Homework 18- Charles Griebell

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Preamble:

```
> with(LinearAlgebra);
  with(VectorCalculus);
  read `C:/Users/cgrie/Dynam Models Bio/Homeworks/HW18/M18.txt`;
  read `C:/Users/cgrie/Dynam Models Bio/Homeworks/HW19/M19.txt`;
```

[&x, Add, Adjoint, BackwardSubstitute, BandMatrix, Basis, BezoutMatrix, BidiagonalForm, BilinearForm, CARE, CharacteristicMatrix, CharacteristicPolynomial, Column, ColumnDimension, ColumnOperation, ColumnSpace, CompanionMatrix, CompressedSparseForm, ConditionNumber, ConstantMatrix, ConstantVector, Copy, CreatePermutation, CrossProduct, DARE, DeleteColumn, DeleteRow, Determinant, Diagonal, DiagonalMatrix, Dimension, Dimensions, DotProduct, EigenConditionNumbers, Eigenvalues, Eigenvectors, Equal, ForwardSubstitute, FrobeniusForm, FromCompressedSparseForm, FromSplitForm, GaussianElimination, GenerateEquations, GenerateMatrix, Generic, GetResultDataType, GetResultShape, GivensRotationMatrix, GramSchmidt, HankelMatrix, HermiteForm, HermitianTranspose, HessenbergForm, HilbertMatrix, HouseholderMatrix, IdentityMatrix, IntersectionBasis, IsDefinite, IsOrthogonal, IsSimilar, IsUnitary, JordanBlockMatrix, JordanForm, KroneckerProduct, LA_Main, LUDecomposition, LeastSquares, LinearSolve, LyapunovSolve, Map, Map2, MatrixAdd, MatrixExponential, MatrixFunction, MatrixInverse, MatrixMatrixMultiply, MatrixNorm, MatrixPower, MatrixScalarMultiply, MatrixVectorMultiply, MinimalPolynomial, Minor, Modular, Multiply, NoUserValue, Norm, Normalize, NullSpace, OuterProductMatrix, Permanent, Pivot, PopovForm, ProjectionMatrix, QRDecomposition, RandomMatrix, RandomVector, Rank, RationalCanonicalForm, ReducedRowEchelonForm, Row, RowDimension, RowOperation, RowSpace, ScalarMatrix, ScalarMultiply, ScalarVector, SchurForm, SingularValues, SmithForm, SplitForm, StronglyConnectedBlocks, SubMatrix, SubVector, SumBasis, SylvesterMatrix, SylvesterSolve, ToeplitzMatrix, Trace, Transpose, TridiagonalForm, UnitVector, VandermondeMatrix, VectorAdd, VectorAngle, VectorMatrixMultiply, VectorNorm, VectorScalarMultiply, ZeroMatrix, ZeroVector, Zip]

[&x, `*`, `+`, `-`, `.`, <,>, <|>, About, AddCoordinates, ArcLength, BasisFormat, Binormal, ConvertVector, CrossProduct, Curl, Curvature, D, Del, DirectionalDiff, Divergence, DotProduct, Flux, GetCoordinateParameters, GetCoordinates, GetNames, GetPVDescription, GetRootPoint, GetSpace, Gradient, Hessian, IsPositionVector, IsRootedVector, IsVectorField, Jacobian, Laplacian, LineInt, MapToBasis, ∇, Norm, Normalize, PathInt, PlotPositionVector, PlotVector, PositionVector, PrincipalNormal, RadiusOfCurvature, RootedVector, ScalarPotential,

```
    SetCoordinateParameters, SetCoordinates, SpaceCurve, SurfaceInt, TNBFrame, TangentLine,
    TangentPlane, TangentVector, Torsion, Vector, VectorField, VectorPotential, VectorSpace,
    Wronskian, diff, eval, evalVF, int, limit, series]
Error, on line 1, syntax error, character `?` unexpected:
<?xml version="1.0" encoding="UTF-8"?>
 ^

Error, while reading ``C:/Users/cgrie/Dynam Models Bio/Homeworks/HW19/M19.txt``
```

Problem 1: Carefully read the answer to the first question in

https://sites.math.rutgers.edu/~zeilberg/Bio21/att18S.pdf

understand it and then write a Maple program that inputs numbers a, b, c, d, e , call it , $C(a, b, c, d, e)$
and outputs the answer to the following question

a chickens lay b eggs in c days, how many eggs do d chickens lay in e days?

Check that $C\left(\frac{3}{2}, \frac{3}{2}, \frac{3}{2}, 3, 3\right) = 6$

```
> C := proc(a,b,c,d,e) local c_inv, a_chickens_daily,
  single_chicken_daily,total_eggs;

  #Step 1: set the units by 1 day (MULTIPLICATIVE INVERSE of c)
  c_inv := 1/c;

  #Find the number of eggs "a" chickens lay in 1 day
  a_chickens_daily := b * c_inv;

  #Step 2: find how many eggs 1 chicken lays in 1 day (Divide by
  "a")
  single_chicken_daily := a_chickens_daily/a;

  #Step 3: find total eggs laid by "d" chickens in "e" days
  total_eggs := single_chicken_daily * d * e;



  end;
```

$$C := \mathbf{proc}(a, b, c, d, e) \quad \textbf{(1)}$$

$$\mathbf{local}\ c\_inv, a\_chickens\_daily, single\_chicken\_daily, total\_eggs;$$

$$c\_inv := VectorCalculus{:}\text{-}\grave{}*\grave{}(1, 1/c);$$

```
    a_chickens_daily := VectorCalculus:-`*`(b, c_inv);
    single_chicken_daily := VectorCalculus:-`*`(a_chickens_daily, 1/a);
    total_eggs := VectorCalculus:-`*`(VectorCalculus:-`*`(single_chicken_daily, d), e)
end proc
```

```
> C(3/2,3/2,3/2,3,3);

  #FINISHED!!!
```

$$6 \qquad \textbf{(2)}$$

Problem 2:
Carefully read the answer to the second question in ATT18s

understand it and then write a Maple program that inputs numbers a, b, k, call it, W(a, b, k) and
outputs the answer to the following question:

```
> W := proc(a,b,k) local F1,F2,F3,F1a,knowns:
  #Our system
  #We are allowed to let the volume V=1
  F1 := A*a + B*a = 1;
  F2 := A*b + C*b = 1;
  F3 := B = k*C;

  #now substitute k*C into the B-value of F1
  F1a := subs(F3,F1);
  #Now solve the system of 2 equations with the 2 unknowns A and C
  knowns := solve({F1a,F2});
  end:
```

Check that W(4,5,2) = 20

```
> W(4,5,2);
```

$$\left\{A = \frac{3}{20}, C = \frac{1}{20}\right\} \qquad \textbf{(3)}$$

Problem 3: Recall that in order to find all the equilibrium points of a continuous-time (first-order) system

$x'(t) = F(\mathbf{x}(t))$

(i) Use algebra to solve, $F(\mathbf{x}) = \mathbf{0}$, getting a (usually) finite set of points in R^k .

These are all the
equilibrium points (That live in R^k) of the dynamical system (but so far you don't know whether they are stable or not).

```
> #All we need to do is
```

(ii) Find the **Jacobian matrix** , $\mathbf{J}(\mathbf{x})$, in general, featuring $x_1, \ldots, x_k$.

