Ph.D. Qualifying Examination

Fluid Mechanics

Fall 2015

Notes:

- 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 are not allowed.

Fluids Fa 2015 **Part 1** (20%) **closed book and closed-notes, no calculator**

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

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

3. 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?

4. Define each term below and discuss how it is used. *Select three of them* and cross out the one you do not want graded.

a) Surface tension

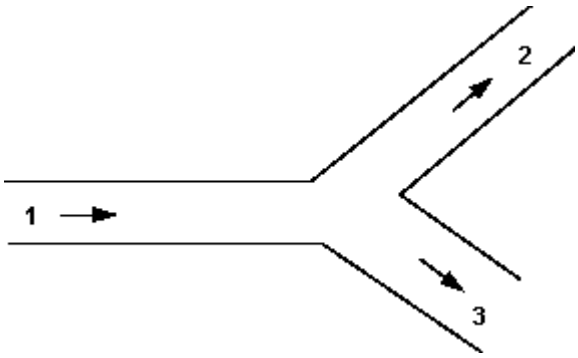
b) Reynolds number

c) streamline

d) minor loss

Fluids Fa 2015 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

1. Consider water flow through a junction of three pipes as sketched. Pipe 1 diameter = 50mm, mean velocity 2 m/s. Pipe 2 diameter = 40mm, it takes 30% of the total discharge. Pipe 3 diameter = 60mm. What are the values of discharge and mean velocities in pipes 2 and 3?



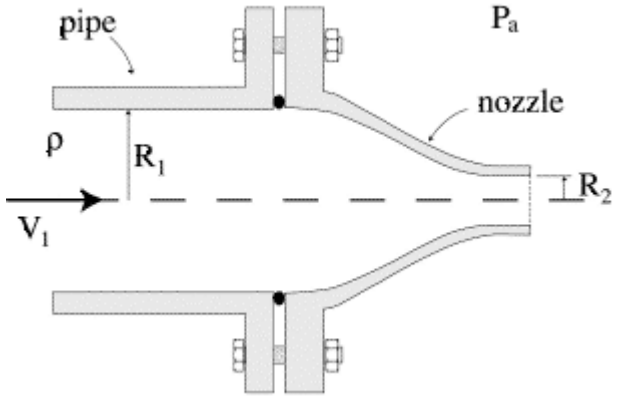
Fluids Fa 2015 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

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.

a) Find the gauge pressure at the nozzle entrance.

b) Find the additional force on the bolts due to the contraction in the nozzle.

c) Provide an estimate of maximum velocity V_1 to sustain a leak-proof connection.



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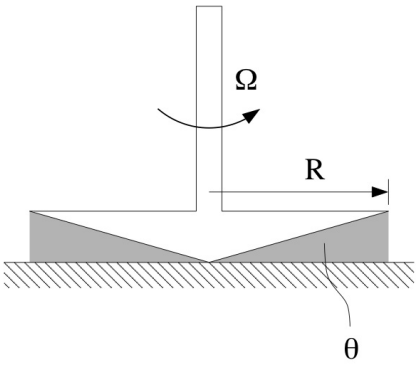
3. The device in the figure is called a cone-and-plate viscometer. The angle θ of the cone is very small, so that $\sin(\theta) \approx \theta$. The gap between the cone and the lower flat plate is filled with Newtonian liquid of viscosity μ (in shaded area). The torque to drive the cone at rate of rotation Ω (rad/sec) is M. Perform a dimensional analysis to write torque in terms of cone angle, viscosity, rate of rotation and cone radius (R). Give a physical explanation for the dependence of torque on R^n , where exponent n is obtained from the dimensional analysis.



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4. What size cast iron pipe (diameter in cm) is needed to transport water at 0.4 m^3/s over a horizontal distance of 1 km with head loss no greater than 2 m? Use the explicit friction factor formula:

$$f = \frac{1.325}{\{\ln[(\varepsilon/3.7D) + (5.74/\mathrm{Re}^{0.9})]\}^2}$$

for $10^{-6} < \varepsilon/D < 10^{-2}$ and $5000 < \mathrm{Re} < 10^{+8}$