converges to that point, but for the other equilibrium points, the orbit goes elsewhere.

```

> alleged_unstable1 := e1 minus s1;
alleged_unstable2 := e2 minus s2;
alleged_unstable3 := e3 minus s3;

```

$$\begin{aligned}
 & \text{alleged\_unstable1} := \left\{ [27, -19], \left[ \frac{3}{17}, \frac{19}{17} \right] \right\} \\
 & \text{alleged\_unstable2} := \left\{ \left[ -\frac{16}{37}, \frac{52}{37} \right], \left[ -\frac{4}{3}, \frac{14}{9} \right], \left[ \frac{2}{11}, \frac{6}{11} \right] \right\} \\
 & \text{alleged\_unstable3} := \left\{ \left[ \frac{3}{5}, \frac{1}{10} \right], \left[ \frac{5}{13}, \frac{2}{13} \right], \left[ \frac{6}{13}, \frac{4}{13} \right] \right\}
 \end{aligned} \tag{8}$$

```

> #Stable equilibria of f1:
  if nops(s1)=0 then print(`no stable equilibra`);
  end if:
  for i in s1 do:
    print(`for stable equilibrium point`, i);
    print(Dis2(F1,x,y,i+[0.01,0.01],0.01,10));
  od:

```

*for stable equilibrium point,  $\left[-\frac{5}{2}, \frac{3}{2}\right]$*

```

[[0.01, [-2.490000000, 1.510000000]], [0.02, [-2.493858000, 1.502816000]], [0.03,
  [-2.495381629, 1.500491456]], [0.04, [-2.496108023, 1.499766597]], [0.05,
  [-2.496552559, 1.499563445]], [0.06, [-2.496886779, 1.499528216]], [0.07,
  [-2.497168511, 1.499545245]], [0.08, [-2.497418112, 1.499576898]], [0.09,
  [-2.497643541, 1.499611074]], [0.10, [-2.497848586, 1.499644009]], [0.11,
  [-2.498035567, 1.499674651]], [0.12, [-2.498206232, 1.499702817]], [0.13,
  [-2.498362054, 1.499728599]], [0.14, [-2.498504339, 1.499752163]], [0.15,
  [-2.498634267, 1.499773688]], [0.16, [-2.498752913, 1.499793346]], [0.17,
  [-2.498861256, 1.499811298]], [0.18, [-2.498960190, 1.499827692]], [0.19,
  [-2.499050531, 1.499842662]], [0.20, [-2.499133026, 1.499856332]], [0.21,
  [-2.499208355, 1.499868815]], [0.22, [-2.499277141, 1.499880214]], [0.23,
  [-2.499339952, 1.499890621]], [0.24, [-2.499397306, 1.499900124]], [0.25,
  [-2.499449677, 1.499908803]], [0.26, [-2.499497498, 1.499916728]], [0.27,
  [-2.499541165, 1.499923964]], [0.28, [-2.499581038, 1.499930571]], [0.29,
  [-2.499617446, 1.499936604]], [0.30, [-2.499650690, 1.499942114]], [0.31,
  [-2.499681046, 1.499947144]], [0.32, [-2.499708764, 1.499951737]], [0.33,
  [-2.499734074, 1.499955931]], [0.34, [-2.499757184, 1.499959760]], [0.35,
  [-2.499778286, 1.499963257]], [0.36, [-2.499797554, 1.499966451]], [0.37,
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  [-2.499871506, 1.499978707]], [0.42, [-2.499882674, 1.499980557]], [0.43,
  [-2.499892871, 1.499982246]], [0.44, [-2.499902181, 1.499983789]], [0.45,
  [-2.499910682, 1.499985198]], [0.46, [-2.499918445, 1.499986484]], [0.47,
  [-2.499925533, 1.499987658]], [0.48, [-2.499932005, 1.499988731]], [0.49,
  [-2.499937914, 1.499989710]], [0.50, [-2.499943310, 1.499990605]], [0.51,
  [-2.499948237, 1.499991421]], [0.52, [-2.499952736, 1.499992167]], [0.53,
  [-2.499956844, 1.499992848]], [0.54, [-2.499960595, 1.499993469]], [0.55,
  [-2.499964020, 1.499994038]], [0.56, [-2.499967147, 1.499994555]], [0.57,
  [-2.499970002, 1.499995029]], [0.58, [-2.499972609, 1.499995461]], [0.59,
  [-2.499974990, 1.499995855]], [0.60, [-2.499977164, 1.499996216]], [0.61,
  [-2.499979149, 1.499996544]], [0.62, [-2.499980961, 1.499996845]], [0.63,

```

[ -2.499982616, 1.499997119 ]], [0.64, [ -2.499984127, 1.499997370 ]], [0.65, [ -2.499985507, 1.499997599 ]], [0.66, [ -2.499986767, 1.499997808 ]], [0.67, [ -2.499987917, 1.499997998 ]], [0.68, [ -2.499988967, 1.499998172 ]], [0.69, [ -2.499989926, 1.499998331 ]], [0.70, [ -2.499990802, 1.499998476 ]], [0.71, [ -2.499991601, 1.499998608 ]], [0.72, [ -2.499992331, 1.499998729 ]], [0.73, [ -2.499992998, 1.499998840 ]], [0.74, [ -2.499993607, 1.499998941 ]], [0.75, [ -2.499994163, 1.499999033 ]], [0.76, [ -2.499994670, 1.499999117 ]], [0.77, [ -2.499995133, 1.499999193 ]], [0.78, [ -2.499995556, 1.499999263 ]], [0.79, [ -2.499995942, 1.499999328 ]], [0.80, [ -2.499996295, 1.499999386 ]], [0.81, [ -2.499996617, 1.499999440 ]], [0.82, [ -2.499996911, 1.499999489 ]], [0.83, [ -2.499997180, 1.499999533 ]], [0.84, [ -2.499997425, 1.499999573 ]], [0.85, [ -2.499997649, 1.499999610 ]], [0.86, [ -2.499997853, 1.499999644 ]], [0.87, [ -2.499998040, 1.499999675 ]], [0.88, [ -2.499998210, 1.499999704 ]], [0.89, [ -2.499998366, 1.499999729 ]], [0.90, [ -2.499998508, 1.499999753 ]], [0.91, [ -2.499998638, 1.499999775 ]], [0.92, [ -2.499998757, 1.499999795 ]], [0.93, [ -2.499998865, 1.499999813 ]], [0.94, [ -2.499998964, 1.499999828 ]], [0.95, [ -2.499999054, 1.499999842 ]], [0.96, [ -2.499999136, 1.499999856 ]], [0.97, [ -2.499999211, 1.499999869 ]], [0.98, [ -2.499999280, 1.499999881 ]], [0.99, [ -2.499999343, 1.499999891 ]], [1.00, [ -2.499999400, 1.499999900 ]], [1.01, [ -2.499999452, 1.499999909 ]], [1.02, [ -2.499999500, 1.499999917 ]], [1.03, [ -2.499999543, 1.499999924 ]], [1.04, [ -2.499999583, 1.499999930 ]], [1.05, [ -2.499999619, 1.499999936 ]], [1.06, [ -2.499999652, 1.499999942 ]], [1.07, [ -2.499999682, 1.499999947 ]], [1.08, [ -2.499999710, 1.499999951 ]], [1.09, [ -2.499999735, 1.499999955 ]], [1.10, [ -2.499999758, 1.499999960 ]], [1.11, [ -2.499999779, 1.499999964 ]], [1.12, [ -2.499999798, 1.499999967 ]], [1.13, [ -2.499999816, 1.499999970 ]], [1.14, [ -2.499999832, 1.499999973 ]], [1.15, [ -2.499999847, 1.499999975 ]], [1.16, [ -2.499999860, 1.499999978 ]], [1.17, [ -2.499999872, 1.499999979 ]], [1.18, [ -2.499999883, 1.499999981 ]], [1.19, [ -2.499999893, 1.499999982 ]], [1.20, [ -2.499999902, 1.499999984 ]], [1.21, [ -2.499999911, 1.499999985 ]], [1.22, [ -2.499999919, 1.499999986 ]], [1.23, [ -2.499999926, 1.499999988 ]], [1.24, [ -2.499999932, 1.499999989 ]], [1.25, [ -2.499999938, 1.499999990 ]], [1.26, [ -2.499999943, 1.499999991 ]], [1.27, [ -2.499999948, 1.499999991 ]], [1.28, [ -2.499999952, 1.499999992 ]], [1.29, [ -2.499999956, 1.499999993 ]], [1.30, [ -2.499999960, 1.499999994 ]], [1.31, [ -2.499999964, 1.499999994 ]], [1.32, [ -2.499999967, 1.499999994 ]], [1.33, [ -2.499999970, 1.499999995 ]], [1.34, [ -2.499999973, 1.499999996 ]], [1.35, [ -2.499999975, 1.499999996 ]], [1.36, [ -2.499999977, 1.499999997 ]], [1.37, [ -2.499999979, 1.499999997 ]], [1.38, [ -2.499999981, 1.499999997 ]], [1.39,



























