

> #OK to post

>

> #Anne Somalwar, hw20, 11.15.2021

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>

> **read** "C:/Users/aks238/OneDrive - Rutgers University/Documents/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)

>

>

> #SIRS(s,i,beta,gamma,nu,N)

> #I

>

```

> #(i)
> #(i)
> EquP(SIRS(s, i,  $\frac{0.3 \cdot 2}{1000}$ , 5, 2, 1000), [s, i])
      { [1000., 0.], [3333.333333, -1666.666667] }

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(2)

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>
>
> #(ii)
>
> SEquP(SIRS(s, i,  $\frac{0.3 \cdot 2}{1000}$ , 5, 2, 1000), [s, i])
      { [1000., 0.] }

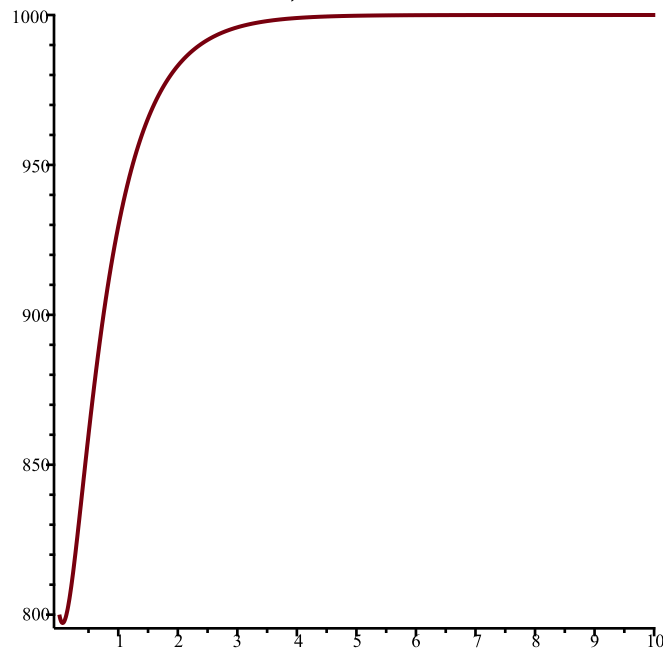
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(3)

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> TimeSeries(SIRS(s, i,  $\frac{0.3 \cdot 2}{1000}$ , 5, 2, 1000), [s, i], [800, 200], 0.01, 10, 1)

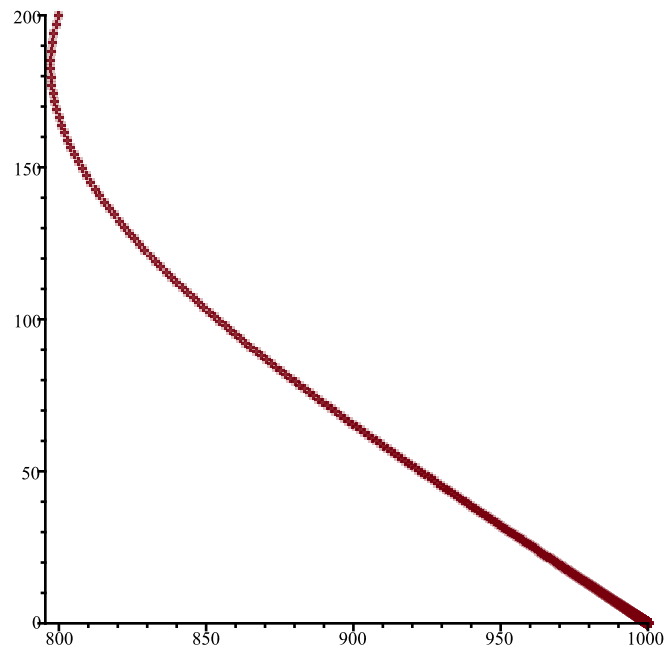
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> PhaseDiag(SIRS(s, i,  $\frac{0.3 \cdot 2}{1000}$ , 5, 2, 1000), [s, i], [800, 200], 0.01, 10)

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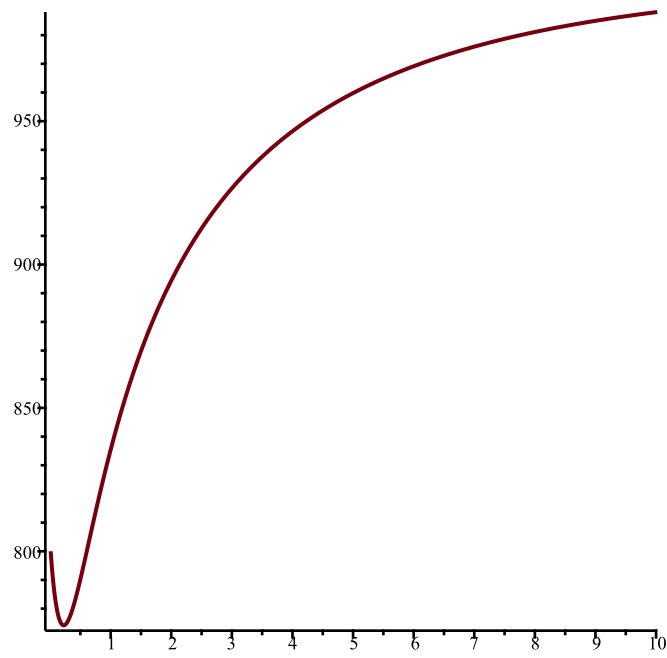
#(i)

$$\text{EquP}\left(\text{SIRS}\left(s, i, \frac{0.9 \cdot 2}{1000}, 5, 2, 1000\right), [s, i]\right) \quad \{[1000., 0.], [1111.111111, -79.36507937]\} \quad (4)$$

#(ii)

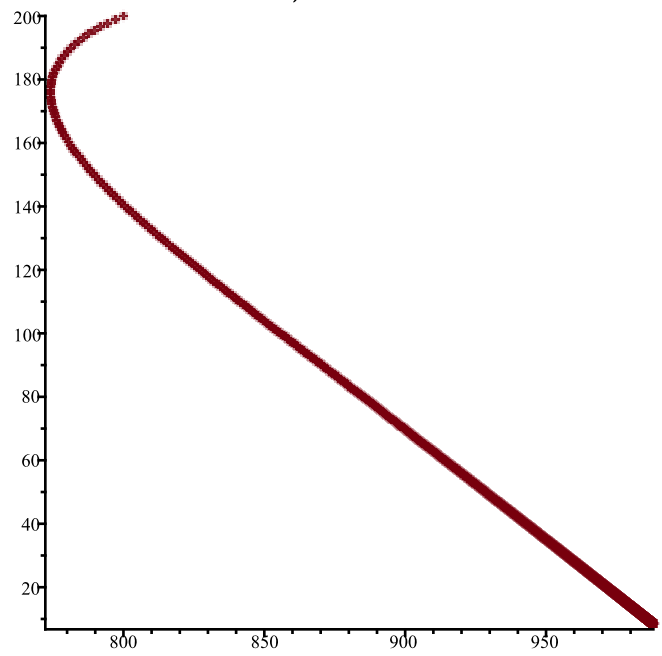
$$\text{SEquP}\left(\text{SIRS}\left(s, i, \frac{0.9 \cdot 2}{1000}, 5, 2, 1000\right), [s, i]\right) \quad \{[1000., 0.]\} \quad (5)$$

$$\text{TimeSeries}\left(\text{SIRS}\left(s, i, \frac{0.9 \cdot 2}{1000}, 5, 2, 1000\right), [s, i], [800, 200], 0.01, 10, 1\right)$$



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> $PhaseDiag\left(SIRS\left(s, i, \frac{0.9 \cdot 2}{1000}, 5, 2, 1000\right), [s, i], [800, 200], 0.01, 10\right)$



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>
> #(i)
> EquP(SIRS(s, i, 3.9*2/1000, 5, 2, 1000), [s, i])
      { [256.4102564, 531.1355311], [1000., 0.] }

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(6)

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>
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>
> #(ii)
> SEquP(SIRS(s, i, 3.9*2/1000, 5, 2, 1000), [s, i])
      { [256.4102564, 531.1355311] }

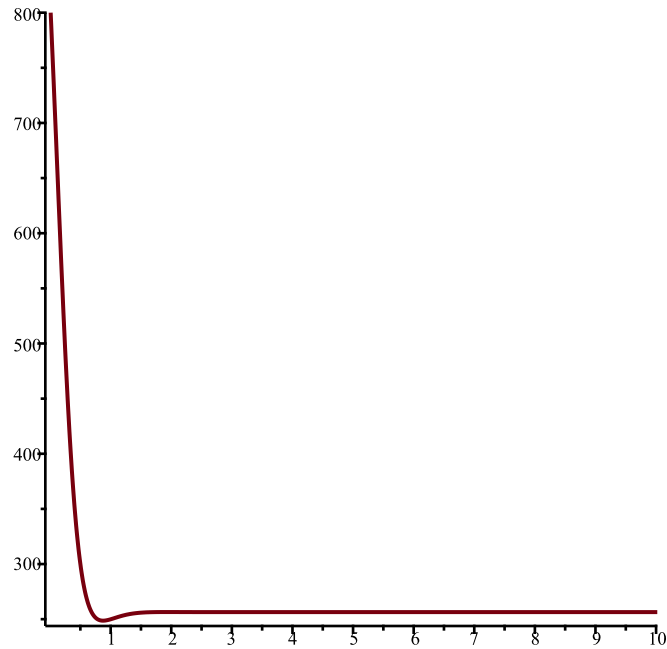
```

