MN61111 Theory of Turbulence

Term Project #1

Due: April 29, 2022.

Turbulent flow field data

- The velocity data (file name: “INS_Vel_xxxxxx.dat”) are obtained from direct numerical simulation of fully developed turbulent channel flow. The data file includes the streamwise variations of the streamwise and wall-normal instantaneous velocity (U and V), measured at given wall-normal (y) and spanwise (z) positions. Use any programming language that you are familiar with, obtain the following quantities and plot the graph.
- Here, x, y, and z denote the streamwise, wall-normal, and spanwise directions, respectively, and the corresponding velocity is U, V, and W.
- You can find a total of 40 files which are measured at 40 different times.
- Each file includes the following information

First row: streamwise position x

Second row: streamwise velocity U

Third row: wall-normal velocity V

1. Plot the signals of U and V with respect to x.
2. Plot the probability density function (PDF) of U and V. Show that the PDF satisfies the equation (3.16) in the textbook.
3. Show that U and V are statistically homogeneous in the x direction.
4. Compute the ensemble averages of U and V.
5. Plot the scatter plot of U and V.
6. Plot the joint probability density function (JPDF) of u and v, where u and v are velocity fluctuations in the streamwise and wall-normal directions, respectively. Show that the JPDF satisfies the equation (3.89) and (3.90) in the textbook
7. Compute the variance of U and V and the covariance of U and V.
8. Plot the autocorrelation functions $f(r/h)$ and $g(r/h)$ and compute the corresponding integral length scales.

$$f(r) = \frac{R_{11}}{\langle u^2 \rangle} = \frac{\langle u(x+r)u(x) \rangle}{\langle u^2 \rangle}$$

$$g(r) = \frac{R_{22}}{\langle v^2 \rangle} = \frac{\langle v(x+r)v(x) \rangle}{\langle v^2 \rangle}$$