[−2.499999993, 1.499999998]], [9.76, [−2.499999993, 1.499999998]], [9.77, [−2.499999993, 1.499999998]], [9.78, [−2.499999993, 1.499999998]], [9.79, [−2.499999993, 1.499999998]], [9.80, [−2.499999993, 1.499999998]], [9.81, [−2.499999993, 1.499999998]], [9.82, [−2.499999993, 1.499999998]], [9.83, [−2.499999993, 1.499999998]], [9.84, [−2.499999993, 1.499999998]], [9.85, [−2.499999993, 1.499999998]], [9.86, [−2.499999993, 1.499999998]], [9.87, [−2.499999993, 1.499999998]], [9.88, [−2.499999993, 1.499999998]], [9.89, [−2.499999993, 1.499999998]], [9.90, [−2.499999993, 1.499999998]], [9.91, [−2.499999993, 1.499999998]], [9.92, [−2.499999993, 1.499999998]], [9.93, [−2.499999993, 1.499999998]], [9.94, [−2.499999993, 1.499999998]], [9.95, [−2.499999993, 1.499999998]], [9.96, [−2.499999993, 1.499999998]], [9.97, [−2.499999993, 1.499999998]], [9.98, [−2.499999993, 1.499999998]], [9.99, [−2.499999993, 1.499999998]], [10.00, [−2.499999993, 1.499999998]], [10.01, [−2.499999993, 1.499999998]]]

for stable equilibrium point,  $\left[ \frac{31}{2}, -\frac{15}{2} \right]$

[[0.01, [15.51000000, −7.490000000]], [0.02, [15.51694200, −7.498984000]], [0.03, [15.52132685, −7.507060780]], [0.04, [15.52298922, −7.513484520]], [0.05, [15.52207267, −7.517768422]], [0.06, [15.51897722, −7.519709737]], [0.07, [15.51428446, −7.519379233]], [0.08, [15.50867241, −7.517080402]], [0.09, [15.50283164, −7.513287482]], [0.10, [15.49739188, −7.508572924]], [0.11, [15.49286511, −7.503534453]], [0.12, [15.48960833, −7.498729848]], [0.13, [15.48780661, −7.494625028]], [0.14, [15.48747505, −7.491558474]], [0.15, [15.48847708, −7.489722835]], [0.16, [15.49055549, −7.489162998]], [0.17, [15.49337195, −7.489788695]], [0.18, [15.49655048, −7.491398836]], [0.19, [15.49972024, −7.493714152]], [0.20, [15.50255336, −7.496414266]], [0.21, [15.50479435, −7.499175161]], [0.22, [15.50627876, −7.501703202]], [0.23, [15.50694009, −7.503762461]], [0.24, [15.50680551, −7.505193010]], [0.25, [15.50598202, −7.505919111]], [0.26, [15.50463577, −7.505947442]], [0.27, [15.50296761, −7.505356704]], [0.28, [15.50118802, −7.504280787]], [0.29, [15.49949410, −7.502888152]], [0.30, [15.49805084, −7.501360125]], [0.31, [15.49697793, −7.499870567]], [0.32, [15.49634287, −7.498568819]], [0.33, [15.49616016, −7.497567284]], [0.34, [15.49639601, −7.496934264]], [0.35, [15.49697740, −7.496692146]], [0.36, [15.49780411, −7.496820453]], [0.37, [15.49876216, −7.497262901]], [0.38, [15.49973714, −7.497937299]], [0.39, [15.50062610, −7.498746972]], [0.40, [15.50134693, −7.499592403]], [0.41, [15.50184446, −7.500381866]], [0.42, [15.50209311, −7.501040045]], [0.43, [15.50209611, −7.501513979]], [0.44, [15.50188178, −7.501775987]], [0.45,

(9)

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```

```
> #unstable equilibrium point of f1:
for i in alleged_unstable1 do:
print(`for unstable equilibrium point`, i);
print(Dis2(F1,x,y,i+[0.01,0.01],0.01,10));
od:
```