(7)

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> TimeSeries(SIRS(s, i, 3.9*2/1000, 5, 2, 1000), [s, i], [800, 200], 0.01, 10, 1)

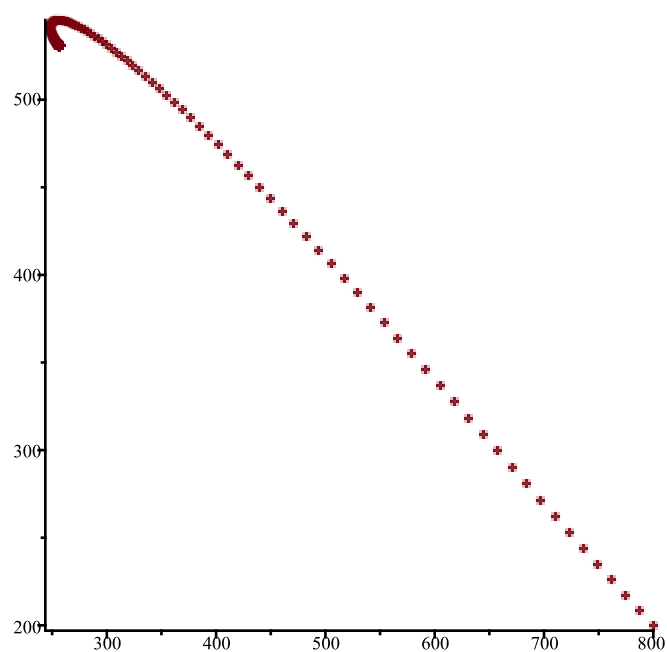
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>
> PhaseDiag(SIRS(s, i, 3.9*2/1000, 5, 2, 1000), [s, i], [800, 200], 0.01, 10)

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> #(ii)
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> #(i)
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```
> EquP(SIRS(s, i,  $\frac{0.3 \cdot 2}{1000}$ , 6, 3, 1000), [s, i])
      { [1000., 0.], [5000., -2666.666667] }
```

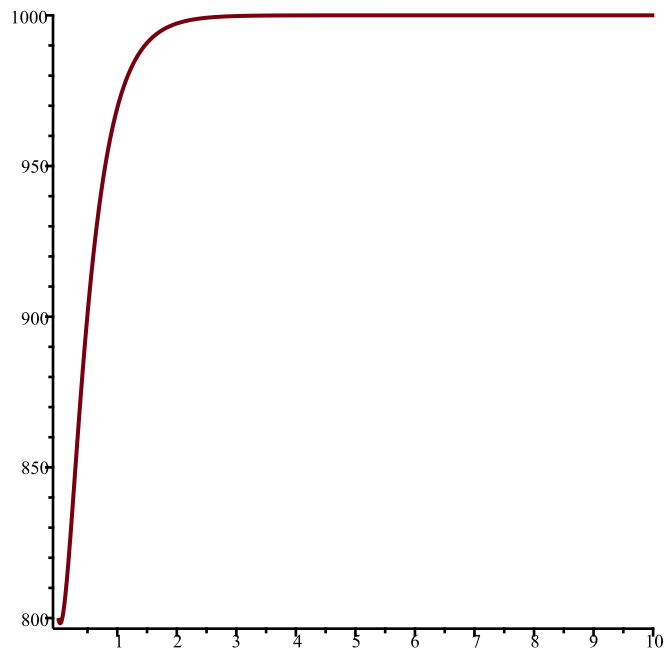
(8)

```
> # (ii)
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```
> SEquP(SIRS(s, i,  $\frac{0.3 \cdot 2}{1000}$ , 6, 3, 1000), [s, i])
      { [1000., 0.] }
```

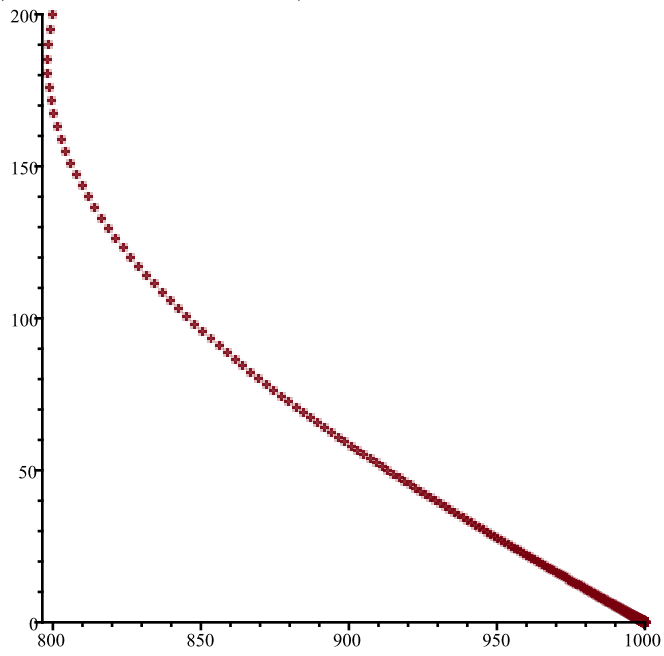
(9)

