Ok to post Homework
Jeton Hida, Assignment 26, November 6, 2021

P14: i. $x'(t) = 2x(t)(1-x(t))(2-x(t))(3-x(t))$

$f(x) = 2x(1-x)(2-x)(3-x)$

$2x(1-x)(2-x)(3-x) = 0$

$x=0;\ x=1;\ x=2;\ x=3$

These values of x satisfy $f(x)=0$ so they are equilibrium points.

ii. Done in Maple (see in attached Maple file)

iii. $f(x) = 2x(1-x)(2-x)(3-x)$

$= 2x - 2x^2(2-x)(3-x)$

$= 4x - 2x^2 - 4x^2 + 2x^3(3-x)$

$= 4x - 6x^2 + 2x^3(3-x)$

$= 12x - 18x^2 + 6x^3 - 4x^2 + 6x^3 - 2x^4$

$= -2x^4 + 12x^3 - 22x^2 + 12x$

$f'(x) = -8x^3 + 36x^2 - 44x + 12$

$f'(0) = 12 > 0$ Not negative, $x(t)=0$ is an unstable equ sol.

$f'(1) = -8 + 36 - 44 + 12 = -4 < 0$ negative so $x(t)=1$ is a stable equ. sol.

$f'(2) = -64 + 144 - 88 + 12 = 4 > 0$ not negative, $x(t)=2$ is an unstable equ. sol.

$f'(3) = -216 + 324 - 132 + 12 = -12 < 0$ negative, $x(t)=3$ is a stable equ. sol.

Set of stable equilibria is [1, 3]

P15: $x(n) = x(n-1)^3 + 2y(n-1)$ $\quad y(n) = x(n-1)^2 + 5y(n-1)^2$

$x(0) = 1$, $y(0) = 3$

$x(0) = 1$ $\quad y(0) = 3$

$x(1) = 1^3 + 2(3) = 7$ $\quad y(1) = 1^2 + 5(3^2) = 46$

$x(2) = 7^3 + 2(46) = 435$ $\quad y(2) = 7^2 + 5(46^2) = 10629$

$x(3) = 435^3 + 2(10629) = 82334133$ $\quad y(3) = 435^2 + 5(10629^2) = 565067430$

First four terms are:

[[1,3],[7,46],[435,10629],[82334133,565067430]]

Will Maple Orb values in attached

P16: Found in Maple Code

P17: Found in Maple Code

```
> read "/Users/jeton/Desktop/Math 336/DMB.txt"
```

First Written: Nov. 2021

This is DMB.txt, A Maple package to explore Dynamical models in Biology (both discrete and continuous)
accompanying the class Dynamical Models in Biology, Rutgers University. Taught by Dr. Z. (Doron Zeilbeger)

The most current version is available on WWW at:
http://sites.math.rutgers.edu/~zeilberg/tokhniot/DMB.txt .
Please report all bugs to: DoronZeil at gmail dot com .

For general help, and a list of the MAIN functions,
type "Help();". For specific help type "Help(procedure_name);"

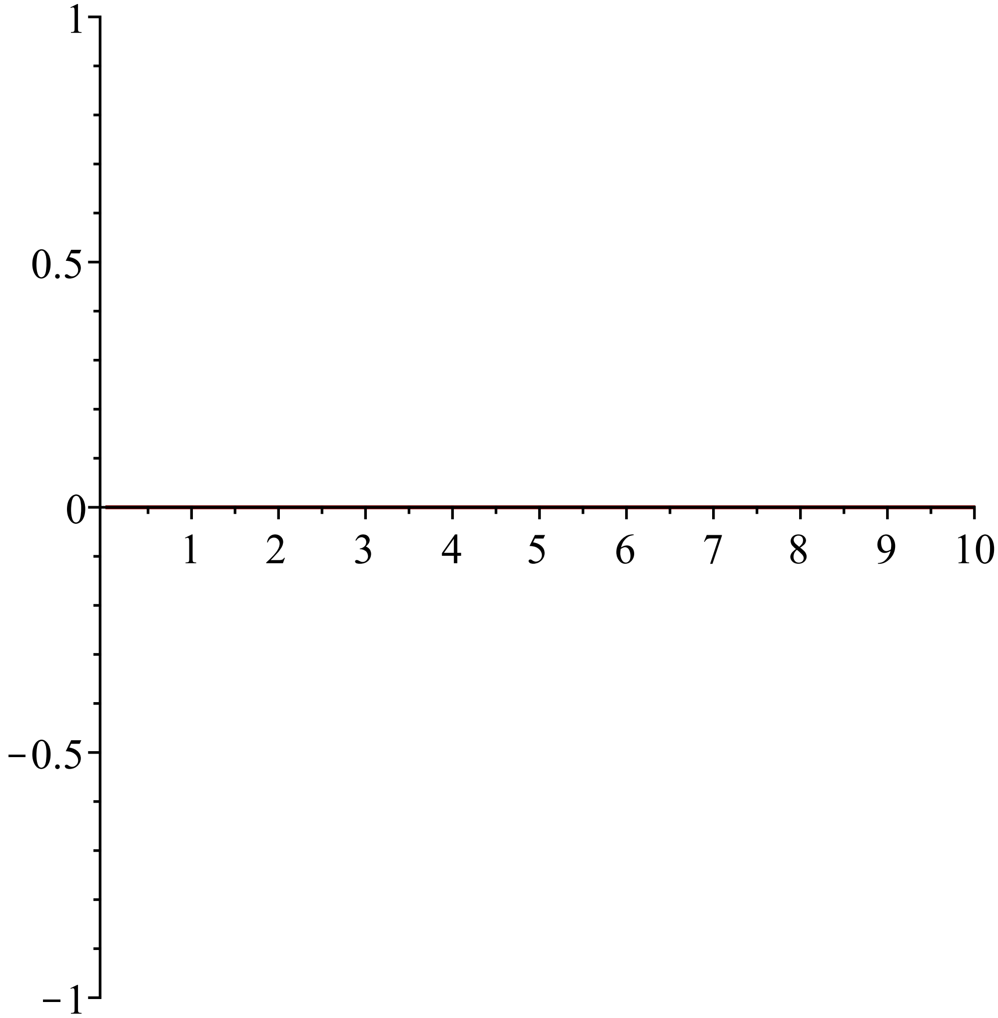
For a list of the supporting functions type: Help1();
For help with any of them type: Help(ProcedureName);

For a list of the functions that give examples of Discrete-time dynamical systems (some famous), type: HelpDDM();
For help with any of them type: Help(ProcedureName);

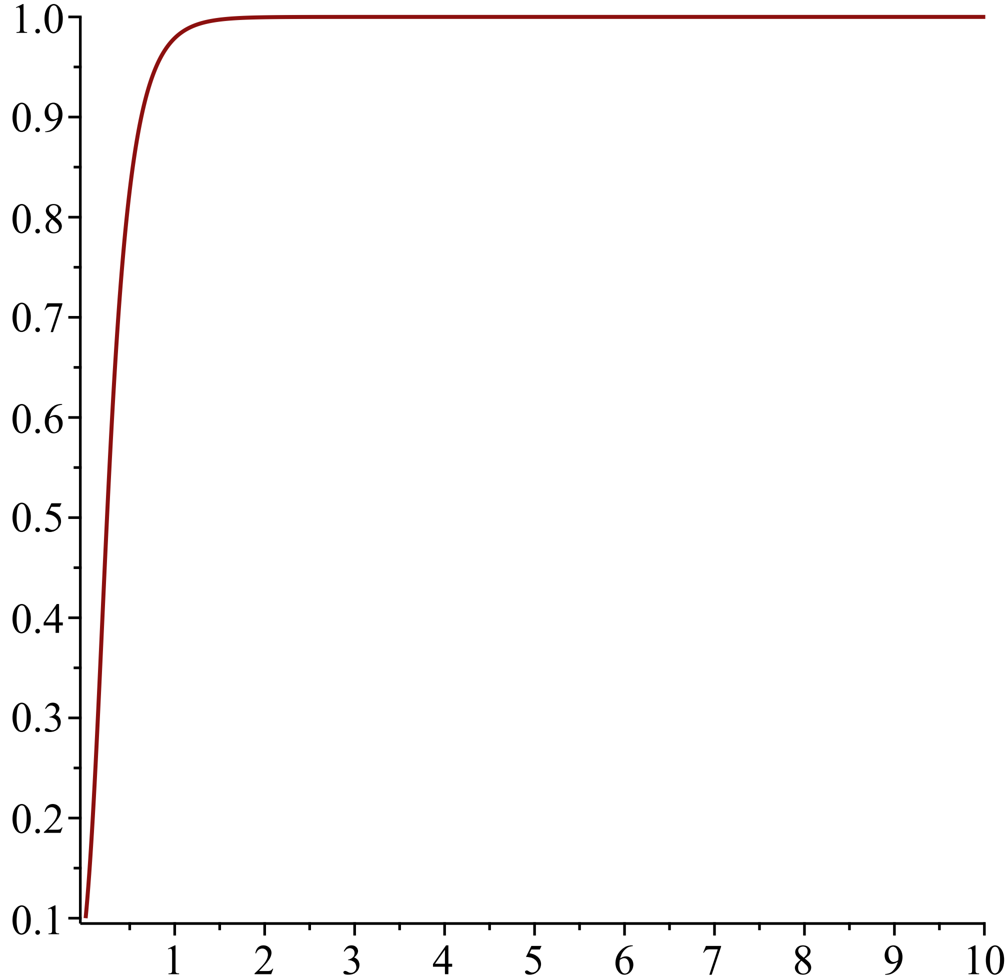
For a list of the functions continuous-time dynamical systems (some famous) type: HelpCDM();
For help with any of them type: Help(ProcedureName);

