Ph.D. Qualifying Examination

Fluid Mechanics

Spring 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 book, open notes, calculator allowed, and 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.

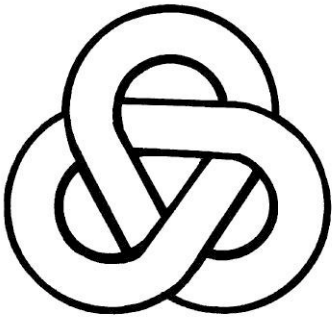
Fluids Sp 2013 **Part 1** (20%) **closed book and closed-notes, no calculator**

1. A person holds a hand out of a car window while driving at speed *V* through still air. Estimate the maximum pressure on the person's hand.

2. Describe two situations where the no-slip boundary condition may not be appropriate (or accurate)? Explain carefully.

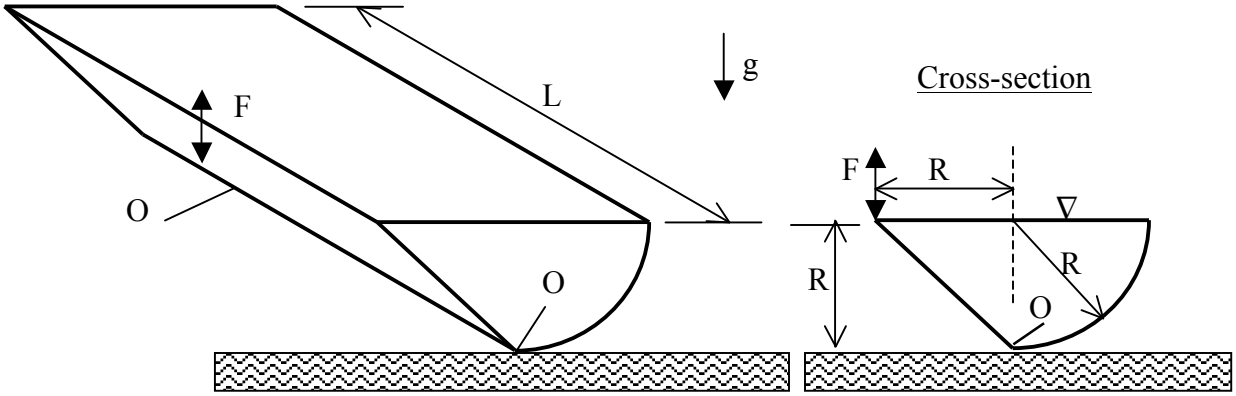
3. For the same Reynolds number characterizing the flow past a lifting surface, will the drag force be greater if the flow is laminar or turbulent? Explain.

4. Can a vortex filament be shaped like this? Explain.



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

5. An open tank filled with liquid has a cross-section made up of a triangle and a quarter-circle. Determine the force F (and its direction) required to hold the tank in the position shown, where it would pivot about edge O. Verify the dimension {F,L,T} of your answer. Neglect the weight of the tank walls.



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

1. The top of a block of metal is attached with a string to a balance. When the block is hanging in air, the balance reads 250 g. When the block is lowered into water, the balance reads 160 g. When the same block is lowered into whisky (don't ask why), the balance reads 170 g. Determine the proof (or alcohol content) of the whisky, given that the density of water is 1 g/cm^3 and the density of pure ethanol is 0.79 g/cm^3.

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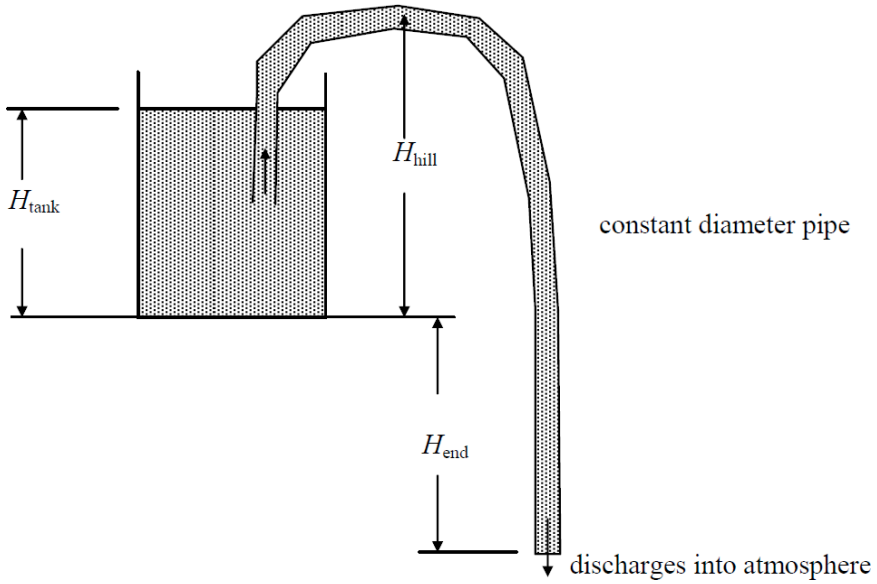
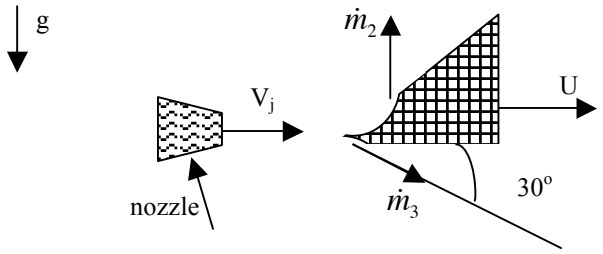
2. Water is siphoned from a large tank through a constant diameter hose. Determine the maximum height of the hill, H_{hill}, over which the water can be siphoned without cavitation occurring. Assume that the vapor pressure of the water is p_v, the height of the water free surface in the tank is H_{tank}, and the vertical distance from the end of the hose to the base of the tank is H_{end}.



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

3. A steady free jet of water with V_j= 35 m/s and diameter D_j= 3 cm strikes a splitter body as shown. Neglect the weight of the body and the weight of water near the splitter body. When the body is moving to the right at constant speed U = 12 m/s,
   a. find the ratio of mass flow rates [$\dot{m}_2 / \dot{m}_3$] so that the net vertical force on the body is zero;
   b. compute the required horizontal force acting on the body to maintain constant speed U.



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

4. The pump power $\dot{W}(V, D, L, \nu, \rho)$ required to circulate water in a piping system depends on: V = avg. velocity, D= pipe diameter, L= pipe length, ν = kinematic viscosity, and ρ= density. A model of the prototype (full-scale) system is to be built.
   a) Perform a dimensional analysis, showing your work. *Do not use ν as one of the repeating variables*. Show that a Reynolds number can be defined in terms of your Pi groups.
   b) For a 1/8th–scale geometrically-similar model, compare *pipe cross-sectional area* and *pipe length* to those of the prototype.
   c) For a prototype system, the required pump power is 2 kW. For a model also using water, compute the required pump power $\dot{W}_m$ (kW) when dynamic similarity is enforced. Explain the result in terms of kinetic energy (or velocity) head.

Fluids, cont. Problem _____