In General, the jacobian matrix is

$$\begin{bmatrix} \frac{\partial}{\partial x[1]}(F[1]) & \cdots & \frac{\partial}{\partial x[k]}(F[1]) \\ \vdots & \ddots & \vdots \\ \frac{\partial}{\partial x[1]}(F[k]) & \cdots & \frac{\partial}{\partial x[k]}(F[k]) \end{bmatrix}$$

#DONE for general case

```
>
```

(iii)

FOR THE GIVEN PROBLEM, SOLVE (i), (ii), and (iii) for the following system:

$$x'(t) = x(t)(1 - x(t) - y(t))$$

$$y'(t) = x(t)(3 - 2\,x(t) - y(t))$$

Answer to using algebra (i)

• By inspection, both $x'(t) = 0$ and $y'(t) = 0$ whenever $x(t) = 0$

To solve the other case, we can treat , which in this case is a friendly system:

$$0 = 1 - x(t) - y(t)$$

$$0 = 3 - 2\,x(t) - y(t)$$

This leaves us with

$2 = x$

$-1 = y$

Answer to (ii):

Finding the Jacobian Matrix, Let:

$$J := \begin{bmatrix} \frac{\partial}{\partial x}(x(1-x-y)) & \frac{\partial}{\partial y}(x(1-x-y)) \\ \frac{\partial}{\partial x}(x(3-2x-y)) & \frac{\partial}{\partial y}(x(3-2x-y)) \end{bmatrix} = \begin{bmatrix} 1-2x-y & -x \\ 3-4x-y & -x \end{bmatrix}$$

to find which equilibriums are stable, plug in the x and y value from each equilibrium point to the respective x and y of the jacobian matrix

$(2,-1) \rightarrow (x, y)$

$$J_{(2,-1)} = \begin{bmatrix} 1-2\cdot(2)-(-1) & -2 \\ 3-4\cdot(2)-(-1) & -(2) \end{bmatrix} = \begin{bmatrix} -2 & -2 \\ -4 & -2 \end{bmatrix}$$

Which has its **maximum eigenvalue**:

```
> evalf(max(Eigenvalues([[-2, -2], [-4, -2]])))
```

0.828427124 **(4)**

being greater than zero, therefore $(2,-1)$ is **NOT** a stable equilibrium point.

for verification purposes use the command:

```
> IsStable([[-2, -2], [-4, -2]])
```

false **(5)**

$(0, 0) \rightarrow (x, y)$

$$J_{(0,\,0)} = \begin{bmatrix} 1-2\cdot(0)-(0) & -(0) \\ 3-4(0)-(0) & -(0) \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 3 & 0 \end{bmatrix}$$

Which has its maximum eigenvalue

```
> max(Eigenvalues([[1, 0], [3, 0]]))
```

1 **(6)**

being greater than zero, therefore

```
> #DO NOT CARE ABOUT INPUTTTING THE IMAGE -waste of ttime
```

Problem 4:

Using the procedure `Dis2(F,x,y,pt,h,A)` with `h=0.01` and `A=10`

to confirm numerically the answers of problem 3 HINT: Take pt to be a value close to the equilibrium

example 1: for equilibrium (0,0) , let pt be (0, 0.1)

```
> eq00 := Dis2([x*(1-x-y),x*(3-(2*x)-y)],x,y,[0.1,0.1],0.01,10):
  eq00seq:= evalf(seq(eq00[i][2],i=1..1000));
  eq00seq_x := seq(eq00seq[i][1],i=1..1000);
  print(`the y vals`);
  eq00seq_y := seq(eq00seq[i][2],i=1..1000);
```

eq00seq := [0.1, 0.1], [0.1008, 0.1027], [0.1016028720, 0.1054172656], [0.1024085623, 0.1081517819], [0.1032170161, 0.1109035318], [0.1040281774, 0.1136724959], [0.1048419891, 0.1164586526], [0.1056583930, 0.1192619779], [0.1064773297, 0.1220824455], [0.1072987387, 0.1249200268], [0.1081225583, 0.1277746910], [0.1089487257, 0.1306464047], [0.1097771771, 0.1335351324], [0.1106078475, 0.1364408360], [0.1114406707, 0.1393634752], [0.1122755796, 0.1423030073], [0.1131125058, 0.1452593870], [0.1139513799, 0.1482325669], [0.1147921315, 0.1512224969], [0.1156346890, 0.1542291246], [0.1164789797, 0.1572523953], [0.1173249300, 0.1602922517], [0.1181724651, 0.1633486340], [0.1190215093, 0.1664214802], [0.1198719858, 0.1695107257], [0.1207238169, 0.1726163035], [0.1215769237, 0.1757381442], [0.1224312264, 0.1788761759], [0.1232866443, 0.1820303243], [0.1241430957, 0.1852005126], [0.1250004979, 0.1883866617], [0.1258587674, 0.1915886899], [0.1267178196, 0.1948065132], [0.1275775692, 0.1980400451], [0.1284379299, 0.2012891968], [0.1292988145, 0.2045538770], [0.1301601351, 0.2078339920], [0.1310218028, 0.2111294458], [0.1318837281, 0.2144401400], [0.1327458206, 0.2177659738], [0.1336079890, 0.2211068441], [0.1344701415, 0.2244626455], [0.1353321855, 0.2278332701], [0.1361940276, 0.2312186079], [0.1370555738, 0.2346185465], [0.1379167294, 0.2380329713], [0.1387773992, 0.2414617654], [0.1396374872, 0.2449048097], [0.1404968969, 0.2483619828], [0.1413555312, 0.2518331613], [0.1422132925, 0.2553182194], [0.1430700828, 0.2588170293], [0.1439258034, 0.2623294611], [0.1447803553, 0.2658553827], [0.1456336390, 0.2693946600], [0.1464855546, 0.2729471568], [0.1473360018, 0.2765127349], [0.1481848800, 0.2800912542], [0.1490320883, 0.2836825725], [0.1498775255, 0.2872865458], [0.1507210901, 0.2909030281], [0.1515626803, 0.2945318716], [0.1524021942, 0.2981729267], [0.1532395298, 0.3018260419], [0.1540745848, 0.3054910639], [0.1549072568, 0.3091678378], [0.1557374434, 0.3128562069], [0.1565650421, 0.3165560129], [0.1573899503, 0.3202670959], [0.1582120656, 0.3239892943], [0.1590312855, 0.3277224450], [0.1598475076, 0.3314663834], [0.1606606297, 0.3352209434], [0.1614705495, 0.3389859575], [0.1622771651, 0.3427612567], [0.1630803747, 0.3465466708], [0.1638800768, 0.3503420283], [0.1646761700, 0.3541471562], [0.1654685533, 0.3579618805], [0.1662571261, 0.3617860259], [0.1670417880, 0.3656194160],