------------------------------ **(1)**

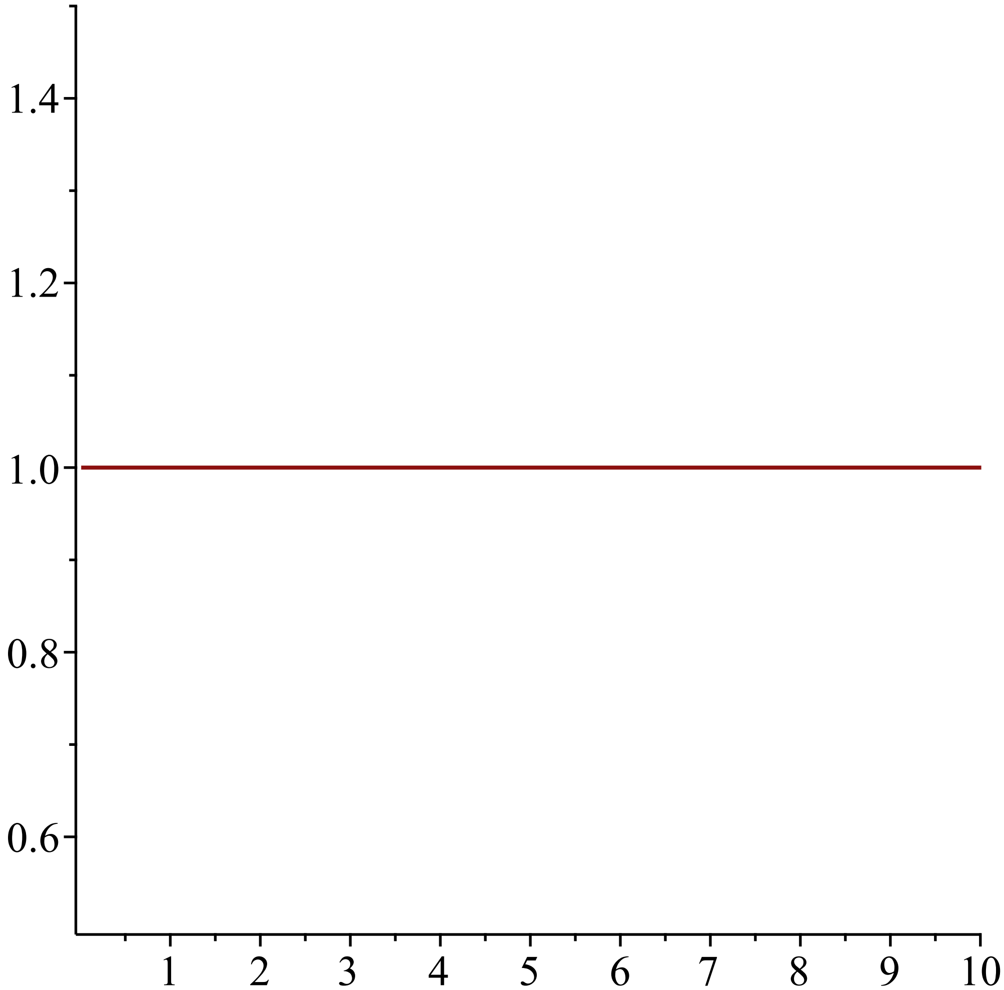
```
> #P14 (ii.)
  TimeSeries([2*x*(1-x)*(2-x)*(3-x)],[x],[0],.01,10,1)
```



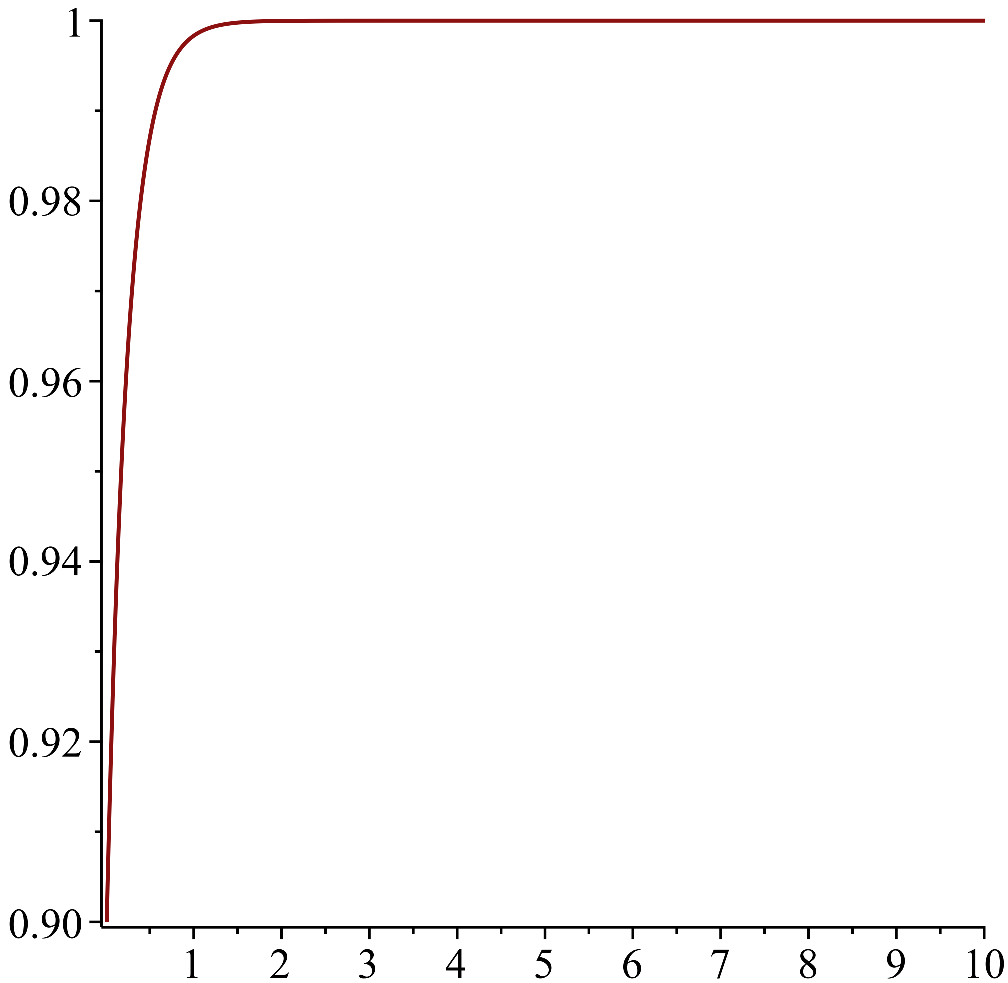

```
> TimeSeries([2*x*(1-x)*(2-x)*(3-x)],[x],[0.1],.01,10,1)
```



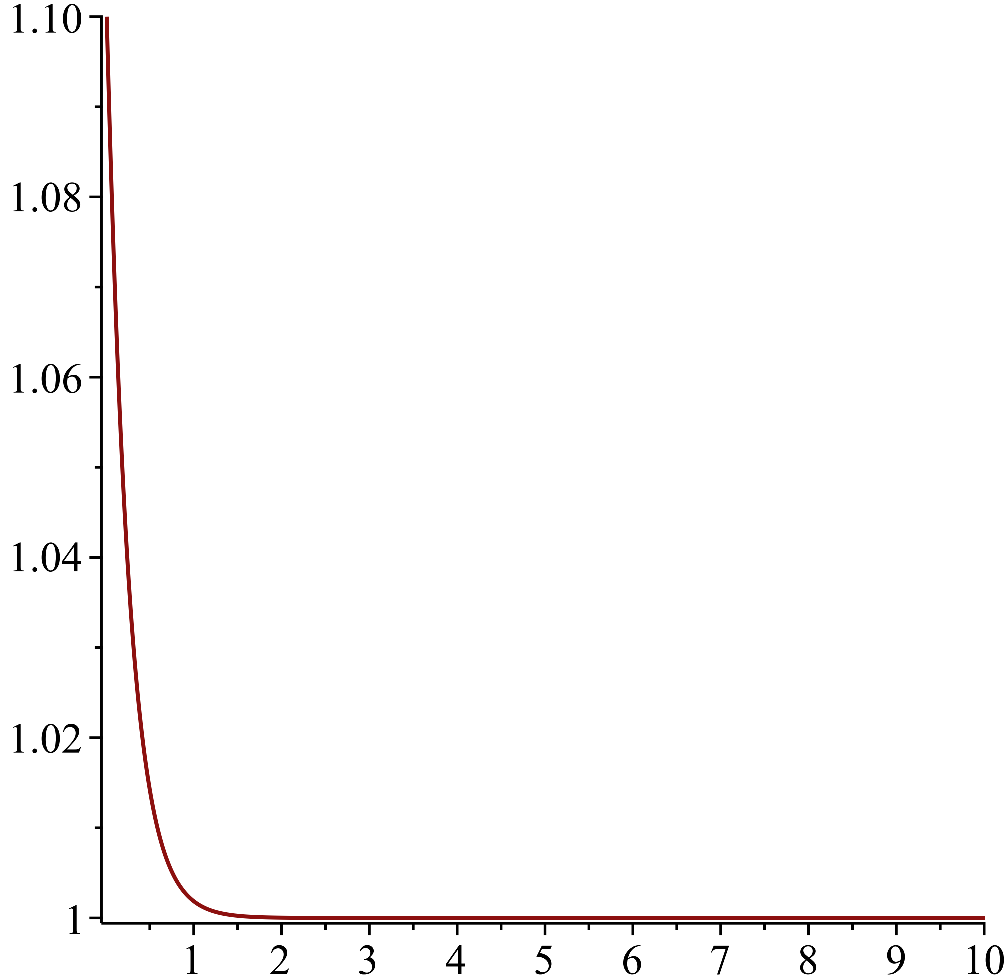

```
> TimeSeries([2*x*(1-x)*(2-x)*(3-x)],[x],[1.],.01,10,1)
```



