University of Dhaka

Department of Computer Science and Engineering

CSE-3212: Numerical Methods Lab
3rd Year 2nd Semester

Session: 2017 -18

Name of the assignment: Bisection Method

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Submitted to:
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Problem Statement:

1) Given the following equation:

$$f(x) = e^x - 5x^2 = 0$$

a) Write a program which will find the value of **f(x)** where **x** is in the range **$-1.0 \leq x \leq 1.0$**. Increase the value of x by 0.1. Print the x and f(x) value in the console and also save the output in a **.csv file** and plot **f(x) vs x** graph from the .csv file.

b) In the same program, take two input **x_{lo}**, **x_{hi}** and **accuracy** where **$f(x_{lo})$** and **$f(x_{hi})$** have different sign. Use **Bisection Method** to find the root of the equation where relative approximate error is less than the accuracy.

2) Given the following equation:

$$\ln(osf) = -139.34411 + \frac{1.575701 \times 10^5}{T_a} - \frac{6.642308 \times 10^7}{T_a^2} + \frac{1.2438 \times 10^{10}}{T_a^3} - \frac{8.621949 \times 10^{11}}{T_a^4}$$

a) Write a program which will find the value of **$f(T_a)$** where **$T_a = t + 273.15$** and t is in the range **$0 \leq t \leq 40$**. Increase the value of t by 1. Print **t**, **T_a** and $f(T_a)$ value in the console and also save the output in a **.csv file** and plot **$f(T_a)$ vs t** graph from the .csv file.

b) In the same program, take two input **t_{lo}**, **t_{hi}** and **accuracy** where **$f(t_{lo} + 273.15)$** and **$f(t_{hi} + 273.15)$** have different sign. Use **Bisection Method** to find the root of the equation where relative approximate error is less than the accuracy. Use 8,10,12 as the value of osf.

Solution:

1) Given equation:

$$f(x) = e^x - 5x^2 = 0$$

Source code of solution:

```
#include<stdio.h>
#include<math.h>
#include<stdlib.h>
#include<string.h>
#include<limits.h>


double lo,hi,accuracy;
FILE *fp1,*fp2;

double func(double x)
{
   return (exp(x)-5.0*x*x);
}

double bisection_method(double lo,double hi)
{
   double prev,present,f,relative_approx_error;
   int cnt = 1;
   prev = (hi+lo)/2.0;
   f = func(prev);
   fprintf(fp2,"Iteration\tXl\tXu\tXr\tRelative Apporximate Error\n");
   fprintf(fp2,"%d\t%0.6lf\t%0.6lf\t%0.6lf\n",cnt,lo,hi,prev);
   cnt++;

   if(!f)  return prev;
   else if(f * func(hi) > 0)            hi = prev;
   else if(f * func(lo) > 0)           lo = prev;

   while(1)
   {
      present = (hi+lo)/2.0;
      f = func(present);

      relative_approx_error = fabs((present-prev)*100.00/present);
```

```
        fprintf(fp2,"%d\t%0.6lf\t%0.6lf\t%0.6lf\t%0.7lf\n",cnt,lo,hi,present,relative_approx_error);

        cnt++;

        if(!f)  return present;
        else if(f * func(hi) > 0)           hi = present;
        else if(f * func(lo) > 0)           lo = present;

        if(relative_approx_error<accuracy)  break;
        prev = present;
    }
    return present;

}
int main()
{
    fp1 = fopen("problem1_1.csv","w");
    fp2 = fopen("problem1_2.csv","w");

    printf("x\tF(x)\n");
    fprintf(fp1,"x\tF(x)\n");
    for(double i=-1.0;i<=1.0;i+=0.1)
    {

        printf("%0.2lf\t%0.6lf\n",i,func(i));
        fprintf(fp1,"%0.2lf\t%0.6lf\n",i,func(i));

    }
    scanf("%lf %lf %lf",&lo,&hi,&accuracy);
    double root = bisection_method(lo,hi);
    printf("Root of the equation: %lf\n",root);
    fclose(fp1);
    fclose(fp2);
}
```

2) Given equation:

$$\ln(osf) = -139.34411 + \frac{1.575701 \times 10^{5}}{T_a} - \frac{6.642308 \times 10^{7}}{T^2_a} + \frac{1.2438 \times 10^{10}}{T^3_a} - \frac{8.621949 \times 10^{11}}{T^4_a}$$