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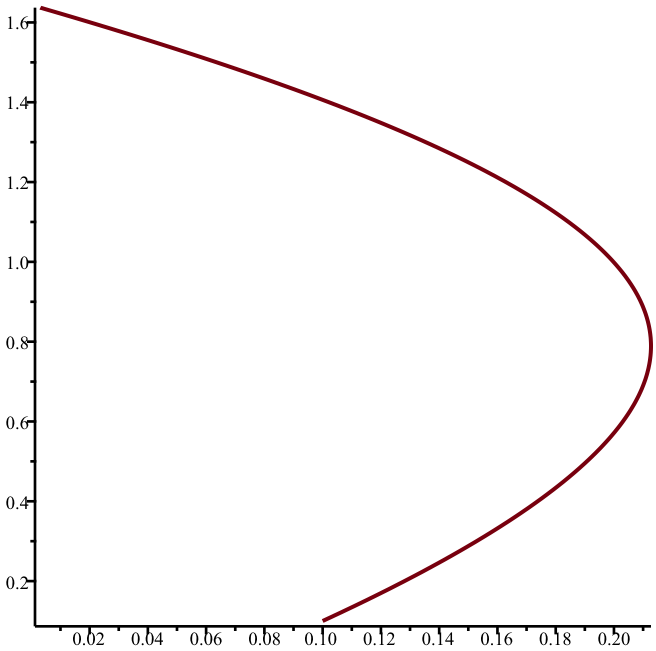
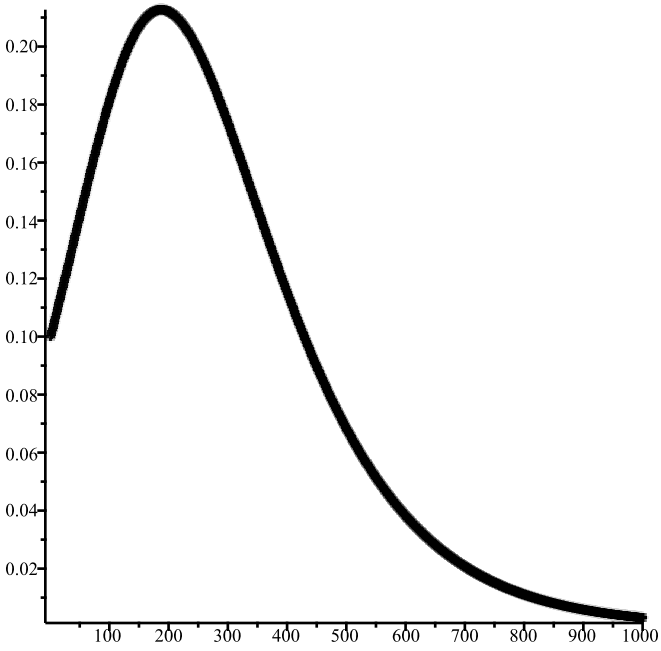
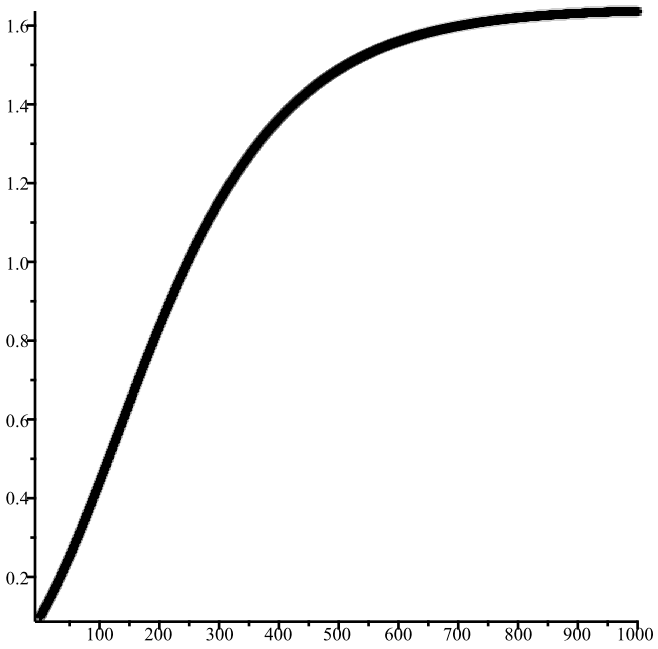
```
> plot([eq00seq]);
```




```
> pointplot({seq([i,eq00seq_x[i]],i=1..1000)});
```




```
> pointplot({seq([i,eq00seq_y[i]],i=1..1000)});
```



It appears that (0,0) is an unstable equilibrium because the values go away from zero. This is supported because the eigenvalues of the jacobian are positive. (This is supporting an answer)

#However, choosing an initial condition between 1 and zero represents boundedness. Is this some form of stability (like a stable domain)?
(This is not what the question is asking for

example 2: for equilibrium (2,-1) let pt be (2.01,-1)

```
> Dis2([x*(1-x-y),x*(3-2*x-y)],x,y,[2.01,-1],0.01,10);
```