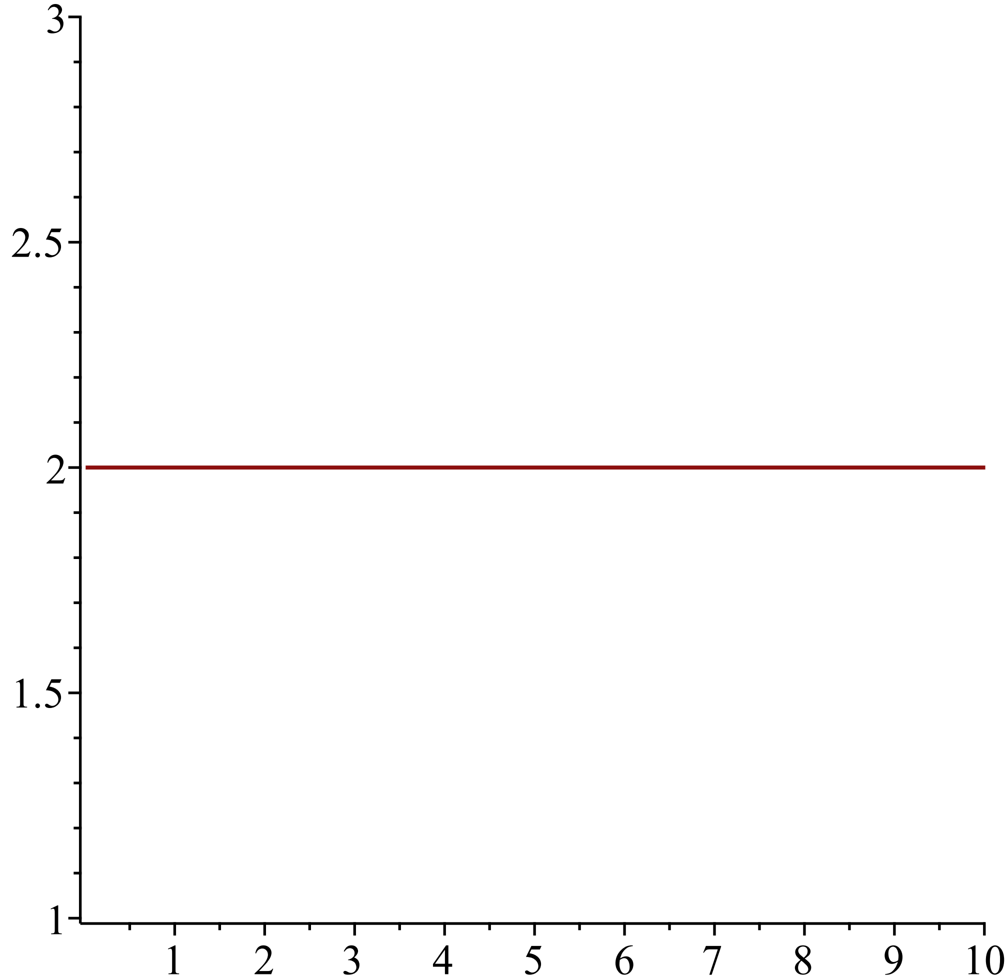

```
> TimeSeries([2*x*(1-x)*(2-x)*(3-x)],[x],[.9],.01,10,1)
```



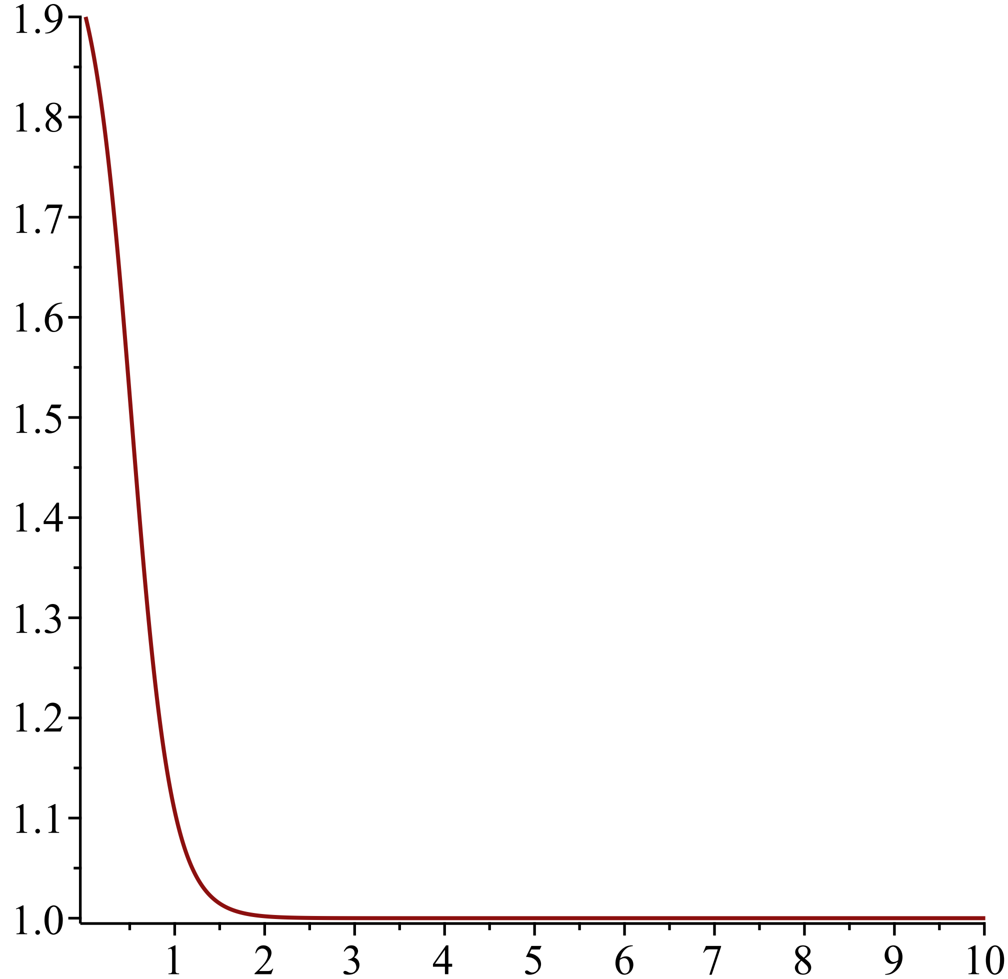

```
> TimeSeries([2*x*(1-x)*(2-x)*(3-x)],[x],[1.1],.01,10,1)
```



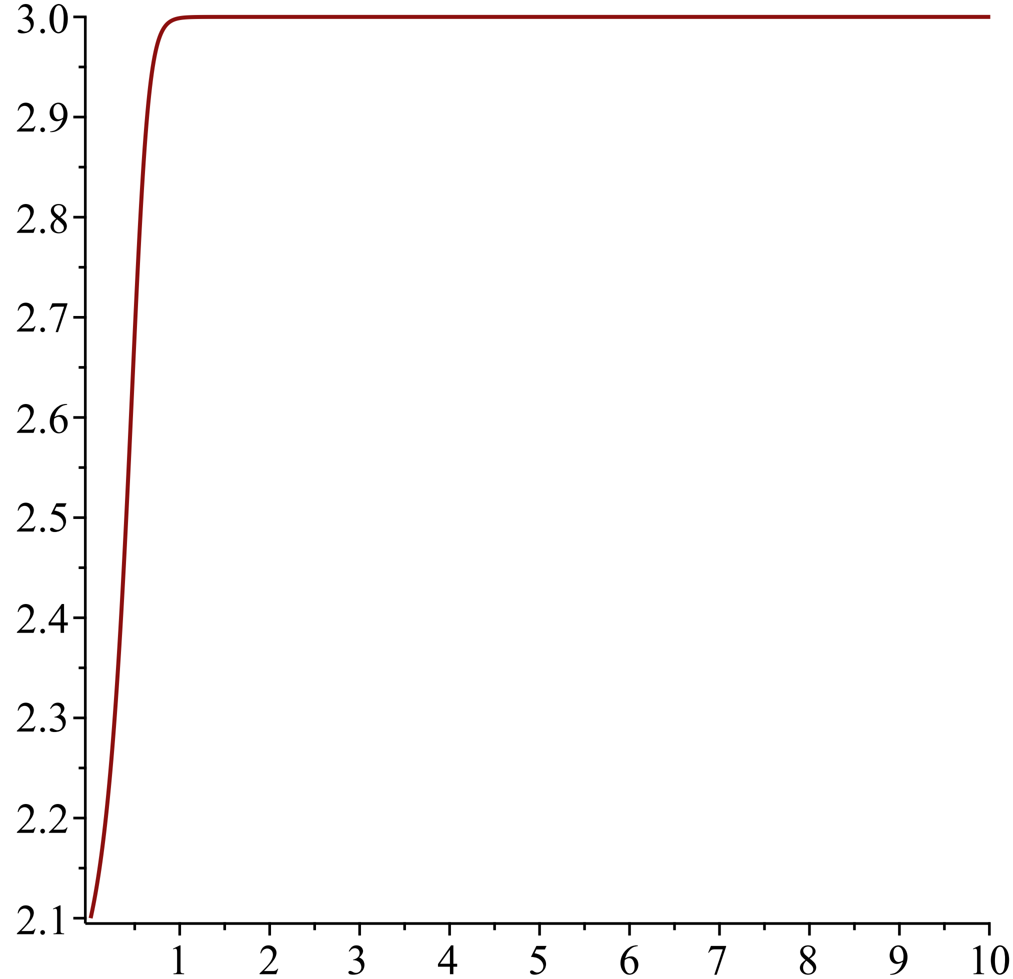

```
> TimeSeries([2*x*(1-x)*(2-x)*(3-x)],[x],[2],.01,10,1)
```