```
> TimeSeries(SIRS(s, i,  $\frac{0.3 \cdot 2}{1000}$ , 6, 3, 1000), [s, i], [800, 200], 0.01, 10, 1)
```



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> $PhaseDiag\left(SIRS\left(s, i, \frac{0.3 \cdot 2}{1000}, 6, 3, 1000\right), [s, i], [800, 200], 0.01, 10\right)$



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> #(i)
> EquP(SIRS(s, i, 0.9*2/1000, 6, 3, 1000), [s, i])
      { [1000., 0.], [1666.666667, -444.444444] }

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(10)

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> #(ii)
> SEquP(SIRS(s, i, 0.9*2/1000, 6, 3, 1000), [s, i])
      { [1000., 0.] }

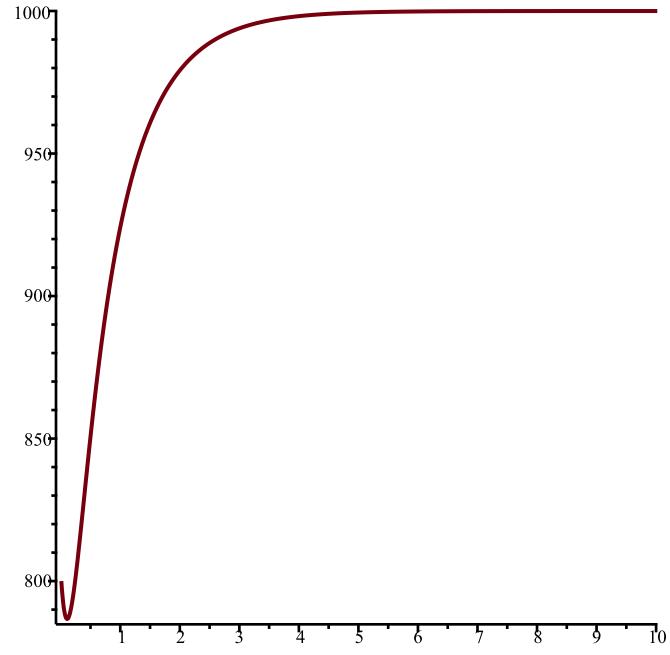
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(11)

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> TimeSeries(SIRS(s, i, 0.9*2/1000, 6, 3, 1000), [s, i], [800, 200], 0.01, 10, 1)

```



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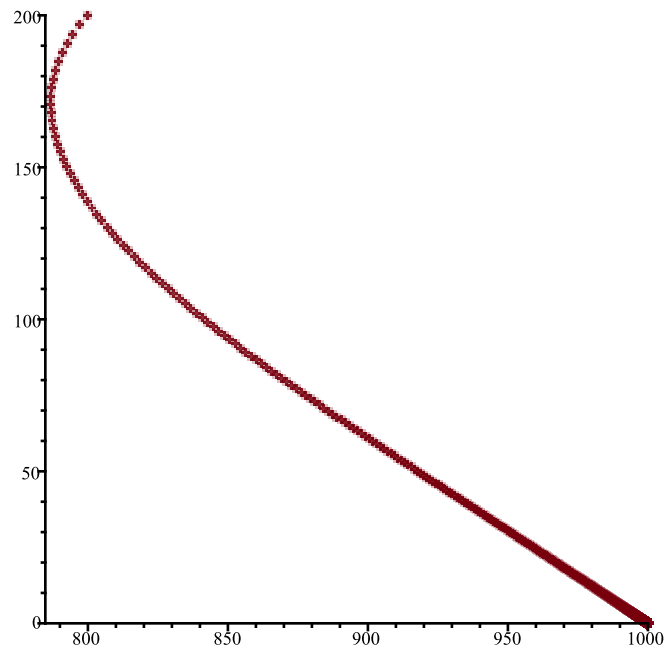
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> PhaseDiag(SIRS(s, i, 0.9*2/1000, 6, 3, 1000), [s, i], [800, 200], 0.01, 10)

```

#(i)

$$\text{EquP}\left(\text{SIRS}\left(s, i, \frac{3.9 \cdot 2}{1000}, 6, 3, 1000\right), [s, i]\right) \\ \{[384.6153846, 410.2564103], [1000., 0.]\}$$

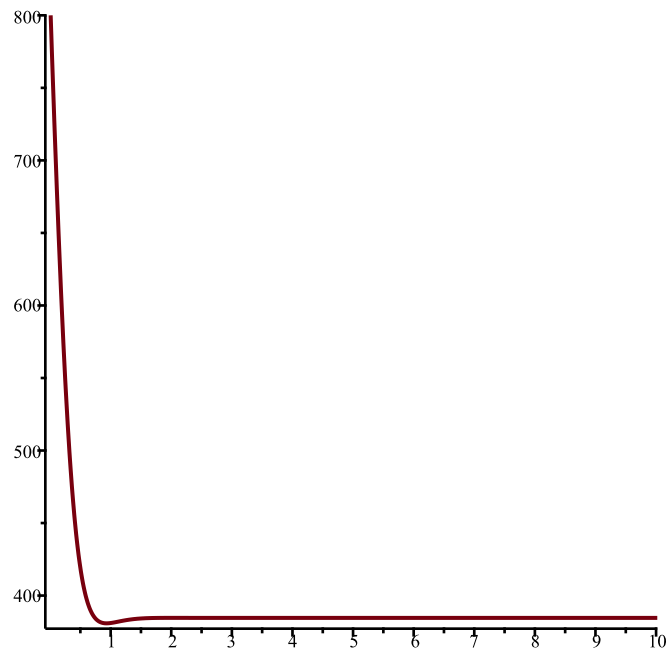
(12)

#(ii)

$$\text{SEquP}\left(\text{SIRS}\left(s, i, \frac{3.9 \cdot 2}{1000}, 6, 3, 1000\right), [s, i]\right) \\ \{[384.6153846, 410.2564103]\}$$

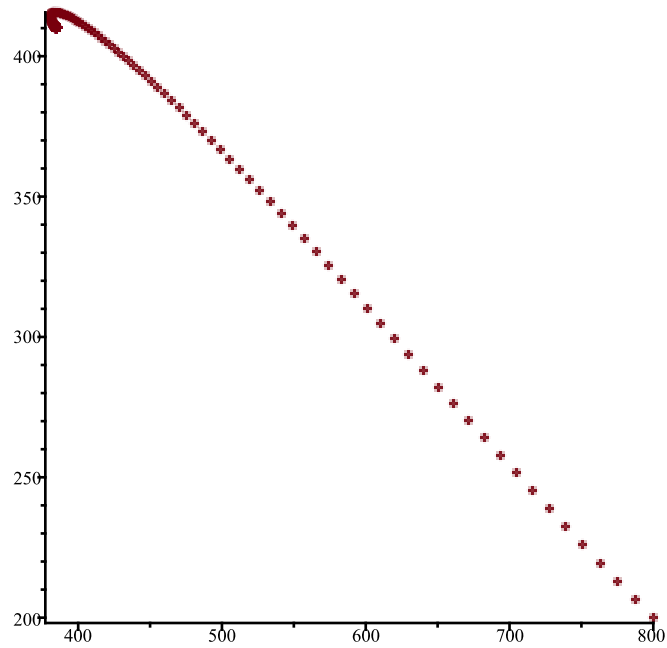
(13)

$$\text{TimeSeries}\left(\text{SIRS}\left(s, i, \frac{3.9 \cdot 2}{1000}, 6, 3, 1000\right), [s, i], [800, 200], 0.01, 10, 1\right)$$



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$$\text{PhaseDiag}\left(\text{SIRS}\left(s, i, \frac{3.9 \cdot 2}{1000}, 6, 3, 1000\right), [s, i], [800, 200], 0.01, 10\right)$$



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#(iii)

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> #(i)
>
> EquP(SIRS(s, i, 0.3*2/1000, 1, 4, 1000), [s, i])
      { [1000., 0.], [6666.666667, -1133.333333] }

```

(14)

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>
> #(ii)
>
> SEquP(SIRS(s, i, 0.3*2/1000, 1, 4, 1000), [s, i])
      { [1000., 0.] }

