

## Homework Submission Template 8

## Problem 1)

Screenshot of text file or comma delimited file with times in left column and rod profile values to the right

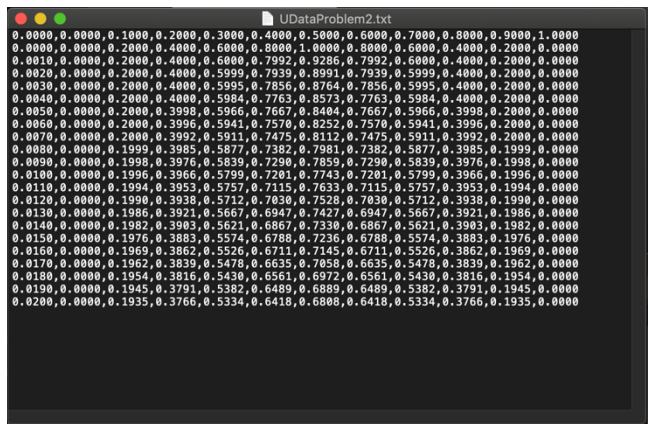
```
0.0000,0.0000,0.1000,0.2000,0.3000,0.4000,0.5000,0.6000,0.7000,0.8000,0.9000,1.0000
0.0000,0.0000,0.2000,0.4000,0.6000,0.8000,1.0000,0.8000,0.6000,0.4000,0.2000,0.0000
0.0010,0.0000,0.2000,0.4000,0.6000,0.8000,0.9600,0.8000,0.6000,0.4000,0.2000,0.0000
0.0020,0.0000,0.2000,0.4000,0.6000,0.7960,0.9280,0.7960,0.6000,0.4000,0.2000,0.0000
0.0030,0.0000,0.2000,0.4000,0.5996,0.7896,0.9016,0.7896,0.5996,0.4000,0.2000,0.0000
0.0040,0.0000,0.2000,0.4000,0.5986,0.7818,0.8792,0.7818,0.5986,0.4000,0.2000,0.0000
0.0050,0.0000,0.2000,0.3988,0.5971,0.7732,0.8597,0.7732,0.5971,0.3998,0.2000,0.0000
0.0060,0.0000,0.2000,0.3996,0.5950,0.7643,0.8424,0.7643,0.5950,0.3996,0.2000,0.0000
0.0070,0.0000,0.1999,0.3992,0.5924,0.7551,0.8268,0.7551,0.5924,0.3992,0.1999,0.0000
0.0080,0.0000,0.1999,0.3986,0.5893,0.7460,0.8125,0.7460,0.5893,0.3986,0.1999,0.0000
0.0090,0.0000,0.1998,0.3978,0.5859,0.7370,0.7992,0.7370,0.5859,0.3978,0.1998,0.0000
0.0100,0.0000,0.1996,0.3968,0.5822,0.7281,0.7867,0.7281,0.5822,0.3968,0.1996,0.0000
0.0110,0.0000,0.1993,0.3956,0.5783,0.7194,0.7750,0.7194,0.5783,0.3956,0.1993,0.0000
0.0120,0.0000,0.1990,0.3942,0.5741,0.7108,0.7639,0.7108,0.5741,0.3942,0.1990,0.0000
0.0130,0.0000,0.1986,0.3927,0.5698,0.7025,0.7533,0.7025,0.5698,0.3927,0.1986,0.0000
0.0140,0.0000,0.1982,0.3910,0.5653,0.6943,0.7431,0.6943,0.5653,0.3910,0.1982,0.0000
0.0150,0.0000,0.1977,0.3892,0.5608,0.6863,0.7333,0.6863,0.5608,0.3892,0.1977,0.0000
0.0160,0.0000,0.1970,0.3872,0.5562,0.6784,0.7239,0.6784,0.5562,0.3872,0.1970,0.0000
0.0170,0.0000,0.1963,0.3851,0.5515,0.6708,0.7148,0.6708,0.5515,0.3851,0.1963,0.0000
0.0180,0.0000,0.1956,0.3828,0.5468,0.6632,0.7060,0.6632,0.5468,0.3828,0.1956,0.0000
0.0190,0.0000,0.1948,0.3805,0.5420,0.6559,0.6975,0.6559,0.5420,0.3805,0.1948,0.0000
0.0200,0.0000,0.1939,0.3781,0.5373,0.6487,0.6891,0.6487,0.5373,0.3781,0.1939,0.0000
```

## Problem 2)

Why don't you need to include boundary conditions or initial conditions in the analytical solution?