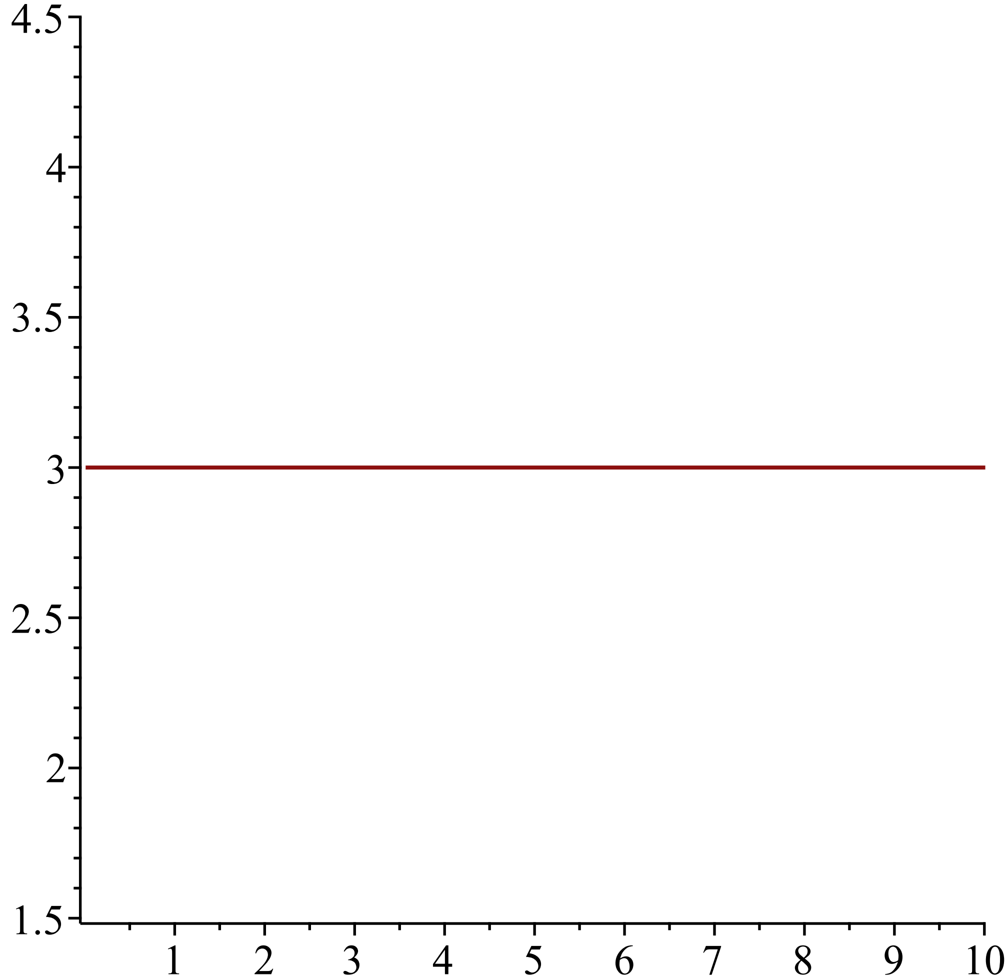

```
> TimeSeries([2*x*(1-x)*(2-x)*(3-x)],[x],[1.9],.01,10,1)
```



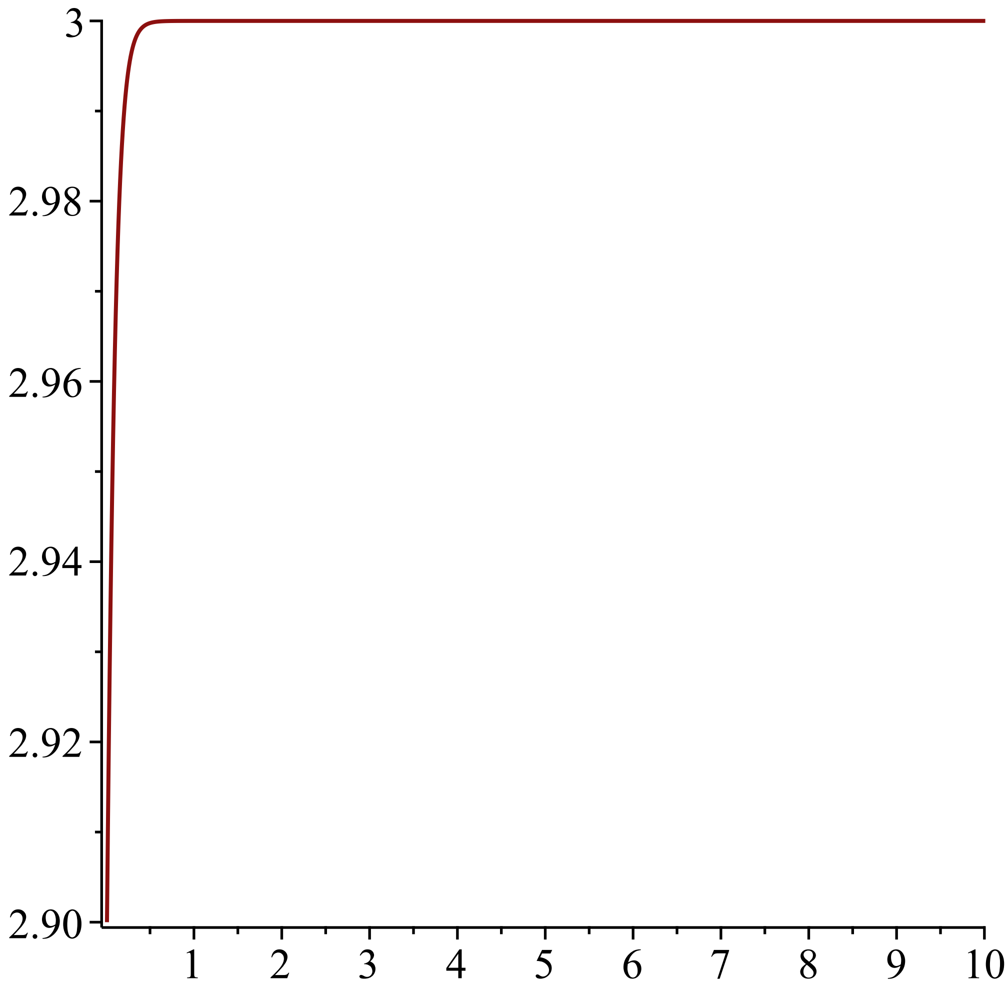

```
> TimeSeries([2*x*(1-x)*(2-x)*(3-x)],[x],[2.1],.01,10,1)
```



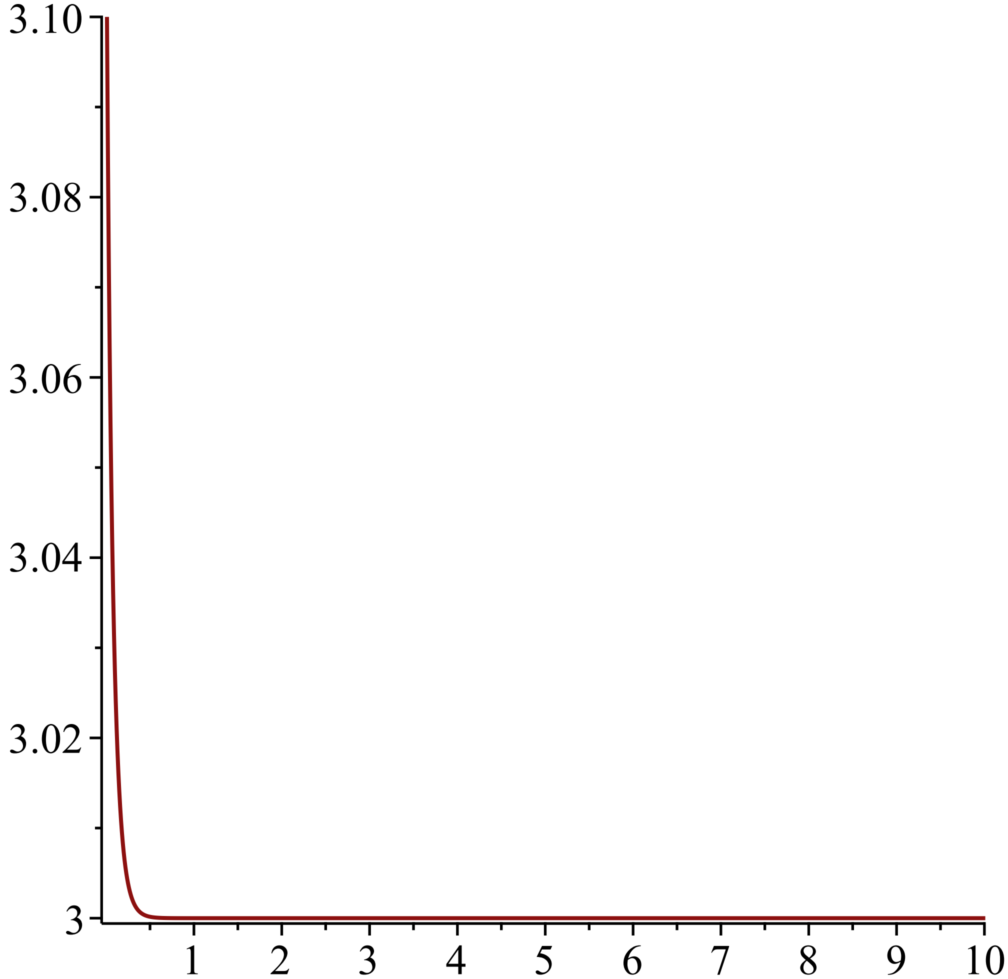

```
> TimeSeries([2*x*(1-x)*(2-x)*(3-x)],[x],[3.],.01,10,1)
```




```
> TimeSeries([2*x*(1-x)*(2-x)*(3-x)],[x],[2.9],.01,10,1)
```




```
> TimeSeries([2*x*(1-x)*(2-x)*(3-x)],[x],[3.1],.01,10,1)
```




```
> #Confirmed that indeed x=0,1,2,3 are all equilibrium points. In
  tests for stability, values near 0 and 2 did not tend towards 0 or
  2 over time. Instead, we saw that initial values greater than 0 and
  less than 2 tended toward 1 over time, therefore 1 is a stable
  equilibrium point. We saw that the same activity was apparent for 3
  with values near it. Therefore 3 is also a stable equilibrium
  point. Therefore the set of stable equilibrium points for the
  continous time dynamic system is [1,3].
```

```
> #P15 Orb input
> Orb([x^3+2*y,x^2+5*y^2],[x,y],[1,3],0,3)
```