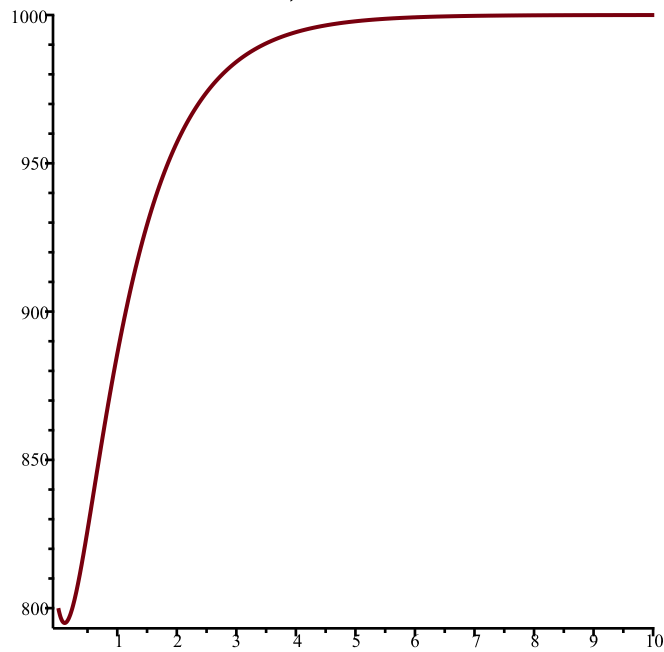
```

(15)

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> TimeSeries(SIRS(s, i, 0.3*2/1000, 1, 4, 1000), [s, i], [800, 200], 0.01, 10, 1)

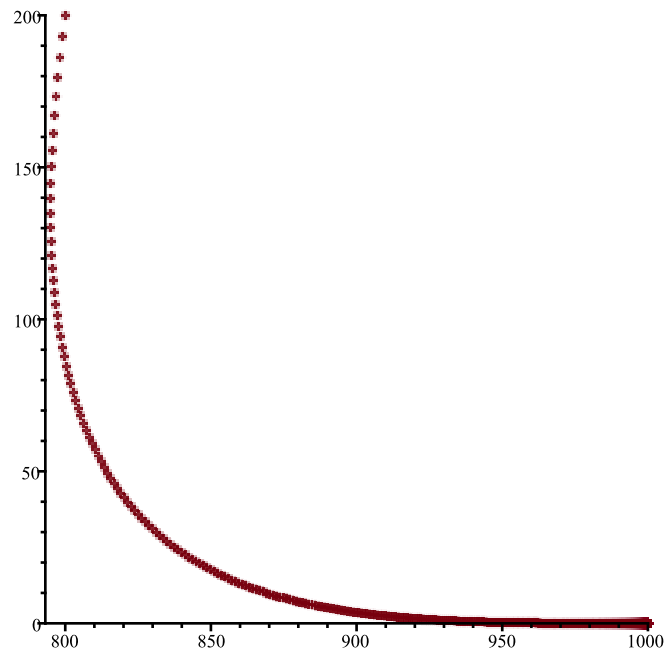
```



