

```
> #John Hermitt hw20
  read "/John/Rutgers/Senior Fall/Dynamic Models/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 i.
  N := 1000;
  v := 2;
  g := 5;
  b1 := 0.3 * v/N;
  b2 := 0.9 * v/N;
  b3 := 3.9 * v/N;
  F := SIRS(s, i, b1, g, v, N);
  EquP(F, [s, i]);
  SEquP(F, [s, i]);
```

(1)

```

TimeSeries(F, [s, i], [800, 200], 0.01, 10, 1);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 2);
PhaseDiag(F, [s, i], [800, 200], 0.01, 10);
F := SIRS(s, i, b2, g, v, N);
EquP(F, [s, i]);
SEquP(F, [s, i]);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 1);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 2);
PhaseDiag(F, [s, i], [800, 200], 0.01, 10);
F := SIRS(s, i, b3, g, v, N);
EquP(F, [s, i]);
SEquP(F, [s, i]);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 1);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 2);
PhaseDiag(F, [s, i], [800, 200], 0.01, 10);

```

$N := 1000$

$v := 2$

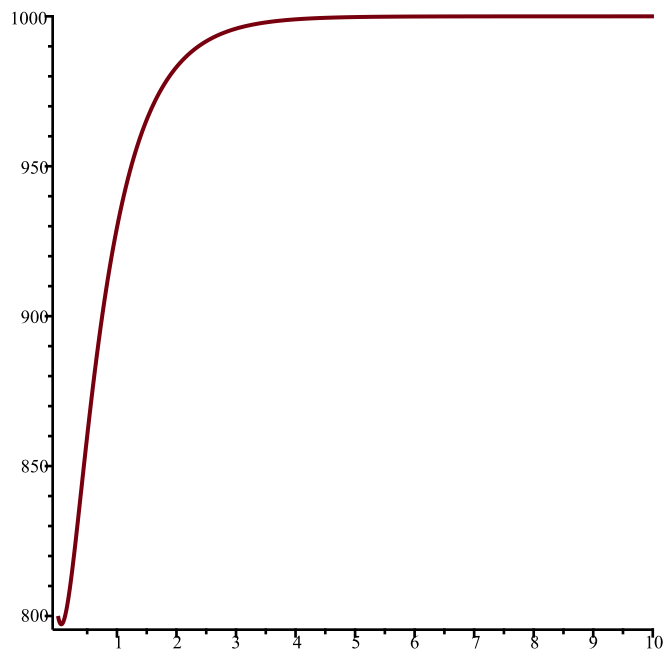
$g := 5$

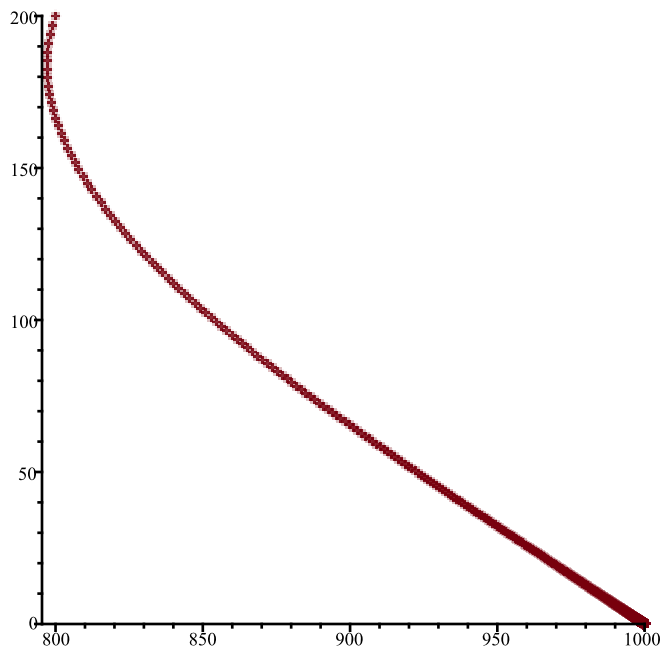
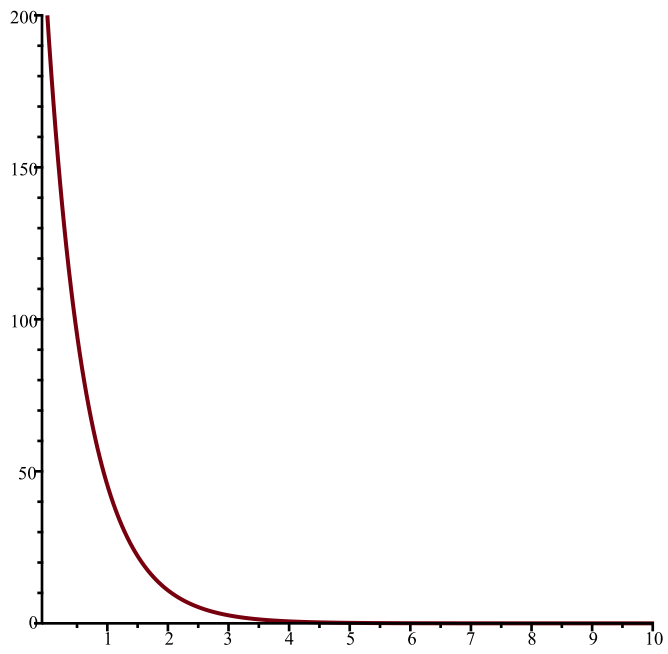
$b1 := 0.0006000000000$

$b2 := 0.0018000000000$

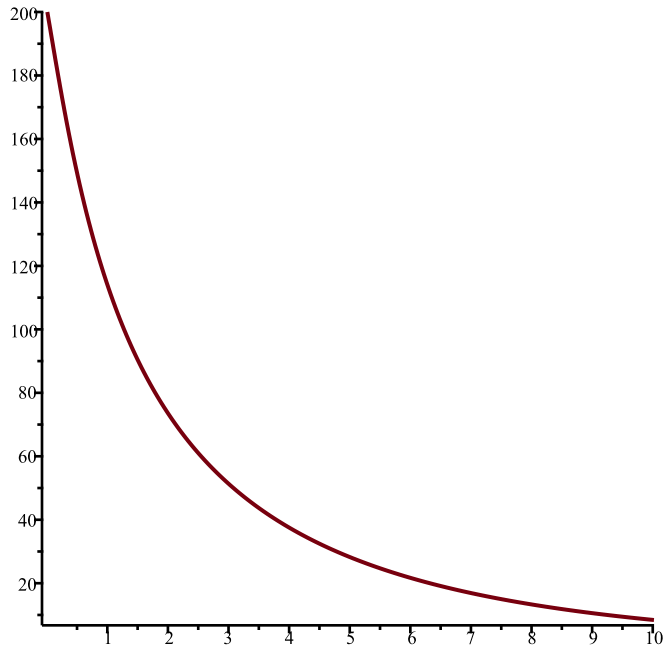
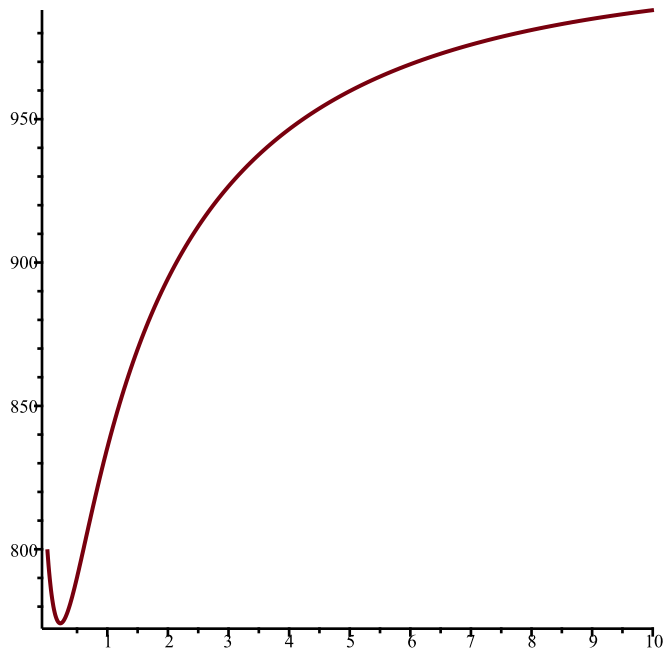
$b3 := 0.0078000000000$

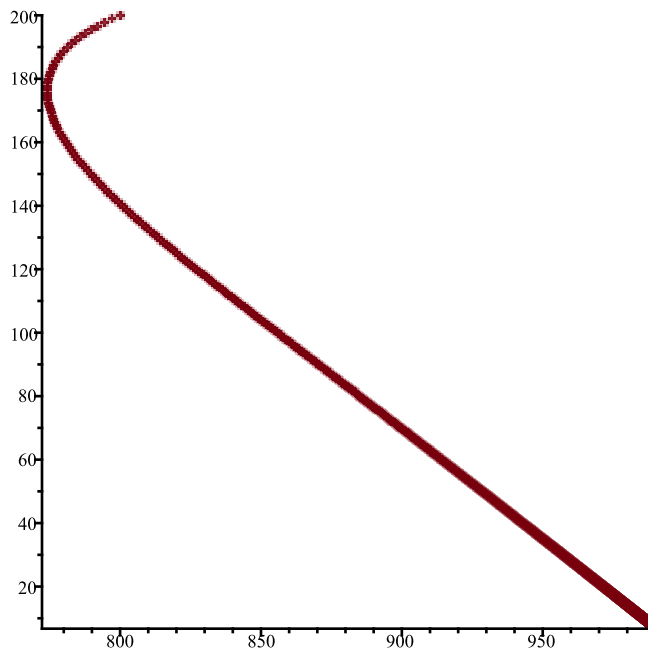
$F := [-0.0006000000000 \ s \ i + 5000 - 5 \ s - 5 \ i, 0.0006000000000 \ s \ i - 2 \ i]$
 $\{[1000., 0.], [3333.333333, -1666.666667]\}$
 $\{[1000., 0.]\}$





$$\begin{aligned}
 F := & [-0.001800000000 \, s \, i + 5000 - 5 \, s - 5 \, i, 0.001800000000 \, s \, i - 2 \, i] \\
 & \{ [1000., 0.], [1111.111111, -79.36507937] \} \\
 & \{ [1000., 0.] \}
 \end{aligned}$$