[[1, 3], [7, 46], [435, 10629], [82334133, 565067430]] **(2)**

```
> #Confirm the values we got by hand.
```

```
> #P16
  SFP([(2+x+y)/(2+2*x+2*y),(2+x+y)/(1+2*x+2*y)],[x,y])
```

{[0.6953496364, 0.8641637014]} **(3)**

```
> #Did receive values as told on p17 of the bc.pdf!
```

```
> Orb([(2+x+y)/(2+2*x+2*y),(2+x+y)/(1+2*x+2*y)],[x,y],[0.5,0.4],
  10000,10010)
```

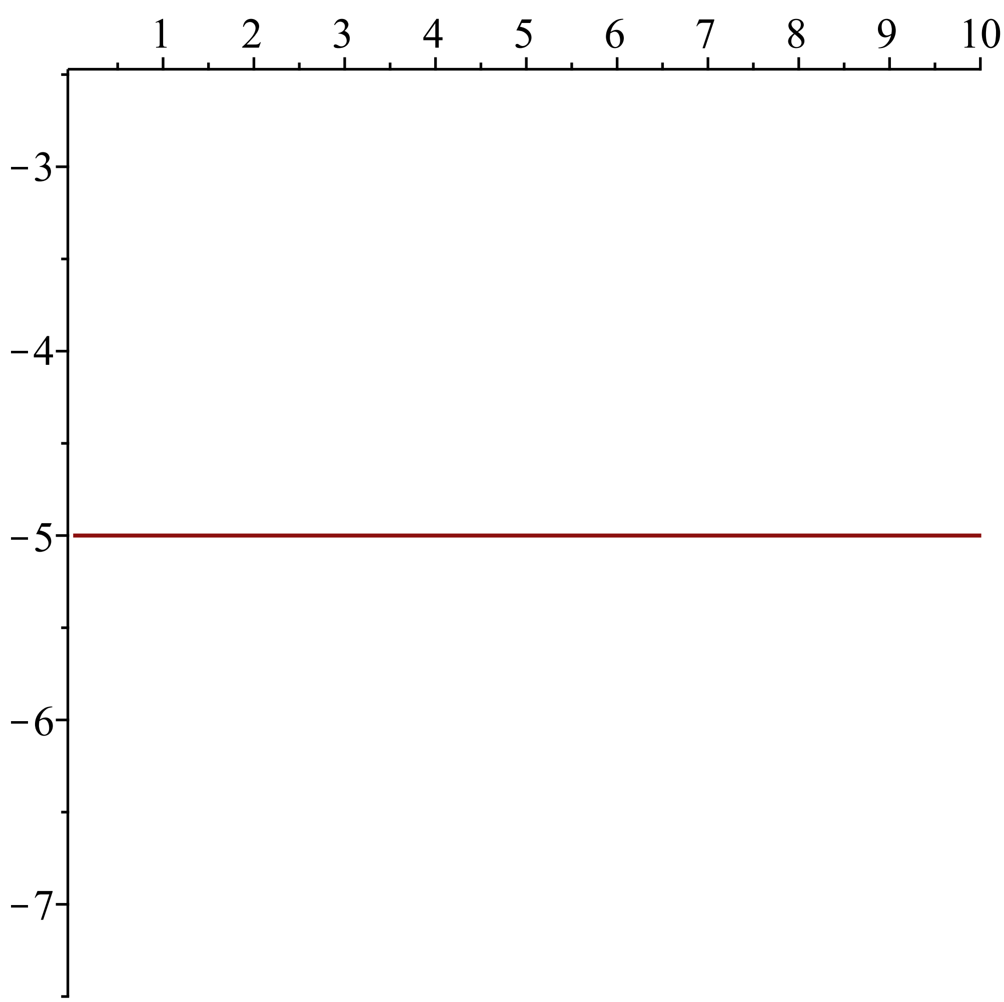
[[0.6953496364, 0.8641637013], [0.6953496362, 0.8641637010], [0.6953496365, **(4)**

0.8641637015], [0.6953496364, 0.8641637013], [0.6953496362, 0.8641637010],
[0.6953496365, 0.8641637015], [0.6953496364, 0.8641637013], [0.6953496362,
0.8641637010], [0.6953496365, 0.8641637015], [0.6953496364, 0.8641637013],
[0.6953496362, 0.8641637010]]

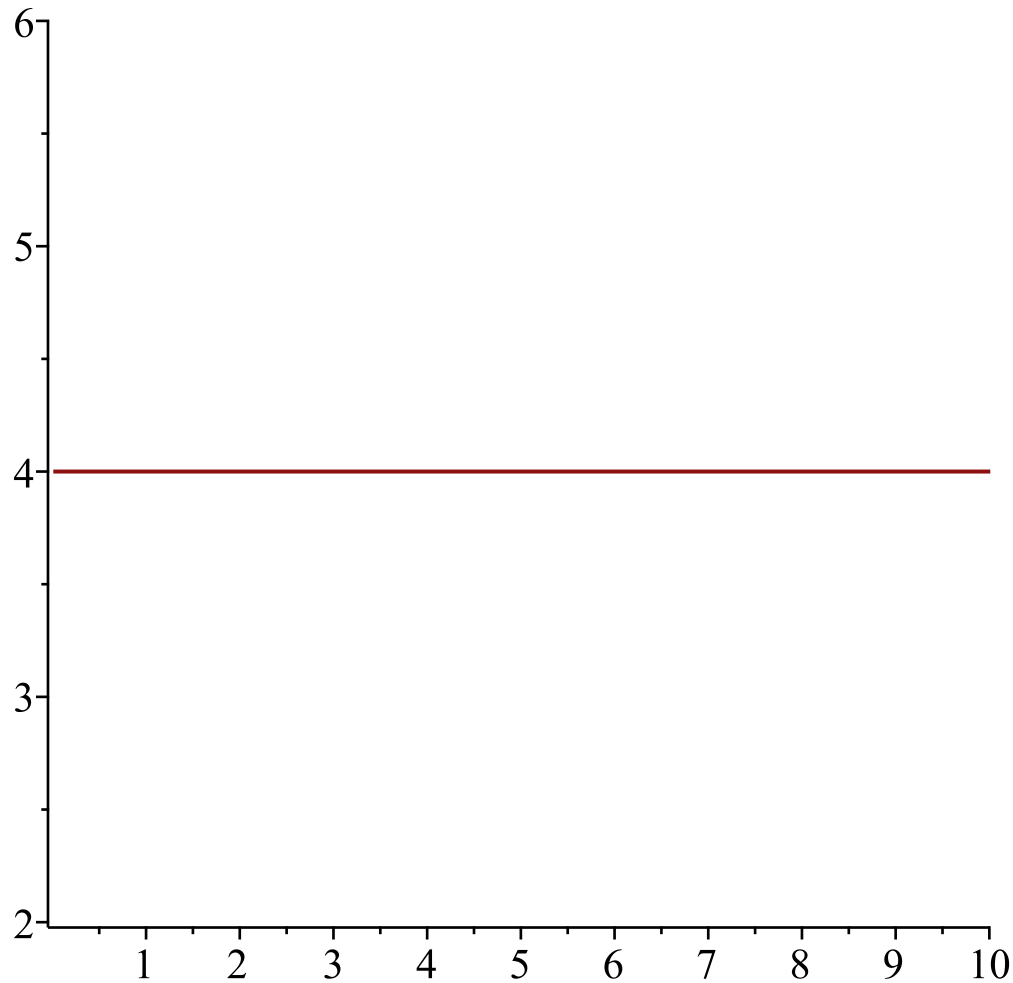
```
> #Last digits we attribute to errors with Maple's rounding, but we
  do confirm that the stable equilibria we received from the SFP
  function, match what is given to us when we run the functions
  through Orb with initial conditions of x(0)=.5 and y(0)=.4
```

```
> #P17
```