The analytical solution is to calculate at any point of the rod and the time, dependent of other spots on the rod. So it will calculate the values at the initial condition at the beginning.

Screenshot of text file or comma delimited file with times in left column and rod profile values to the right



```
UDataProblem2.txt
0.0000,0.0000,0.1000,0.2000,0.3000,0.4000,0.5000,0.6000,0.7000,0.8000,0.9000,1.0000
0.0000,0.0000,0.2000,0.4000,0.6000,0.8000,1.0000,0.8000,0.6000,0.4000,0.2000,0.0000
0.0010,0.0000,0.2000,0.4000,0.6000,0.7992,0.9286,0.7992,0.6000,0.4000,0.2000,0.0000
0.0020,0.0000,0.2000,0.4000,0.5999,0.7939,0.8991,0.7939,0.5999,0.4000,0.2000,0.0000
0.0030,0.0000,0.2000,0.4000,0.5995,0.7856,0.8764,0.7856,0.5995,0.4000,0.2000,0.0000
0.0040,0.0000,0.2000,0.4000,0.5984,0.7763,0.8573,0.7763,0.5984,0.4000,0.2000,0.0000
0.0050,0.0000,0.2000,0.3998,0.5966,0.7667,0.8404,0.7667,0.5966,0.3998,0.2000,0.0000
0.0060,0.0000,0.2000,0.3996,0.5941,0.7570,0.8252,0.7570,0.5941,0.3996,0.2000,0.0000
0.0070,0.0000,0.2000,0.3992,0.5911,0.7475,0.8112,0.7475,0.5911,0.3992,0.2000,0.0000
0.0080,0.0000,0.1999,0.3985,0.5877,0.7382,0.7981,0.7382,0.5877,0.3985,0.1999,0.0000
0.0090,0.0000,0.1998,0.3976,0.5839,0.7290,0.7859,0.7290,0.5839,0.3976,0.1998,0.0000
0.0100,0.0000,0.1996,0.3966,0.5799,0.7201,0.7743,0.7201,0.5799,0.3966,0.1996,0.0000
0.0110,0.0000,0.1994,0.3953,0.5757,0.7115,0.7633,0.7115,0.5757,0.3953,0.1994,0.0000
0.0120,0.0000,0.1990,0.3938,0.5712,0.7030,0.7529,0.7030,0.5712,0.3938,0.1990,0.0000
0.0130,0.0000,0.1986,0.3921,0.5667,0.6947,0.7427,0.6947,0.5667,0.3921,0.1986,0.0000
0.0140,0.0000,0.1982,0.3903,0.5621,0.6867,0.7330,0.6867,0.5621,0.3903,0.1982,0.0000
0.0150,0.0000,0.1976,0.3883,0.5574,0.6788,0.7236,0.6788,0.5574,0.3883,0.1976,0.0000
0.0160,0.0000,0.1969,0.3862,0.5526,0.6711,0.7145,0.6711,0.5526,0.3862,0.1969,0.0000
0.0170,0.0000,0.1962,0.3839,0.5470,0.6635,0.7058,0.6635,0.5470,0.3839,0.1962,0.0000
0.0180,0.0000,0.1954,0.3816,0.5430,0.6561,0.6972,0.6561,0.5430,0.3816,0.1954,0.0000
0.0190,0.0000,0.1945,0.3791,0.5382,0.6489,0.6889,0.6489,0.5382,0.3791,0.1945,0.0000
0.0200,0.0000,0.1935,0.3766,0.5334,0.6418,0.6808,0.6418,0.5334,0.3766,0.1935,0.0000
```

Problem 3)