*for unstable equilibrium point, [27, -19]*

```
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for unstable equilibrium point,  $\left[ \frac{3}{17}, \frac{19}{17} \right]$

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(10)

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 $\times 10^{8869629760585564}]$ , [1.13, [9.541030903  $\times 10^{17739259521171129}$ , 2.860422682  
 $\times 10^{17739259521171129}]$ , [1.14, [1.222927535  $\times 10^{35478519042342259}$ , 3.666364455  
 $\times 10^{35478519042342258}]$ , [1.15, [2.009146316  $\times 10^{70957038084684517}$ , 6.023466172  
 $\times 10^{70957038084684516}]$ , [1.16, [5.422920641  $\times 10^{141914076169369033}$ , 1.625803894  
 $\times 10^{141914076169369033}]$ , [1.17, [3.950723325  $\times 10^{283828152338738066}$ , 1.184435804  
 $\times 10^{283828152338738066}]$ , [1.18, [2.096830629  $\times 10^{567656304677476132}$ , 6.286345725  
 $\times 10^{567656304677476131}]$ , [1.19, [5.906589945  $\times 10^{1135312609354952263}$ , 1.770809048  
 $\times 10^{1135312609354952263}]$ , [1.20, [4.686879220  $\times 10^{2270625218709904526}$ , 1.405137009  
 $\times 10^{2270625218709904526}]$ , [1.21, [2.951057303  $\times 10^{4541250437419809052}$ , 8.847336649  
 $\times 10^{4541250437419809051}]$ , [1.22, [1.169944886  $\times 10^{9082500874839618104}$ , 3.507521275  
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[1.25, [Float(∞), Float(∞)]], [1.26, [Float(∞), Float(∞)]], [1.27, [Float(∞),  
Float(∞)]], [1.28, [Float(∞), Float(∞)]], [1.29, [Float(∞), Float(∞)]], [1.30, [  
Float(∞), Float(∞)]], [1.31, [Float(∞), Float(∞)]], [1.32, [Float(∞), Float(∞)]],  
[1.33, [Float(∞), Float(∞)]], [1.34, [Float(∞), Float(∞)]], [1.35, [Float(∞),  
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Float(∞)]], [1.44, [Float(∞), Float(∞)]], [1.45, [Float(∞), Float(∞)]], [1.46, [  
Float(∞), Float(∞)]], [1.47, [Float(∞), Float(∞)]], [1.48, [Float(∞), Float(∞)]],  
[1.49, [Float(∞), Float(∞)]], [1.50, [Float(∞), Float(∞)]], [1.51, [Float(∞),  
Float(∞)]], [1.52, [Float(∞), Float(∞)]], [1.53, [Float(∞), Float(∞)]], [1.54, [  
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[1.57, [Float(∞), Float(∞)]], [1.58, [Float(∞), Float(∞)]], [1.59, [Float(∞),  
Float(∞)]], [1.60, [Float(∞), Float(∞)]], [1.61, [Float(∞), Float(∞)]], [1.62, [  
Float(∞), Float(∞)]], [1.63, [Float(∞), Float(∞)]], [1.64, [Float(∞), Float(∞)]],  
[1.65, [Float(∞), Float(∞)]], [1.66, [Float(∞), Float(∞)]], [1.67, [Float(∞),  
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Float(∞), Float(∞)]], [1.71, [Float(∞), Float(∞)]], [1.72, [Float(∞), Float(∞)]],



















```
Float(∞)], [9.84, [Float(∞), Float(∞)]], [9.85, [Float(∞), Float(∞)]], [9.86, [
Float(∞), Float(∞)]], [9.87, [Float(∞), Float(∞)]], [9.88, [Float(∞), Float(∞)]],
[9.89, [Float(∞), Float(∞)]], [9.90, [Float(∞), Float(∞)]], [9.91, [Float(∞),
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[9.97, [Float(∞), Float(∞)]], [9.98, [Float(∞), Float(∞)]], [9.99, [Float(∞),
Float(∞)]], [10.00, [Float(∞), Float(∞)]], [10.01, [Float(∞), Float(∞)]]]
```

```
> #Stable equilibrium points of f2
if nops(s2)=0 then print(`no stable equilibra`);
end if:
for i in s2 do:
print(`for stable equilibrium point`, i);
print(Dis2(F2,x,y,i+[0.01,0.01],0.01,10));
od:
```

*no stable equilibra*

(11)

```
> #unstable equilibrium point of f2:
for i in alleged_unstable2 do:
print(`for unstable equilibrium point`, i);
print(Dis2(F2,x,y,i+[0.01,0.01],0.01,10));
od:
```

*for unstable equilibrium point,  $\left[-\frac{16}{37}, \frac{52}{37}\right]$*