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>
> PhaseDiag(SIRS(s, i, 0.3*2/1000, 1, 4, 1000), [s, i], [800, 200], 0.01, 10)

```



#(i)

$$\text{EquP}\left(\text{SIRS}\left(s, i, \frac{0.9 \cdot 2}{1000}, 1, 4, 1000\right), [s, i]\right) \{ [1000., 0.], [2222.222222, -244.4444444] \}$$

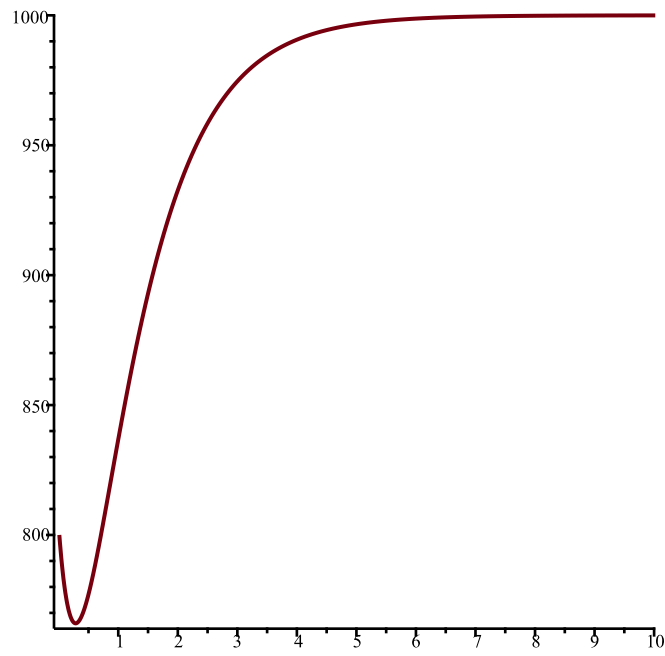
(16)

#(ii)

$$\text{SEquP}\left(\text{SIRS}\left(s, i, \frac{0.9 \cdot 2}{1000}, 1, 4, 1000\right), [s, i]\right) \{ [1000., 0.] \}$$

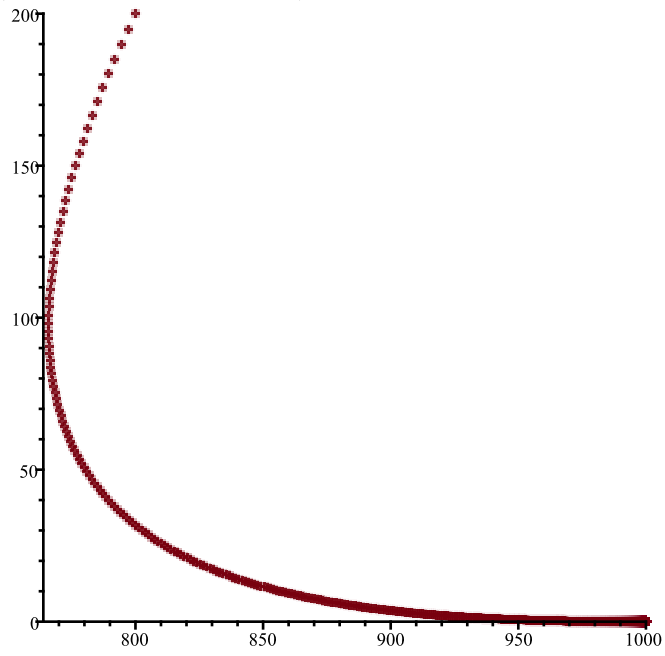
(17)

$$\text{TimeSeries}\left(\text{SIRS}\left(s, i, \frac{0.9 \cdot 2}{1000}, 1, 4, 1000\right), [s, i], [800, 200], 0.01, 10, 1\right)$$



>>

> $PhaseDiag\left(SIRS\left(s, i, \frac{0.9 \cdot 2}{1000}, 1, 4, 1000\right), [s, i], [800, 200], 0.01, 10\right)$



>>>>>>>

#(i)

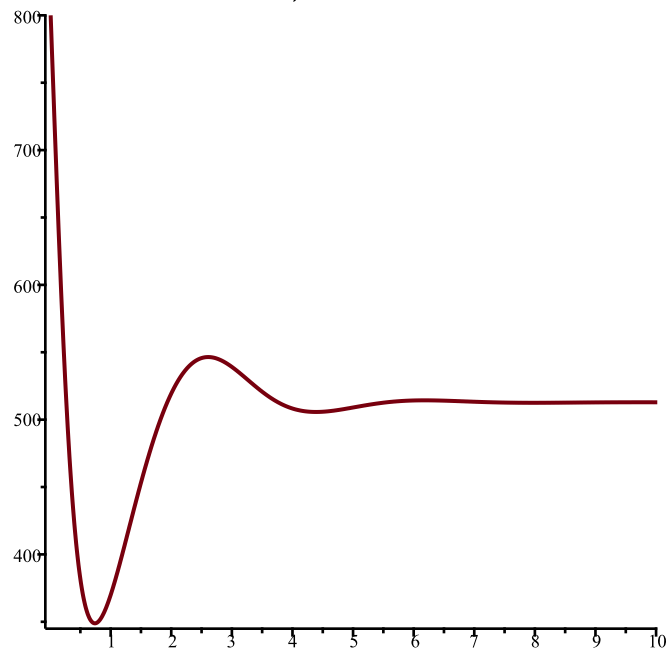
> $EquP\left(SIRS\left(s, i, \frac{3.9 \cdot 2}{1000}, 1, 4, 1000\right), [s, i]\right)$
{ [512.8205128, 97.43589744], [1000., 0.] } (18)

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#(ii)

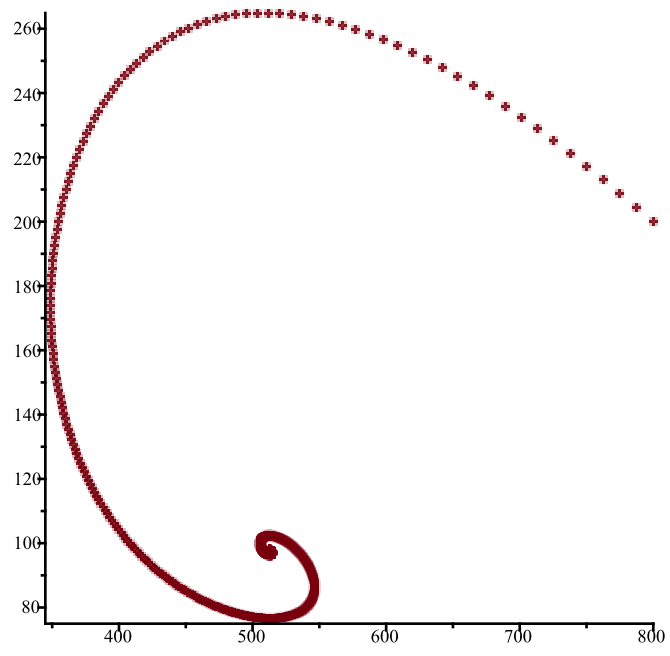
> $SEquP\left(SIRS\left(s, i, \frac{3.9 \cdot 2}{1000}, 1, 4, 1000\right), [s, i]\right)$
{ [512.8205128, 97.43589744] } (19)

> $TimeSeries\left(SIRS\left(s, i, \frac{3.9 \cdot 2}{1000}, 1, 4, 1000\right), [s, i], [800, 200], 0.01, 10, 1\right)$



>
 >

> $PhaseDiag\left(SIRS\left(s, i, \frac{3.9 \cdot 2}{1000}, 1, 4, 1000\right), [s, i], [800, 200], 0.01, 10\right)$



#(iv)

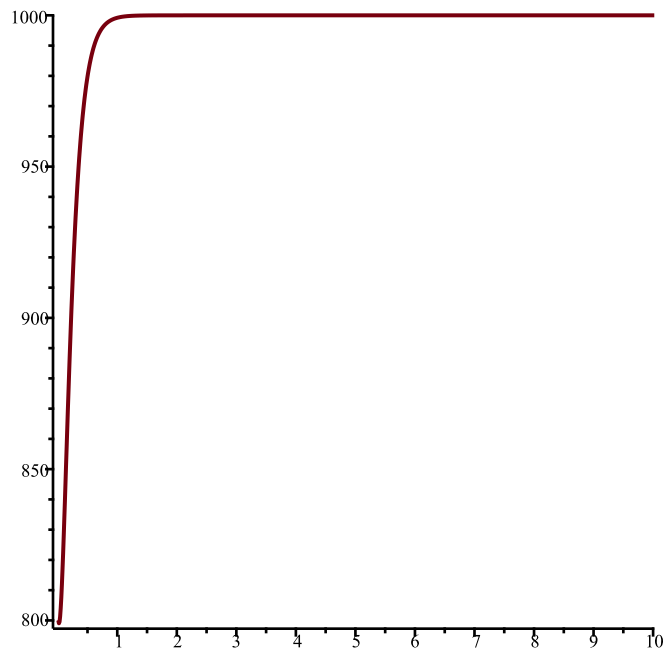
#(i)

$$\begin{aligned}
 &> \text{EquP}\left(\text{SIRS}\left(s, i, \frac{0.3 \cdot 2}{1000}, 10, 7, 1000\right), [s, i]\right) \\
 &\quad \{[1000., 0.], [11666.66667, -6274.509804]\} \tag{20}
 \end{aligned}$$

#(ii)

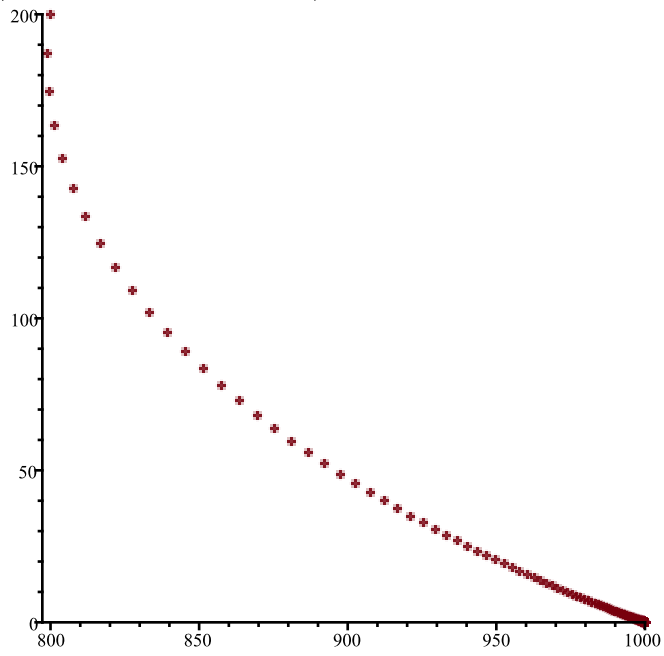
$$\begin{aligned}
 &> \text{SEquP}\left(\text{SIRS}\left(s, i, \frac{0.3 \cdot 2}{1000}, 10, 7, 1000\right), [s, i]\right) \\
 &\quad \{[1000., 0.]\} \tag{21}
 \end{aligned}$$

$$> \text{TimeSeries}\left(\text{SIRS}\left(s, i, \frac{0.3 \cdot 2}{1000}, 10, 7, 1000\right), [s, i], [800, 200], 0.01, 10, 1\right)$$



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> $PhaseDiag\left(SIRS\left(s, i, \frac{0.3 \cdot 2}{1000}, 10, 7, 1000\right), [s, i], [800, 200], 0.01, 10\right)$



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> #(i)
> EquP(SIRS(s, i, 0.9*2/1000, 10, 7, 1000), [s, i])
      { [1000., 0.], [3888.888889, -1699.346405] }

```

(22)

```

>
>
>
> #(ii)
>
> SEquP(SIRS(s, i, 0.9*2/1000, 10, 7, 1000), [s, i])
      { [1000., 0.] }

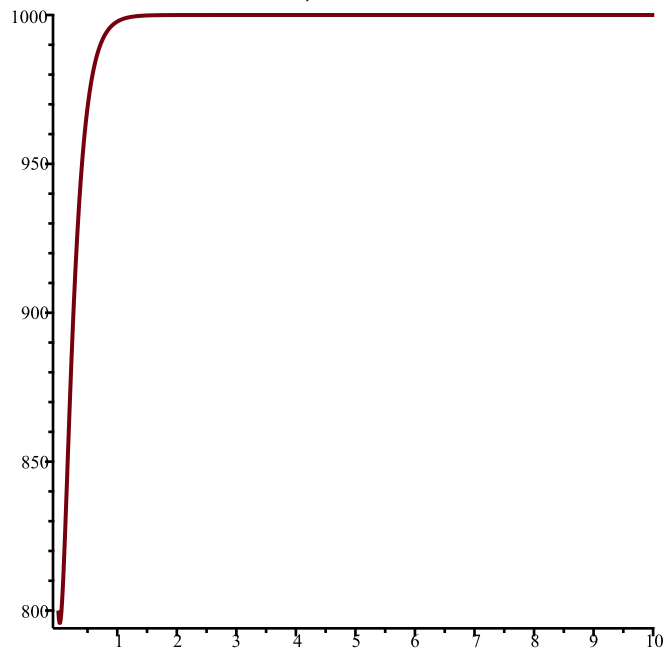
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(23)