Case 1				
Time	Fine - Difference x=0.5	Analytical Solution x=0.5	Difference	Percent Error
0.005	0.8597	0.8404	0.0193	2.30%
0.01	0.7867	0.7743	0.0124	1.60%
0.015	0.7333	0.7236	0.0097	1.34%
0.02	0.6891	0.6808	0.0083	1.22%

Case 2				
Time	Fine - Difference x=0.5	Analytical Solution x=0.5	Difference	Percent Error
0.005	0.96	0.8404	0.1196	14.23%
0.01	0.928	0.7743	0.1537	19.85%
0.015	0.9016	0.7236	0.178	24.60%
0.02	0.8792	0.6808	0.1984	29.14%

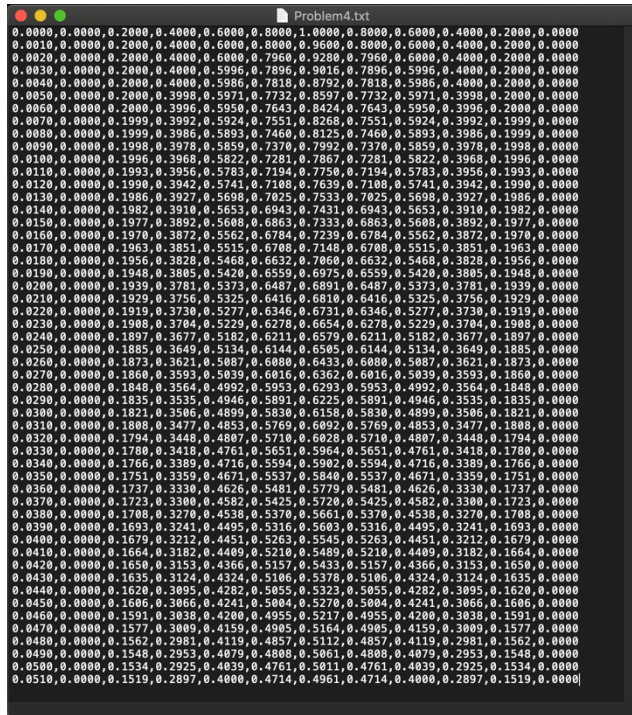
Case 3				
Time	Fine – Difference x=0.5	Analytical Solution x=0.5	Difference	Percent Error
0.01	0.96	0.7743	0.1857	23.98%
0.02	0.928	0.6808	0.2472	36.31%

Michael Einreinhof

#### Problem 4)

How long did it take for the center value of the rod to reach a value less than 0.5 units?  
.051s