Source code of solution:

```
#include<stdio.h>
#include<math.h>
#include<stdlib.h>
#include<string.h>
#include<limits.h>
#define osf 12 //changed file name for different osf value

double lo,hi,accuracy;
FILE *fp1,*fp2;

double func(double x)
{
   return(-log(osf) - 139.34411 + (1.575701e5/x) - (6.642308e7/(x*x)) + (1.2438e10/(x*x*x)) -
((8.621949e11)/(x*x*x*x)));
}
double bisection_method(double lo,double hi)
{
   double prev,present,f,relative_approx_error;
   int cnt = 1;
   prev = (hi+lo)/2.0;
   f = func(prev);
   fprintf(fp2,"Iteration\tXl\tXu\tXr\tRelative Apporximate Error\n");
   fprintf(fp2,"%d\t%0.6lf\t%0.6lf\t%0.6lf\n",cnt,lo-273.15,hi-273.15,prev-273.15);
   cnt++;


   if(!f)  return prev;
   else if(f * func(hi) > 0)           hi = prev;
   else if(f * func(lo) > 0)           lo = prev;

   while(1)
   {
      present = (hi+lo)/2.0;
      f = func(present);

      relative_approx_error = fabs((present-prev)*100.00/present);
```

```
fprintf(fp2,"%d\t%0.6lf\t%0.6lf\t%0.6lf\t%0.7lf\n",cnt,lo-273.15,hi-273.15,present-273.15,relative_appr
ox_error);
        cnt++;

        if(!f)  return present;
        else if(f * func(hi) > 0)            hi = present;
        else if(f * func(lo) > 0)           lo = present;

        if(relative_approx_error<accuracy)  break;
        prev = present;
    }
    return present-273.15;

}
int main()
{
    fp1 = fopen("osf12_1.csv","w");
    fp2 = fopen("osf12_2.csv","w");

    fprintf(fp1,"t\tTa\tF(Ta)\n");
    for(int i=0;i<=40;i++)
    {
        double x = i+273.15;
        printf("%d\t%0.2lf\t%0.6lf\n",i,x,func(x));
        fprintf(fp1,"%d\t%0.2lf\t%0.6lf\n",i,x,func(x));
    }
    scanf("%lf %lf %lf",&lo,&hi,&accuracy);
    lo = lo + 273.15;
    hi = hi + +273.15;
    double root = bisection_method(lo,hi);
    printf("Root of the equation: %0.6lf\n",root);
    fclose(fp1);
    fclose(fp2);
}
```

Sample Input/Output:

1) Given equation:

$$f(x) = e^x - 5x^2 = 0$$

```
x        F(x)
-1.00    -4.632121
-0.90    -3.643430
-0.80    -2.750671
-0.70    -1.953415
-0.60    -1.251188
-0.50    -0.643469
-0.40    -0.129680
-0.30    0.290818
-0.20    0.618731
-0.10    0.854837
-0.00    1.000000
0.10     1.055171
0.20     1.021403
0.30     0.899859
0.40     0.691825
0.50     0.398721
0.60     0.022119
0.70     -0.436247
0.80     -0.974459
0.90     -1.590397
1.00     -2.281718
-1.0 0.60 0.000001
Root of the equation: -0.371418

Process returned 0 (0x0)   execution time : 21.568 s
Press ENTER to continue.
```

Snapshot of Console

2) Given equation:

$$\ln(osf) = -139.34411 + \frac{1.575701 \times 10^{5}}{T_a} - \frac{6.642308 \times 10^{7}}{T_a^{2}} + \frac{1.2438 \times 10^{10}}{T_a^{3}} - \frac{8.621949 \times 10^{11}}{T_a^{4}}$$

OSF = 8:

```
0       273.15  0.603006
1       274.15  0.574956
2       275.15  0.547411
3       276.15  0.520365
4       277.15  0.493809
5       278.15  0.467735
6       279.15  0.442136
7       280.15  0.417001
8       281.15  0.392323
9       282.15  0.368090
10      283.15  0.344294
11      284.15  0.320924
12      285.15  0.297970
13      286.15  0.275420
14      287.15  0.253266
15      288.15  0.231494
16      289.15  0.210096
17      290.15  0.189058
18      291.15  0.168371
19      292.15  0.148022
20      293.15  0.128000
21      294.15  0.108295
22      295.15  0.088893
23      296.15  0.069785
24      297.15  0.050958
25      298.15  0.032401
26      299.15  0.014103
27      300.15  -0.003948
28      301.15  -0.021763
29      302.15  -0.039353
30      303.15  -0.056730
31      304.15  -0.073904
32      305.15  -0.090887
33      306.15  -0.107690
34      307.15  -0.124323
35      308.15  -0.140798
36      309.15  -0.157124
37      310.15  -0.173313
38      311.15  -0.189375
39      312.15  -0.205320
40      313.15  -0.221158
0.0 40.0 0.000001
Root of the equation: 26.780164

Process returned 0 (0x0)   execution time : 11.123 s
```

