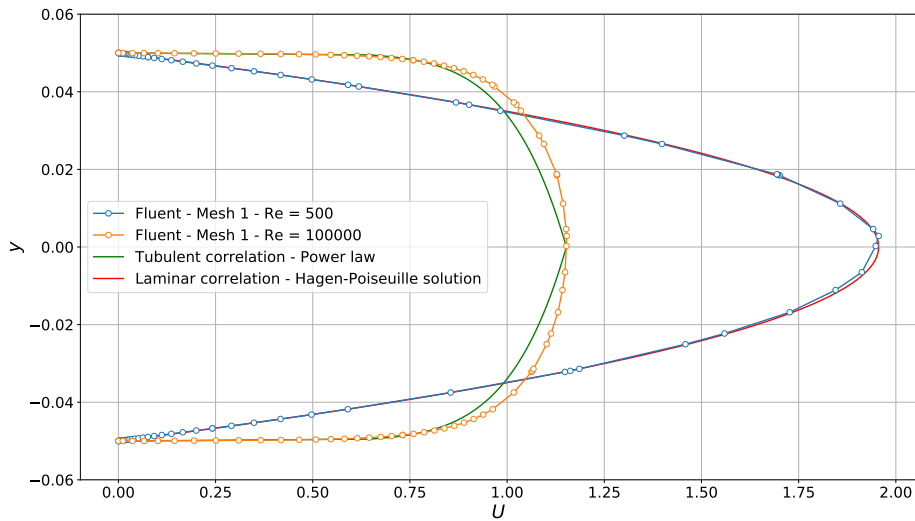


# Homework 1

## Turbulence and CFD models: Theory and applications Hands-on session 1 and 2

### Task 1

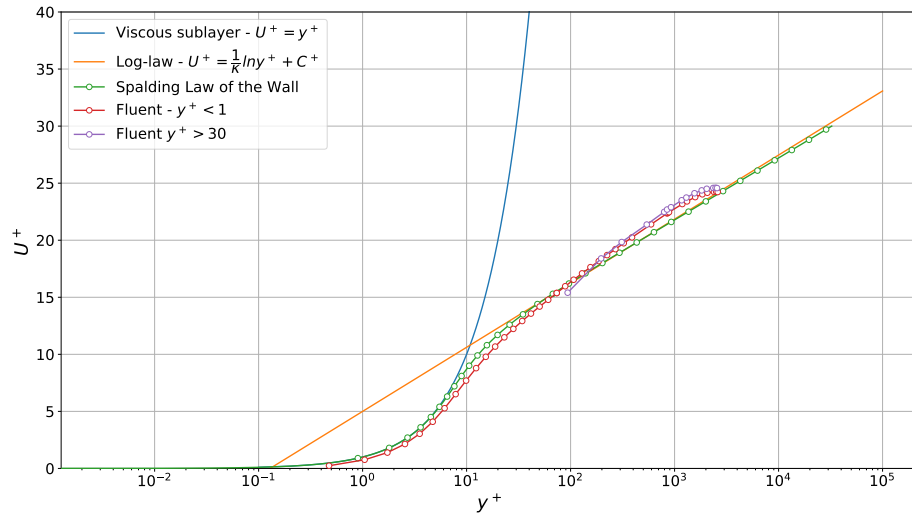
Based on the cases used in tutorials 1 and 2, you are asked to reproduce the plots shown in figures 1 and 2.



**Figure 1:** Laminar and turbulent physical velocity profiles. The units of normal distance  $y$  are meters. The units of the velocity  $U$  are  $m/s$ .

Using a Reynolds number different from 100 000 and 500, you must plot the following information,

- Physical velocity profile of a laminar case.
- Comparison of the physical velocity profile of the laminar case against the Hagen-Poiseuille solution.
- Physical velocity profile of a turbulent case.



