Ph.D. Qualifying Examination

Fluid Mechanics

Spring 2014

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 Sp 2014 **Part 1** (20%) **closed book and closed-notes, no calculator**

1. Consider a steady, laminar flow of incompressible Newtonian fluid through a straight circular pipe of constant diameter. Which of the following statements does NOT apply to this flow? Explain.
    a) the shear at the pipe centerline = 0
    b) the maximum velocity at a section is twice the average velocity at this section
    c) the average velocity along the pipe decreases
    d) the velocity gradient at pipe centerline= 0

2. Define Reynolds number, explain its physical meaning. What does “critical Reynolds number” usually define?

3. A vacuum pump is used to drain water out of the bilge of a ship. Given that the water vapor pressure is 2.34 kPa, and the pump cannot lift water higher than 10.5 m, estimate the atmospheric pressure (kPa) at sea level.

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) cavitation

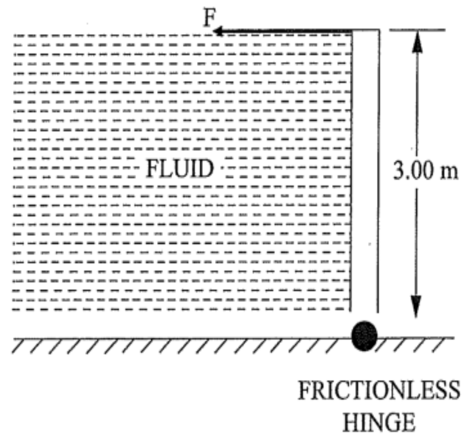
   b) Mach number

   c) specific weight

   d) dynamic similarity

Fluids Sp 2014 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

1. A rectangular vertical gate is 3 m tall and 1 m wide (into page). It has a hinge at the bottom. On the left of the gate is fluid with specific gravity 1.6, level with the top of the gate. Find the force F (applied at top of the gate) necessary to keep the gate closed.



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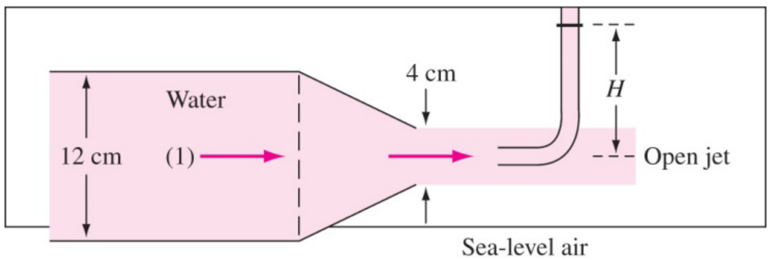
2. In the figure below, the open jet of water (density ρ=1000 kg/m^3) exits a nozzle into sea-level air (101 kPa) and strikes a stagnation tube of height H as shown. The pressure at centerline at section 1 is 110 kPa, losses in the nozzle are given by

$$h_f = K \frac{v_1^2}{\rho g}$$

where v_1 is average velocity in section 1 and K»2.5 is a dimensionless loss coefficient. If necessary, assume that the kinetic energy correction factor is unity both for the pipe and the jet flows. Estimate: a) the mass flow rate in kg/s, and b) the height H of the fluid in the stagnation tube.



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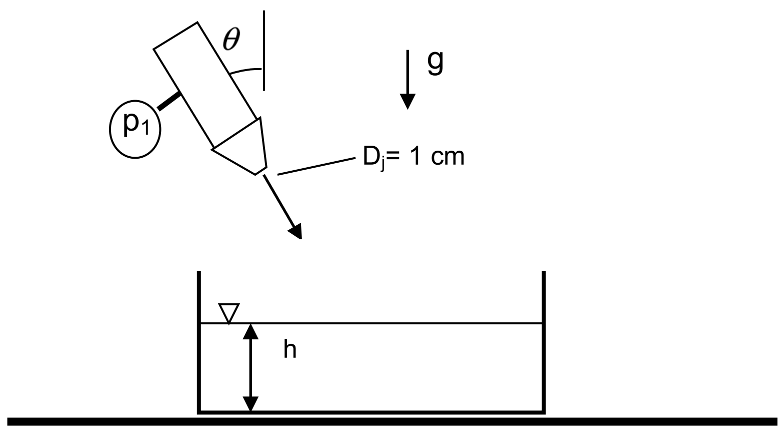
3. A tank (weight 15 N) is prevented from sliding by static friction, with coefficient of static friction $\mu_s = 0.2$. A water jet at angle θ will cause the tank to begin to slide when the water depth is h=10 cm. The surface area of water in the tank is 200 cm^2. The pressure just upstream of the nozzle is p_1= 500 kPa where D_1= 4 cm. The diameter of the jet is 1 cm; ignore viscous losses in the nozzle. Find θ. *Note: You cannot solve directly for* θ. Set up the equations and try θ= 10°, 20°, 30° … Then you can estimate θ to within about 1°.



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4. A solid cube is partially submerged in a river. The drag D on the cube depends on river depth d, stream velocity V, cube side h, fluid density ρ, and the acceleration of gravity g. *Neglect viscous effects*.

a. Perform a dimensional analysis of this problem. Use g as a repeating variable.
b. Drag will be measured on a model with 1:5 length scale ratio using SAE 30 oil. The prototype cube side is h= 3 ft. For prototype stream velocity 9 ft/s, what model stream velocity (ft/s) should be used?
c. If measured drag is 13 lbf on the model, what is the expected drag on the prototype (lbf)?
d. Consider viscous effects by computing the ratio Re_m/Re_p. Explain the significance of this ratio to the model tests.