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```
%Author:Sage Herrin
%Created: 4/11/12
%APPM 4650 hw10
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
```

Section 5.5, problem 2a

```
clear all;clc
%begin by obtaining initial values from 4th order RK method for 2-step
%AB method
clear all;clc
t = [0:.1:1];
h = .1;
y(1) = 1;
order = 2;
%define DE
f = @(t,y) (2 - 2*t*y)/(t^2 + 1);
%run RK
for i = 1:(order - 1)
    k1 = h*f(t(i),y(i));
    k2 = h*f((t(i)+h/2),(y(i)+.5*k1));
    k3 = h*f((t(i)+h/2),(y(i)+.5*k2));
    k4 = h*f(t(i+1),(y(i) + k3));
    y(i+1) = y(i) + (1/6)*(k1 + 2*k2 + 2*k3 + k4);
end
for j = order:length(t) - 1
    y(j+1) = y(j) + (h/2)*(3*f(t(j),y(j)) - f(t(j-1),y(j-1)));
end
%compare approx., exact, and error
exact = (2.*t + 1)./(t.^2 + 1)
y
error = abs(y - exact)
%repeat process for 3-stop AB method
clear y;clc
y(1) = 1;
order = 3;
for i = 1:(order - 1)
    k1 = h*f(t(i),y(i));
    k2 = h*f((t(i)+h/2),(y(i)+.5*k1));
    k3 = h*f((t(i)+h/2),(y(i)+.5*k2));
```

```
    k4 = h*f(t(i+1),(y(i) + k3));
    y(i+1) = y(i) + (1/6)*(k1 + 2*k2 + 2*k3 + k4);
end
for j = order:length(t) - 1
    y(j+1) = y(j) + (h/12)*(23*f(t(j),y(j)) - 16*f(t(j-1),y(j-1)) +
 5*f(t(j-2),y(j-2)));
end
%compare approx., exact, and error
y
error = abs(y - exact)
%4-step order AB method
clear y;clc
y(1) = 1;
order = 4;
for i = 1:(order - 1)
    k1 = h*f(t(i),y(i));
    k2 = h*f((t(i)+h/2),(y(i)+.5*k1));
    k3 = h*f((t(i)+h/2),(y(i)+.5*k2));
    k4 = h*f(t(i+1),(y(i) + k3));
    y(i+1) = y(i) + (1/6)*(k1 + 2*k2 + 2*k3 + k4);
end
for j = order:length(t) - 1
    y(j+1) = y(j) + (h/24)*(55*f(t(j),y(j)) - 59*f(t(j-1),y(j-1)) +
 37*f(t(j-2),y(j-2)) - 9*f(t(j-3),y(j-3)));
end
%compare approx., exact, and error
y
error = abs(y - exact)
%5-step order AB method
clear y;clc
y(1) = 1;
order = 5;
for i = 1:(order - 1)
    k1 = h*f(t(i),y(i));
    k2 = h*f((t(i)+h/2),(y(i)+.5*k1));
    k3 = h*f((t(i)+h/2),(y(i)+.5*k2));
    k4 = h*f(t(i+1),(y(i) + k3));
    y(i+1) = y(i) + (1/6)*(k1 + 2*k2 + 2*k3 + k4);
end
for j = order:length(t) - 1
    y(j+1) = y(j) + (h/720)*(1901*f(t(j),y(j)) - 2774*f(t(j-1),y(j-1))
 + 2616*f(t(j-2),y(j-2)) - 1274*f(t(j-3),y(j-3)) +
 251*f(t(j-4),y(j-4)));
end
%compare approx., exact, and error
y
error
```