```

> TimeSeries(SIRS(s, i, 0.9*2/1000, 10, 7, 1000), [s, i], [800, 200], 0.01, 10, 1)

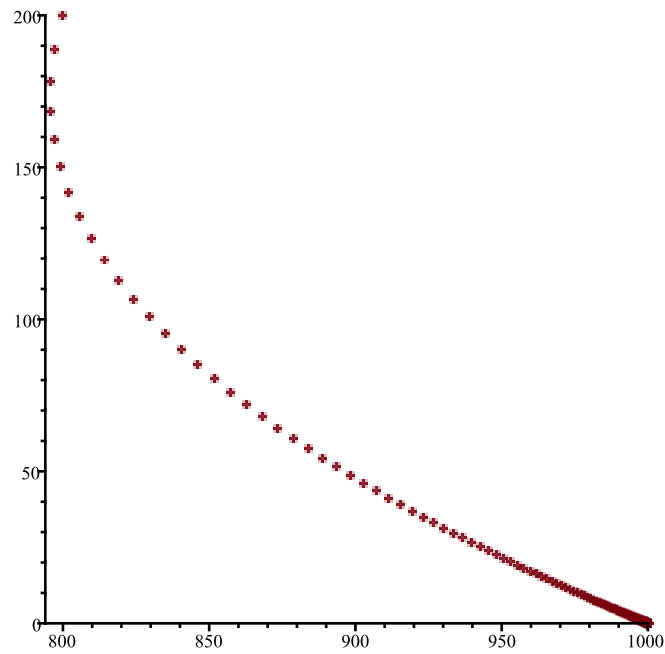
```



```

>
>
> PhaseDiag(SIRS(s, i, 0.9*2/1000, 10, 7, 1000), [s, i], [800, 200], 0.01, 10)

```



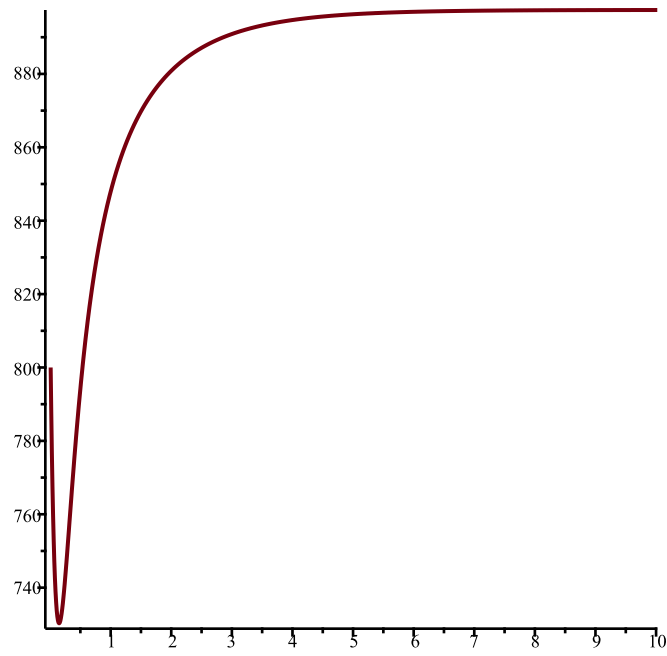
#(i)

$$\begin{aligned} &> \text{EquP}\left(\text{SIRS}\left(s, i, \frac{3.9 \cdot 2}{1000}, 10, 7, 1000\right), [s, i]\right) \\ &\quad \{[897.4358974, 60.33182504], [1000., 0.]\} \end{aligned} \tag{24}$$

#(ii)

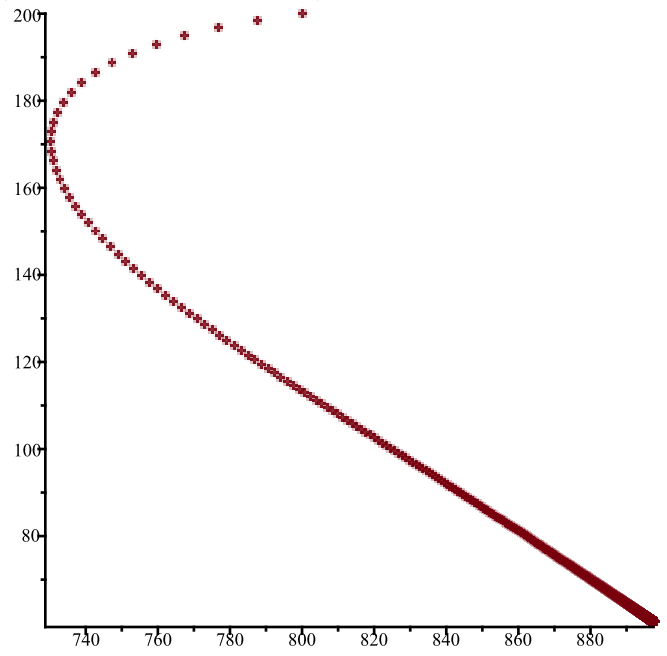
$$\begin{aligned} &> \text{SEquP}\left(\text{SIRS}\left(s, i, \frac{3.9 \cdot 2}{1000}, 10, 7, 1000\right), [s, i]\right) \\ &\quad \{[897.4358974, 60.33182504]\} \end{aligned} \tag{25}$$

$$\begin{aligned} &> \text{TimeSeries}\left(\text{SIRS}\left(s, i, \frac{3.9 \cdot 2}{1000}, 10, 7, 1000\right), [s, i], [800, 200], 0.01, 10, 1\right) \end{aligned}$$



>>

> $PhaseDiag\left(SIRS\left(s, i, \frac{3.9 \cdot 2}{1000}, 10, 7, 1000\right), [s, i], [800, 200], 0.01, 10\right)$



>>>>>>>>

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>
>
>
> #2
>
> #(i)
> F := RandNice([x, y], 3)
      F := [(2 - 2x - 3y) (2 - x - 3y), (1 - x - 2y) (3 - 2x - 2y)]

