Hyperbolic Functions

Due Time: 23.59, Sun 25 Feb 2018 **Earnings:** 8% of your final grade

NOTE: Plan to finish a few days early to avoid last minute hardware/software holdups for which no allowance is given.
NOTE: The code in this assignment must be your own work. It must not be code taken from another student or written for you by someone else, even if you give a reference to the person you got it from (attribution); if it is not entirely your own work it will be treated as plagiarism and given a fail mark, or less.

Purpose: Investigate Maclaurin series approximations to the hyperbolic functions sinh(x) and cosh(x).
Algorithm
Write a program named *ass1* that will enable the user to generate Maclaurin series approximations to the hyperbolic functions sinh(x) and cosh(x). Hyperbolic functions are important in engineering and Nature in general. The cosh function is called the ***catenary*** and is the shape a simple necklace hangs in around your neck or the shape of a simple suspension bridge or the strands of a spider's web:


A hanging chain forms a catenary.


Freely-hanging transmission lines also form catenaries.


The silk on a spider's web forming multiple (approximate) catenaries.

The cosh functions are combinations of the exponentials (cosh is even and sinh is odd):

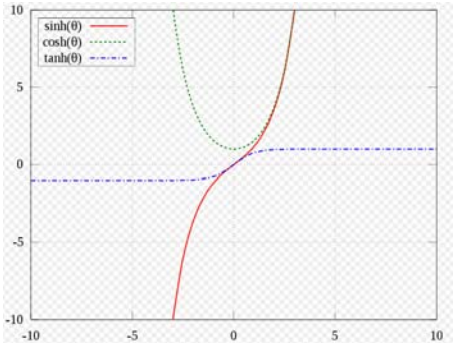
The hyperbolic functions are:

- Hyperbolic sine:

$$\sinh x = \tfrac{1}{2}\left(e^{x} - e^{-x}\right)$$

- Hyperbolic cosine:

$$\cosh x = \tfrac{1}{2}\left(e^{x} + e^{-x}\right)$$



In this assignment the functions are approximated by finite Maclaurin series in order to speed up their execution but lower their accuracy and the resulting errors are calculated in two ways: from comparison with the math library function (taken as exact) and also from the first truncated term as explained below. This gives you an idea of how well the first truncated term approximates to the error. The details are given below.

Algorithm: While the user wishes to continue, the value of the highest power of x in the series is selected. Then the user can select a range of x, somewhere between -10.0 and +10.0 over which the series is evaluated from 0 in ten equal increments. For each value of x the Maclaurin series approximation is output

together with the exact value from the math library. Also output the relative error in two ways:

1. % Relative Exact Error (%RExactE) by comparison with the exact value from the math library defined by:
   % Relative Exact Error (%RExactE) =100*(exact value – series value)/exact value

2. % Relative Series Error (%RSerE) from the first truncated term defined by:

   % Relative Series Error (%RSerE) =100*first truncated term/series value.

Set up a Win32 console project in MS Visual Studio 2015 with the name ass1. Write the code to implement the application, as described above, in a file named ass1.cpp using the C (or/C++) programming language. Example output is given at the end. Yours should be very similar, but may differ slightly due to roundoff errors from the way you have evaluated you series. Note than your assignment might be tested with different upper and lower limits than shown. See the Marking Sheet for how you can lose marks (you definitely lose 60% if the series is wrong).

What to Submit : Use Blackboard to submit this assignment as a zip file (**not** RAR, not 9zip, not 7 zip) containing only the single source code file (ass1.cpp). The name of the zipped folder **must** contain your name as a prefix so that I can identify it, for example using my name the file would be tyleraAss1CST8233.zip. It is also vital that you include the Cover Information (as specified in the Submission Standard) as a file header in your source file so the file can be identified as yours. Use comment lines in the file to include the header.

Before you submit the code

- check that it builds and executes in Visual Studio 2015 as you expect - if it doesn't build for me, for whatever reason, you get a deduction of at least 60%.
- **make sure you have submitted the correct file – if I cannot build it because the file is wrong or missing from the zip, even if it's an honest mistake, you get 0 – no compromises.**

There is a late penalty of 25% per day. Don't send me the file as an email attachment – it will get 0.