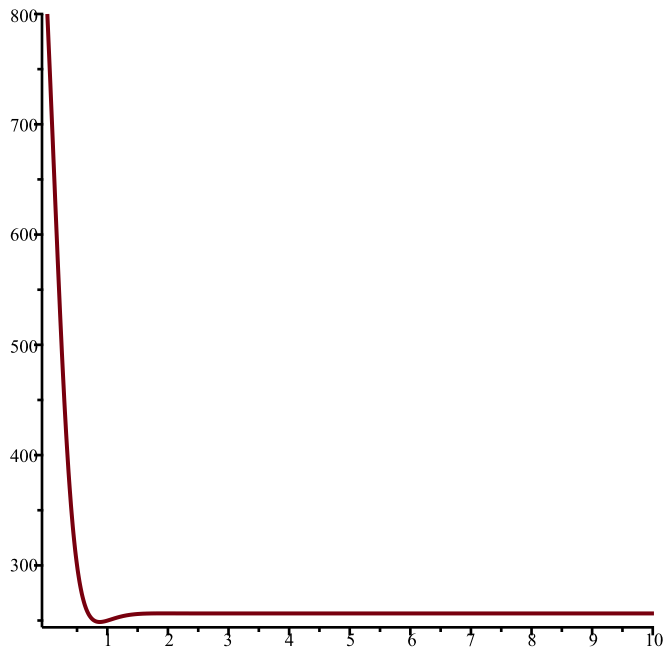


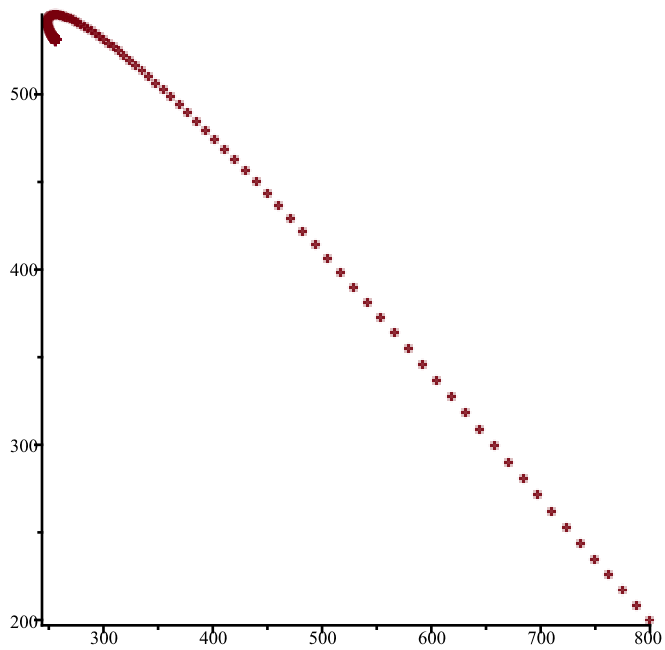
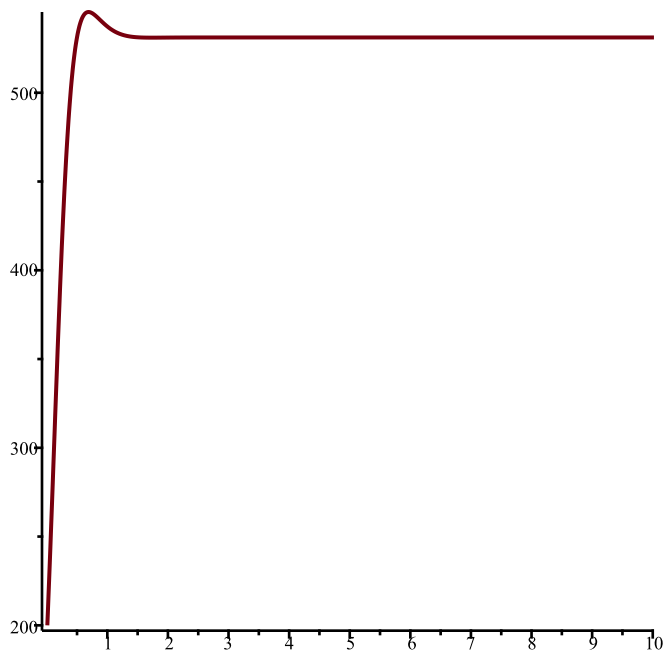


$$F := [-0.007800000000 s i + 5000 - 5 s - 5 i, 0.007800000000 s i - 2 i]$$

$$\{ [256.4102564, 531.1355311], [1000., 0.] \}$$

$$\{ [256.4102564, 531.1355311] \}$$





```

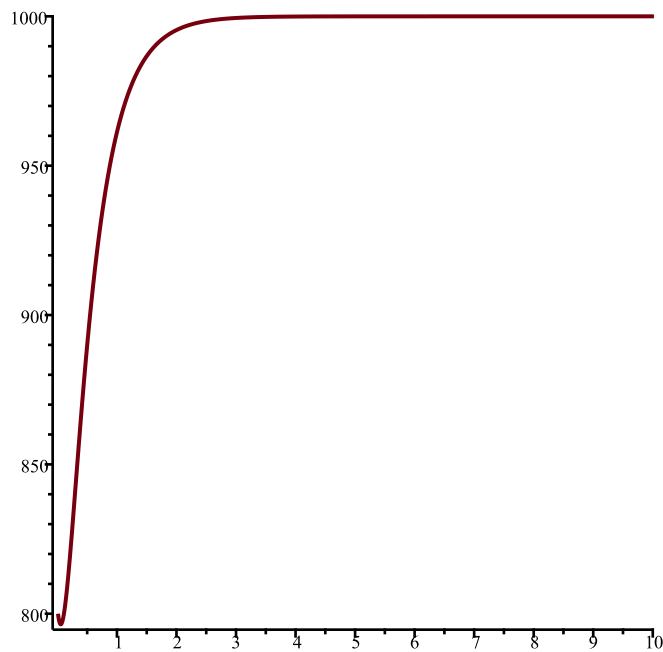
> # ii
  N := 1000;
  v := 3;
  g := 6;
  b1 := 0.3 * v / N;
  b2 := 0.9 * v / N;
  b3 := 3.9 * v / N;
  F := SIRS(s, i, b1, g, v, N);
  EquP(F, [s, i]);
  SEquP(F, [s, i]);
  TimeSeries(F, [s, i], [800, 200], 0.01, 10, 1);
  TimeSeries(F, [s, i], [800, 200], 0.01, 10, 2);
  PhaseDiag(F, [s, i], [800, 200], 0.01, 10);

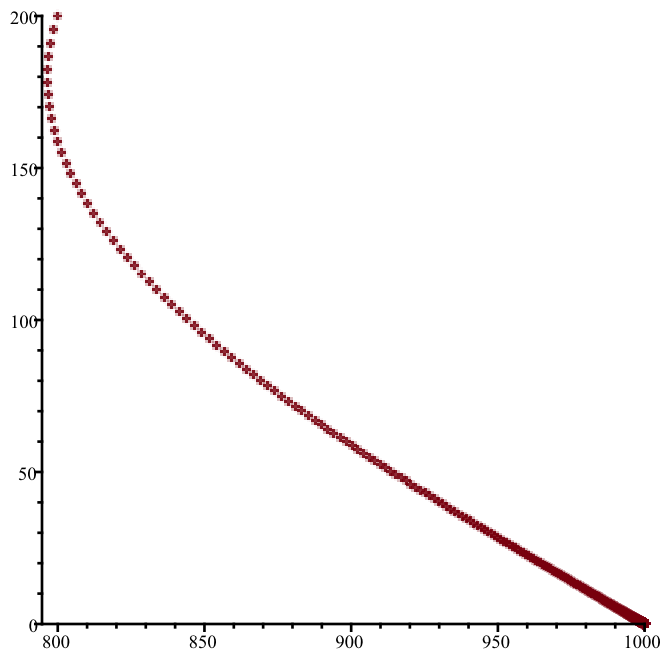
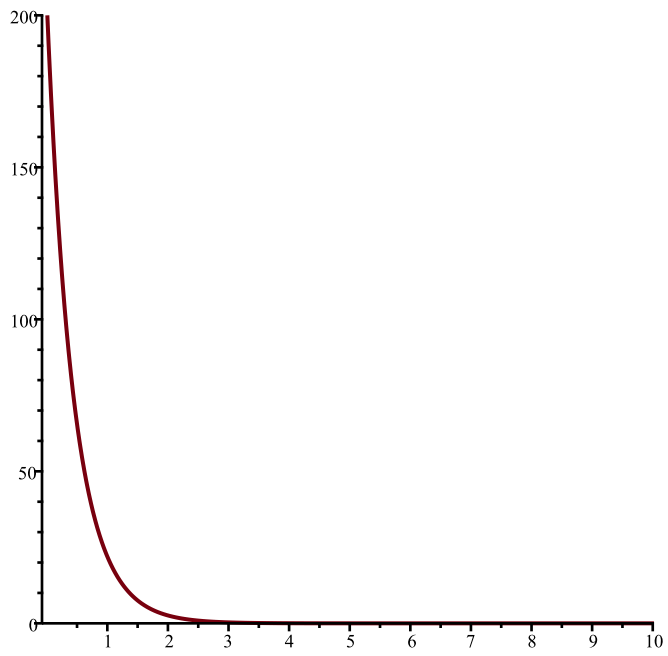
```