```

(26)

```

> EquP(F, [x, y])
      {[-1, 1], [1, 0], [5/2, -1], [5/4, 1/4]}

```

(27)

```

>
> #(ii)
> SEquP(F, [x, y])
      {[1., 0.]}

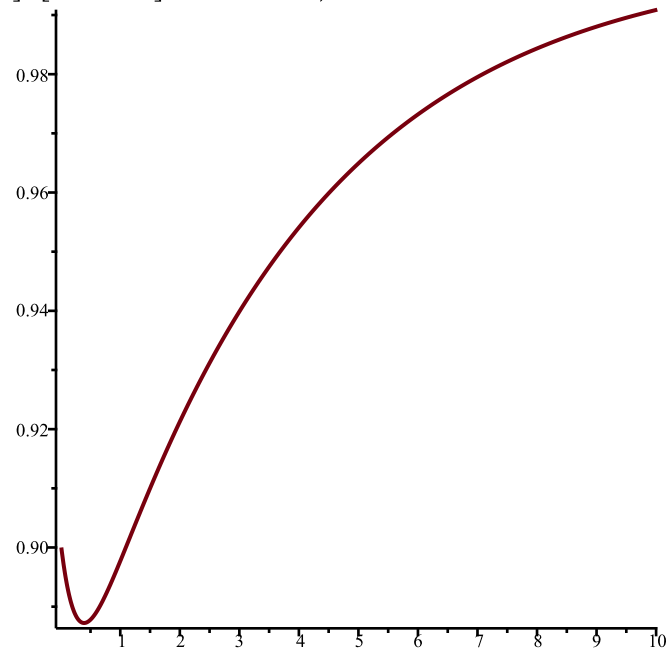
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(28)

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>
> #(iii)
> TimeSeries(F, [x, y], [0.9, 0.1], 0.01, 10, 1)

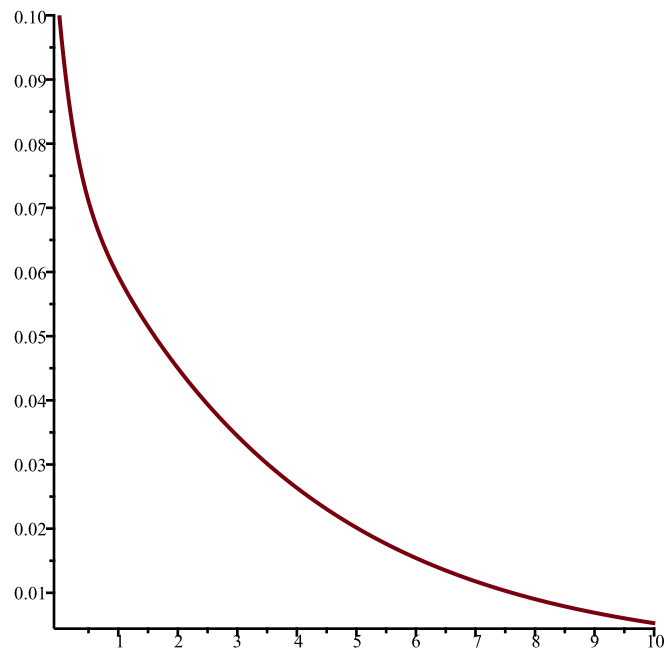
```



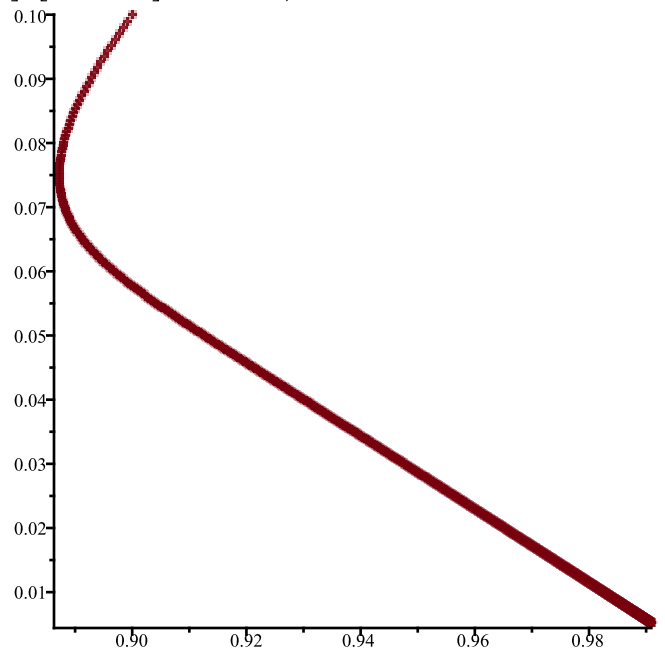
```

> TimeSeries(F, [x, y], [0.9, 0.1], 0.01, 10, 2)

```



> PhaseDiag(F, [x, y], [0.9, 0.1], 0.01, 10)



>

>

>

> F := RandNice([x, y], 3)

$$F := [(3 - x - 3y) (3 - 2x - 3y), (1 - x - 3y) (1 - x - 2y)] \quad (29)$$

>

>

>

> EquP(F, [x, y])

(30)

$$\left\{ [-3, 2], \left[2, -\frac{1}{3} \right], [3, -1] \right\} \quad (30)$$

>

> #(ii)

>

> *SEquP*(*F*, [*x*, *y*])

$$\{ [3., -1.] \} \quad (31)$$

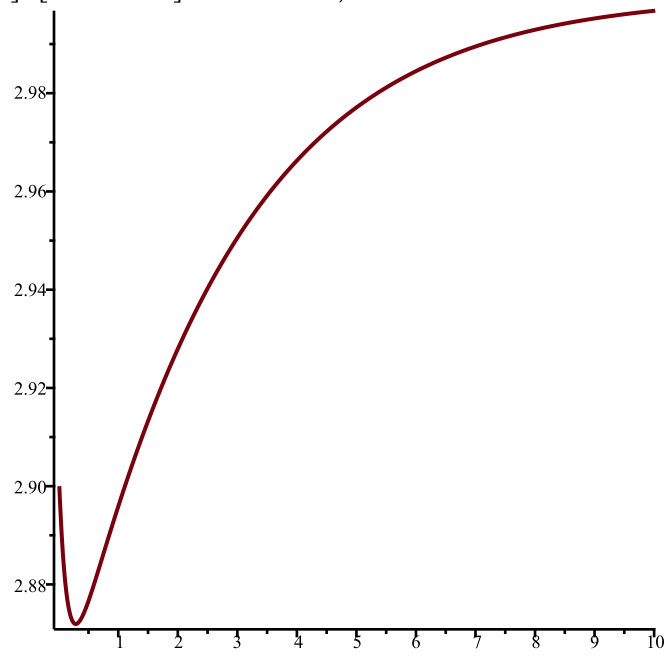
>

>

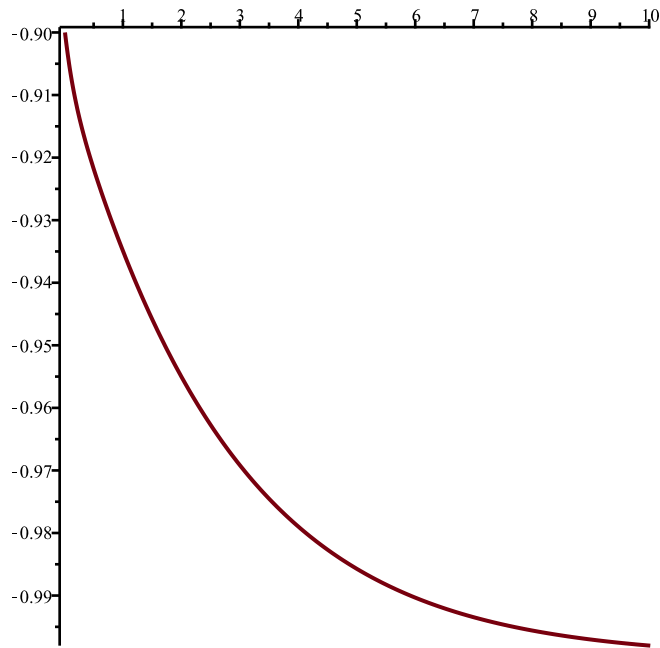
> #(iii)

