C PROGRAMMING: ANOTHER WEIRD SUM!

We are going now to compute this sum:

\[ x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \cdots + \frac{x^N}{N!} \]

It looks like the exponential that we just did, except with only the odd powers and also with some minus signs sprinkled in.

/* this is a program to do a second weird sum*/
#include <stdio.h>
#include <math.h>
int main(void)
{
    double prod=1, sum=0, x;
    int j, N;
    printf("Enter N and x");
    printf("\n");
    scanf("%i %.1lf", &N, &x);
    for (j=1; j<N; j=j+2)
    {
        sum=sum+pow(-1,j/2)*pow(x,j)/prod;
        printf("\n   %i", j);
        printf(" ");
        printf("%20.10lf", sum);
        prod=prod*(j+1);
        prod=prod*(j+2);
    }
    printf("\n");
    return 0;
}
Comments:

[1] It is important to understand integer arithmetic in looking at this program. When you do arithmetic with integers, C throws away whatever would occur after the decimal point. Thus $1/2 = 0$, $3/2 = 1$, $4/3 = 1$, $9/4 = 2$, etc. Why is this important to the operation of the program?

[2] This code is sort of tricky in other ways too! Step through the loop “manually” to make sure it is doing the right thing. This is a very useful way to write and verify codes!

[3] Run your program with $N = 10$ and $x = 1$. Do you recognize the number you are getting? Probably not! Use a calculator to compute $\sin(1 \text{ radian})$. What do you notice? Run your program with $N = 10$ and $x = 0.5$ and compare with $\sin(0.5 \text{ radian})$. Run your program with $N = 10$ and $x = 0.8$ and compare with $\sin(0.8 \text{ radian})$.

[4] So here’s the amazing fact: If $N$ is large enough,

$$\sin(x) = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \cdots$$

Just as with the exponential we see that a trigonometric function can be written as a polynomial of very high (infinite) order.

[5] Write a program to do this sum:

$$1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \frac{x^8}{8!} + \cdots$$

and verify you get $\cos(x)$.

[6] If you are really into complex numbers, use these equations you learned for $e^x$, $\sin(x)$, $\cos(x)$ to prove de Moivre’s theorem:

$$e^{ix} = \cos(x) + i \sin(x)$$

This equation tells you that $e^{i\pi} = -1$! Who knew that $e$ and $\pi$ had anything to do with each other!