```
exact =

  Columns 1 through 3

   1.000000000000000   1.188118811881188   1.346153846153846
```

```
  Columns 4 through 6

   1.467889908256881   1.551724137931034   1.600000000000000

  Columns 7 through 9

   1.617647058823530   1.610738255033557   1.585365853658536

  Columns 10 through 11

   1.546961325966851   1.500000000000000

y =

  Columns 1 through 3

   1.000000000000000   1.188118764675268   1.349857811269072

  Columns 4 through 6

   1.473196588677409   1.556590819080956   1.602988448114635

  Columns 7 through 9

   1.618098483274705   1.608646163118815   1.581123788571847

  Columns 10 through 11

   1.541126535638776   1.493132968263878

error =

  Columns 1 through 3

                   0   0.000000047205920   0.003703965115226

  Columns 4 through 6

   0.005306680420528   0.004866681149921   0.002988448114635

  Columns 7 through 9

   0.000451424451176   0.002092091914742   0.004242065086689

  Columns 10 through 11

   0.005834790328074   0.006867031736122

y =
```

```
  Columns 1 through 3

   1.000000000000000   1.188118764675268   1.346153608557930

  Columns 4 through 6

   1.466184072493249   1.548505437114575   1.595794459693531

  Columns 7 through 9

   1.613103413962713   1.606388445380196   1.581537429185894

  Columns 10 through 11

   1.543788714803801   1.497482320601062

error =

  Columns 1 through 3

                   0   0.000000047205920   0.000000237595916

  Columns 4 through 6

   0.001705835763632   0.003218700816460   0.004205540306470

  Columns 7 through 9

   0.004543644860817   0.004349809653361   0.003828424472643

  Columns 10 through 11

   0.003172611163049   0.002517679398938

y =

  Columns 1 through 3

   1.000000000000000   1.188118764675268   1.346153608557930

  Columns 4 through 6

   1.467889340629606   1.551742825287962   1.600396713821270

  Columns 7 through 9

   1.618495896231417   1.611961238416684   1.586784646459038

  Columns 10 through 11

   1.548411983332391   1.501365685577498
```

```
error =

  Columns 1 through 3

                  0   0.000000047205920   0.000000237595916

  Columns 4 through 6

   0.000000567627275   0.000018687356928   0.000396713821270

  Columns 7 through 9

   0.000848837407888   0.001222983383127   0.001418792800502

  Columns 10 through 11

   0.001450657365540   0.001365685577498

y =

  Columns 1 through 3

   1.000000000000000   1.188118764675268   1.346153608557930

  Columns 4 through 6

   1.467889340629606   1.551723173322634   1.600339369926289

  Columns 7 through 9

   1.618045412727204   1.611098226129188   1.585534486294508

  Columns 10 through 11

   1.546992422198530   1.499907131186876

error =

  Columns 1 through 3

                  0   0.000000047205920   0.000000237595916

  Columns 4 through 6

   0.000000567627275   0.000018687356928   0.000396713821270

  Columns 7 through 9

   0.000848837407888   0.001222983383127   0.001418792800502

  Columns 10 through 11
```

0.001450657365540 0.001365685577498

Problem 2b, reusing above script and changing IVP parameters

```
clear all;clc
t = [1:.1:2];
h = .1;
y(1) = -log(2)^-1;
order = 2;
%define DE
f = @(t,y) y^2/(t + 1);
%run RK
for i = 1:(order - 1)
    k1 = h*f(t(i),y(i));
    k2 = h*f((t(i)+h/2),(y(i)+.5*k1));
    k3 = h*f((t(i)+h/2),(y(i)+.5*k2));
    k4 = h*f(t(i+1),(y(i) + k3));
    y(i+1) = y(i) + (1/6)*(k1 + 2*k2 + 2*k3 + k4);
end
for j = order:length(t) - 1
    y(j+1) = y(j) + (h/2)*(3*f(t(j),y(j)) - f(t(j-1),y(j-1)));
end
%compare approx., exact, and error
exact = -1./(log(t + 1))
y
error = abs(y - exact)
%repeat process for 3-stop AB method
clear y;clc
y(1) = -log(2)^-1;
order = 3;
for i = 1:(order - 1)
    k1 = h*f(t(i),y(i));
    k2 = h*f((t(i)+h/2),(y(i)+.5*k1));
    k3 = h*f((t(i)+h/2),(y(i)+.5*k2));
    k4 = h*f(t(i+1),(y(i) + k3));
    y(i+1) = y(i) + (1/6)*(k1 + 2*k2 + 2*k3 + k4);
end
for j = order:length(t) - 1
    y(j+1) = y(j) + (h/12)*(23*f(t(j),y(j)) - 16*f(t(j-1),y(j-1)) +
 5*f(t(j-2),y(j-2)));
end
%compare approx., exact, and error
y
error = abs(y - exact)
%4-step order AB method
clear y;clc
y(1) = -log(2)^-1;
order = 4;
for i = 1:(order - 1)
```