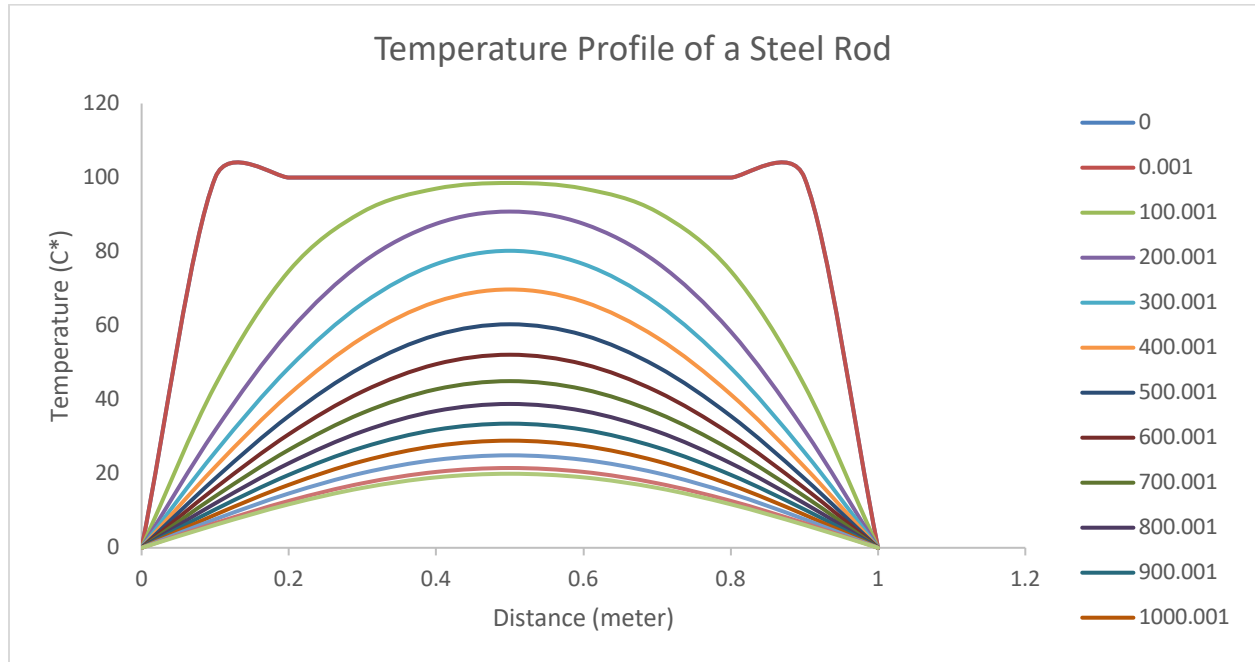
Screen shot of opened data file



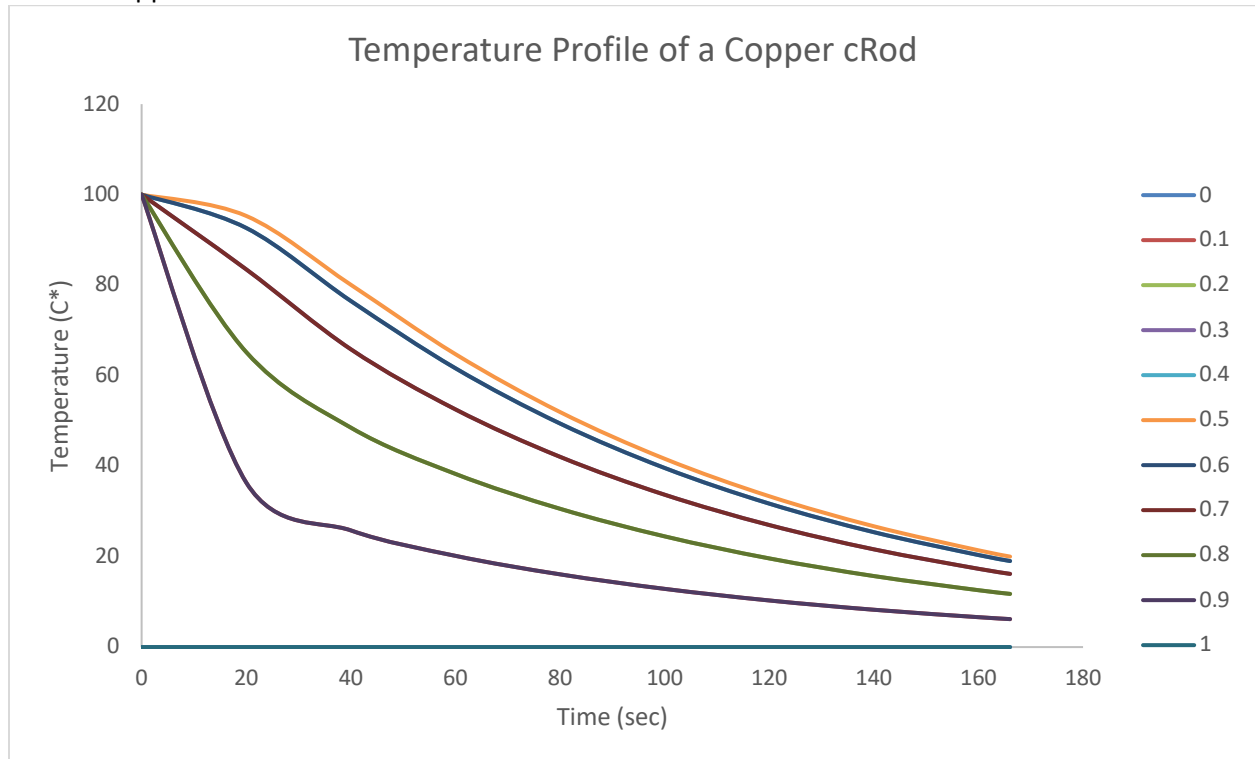
The screenshot shows a text file named "Problem4.txt" containing a grid of numerical data. The data is organized into rows and columns, with each row representing a time step and each column representing a spatial position along the rod. The values range from 0.0000 to 1.0000, with the center value (at position 0.5) starting at 1.0000 and decreasing over time. The file is displayed in a dark-themed editor window.

```
0.0000,0.0000,0.2000,0.4000,0.6000,0.8000,1.0000,0.8000,0.6000,0.4000,0.2000,0.0000
0.0010,0.0000,0.2000,0.4000,0.6000,0.8000,0.9600,0.8000,0.6000,0.4000,0.2000,0.0000
0.0020,0.0000,0.2000,0.4000,0.6000,0.7960,0.9200,0.7960,0.6000,0.4000,0.2000,0.0000
0.0030,0.0000,0.2000,0.4000,0.5996,0.7896,0.9016,0.7896,0.5996,0.4000,0.2000,0.0000
0.0040,0.0000,0.2000,0.4000,0.5986,0.7818,0.8792,0.7818,0.5986,0.4000,0.2000,0.0000
0.0050,0.0000,0.2000,0.3998,0.5971,0.7732,0.8597,0.7732,0.5971,0.3998,0.2000,0.0000
0.0060,0.0000,0.2000,0.3996,0.5950,0.7643,0.8424,0.7643,0.5950,0.3996,0.2000,0.0000
0.0070,0.0000,0.1999,0.3992,0.5924,0.7551,0.8268,0.7551,0.5924,0.3992,0.1999,0.0000
0.0080,0.0000,0.1999,0.3986,0.5893,0.7460,0.8125,0.7460,0.5893,0.3986,0.1999,0.0000
0.0090,0.0000,0.1998,0.3978,0.5859,0.7370,0.7992,0.7370,0.5859,0.3978,0.1998,0.0000
0.0100,0.0000,0.1996,0.3968,0.5822,0.7281,0.7867,0.7281,0.5822,0.3968,0.1996,0.0000
0.0110,0.0000,0.1993,0.3956,0.5783,0.7194,0.7750,0.7194,0.5783,0.3956,0.1993,0.0000
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0.0130,0.0000,0.1986,0.3927,0.5698,0.7025,0.7533,0.7025,0.5698,0.3927,0.1986,0.0000