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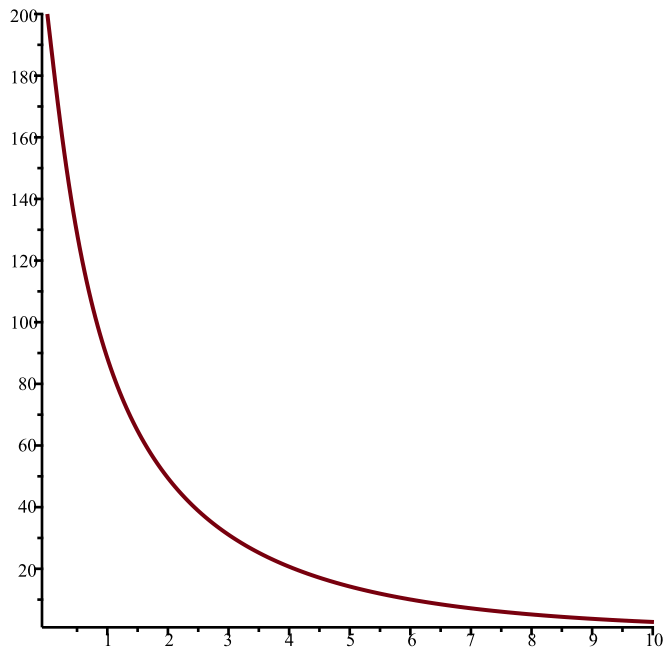
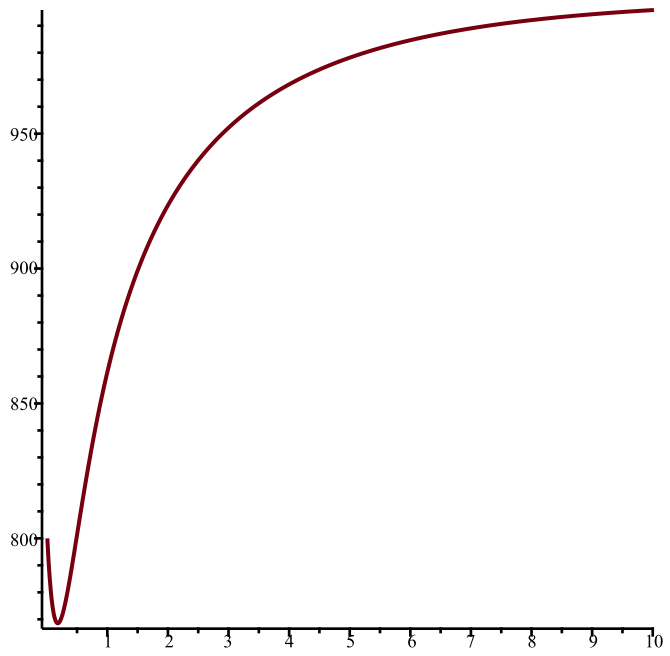
F := SIRS(s, i, b2, g, v, N);
EquP(F, [s, i]);
SEquP(F, [s, i]);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 1);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 2);
PhaseDiag(F, [s, i], [800, 200], 0.01, 10);
F := SIRS(s, i, b3, g, v, N);
EquP(F, [s, i]);
SEquP(F, [s, i]);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 1);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 2);
PhaseDiag(F, [s, i], [800, 200], 0.01, 10);
N := 1000
v := 3
g := 6
b1 := 0.0009000000000
b2 := 0.0027000000000
b3 := 0.0117000000000
F := [-0.0009000000000 s i + 6000 - 6 s - 6 i, 0.0009000000000 s i - 3 i]
      {[1000., 0.], [3333.333333, -1555.555556]}
      {[1000., 0.]}

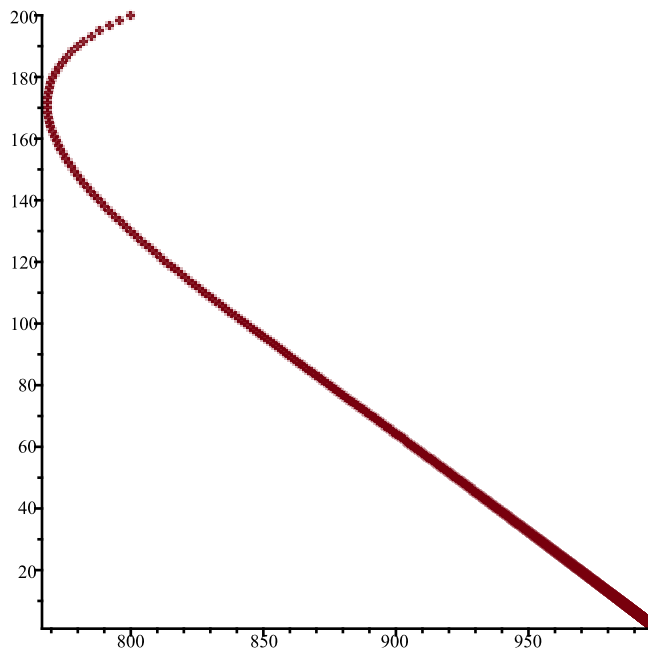
```





$$\begin{aligned}
 F := & [-0.002700000000 \, s \, i + 6000 - 6 \, s - 6 \, i, 0.002700000000 \, s \, i - 3 \, i] \\
 & \{ [1000., 0.], [1111.111111, -74.07407407] \} \\
 & \{ [1000., 0.] \}
 \end{aligned}$$

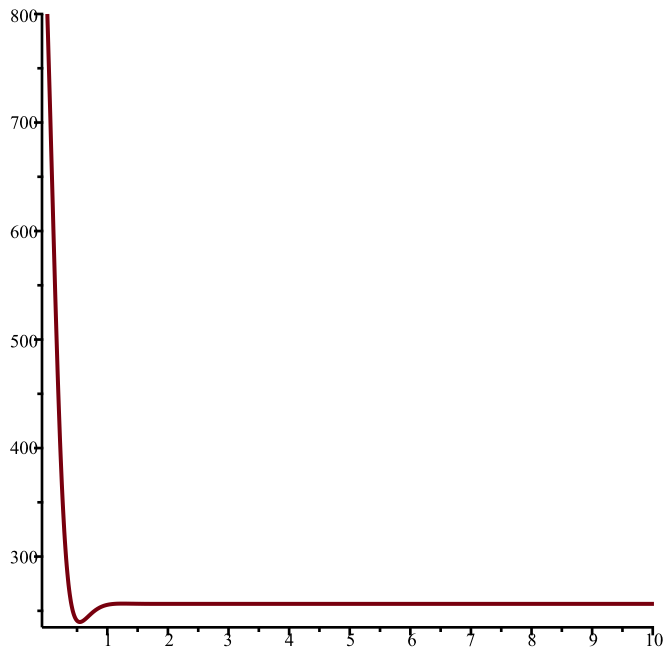


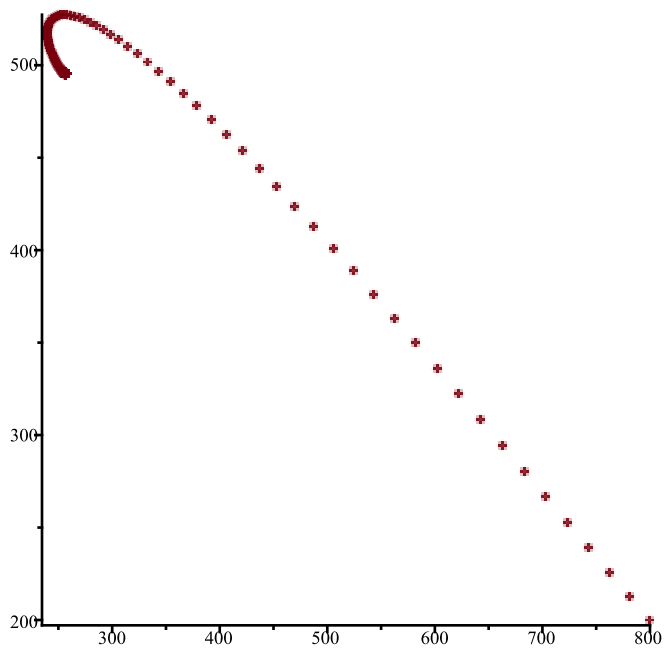
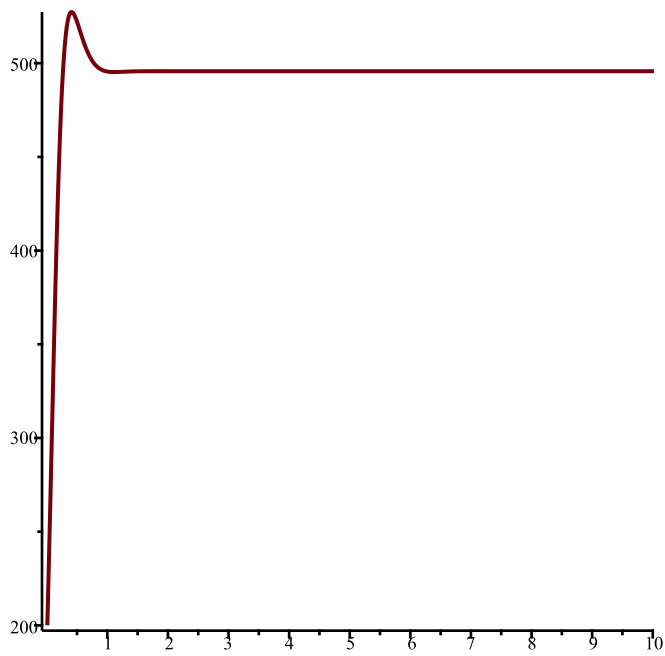


$$F := [-0.01170000000 \, s \, i + 6000 - 6 \, s - 6 \, i, 0.01170000000 \, s \, i - 3 \, i]$$

$$\{ [256.4102564, 495.7264957], [1000., 0.] \}$$

$$\{ [256.4102564, 495.7264957] \}$$





