Ph.D. Qualifying Examination

Fluid Mechanics

Fall 2016

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

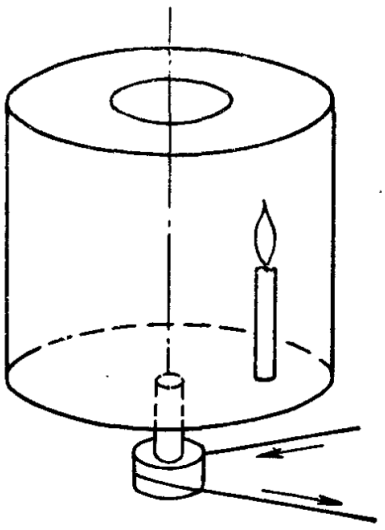
Part 1 (20%, closed book, closed notes)

1. Describe a velocity and a thermal boundary layer. How is the boundary layer thickness defined? How are the thicknesses of velocity and thermal boundary layers related? What dimensionless parameters are relevant?

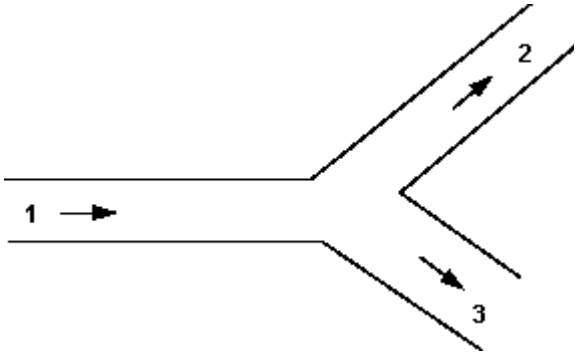
2. Can pressure in fluid be zero or negative? Explain.

3. Can moving fluid be at rest? If yes, under what conditions?

4. A cylinder with a burning candle inside rotates with a constant angular velocity. Is the flame of the candle deflected, and if yes, in what direction? Explain.

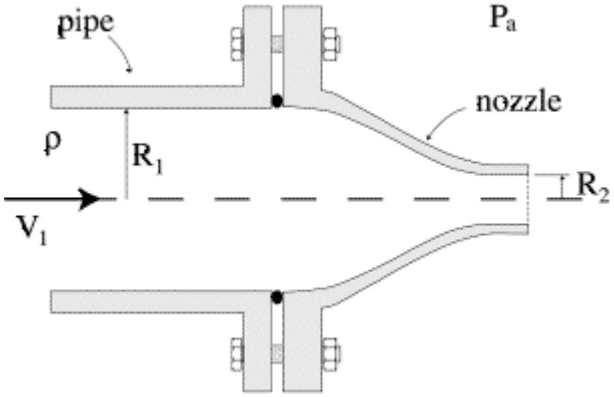


Part 2 (80%, notes, textbook, calculator)
Problem 2.1.



Consider water flow through a junction of three pipes as sketched. Pipe 1 diameter = 25 mm, mean velocity 1.2 m/s. Pipe 2 diameter = 20 mm, it takes 30% of the total discharge. Pipe 3 diameter = 30 mm. What are the values of discharge and mean velocities in pipes 2 and 3?

Problem 2.2.

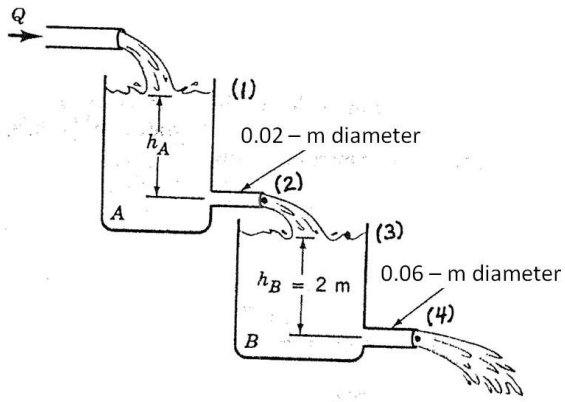


A circular pipe with radius R_1 carries incompressible fluid with density ρ to a converging nozzle with exit radius R_2, mounted at its end. Before the flow is started, the bolts that compress the nozzle against the pipe flange (see the figure) are tightened until the collective tensile force on them is F_B. The gasket provides a leak-proof seal. A steady flow is then established with a velocity V_1 at the entrance to the nozzle. The ambient pressure is p_a.

Find the gauge pressure at the nozzle entrance.

Find the additional force on the bolts due to the contraction in the nozzle. Provide an estimate of maximum velocity V_1 to sustain a leak-proof connection.

Problem 2.3.
Water flows steadily through the tanks shown in the figure. Determine the water depth in tank A.



Problem 2.4. A bend in a stream has an average radius of curvature 30 m and average width 3 m. Two manometers are placed at equal depth near the outer and inner shores of the bend. Their readings differ by 400 Pa. Based on this information, estimate the stream average velocity. Disregard viscous effects. Hint: assume that the stream velocity is uniform before the bend.