0.0140,0.0000,0.1982,0.3910,0.5653,0.6943,0.7431,0.6943,0.5653,0.3910,0.1982,0.0000
0.0150,0.0000,0.1977,0.3892,0.5608,0.6863,0.7333,0.6863,0.5608,0.3892,0.1977,0.0000
0.0160,0.0000,0.1970,0.3872,0.5562,0.6784,0.7239,0.6784,0.5562,0.3872,0.1970,0.0000
0.0170,0.0000,0.1963,0.3851,0.5515,0.6700,0.7148,0.6700,0.5515,0.3851,0.1963,0.0000
0.0180,0.0000,0.1956,0.3828,0.5468,0.6632,0.7060,0.6632,0.5468,0.3828,0.1956,0.0000
0.0190,0.0000,0.1948,0.3805,0.5420,0.6559,0.6975,0.6559,0.5420,0.3805,0.1948,0.0000
0.0200,0.0000,0.1939,0.3781,0.5373,0.6487,0.6891,0.6487,0.5373,0.3781,0.1939,0.0000
0.0210,0.0000,0.1929,0.3756,0.5325,0.6416,0.6810,0.6416,0.5325,0.3756,0.1929,0.0000
0.0220,0.0000,0.1919,0.3730,0.5277,0.6346,0.6711,0.6346,0.5277,0.3730,0.1919,0.0000
0.0230,0.0000,0.1908,0.3704,0.5229,0.6278,0.6654,0.6278,0.5229,0.3704,0.1908,0.0000
0.0240,0.0000,0.1897,0.3677,0.5182,0.6211,0.6579,0.6211,0.5182,0.3677,0.1897,0.0000
0.0250,0.0000,0.1885,0.3649,0.5134,0.6144,0.6505,0.6144,0.5134,0.3649,0.1885,0.0000
0.0260,0.0000,0.1873,0.3621,0.5087,0.6080,0.6433,0.6080,0.5087,0.3621,0.1873,0.0000
0.0270,0.0000,0.1860,0.3593,0.5039,0.6016,0.6362,0.6016,0.5039,0.3593,0.1860,0.0000
0.0280,0.0000,0.1848,0.3564,0.4992,0.5953,0.6293,0.5953,0.4992,0.3564,0.1848,0.0000
0.0290,0.0000,0.1835,0.3535,0.4946,0.5891,0.6225,0.5891,0.4946,0.3535,0.1835,0.0000
0.0300,0.0000,0.1821,0.3506,0.4899,0.5830,0.6158,0.5830,0.4899,0.3506,0.1821,0.0000
0.0310,0.0000,0.1808,0.3477,0.4853,0.5769,0.6092,0.5769,0.4853,0.3477,0.1808,0.0000
0.0320,0.0000,0.1794,0.3448,0.4807,0.5710,0.6026,0.5710,0.4807,0.3448,0.1794,0.0000
