Ph.D. Qualifying Examination

Fluid Mechanics

Fall 2009

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 Sp09 Part 1 (20%)   closed book and closed-notes, no calculator

Work 4 of 5 problems (on additional pages). Clearly indicate which problem should <u>not</u> be graded.

1. An old parlor trick uses an empty thread spool and a playing card. The playing card is placed against the bottom of the spool. Contrary to intuition, when one blows downward through the central hole in the spool, the card is not blown away. Instead, it is `sucked' up against the spool. Explain.

2. The stream function and velocity potential each satisfies a Laplace equation, which is a linear, homogeneous PDE. Thus, many stream functions (or velocity potentials) can be superimposed, with the result remaining a valid solution. Why would we do this?

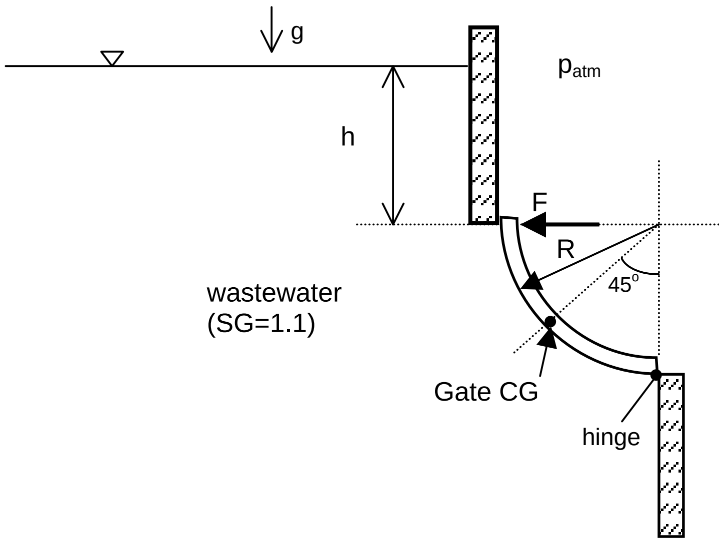
3. In a chemical process, it is necessary to measure small level differences between two large tanks of water with high accuracy. An engineer claims that this can be done by using a ‘U’ shaped manometer between the two tanks, and a liquid immiscible in water with a density slightly lower than that of water, which would have the effect of magnifying the level difference. Draw the arrangement and explain why this is effective.

4. What is the difference between a Newtonian and a non-Newtonian fluid?

5. Define Reynolds number, Froude number, Strouhal number and Mach number, and give examples of their use in fluid mechanics.

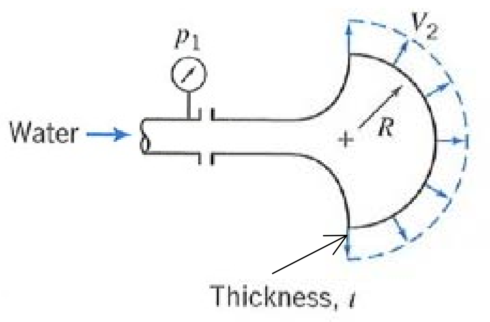
Fluids Sp09 Part 2 (80%) open book (1 textbook), open notes, calculator allowed

1. A thin, quarter-circle gate (R= 3 m) in a wastewater (SG = 1.1) reservoir is L=5 m long (into page). Its mass is 15,000 kg; the gate center of gravity is halfway along the arc as shown. What horizontal force F (kN) is required to keep the gate closed when h= 4 m?



Fluids Sp09 Part 2 (80%) open book (1 textbook), open notes, calculator allowed

2. A nozzle for a spray system is designed to produce a flat radial sheet of water. The sheet leaves the nozzle at V_2 = 10 m/s, covers an arc of 180^o, and has thickness t = 1.5 mm. The nozzle discharge radius is R = 50 mm. The water supply pipe is 35 mm in diameter and the inlet pressure p_1 is 150 kPa (abs). Evaluate the force exerted by the nozzle on the coupling. Gravity is acting out of the plane of the paper.



Fluids Sp09 Part 2 (80%) open book (1 textbook), open notes, calculator allowed

3. The load upon a rotating shaft is supported by a *journal bearing*. The load W depends on fluid dynamic viscosity and density. The length of the bearing (along the shaft) is B, its diameter is D, and C is the average clearance between the shaft and bearing sleeve. The shaft rotates with angular velocity ω. In the prototype bearing, (unused) engine oil at 20C supports load W= 6 kN with ω=1200 rpm, B=3 cm, D= 8 cm and C= 1 mm.

a) Perform a dimensional analysis to determine the relevant dimensionless groups using μ as a repeating variable; do not use ρ as a repeating variable .
b) Identify a Reynolds number from among your dimensionless groups; what is its velocity scale (L/T)?
c) For a 1/5th scale model using water at 20C, what angular velocity ω, length B, diameter D and clearance C should be specified to achieve dynamic similarity? What is the expected load W? Do you see any problem in making laboratory measurements of this load?
d) If experiments show that load is ***directly proportional*** to density, how does the load W change if angular velocity ω is halved?