```
[[0.01, [-0.4224324324, 1.415405405]], [0.02, [-0.4207508108, 1.419245189]], [0.03,
[-0.4186127186, 1.424468035]], [0.04, [-0.4158545210, 1.431586299]], [0.05,
[-0.4122415216, 1.441320559]], [0.06, [-0.4074295126, 1.454700222]], [0.07,
[-0.4008995440, 1.473226309]], [0.08, [-0.3918420907, 1.499146581]], [0.09,
[-0.3789402830, 1.535945032]], [0.10, [-0.3599386012, 1.589267109]], [0.11,
[-0.3307195297, 1.668799973]], [0.12, [-0.2831411378, 1.792447683]], [0.13,
[-0.1993644865, 1.996695977]], [0.14, [-0.0345955061, 2.366365087]], [0.15,
[0.3471569686, 3.138661083]], [0.16, [1.492607022, 5.186428835]], [0.17, [6.849781371,
13.50441920]], [0.18, [65.05170752, 91.28852853]], [0.19, [3714.144767, 4325.200538]],
[0.20, [9.719302001 × 106, 1.008383417 × 107]], [0.21, [5.886006570 × 1013, 5.639282587
× 1013]], [0.22, [1.991032133 × 1027, 1.801815520 × 1027]], [0.23, [2.154086634 × 1054,
1.869559977 × 1054]], [0.24, [2.422330857 × 10108, 2.037943025 × 10108]], [0.25,
[2.974795320 × 10216, 2.444780210 × 10216]], [0.26, [4.390002974 × 10432, 3.544266882
```

$\times 10^{432}]$ , [0.27, [9.405767886  $\times 10^{864}$ , 7.491403384  $\times 10^{864}$ ]], [0.28, [4.264709884  $\times 10^{1729}$ , 3.361566923  $\times 10^{1729}$ ]], [0.29, [8.685498266  $\times 10^{3458}$ , 6.791627016  $\times 10^{3458}$ ]], [0.30, [3.576671889  $\times 10^{6917}$ , 2.779590817  $\times 10^{6917}$ ]], [0.31, [6.031802363  $\times 10^{13834}$ , 4.665317328  $\times 10^{13834}$ ]], [0.32, [1.708183178  $\times 10^{27669}$ , 1.316343979  $\times 10^{27669}$ ]], [0.33, [1.365471347  $\times 10^{55338}$ , 1.049251079  $\times 10^{55338}$ ]], [0.34, [8.703147618  $\times 10^{110675}$ , 6.672887042  $\times 10^{110675}$ ]], [0.35, [3.528666971  $\times 10^{221351}$ , 2.700873053  $\times 10^{221351}$ ]], [0.36, [5.791865245  $\times 10^{442702}$ , 4.427257910  $\times 10^{442702}$ ]], [0.37, [1.558553549  $\times 10^{885405}$ , 1.190118488  $\times 10^{885405}$ ]], [0.38, [1.127537437  $\times 10^{1770810}$ , 8.603035793  $\times 10^{1770809}$ ]], [0.39, [5.897136244  $\times 10^{3541619}$ , 4.496679352  $\times 10^{3541619}$ ]], [0.40, [1.612212355  $\times 10^{7083239}$ , 1.228749374  $\times 10^{7083239}$ ]], [0.41, [1.204477294  $\times 10^{14166478}$ , 9.176494365  $\times 10^{14166477}$ ]], [0.42, [6.720585027  $\times 10^{28332955}$ , 5.118688890  $\times 10^{28332955}$ ]], [0.43, [2.091760424  $\times 10^{56665911}$ , 1.592814844  $\times 10^{56665911}$ ]], [0.44, [2.025977490  $\times 10^{113331822}$ , 1.542451767  $\times 10^{113331822}$ ]], [0.45, [1.900256982  $\times 10^{226663644}$ , 1.446538411  $\times 10^{226663644}$ ]], [0.46, [1.671534091  $\times 10^{453327288}$ , 1.272291897  $\times 10^{453327288}$ ]], [0.47, [1.293243248  $\times 10^{906654576}$ , 9.842737704  $\times 10^{906654575}$ ]], [0.48, [7.740668385  $\times 10^{1813309151}$ , 5.890963231  $\times 10^{1813309151}$ ]], [0.49, [2.773002754  $\times 10^{3626618303}$ , 2.110262661  $\times 10^{3626618303}$ ]], [0.50, [3.558564365  $\times 10^{7253236606}$ , 2.707972354  $\times 10^{7253236606}$ ]], [0.51, [5.860153503  $\times 10^{14506473212}$ , 4.459286004  $\times 10^{14506473212}$ ]], [0.52, [1.589153178  $\times 10^{29012946425}$ , 1.209238435  $\times 10^{29012946425}$ ]], [0.53, [1.168611916  $\times 10^{58025892850}$ , 8.892187301  $\times 10^{58025892849}$ ]], [0.54, [6.319350230  $\times 10^{116051785699}$ , 4.808444256  $\times 10^{116051785699}$ ]], [0.55, [1.847869208  $\times 10^{232103571399}$ , 1.406043069  $\times 10^{232103571399}$ ]], [0.56, [1.580027397  $\times 10^{464207142798}$ , 1.202232073  $\times 10^{464207142798}$ ]], [0.57, [1.155175894  $\times 10^{928414285596}$ , 8.789596375  $\times 10^{928414285595}$ ]], [0.58, [6.174653206  $\times 10^{1856828571191}$ , 4.698196201  $\times 10^{1856828571191}$ ]], [0.59, [1.764166203  $\times 10^{3713657142383}$ , 1.342320859  $\times 10^{3713657142383}$ ]], [0.60, [1.440097227  $\times 10^{7427314284766}$ , 1.095739468  $\times 10^{7427314284766}$ ]], [0.61, [9.596110751  $\times 10^{14854628569531}$ , 7.301459706  $\times 10^{14854628569531}$ ]], [0.62, [4.260898585  $\times 10^{29709257139063}$ , 3.242013531  $\times 10^{29709257139063}$ ]], [0.63, [8.400639875  $\times 10^{59418514278126}$ , 6.391832111  $\times 10^{59418514278126}$ ]], [0.64, [3.265383141  $\times 10^{118837028556253}$ , 2.484543732  $\times 10^{118837028556253}$ ]], [0.65, [4.933751459  $\times 10^{237674057112506}$ , 3.753957781  $\times 10^{237674057112506}$ ]], [0.66, [1.126323569  $\times 10^{475348114225013}$ , 8.569884935  $\times 10^{475348114225012}$ ]], [0.67, [5.869954261  $\times 10^{950696228450025}$ , 4.466283686

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 $\times 10^{15211139655200407}]$ ], [0.72, [ $1.662878661 \times 10^{30422279310400814}$ , 1.265236086  
 $\times 10^{30422279310400814}]$ ], [0.73, [ $1.279466082 \times 10^{60844558620801628}$ , 9.735084740  
 $\times 10^{60844558620801627}]$ ], [0.74, [ $7.574695285 \times 10^{121689117241603255}$ , 5.763364486  
 $\times 10^{121689117241603255}]$ ], [0.75, [ $2.654837298 \times 10^{243378234483206511}$ , 2.019988044  
 $\times 10^{243378234483206511}]$ ], [0.76, [ $3.261244583 \times 10^{486756468966413022}$ , 2.481385472  
 $\times 10^{486756468966413022}]$ ], [0.77, [ $4.921236878 \times 10^{973512937932826044}$ , 3.744424822  
 $\times 10^{973512937932826044}]$ ], [0.78, [ $1.120614020 \times 10^{1947025875865652089}$ , 8.526423165  