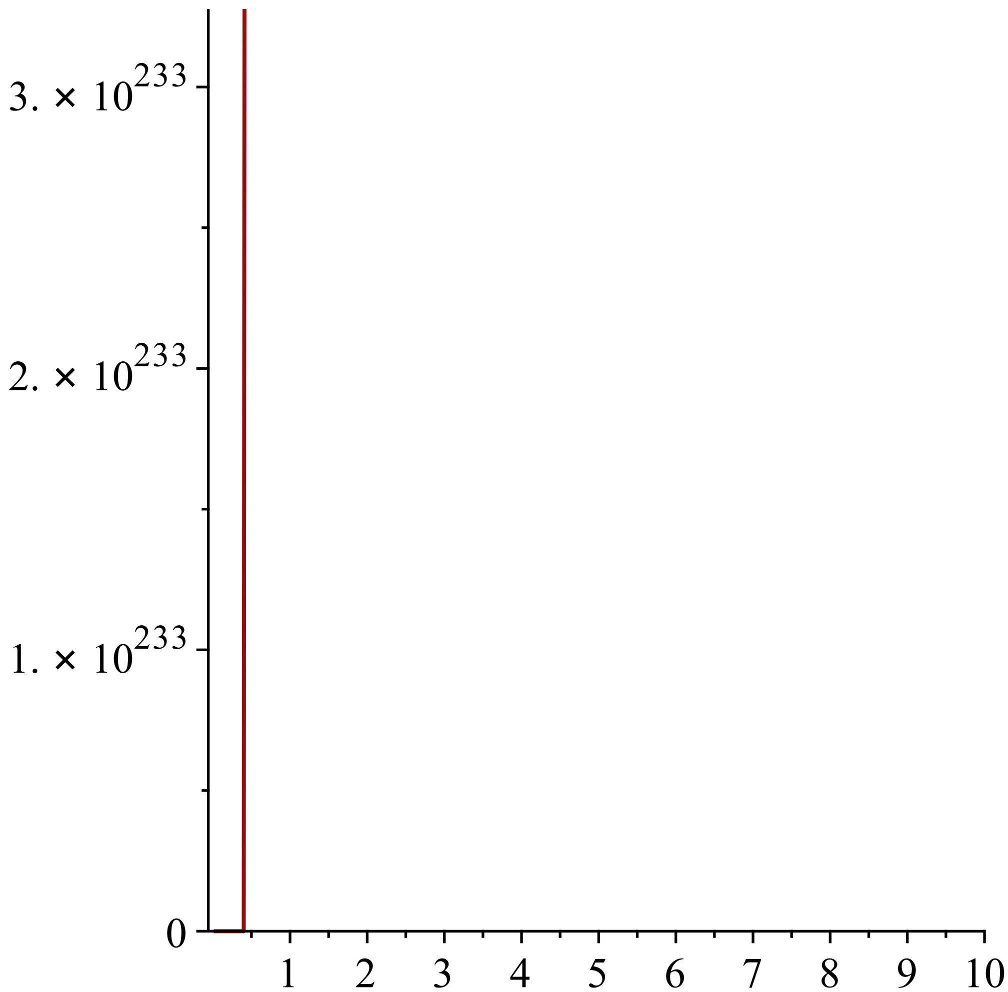
```
> TimeSeries([(1-2*x-3*y)*(2-2*x-3*y), (3-x-2*y)*(1-x-2*y)],[x,y],
  [-5,4],0.01,10,1)
```



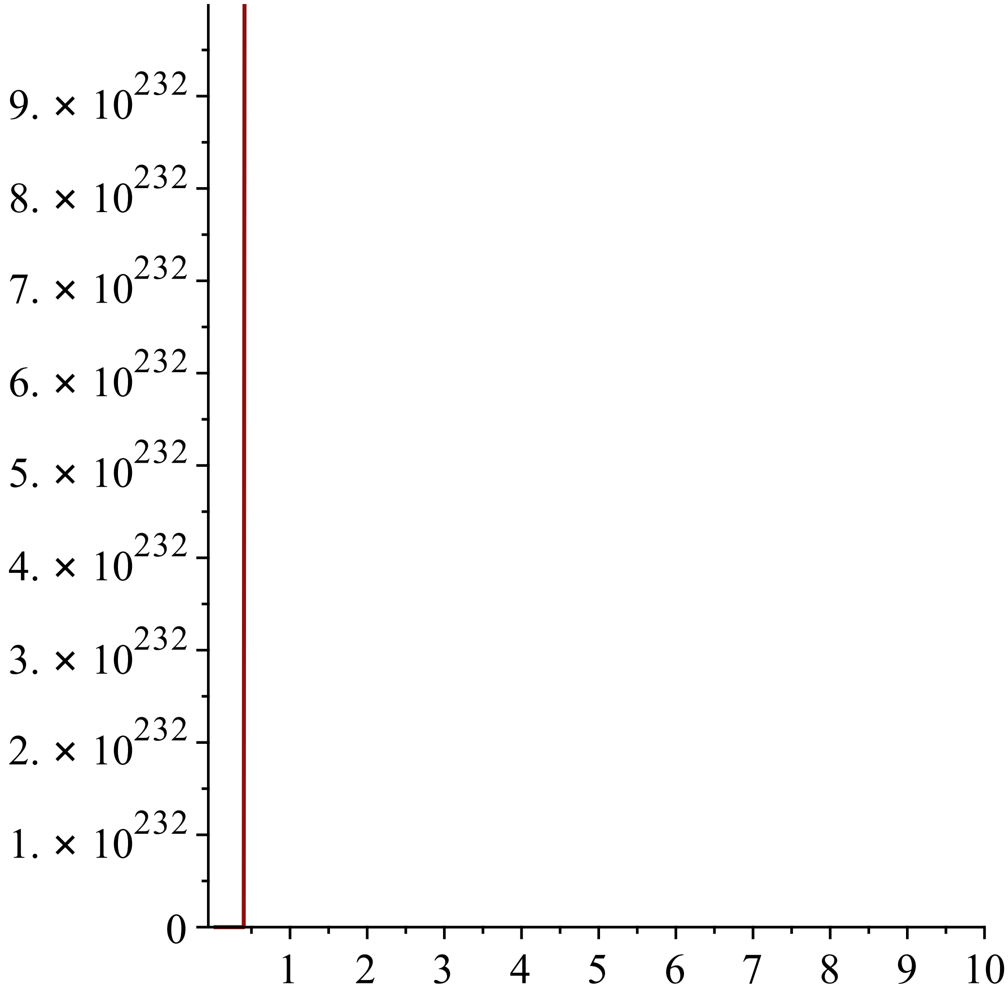

```
> TimeSeries([(1-2*x-3*y)*(2-2*x-3*y), (3-x-2*y)*(1-x-2*y)],[x,y],
  [-5,4],0.01,10,2)
```




```
> TimeSeries([(1-2*x-3*y)*(2-2*x-3*y), (3-x-2*y)*(1-x-2*y)],[x,y],
  [-4.9,4.1],0.01,10,1)
```

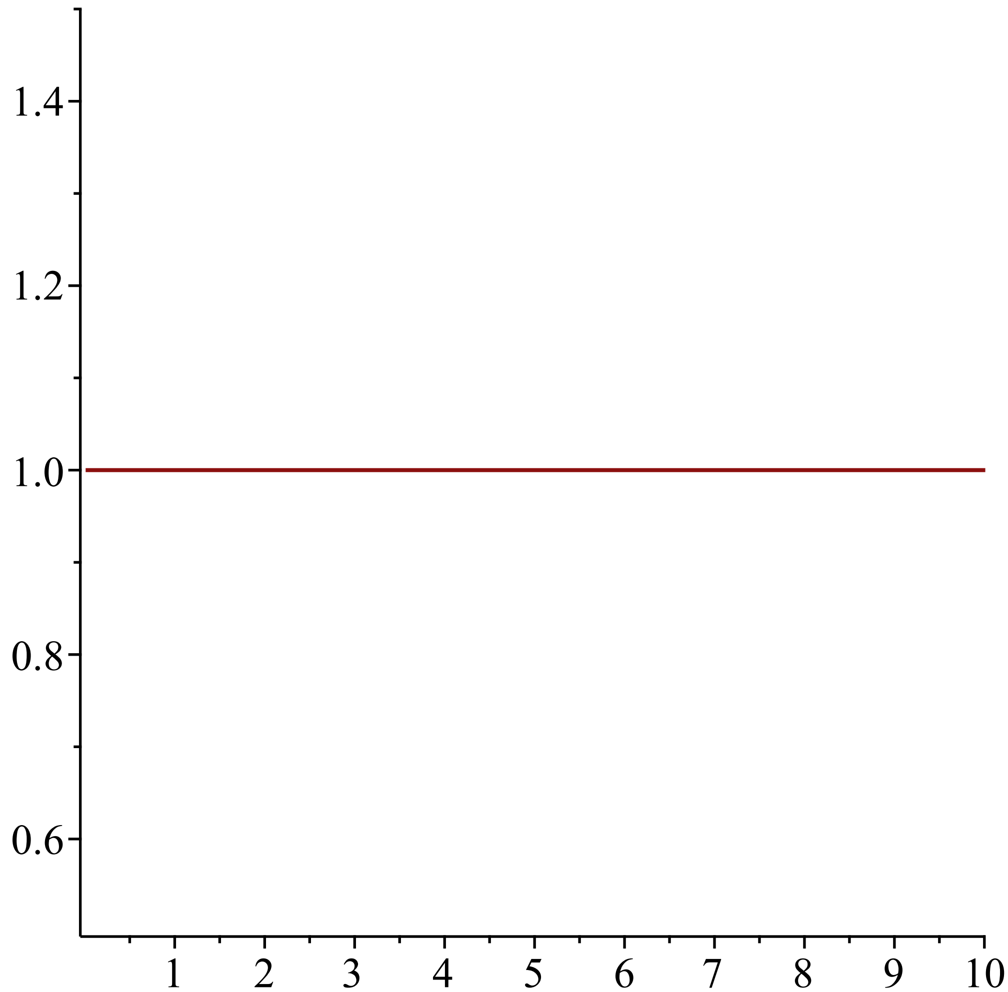



```
> TimeSeries([(1-2*x-3*y)*(2-2*x-3*y), (3-x-2*y)*(1-x-2*y)],[x,y],
  [-4.9,4.1],0.01,10,2)
```

