Ph.D. Qualifying Examination

Fluid Mechanics

Spring 2018

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 2018 **Part 1** (20%) **closed book and closed-notes, no calculator**

1. Why does the fluid pressure drop when the flow velocity increases?

2. Golf balls have dimpled surface to trigger early transition to turbulence. How does this early transition help golf balls to travel greater distances?

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

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) Shear-thinning fluid

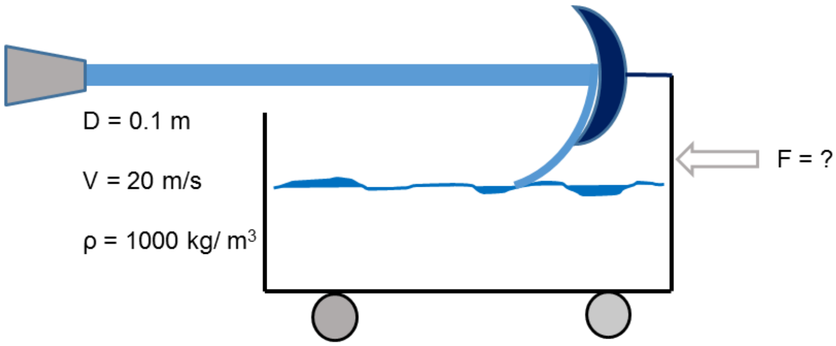
b) Reynolds number

c) Drag coefficient

d) Hydraulic diameter

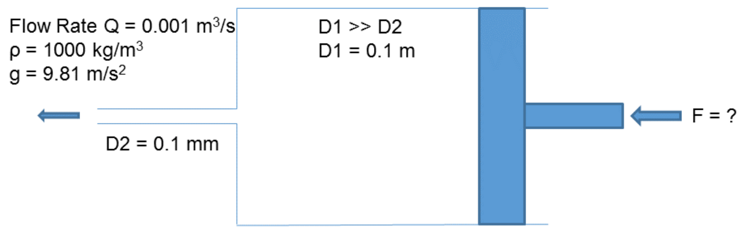
Fluids Sp 2018 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

1. What is the force required to hold the cart at rest for the given configuration? The diameter of the water jet is 0.1 m traveling at velocity of 20 m/s. The water density is 1000 kg/m^3.



Fluids Sp 2018 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

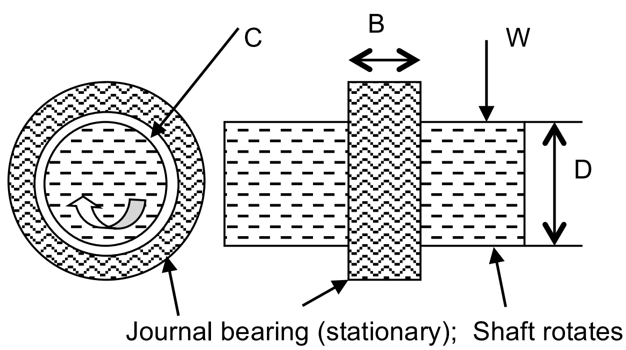
2. A steady push on the piston causes a flow rate of 0.001 m^3/s through the needle whose diamter is 0.1 mm. The water density is 1000 kg/m^3. Ignoring viscous effect, what is the force required to maintain the flow? Assume that diamter D1(0.1m) is much greater than D2 (0.1 mm).



Fluids Sp 2018 **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 dynamic viscosity and density of the fluid between the housing and the shaft. The length of the bearing (along the shaft) is B, shaft diameter is D, and C is the average clearance between the bearing sleeve and the shaft rotating with angular velocity ω. In the *prototype* bearing, SAE 30 oil at 15.6°C supports load W= 6 kN with ω =1200 rpm, B=3 cm, D= 8 cm, C= 1 mm, $\mu = 0.38\frac{kg}{m \bullet s}$ and $\rho = 912\frac{kg}{m^3}$.

a) Perform a dimensional analysis to determine the relevant dimensionless groups using D as a repeating variable; do not use μ as a repeating variable.
b) Identify a Reynolds number; what is its velocity scale (L/T) in terms of above variables?
c) For a 1/5th scale model using water at 30°C, what angular velocity ω(rpm), length B (cm), diameter D (cm) and clearance C (mm) should be specified to achieve dynamic similarity? What is the expected load W_m? Do you see any problem in making laboratory measurements of this load?
d) If experiments show that load is *directly proportional* to viscosity, how does the load W change if angular velocity ω is halved (and all other variables are held fixed)?



Fluids Sp 2018 **Part 2** (80%) **open book (1 textbook), open notes, calculator allowed**

4. What size cast iron pipe (diameter in cm) is needed to transport water at 0.4 m^3/s over a horizontal distance of 1 km with head loss no greater than 2 m? Use the 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

Problem #______, continued

Problem #______, continued

Problem #______, continued