 $\times 10^{1947025875865652088}]$ ], [0.79, [ $5.810581569 \times 10^{3894051751731304177}$ , 4.421100856  
 $\times 10^{3894051751731304177}]$ ], [0.80, [ $1.562236188 \times 10^{7788103503462608355}$ , 1.188659608  
 $\times 10^{7788103503462608355}]$ ], [0.81, [Float(∞), Float(∞) ]], [0.82, [Float(∞), Float(∞) ]],  
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[1.23, [Float(∞), Float(∞) ]], [1.24, [Float(∞), Float(∞) ]], [1.25, [Float(∞),  
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Float(∞)], [9.50, [Float(∞), Float(∞)]], [9.51, [Float(∞), Float(∞)]], [9.52, [Float(∞), Float(∞)]], [9.53, [Float(∞), Float(∞)]], [9.54, [Float(∞), Float(∞)]], [9.55, [Float(∞), Float(∞)]], [9.56, [Float(∞), Float(∞)]], [9.57, [Float(∞), Float(∞)]], [9.58, [Float(∞), Float(∞)]], [9.59, [Float(∞), Float(∞)]], [9.60, [Float(∞), Float(∞)]], [9.61, [Float(∞), Float(∞)]], [9.62, [Float(∞), Float(∞)]], [9.63, [Float(∞), Float(∞)]], [9.64, [Float(∞), Float(∞)]], [9.65, [Float(∞), Float(∞)]], [9.66, [Float(∞), Float(∞)]], [9.67, [Float(∞), Float(∞)]], [9.68, [Float(∞), Float(∞)]], [9.69, [Float(∞), Float(∞)]], [9.70, [Float(∞), Float(∞)]], [9.71, [Float(∞), Float(∞)]], [9.72, [Float(∞), Float(∞)]], [9.73, [Float(∞), Float(∞)]], [9.74, [Float(∞), Float(∞)]], [9.75, [Float(∞), Float(∞)]], [9.76, [Float(∞), Float(∞)]], [9.77, [Float(∞), Float(∞)]], [9.78, [Float(∞), Float(∞)]], [9.79, [Float(∞), Float(∞)]], [9.80, [Float(∞), Float(∞)]], [9.81, [Float(∞), Float(∞)]], [9.82, [Float(∞), Float(∞)]], [9.83, [Float(∞), Float(∞)]], [9.84, [Float(∞), Float(∞)]], [9.85, [Float(∞), Float(∞)]], [9.86, [Float(∞), Float(∞)]], [9.87, [Float(∞), Float(∞)]], [9.88, [Float(∞), Float(∞)]], [9.89, [Float(∞), Float(∞)]], [9.90, [Float(∞), Float(∞)]], [9.91, [Float(∞), Float(∞)]], [9.92, [Float(∞), Float(∞)]], [9.93, [Float(∞), Float(∞)]], [9.94, [Float(∞), Float(∞)]], [9.95, [Float(∞), Float(∞)]], [9.96, [Float(∞), Float(∞)]], [9.97, [Float(∞), Float(∞)]], [9.98, [Float(∞), Float(∞)]], [9.99, [Float(∞), Float(∞)]], [10.00, [Float(∞), Float(∞)]], [10.01, [Float(∞), Float(∞)]]]

*for unstable equilibrium point,  $\left[-\frac{4}{3}, \frac{14}{9}\right]$*

[ [0.01, [-1.323333333, 1.565555556]], [0.02, [-1.326051111, 1.569500445]], [0.03, [-1.329116321, 1.574648714]], [0.04, [-1.332684939, 1.581411134]], [0.05, [-1.336960713, 1.590348640]], [0.06, [-1.342212217, 1.602236973]], [0.07, [-1.348796489, 1.618166325]], [0.08, [-1.357192127, 1.639700493]], [0.09, [-1.368045912, 1.669141777]], [0.10, [-1.382238316, 1.709993619]], [0.11, [-1.400972966, 1.767815552]], [0.12, [-1.425886183, 1.851913252]], [0.13, [-1.459124968, 1.978964960]], [0.14, [-1.503120752, 2.181642982]], [0.15, [-1.558723228, 2.532009100]], [0.16, [-1.614516507, 3.217323041]], [0.17, [-1.579796474, 4.855488846]], [0.18, [-0.7125891290, 10.41026619]], [0.19, [11.26140272, 47.04519994]], [0.20, [512.4926944, 1008.084558]], [0.21, [349541.1949, 496748.0816]], [0.22, [1.079455430 × 10<sup>11</sup>, 1.274328929 × 10<sup>11</sup>]], [0.23, [8.331486942 × 10<sup>21</sup>, 8.725217790 × 10<sup>21</sup>]], [0.24, [4.367248006 × 10<sup>43</sup>, 4.211872040 × 10<sup>43</sup>]], [0.25, [1.103340946 × 10<sup>87</sup>, 1.003272998 × 10<sup>87</sup>]], [0.26, [6.645692556 × 10<sup>173</sup>, 5.788312132 × 10<sup>173</sup>]], [0.27, [2.313369202 × 10<sup>347</sup>, 1.951432095 × 10<sup>347</sup>]], [0.28, [2.719906573



$\times 10^{694}$ ,  $2.239783180 \times 10^{694}$ ], [0.29, [ $3.676719460 \times 10^{1388}$ ,  $2.972923097 \times 10^{1388}$ ]],  
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 $2.347339744 \times 10^{2843136}$ ]], [0.41, [ $4.385906509 \times 10^{5686272}$ ,  $3.346649202 \times 10^{5686272}$ ]],  
 [0.42, [ $8.923281822 \times 10^{11372544}$ ,  $6.804539096 \times 10^{11372544}$ ]], [0.43, [ $3.691559124$   
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 $\times 10^{45490178}$ ]], [0.45, [ $1.847574752 \times 10^{90980357}$ ,  $1.407228478 \times 10^{90980357}$ ]], [0.46,  
 $1.580925883 \times 10^{181960714}$ ,  $1.203852735 \times 10^{181960714}$ ]], [0.47, [ $1.157287546 \times 10^{363921428}$ ,  
 $8.810993111 \times 10^{363921427}$ ]], [0.48, [ $6.200568549 \times 10^{727842855}$ ,  $4.720133468$   
 $\times 10^{727842855}$ ]], [0.49, [ $1.779746449 \times 10^{1455685711}$ ,  $1.354670413 \times 10^{1455685711}$ ]], [0.50,  
 $1.466120083 \times 10^{2911371422}$ ,  $1.115856465 \times 10^{2911371422}$ ]], [0.51, [ $9.948551485$   
 $\times 10^{5822742843}$ ,  $7.571293987 \times 10^{5822742843}$ ]], [0.52, [ $4.580524510 \times 10^{11645485687}$ ,  
 $3.485806672 \times 10^{11645485687}$ ]], [0.53, [ $9.709710994 \times 10^{23290971374}$ ,  $7.388855248$   
 $\times 10^{23290971374}$ ]], [0.54, [ $4.362879674 \times 10^{46581942749}$ ,  $3.319943564 \times 10^{46581942749}$ ]],  
 [0.55, [ $8.808363889 \times 10^{93163885498}$ ,  $6.702584659 \times 10^{93163885498}$ ]], [0.56, [ $3.590294404$   
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 $4.538634647 \times 10^{372655541994}$ ]], [0.58, [ $1.646311130 \times 10^{745311083989}$ ,  $1.252678783$   
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 $2.115008531 \times 10^{11924977343822}$ ]], [0.63, [ $3.575223658 \times 10^{23849954687644}$ ,  $2.720312663$   
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 $\times 10^{190799637501153}$ ]], [0.67, [ $6.800140552 \times 10^{381599275002307}$ ,  $5.174047735$   