Snapshot of Console

OSF = 10:

```
0       273.15  0.379862
1       274.15  0.351812
2       275.15  0.324268
3       276.15  0.297221
4       277.15  0.270665
5       278.15  0.244592
6       279.15  0.218992
7       280.15  0.193858
8       281.15  0.169179
9       282.15  0.144947
10      283.15  0.121150
11      284.15  0.097780
12      285.15  0.074826
13      286.15  0.052277
14      287.15  0.030122
15      288.15  0.008351
16      289.15  -0.013048
17      290.15  -0.034085
18      291.15  -0.054773
19      292.15  -0.075122
20      293.15  -0.095143
21      294.15  -0.114849
22      295.15  -0.134250
23      296.15  -0.153359
24      297.15  -0.172185
25      298.15  -0.190742
26      299.15  -0.209040
27      300.15  -0.227091
28      301.15  -0.244906
29      302.15  -0.262496
30      303.15  -0.279873
31      304.15  -0.297048
32      305.15  -0.314031
33      306.15  -0.330834
34      307.15  -0.347467
35      308.15  -0.363942
36      309.15  -0.380268
37      310.15  -0.396457
38      311.15  -0.412519
39      312.15  -0.428463
40      313.15  -0.444301
0.0 40.0 0.000001
Root of the equation: 15.388210

Process returned 0 (0x0)   execution time : 16.572 s
```

Snapshot of Console

OSF = 12:

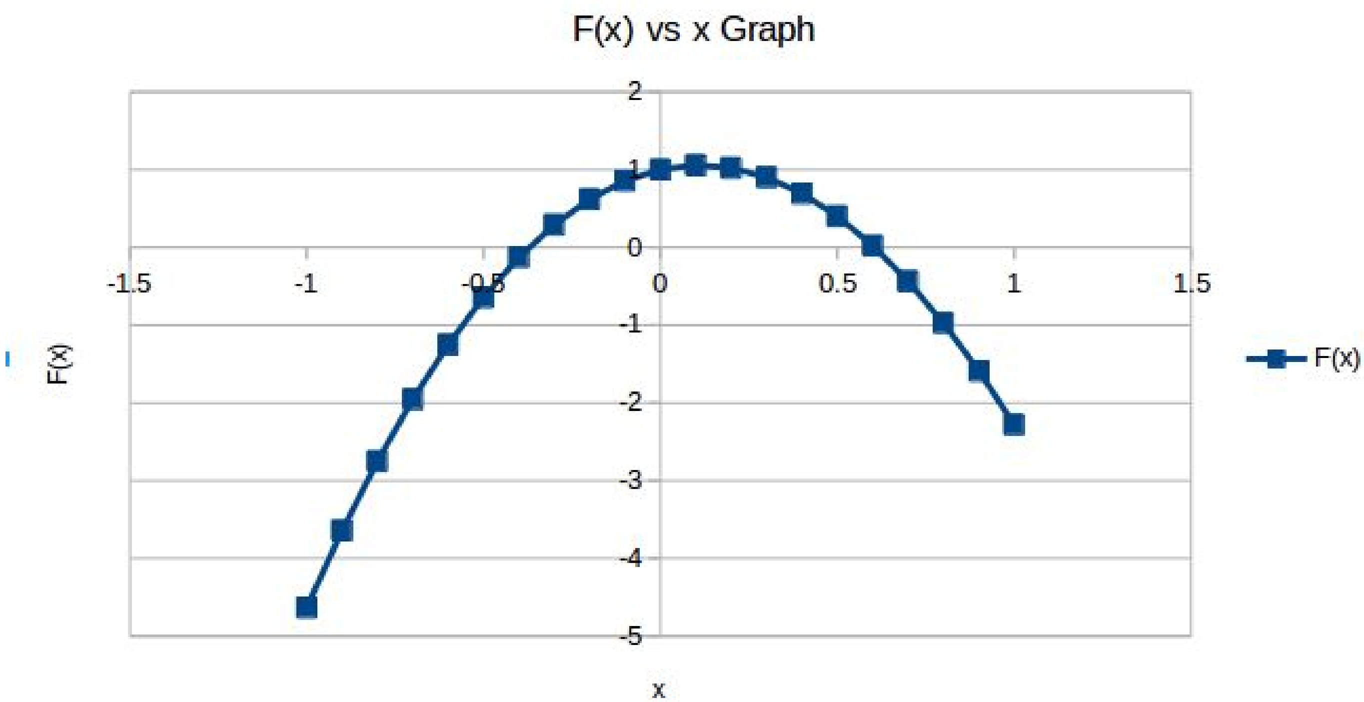
```
0       273.15  0.197541
1       274.15  0.169491
2       275.15  0.141946
3       276.15  0.114900
4       277.15  0.088344
5       278.15  0.062270
6       279.15  0.036671
7       280.15  0.011536
8       281.15  -0.013142
9       282.15  -0.037375
10      283.15  -0.061171
11      284.15  -0.084541
12      285.15  -0.107496
13      286.15  -0.130045
14      287.15  -0.152199
15      288.15  -0.173971
16      289.15  -0.195369
17      290.15  -0.216407
18      291.15  -0.237095
19      292.15  -0.257443
20      293.15  -0.277465
21      294.15  -0.297171
22      295.15  -0.316572
23      296.15  -0.335680
24      297.15  -0.354507
25      298.15  -0.373064
26      299.15  -0.391362
27      300.15  -0.409413
28      301.15  -0.427228
29      302.15  -0.444818
30      303.15  -0.462195
31      304.15  -0.479369
32      305.15  -0.496352
33      306.15  -0.513155
34      307.15  -0.529789
35      308.15  -0.546263
36      309.15  -0.562590
37      310.15  -0.578778
38      311.15  -0.594840
39      312.15  -0.610785
40      313.15  -0.626623
0.0 40.0 0.000001
Root of the equation: 7.465189

Process returned 0 (0x0)   execution time : 15.273 s
```