```

> #iii
N := 1000;
v := 4;
g := 1;
b1 := 0.3 * v / N;
b2 := 0.9 * v / N;
b3 := 3.9 * v / N;
F := SIRS(s, i, b1, g, v, N);
EquP(F, [s, i]);
SEquP(F, [s, i]);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 1);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 2);
PhaseDiag(F, [s, i], [800, 200], 0.01, 10);

```

```

F := SIRS(s, i, b2, g, v, N);
EquP(F, [s, i]);
SEquP(F, [s, i]);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 1);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 2);
PhaseDiag(F, [s, i], [800, 200], 0.01, 10);
F := SIRS(s, i, b3, g, v, N);
EquP(F, [s, i]);
SEquP(F, [s, i]);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 1);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 2);
PhaseDiag(F, [s, i], [800, 200], 0.01, 10);

```

$N := 1000$

$v := 4$

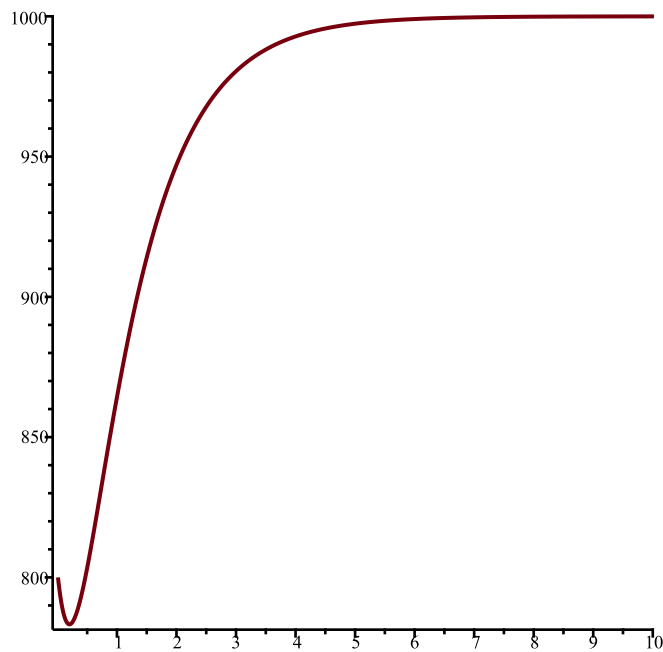
$g := 1$

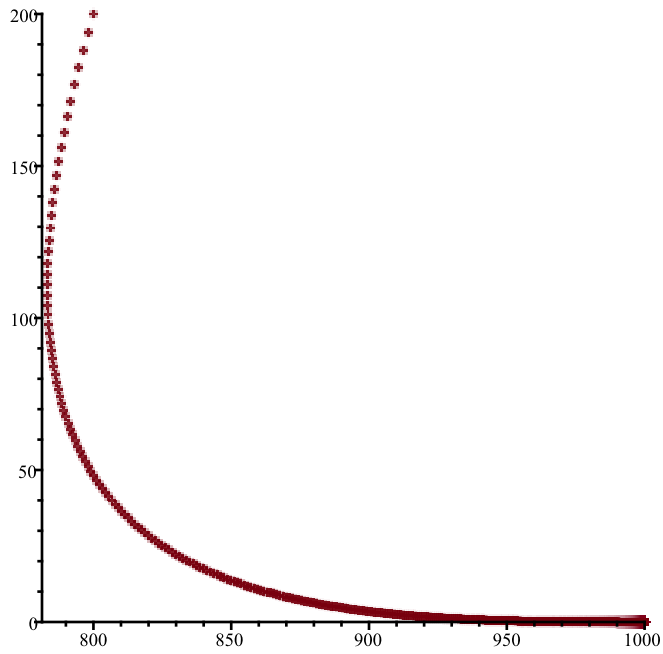
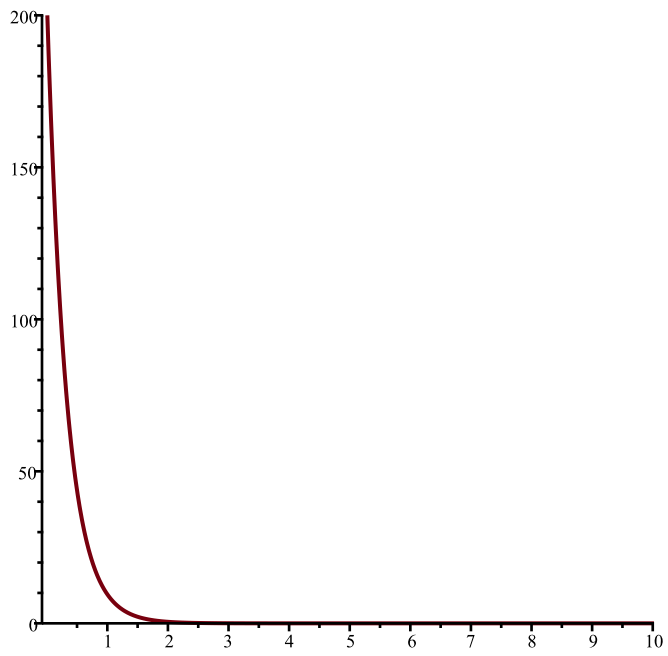
$b1 := 0.001200000000$

$b2 := 0.003600000000$

$b3 := 0.015600000000$

$F := [-0.001200000000 \ s \ i + 1000 - s - i, 0.001200000000 \ s \ i - 4 \ i]$
 $\{[1000., 0.], [3333.333333, -466.6666667]\}$
 $\{[1000., 0.]\}$

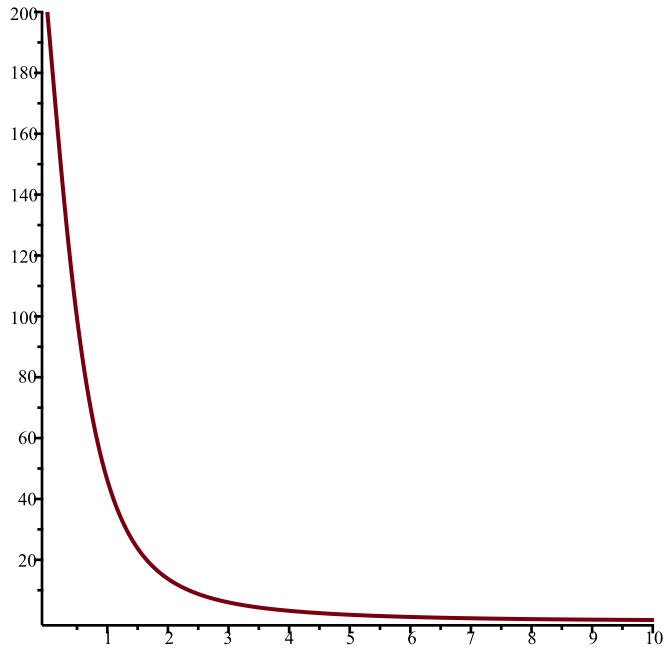
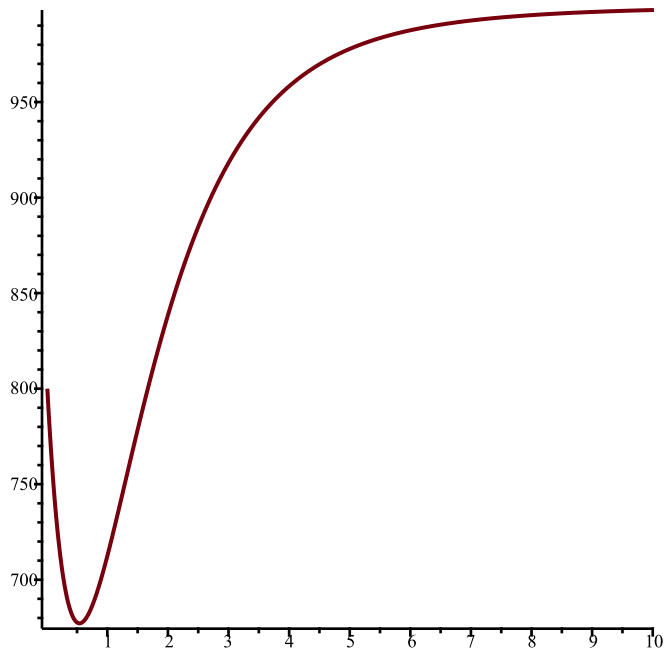


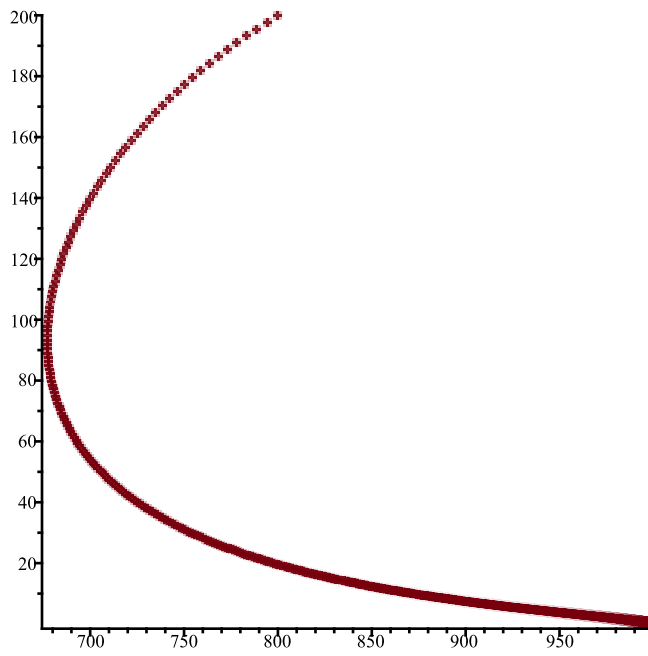


$$F := [-0.003600000000 \, s \, i + 1000 - s - i, 0.003600000000 \, s \, i - 4 \, i]$$

$$\{ [1000., 0.], [1111.111111, -22.22222222] \}$$

$$\{ [1000., 0.] \}$$

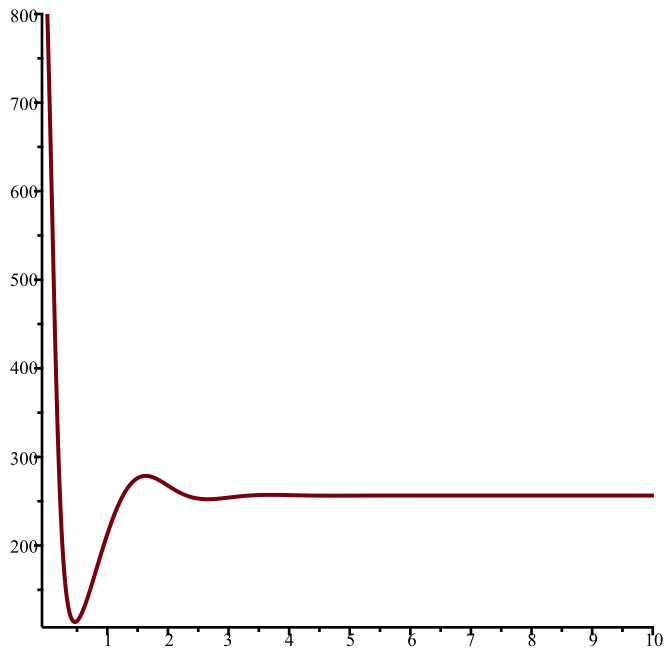


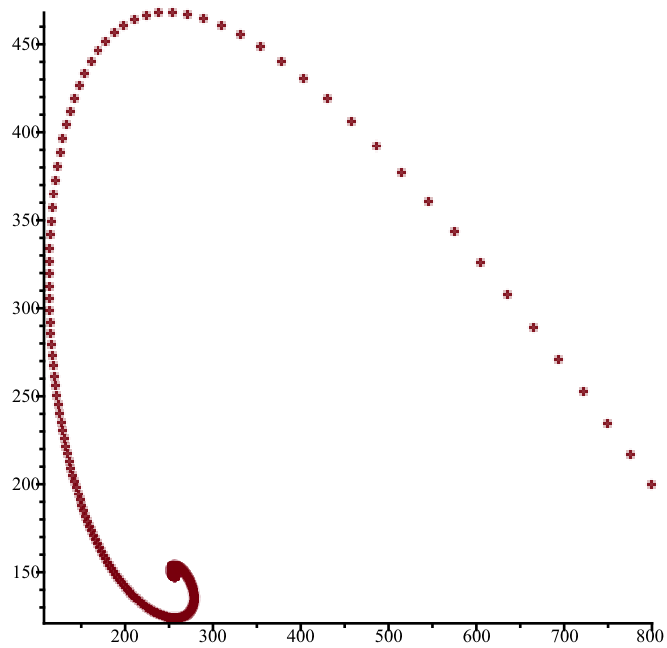
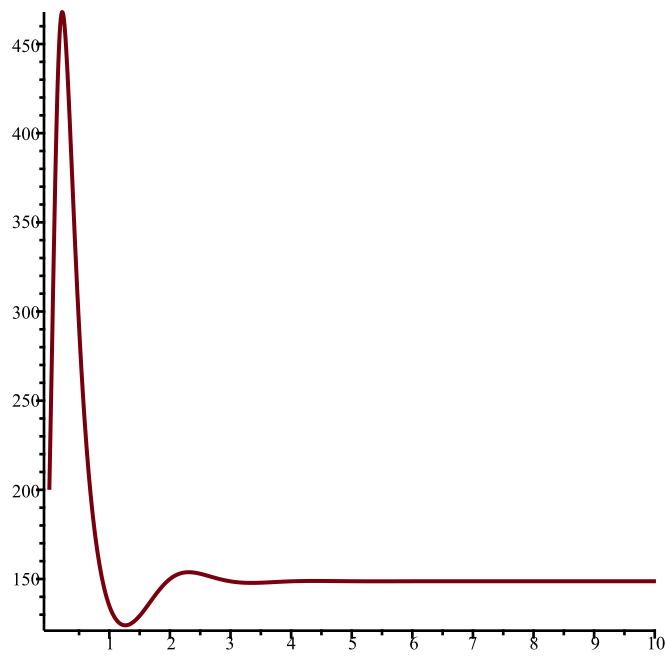


$$F := [-0.01560000000 \, s \, i + 1000 - s - i, 0.01560000000 \, s \, i - 4 \, i]$$

$$\{[256.4102564, 148.7179487], [1000., 0.]\}$$

$$\{[256.4102564, 148.7179487]\}$$