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$\times 10^{1526397100009230}]$ , [0.70, [ $2.076370710 \times 10^{3052794200018460}$ , 1.579852354  
 $\times 10^{3052794200018460}]$ , [0.71, [ $1.994885502 \times 10^{6105588400036920}$ , 1.517851896  
 $\times 10^{6105588400036920}]$ , [0.72, [ $1.841382330 \times 10^{12211176800073840}$ , 1.401055217  
 $\times 10^{12211176800073840}]$ , [0.73, [ $1.568902082 \times 10^{24422353600147680}$ , 1.193732473  
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 $\times 10^{97689414400590719}]$ , [0.76, [ $1.666944001 \times 10^{195378828801181439}$ , 1.268329149  
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 $\times 10^{390757657602362877}]$ , [0.78, [ $7.649038617 \times 10^{781515315204725755}$ , 5.819929773  
 $\times 10^{781515315204725755}]$ , [0.79, [ $2.707205718 \times 10^{1563030630409451511}$ , 2.059833538  
 $\times 10^{1563030630409451511}]$ , [0.80, [ $3.391173794 \times 10^{3126061260818903022}$ , 2.580244703  
 $\times 10^{3126061260818903022}]$ , [0.81, [ $5.321175817 \times 10^{6252122521637806044}$ , 4.048726510  
 $\times 10^{6252122521637806044}]$ , [0.82, [Float(∞), Float(∞)]], [0.83, [Float(∞), Float(∞)]],  
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Float(∞)]], [1.03, [Float(∞), Float(∞)]], [1.04, [Float(∞), Float(∞)]], [1.05, [  
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[1.08, [Float(∞), Float(∞)]], [1.09, [Float(∞), Float(∞)]], [1.10, [Float(∞),  
Float(∞)]], [1.11, [Float(∞), Float(∞)]], [1.12, [Float(∞), Float(∞)]], [1.13, [  
Float(∞), Float(∞)]], [1.14, [Float(∞), Float(∞)]], [1.15, [Float(∞), Float(∞)]],  
[1.16, [Float(∞), Float(∞)]], [1.17, [Float(∞), Float(∞)]], [1.18, [Float(∞),  
Float(∞)]], [1.19, [Float(∞), Float(∞)]], [1.20, [Float(∞), Float(∞)]], [1.21, [  
Float(∞), Float(∞)]], [1.22, [Float(∞), Float(∞)]], [1.23, [Float(∞), Float(∞)]],  
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Float(∞)]], [1.27, [Float(∞), Float(∞)]], [1.28, [Float(∞), Float(∞)]], [1.29, [  
Float(∞), Float(∞)]], [1.30, [Float(∞), Float(∞)]], [1.31, [Float(∞), Float(∞)]],  
[1.32, [Float(∞), Float(∞)]], [1.33, [Float(∞), Float(∞)]], [1.34, [Float(∞),  
Float(∞)]], [1.35, [Float(∞), Float(∞)]], [1.36, [Float(∞), Float(∞)]], [1.37, [  
Float(∞), Float(∞)]], [1.38, [Float(∞), Float(∞)]], [1.39, [Float(∞), Float(∞)]],  
[1.40, [Float(∞), Float(∞)]], [1.41, [Float(∞), Float(∞)]], [1.42, [Float(∞),  
Float(∞)]], [1.43, [Float(∞), Float(∞)]], [1.44, [Float(∞), Float(∞)]], [1.45, [



















[9.56, [Float(∞), Float(∞) ]], [9.57, [Float(∞), Float(∞) ]], [9.58, [Float(∞), Float(∞) ]], [9.59, [Float(∞), Float(∞) ]], [9.60, [Float(∞), Float(∞) ]], [9.61, [Float(∞), Float(∞) ]], [9.62, [Float(∞), Float(∞) ]], [9.63, [Float(∞), Float(∞) ]], [9.64, [Float(∞), Float(∞) ]], [9.65, [Float(∞), Float(∞) ]], [9.66, [Float(∞), Float(∞) ]], [9.67, [Float(∞), Float(∞) ]], [9.68, [Float(∞), Float(∞) ]], [9.69, [Float(∞), Float(∞) ]], [9.70, [Float(∞), Float(∞) ]], [9.71, [Float(∞), Float(∞) ]], [9.72, [Float(∞), Float(∞) ]], [9.73, [Float(∞), Float(∞) ]], [9.74, [Float(∞), Float(∞) ]], [9.75, [Float(∞), Float(∞) ]], [9.76, [Float(∞), Float(∞) ]], [9.77, [Float(∞), Float(∞) ]], [9.78, [Float(∞), Float(∞) ]], [9.79, [Float(∞), Float(∞) ]], [9.80, [Float(∞), Float(∞) ]], [9.81, [Float(∞), Float(∞) ]], [9.82, [Float(∞), Float(∞) ]], [9.83, [Float(∞), Float(∞) ]], [9.84, [Float(∞), Float(∞) ]], [9.85, [Float(∞), Float(∞) ]], [9.86, [Float(∞), Float(∞) ]], [9.87, [Float(∞), Float(∞) ]], [9.88, [Float(∞), Float(∞) ]], [9.89, [Float(∞), Float(∞) ]], [9.90, [Float(∞), Float(∞) ]], [9.91, [Float(∞), Float(∞) ]], [9.92, [Float(∞), Float(∞) ]], [9.93, [Float(∞), Float(∞) ]], [9.94, [Float(∞), Float(∞) ]], [9.95, [Float(∞), Float(∞) ]], [9.96, [Float(∞), Float(∞) ]], [9.97, [Float(∞), Float(∞) ]], [9.98, [Float(∞), Float(∞) ]], [9.99, [Float(∞), Float(∞) ]], [10.00, [Float(∞), Float(∞) ]], [10.01, [Float(∞), Float(∞) ]]

*for unstable equilibrium point,  $\left[ \frac{2}{11}, \frac{6}{11} \right]$*

[[0.01, [0.1918181818, 0.5554545455 ]], [0.02, [0.1918781818, 0.5518741819 ]], [0.03, [0.1919185523, 0.5494010141 ]], [0.04, [0.1919475278, 0.5476989552 ]], [0.05, [0.1919696956, 0.5465304972 ]], [0.06, [0.1919876827, 0.5457296532 ]], [0.07, [0.1920030400, 0.5451812986 ]], [0.08, [0.1920167109, 0.5448059996 ]], [0.09, [0.1920292850, 0.5445491425 ]], [0.10, [0.1920411393, 0.5443732693 ]], [0.11, [0.1920525192, 0.5442527310 ]], [0.12, [0.1920635868, 0.5441699844 ]], [0.13, [0.1920744500, 0.5441130399 ]], [0.14, [0.1920851815, 0.5440737077 ]], [0.15, [0.1920958302, 0.5440463953 ]], [0.16, [0.1921064294, 0.5440272849 ]], [0.17, [0.1921170016, 0.5440137708 ]], [0.18, [0.1921275623, 0.5440040744 ]], [0.19, [0.1921381220, 0.5439969822 ]], [0.20, [0.1921486878, 0.5439916660 ]], [0.21, [0.1921592647, 0.5439875606 ]], [0.22, [0.1921698561, 0.5439842804 ]], [0.23, [0.1921804642, 0.5439815623 ]], [0.24, [0.1921910907, 0.5439792267 ]], [0.25, [0.1922017368, 0.5439771511 ]], [0.26, [0.1922124032, 0.5439752520 ]], [0.27, [0.1922230904, 0.5439734723 ]], [0.28, [0.1922337989, 0.5439717730 ]], [0.29, [0.1922445290, 0.5439701276 ]], [0.30, [0.1922552809, 0.5439685180 ]], [0.31, [0.1922660547, 0.5439669318 ]], [0.32, [0.1922768506, 0.5439653606 ]], [0.33, [0.1922876688, 0.5439637986 ]], [0.34, [0.1922985093, 0.5439622419 ]], [0.35, [0.1923093722, 0.5439606878 ]], [0.36, [0.1923202576, 0.5439591344 ]], [0.37,

**(12)**

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Analyzing F3:

