

Laminar Pipe Flow - Exercises

Author: Rajesh Bhaskaran, Cornell University

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Exercises

Exercise 1: Vertical Channel Flow

[Problem Specification](#) (pdf file)

Exercise 2: Laminar Flow within Two Rotating Concentric Cylinders

Contributed by Prof. John Cimbala and Matthew Erdman, The Pennsylvania State University

[Problem Specification](#) (pdf file)

The video below shows how to use ANSYS Fluent to set up and solve a problem like this.

Exercise 3: Laminar Pipe Flow

Consider developing flow in a pipe of length $L = 8$ m, diameter $D = 0.2$ m, $\rho = 1$ kg/m³, $\mu = 2 \times 10^{-3}$ kg/m s, and entrance velocity $u_{in} = 1$ m/s (the conditions specified in the [Problem Specification](#) section). Use FLUENT with the "second-order upwind" scheme for momentum to solve for the flow on meshes of 100×5 , 100×10 and 100×20 (axial divisions $\times$ radial divisions).

- Plot the axial velocity profiles at the exit obtained from the three meshes. Also, plot the corresponding velocity profile obtained from fully-developed pipe analysis. Indicate the equation you used to generate this profile. In all, you should have four curves in a single plot. Use a legend to identify the various curves. Axial velocity u should be on the abscissa and r on the ordinate.
- Calculate the shear stress τ_{xy} at the wall in the fully-developed region for the three meshes. Calculate the corresponding value from fully-developed pipe analysis. For each mesh, calculate the % error relative to the analytical value. Include your results as a table:

Mesh	τ_{xy}	% error

- At the exit of the pipe where the flow is fully-developed, we can define the error in the centerline velocity as

$$\epsilon = \frac{|u_c - u_{exact}|}{u_{exact}}$$

where u_c is the centerline value from FLUENT and u_{exact} is the corresponding exact (analytical) value. We expect the error to take the form

$$\epsilon = K \Delta r^p$$

where the coefficient K and power p depend upon the order of accuracy of the discretization. Using MATLAB, perform a linear least squares fit of

$$\ln \epsilon = \ln K + p \ln \Delta r$$

to obtain the coefficients p and K . Plot $\ln \epsilon$ vs. $\ln \Delta r$ (using symbols) on a log-log plot. Add a line corresponding to the least-squares fit to this plot.

Hint: In FLUENT, you can write out the data in any "XY" plot to a file by selecting the "Write to File" option in the Solution XY Plot menu. Then click on Write and enter a filename. You can strip the headers and footers in this file and read this into MATLAB as column data using the load function in MATLAB.

4. Let's see how p changes when using a first-order accurate discretization. In FLUENT, use "first-order upwind" scheme for momentum to solve for the flow on the three meshes. Repeat the calculation of coefficients p and K as above. Add this p vs. r data (using symbols) to the above log-log plot. Add a line corresponding to the least-squares fit to this plot. In all, you should have four curves on this plot (two each for second- and first-order discretization). Make sure you include an appropriate legend in the figure.

Contrast the value of p obtained in the two cases and briefly explain your results (2-3 sentences).

Hint: To interpret your results, you should keep in mind that the first or second-order upwind discretization applies only to the inertia terms in the momentum equation. The discretization of the viscous terms is always second-order accurate.

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