```
    k1 = h*f(t(i),y(i));
    k2 = h*f((t(i)+h/2),(y(i)+.5*k1));
    k3 = h*f((t(i)+h/2),(y(i)+.5*k2));
    k4 = h*f(t(i+1),(y(i) + k3));
    y(i+1) = y(i) + (1/6)*(k1 + 2*k2 + 2*k3 + k4);
end
for j = order:length(t) - 1
    y(j+1) = y(j) + (h/24)*(55*f(t(j),y(j)) - 59*f(t(j-1),y(j-1)) +
 37*f(t(j-2),y(j-2)) - 9*f(t(j-3),y(j-3)));
end
%compare approx., exact, and error
y
error = abs(y - exact)
%5-step order AB method
clear y;clc
y(1) = -log(2)^-1;
order = 5;
for i = 1:(order - 1)
    k1 = h*f(t(i),y(i));
    k2 = h*f((t(i)+h/2),(y(i)+.5*k1));
    k3 = h*f((t(i)+h/2),(y(i)+.5*k2));
    k4 = h*f(t(i+1),(y(i) + k3));
    y(i+1) = y(i) + (1/6)*(k1 + 2*k2 + 2*k3 + k4);
end
for j = order:length(t) - 1
    y(j+1) = y(j) + (h/720)*(1901*f(t(j),y(j)) - 2774*f(t(j-1),y(j-1))
 + 2616*f(t(j-2),y(j-2)) - 1274*f(t(j-3),y(j-3)) +
 251*f(t(j-4),y(j-4)));
end
%compare approx., exact, and error
y
error
```

```
exact =

  Columns 1 through 3

  -1.442695040888963  -1.347822706464185  -1.268299403709030

  Columns 4 through 6

  -1.200611174093137  -1.142245242271581  -1.091356667937291

  Columns 7 through 9

  -1.046559939395897  -1.006794074949662  -0.971232654817011

  Columns 10 through 11

  -0.939222236853531  -0.910239226626838


y =
```

```
  Columns 1 through 3

  -1.442695040888963  -1.347822674884314  -1.270097902057147

  Columns 4 through 6

  -1.203363491119358  -1.145585720370877  -1.095042885456653

  Columns 7 through 9

  -1.050436721920583  -1.010760409565795  -0.975222383960341

  Columns 10 through 11

  -0.943192007242693  -0.914160827806065

error =

  Columns 1 through 3

                   0   0.000000031579870   0.001798498348117

  Columns 4 through 6

   0.002752317026221   0.003340478099296   0.003686217519361

  Columns 7 through 9

   0.003876782524686   0.003966334616133   0.003989729143330

  Columns 10 through 11

   0.003969770389162   0.003921601179227

y =

  Columns 1 through 3

  -1.442695040888963  -1.347822674884314  -1.268299355137524

  Columns 4 through 6

  -1.200137109438933  -1.141555414249868  -1.090516252148282

  Columns 7 through 9

  -1.045646517508684  -1.005846294444148  -0.970276352998182

  Columns 10 through 11

  -0.938272557686463  -0.909305377447475
```

```
error =
   1.0e-03 *
  Columns 1 through 3
                  0   0.000031579870274   0.000048571506150
  Columns 4 through 6
   0.474064654203188   0.689828021712913   0.840415789009841
  Columns 7 through 9
   0.913421887212662   0.947780505513585   0.956301818829330
  Columns 10 through 11
   0.949679167068451   0.933849179362900

y =
  Columns 1 through 3
  -1.442695040888963  -1.347822674884314  -1.268299355137524
  Columns 4 through 6
  -1.200611116801790  -1.142395928967874  -1.091566924443562
  Columns 7 through 9
  -1.046822254707184  -1.007069701167645  -0.971516319366565
  Columns 10 through 11
  -0.939503773854617  -0.910516392292800

error =
   1.0e-03 *
  Columns 1 through 3
                  0   0.000031579870274   0.000048571506150
  Columns 4 through 6
   0.000057291346556   0.150686696293478   0.210256506270490
```

```
  Columns 7 through 9

   0.262315311286621   0.275626217982827   0.283664549553975

  Columns 10 through 11

   0.281537001086352   0.277165665962698

y =

  Columns 1 through 3

  -1.442695040888963  -1.347822674884314  -1.268299355137524

  Columns 4 through 6

  -1.200611116801790  -1.142245181015467  -1.091301753330997

  Columns 7 through 9

  -1.046486049761775  -1.006698439099802  -0.971138529060901

  Columns 10 through 11

  -0.939123426102761  -0.910144223217906

error =

   1.0e-03 *

  Columns 1 through 3

                  0   0.000031579870274   0.000048571506150

  Columns 4 through 6

   0.000057291346556   0.150686696293478   0.210256506270490

  Columns 7 through 9

   0.262315311286621   0.275626217982827   0.283664549553975

  Columns 10 through 11

   0.281537001086352   0.277165665962698
```

5.9, question 2a

```
clear y;clc
u1(1) = -1;
```

```
u2(1) = 0;
h = 0.1;
t = [0:0.1:1];

