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> #Nikita John, Assignment 18
 #Okay to Post; November 8th 2021
> #Maple code for Lecture 18

Help18 :=proc( ) : print( `Dis2(F,x,y,pt,h,A), SIRS(s,i,beta,gamma,nu,N) `) :end:



   #SIRS(s,i,beta,gamma,nu,N): The SIRS dynamical model with parameters beta,gamma, nu,N
   (see  section 6.6 of Edelstein-Keshet), s is the number of

   #Susceptibles, i is the number of infected, (the number of removed is given by N-s-i). N is the
   total population
SIRS :=proc(s, i, beta, gamma, nu, N ) : [ -beta*s*i + gamma*(N-s-i), beta*s*i-nu*i] :
   end:


   #Dis2(F,x,y,pt,h,A): The approximate orbit of the Dynamical system approximating the 2D
   for the autonomous  continuous dynamical  process
#dx/dt=F[1](x(t),y(t))
#dy/dt=F[2](x(t),y(t)) , x(0)=pt[1], y(0)=pt[2] with mesh size h from t=0 to t=A
Dis2 :=proc(F, x, y, pt, h, A) 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:



#OLD STUFF

Help17 :=proc( ) : print( ` HW3g(u,v,w,M), HW2g(u,v,M) `) :end:



   #HW3g(u,v,w,M): The Hardy-Weinberg unerlying transformation with (u,v,w),
   GENERALIZED Eqs. with the 3 by 3 matrix M  (53a,53b,53c) in Edelestein-Keshet Ch. 3
#Based on Anne Somalwar's solution of the bonus problem from hw15, see the end of
#from https://sites.math.rutgers.edu/~zeilberg/Bio21/HW15posted/hw15AnneSomalwar.pdf
HW3g :=proc(u, v, w, M) local tot, LI :
LI := [

M[1][1]*u^2 + (M[1][2] + M[2][1])/2*u*v + M[2][2]*(1/4)*v^2,

(M[1][2] + M[2][1])/2*u*v + (M[1][3] + M[3][1])*u*w + M[2][2]/2*v^2
    + (M[2][3] + M[3][2])/2*v*w,

M[2][2]*1/4*v^2 + (M[2][3] + M[3][2])/2*v*w  + M[3][3]*w^2] :
```

```
tot := LI[1] + LI[2] + LI[3] :
[LI[1]/tot, LI[2]/tot, LI[3]/tot] :
end:


#HW2g(u,v,M): The Generalized Hardy-Weinberg unerlying transformation with (u,v), M is the survival matrix. Based on Ann Somalwar's HW3g(u,v,w) (only retain the first two components and replace w by 1-u-v)
HW2g :=proc(u, v, M) local LI, w :
LI := HW3g(u, v, w, M) :
normal(subs(w = 1-u-v, [LI[1], LI[2]])) :
end:




#OLD STUFF

Help15 :=proc( ) : print(`HW3(u,v,w), HW2(u,v) , Dis1(F,x,x0,h,A), ToSys(k,z,f,INI) `) :end:


#ToSys(k,z,f,INI): converts the kth order difference equation x(n)=f(x[n-1],x[n-2],...x[n-k]) to a first-order system
#x1(n)=F(x1(n-1),x2(n-1), ...,xk(n-1))
#x2(n)=x1(n-1)
#...

#xk(n)=x[k-1](n-1). It gives the underlying transformation phrased in terms of z[1],...z[k], followed by the initial conditions. Try:
#ToSys:=proc(2,z,z[1]+z[2],[1,1])
ToSys :=proc(k, z, f, INI) local i :
[f, seq(z[i-1], i = 2 ..k)], INI :
end:


#HW3(u,v,w): The Hardy-Weinberg unerlying transformation witu (u,v,w), Eqs. (53a,53b, 53c) in Edelestein-Keshet Ch. 3
HW3 :=proc(u, v, w) : [u^2 + u*v + (1/4)*v^2, u*v + 2*u*w + 1/2*v^2 + v*w, 1/4*v^2 + v*w + w^2] :end:


#HW2(u,v): The Hardy-Weinberg unerlying transformation witu (u,v,w), Eqs. (53a,53b,53c) in Edelestein-Keshet Ch. 3 using the fact that u+v+w=1
HW2 :=proc(u, v) : expand([u^2 + u*v + (1/4)*v^2 , u*v + 2*u*(1-u-v) + 1/2*v^2 + v*(1-u-v)]) :end:
```