0.0330,0.0000,0.1780,0.3418,0.4761,0.5651,0.5964,0.5651,0.4761,0.3418,0.1780,0.0000
0.0340,0.0000,0.1766,0.3389,0.4716,0.5594,0.5902,0.5594,0.4716,0.3389,0.1766,0.0000
0.0350,0.0000,0.1751,0.3359,0.4671,0.5537,0.5840,0.5537,0.4671,0.3359,0.1751,0.0000
0.0360,0.0000,0.1737,0.3330,0.4626,0.5481,0.5779,0.5481,0.4626,0.3330,0.1737,0.0000
0.0370,0.0000,0.1723,0.3300,0.4582,0.5425,0.5720,0.5425,0.4582,0.3300,0.1723,0.0000
0.0380,0.0000,0.1708,0.3270,0.4538,0.5370,0.5661,0.5370,0.4538,0.3270,0.1708,0.0000
0.0390,0.0000,0.1693,0.3241,0.4495,0.5316,0.5603,0.5316,0.4495,0.3241,0.1693,0.0000
0.0400,0.0000,0.1679,0.3212,0.4451,0.5263,0.5545,0.5263,0.4451,0.3212,0.1679,0.0000
0.0410,0.0000,0.1664,0.3182,0.4409,0.5201,0.5489,0.5201,0.4409,0.3182,0.1664,0.0000
0.0420,0.0000,0.1650,0.3153,0.4366,0.5157,0.5433,0.5157,0.4366,0.3153,0.1650,0.0000
0.0430,0.0000,0.1635,0.3124,0.4324,0.5106,0.5378,0.5106,0.4324,0.3124,0.1635,0.0000
0.0440,0.0000,0.1620,0.3095,0.4282,0.5055,0.5323,0.5055,0.4282,0.3095,0.1620,0.0000
0.0450,0.0000,0.1606,0.3066,0.4241,0.5004,0.5270,0.5004,0.4241,0.3066,0.1606,0.0000
0.0460,0.0000,0.1591,0.3038,0.4200,0.4955,0.5217,0.4955,0.4200,0.3038,0.1591,0.0000
0.0470,0.0000,0.1577,0.3009,0.4159,0.4905,0.5164,0.4905,0.4159,0.3009,0.1577,0.0000
0.0480,0.0000,0.1562,0.2981,0.4119,0.4857,0.5112,0.4857,0.4119,0.2981,0.1562,0.0000
0.0490,0.0000,0.1548,0.2953,0.4079,0.4808,0.5061,0.4808,0.4079,0.2953,0.1548,0.0000
0.0500,0.0000,0.1534,0.2925,0.4039,0.4761,0.5011,0.4761,0.4039,0.2925,0.1534,0.0000
0.0510,0.0000,0.1519,0.2897,0.4000,0.4714,0.4961,0.4714,0.4000,0.2897,0.1519,0.0000
```