% f1 = @(t,u1,u2) u1 - u2 + 2;
% f2 = @(t,u1,u2) -u1 +u2 +4*t;

for i = 1:length(t) - 1
    for j = 1:2
        k(1,j) = h*funcgrab1(j,t(i),u1(i),u2(i));
    end
    for j = 1:2
        k(2,j) =
 h*funcgrab1(j,t(i)+h/2,u1(i)+(k(1,1)*.5),u2(i)+(k(1,2)*.5));
    end
    for j = 1:2
        k(3,j) =
 h*funcgrab1(j,t(i)+h/2,u1(i)+(.5*k(2,1)),u2(i)+(.5*k(2,2)));
    end
    for j = 1:2
        k(4,j) = h*funcgrab1(j,t(i)+h,u1(i)+k(3,1),u2(i)+k(3,2));
    end
   u1(i+1) = u1(i) + (k(1,1) + 2*k(2,1) + 2*k(3,1) + k(4,1))/6;
   u2(i+1) = u2(i) + (k(1,2) + 2*k(2,2) + 2*k(3,2) + k(4,2))/6;
end

u1
u2

exact_u1 = -.5*exp(2.*t) + t.^2 + 2.*t - .5
exact_u2 = .5*exp(2.*t) + t.^2 - .5
%compare approx. and actual soln. with error
error_u1 = abs(exact_u1 - u1)
error_u2 = abs(exact_u2 - u2)


u1 =

  Columns 1 through 3

  -1.000000000000000  -0.900700000000000  -0.805908980000000

  Columns 4 through 6

  -0.721053228172000  -0.652760412889281  -0.609125568302967

  Columns 7 through 9

  -0.600035969125244  -0.637567932689573  -0.736471472987045

  Columns 10 through 11

  -0.914762257106377  -1.194444620829729
```

```
u2 =
  Columns 1 through 3
                  0   0.120700000000000   0.285908980000000
  Columns 4 through 6
   0.501053228172000   0.772760412889281   1.109125568302967
  Columns 7 through 9
   1.520035969125245   2.017567932689574   2.616471472987045
  Columns 10 through 11
   3.334762257106377   4.194444620829729

exact_u1 =
  Columns 1 through 3
  -1.000000000000000  -0.900701379080085  -0.805912348820635
  Columns 4 through 6
  -0.721059400195254  -0.652770464246234  -0.609140914229523
  Columns 7 through 9
  -0.600058461368274  -0.637599983422337  -0.736516212197557
  Columns 10 through 11
  -0.914823732206473  -1.194528049465325

exact_u2 =
  Columns 1 through 3
                  0   0.120701379080085   0.285912348820635
  Columns 4 through 6
   0.501059400195255   0.772770464246234   1.109140914229523
  Columns 7 through 9
   1.520058461368273   2.017599983422337   2.616516212197558
  Columns 10 through 11
```

```
   3.334823732206473   4.194528049465325

error_u1 =

   1.0e-04 *

  Columns 1 through 3

                  0   0.013790800849067   0.033688206352300

  Columns 4 through 6

   0.061720232544804   0.100513569532001   0.153459265553879

  Columns 7 through 9

   0.224922430294150   0.320507327639108   0.447392105121791

  Columns 10 through 11

   0.614751000962421   0.834286355964053

error_u2 =

   1.0e-04 *

  Columns 1 through 3

                  0   0.013790800849484   0.033688206352300

  Columns 4 through 6

   0.061720232547025   0.100513569532001   0.153459265552769

  Columns 7 through 9

   0.224922430289709   0.320507327633557   0.447392105122901

  Columns 10 through 11

   0.614751000962421   0.834286355964053
```

5.9, question 2b

```
clear y;clc
u1(1) = -3;
u2(1) = 5;
h = 0.2;
t = [0:0.2:2];
```

```
% f1 = @(t,u1,u2) u1 - u2 + 2;
% f2 = @(t,u1,u2) -u1 +u2 +4*t;