```
#Dis1(F,x,x0,h,A): The approximate orbit of the Dynamical system approximating the 1D for
the autonomous  continuous dynamical  process dy/dt=F(y(t)) , y(0)=y0 with mesh size h
from t=0 to t=A
Dis1 :=proc(F, x, x0, h, A) local L, i :
L := Orb(x + h*F, x, x0, 0, trunc(A/h)) :

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

##old stuff

#M13.txt: Maple code for Lecture 13 of Dynamical Modesl in Biology, Fall 2021 (taught by
Dr. Z.)
Help13 :=proc( ) :
print(` RT2(x,y,d,K), Orb2(F,x,y,pt0,K1,K2), FP2(F,x,y), SFP2(F,x,y), PlotOrb2(L), FP2drz
(F,x,y), SFP2drz(F,x,y) `) :end:

with(LinearAlgebra) :


#RT2(x,y,d,K): A random rational transformation of degree d from R^2 to R^2 with postiive
integer coefficients from 1 to K The inputs are variables x and y and
#the output is a pair of expressions  of (x,y) representing functions. It is for generating examples
#Try:
#RT2(x,y,2,10);
RT2 :=proc(x, y, d, K) local ra, i, j, f, g :
ra := rand(1 ..K) : #random integer from -K to K
f := add(add(ra( ) * x^i * y^j, j=0 ..d-i), i=0 ..d) / add(add(ra( ) * x^i * y^j, j=0 ..d-i), i=0
 ..d) :
g := add(add(ra( ) * x^i * y^j, j=0 ..d-i), i=0 ..d) / add(add(ra( ) * x^i * y^j, j=0 ..d-i), i=0
 ..d) :
[f, g] :
end:



#Orb2(F,x,y,pt,K1,K2): Inputs a mapping F=[f,g] from R^2  to R^2 where f and g describe
functions of x and y, an initial point pt0=[x0,y0]
#outputs the orbit starting at discrete time K1 and ending in discrete time K2. Try
#F:=RT2(x,y,2,10);
#Orb2(F,x,y,[1.1,1.2],1000,1010);
Orb2 :=proc(F, x, y, pt0, K1, K2)  local pt, L, i :
pt := pt0 :

for i from 1 to K1-1 do
pt := subs({x=pt[1], y=pt[2]}, F) :
od:
```

```
L := [ ]:
for i from K1 to K2 do
L := [op(L), pt]:
pt := normal(subs({x=pt[1], y=pt[2]}, F)) :

od:
L:
end:

#FP2(F,x,y): The list of fixed points of the transformation [x,y]->F. Try
#FP2([x-y,x=y],x,y);
FP2 :=proc(F, x, y) local L, i :
L := [solve({F[1]=x, F[2]=y}, {x, y})]:

[seq(subs(L[i], [x, y]), i=1..nops(L))]:
end:


#SFP2(F,x,y): The list of Stable fixed points of the transformation [x,y]->F. Try
#SFP2([(1+x)/(1+y), (1+7*y)/(4+x)],x,y);
SFP2 :=proc(F, x, y) local L, J, S, J0, i, pt, EV:

L := evalf(FP2(F, x, y)) :
    #F is the list of ALL fixed points of the transformation [x,y]->F using the previous procedure
    FP2(F,x,y), but since we are interested in numbers we take the floating point version using
    evalf

J := Matrix(normal([[diff(F[1], x), diff(F[1], y)], [diff(F[2], x), diff(F[2], y)]])) :
    #J is the Jacobian matrix in general (in terms of the variables x and y). Note that J is a
    SYMBOLIC matrix featuring variables x and y

S := [ ]:  #S is the list of stable fixed points that starts out empty

for i from 1 to nops(L) do   #we examime it case by case
pt := L[i]: #pt is the current fixed point to be examined

J0 := subs({x=pt[1], y=pt[2]}, J) :
    #J0 is the NUMERICAL matrix obtained by plugging-in the examined fixed pt

EV := Eigenvalues(J0) :
    # We used Maple's command Eigenavalues to find the eigenvalues of this 2 by 2 matrix

if abs(EV[1]) < 1 and abs(EV[2]) < 1 then
 S := [op(S), pt]:
    #If both eigenvalues have absolute value less than 1 it means that they are stable, so we
    append the examined fixed point, pt, to the list of fixed points
fi:

od:
```

```
S : #the output is S
end:




###added Oct. 17, 20221
with(plots) :

PlotOrb1 :=proc(L) local i, d :

d := textplot([L[1], 0, 0]) :

for i from 2 to nops(L) do
d := d, textplot([L[i], 0, i-1]) :
od:
display(d) :
end:


PlotOrb2 :=proc(L) local i, d :

d := textplot([op(L[1]), 0]) :

for i from 2 to nops(L) do
d := d, textplot([op(L[i]), i-1]) :
od:
display(d) :
end:
###End added Oct. 17, 20221


###old stuff
#M11.txt: Maple code for Lecture 11 of Dynamical Models in Biology taught by Dr. Z.
Help11 :=proc( ) : print(`SFPe(f,x), Orbk(k,z,f,INI,K1,K2) `) :end:


   #SFPe(f,x): The set of fixed points of x->f(x) done exactly (and allowing symbolic
   parameters), followed by the condition of stability (if it is netween -1 and 1 it is stable)
#Try: FPe(k*x*(1-x),x);
#VERSION OF Oct. 12, 2021 (avoiding division by 0)
SFPe :=proc(f, x) local f1, L, i, M :
f1 := normal(diff(f, x)) :
L := [solve(numer(f-x), x)] :
M := [ ] :

for i from 1 to nops(L) do
 if subs(x=L[i], denom(f1) ) ≠ 0 then
  M := [op(M), [L[i], normal(subs(x=L[i], f1))]] :
 fi:
```

```
od:
M:

end:


#Added after class

    #Orbk(k,z,f,INI,K1,K2): Given a positive integer k, a letter (symbol), z, an expression f of z
    [1], ..., z[k] (representing a multi-variable function of the variables z[1],...,z[k]

    #a vector INI representing the initial values [x[1],..., x[k]], and (in applications) positive
    integres K1 and K2, outputs the

    #values of the sequence starting at n=K1 and ending at n=K2. of the sequence satisfying the
    difference equation
##x[n]=f(x[n-1],x[n-2],..., x[n-k+1]):

    #This is a generalization to  higher-order difference equation of procedure Orb(f,x,x0,K1,K2)
    . For example
#Orbk(1,z,5/2*z[1]*(1-z[1]),[0.5],1000,1010);  should be the same as
#Orb(5/2*z[1]*(1-z[1]),z[1],[0,5],1000,1010);
#Try:
#Orbk(2,z,(5/4)*z[1]-(3/8)*z[2],[1,2],1000,1010);
Orbk := proc(k, z, f, INI, K1, K2) local L, i, newguy:
L := INI:  #We start out with the list of initial values

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 K1 > 0 and K2 > K1) then
    #checking that the input is OK
 print(`bad input`) :
 RETURN(FAIL) :
fi:

while nops(L) < K2 do
 newguy := subs({seq(z[i]=L[-i], i=1..k)}, f) :
    #Using what we know about the value yesterday, the day before yesterday, ... up to k days
    before yesterday we find the value of the sequence today
 L := [op(L), newguy]:  #we append the new value to the running list of values of our sequence
od:

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

end:


####STAFT FROM M9.txt
#M9.txt: Maple Code for "Dynamical models in Biology" (Math 336) taught by Dr. Z., Lecture 9
```

```
Help9 :=proc( ) :
    print( ` Orb(f,x,x0,K1,K2), Orb2D(f,x,x0,K) , FP(f,x) , SFP(f,x) , Comp(f,x)  `) :end:


   #Orb(f,x,x0,K1,K2): Inputs an expression f in x (desccribing) a function of x, an initial point,
   x0, and a positive integer K, outputs
#the values of x[n] from n=K1 to n=K2. Try: where x[n]=f(x[n-1]), . Try:
#Orb(2*x*(1-x),x,0.4,1000,2000);
Orb :=proc( f, x, x0, K1, K2 ) local x1, i, L :
x1 := x0 :

for i from 1 to K1 do
 x1 := subs(x=x1, f ) :
   #we don't record the first values of K1, since we are interested in the long-time behavior of
   the orbit
od:

L := [x1] :

for i from K1 to K2 do
 x1 := subs(x=x1, f ) :   #we compute the next member of the orbit
 L := [op(L), x1] : #we append it to the list
od:

L : #that's the output

end:

#Orb2D(f,x,x0,K): 2D version of Orb(f,x,x0,0,K), just for illustration
Orb2D :=proc( f, x, x0, K ) local L, L1, i :
L := Orb( f, x, x0, 0, K ) :
L1 := [ [L[1], 0], [L[1], L[2]], [L[2], L[2]] ] :
for i from 3 to nops(L) do
 L1 := [op(L1), [L[i-1], L[i]], [L[i], L[i]]] :
od:
L1 :
end:


#FP(f,x): The list of fixed points of the map x->f where f is an expression in x. Try:
#FP(2*x*(1-x),x);
FP :=proc( f, x )
evalf ( [solve( f=x, x ) ]) :
end:


#SFP(f,x): The list of stable fixed points of the map x->f where f is an expression in x. Try:
#SFP(2*x*(1-x),x);
SFP :=proc( f, x ) local L, i, f1, pt, Ls :
```

```
L := FP(f, x) : #The list of fixed points (including complex ones)

Ls := [ ] :        #Ls is the list of stable fixed points, that starts out as the empty list

f1 := diff (f, x) :  #The derivative of the function f w.r.t. x

for i from 1 to nops(L) do
pt := L[i] :

if abs(subs(x = pt, f1)) < 1 then

 Ls := [op(Ls), pt] :  # if pt,  is stable we add it to the list of stable points

fi:

od:

Ls :   #The last line is the output

end:

#Comp(f,x): f(f(x))
Comp :=proc(f, x) : normal(subs(x = f, f) ) :end:



##added Oct. 17, 2021
#FP2drz(F,x,y): The list of fixed points of the transformation [x,y]->F. Dr. Z.'s way
#FP2([x-y,x+y],x,y);
FP2drz :=proc(F, x, y) local eq, i, L, S1 :
eq := [numer(F[1]-x), numer(F[2]-y)] :

L := Groebner[Basis](eq, plex(x, y)) :

S1 := evalf([solve(L[1], y)]) :
[seq([solve(subs(y = S1[i], L[2]), x), S1[i]], i = 1 ..nops(S1))] :
end:


#SFP2drz(F,x,y): The list of Stable fixed points of the transformation [x,y]->F. Try
#SFP2drz([(1+x)/(1+y), (1+7*y)/(4+x)],x,y);
SFP2drz :=proc(F, x, y) local L, J, S, J0, i, pt, EV :

L := FP2drz(F, x, y) :
     #F is the list of ALL fixed points of the transformation [x,y]->F using the previous procedure
     FP2(F,x,y), but since we are interested in numbers we take the floating point version using
     evalf

J := Matrix(normal([[diff(F[1], x), diff(F[2], x)], [diff(F[1], y), diff(F[2], y)]])) :
```

```
    #J is the Jacobian matrix in general (in terms of the variables x and y). Note that J is a
    SYMBOLIC matrix featuring variables x and y

S := [ ] :  #S is the list of stable fixed points that starts out empty

for i from 1 to nops(L) do   #we examime it case by case
pt := L[i] : #pt is the current fixed point to be examined

J0 := subs({x = pt[1], y = pt[2]}, J) :
    #J0 is the NUMERICAL matrix obtained by plugging-in the examined fixed pt

EV := Eigenvalues(J0) :
    # We used Maple's command Eigenavalues to find the eigenvalues of this 2 by 2 matrix

if abs(EV[1]) < 1 and abs(EV[2]) < 1 then
 S := [op(S), pt] :
    #If both eigenvalues have absolute value less than 1 it means that they are stable, so we
    append the examined fixed point, pt, to the list of fixed points
fi:

od:
S : #the output is S
end:
> #1
 C := proc(a, b, c, d, e) local numEggPerChicken, numEggPerDay, numEgg, numEggTot :
 numEggPerChicken := a/b :
 numEggPerDay := numEggPerChicken/c :
 numEgg := numEggPerDay·d :
 numEggTot := numEgg·e :
 numEggTot :
 end:
> C(3/2, 3/2, 3/2, 3, 3);
```

$$6 \quad (1)$$