```

> #iv
  N := 1000;
  v := 7;
  g := 10;
  b1 := 0.3 * v/N;
  b2 := 0.9 * v/N;
  b3 := 3.9 * v/N;
  F := SIRS(s, i, b1, g, v, N);
  EquP(F, [s, i]);
  SEquP(F, [s, i]);
  TimeSeries(F, [s, i], [800, 200], 0.01, 10, 1);
  TimeSeries(F, [s, i], [800, 200], 0.01, 10, 2);
  PhaseDiag(F, [s, i], [800, 200], 0.01, 10);

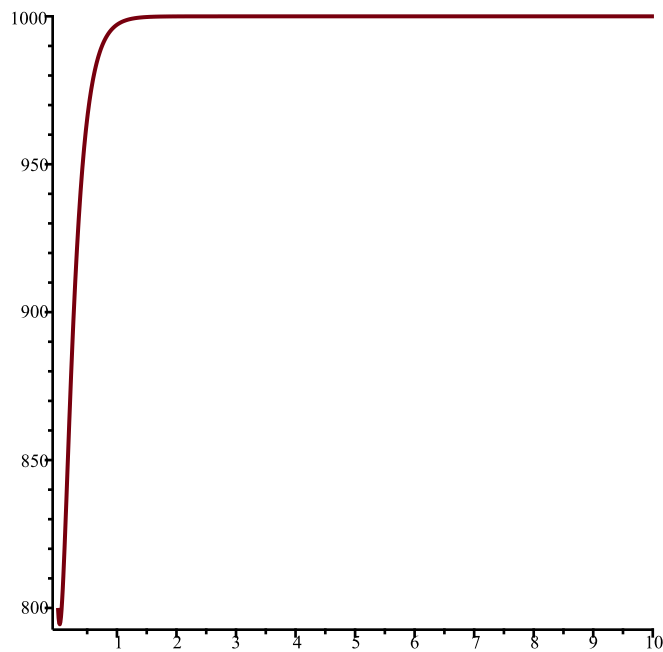
```

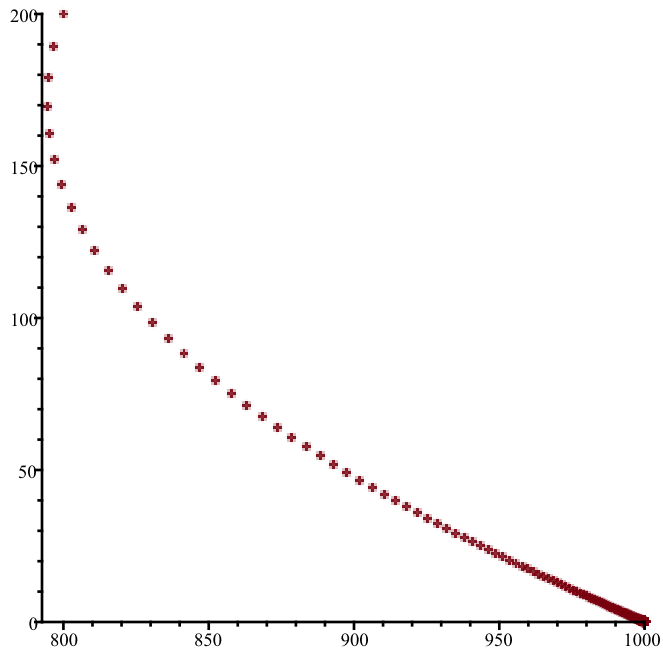
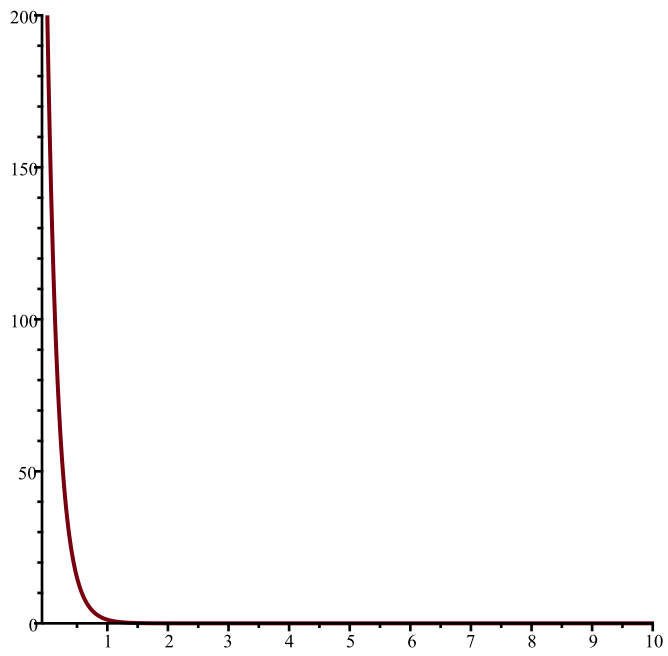


