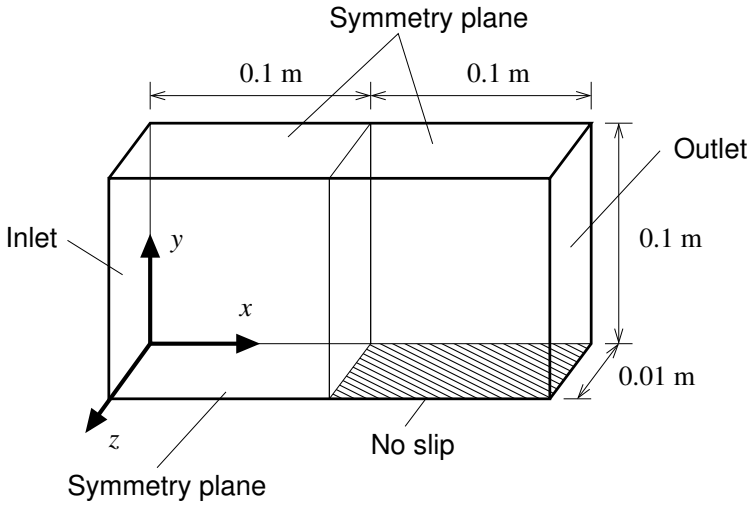
Homework Assignment 4

OpenFOAM Exercise, Macroscopic balances

1. (20 marks) Compute the flow past a plate in a finite system at different Reynolds numbers using `OpenFOAM`. A schematic view of the geometry is given below.



   The velocity at the inlet is $U = 1$ m/s and the pressure at the outlet may be taken to be $P = 0$. Start with the files of the `blt` case uploaded on moodle for the flow defined above.

   (a) Execute `blockMesh` to generate the mesh and view using `paraFoam`. Set `deltaT` to be 0.005 and `endTime` to be 0.5 and execute `icoFoam`. View results using `paraFoam`.

   (b) Once the above base case is established, generate results for lower values of ν ($\nu = 10^{-3}$ and 10^{-4}). You will need to use a finer mesh and grading to get accurate results (profile should become independent of further refinement of mesh). Lower mesh sizes will require lower `deltaT` for stability (Courant number less than 1) and lower ν will require higher `endTime` to reach a steady state.

   (c) Make graphs of v_x versus y for different positions x. Check for self-similarity by plotting v_x versus $\eta = y/(\nu x/U)^{1/2}$.

2. (10 marks) Water is flowing in a U-shaped pipe bend at 0.5 l/s under turbulent conditions (see below). The pipe inner diameter is 10 cm and the inlet and outlet pressures are 0.13 Mpa and 0.15 MPa, respectively. Find the horizontal force on the pipe and viscous dissipation in the system, neglecting gravity.

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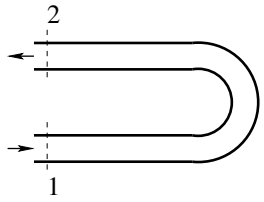

3. (10 marks) Velocity varies with radius in pipe flow as follows:

$$\text{laminar flow:} \quad v_z = 2\langle v\rangle\left[1-(r/R)^2\right]$$

$$\text{turbulent flow:} \quad v_z = 1.22\langle v\rangle\left[1-(r/R)\right]^{1/7}$$

Calculate $\langle v^2\rangle / \langle v\rangle^2$ and $\langle v^3\rangle / \langle v\rangle^3$ for the two cases.

4. (10 marks) A plane jet impinges on a flat plate and splits into two streams as shown below. Determine the force on the plate and the split in the flow. The jet approaches the plate with a flow rate Q_0 and thickness h_0; the width of the plane jet is W. Neglect viscous dissipation in the system.