```
> #2
 W := proc(a, b, k) local eqSys, x, y, K, c :
 eqSys := {1/x + 1/y = 1/a, 1/x + 1/(k·y) = 1/b} :
K := solve(eqSys, {x, y}) :
 c := k·K[2] :
 c :
 end:
> W(4, 5, 2);
```

$$2\,y = 20 \quad (2)$$

```
> #3
```

```
with(LinearAlgebra) :
M1 := Matrix([[2, 0], [4, 0]]) :
Eigenvalues(M1);
```

$$\begin{bmatrix} 0 \\ 2 \end{bmatrix} \quad (3)$$

```
> M2 := Matrix([[-2,-2], [-4,-2]]) :
  Eigenvalues(M2);
```

$$\begin{bmatrix} -2 + 2\sqrt{2} \\ -2 - 2\sqrt{2} \end{bmatrix} \quad (4)$$

```
> #4
  Dis2([x·(1 - x - y), x·(3 - 2·x - y)], x, y, [0.01, -1.01], 0.01, 10);
```

[[0.01, [0.01, −1.01]], [0.02, [0.010200, −1.009601]], [0.03, [0.01040393890, −1.009194101]], [0.04, [0.01061189181, −1.008779152]], [0.05, [0.01082393516, −1.008355997]], [0.06, [0.01104014674, −1.007924478]], [0.07, [0.01126060570, −1.007484435]], [0.08, [0.01148539259, −1.007035704]], [0.09, [0.01171458938, −1.006578119]], [0.10, [0.01194827945, −1.006111509]], [0.11, [0.01218654765, −1.005635703]], [0.12, [0.01242948028, −1.005150525]], [0.13, [0.01267716515, −1.004655795]], [0.14, [0.01292969157, −1.004151332]], [0.15, [0.01318715039, −1.003636951]], [0.16, [0.01344963400, −1.003112463]], [0.17, [0.01371723637, −1.002577677]], [0.18, [0.01399005306, −1.002032397]], [0.19, [0.01426818124, −1.001476425]], [0.20, [0.01455171971, −1.000909559]], [0.21, [0.01484076894, −1.000331593]], [0.22, [0.01513543105, −0.9997423180]], [0.23, [0.01543580986, −0.9991415214]], [0.24, [0.01574201090, −0.9985289868]], [0.25, [0.01605414144, −0.9979044941]], [0.26, [0.01637231050, −0.9972678196]], [0.27, [0.01669662886, −0.9966187356]], [0.28, [0.01702720911, −0.9959570106]], [0.29, [0.01736416563