>

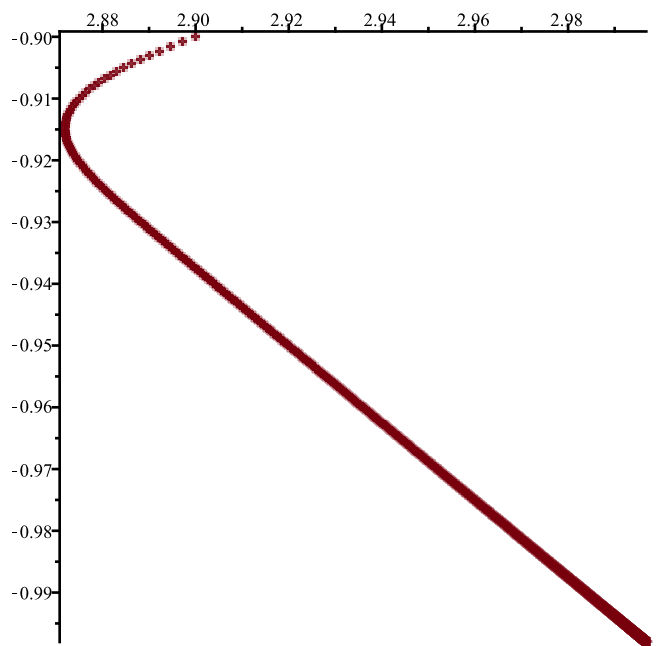
> *TimeSeries*(*F*, [*x*, *y*], [2.9, -0.9], 0.01, 10, 1)



> *TimeSeries*(*F*, [*x*, *y*], [2.9, -0.9], 0.01, 10, 2)



```
> PhaseDiag(F, [x, y], [2.9, -0.9], 0.01, 10)
```



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>
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>
```

```
> F := RandNice([x, y], 3)
      F := [(2 - 2x - 3y)(2 - 3x - 2y), (1 - x - y)(3 - x - 3y)]
```

```
> EquP(F, [x, y])
```

$$\left\{ \left[-1, \frac{4}{3} \right], [0, 1], [1, 0] \right\}$$

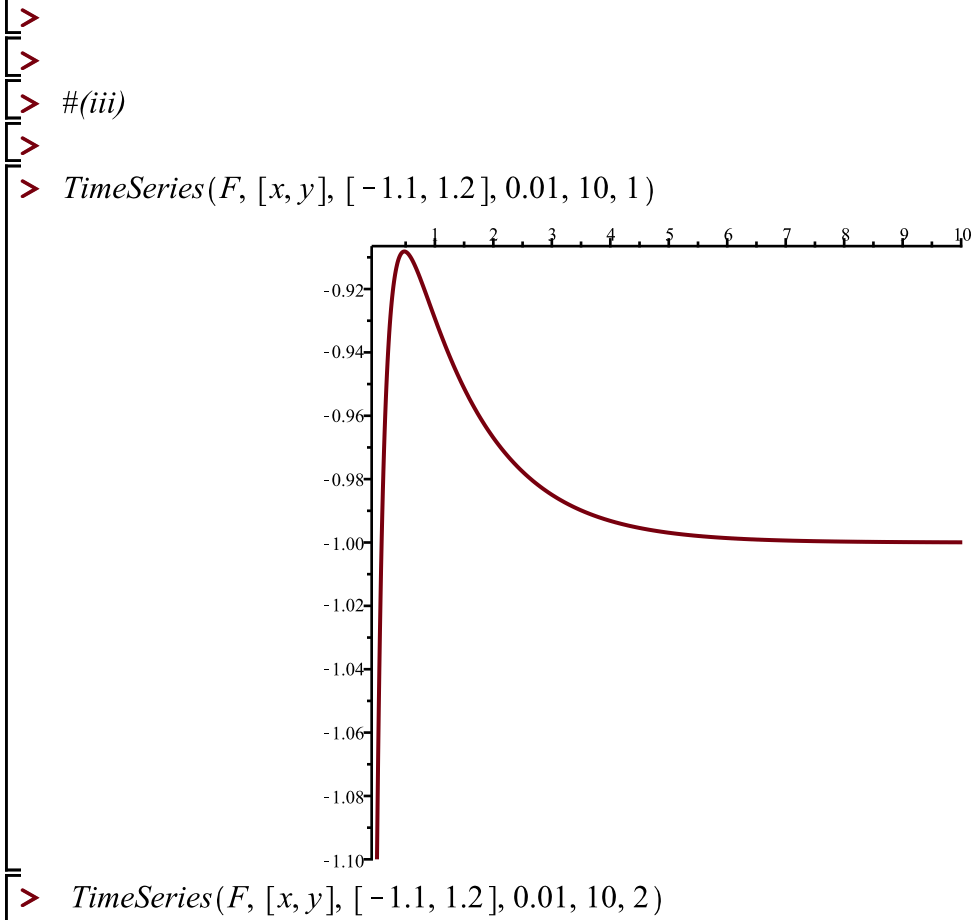
(33)

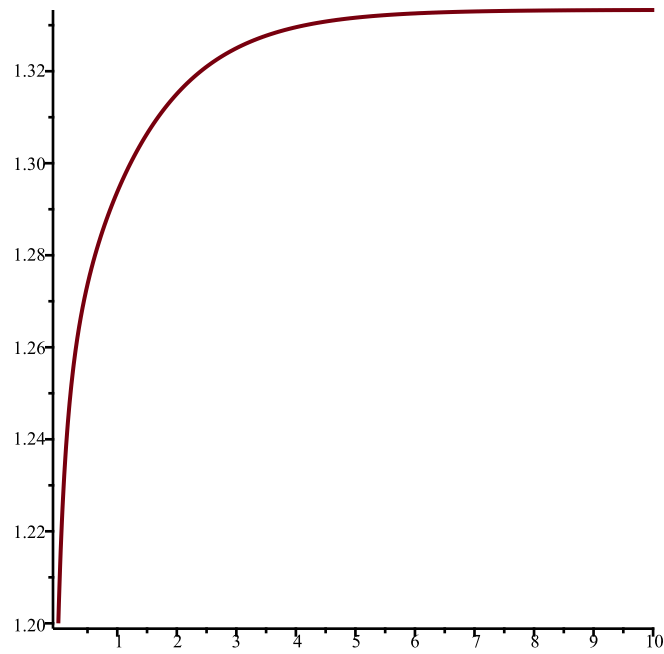
```
> #(ii)
```

```
> SEquP(F, [x, y])
```

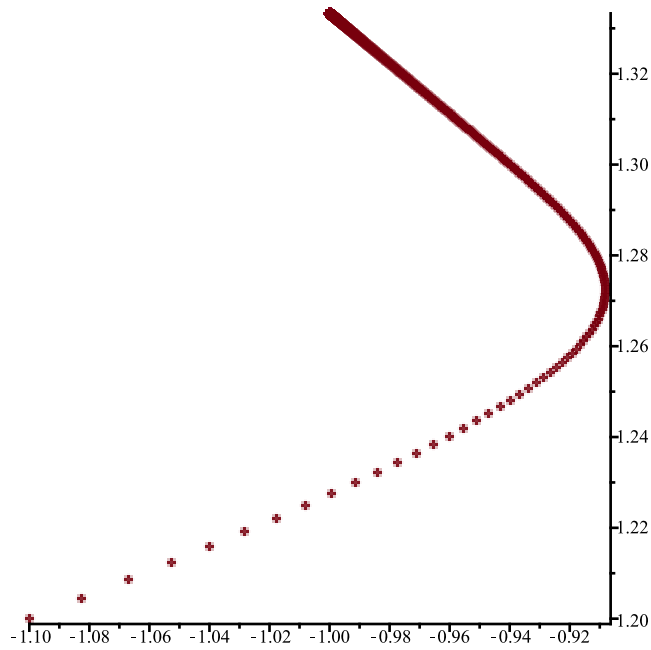
$$\{ [-1., 1.333333333], [1., 0.] \}$$

(34)





```
> PhaseDiag(F, [x, y], [-1.1, 1.2], 0.01, 10)
```



```
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>
```

#3

```
> Orbk(4, z, (3 + z[2] + z[3] + z[4]) / (1 + z[1] + z[3]), [1., 1., 1., 1.], 1, 100)
```