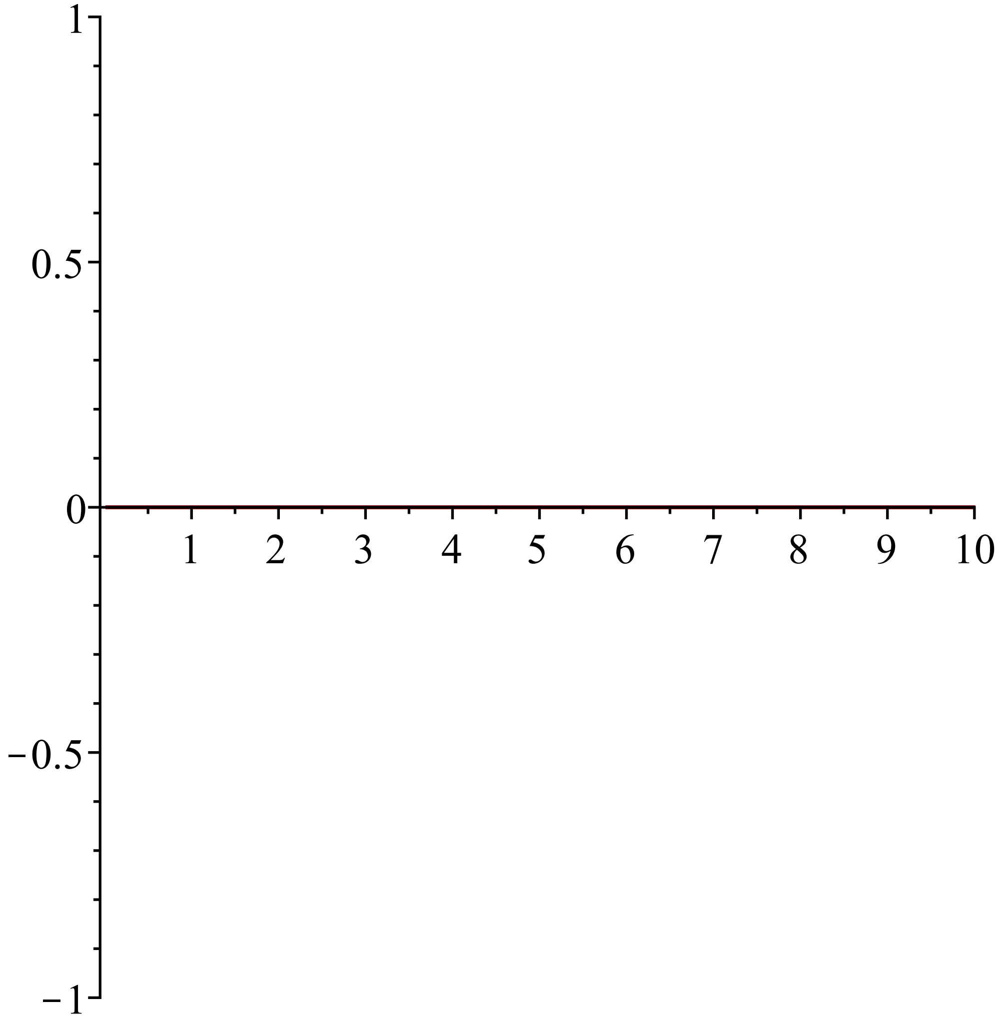



```
> #We see that [-5,4] is unstable as we do not reach any horizontal
  asymptotes when we play with values around this initial point, and
  instead the functions blow up!
```

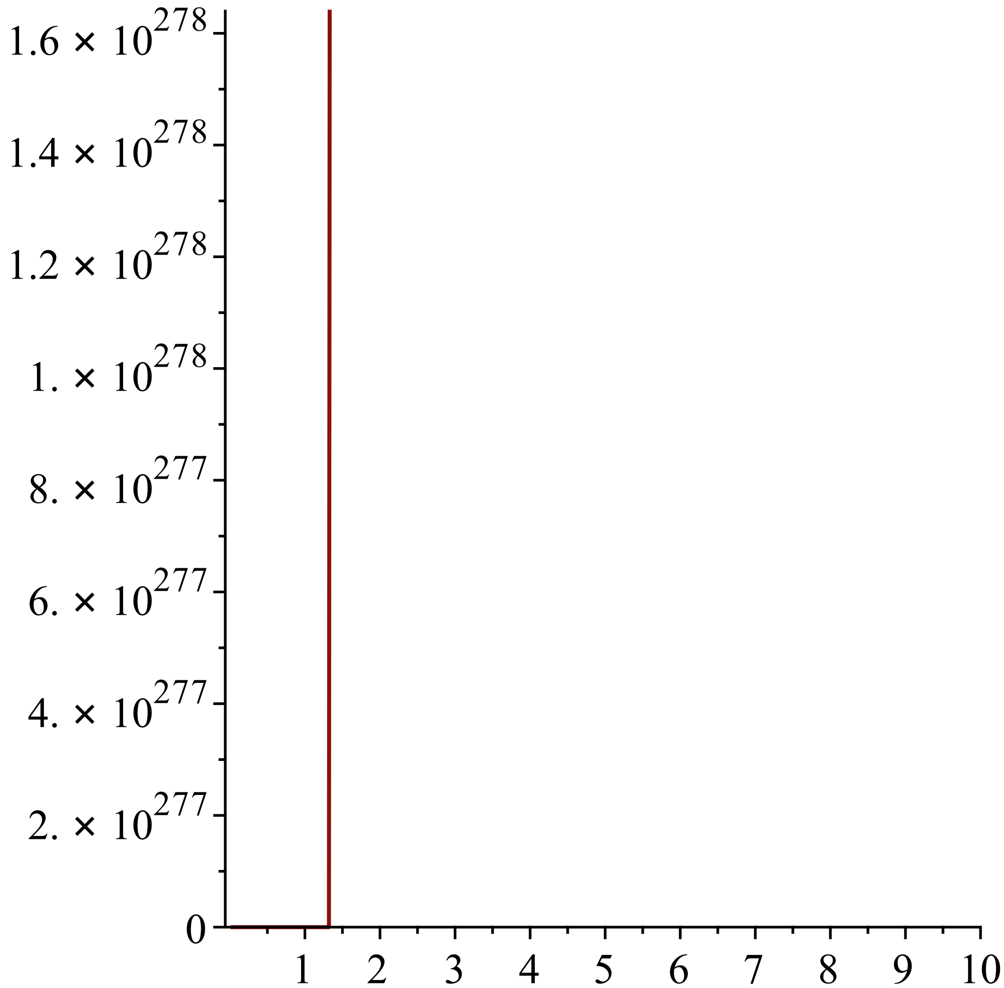
```
> TimeSeries([(1-2*x-3*y)*(2-2*x-3*y), (3-x-2*y)*(1-x-2*y)],[x,y],[1,
  0],0.01,10,1)
```



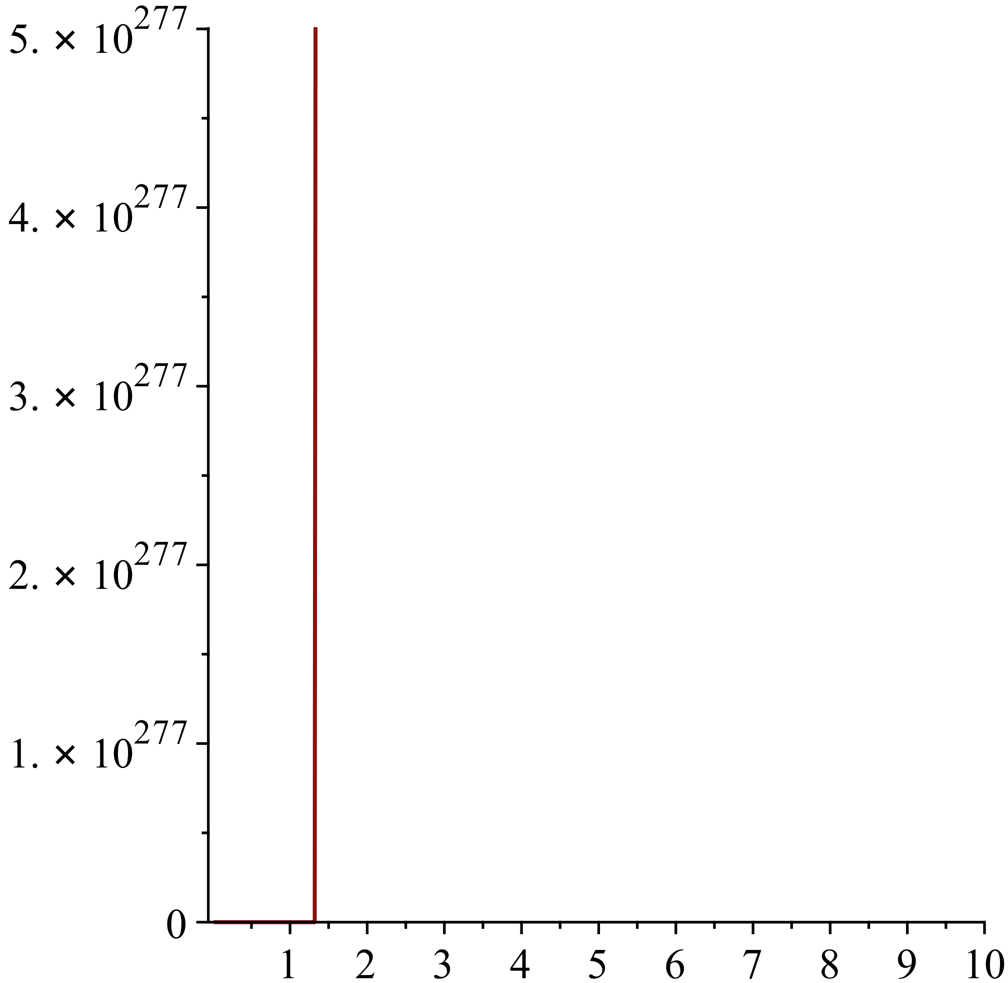

```
> TimeSeries([(1-2*x-3*y)*(2-2*x-3*y), (3-x-2*y)*(1-x-2*y)],[x,y],[1,
  0],0.01,10,2)
```