, −0.9952824092]], [0.30, [0.01770761463, −0.9945946920]], [0.31, [0.01805767418, −0.9938936158]], [0.32, [0.01841446420, −0.9931789331]], [0.33, [0.01877810650, −0.9924503924]], [0.34, [0.01914872478, −0.9917077382]], [0.35, [0.01952644468, −0.9909507105]], [0.36, [0.01991139375, −0.9901790454]], [0.37, [0.02030370150, −0.9893924744]], [0.38, [0.02070349941, −0.9885907249]], [0.39, [0.02111092093, −0.9877735197]], [0.40, [0.02152610152, −0.9869405774]], [0.41, [0.02194917864, −0.9860916120]], [0.42, [0.02238029177, −0.9852263330]], [0.43, [0.02281958244, −0.9843444453]], [0.44, [0.02326719422, −0.9834456492]], [0.45, [0.02372327275, −0.9825296404]], [0.46, [0.02418796573, −0.9815961099]], [0.47, [0.02466142294, −0.9806447440]], [0.48, [0.02514379626, −0.9796752241]], [0.49, [0.02563523966, −0.9786872269]], [0.50, [0.02613590922, −0.9776804242]], [0.51, [0.02664596312, −0.9766544830]], [0.52, [0.02716556167, −0.9756090653]], [0.53, [0.02769486729, −0.9745438281]], [0.54, [0.02823404453, −0.9734584236]], [0.55, [0.02878326005, (5)

−0.9723524988]], [0.56, [0.02934268264, −0.9712256958]], [0.57, [0.02991248321,
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−0.9420514435]], [0.78, [0.04460036656, −0.9403643427]], [0.79, [0.04544588424,
−0.9386467096]], [0.80, [0.04630626610, −0.9368980633]], [0.81, [0.04718172857,
−0.9351179182]], [0.82, [0.04807248950, −0.9333057839]], [0.83, [0.04897876808,
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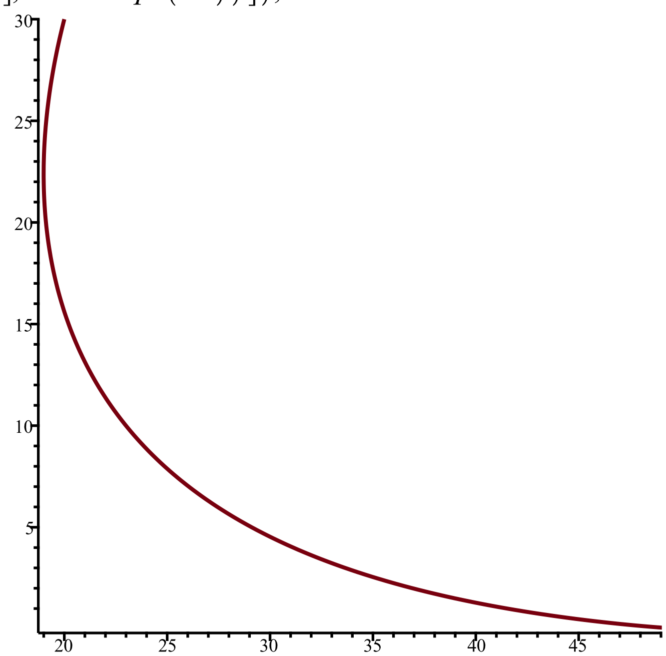
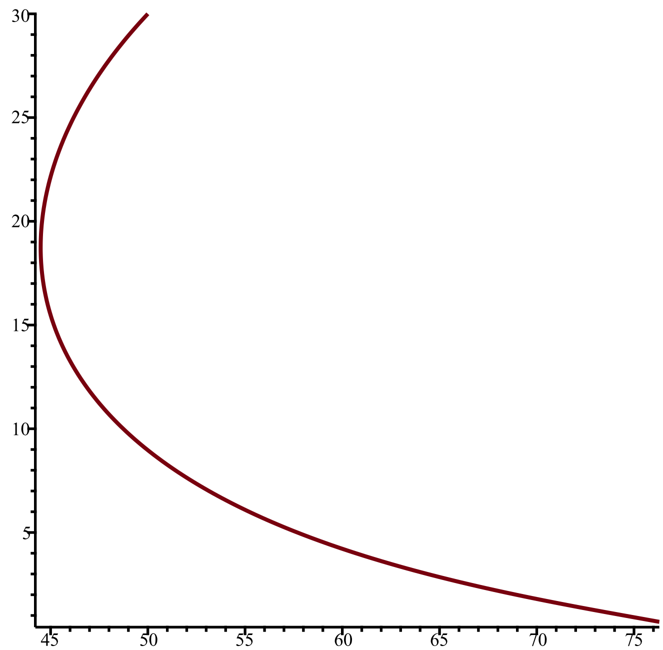
```
> #5
L1 := Dis2(SIRS(s, i, 0.01, 0.5, 1, 50), s, i, [20, 30], 0.01, 10) :
plot([seq(L1[i][2], i=1..nops(L1))]);
```