```

F := SIRS(s, i, b2, g, v, N);
EquP(F, [s, i]);
SEquP(F, [s, i]);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 1);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 2);
PhaseDiag(F, [s, i], [800, 200], 0.01, 10);
F := SIRS(s, i, b3, g, v, N);
EquP(F, [s, i]);
SEquP(F, [s, i]);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 1);
TimeSeries(F, [s, i], [800, 200], 0.01, 10, 2);
PhaseDiag(F, [s, i], [800, 200], 0.01, 10);
N := 1000
v := 7
g := 10
b1 := 0.002100000000
b2 := 0.006300000000
b3 := 0.027300000000
F := [-0.002100000000 s i + 10000 - 10 s - 10 i, 0.002100000000 s i - 7 i]
      {[1000., 0.], [3333.333333, -1372.549020]}
      {[1000., 0.]}

```

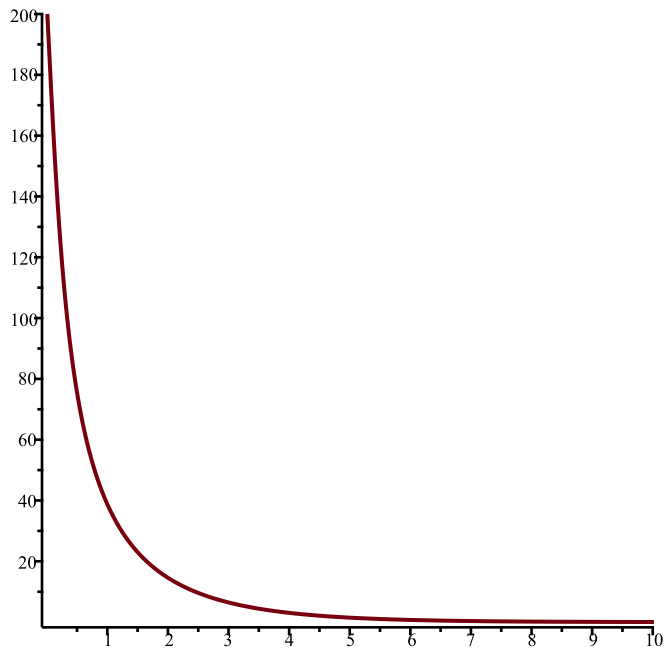
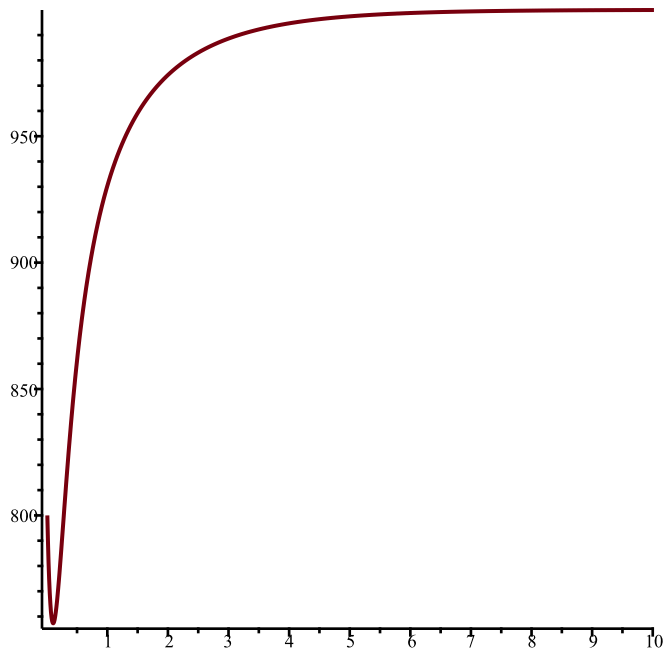


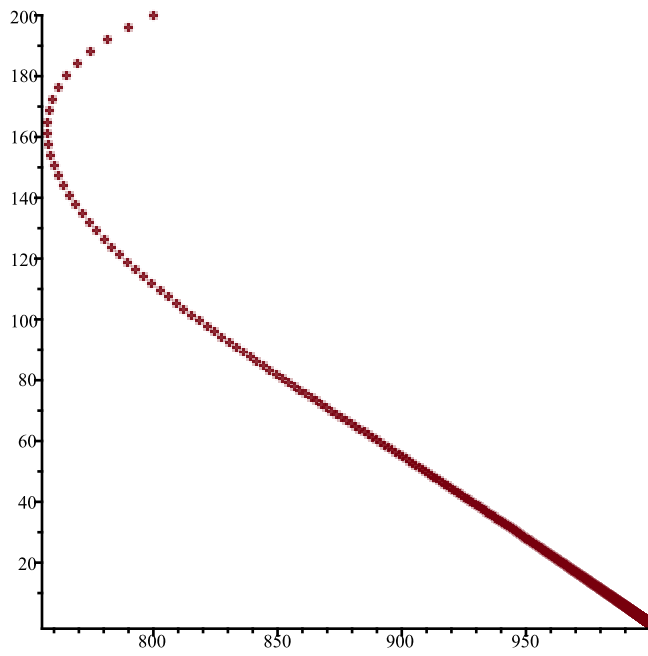


$$F := [-0.006300000000 \, s \, i + 10000 - 10 \, s - 10 \, i, 0.006300000000 \, s \, i - 7 \, i]$$

$$\{ [1000., 0.], [1111.111111, -65.35947712] \}$$

$$\{ [1000., 0.] \}$$

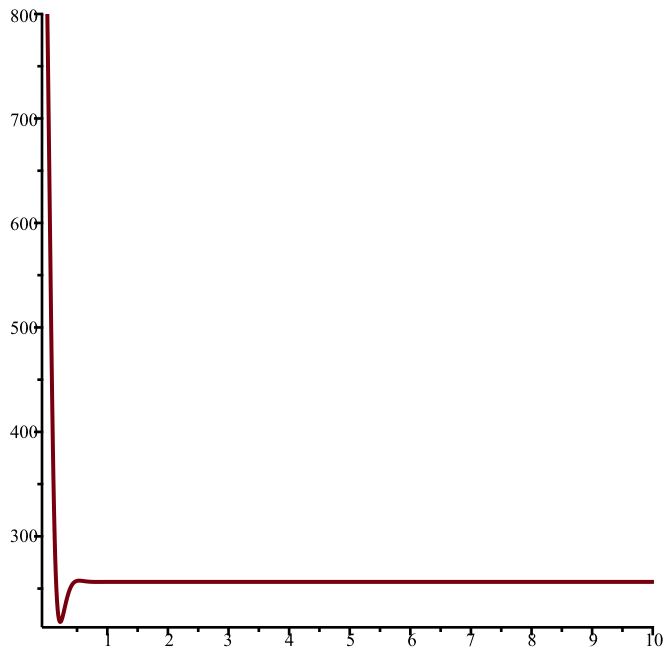


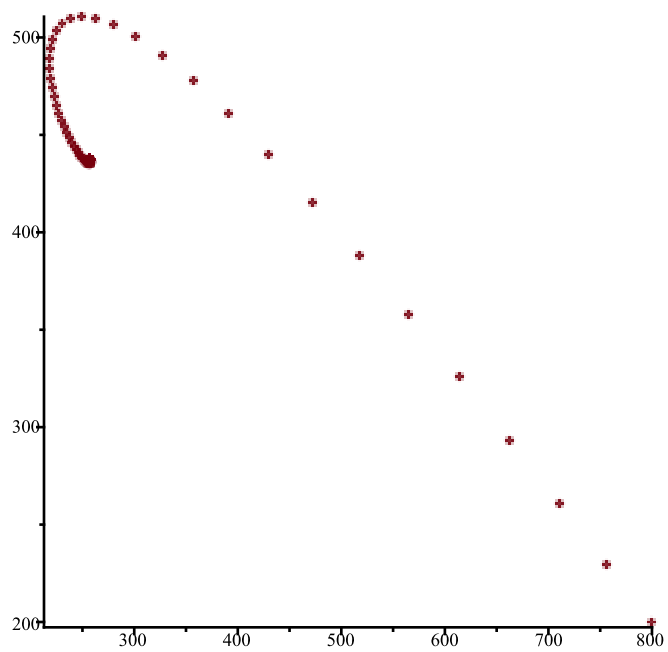
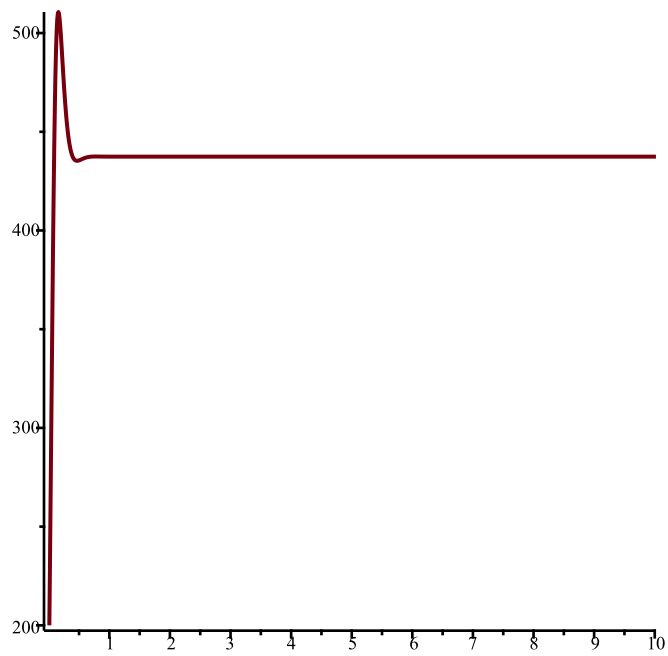


$$F := [-0.02730000000 \, s \, i + 10000 - 10 \, s - 10 \, i, 0.02730000000 \, s \, i - 7 \, i]$$

$$\{ [256.4102564, 437.4057315], [1000., 0.] \}$$

$$\{ [256.4102564, 437.4057315] \}$$





> #2

