TFS Fluids Qualifying Exam Questions
Fall 2015

Attached are three problems on which you will be questioned in the fluids oral qualifying exam. You have one hour to consider these questions in private before the start of the exam. You may make notes if you wish and bring them to the exam, but you may not consult any materials or talk to anyone.

In the oral exam, you will be asked questions related to these problems, but you will not necessarily need to solve them completely. It is recommended that you spend your one hour preparation time thinking through how the problems would be solved, rather than working out detailed solutions. We will spend approximately 15 minutes on each of the three questions during the oral examination.

Good Luck !

1. Dimensional analysis: Consider an incompressible flow through a straight pipe of length L. We will use dimensional analysis to derive a scaling law for the overall pressure drop Δp across the length of the pipe as a function of the mean velocity v, the fluid density ρ, the dynamic viscosity μ, and the relative roughness of the wall r/D (the average size of the fluctuations of the pipe's diameter D).

   (a) Give the units of all variables in terms of length L, mass M, and time T.

   (b) D, ρ, and v can be used to define the Π groups. Explain why.

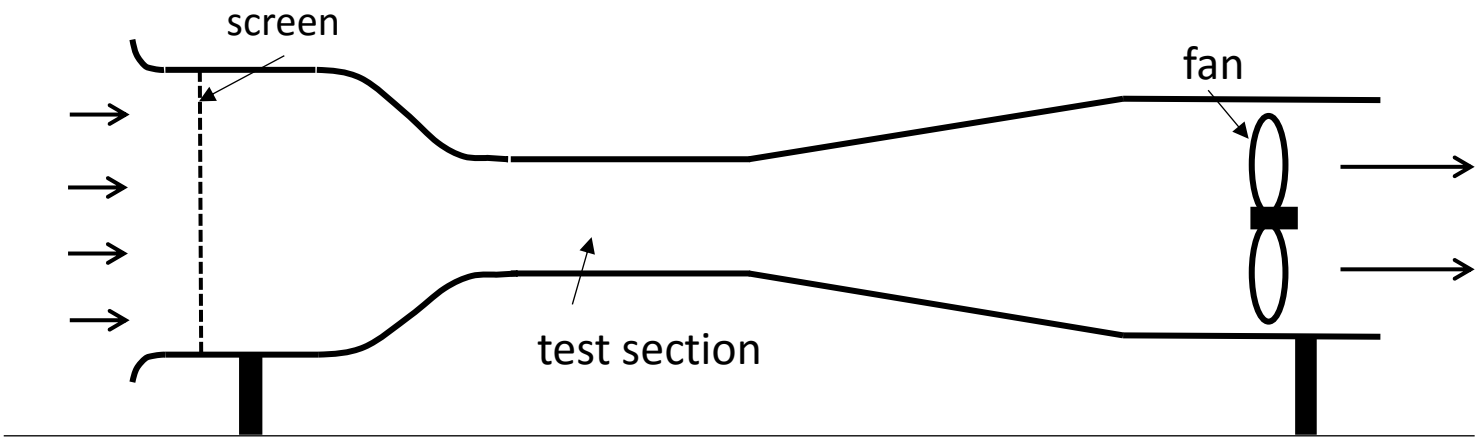
   (c) Using D, ρ, and v as the basic variables for the dimensional analysis, derive a scaling law for the pressure drop Δp.

2. Air is drawn into a wind tunnel by a downstream fan as shown schematically below. The cross-sectional areas at various points in the tunnel are known.

   a. Show the qualitative variation of static and stagnation pressures from upstream of the wind tunnel to the downstream exit. Include explanations of any change in stagnation pressure.

   b. Given a measurement of the test section static pressure, how would you estimate is the test section velocity? Indicate all assumptions made in your analysis.

   c. Indicate how you would estimate the horizontal force applied on the floor when the wind tunnel is operating with a known test section velocity.



3. The figure below shows the pressure distribution around a cylinder for three cases: inviscid, laminar, and turbulent flows. Referring to these pressure distributions please answer the following questions:

a. Why is the shape of the inviscid distribution symmetric about the 90° point? This explanation should include a physical rationale for why this occurs.
b. Why are the "turbulent" and "laminar" profiles different?
c. How could these C_p distributions be used to estimate the drag on the cylinder? What approximations or assumptions are necessary for this estimate, and what are the justifications for these approximations or assumptions? Be sure to address all three cases, i.e. inviscid, laminar, and turbulent flows.
d. For the laminar and turbulent cases, if the surface was roughened, how would this affect the drag on the cylinder? Explain.
e. Can these pressure distributions be predicted analytically using potential flow analysis? Explain.