$$[[0.01, [2.01, -1]], [0.02, [2.009799, -1.000402]], [0.03, [2.009610139, -1.000787801]], \quad \textbf{(8)}$$
$$[0.04, [2.009432844, -1.001158222]], [0.05, [2.009266571, -1.001514042]], [0.06,$$
$$[2.009110802, -1.001856001]], [0.07, [2.008965045, -1.002184804]], [0.08,$$
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[8.17, [Float(- ∞), Float(- ∞)]], [8.18, [Float(- ∞), Float(- ∞)]], [8.19, [Float(- ∞), Float(- ∞)]], [8.20, [Float(- ∞), Float(- ∞)]], [8.21, [Float(- ∞), Float(- ∞)]], [8.22, [Float(- ∞), Float(- ∞)]], [8.23, [Float(- ∞), Float(- ∞)]], [8.24, [Float(- ∞), Float(- ∞)]], [8.25, [Float(- ∞), Float(- ∞)]], [8.26, [Float(- ∞), Float(- ∞)]], [8.27, [Float(- ∞), Float(- ∞)]], [8.28, [Float(- ∞), Float(- ∞)]], [8.29, [Float(- ∞), Float(- ∞)]], [8.30, [Float(- ∞), Float(- ∞)]], [8.31, [Float(- ∞), Float(- ∞)]], [8.32, [Float(- ∞), Float(- ∞)]], [8.33, [Float(- ∞), Float(- ∞)]], [8.34, [Float(- ∞), Float(- ∞)]], [8.35, [Float(- ∞), Float(- ∞)]], [8.36, [Float(- ∞), Float(- ∞)]], [8.37, [Float(- ∞), Float(- ∞)]], [8.38, [Float(- ∞), Float(- ∞)]], [8.39, [Float(- ∞), Float(- ∞)]], [8.40, [Float(- ∞), Float(- ∞)]], [8.41, [Float(- ∞), Float(- ∞)]], [8.42, [Float(- ∞), Float(- ∞)]], [8.43, [Float(- ∞), Float(- ∞)]], [8.44, [Float(- ∞), Float(- ∞)]], [8.45, [Float(- ∞), Float(- ∞)]], [8.46, [Float(- ∞), Float(- ∞)]], [8.47, [Float(- ∞), Float(- ∞)]], [8.48, [Float(- ∞), Float(- ∞)]], [8.49, [Float(- ∞), Float(- ∞)]], [8.50, [Float(- ∞), Float(- ∞)]], [8.51, [Float(- ∞), Float(- ∞)]], [8.52, [Float(- ∞), Float(- ∞)]], [8.53, [Float(- ∞), Float(- ∞)]], [8.54, [Float(- ∞), Float(- ∞)]], [8.55, [Float(- ∞), Float(- ∞)]], [8.56, [Float(- ∞), Float(- ∞)]], [8.57, [Float(- ∞), Float(- ∞)]], [8.58, [Float(- ∞), Float(- ∞)]], [8.59, [Float(- ∞), Float(- ∞)]], [8.60, [Float(- ∞), Float(- ∞)]], [8.61, [Float(- ∞), Float(- ∞)]], [8.62, [Float(- ∞), Float(- ∞)]], [8.63, [Float(- ∞), Float(- ∞)]], [8.64, [Float(- ∞), Float(- ∞)]], [8.65, [Float(- ∞), Float(- ∞)]], [8.66, [Float(- ∞), Float(- ∞)]], [8.67, [Float(- ∞), Float(- ∞)]], [8.68, [Float(- ∞), Float(- ∞)]], [8.69, [Float(- ∞), Float(- ∞)]], [8.70, [Float(- ∞), Float(- ∞)]], [8.71, [Float(- ∞), Float(- ∞)]], [8.72, [Float(- ∞), Float(- ∞)]], [8.73, [Float(- ∞), Float(- ∞)]], [8.74, [Float(- ∞), Float(- ∞)]], [8.75, [Float(- ∞), Float(- ∞)]], [8.76, [Float(- ∞), Float(- ∞)]], [8.77, [Float(- ∞), Float(- ∞)]], [8.78, [Float(- ∞), Float(- ∞)]], [8.79, [Float(- ∞), Float(- ∞)]], [8.80, [Float(- ∞), Float(- ∞)]], [8.81, [Float(- ∞), Float(- ∞)]], [8.82, [Float(- ∞), Float(- ∞)]], [8.83, [Float(- ∞), Float(- ∞)]], [8.84, [Float(- ∞), Float(- ∞)]], [8.85, [Float(- ∞), Float(- ∞)]], [8.86, [Float(- ∞), Float(- ∞)]], [8.87, [Float(- ∞), Float(- ∞)]], [8.88, [Float(- ∞), Float(- ∞)]], [8.89, [Float(- ∞), Float(- ∞)]], [8.90, [Float(- ∞), Float(- ∞)]], [8.91, [Float(- ∞), Float(- ∞)]], [8.92, [Float(- ∞), Float(- ∞)]], [8.93, [Float(- ∞), Float(- ∞)]], [8.94, [Float(- ∞), Float(- ∞)]], [8.95, [Float(- ∞), Float(- ∞)]], [8.96, [Float(- ∞), Float(- ∞)]], [8.97, [Float(- ∞), Float(- ∞)]], [8.98, [Float(- ∞), Float(- ∞)]], [8.99, [Float(- ∞), Float(- ∞)]], [9.00, [Float(- ∞), Float(- ∞)]], [9.01, [Float(- ∞), Float(- ∞)]], [9.02, [Float(- ∞), Float(- ∞)]], [9.03, [Float(- ∞), Float(- ∞)]], [9.04, [Float(- ∞), Float(- ∞)]], [9.05, [Float(- ∞), Float(- ∞)]], [9.06, [Float(- ∞), Float(- ∞)]], [9.07, [Float(- ∞), Float(- ∞)]], [9.08, [Float(- ∞), Float(- ∞)]], [9.09, [Float(- ∞), Float(- ∞)]], [9.10, [Float(- ∞), Float(- ∞)]], [9.11, [Float(- ∞), Float(- ∞)]], [9.12, [Float(- ∞), Float(- ∞)]], [9.13, [Float(- ∞), Float(- ∞)]], [9.14, [Float(- ∞), Float(- ∞)]], [9.15, [Float(- ∞), Float(

[9.16, [Float(-∞), Float(-∞)]], [9.17, [Float(-∞), Float(-∞)]], [9.18, [Float(-∞), Float(-∞)]], [9.19, [Float(-∞), Float(-∞)]], [9.20, [Float(-∞), Float(-∞)]], [9.21, [Float(-∞), Float(-∞)]], [9.22, [Float(-∞), Float(-∞)]], [9.23, [Float(-∞), Float(-∞)]], [9.24, [Float(-∞), Float(-∞)]], [9.25, [Float(-∞), Float(-∞)]], [9.26, [Float(-∞), Float(-∞)]], [9.27, [Float(-∞), Float(-∞)]], [9.28, [Float(-∞), Float(-∞)]], [9.29, [Float(-∞), Float(-∞)]], [9.30, [Float(-∞), Float(-∞)]], [9.31, [Float(-∞), Float(-∞)]], [9.32, [Float(-∞), Float(-∞)]], [9.33, [Float(-∞), Float(-∞)]], [9.34, [Float(-∞), Float(-∞)]], [9.35, [Float(-∞), Float(-∞)]], [9.36, [Float(-∞), Float(-∞)]], [9.37, [Float(-∞), Float(-∞)]], [9.38, [Float(-∞), Float(-∞)]], [9.39, [Float(-∞), Float(-∞)]], [9.40, [Float(-∞), Float(-∞)]], [9.41, [Float(-∞), Float(-∞)]], [9.42, [Float(-∞), Float(-∞)]], [9.43, [Float(-∞), Float(-∞)]], [9.44, [Float(-∞), Float(-∞)]], [9.45, [Float(-∞), Float(-∞)]], [9.46, [Float(-∞), Float(-∞)]], [9.47, [Float(-∞), Float(-∞)]], [9.48, [Float(-∞), Float(-∞)]], [9.49, [Float(-∞), 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(-∞)]]]

The equilibrium point (2,-1) is an unstable equilibrium because both the x and y values approach *NEGATIVE* ∞

Problem 5: and convince yourself that the SIRS dynamical system given in Eqs (28) Once we use $R = N - S - I$
is represented by procedure

```
SIRS(s,i,beta,gamma,nu,N)
```

Using procedure

```
Dis2(SIRS(s,i,beta,gamma,nu,N),x,y,[N-30,30],0.01,10)
```

with $\beta = 0.01$ and $\nu = 1$ (so $\frac{\nu}{\beta} = 100$)

With $N = 50, N = 80, N = 120$ confirm the prediction that the epidemic will be eradicated (eventually the number of infected individuals will go to 0) if $N < \frac{\nu}{\beta} = 100$ but will persist if $N > \frac{\nu}{\beta} = 100$

```
> Help18();
  print(SIRS);
```

Dis2(F,x,y,pt,h,A), SIRS(s,i,beta,gamma,nu,N)

proc$(s, i, \beta, \gamma, \nu, N)$ **(9)**

[*VectorCalculus*:-`+`(*VectorCalculus*:-`-`(*VectorCalculus*:-`*`(*VectorCalculus*:-`*`(β, *s*), *i*)), *VectorCalculus*:-`*`(γ, *VectorCalculus*:-`+`(*VectorCalculus*:-`+`(*N*, *VectorCalculus*:-`-`(*s*)), *VectorCalculus*:-`-`(*i*)))), *VectorCalculus*:-`+`(*VectorCalculus*:-`*`(*VectorCalculus*:-`*`(β, *s*), *i*), *VectorCalculus*:-`-`(*VectorCalculus*:-`*`(ν, *i*)))]

end proc

```
> #Trial when N=50 < nu/beta
  #Choose an S and i that add up to N. To create agreement with the
  pt value in Dis2, let s=20 and i=30
  #The initial condition [N-30,30] is probably not very interesting
  mathematically
  #
  Dis2(SIRS(20,30,0.01,gamma,1,50),x,y,[50-30,30],0.01,10) ;
```