```
F1 := RandNice([x, y], 3);
EquP(F1, [x, y]);
SEquP(F1, [x, y]);
```

```
F2 := RandNice([x, y], 3);
EquP(F2, [x, y]);
SEquP(F2, [x, y]);
```

```
F3 := RandNice([x, y], 3);
EquP(F3, [x, y]);
SEquP(F3, [x, y]);
```

```
F1 := [(2 - 2x - 3y) (2 - x - 3y), (1 - x - 2y) (3 - 2x - 2y)]
```

$$\left\{ [-1, 1], [1, 0], \left[\frac{5}{2}, -1 \right], \left[\frac{5}{4}, \frac{1}{4} \right] \right\}$$

$$\{ [1., 0.] \}$$

$$F2 := [(1 - 2x - y)(1 - 2x - 2y), (3 - 3x - 2y)(2 - x - y)]$$

$$\left\{ [-1, 3], \left[2, -\frac{3}{2} \right] \right\}$$

$$\{ [2., -1.500000000] \}$$

$$F3 := [(3 - x - 2y)(1 - 2x - 3y), (3 - 3x - 2y)(1 - 3x - 3y)]$$

$$\left\{ \left[0, \frac{1}{3} \right], \left[0, \frac{3}{2} \right], \left[-\frac{7}{3}, \frac{8}{3} \right], \left[\frac{7}{5}, -\frac{3}{5} \right] \right\}$$

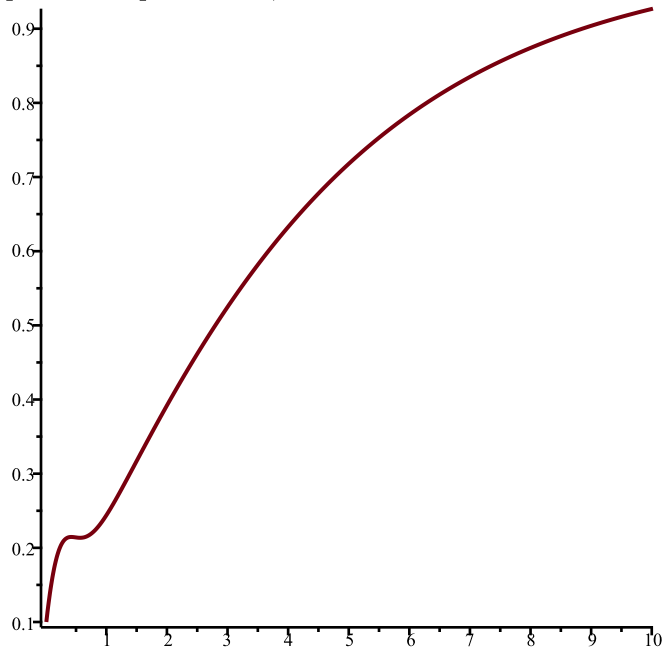
$$\{ [-2.333333333, 2.666666667], [1.400000000, -0.600000000] \}$$

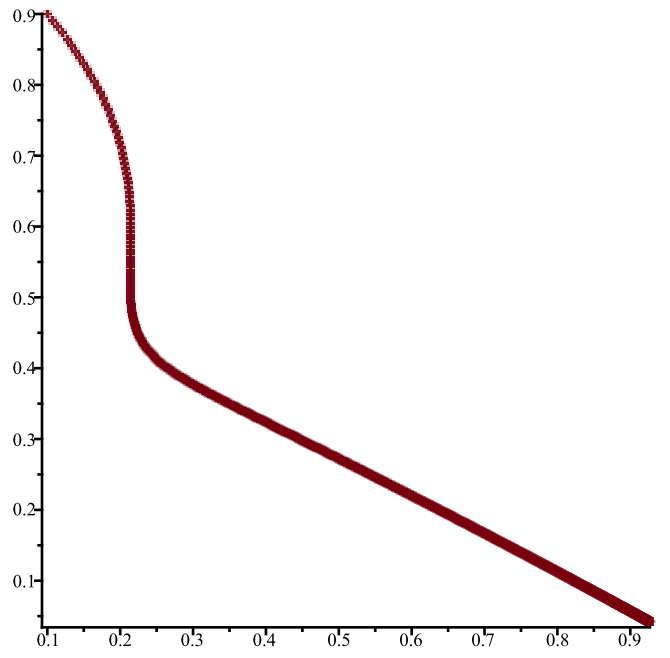
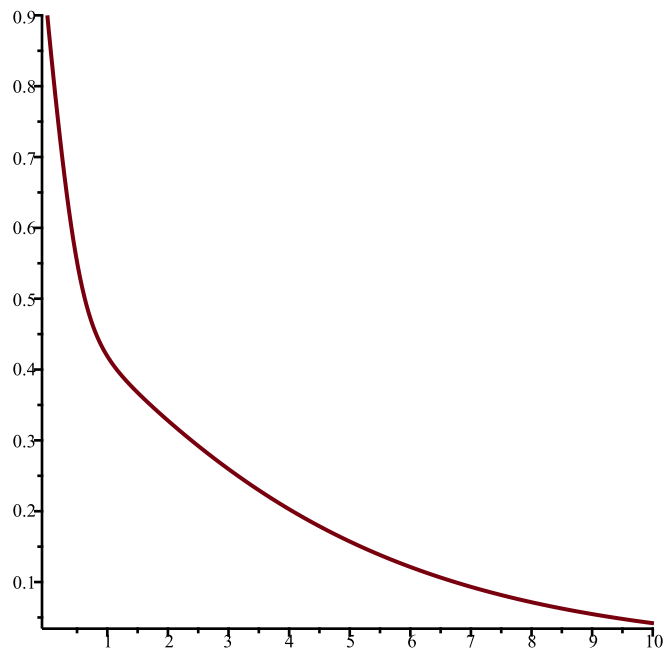
(2)

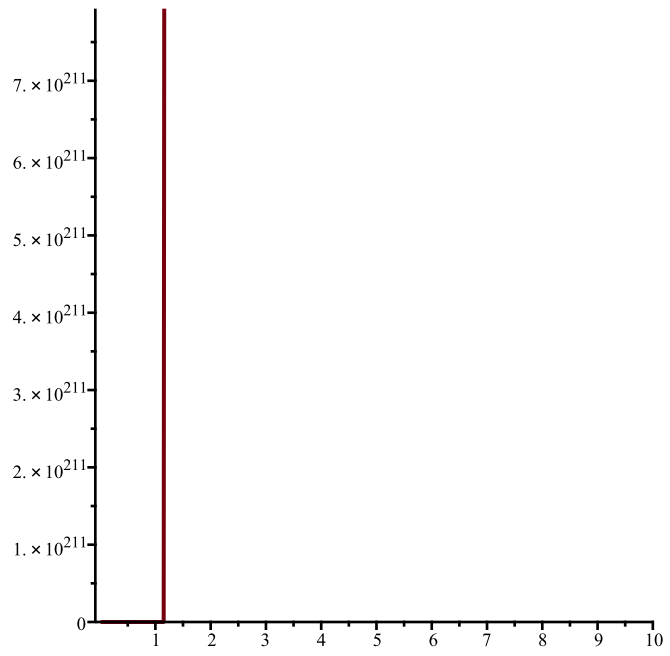
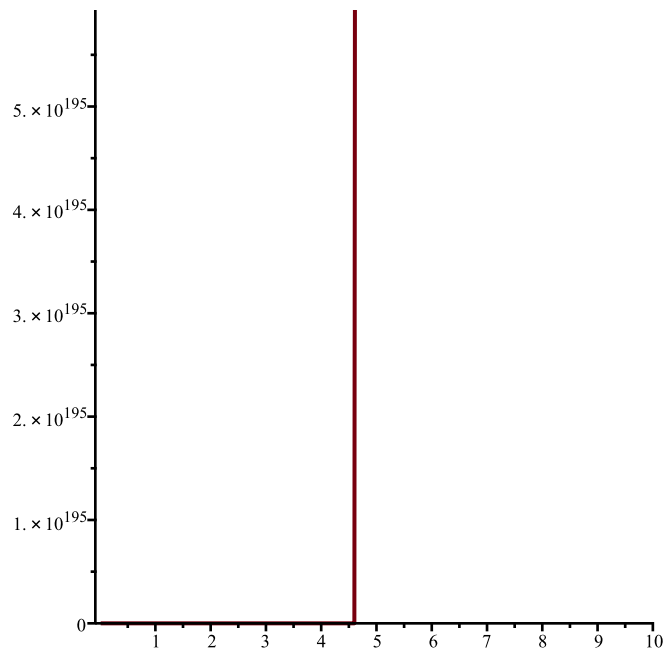
> *TimeSeries*(F1, [x, y], [0.1, 0.9], 0.01, 10, 1);
TimeSeries(F1, [x, y], [0.1, 0.9], 0.01, 10, 2);
PhaseDiag(F1, [x, y], [0.1, 0.9], 0.01, 10);

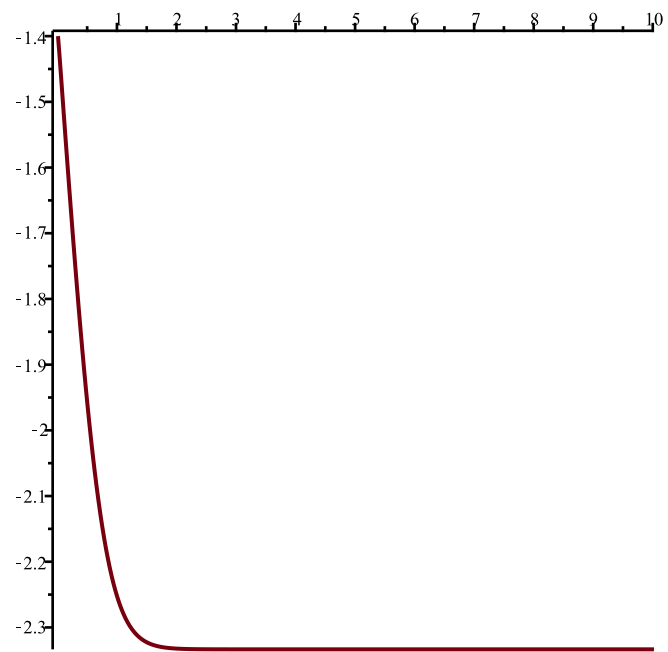