for i = 1:length(t) - 1
    for j = 1:2
        k(1,j) = h*funcgrab2(j,t(i),u1(i),u2(i));
    end
    for j = 1:2
        k(2,j) =
 h*funcgrab2(j,t(i)+h/2,u1(i)+(k(1,1)*.5),u2(i)+(k(1,2)*.5));
    end
    for j = 1:2
        k(3,j) =
 h*funcgrab2(j,t(i)+h/2,u1(i)+(.5*k(2,1)),u2(i)+(.5*k(2,2)));
    end
    for j = 1:2
        k(4,j) = h*funcgrab2(j,t(i)+h,u1(i)+k(3,1),u2(i)+k(3,2));
    end
   u1(i+1) = u1(i) + (k(1,1) + 2*k(2,1) + 2*k(3,1) + k(4,1))/6;
   u2(i+1) = u2(i) + (k(1,2) + 2*k(2,2) + 2*k(3,2) + k(4,2))/6;
end

u1
u2

exact_u1 = -3*exp(t) + t.^2
exact_u2 = 4*exp(t) - 3.*t + 1
%compare approx. and actual soln. with error
error_u1 = abs(exact_u1 - u1)
error_u2 = abs(exact_u2 - u2)


u1 =

  Columns 1 through 3

  -3.000000000000000  -3.624200009144948  -4.315453898495391

  Columns 4 through 6

  -5.106319397087947  -6.036562515167024  -7.154753457644198

  Columns 7 through 9

  -8.520215872797515 -10.205407664632787 -12.298828917101721

  Columns 10 through 11

 -14.908573632741899 -18.166667826251675


u2 =
```

```
  Columns 1 through 3

   5.000000000000000   5.285600000000000   5.767271839999999

  Columns 4 through 6

   6.488425825375999   7.502083303114246   8.873004546423740

  Columns 7 through 9

  10.680287753001956  13.020543461516588  16.011771783896361

  Columns 10 through 11

  19.798098056851018  24.555556966637834

exact_u1 =

  Columns 1 through 3

  -3.000000000000000  -3.624208274480510  -4.315474092923811

  Columns 4 through 6

  -5.106356401171527  -6.036622785477403  -7.154845485377137

  Columns 7 through 9

  -8.520350768209642 -10.205599900534024 -12.299097273185344

  Columns 10 through 11

 -14.908942393238840 -18.167168296791949

exact_u2 =

  Columns 1 through 3

   5.000000000000000   5.285611032640679   5.767298790565081

  Columns 4 through 6

   6.488475201562036   7.502163713969871   8.873127313836182

  Columns 7 through 9

  10.680467690946189  13.020799867378699  16.012129697580459

  Columns 10 through 11

  19.798589857651784  24.556224395722602
```

```
error_u1 =

   1.0e-03 *

  Columns 1 through 3

                  0   0.008265335562196   0.020194428420162

  Columns 4 through 6

   0.037004083579539   0.060270310379806   0.092027732939037

  Columns 7 through 9

   0.134895412127634   0.192235901236515   0.268356083623189

  Columns 10 through 11

   0.368760496941789   0.500470540274023


error_u2 =

   1.0e-03 *

  Columns 1 through 3

                  0   0.011032640679254   0.026950565081840

  Columns 4 through 6

   0.049376186036731   0.080410855625601   0.122767412442215

  Columns 7 through 9

   0.179937944233544   0.256405862110398   0.357913684098321

  Columns 10 through 11

   0.491800800766384   0.667429084767690
```

5.9, question 4a

```
clear all;clc
u1(1) = 3;
u2(1) = -1;
u3(1) = 9;
h = 0.2;
t = [0:0.2:2];

% f1 = @(t,u1,u2) u1 - u2 + 2;
```

```
% f2 = @(t,u1,u2) -u1 +u2 +4*t;

for i = 1:length(t) - 1
    for j = 1:3
        k(1,j) = h*funcgrab3(j,t(i),u1(i),u2(i),u3(i));
    end
    for j = 1:3
        k(2,j) =
 h*funcgrab3(j,t(i)+h/2,u1(i)+(k(1,1)*.5),u2(i)+(k(1,2)*.5),u3(i)+(k(1,3)*.5));
    end
    for j = 1:3
        k(3,j) =
 h*funcgrab3(j,t(i)+h/2,u1(i)+(.5*k(2,1)),u2(i)+(.5*k(2,2)),u3(i)+(.5*k(2,3)));
    end
    for j = 1:3
        k(4,j) =
 h*funcgrab3(j,t(i)+h,u1(i)+k(3,1),u2(i)+k(3,2),u3(i)+k(3,3));
    end
   u1(i+1) = u1(i) + (k(1,1) + 2*k(2,1) + 2*k(3,1) + k(4,1))/6;
   u2(i+1) = u2(i) + (k(1,2) + 2*k(2,2) + 2*k(3,2) + k(4,2))/6;
   u3(i+1) = u3(i) + (k(1,3) + 2*k(2,3) + 2*k(3,3) + k(4,3))/6;
end
u1
exact = exp(-t) + exp(2.*t) + exp(-2.*t)
error = abs(exact - u1)