[[0.01, [20, 30]], [0.02, [19.9400, 29.7600]], [0.03, [19.8800, 29.5200]], [0.04, [19.8200, 29.2800]], [0.05, [19.7600, 29.0400]], [0.06, [19.7000, 28.8000]], [0.07, [19.6400, 28.5600]], [0.08, [19.5800, 28.3200]], [0.09, [19.5200, 28.0800]], [0.10, [19.4600, **(10)**

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−186.4800]], [9.04, [−34.1800, −186.7200]], [9.05, [−34.2400, −186.9600]], [9.06,
[−34.3000, −187.2000]], [9.07, [−34.3600, −187.4400]], [9.08, [−34.4200,
−187.6800]], [9.09, [−34.4800, −187.9200]], [9.10, [−34.5400, −188.1600]], [9.11,
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−188.8800]], [9.14, [−34.7800, −189.1200]], [9.15, [−34.8400, −189.3600]], [9.16,
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−190.0800]], [9.19, [−35.0800, −190.3200]], [9.20, [−35.1400, −190.5600]], [9.21,
[−35.2000, −190.8000]], [9.22, [−35.2600, −191.0400]], [9.23, [−35.3200,
−191.2800]], [9.24, [−35.3800, −191.5200]], [9.25, [−35.4400, −191.7600]], [9.26,
[−35.5000, −192.0000]], [9.27, [−35.5600, −192.2400]], [9.28, [−35.6200,
−192.4800]], [9.29, [−35.6800, −192.7200]], [9.30, [−35.7400, −192.9600]], [9.31,
[−35.8000, −193.2000]], [9.32, [−35.8600, −193.4400]], [9.33, [−35.9200,
−193.6800]], [9.34, [−35.9800, −193.9200]], [9.35, [−36.0400, −194.1600]], [9.36,

[−36.1000, −194.4000]], [9.37, [−36.1600, −194.6400]], [9.38, [−36.2200, −194.8800]], [9.39, [−36.2800, −195.1200]], [9.40, [−36.3400, −195.3600]], [9.41, [−36.4000, −195.6000]], [9.42, [−36.4600, −195.8400]], [9.43, [−36.5200, −196.0800]], [9.44, [−36.5800, −196.3200]], [9.45, [−36.6400, −196.5600]], [9.46, [−36.7000, −196.8000]], [9.47, [−36.7600, −197.0400]], [9.48, [−36.8200, −197.2800]], [9.49, [−36.8800, −197.5200]], [9.50, [−36.9400, −197.7600]], [9.51, [−37.0000, −198.0000]], [9.52, [−37.0600, −198.2400]], [9.53, [−37.1200, −198.4800]], [9.54, [−37.1800, −198.7200]], [9.55, [−37.2400, −198.9600]], [9.56, [−37.3000, −199.2000]], [9.57, [−37.3600, −199.4400]], [9.58, [−37.4200, −199.6800]], [9.59, [−37.4800, −199.9200]], [9.60, [−37.5400, −200.1600]], [9.61, [−37.6000, −200.4000]], [9.62, [−37.6600, −200.6400]], [9.63, [−37.7200, −200.8800]], [9.64, [−37.7800, −201.1200]], [9.65, [−37.8400, −201.3600]], [9.66, [−37.9000, −201.6000]], [9.67, [−37.9600, −201.8400]], [9.68, [−38.0200, −202.0800]], [9.69, [−38.0800, −202.3200]], [9.70, [−38.1400, −202.5600]], [9.71, [−38.2000, −202.8000]], [9.72, [−38.2600, −203.0400]], [9.73, [−38.3200, −203.2800]], [9.74, [−38.3800, −203.5200]], [9.75, [−38.4400, −203.7600]], [9.76, [−38.5000, −204.0000]], [9.77, [−38.5600, −204.2400]], [9.78, [−38.6200, −204.4800]], [9.79, [−38.6800, −204.7200]], [9.80, [−38.7400, −204.9600]], [9.81, [−38.8000, −205.2000]], [9.82, [−38.8600, −205.4400]], [9.83, [−38.9200, −205.6800]], [9.84, [−38.9800, −205.9200]], [9.85, [−39.0400, −206.1600]], [9.86, [−39.1000, −206.4000]], [9.87, [−39.1600, −206.6400]], [9.88, [−39.2200, −206.8800]], [9.89, [−39.2800, −207.1200]], [9.90, [−39.3400, −207.3600]], [9.91, [−39.4000, −207.6000]], [9.92, [−39.4600, −207.8400]], [9.93, [−39.5200, −208.0800]], [9.94, [−39.5800, −208.3200]], [9.95, [−39.6400, −208.5600]], [9.96, [−39.7000, −208.8000]], [9.97, [−39.7600, −209.0400]], [9.98, [−39.8200, −209.2800]], [9.99, [−39.8800, −209.5200]], [10.00, [−39.9400, −209.7600]], [10.01, [−40.0000, −210.0000]]]

#When N (the population of) = 50, the disease is eventually eradicated because people die (there is no such thing as negative)

```
> Dis2(SIRS(49,1,0.01,1,1,50),x,y,[49,1],0.01,10) ;
```

(11)

[[0.01, [49, 1]], [0.02, [48.9951, 0.9949]], [0.03, [48.9902, 0.9898]], [0.04, [48.9853, 0.9847]], [0.05, [48.9804, 0.9796]], [0.06, [48.9755, 0.9745]], [0.07, [48.9706, 0.9694]], [0.08, [48.9657, 0.9643]], [0.09, [48.9608, 0.9592]], [0.10, [48.9559, 0.9541]], [0.11, [48.9510, 0.9490]], [0.12, [48.9461, 0.9439]], [0.13, [48.9412, 0.9388]], [0.14, [48.9363, 0.9337]], [0.15, [48.9314, 0.9286]], [0.16, [48.9265, 0.9235]], [0.17, [48.9216, 0.9184]], [0.18, [48.9167, 0.9133]], [0.19, [48.9118, 0.9082]], [0.20, [48.9069, 0.9031]], [0.21, [48.9020, 0.8980]], [0.22, [48.8971, 0.8929]], [0.23, [48.8922, 0.8878]], [0.24, [48.8873, 0.8827]], [0.25, [48.8824, 0.8776]], [0.26, [48.8775, 0.8725]], [0.27, [48.8726, 0.8674]],