```
> #Stable equilibrium of f3
if nops(s3)=0 then print(`no stable equilibra`);
end if:
for i in s3 do:
print(`for stable equilibrium point`, i);
print(Dis2(F3,x,y,i+[0.01,0.01],0.01,10));
od:
```

*for stable equilibrium point,  $\left[ \frac{1}{18}, \frac{7}{18} \right]$*

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(13)



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```
> #unstable equilibrium points of f3:
for i in alleged_unstable3 do:
print(`for unstable equilibrium point`, i);
print(Dis2(F3,x,y,i+[0.01,0.01],0.01,10));
od:
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*for unstable equilibrium point,  $\left[ \frac{3}{5}, \frac{1}{10} \right]$*

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Float(∞)], [9.74, [Float(∞), Float(∞)]], [9.75, [Float(∞), Float(∞)]], [9.76, [Float(∞), Float(∞)]], [9.77, [Float(∞), Float(∞)]], [9.78, [Float(∞), Float(∞)]], [9.79, [Float(∞), Float(∞)]], [9.80, [Float(∞), Float(∞)]], [9.81, [Float(∞), Float(∞)]], [9.82, [Float(∞), Float(∞)]], [9.83, [Float(∞), Float(∞)]], [9.84, [Float(∞), Float(∞)]], [9.85, [Float(∞), Float(∞)]], [9.86, [Float(∞), Float(∞)]], [9.87, [Float(∞), Float(∞)]], [9.88, [Float(∞), Float(∞)]], [9.89, [Float(∞), Float(∞)]], [9.90, [Float(∞), Float(∞)]], [9.91, [Float(∞), Float(∞)]], [9.92, [Float(∞), Float(∞)]], [9.93, [Float(∞), Float(∞)]], [9.94, [Float(∞), Float(∞)]], [9.95, [Float(∞), Float(∞)]], [9.96, [Float(∞), Float(∞)]], [9.97, [Float(∞), Float(∞)]], [9.98, [Float(∞), Float(∞)]], [9.99, [Float(∞), Float(∞)]], [10.00, [Float(∞), Float(∞)]], [10.01, [Float(∞), Float(∞)]]]

*for unstable equilibrium point,  $\left[ \frac{5}{13}, \frac{2}{13} \right]$*

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*for unstable equilibrium point,  $\left[ \frac{6}{13}, \frac{4}{13} \right]$*

[ [0.01, [0.4715384615, 0.3176923077]], [0.02, [0.4719838461, 0.3192738462]], [0.03, [0.4724958648, 0.3210121931]], [0.04, [0.4730826168, 0.3229279607]], [0.05, [0.4737535130, 0.3250450166]], [0.06, [0.4745195416, 0.3273911414]], [0.07, [0.4753936013, 0.3299988528]], [0.08, [0.4763909226, 0.3329064467]], [0.09, [0.4775296053, 0.3361593252]], [0.10, [0.4788313112, 0.3398117066]], [0.11, [0.4803221671, 0.3439288527]], [0.12, [0.4820339549, 0.3485900032]], [0.13, [0.4840057009, 0.3538922915]], [0.14, [0.4862858278, 0.3599560449]], [0.15, [0.4889351141, 0.3669320679]], [0.16, [0.4920308333, 0.3750118240]], [0.17, [0.4956726524, 0.3844419389]], [0.18, [0.4999912174, 0.3955452986]], [0.19, [0.5051609467, 0.4087524738]], [0.20, [0.5114196103, 0.4246497906]], [0.21, [0.5190992191, 0.4440551352]], [0.22, [0.5286764882, 0.4681417452]], [0.23, [0.5408586917, 0.4986487355]], [0.24, [0.5567368541, 0.5382566046]], [0.25, [0.5780750396, 0.5912961029]], [0.26, [0.6078954354, 0.6651814561]], [0.27, [0.6517660949, 0.7735639277]], [0.28, [0.7209544686, 0.9440525743]], [0.29, [0.8412995090, 1.239931056]], [0.30, [1.083316945, 1.833835507]], [0.31, [1.695541367, 3.334047842]], [0.32, [3.991943959, 8.955896088]], [0.33, [22.14651944, 53.38143473]], [0.34, [695.7819033, 1701.727450]], [0.35, [691032.8960, 1.690935186 × 10<sup>6</sup>]], [0.36, [6.817923412 × 10<sup>11</sup>, 1.668316936 × 10<sup>12</sup>]], [0.37, [6.636748016 × 10<sup>23</sup>, 1.623987371 × 10<sup>24</sup>]], [0.38, [6.288735934 × 10<sup>47</sup>, 1.538828755 × 10<sup>48</sup>]], [0.39, [5.646491965 × 10<sup>95</sup>, 1.381674738 × 10<sup>96</sup>]], [0.40, [4.552078412 × 10<sup>191</sup>, 1.113875787 × 10<sup>192</sup>]], [0.41,

**(14)**

$[2.958500449 \times 10^{383}, 7.239335445 \times 10^{383}]$ ,  $[0.42, [1.249670473 \times 10^{767}, 3.057894906 \times 10^{767}]]$ ,  $[0.43, [2.229683500 \times 10^{1534}, 5.455948641 \times 10^{1534}]]$ ,  $[0.44, [7.098043477 \times 10^{3068}, 1.736863568 \times 10^{3069}]]$ ,  $[0.45, [7.193322310 \times 10^{6137}, 1.760177933 \times 10^{6138}]]$ ,  $[0.46, [7.387734045 \times 10^{12275}, 1.807749723 \times 10^{12276}]]$ ,  $[0.47, [7.792462412 \times 10^{24551}, 1.906785179 \times 10^{24552}]]$ ,  $[0.48, [8.669651576 \times 10^{49103}, 2.121429946 \times 10^{49104}]]$ ,  $[0.49, [1.073137816 \times 10^{98208}, 2.625926405 \times 10^{98208}]]$ ,  $[0.50, [1.644232429 \times 10^{196416}, 4.023372664 \times 10^{196416}]]$ ,  $[0.51, [3.859922905 \times 10^{392832}, 9.445080893 \times 10^{392832}]]$ ,  $[0.52, [2.127205623 \times 10^{785665}, 5.205189243 \times 10^{785665}]]$ ,  $[0.53, [6.460574752 \times 10^{1571330}, 1.580877460 \times 10^{1571331}]]$ ,  $[0.54, [5.959290043 \times 10^{3142661}, 1.458215045 \times 10^{3142662}]]$ ,  $[0.55, [5.070388748 \times 10^{6285323}, 1.240704363 \times 10^{6285324}]]$ ,  $[0.56, [3.670580285 \times 10^{12570647}, 8.981766886 \times 10^{12570647}]]$ ,  $[0.57, [1.923630555 \times 10^{25141295}, 4.707048987 \times 10^{25141295}]]$ ,  $[0.58, [5.283181673 \times 10^{50282590}, 1.292773962 \times 10^{50282591}]]$ ,  $[0.59, [3.985137415 \times 10^{100565181}, 9.751475921 \times 10^{100565181}]]$ ,  $[0.60, [2.267455717 \times 10^{201130363}, 5.548375756 \times 10^{201130363}]]$ ,  $[0.61, [7.340570930 \times 10^{402260726}, 1.796209093 \times 10^{402260727}]]$ ,  $[0.62, [7.693286216 \times 10^{804521453}, 1.882517150 \times 10^{804521454}]]$ ,  $[0.63, [8.450375184 \times 10^{1609042907}, 2.067773869 \times 10^{1609042908}]]$ ,  $[0.64, [1.019539823 \times 10^{3218085816}, 2.494774208 \times 10^{3218085816}]]$ ,  $[0.65, [1.484091234 \times 10^{6436171632}, 3.631513400 \times 10^{6436171632}]]$ ,  $[0.66, [3.144657930 \times 10^{12872343264}, 7.694855383 \times 10^{12872343264}]]$ ,  $[0.67, [1.411884053 \times 10^{25744686529}, 3.454825243 \times 10^{25744686529}]]$ ,  $[0.68, [2.846100797 \times 10^{51489373058}, 6.964297714 \times 10^{51489373058}]]$ ,  $[0.69, [1.156518983 \times 10^{102978746117}, 2.829956870 \times 10^{102978746117}]]$ ,  $[0.70, [1.909667434 \times 10^{205957492234}, 4.672881777 \times 10^{205957492234}]]$ ,  $[0.71, [5.206761629 \times 10^{411914984468}, 1.274074276 \times 10^{411914984469}]]$ ,  $[0.72, [3.870682983 \times 10^{823829968937}, 9.471410385 \times 10^{823829968937}]]$ ,  $[0.73, [2.139081923 \times 10^{1647659937875}, 5.234250089 \times 10^{1647659937875}]]$ ,  $[0.74, [6.532915589 \times 10^{3295319875750}, 1.598578981 \times 10^{3295319875751}]]$ ,  $[0.75, [6.093492842 \times 10^{6590639751501}, 1.491053947 \times 10^{6590639751502}]]$ ,  $[0.76, [5.301329790 \times 10^{13181279503003}, 1.297214736 \times 10^{13181279503004}]]$ ,  $[0.77, [4.012562921 \times 10^{26362559006007}, 9.818585065 \times 10^{26362559006007}]]$ ,  $[0.78, [2.298772128 \times 10^{52725118012015}, 5.625005794 \times 10^{52725118012015}]]$ ,  $[0.79, [7.544736160 \times 10^{105450236024030}, 1.846167530 \times 10^{105450236024031}]]$ ,  $[0.80, [8.127188364 \times 10^{210900472048061}, 1.988691315 \times 10^{210900472048062}]]$ ,  $[0.81, [9.430459684 \times 10^{421800944096123}, 2.307596725 \times 10^{421800944096124}]]$ ,  $[0.82, [1.269749167 \times 10^{843601888192248}, 3.107026719$



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```

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Float(∞), Float(∞)]], [10.00, [Float(∞), Float(∞)]], [10.01, [Float(∞), Float(∞)]]]

