Ph.D. Qualifying Examination

Fluid Mechanics

Fail 2017

Procedure:

● Time allowed: 2.5 hours.

● Part 1 of exam (20%) is closed-book and closed-notes, no calculator (turn it in before beginning work on part 2)

● Part 2 of exam (80%) is open-notes (no photocopies), calculator allowed, with 1 textbook allowed

● State your assumptions, methods, and procedures. Show your work on these exam sheets. (Add additional sheets, if needed)

● Laptops and cell phones not allowed

● Small lapdogs may be brought in for emotional comfort
1. (5%) In many cases, scale models are tested in wind tunnels or water tanks to predict the performance of a larger device. What dimensionless numbers should match for the model data to be scalable to the full-size apparatus? Explain.

2. (5%) Explain the difference between an Newtonian and a non-Newtonian fluid.

3. (5%) Consider a two-dimensional potential flow through a right-angle channel, with streamlines as depicted. Comment on and/or sketch corresponding lines of constant vorticity.

4. (5%) Formulate the statement of D'Alembert’s paradox, explain what it means in terms of practical application of hydrodynamic theory.
Part 2 (80%) open book (1 textbook), open notes, calculator allowed. Use extra sheets as necessary.

Problem 1 (20%)

A hot-air balloon must support its own weight plus a person for a total weight of 1000N. Ambient air is at 25°C and 100 kPa. The hot air inside the balloon is at 70°C and 100 kPa. Gas constant for dry air is 287.058 J kg$^{-1}$ K$^{-1}$. What diameter spherical balloon will just support the weight? Neglect the size of the hot-air inlet vent.
Problem 2 (20%)

A perfectly balanced 500 N weight and platform are supported by a steady water jet. What is the proper jet velocity assuming that the diameter of the vertical water column is 5 cm and the water density is 1000 kg/m³.
Consider a waterjet-powered jetski. The waterjet pump (3) provides a volume flow rate $Q$ and a horizontal discharge (4) velocity $v_j$ relative to the boat. Assuming that the drag on the jetski is $k v^2$, where $k$ is a constant and $v$ is the jetski velocity with respect to quiescent water far away from the boat, state your assumptions and write an expression for $v$. 

Problem 4 (20%)

Two water streams merge into one. At a location downstream of the junction, the approximate velocity profile is as shown in the figure. Assume the stream depth to be constant at 1.5 m. Find velocity $V$. Explain your assumptions.