[0.28, [48.8677, 0.8623]], [0.29, [48.8628, 0.8572]], [0.30, [48.8579, 0.8521]], [0.31, [48.8530, 0.8470]], [0.32, [48.8481, 0.8419]], [0.33, [48.8432, 0.8368]], [0.34, [48.8383, 0.8317]], [0.35, [48.8334, 0.8266]], [0.36, [48.8285, 0.8215]], [0.37, [48.8236, 0.8164]], [0.38, [48.8187, 0.8113]], [0.39, [48.8138, 0.8062]], [0.40, [48.8089, 0.8011]], [0.41, [48.8040, 0.7960]], [0.42, [48.7991, 0.7909]], [0.43, [48.7942, 0.7858]], [0.44, [48.7893, 0.7807]], [0.45, [48.7844, 0.7756]], [0.46, [48.7795, 0.7705]], [0.47, [48.7746, 0.7654]], [0.48, [48.7697, 0.7603]], [0.49, [48.7648, 0.7552]], [0.50, [48.7599, 0.7501]], [0.51, [48.7550, 0.7450]], [0.52, [48.7501, 0.7399]], [0.53, [48.7452, 0.7348]], [0.54, [48.7403, 0.7297]], [0.55, [48.7354, 0.7246]], [0.56, [48.7305, 0.7195]], [0.57, [48.7256, 0.7144]], [0.58, [48.7207, 0.7093]], [0.59, [48.7158, 0.7042]], [0.60, [48.7109, 0.6991]], [0.61, [48.7060, 0.6940]], [0.62, [48.7011, 0.6889]], [0.63, [48.6962, 0.6838]], [0.64, [48.6913, 0.6787]], [0.65, [48.6864, 0.6736]], [0.66, [48.6815, 0.6685]], [0.67, [48.6766, 0.6634]], [0.68, [48.6717, 0.6583]], [0.69, [48.6668, 0.6532]], [0.70, [48.6619, 0.6481]], [0.71, [48.6570, 0.6430]], [0.72, [48.6521, 0.6379]], [0.73, [48.6472, 0.6328]], [0.74, [48.6423, 0.6277]], [0.75, [48.6374, 0.6226]], [0.76, [48.6325, 0.6175]], [0.77, [48.6276, 0.6124]], [0.78, [48.6227, 0.6073]], [0.79, [48.6178, 0.6022]], [0.80, [48.6129, 0.5971]], [0.81, [48.6080, 0.5920]], [0.82, [48.6031, 0.5869]], [0.83, [48.5982, 0.5818]], [0.84, [48.5933, 0.5767]], [0.85, [48.5884, 0.5716]], [0.86, [48.5835, 0.5665]], [0.87, [48.5786, 0.5614]], [0.88, [48.5737, 0.5563]], [0.89, [48.5688, 0.5512]], [0.90, [48.5639, 0.5461]], [0.91, [48.5590, 0.5410]], [0.92, [48.5541, 0.5359]], [0.93, [48.5492, 0.5308]], [0.94, [48.5443, 0.5257]], [0.95, [48.5394, 0.5206]], [0.96, [48.5345, 0.5155]], [0.97, [48.5296, 0.5104]], [0.98, [48.5247, 0.5053]], [0.99, [48.5198, 0.5002]], [1.00, [48.5149, 0.4951]], [1.01, [48.5100, 0.4900]], [1.02, [48.5051, 0.4849]], [1.03, [48.5002, 0.4798]], [1.04, [48.4953, 0.4747]], [1.05, [48.4904, 0.4696]], [1.06, [48.4855, 0.4645]], [1.07, [48.4806, 0.4594]], [1.08, [48.4757, 0.4543]], [1.09, [48.4708, 0.4492]], [1.10, [48.4659, 0.4441]], [1.11, [48.4610, 0.4390]], [1.12, [48.4561, 0.4339]], [1.13, [48.4512, 0.4288]], [1.14, [48.4463, 0.4237]], [1.15, [48.4414, 0.4186]], [1.16, [48.4365, 0.4135]], [1.17, [48.4316, 0.4084]], [1.18, [48.4267, 0.4033]], [1.19, [48.4218, 0.3982]], [1.20, [48.4169, 0.3931]], [1.21, [48.4120, 0.3880]], [1.22, [48.4071, 0.3829]], [1.23, [48.4022, 0.3778]], [1.24, [48.3973, 0.3727]], [1.25, [48.3924, 0.3676]], [1.26, [48.3875, 0.3625]], [1.27, [48.3826, 0.3574]], [1.28, [48.3777, 0.3523]], [1.29, [48.3728, 0.3472]], [1.30, [48.3679, 0.3421]], [1.31, [48.3630, 0.3370]], [1.32, [48.3581, 0.3319]], [1.33, [48.3532, 0.3268]], [1.34, [48.3483, 0.3217]], [1.35, [48.3434, 0.3166]], [1.36, [48.3385, 0.3115]], [1.37, [48.3336, 0.3064]], [1.38, [48.3287, 0.3013]], [1.39, [48.3238, 0.2962]], [1.40, [48.3189, 0.2911]], [1.41, [48.3140, 0.2860]], [1.42, [48.3091, 0.2809]], [1.43, [48.3042, 0.2758]], [1.44, [48.2993, 0.2707]], [1.45, [48.2944, 0.2656]], [1.46, [48.2895, 0.2605]], [1.47, [48.2846, 0.2554]], [1.48, [48.2797, 0.2503]], [1.49, [48.2748, 0.2452]], [1.50, [48.2699, 0.2401]], [1.51, [48.2650, 0.2350]], [1.52, [48.2601, 0.2299]], [1.53, [48.2552, 0.2248]], [1.54, [48.2503,

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[8.34, [44.9183, −3.2483]], [8.35, [44.9134, −3.2534]], [8.36, [44.9085, −3.2585]],
[8.37, [44.9036, −3.2636]], [8.38, [44.8987, −3.2687]], [8.39, [44.8938, −3.2738]],
[8.40, [44.8889, −3.2789]], [8.41, [44.8840, −3.2840]], [8.42, [44.8791, −3.2891]],

[8.43, [44.8742, −3.2942]], [8.44, [44.8693, −3.2993]], [8.45, [44.8644, −3.3044]],
[8.46, [44.8595, −3.3095]], [8.47, [44.8546, −3.3146]], [8.48, [44.8497, −3.3197]],
[8.49, [44.8448, −3.3248]], [8.50, [44.8399, −3.3299]], [8.51, [44.8350, −3.3350]],
[8.52, [44.8301, −3.3401]], [8.53, [44.8252, −3.3452]], [8.54, [44.8203, −3.3503]],
[8.55, [44.8154, −3.3554]], [8.56, [44.8105, −3.3605]], [8.57, [44.8056, −3.3656]],
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[8.61, [44.7860, −3.3860]], [8.62, [44.7811, −3.3911]], [8.63, [44.7762, −3.3962]],
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[8.67, [44.7566, −3.4166]], [8.68, [44.7517, −3.4217]], [8.69, [44.7468, −3.4268]],
[8.70, [44.7419, −3.4319]], [8.71, [44.7370, −3.4370]], [8.72, [44.7321, −3.4421]],
[8.73, [44.7272, −3.4472]], [8.74, [44.7223, −3.4523]], [8.75, [44.7174, −3.4574]],
[8.76, [44.7125, −3.4625]], [8.77, [44.7076, −3.4676]], [8.78, [44.7027, −3.4727]],
[8.79, [44.6978, −3.4778]], [8.80, [44.6929, −3.4829]], [8.81, [44.6880, −3.4880]],
[8.82, [44.6831, −3.4931]], [8.83, [44.6782, −3.4982]], [8.84, [44.6733, −3.5033]],
[8.85, [44.6684, −3.5084]], [8.86, [44.6635, −3.5135]], [8.87, [44.6586, −3.5186]],
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[8.91, [44.6390, −3.5390]], [8.92, [44.6341, −3.5441]], [8.93, [44.6292, −3.5492]],
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[8.97, [44.6096, −3.5696]], [8.98, [44.6047, −3.5747]], [8.99, [44.5998, −3.5798]],
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[9.03, [44.5802, −3.6002]], [9.04, [44.5753, −3.6053]], [9.05, [44.5704, −3.6104]],
[9.06, [44.5655, −3.6155]], [9.07, [44.5606, −3.6206]], [9.08, [44.5557, −3.6257]],
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[9.18, [44.5067, −3.6767]], [9.19, [44.5018, −3.6818]], [9.20, [44.4969, −3.6869]],
[9.21, [44.4920, −3.6920]], [9.22, [44.4871, −3.6971]], [9.23, [44.4822, −3.7022]],
[9.24, [44.4773, −3.7073]], [9.25, [44.4724, −3.7124]], [9.26, [44.4675, −3.7175]],
[9.27, [44.4626, −3.7226]], [9.28, [44.4577, −3.7277]], [9.29, [44.4528, −3.7328]],
[9.30, [44.4479, −3.7379]], [9.31, [44.4430, −3.7430]], [9.32, [44.4381, −3.7481]],
[9.33, [44.4332, −3.7532]], [9.34, [44.4283, −3.7583]], [9.35, [44.4234, −3.7634]],
[9.36, [44.4185, −3.7685]], [9.37, [44.4136, −3.7736]], [9.38, [44.4087, −3.7787]],
[9.39, [44.4038, −3.7838]], [9.40, [44.3989, −3.7889]], [9.41, [44.3940, −3.7940]],
[9.42, [44.3891, −3.7991]], [9.43, [44.3842, −3.8042]], [9.44, [44.3793, −3.8093]],
[9.45, [44.3744, −3.8144]], [9.46, [44.3695, −3.8195]], [9.47, [44.3646, −3.8246]],
[9.48, [44.3597, −3.8297]], [9.49, [44.3548, −3.8348]], [9.50, [44.3499, −3.8399]],
[9.51, [44.3450, −3.8450]], [9.52, [44.3401, −3.8501]], [9.53, [44.3352, −3.8552]],
[9.54, [44.3303, −3.8603]], [9.55, [44.3254, −3.8654]], [9.56, [44.3205, −3.8705]],