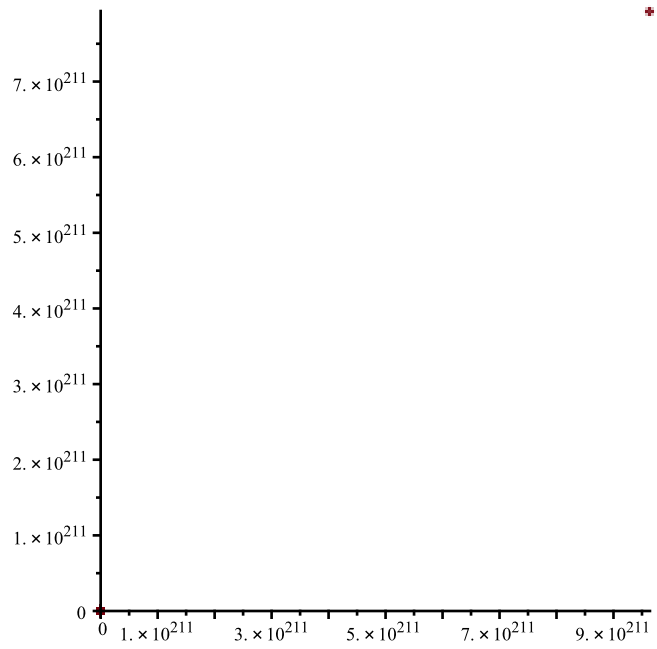
TimeSeries(F2, [x, y], [-1.4, 0.6], 0.01, 10, 1);
TimeSeries(F2, [x, y], [0.12, 0.6], 0.01, 10, 2);
PhaseDiag(F2, [x, y], [0.12, 0.6], 0.01, 10);

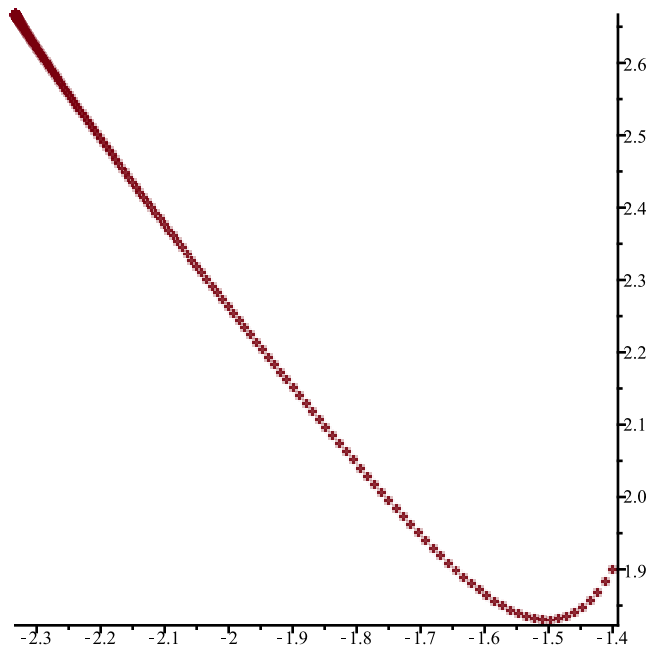
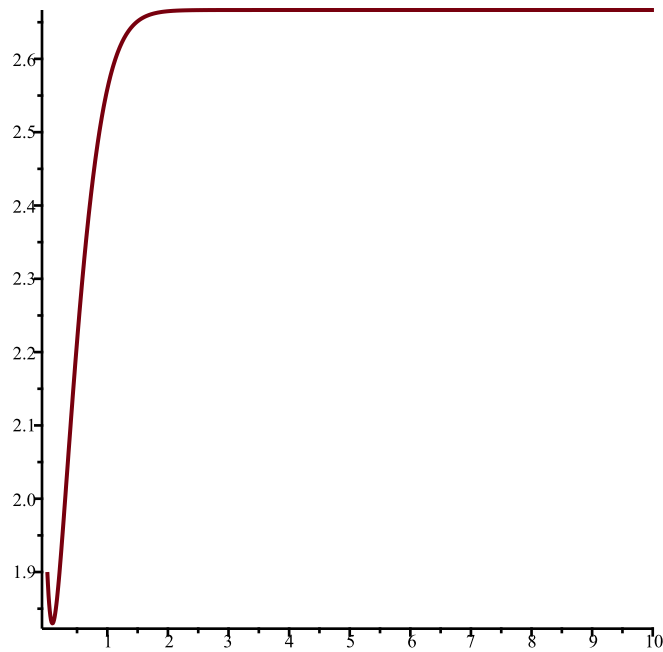
TimeSeries(F3, [x, y], [-1.4, 1.9], 0.01, 10, 1);
TimeSeries(F3, [x, y], [-1.4, 1.9], 0.01, 10, 2);
PhaseDiag(F3, [x, y], [-1.4, 1.9], 0.01, 10);











> #3

```
#x(n) = (3 + x(n-2) + x(n-3) + x(n-4))/(1 + x(n-1) + x(n-3));
Orbk(4, z, (3 + z[2] + z[3] + z[4]) / (1 + z[1] + z[3]), [1., 2., 3., 4.], 1000,
1005);
Orbk(4, z, (3 + z[2] + z[3] + z[4]) / (1 + z[1] + z[3]), [0., 1., 0., 4.], 1000,
1005);
Orbk(4, z, (3 + z[2] + z[3] + z[4]) / (1 + z[1] + z[3]), [0., 2., 1., 0.], 1000,
1005);
g := (3 + z[2] + z[3] + z[4]) / (1 + z[1] + z[3]);
G := ToSys(4, z, g);
SFP(G);
```

[2.514430208, 1.368732008, 2.514430208, 1.368732008, 2.514430208, 1.368732008]

[5.230601980, 0.8699317777, 5.230601980, 0.8699317777, 5.230601980, 0.8699317777]
[1.376781353, 2.495936608, 1.376781353, 2.495936608, 1.376781353, 2.495936608]

$$g := \frac{3 + z_2 + z_3 + z_4}{1 + z_1 + z_3}$$

$$G := \left[\frac{3 + z_2 + z_3 + z_4}{1 + z_1 + z_3}, z_1, z_2, z_3 \right], [z_1, z_2, z_3, z_4]$$

{[1.822875656, 1.822875656, 1.822875656, 1.822875656]}

(3)