```

### PROBLEM 3:

Use EquPts(F,var) together with SIRS to find all the equilibrium points of the SIRS model,  
confirming Equations

### Problems 4:

Write a Maple code Chemostat(N,C,a1,a2) (analogous to SIRS) giving the underlying transformation

#Chemostat info is on page 126 of the book

#Parameters:

#

```

[ > print(SIRS);
      proc(s, i, β, γ, v, N) [ -β*s*i + γ*(N - s - i), β*s*i - v*i ] end proc (15)

```

```

[ > Chemostat := proc(N, C, a1, a2);
      [a1*C/(1+C)*N - N, -C/(1+C)*N+a2];
      end:

```

#Writing the underlying transformation is done

```
> Chemostat(N,C,a1,a2);
```

$$\left[ \frac{a1 CN}{C+1} - N, -\frac{CN}{C+1} + a2 \right] \quad (16)$$

$$\left[ 1, \frac{10}{3} \right] \quad (17)$$

NOW FIND THE EQUILIBRIUM POINTS of chemostat  
 #In the chemostat model, the "N" and "C" are the "x" and "y"

```
> EquPts(Chemostat(y,x,y,x),[x,y]);
```

```
{[0,0],[1,2]} (18)
```

Problem 5 (10 brownie points) Write a Dis3(x

```
> print(Dis2);
```

```
proc(F,x,y,pt,h,A) (19)
```

```
local L,i;
```

```
L := Orb2([x+h*F[1],y+h*F[2]],x,y,pt,0,trunc(A/h));
```

```
L := [seq([i*h,[L[i][1],L[i][2]]],i=1..nops(L))]
```

```
end proc
```

```
> print(Orbk);
```

```
proc(k,z,f,INI,K1,K2) (20)
```

```
local L,i,newguy;
```

```
L := INI;
```

```
if not (type(k,integer) and type(z,symbol) and type(INI,list) and nops(INI)=k and  

type(K1,integer) and type(K2,integer) and 0 < K1 and K1 < K2) then
```

```
print(bad input); RETURN(FAIL)
```

```
end if;
```

```
while nops(L) < K2 do
```

```
newguy := subs({seq(z[i]=L[-i],i=1..k)},f); L := [op(L),newguy]
```

```
end do;
```

```
[op(K1..K2,L)]
```

```
end proc
```

Code for dis3

```
> Dis3 := proc(F,x,y,z,pt,h,A) local L;
```

```
L := Orbk(3,g,g[1]+h*F[1]+g[2]+h*F[2]+g[3]+h*F[3],10,100);
```

```
print(L);
```

```
end;
```

```
Dis3 := proc(F,x,y,z,pt,h,A) (21)
```

```
local L;
```

```
L := Orbk(3, g, g[1] + h * F[1] + g[2] + h * F[2] + g[3] + h * F[3], 10, 100); print(L)
```

```
end proc
```

```
> dF1 := RandNice([x,y,z],10);
```

```
print(Dis3(dF1,x,y,z,[1,1,1],0.01,100));
```

```
dF2 := RandNice([x,y,z],10);
```

```
dF1 := [(2 - 2x - y - 3z) (5 - 4x - 3y - 10z), (1 - 8x - 3y - 8z) (8 - 7x - 5y  
- 6z), (7 - x - 5y - 6z) (6 - 6x - 4y - 10z)]
```

*bad input*

*FAIL*

```
dF2 := [(10 - 5x - 9y - 9z) (5 - 10x - 9y - 5z), (5 - 2x - 4y - 9z) (10 - 3x - 7y - z), (4 - 9x - 5y - 9z) (10 - 7x - 9y - 6z)] (22)
```