[9.57, [44.3156, −3.8756]], [9.58, [44.3107, −3.8807]], [9.59, [44.3058, −3.8858]],
[9.60, [44.3009, −3.8909]], [9.61, [44.2960, −3.8960]], [9.62, [44.2911, −3.9011]],
[9.63, [44.2862, −3.9062]], [9.64, [44.2813, −3.9113]], [9.65, [44.2764, −3.9164]],
[9.66, [44.2715, −3.9215]], [9.67, [44.2666, −3.9266]], [9.68, [44.2617, −3.9317]],
[9.69, [44.2568, −3.9368]], [9.70, [44.2519, −3.9419]], [9.71, [44.2470, −3.9470]],
[9.72, [44.2421, −3.9521]], [9.73, [44.2372, −3.9572]], [9.74, [44.2323, −3.9623]],
[9.75, [44.2274, −3.9674]], [9.76, [44.2225, −3.9725]], [9.77, [44.2176, −3.9776]],
[9.78, [44.2127, −3.9827]], [9.79, [44.2078, −3.9878]], [9.80, [44.2029, −3.9929]],
[9.81, [44.1980, −3.9980]], [9.82, [44.1931, −4.0031]], [9.83, [44.1882, −4.0082]],
[9.84, [44.1833, −4.0133]], [9.85, [44.1784, −4.0184]], [9.86, [44.1735, −4.0235]],
[9.87, [44.1686, −4.0286]], [9.88, [44.1637, −4.0337]], [9.89, [44.1588, −4.0388]],
[9.90, [44.1539, −4.0439]], [9.91, [44.1490, −4.0490]], [9.92, [44.1441, −4.0541]],
[9.93, [44.1392, −4.0592]], [9.94, [44.1343, −4.0643]], [9.95, [44.1294, −4.0694]],
[9.96, [44.1245, −4.0745]], [9.97, [44.1196, −4.0796]], [9.98, [44.1147, −4.0847]],
[9.99, [44.1098, −4.0898]], [10.00, [44.1049, −4.0949]], [10.01, [44.1000, −4.1000]]]

#It appears that Letting I=1 and S=49 is a case where the Infected becomes negative (formally terminates at zero because no such thing as negative infected) but the suceptible population still lives (48 people at step 1.97, because I = 0.0004 is the last nonzero entry)

```
> #Trial when N=80 < nu/beta
  print(SIRS);
  Dis2(SIRS(50,30,0.01,gamma,1,80),x,y,[50,30],0.01,10);
```

proc(*s*, *i*, beta, gamma, nu, *N*)

[*VectorCalculus*:-`+`(*VectorCalculus*:-`-`(*VectorCalculus*:-`*`(*VectorCalculus*:-`*`(beta, *s*), *i*)), *VectorCalculus*:-`*`(gamma, *VectorCalculus*:-`+`(*VectorCalculus*:-`+`(*N*, *VectorCalculus*:-`-`(*s*)), *VectorCalculus*:-`-`(*i*)))), *VectorCalculus*:-`+`(*VectorCalculus*:-`*`(*VectorCalculus*:-`*`(beta, *s*), *i*), *VectorCalculus*:-`-`(*VectorCalculus*:-`*`(nu, *i*)))]

end proc

(12)

[[0.01, [50, 30]], [0.02, [49.8500, 29.8500]], [0.03, [49.7000, 29.7000]], [0.04, [49.5500, 29.5500]], [0.05, [49.4000, 29.4000]], [0.06, [49.2500, 29.2500]], [0.07, [49.1000, 29.1000]], [0.08, [48.9500, 28.9500]], [0.09, [48.8000, 28.8000]], [0.10, [48.6500, 28.6500]], [0.11, [48.5000, 28.5000]], [0.12, [48.3500, 28.3500]], [0.13, [48.2000, 28.2000]], [0.14, [48.0500, 28.0500]], [0.15, [47.9000, 27.9000]], [0.16, [47.7500, 27.7500]], [0.17, [47.6000, 27.6000]], [0.18, [47.4500, 27.4500]], [0.19, [47.3000, 27.3000]], [0.20, [47.1500, 27.1500]], [0.21, [47.0000, 27.0000]], [0.22, [46.8500, 26.8500]], [0.23, [46.7000, 26.7000]], [0.24, [46.5500, 26.5500]], [0.25, [46.4000, 26.4000]], [0.26, [46.2500, 26.2500]], [0.27, [46.1000, 26.1000]], [0.28, [45.9500, 25.9500]], [0.29, [45.8000, 25.8000]], [0.30, [45.6500, 25.6500]], [0.31, [45.5000,

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−115.8000]], [9.74, [−95.9500, −115.9500]], [9.75, [−96.1000, −116.1000]], [9.76,

```
    [−96.2500, −116.2500]], [9.77, [−96.4000, −116.4000]], [9.78, [−96.5500,
    −116.5500]], [9.79, [−96.7000, −116.7000]], [9.80, [−96.8500, −116.8500]], [9.81,
    [−97.0000, −117.0000]], [9.82, [−97.1500, −117.1500]], [9.83, [−97.3000,
    −117.3000]], [9.84, [−97.4500, −117.4500]], [9.85, [−97.6000, −117.6000]], [9.86,
    [−97.7500, −117.7500]], [9.87, [−97.9000, −117.9000]], [9.88, [−98.0500,
    −118.0500]], [9.89, [−98.2000, −118.2000]], [9.90, [−98.3500, −118.3500]], [9.91,
    [−98.5000, −118.5000]], [9.92, [−98.6500, −118.6500]], [9.93, [−98.8000,
    −118.8000]], [9.94, [−98.9500, −118.9500]], [9.95, [−99.1000, −119.1000]], [9.96,
    [−99.2500, −119.2500]], [9.97, [−99.4000, −119.4000]], [9.98, [−99.5500,
    −119.5500]], [9.99, [−99.7000, −119.7000]], [10.00, [−99.8500, −119.8500]], [10.01,
    [−100.0000, −120.0000]]]
```