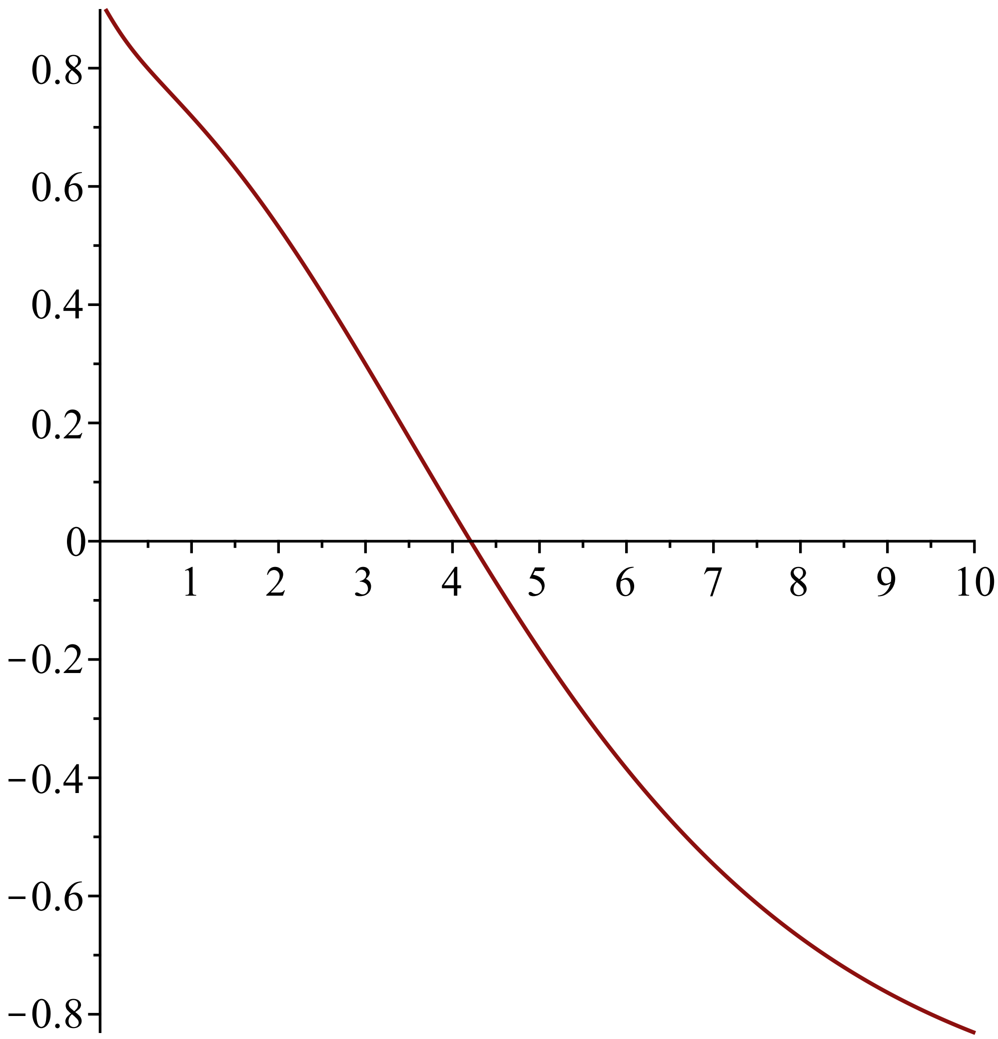

```
> TimeSeries([(1-2*x-3*y)*(2-2*x-3*y), (3-x-2*y)*(1-x-2*y)],[x,y],
  [1.1,0.1],0.01,10,1)
```



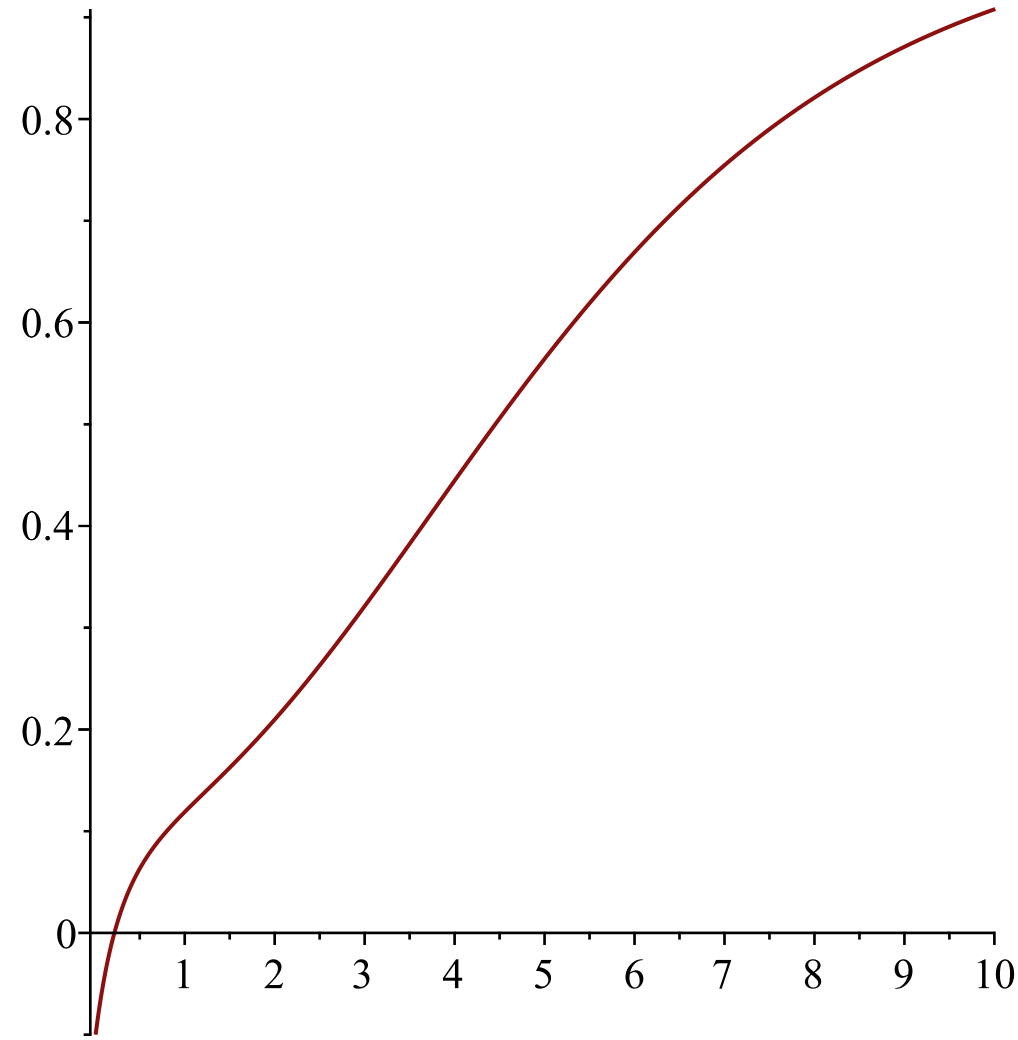

```
> TimeSeries([(1-2*x-3*y)*(2-2*x-3*y), (3-x-2*y)*(1-x-2*y)],[x,y],
  [1.1,0.1],0.01,10,2)
```




```
> TimeSeries([(1-2*x-3*y)*(2-2*x-3*y), (3-x-2*y)*(1-x-2*y)],[x,y],
  [.9,-0.1],0.01,10,1)
```




```
> TimeSeries([(1-2*x-3*y)*(2-2*x-3*y), (3-x-2*y)*(1-x-2*y)],[x,y],
  [.9,-.1],0.01,10,2)
```



> #Again we see that even for the point [1,0] it is unstable, in both instances whether we got an increment of .1 up on both coordinates or .1 down, the function's behavior does not tend to the point [1, 0] in goes away from them and blows up (when starting at [1.1,0.1] or goes to the stable equilibria [-1,1] (when starting at [.9,-.1])