Ph.D. Qualifying Examination

Fluid Mechanics

Spring 2016

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 2016 **Part 1** (20%) **closed book and closed-notes, no calculator**

1. Discuss when and how cavitation occurs in fluid flows. When is cavitation harmful?

2. Explain how a water strider walks on water.

3. A test tube containing a piece of silly putty floats on the surface of water. If the silly putty is removed from the inside of the test tube and stuck to the bottom of the test tube, how will the equilibrium submerged depth of the test tube change? Increase? Decrease? Stay the same? Explain.

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) Kinematic viscosity

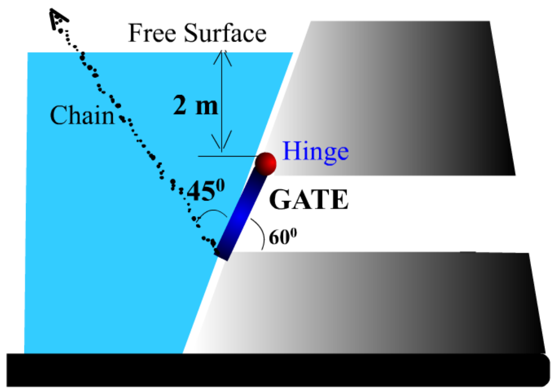
b) Reynolds number

c) Stream function

d) friction factor

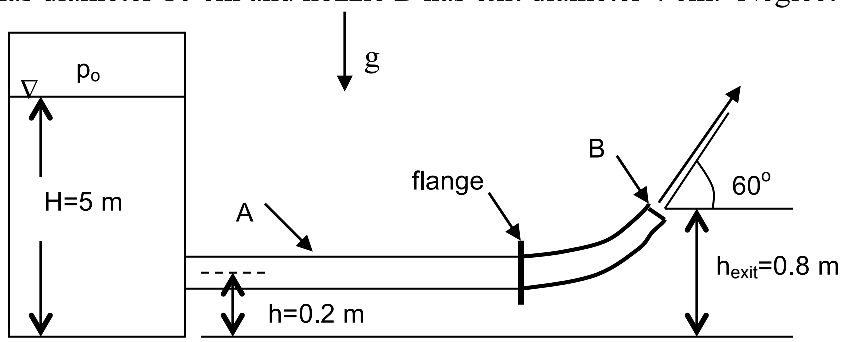
Fluids Sp 2016 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

1. An opening in a dam is covered with a square plate (1 m by 1m) and is hinged on the top and inclined at 60^o to the horizontal. If the top edge of the gate is 2 m below the water level what is the force required to open the gate by pulling a chain set at 45^o angle to the plate and attached to the lower end of the plate. The mass of the plate is 225 kg. Neglect the mass of the chain.



Fluids Sp 2016 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

2. Water at 40°C is ejected through the pipe and curved nozzle from the tank pressurized by air to p_o= 180 kPa (abs). Determine the force that must be applied *at the fla*nge to hold the nozzle in place; show the direction of each force component. The weight of the nozzle and the water within it is 150 N. Pipe A has diameter 10 cm and nozzle B has exit diameter 4 cm. Neglect all viscous losses.



Fluids Sp 2016 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

3. A turbine flowmeter measures flow in a pipe with a free-wheeling rotor whose rotation rate is picked off by a magnetic sensor. The flow rate Q depends on rotor angular velocity Ω, rotor radius R, and fluid kinematic viscosity ν.

a. Perform a dimensional analysis of this system. Identify a Reynolds number among your dimensionless groups, noting the velocity scale used.

b. A prototype meter rotates at 500 rpm for a flow rate of 0.8 m^3/s. For a 1:4 scale model determine the rotor angular velocity Ω_m (rpm) and Q_m flow rate (m^3/s) if it is properly scaled.

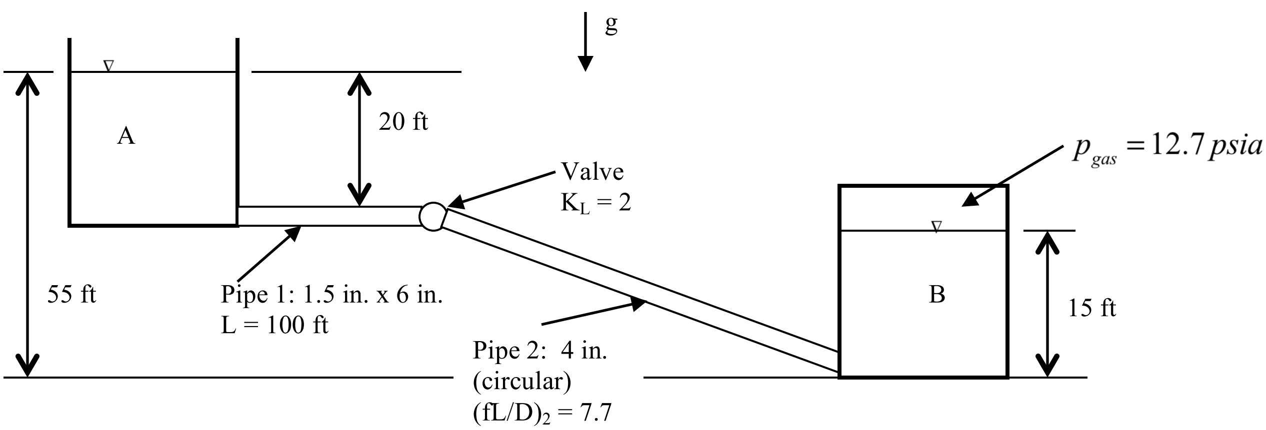
Fluids Sp 2016 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

4. Water at 90^{o}F flows between 2 large tanks through cast-iron pipes in series. Pipe 1 has rectangular cross-section and Pipe 2 is circular. The entrance to pipe 1 and exit from pipe 2 have sharp edges. The valve minor loss coefficient accounts for changes in pipe cross-section and is based on the higher velocity.

What is the flow rate (gpm) from tank A to tank B when tank levels are as shown? *One complete iteration for friction factor f_1 and flow rate Q is sufficient.* Use the *fully-rough (or wholly turbulent)* value of friction factor as your initial guess. List all values of Reynolds number, roughness ratio, friction factor and velocity used. Note that $(fL/D)_2$=7.7 is given. Use this 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 $5000 < \mathrm{Re} < 10^{+8}$



Problem #______, continued

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