**Figure 2:** Non-dimensional turbulent velocity profile  $y^+$  vs.  $U^+$ .

- Comparison of the physical velocity turbulent profile against the power-law profile. Remember, the coefficient of the power-law equation must be calibrated according to the Reynolds number.
- Plot the non-dimensional turbulent velocity profile  $y^+$  vs.  $U^+$ , and compare it against the analytical correlations (viscous sublayer, log-law layer, and Spalding law). You must plot two numerical profiles, one corresponding to a wall resolving solution and the other one corresponding to a wall modeling solution (as shown in figure 2).

You must also write a small overview of your case setup, that is, turbulence model used, mesh used, boundary conditions, discretization schemes, solution method, average and maximum  $y^+$ , and so on. You can also add a few images showing the contours of velocity, pressure, turbulent kinetic energy, eddy viscosity, and so on.

You do not need to reproduce the results of both tutorials. Pick only one case, 2D or 3D, and reproduce the results.

## Task 2 (optional)

If you want to go for the extra mile, you can try to complete the following tasks,

- Compare the non-dimensional profiles for different turbulence models.
- Compare the outcome of the COUPLED method against the outcome of the SIMPLE method. Is the computing time the same? Is the accuracy the same? Which method has the lowest cost per iteration?
- Where do the laminar sublayer profile intersects the log-law profile? Use the same coefficients as the ones used in the lecture notes.
- Compute the pressure drop along the axis of the pipe and compare it against the analytical correlation.
- Determine at what distance along the pipe's axis the flow becomes fully developed in the numerical solution and compare this value with the analytical correlation for entrance length.
- Run at different Reynolds number values in the turbulent regime and compare the extension of the log-law region in each case. Is the extension of the region the same in each case?
- Compute the integral length scales and give a physical interpretation to the output.
- Compute the integral length scales using a fine mesh and a coarse mesh and compare the solution. Are the integral length scales the same? Any comments?

## General guidelines

- For plotting, you can use Matlab, Python, GNUPLOT, or EXCEL.
- Please, do not overdo. You can write this report in no more than 6 pages (figures and tables included).
- It will be highly appreciated if you write your homework using L<sup>A</sup>T<sub>E</sub>X (this is not compulsory). You can use overleaf, which is a free online L<sup>A</sup>T<sub>E</sub>X editor.

- <https://www.overleaf.com/>
- You can get a quick start on using  $\text{\LaTeX}$  at this link:
  - [https://www.overleaf.com/learn/latex/Learn\\_LaTeX\\_in\\_30\\_minute](https://www.overleaf.com/learn/latex/Learn_LaTeX_in_30_minute)
- You can also deliver your homework in a Python notebook (this is not compulsory). At the following links, you can find a few examples of Python notebooks reports,
  - [https://nbviewer.jupyter.org/github/joelguerrero/first-tutorial/blob/master/c1/laminar\\_pipe\\_notebook.ipynb](https://nbviewer.jupyter.org/github/joelguerrero/first-tutorial/blob/master/c1/laminar_pipe_notebook.ipynb)
  - [https://nbviewer.jupyter.org/github/joelguerrero/data\\_science/blob/master/sport\\_analytics1/sport\\_analytics\\_1.ipynb](https://nbviewer.jupyter.org/github/joelguerrero/data_science/blob/master/sport_analytics1/sport_analytics_1.ipynb)
  - [https://github.com/barbagroup/teaching-materials/blob/master/IPython/clap\\_and\\_fling.ipynb](https://github.com/barbagroup/teaching-materials/blob/master/IPython/clap_and_fling.ipynb)
  - [https://github.com/barbagroup/AeroPython/blob/master/lessons/02\\_Lesson02\\_sourceSinkFreestream.ipynb](https://github.com/barbagroup/AeroPython/blob/master/lessons/02_Lesson02_sourceSinkFreestream.ipynb)
- You can write your report in English or Italian.
- Try to be technical when written the overview of your case setup. This is very important when writing technical reports.
- I strongly recommend to run 2D cases as they are very fast, so you will be able to explore many case setups.
- Do not hesitate to contact me if you have any questions.

## Deadline

The deadline to submit your homework is 24MAY2023. You must submit your homework via the Teams channel.