```
> L2 := Dis2(SIRS(s, i, 0.01, 0.5, 1, 80), s, i, [50, 30], 0.01, 10) :
plot([seq(L2[i][2], i=1..nops(L2))]);
```



> $L3 := Dis2(SIRS(s, i, 0.01, 0.5, 1, 120), s, i, [90, 30], 0.01, 10);$
> $plot([seq(L3[i][2], i = 1..nops(L3))]);$

L3 := [[0.01, [90, 30]], [0.02, [89.7300, 29.9700]], [0.03, [89.46257919, 29.93922081]], [0.04, [89.19772620, 29.90767259]], [0.05, [88.93542957, 29.87536550]], [0.06, [88.67567774, 29.84230969]], [0.07, [88.41845910, 29.80851529]], [0.08, [88.16376192, 29.77399244]], [0.09, [87.91157443, 29.73875124]], [0.10, [87.66188476, 29.70280177]], [0.11, [87.41468097, 29.66615411]], [0.12, [87.16995106, 29.62881831]], [0.13, [86.92768295, 29.59080439]], [0.14, [86.68786451, 29.55212236]], [0.15, [86.45048354, 29.51278218]], [0.16, [86.21552778, 29.47279379]], [0.17, [85.98298492, 29.43216710]], [0.18, [85.75284260, 29.39091199]], [0.19, [85.52508840, 29.34903830]], [0.20, [85.29970986, 29.30655583]], [0.21, [85.07669446, 29.26347434]], [0.22, [84.85602965, 29.21980357]], [0.23, [84.63770283, 29.17555318]], [0.24, [84.42170137, 29.13073283]], [0.25, [84.20801260, 29.08535210]], [0.26, [83.99662381, 29.03942055]], [0.27, [83.78752226, 28.99294767]], [0.28, [83.58069519, 28.94594291]], [0.29, [83.37612980, 28.89841568]], [0.30, [83.17381326, 28.85037533]], [0.31, [82.97373274, 28.80183115]], [0.32, [82.77587538, 28.75279238]], [0.33, [82.58022828, 28.70326822]], [0.34, [82.38677856, 28.65326778]], [0.35, [82.19551329, 28.60280014]], [0.36, [82.00641954, 28.55187432]], [0.37, [81.81948437, 28.50049928]], [0.38, [81.63469483, 28.44868391]], [0.39, [81.45203798, 28.39643703]], [0.40, [81.27150083, 28.34376743]], [0.41, [81.09307044, 28.29068381]], [0.42, [80.91673383, 28.23719481]], [0.43, [80.74247803, 28.18330902]], [0.44, [80.57029007, 28.12903495]], [0.45, [80.40015700, 28.07438105]], [0.46,

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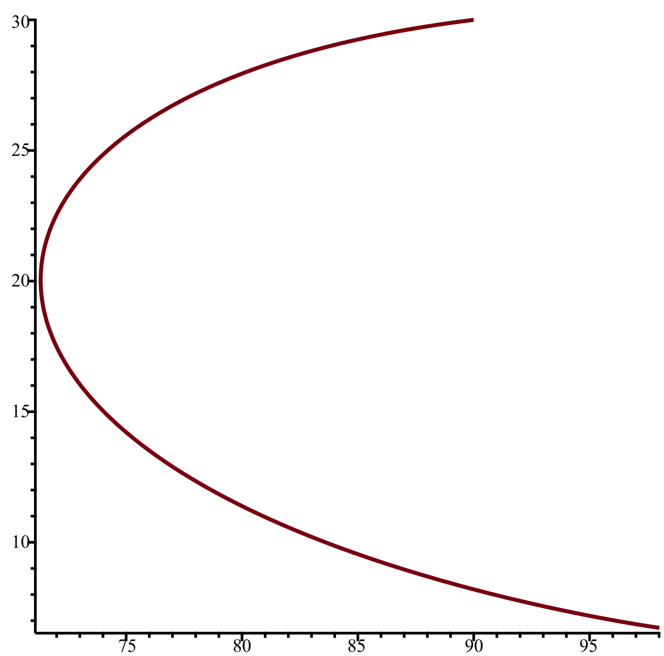

> *#In the long run, if N=120, then 98 individuals will be infected*

Dynamic Modeling HW18

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

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

$F(x,y) = x(1-x-y)$

$G(x,y) = x(3-2x-y)$

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

$x=0, \quad x+y=1$

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

$x=0, \quad 2x+y=3$

$(x+y=1)\cdot -1$

$+\ 2x+y=3$

$x=2$

$2+y=1 \Rightarrow y=-1$

Equilibrium points: (0,-1), (2,-1)

Jacobian: $\begin{bmatrix} 1-2x-y & -x \\ 3-4x-y & -x \end{bmatrix}$

$F(x,y) = x - x^2 - xy$

$G(x,y) = 3x - 2x^2 - xy$

* (0,-1)

$\begin{bmatrix} 2 & 0 \\ 4 & 0 \end{bmatrix} \Rightarrow$ Eigenvalues: (on Maple) $\lambda = 0, 2$

Both eigenvalues >0, (0,-1) is unstable

* (2,-1)

$\begin{bmatrix} -2 & -2 \\ -4 & -2 \end{bmatrix} \Rightarrow$ Eigenvalues: (on Maple) $\lambda = -2 \pm 2\sqrt{2}$

At least one eigenvalue >0, (2,-1) is unstable