Given initial conditions [S=50,I=30] only 20 people are left living (at step 2.10) but humanity survives and the disease is gone

```
> #Trial when N=120 > nu/beta
  Dis2(SIRS(90,30,0.01,gamma,1,120),x,y,[90,30],0.01,10);
```

(13)

```
[[0.01, [90, 30]], [0.02, [89.7300, 29.9700]], [0.03, [89.4600, 29.9400]], [0.04, [89.1900,
    29.9100]], [0.05, [88.9200, 29.8800]], [0.06, [88.6500, 29.8500]], [0.07, [88.3800,
    29.8200]], [0.08, [88.1100, 29.7900]], [0.09, [87.8400, 29.7600]], [0.10, [87.5700,
    29.7300]], [0.11, [87.3000, 29.7000]], [0.12, [87.0300, 29.6700]], [0.13, [86.7600,
    29.6400]], [0.14, [86.4900, 29.6100]], [0.15, [86.2200, 29.5800]], [0.16, [85.9500,
    29.5500]], [0.17, [85.6800, 29.5200]], [0.18, [85.4100, 29.4900]], [0.19, [85.1400,
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    29.3700]], [0.23, [84.0600, 29.3400]], [0.24, [83.7900, 29.3100]], [0.25, [83.5200,
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    29.1900]], [0.29, [82.4400, 29.1600]], [0.30, [82.1700, 29.1300]], [0.31, [81.9000,
    29.1000]], [0.32, [81.6300, 29.0700]], [0.33, [81.3600, 29.0400]], [0.34, [81.0900,
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    28.9200]], [0.38, [80.0100, 28.8900]], [0.39, [79.7400, 28.8600]], [0.40, [79.4700,
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    28.3800]], [0.56, [75.1500, 28.3500]], [0.57, [74.8800, 28.3200]], [0.58, [74.6100,
    28.2900]], [0.59, [74.3400, 28.2600]], [0.60, [74.0700, 28.2300]], [0.61, [73.8000,
    28.2000]], [0.62, [73.5300, 28.1700]], [0.63, [73.2600, 28.1400]], [0.64, [72.9900,
    28.1100]], [0.65, [72.7200, 28.0800]], [0.66, [72.4500, 28.0500]], [0.67, [72.1800,
```

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[−154.8900, 2.7900]], [9.09, [−155.1600, 2.7600]], [9.10, [−155.4300, 2.7300]], [9.11,
[−155.7000, 2.7000]], [9.12, [−155.9700, 2.6700]], [9.13, [−156.2400, 2.6400]], [9.14,
[−156.5100, 2.6100]], [9.15, [−156.7800, 2.5800]], [9.16, [−157.0500, 2.5500]], [9.17,
[−157.3200, 2.5200]], [9.18, [−157.5900, 2.4900]], [9.19, [−157.8600, 2.4600]], [9.20,
[−158.1300, 2.4300]], [9.21, [−158.4000, 2.4000]], [9.22, [−158.6700, 2.3700]], [9.23,
[−158.9400, 2.3400]], [9.24, [−159.2100, 2.3100]], [9.25, [−159.4800, 2.2800]], [9.26,
[−159.7500, 2.2500]], [9.27, [−160.0200, 2.2200]], [9.28, [−160.2900, 2.1900]], [9.29,
[−160.5600, 2.1600]], [9.30, [−160.8300, 2.1300]], [9.31, [−161.1000, 2.1000]], [9.32,
[−161.3700, 2.0700]], [9.33, [−161.6400, 2.0400]], [9.34, [−161.9100, 2.0100]], [9.35,
[−162.1800, 1.9800]], [9.36, [−162.4500, 1.9500]], [9.37, [−162.7200, 1.9200]], [9.38,
[−162.9900, 1.8900]], [9.39, [−163.2600, 1.8600]], [9.40, [−163.5300, 1.8300]], [9.41,
[−163.8000, 1.8000]], [9.42, [−164.0700, 1.7700]], [9.43, [−164.3400, 1.7400]], [9.44,
[−164.6100, 1.7100]], [9.45, [−164.8800, 1.6800]], [9.46, [−165.1500, 1.6500]], [9.47,
[−165.4200, 1.6200]], [9.48, [−165.6900, 1.5900]], [9.49, [−165.9600, 1.5600]], [9.50,
[−166.2300, 1.5300]], [9.51, [−166.5000, 1.5000]], [9.52, [−166.7700, 1.4700]], [9.53,
[−167.0400, 1.4400]], [9.54, [−167.3100, 1.4100]], [9.55, [−167.5800, 1.3800]], [9.56,
[−167.8500, 1.3500]], [9.57, [−168.1200, 1.3200]], [9.58, [−168.3900, 1.2900]], [9.59,
[−168.6600, 1.2600]], [9.60, [−168.9300, 1.2300]], [9.61, [−169.2000, 1.2000]], [9.62,
[−169.4700, 1.1700]], [9.63, [−169.7400, 1.1400]], [9.64, [−170.0100, 1.1100]], [9.65,
[−170.2800, 1.0800]], [9.66, [−170.5500, 1.0500]], [9.67, [−170.8200, 1.0200]], [9.68,
[−171.0900, 0.9900]], [9.69, [−171.3600, 0.9600]], [9.70, [−171.6300, 0.9300]], [9.71,
[−171.9000, 0.9000]], [9.72, [−172.1700, 0.8700]], [9.73, [−172.4400, 0.8400]], [9.74,
[−172.7100, 0.8100]], [9.75, [−172.9800, 0.7800]], [9.76, [−173.2500, 0.7500]], [9.77,
[−173.5200, 0.7200]], [9.78, [−173.7900, 0.6900]], [9.79, [−174.0600, 0.6600]], [9.80,
[−174.3300, 0.6300]], [9.81, [−174.6000, 0.6000]], [9.82, [−174.8700, 0.5700]], [9.83,

[−175.1400, 0.5400]], [9.84, [−175.4100, 0.5100]], [9.85, [−175.6800, 0.4800]], [9.86, [−175.9500, 0.4500]], [9.87, [−176.2200, 0.4200]], [9.88, [−176.4900, 0.3900]], [9.89, [−176.7600, 0.3600]], [9.90, [−177.0300, 0.3300]], [9.91, [−177.3000, 0.3000]], [9.92, [−177.5700, 0.2700]], [9.93, [−177.8400, 0.2400]], [9.94, [−178.1100, 0.2100]], [9.95, [−178.3800, 0.1800]], [9.96, [−178.6500, 0.1500]], [9.97, [−178.9200, 0.1200]], [9.98, [−179.1900, 0.0900]], [9.99, [−179.4600, 0.0600]], [10.00, [−179.7300, 0.0300]], [10.01, [−180.0000, 0.]]]

Given the larger value of N=120 and initial S=90 and I=30, the population actually dies. (Interestingly, more not sick (but susceptible) people than the last trial (S=50 vs S=90) can increase chances of death) In this scenario, personally going on a spaceship with infected people and leaving the healthy people on earth can actually save you in the long run due to less reinfections.