Ph.D. Qualifying Examination

Fluid Mechanics

Fail 2017

Procedure:

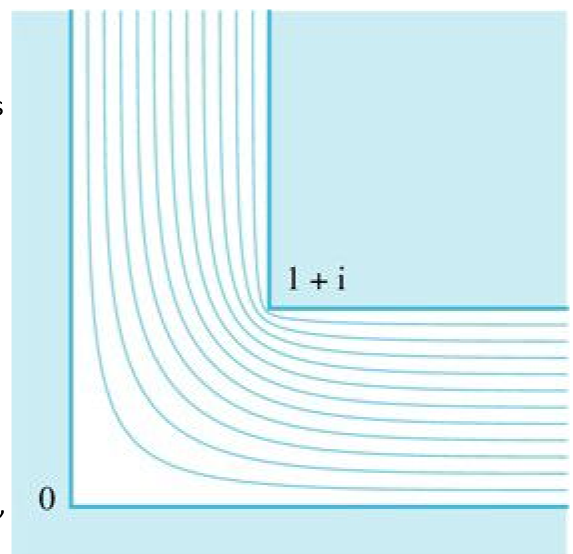
- Time allowed: 2.5 hours.
- Part 1 of exam (20%) is closed-book and closed-notes, no calculator (turn it in before beginning work on part 2)
- Part 2 of exam (80%) is open-notes (no photocopies), calculator allowed, with 1 textbook allowed
- State your assumptions, methods, and procedures. Show your 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

Part 1 (20%): closed book and closed-notes, no calculator. Use extra sheets if necessary.

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.

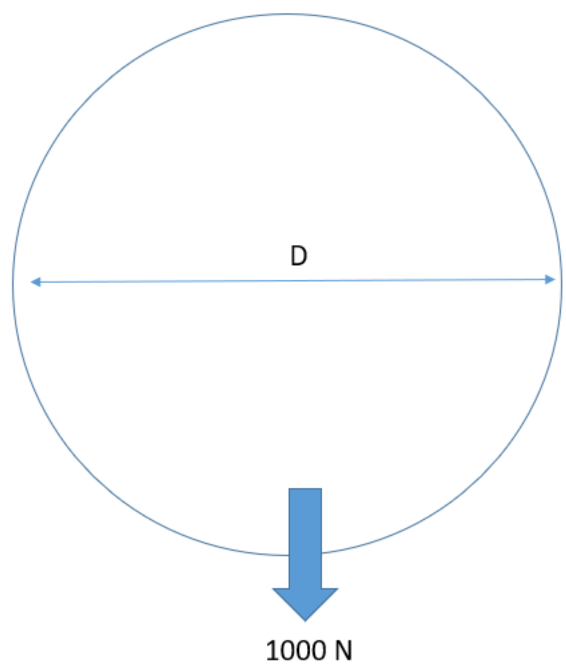


4. (5%) Formulate the statement of D'Alembert's paradox, explain what it means in terms of practical application of hydrodynamic theory.

Part 2 (80%) open book (1 textbook), open notes, calculator allowed. Use extra sheets as necessary.

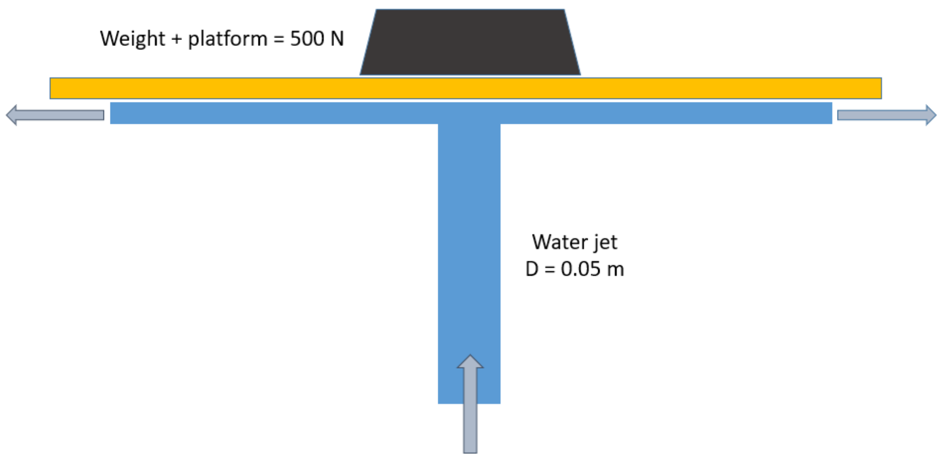
Problem 1 (20%)

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.



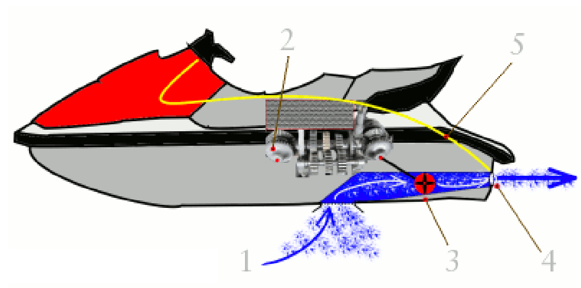
Problem 2 (20%)

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/m^3.



Problem 3 (20%)

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 kv^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.