Example Output

```
*********************************
        Maclaurin Series
Select the function to evaluate
1 = sinh(x)
2 = cosh(x)
3 - quit
*********************************
1

Evaluating sinh series

Please enter the highest power of x in the sinh series (1, 3, 5, 7, or 9): 9
order = 9

Please enter the value of x at which to evaluate to in 10 increments from 0 (-10.0 through 10.0):
10

SINH MACLAURIN SERIES TO x^9 from x = 0 to x = 10.000000
  x          Series         Exact        Exact % Error     Trunc. % Error
0.000e+00   0.00000e+00   0.00000e+00     0.00000e+00       0.00000e+00
1.000e+00   1.17520e+00   1.17520e+00     2.14546e-06       2.13173e-06
2.000e+00   3.62681e+00   3.62686e+00     1.45161e-03       1.41465e-03
3.000e+00   1.00132e+01   1.00179e+01     4.69689e-02       4.43207e-02
4.000e+00   2.71732e+01   2.72899e+01     4.27722e-01       3.86691e-01
5.000e+00   7.27583e+01   7.42032e+01     1.94726e+00       1.68125e+00
6.000e+00   1.90114e+02   2.01713e+02     5.75018e+00       4.78072e+00
7.000e+00   4.78830e+02   5.48316e+02     1.26726e+01       1.03453e+01
8.000e+00   1.15237e+03   1.49048e+03     2.26846e+01       1.86742e+01
9.000e+00   2.63920e+03   4.05154e+03     3.48593e+01       2.97878e+01
```

```
1.000e+01   5.74986e+03   1.10132e+04     4.77914e+01       4.35700e+01

*********************************
        Maclaurin Series
Select the function to evaluate
1 = sinh(x)
2 = cosh(x)
3 - quit
*********************************
2

Evaluating cosh series

Please enter the highest power of x in the cosh series (0, 2, 4, 6, 8, or 10): 10

Please enter the value of x at which to evaluate to in 10 increments from 0 (-10.0 through 10.0):
-10

COSH MACLAURIN SERIES TO x^10 from x = 0 to x = -10.000000
  x          Series         Exact         Exact % Error    Trunc. % Error
-0.000e+00   1.00000e+00   1.00000e+00      0.00000e+00      0.00000e+00
-1.000e+00   1.54308e+00   1.54308e+00      1.36039e-07      1.35293e-07
-2.000e+00   3.76219e+00   3.76220e+00      2.32370e-04      2.27291e-04
-3.000e+00   1.00665e+01   1.00677e+01      1.15862e-02      1.10215e-02
-4.000e+00   2.72699e+01   2.73082e+01      1.40328e-01      1.28440e-01
-5.000e+00   7.36223e+01   7.42099e+01      7.91846e-01      6.92299e-01
-6.000e+00   1.96120e+02   2.01716e+02      2.77402e+00      2.31716e+00
-7.000e+00   5.09762e+02   5.48317e+02      7.03154e+00      5.66855e+00
-8.000e+00   1.27975e+03   1.49048e+03      1.41382e+01      1.12103e+01
-9.000e+00   3.08148e+03   4.05154e+03      2.39431e+01      1.91344e+01
-1.000e+01   7.09245e+03   1.10132e+04      3.56007e+01      2.94352e+01

*********************************
        Maclaurin Series
Select the function to evaluate
1 = sinh(x)
2 = cosh(x)
3 - quit
*********************************
1

Evaluating sinh series

Please enter the highest power of x in the sinh series (1, 3, 5, 7, or 9): 6

Please enter the highest power of x in the sinh series (1, 3, 5, 7, or 9): 5
order = 5

Please enter the value of x at which to evaluate to in 10 increments from 0 (-10.0 through 10.0):
20

Please enter the value of x at which to evaluate to in 10 increments from 0 (-10.0 through 10.0):
1.0

SINH MACLAURIN SERIES TO x^5 from x = 0 to x = 1.000000
  x          Series         Exact        Exact % Error     Trunc. % Error
0.000e+00   0.00000e+00   0.00000e+00     0.00000e+00       0.00000e+00
1.000e-01   1.00167e-01   1.00167e-01     1.98110e-08       1.98082e-08
2.000e-01   2.01336e-01   2.01336e-01     1.26212e-06       1.26142e-06
3.000e-01   3.04520e-01   3.04520e-01     1.42674e-05       1.42496e-05
4.000e-01   4.10752e-01   4.10752e-01     7.93186e-05       7.91425e-05
5.000e-01   5.21094e-01   5.21095e-01     2.98505e-04       2.97470e-04
6.000e-01   6.36648e-01   6.36654e-01     8.76795e-04       8.72426e-04
7.000e-01   7.58567e-01   7.58584e-01     2.16876e-03       2.15408e-03
8.000e-01   8.88064e-01   8.88106e-01     4.72716e-03       4.68549e-03
9.000e-01   1.02642e+00   1.02652e+00     9.34965e-03       9.24574e-03
1.000e+00   1.17500e+00   1.17520e+00     1.71199e-02       1.68862e-02

*********************************
        Maclaurin Series
Select the function to evaluate
1 = sinh(x)
2 = cosh(x)
3 - quit
*********************************
```

```
2

Evaluating cosh series

Please enter the highest power of x in the cosh series (0, 2, 4, 6, 8, or 10): 3

Please enter the highest power of x in the cosh series (0, 2, 4, 6, 8, or 10): 4

Please enter the value of x at which to evaluate to in 10 increments from 0 (-10.0 through 10.0):
0.5

COSH MACLAURIN SERIES TO x^4 from x = 0 to x = 0.500000
  x          Series         Exact         Exact % Error    Trunc. % Error
0.000e+00   1.00000e+00   1.00000e+00      0.00000e+00      0.00000e+00
5.000e-02   1.00125e+00   1.00125e+00      2.16753e-09      2.16742e-09
1.000e-01   1.00500e+00   1.00500e+00      1.38222e-07      1.38197e-07
1.500e-01   1.01127e+00   1.01127e+00      1.56503e-06      1.56440e-06
2.000e-01   1.02007e+00   1.02007e+00      8.72025e-06      8.71403e-06
2.500e-01   1.03141e+00   1.03141e+00      3.29124e-05      3.28757e-05
3.000e-01   1.04534e+00   1.04534e+00      9.70144e-05      9.68587e-05
3.500e-01   1.06188e+00   1.06188e+00      2.40964e-04      2.40438e-04
4.000e-01   1.08107e+00   1.08107e+00      5.27733e-04      5.26229e-04
4.500e-01   1.10296e+00   1.10297e+00      1.04942e-03      1.04564e-03
5.000e-01   1.12760e+00   1.12763e+00      1.93314e-03      1.92456e-03

*********************************
        Maclaurin Series
Select the function to evaluate
1 = sinh(x)
2 = cosh(x)
3 - quit
*********************************
```