Ph.D. Qualifying Examination

Fluid Mechanics

Fall 2013

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.

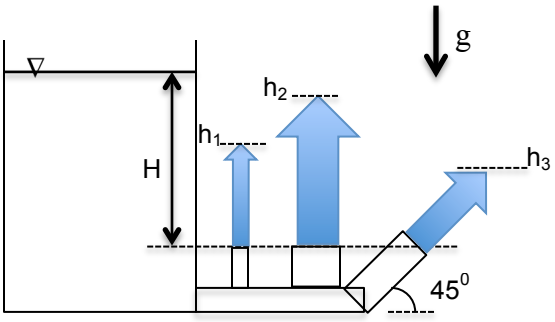
Fluids Fa 2013 **Part 1** (20%) **closed book and closed-notes, no calculator**

1. For laminar flow in a round pipe of diameter *D*, at what distance from the centerline is the actual velocity equal to the average velocity?

2. A child in a car holds a string attached to a floating helium-filled balloon. As the car decelerates to a stop, the balloon tilts backwards. As the car makes a right-hand turn, the balloon tilts to the right. On the other hand, the child tends to be forced forward as the car decelerates and to the left as the car makes a right-hand turn. Explain these observed effects on the balloon and child.

Continued: Fluids Fa 2013 **Part 1** (20%) **closed book and closed-notes, no calculator**

3. Water flows from the large open tank through 3 nozzles. If viscous effects are negligible, find h_1/H, h_2/H, and h_3/H, the heights to which each stream rises. The nozzle diameters are $D_2=3D_1$ and $D_3=2D_1$



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) hydraulic diameter

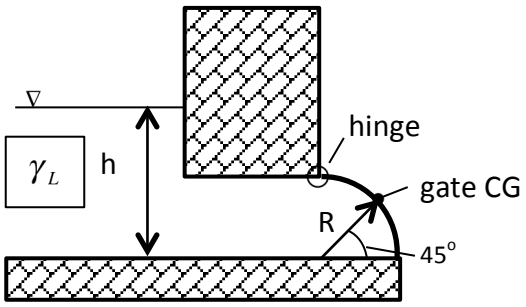
   b) Reynolds number

   c) Specific gravity

   d) Head loss

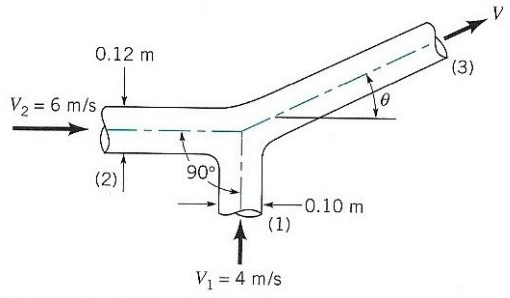
Fluids Fa 2013 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

1. Find the weight (kN) of a gate that opens just as liquid depth reaches h = 2 m. The gate is constructed from one-quarter (90^o section) of a circular pipe of radius R = 80 cm. The width of the gate into the page (or length of the pipe section) is w = 4 m. The liquid has specific gravity SG = 1.20.



Fluids Fa 2013 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

2. Two water jets collide and form one homogeneous jet as shown in the figure below.
   (a) Determine the speed, V, and direction, θ, of the combined jet at (3).
   (b) Determine the loss for a fluid particle flowing from (1) to (3), and for a particle flowing from (2) to (3). Gravity is negligible.



Fluids Fa 2013 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

3. Water is pumped between two large open reservoirs through 1.5 km of smooth pipe. The water surfaces in the two reservoirs are at the same elevation. When the pump adds 20 kW to the water the flowrate is 1 m^3/s. If minor losses are negligible, determine the pipe diameter.

Fluids Fa 2013 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

4. The torque required to rotate a circular disk in a viscous fluid, $T(\Omega, R, \upsilon, \rho)$, depends on
   Ω =disk angular velocity, R =disk radius, υ =fluid kinematic viscosity, and ρ =fluid density.
   a) Perform a dimensional analysis, using υ as one of the repeating variables. Verify that one of the Pi groups is a Reynolds number.
   b) For a model disk of R=10 cm, which rotates at Ω =90 rpm in water at 20^{o}C, the measured torque is 19 N-m. If the prototype disk of R=30 cm also rotates in water at 20^{o}C, what should the angular velocity be to achieve dynamic similarity? What is the prototype torque?