u1 =

  Columns 1 through 3

   3.000000000000000   2.980866666666667   3.345028768888889

  Columns 4 through 6

   4.169625781639407   5.603146665472463   7.890094976913602

  Columns 7 through 9

  11.411109228288309  16.745061449784984  24.763215867629949

  Columns 10 through 11

  36.770723451050408  54.718398568739595


exact =

  Columns 1 through 3

   3.000000000000000   2.980875496754892   3.345189938645329

  Columns 4 through 6
```

```
    4.170122770742776   5.604257906506992   7.892270823338706

  Columns 7 through 9

  11.415088545843217  16.752053797663873  24.775188919082375

  Columns 10 through 11

  36.790857054346866  54.751800955269587


error =

  Columns 1 through 3

                   0   0.000008830088225   0.000161169756440

  Columns 4 through 6

    0.000496989103369   0.001111241034529   0.002175846425104

  Columns 7 through 9

    0.003979317554908   0.006992347878889   0.011973051452426

  Columns 10 through 11

    0.020133603296458   0.033402386529993
```

5.9, question 4b

```
clear all;clc
u1(1) = 2;
u2(1) = 8;
u3(1) = 6;
h = 0.1;
t = [1:0.1:2];

% f1 = @(t,u1,u2) u1 - u2 + 2;
% f2 = @(t,u1,u2) -u1 +u2 +4*t;

for i = 1:length(t) - 1
    for j = 1:3
        k(1,j) = h*funcgrab4(j,t(i),u1(i),u2(i),u3(i));
    end
    for j = 1:3
        k(2,j) =
 h*funcgrab4(j,t(i)+h/2,u1(i)+(k(1,1)*.5),u2(i)+(k(1,2)*.5),u3(i)+(k(1,3)*.5));
    end
    for j = 1:3
        k(3,j) =
 h*funcgrab4(j,t(i)+h/2,u1(i)+(.5*k(2,1)),u2(i)+(.5*k(2,2)),u3(i)+(.5*k(2,3)));
```

```
    end
    for j = 1:3
        k(4,j) =
 h*funcgrab4(j,t(i)+h,u1(i)+k(3,1),u2(i)+k(3,2),u3(i)+k(3,3));
    end
   u1(i+1) = u1(i) + (k(1,1) + 2*k(2,1) + 2*k(3,1) + k(4,1))/6;
   u2(i+1) = u2(i) + (k(1,2) + 2*k(2,2) + 2*k(3,2) + k(4,2))/6;
   u3(i+1) = u3(i) + (k(1,3) + 2*k(2,3) + 2*k(3,3) + k(4,3))/6;
end
u1
exact = 2.*t - t.^-1 + t.^2 + t.^3 - 1
error = abs(exact - u1)


u1 =

  Columns 1 through 3

   2.000000000000000   2.831908073282223   3.734666312717679

  Columns 4 through 6

   4.717770472743966   5.789717699109209   6.958339315905182

  Columns 7 through 9

   8.231008857995716   9.614776697439808  11.116459802216719

  Columns 10 through 11

  12.742703153800006  14.500022741313533


exact =

  Columns 1 through 3

   2.000000000000000   2.831909090909091   3.734666666666666

  Columns 4 through 6

   4.717769230769231   5.789714285714284   6.958333333333334

  Columns 7 through 9

   8.231000000000002   9.614764705882351  11.116444444444445

  Columns 10 through 11

  12.742684210526313  14.500000000000000


error =
```

```
 1.0e-04 *

Columns 1 through 3

                0   0.010176268685491   0.003539489865645

Columns 4 through 6

 0.012419747354997   0.034133949249338   0.059825718476958

Columns 7 through 9

 0.088579957147061   0.119915574572360   0.153577722734610

Columns 10 through 11

 0.189432736927841   0.227413135327481
```

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