Snapshot of Console

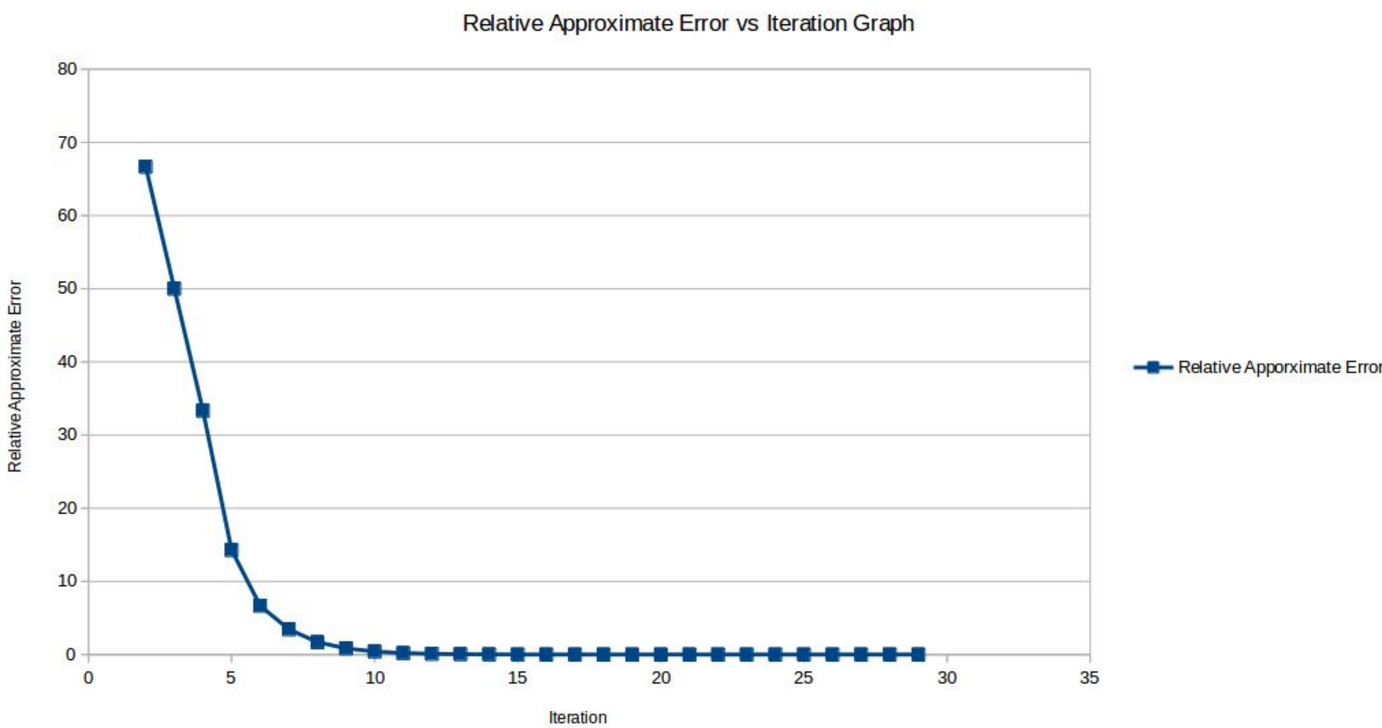
Graphs:

1) Given equation:

$$f(x) = e^x - 5x^2 = 0$$



F(x) vs x Graph

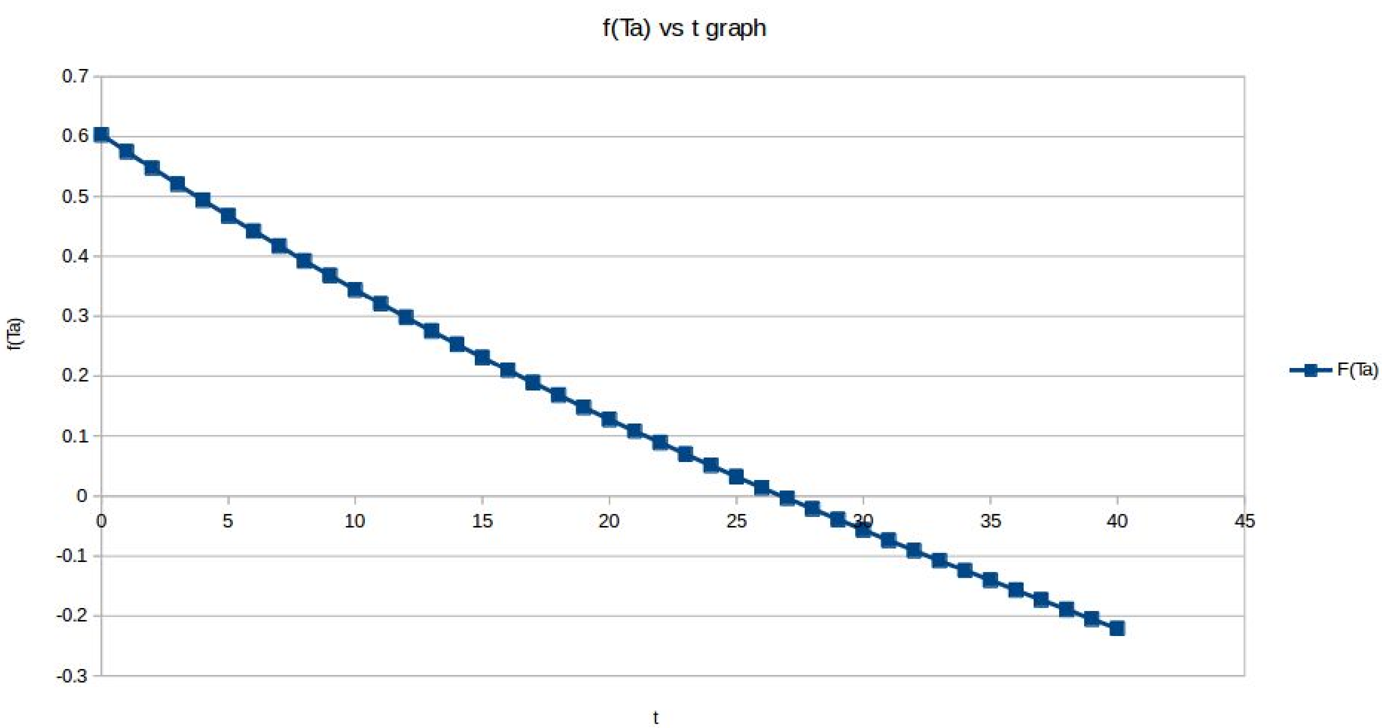


Relative Approximate Error vs Iteration Graph

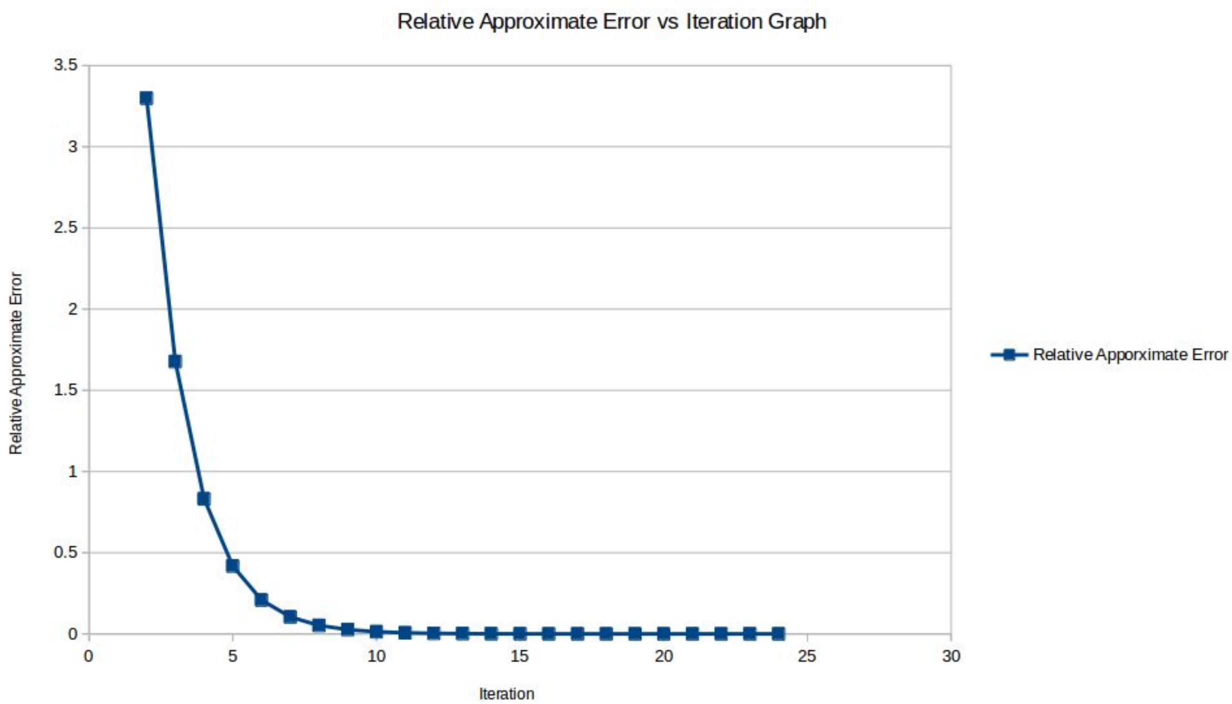
2) Given equation:

$$\ln(osf) = -139.34411 + \frac{1.575701 \times 10^5}{T_a} - \frac{6.642308 \times 10^7}{T_a^2} + \frac{1.2438 \times 10^{10}}{T_a^3} - \frac{8.621949 \times 10^{11}}{T_a^4}$$

OSF = 8:

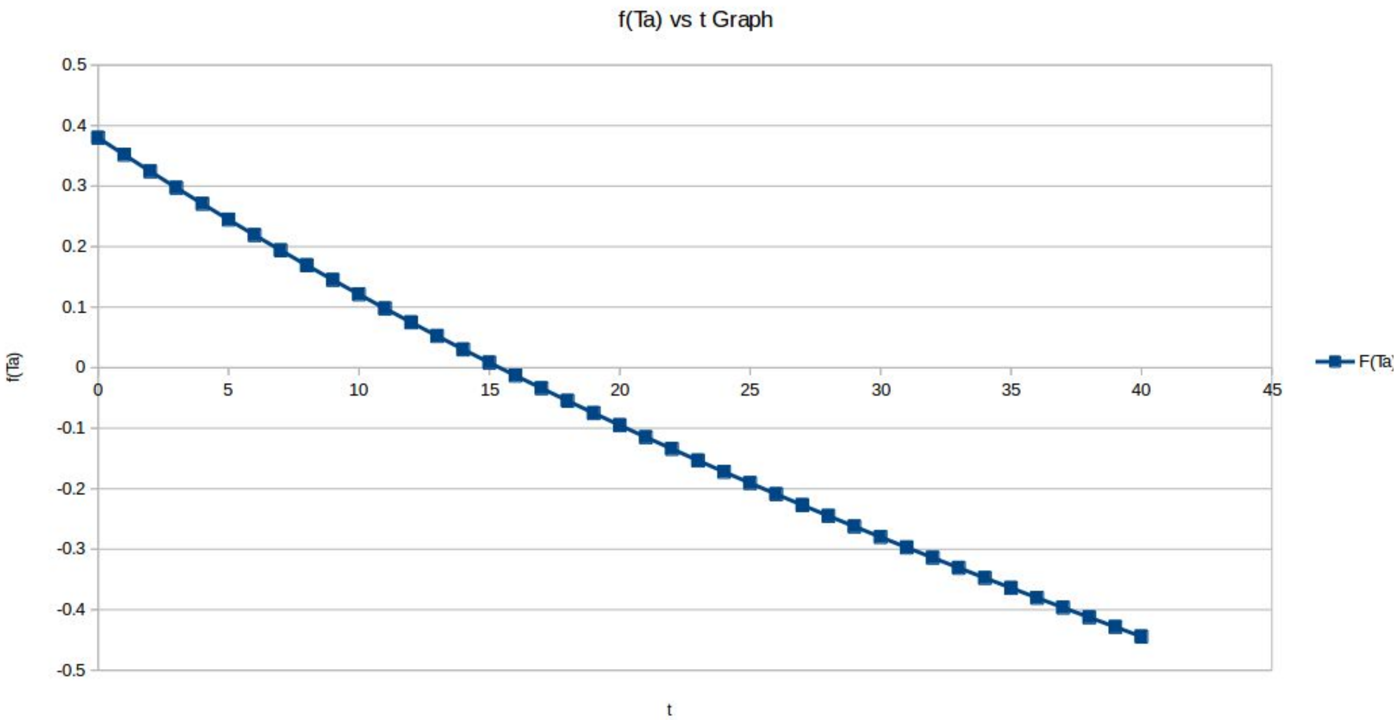


f(T_a) vs t Graph

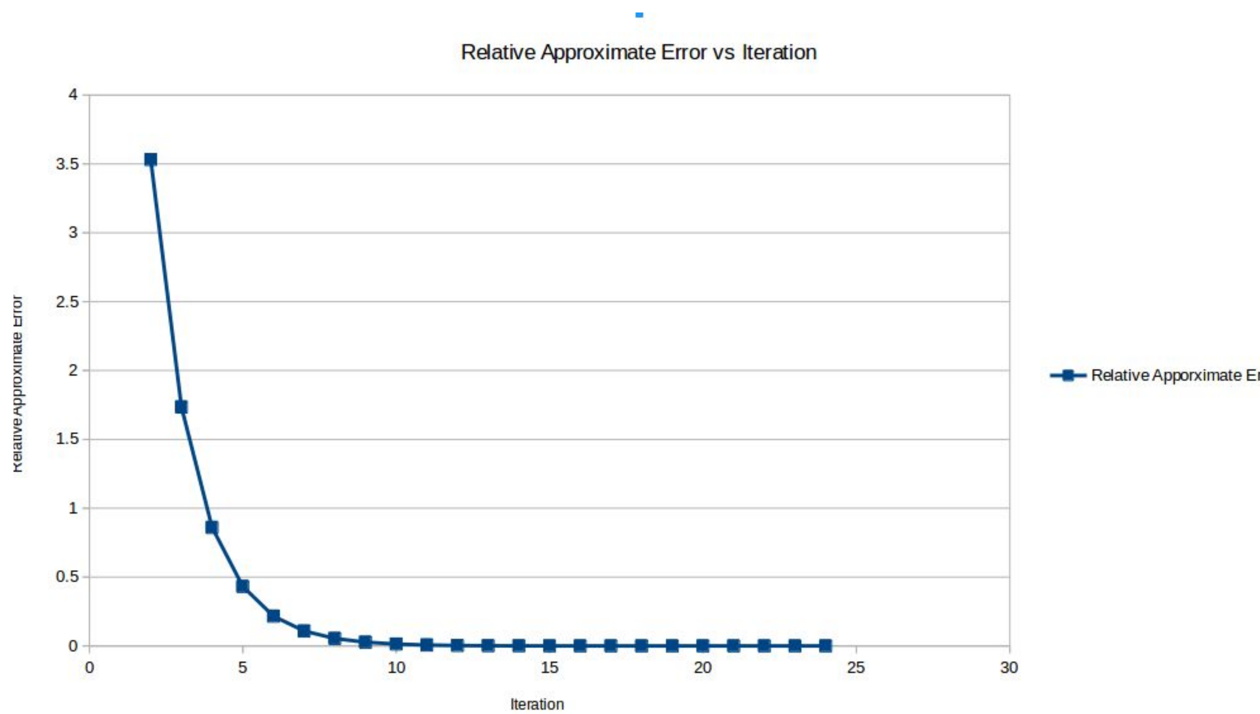


Relative Approximate Error vs Iteration Graph

OSF = 10:

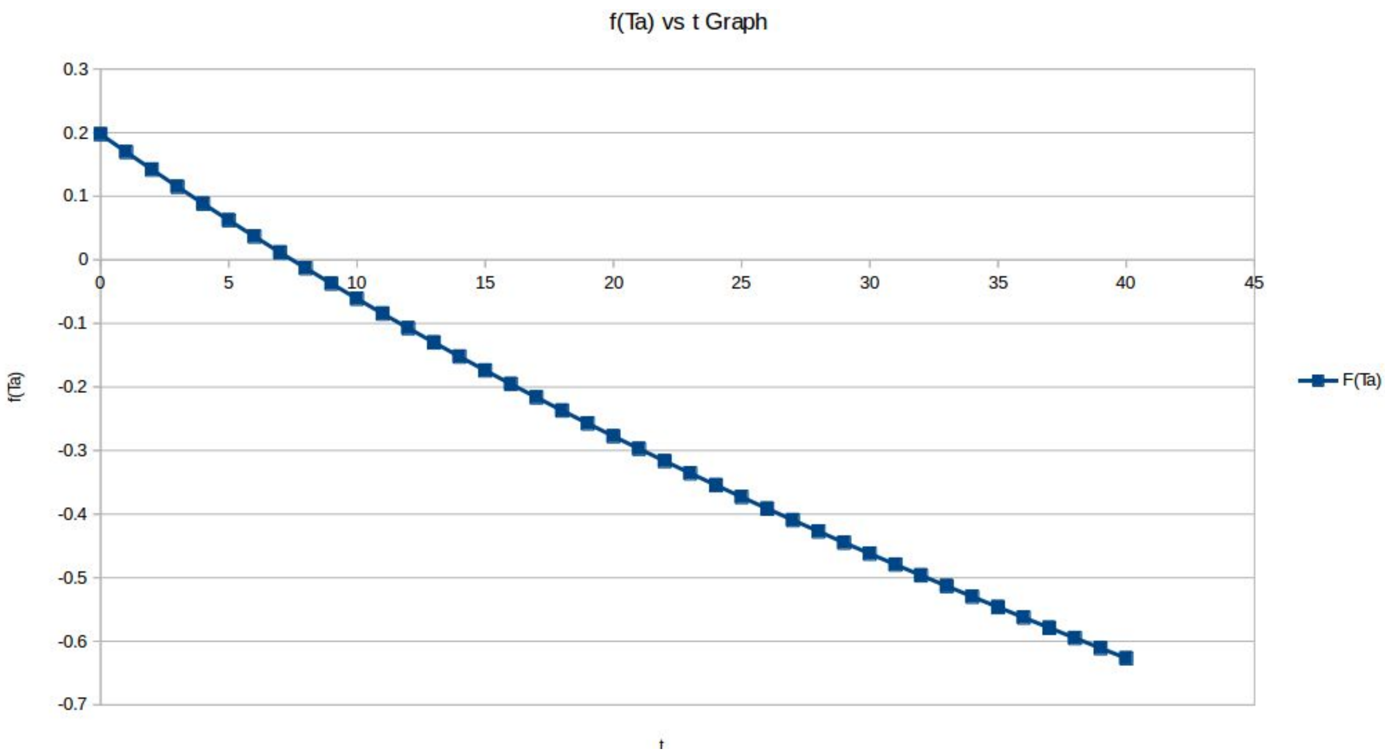


f(T_a) vs t Graph

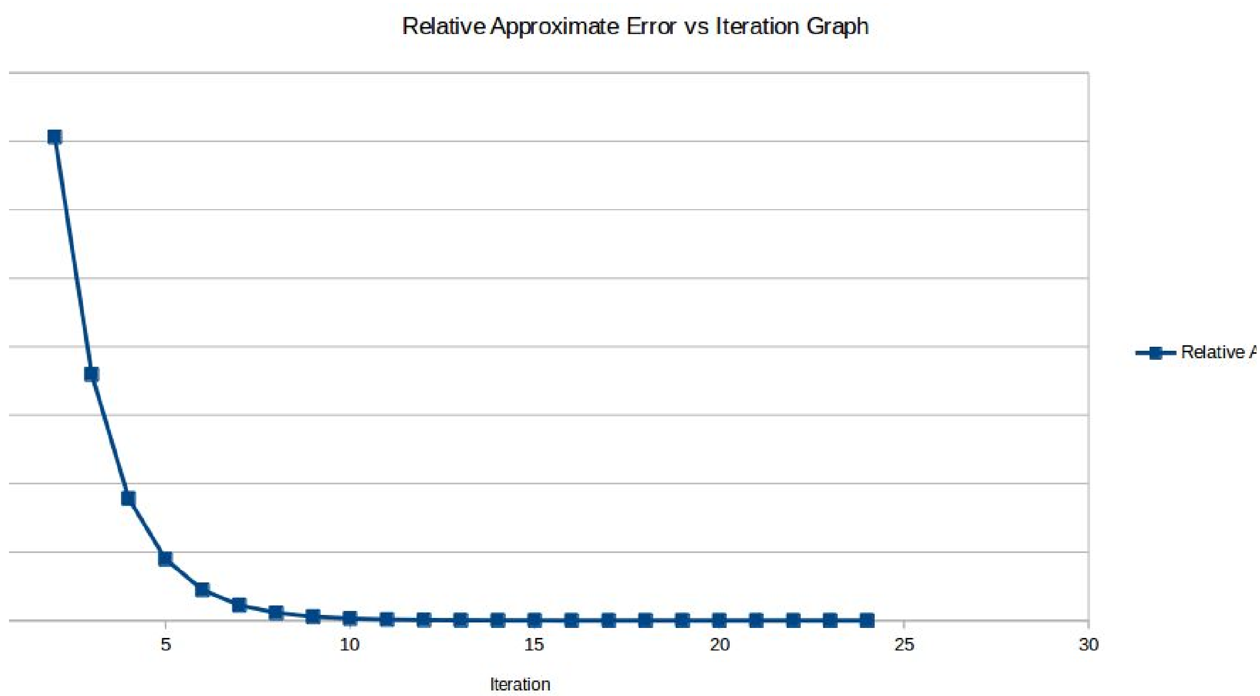


Relative Approximate Error vs Iteration Graph

OSF = 12:



$f(T_a)$ vs t Graph



Relative Approximate Error vs Iteration Graph