Problem 5)  
Plot of steel



Plot for Copper



Michael Einreinhof

What time step values are the maximum you can use and still maintain stability for steel?

33.223s

What time step values are the maximum you can use and still maintain stability for copper?

4.4109s

Screen shot of opened file for steel

ProblemSteel.txt

```
0.0000,0.0000,100.0000,100.0000,100.0000,100.0000,100.0000,100.0000,100.0000,100.0000,0.0000,0.0000
0.0010,0.0000,99.9985,100.0000,100.0000,100.0000,100.0000,100.0000,100.0000,100.0000,99.9985,0.0000
100.0010,0.0000,43.9158,74.7629,90.7197,97.0141,98.5364,97.0141,90.7197,74.7629,43.9158,0.0000
200.0010,0.0000,31.7671,58.4013,77.0532,87.5174,90.8152,87.5174,77.0532,58.4013,31.7671,0.0000
300.0010,0.0000,25.8518,48.6107,65.9555,76.6356,80.2194,76.6356,65.9555,48.6107,25.8518,0.0000
400.0010,0.0000,21.8680,41.4339,56.7543,66.4579,69.7733,66.4579,56.7543,41.4339,21.8680,0.0000
500.0010,0.0000,18.7449,35.6084,48.9314,57.4468,60.3728,57.4468,48.9314,35.6084,18.7449,0.0000
600.0010,0.0000,16.1404,30.6873,42.2145,49.6043,52.1483,49.6043,42.2145,30.6873,16.1404,0.0000
700.0010,0.0000,13.9187,26.4711,36.4277,42.8171,45.0180,42.8171,36.4277,26.4711,13.9187,0.0000
800.0010,0.0000,12.0090,22.8414,31.4366,36.9541,38.8551,36.9541,31.4366,22.8414,12.0090,0.0000
900.0010,0.0000,10.3631,19.7114,27.1299,31.8926,33.5337,31.8926,27.1299,19.7114,10.3631,0.0000
1000.0010,0.0000,8.9433,17.0110,23.4135,27.5240,28.9404,27.5240,23.4135,17.0110,8.9433,0.0000
1100.0010,0.0000,7.7181,14.6807,20.2062,23.7537,24.9761,23.7537,20.2062,14.6807,7.7181,0.0000
1200.0010,0.0000,6.6608,12.6696,17.4383,20.4999,21.5548,20.4999,17.4383,12.6696,6.6608,0.0000
1250.8210,0.0000,6.1803,11.7557,16.1803,19.0211,20.0000,19.0211,16.1803,11.7557,6.1803,0.0000
```

Screen shot of opened file for copper

```

0.0000,0.0000,100.0000,100.0000,100.0000,100.0000,100.0000,100.0000,100.0000,100.0000,0.0000
0.0010,0.0000,99.9887,100.0000,100.0000,100.0000,100.0000,100.0000,100.0000,100.0000,99.9887,0.0000
20.0010,0.0000,36.3714,65.1975,83.4824,92.6358,95.2941,92.6358,83.4824,65.1975,36.3714,0.0000
40.0010,0.0000,25.7905,48.5033,65.8234,76.4949,80.0773,76.4949,65.8234,48.5033,25.7905,0.0000
60.0010,0.0000,20.1668,38.2749,52.5369,61.6240,64.7403,61.6240,52.5369,38.2749,20.1668,0.0000
80.0010,0.0000,16.0774,30.5680,42.0510,49.4128,51.9472,49.4128,42.0510,30.5680,16.0774,0.0000
100.0010,0.0000,12.8657,24.4700,33.6766,39.5859,41.6218,39.5859,33.6766,24.4700,12.8657,0.0000
120.0010,0.0000,10.3031,19.5973,26.9728,31.7079,33.3995,31.7079,26.9728,19.5973,10.3031,0.0000
140.0010,0.0000,8.2520,15.6962,21.6039,25.3969,26.7038,25.3969,21.6039,15.6962,8.2520,0.0000
160.0010,0.0000,6.6095,12.5719,17.3038,20.3418,21.3886,20.3418,17.3038,12.5719,6.6095,0.0000
166.0500,0.0000,6.1803,11.7557,16.1803,19.0211,20.0000,19.0211,16.1803,11.7557,6.1803,0.0000

```