

## Homework 4

Due April 15, 19:00

### Problem 4.1

Recall **The gamma function** from previous homework:

$$\Gamma(x) = \int_0^{\infty} t^{x-1} e^{-t} dt.$$

Write a program to compute the value of this function from the definition using each of the following approaches:

- Truncate the infinite interval of integration and use a composite Simpson's rule. You will need to do some experimentation or analysis to determine where to truncate the interval, based on the usual trade-off between efficiency and accuracy.
- Truncate the interval and use a built-in adaptive quadrature routine of your choice available in MATLAB/GNU Octave or Python. Again, explore the trade-off between accuracy and efficiency.
- For each method, compute the approximate value of the integral for several values of  $x$  in the interval  $[1, 10]$ . Compare your results with the values given by the built-in function `gamma`. How do the various methods compare in efficiency for a given level of accuracy?

### Problem 4.2

It can be easily verified that

$$\pi = \int_0^1 \frac{4}{1+x^2} dx.$$

Thus, an approximate value for  $\pi$  can be computed by using numerical integration of the above integral.

- Write your own implementation of midpoint, trapezoidal, and Simpson's composite rules to compute the approximation of  $\pi$  for various values of stepsize  $h$ . What is the order of the error as a function of  $h$  for each rule? Compare the accuracy of the rules with each other (based on the known value of  $\pi$ ). Is there any point beyond which decreasing  $h$  yields no further improvement, and if yes, why?
- Compute approximation of  $\pi$  again by using any adaptive quadrature routine available in MATLAB/GNU Octave or Python and try various error tolerances.
- Compare the computational work required (elapsed time) for parts a) and b). To measure elapsed time you might use MATLAB/GNU Octave commands `tic` and `toc`.

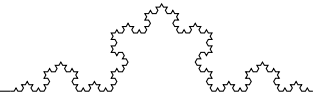
### Problem 4.3

The intensity of diffracted light near a straight edge is determined by the values of Fresnel integrals

$$C(x) = \int_0^x \cos\left(\frac{\pi t^2}{2}\right) dt,$$
$$S(x) = \int_0^x \sin\left(\frac{\pi t^2}{2}\right) dt,$$

Evaluate these integrals for enough values of  $x$  to draw a smooth plot of functions  $C(x)$  and  $S(x)$  over the interval  $[0, 5]$  by:

- Using composite Simpson's rule.
- Using an adaptive quadrature routine of your choice available in MATLAB/GNU Octave or Python.
- Compare your results by computing Fresnel integrals using built-in functions `fresnelc` and `fresnels` in MATLAB/GNU Octave or `scipy.special.fresnel` in Python.

**Problem 4.4**

Apply Simpson's rule (with  $n = 4, 8, 16, 32, 64$ ) and Gaussian quadrature (with  $n = 4, 8, 16, 32, 64$ ) to compute the integral

$$\int_1^4 \frac{1}{(x-1)^{5/2}} dx.$$

Use your own written code. To generate Gaussian nodes and weights you may use built-in functions. Explain your results. Make conclusions!