QUIZ II SOLUTION

MAE101B: Advanced Fluid Mechanics Winter Quarter 2020

http://web.eng.ucsd.edu/~sgls/MAE101_2020/

Quiz II

This is a 50 minute closed-book exam. Please put your name on the top sheet. Answer all three questions. Explain your working and state any assumptions you have made.

1 (3 points) Circle the correct answer.

1. The First Law of thermodynamics in fluids mechanics
   - can be viewed as generalizing Bernoulli's equation.
   - is Newton's Second Law times velocity.
   - ignores gravity.
   - requires no shaft work.
   - is a vector equation.
2. Circulation
   - is zero for viscous flows.
   - is a vector.
   - is not defined for unsteady flows.
   - can be calculated by integrating the pressure.
   - is the integral of vorticity over a bounding surface.
3. Being able to scale up from model to full-size requires
   - luck.
   - the same density fluid.
   - dynamic and geometric similarity.
   - knowing the torque acting on the model.
   - incompressible flow.

2 (7 points) Ships generate waves in their wake and this is one of the mechanisms that induces drag. Derive a nondimensional parameter relating drag D (a force) for a ship of length L moving at velocity V when the acceleration due to gravity is g. It is easiest to obtain a number proportional to L (the Froude number). What is its value for a Nimitz class aircraft carrier (length at waterline 317 m, speed 30 knots)? What about for a duck (estimate L and U)? [One nautical mile = 1,852 m.]

D : MLT^{-2}
L : L
V : LT^{-1}
g : LT^{-2}

$k=4, r=3$

1 π group

$$\pi_1 = \frac{Lg}{V^2}$$

Nimitz: $$\frac{317 \times 10}{(30 \times 1.8352 \times 10^{-3}/3600)^2} = 13.3$$

Duck: say $L = 20\,cm$, $V = 0.5\,ms^{-1}$

$$\pi_1 = \frac{0.2 \times 10}{(0.5)^2} = 8$$

Note: Couldn't non-dimensionalize D.

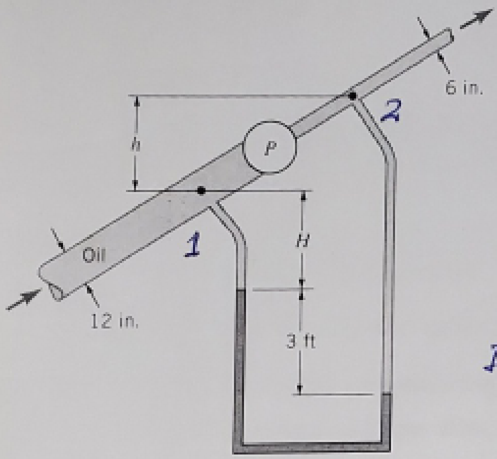
Needed another parameter, e.g.: ρ : ML^{-3}

$$\pi_2 = \frac{D}{\rho g L^3}$$

Froude Number: Usually defined as $\frac{V}{\sqrt{gL}}$

[Nimitz: 0.275
Duck: 0.35]

3 (10 points) Oil (SG = 0.92) flows in an inclined pipe at a rate of 4 ft^3/s as shown in the figure below. If the differential reading in the mercury manometer is 3 ft, calculate the power that the pump supplies to the oil if head losses are negligible.



$$\frac{P_{out}}{\gamma} + \frac{V_{out}^2}{2g} + z_{out} = \frac{P_{in}}{\gamma} + \frac{V_{in}^2}{2g} + z_{in} + h_s - h_L$$

In this case,

$$\frac{P_2}{\gamma_{oil}} + \frac{V_2^2}{2g} + z_2 = \frac{P_1}{\gamma_{oil}} + \frac{V_1^2}{2g} + z_1 + h_s - h_L^{\nearrow 0}$$

$Q = 4\ ft^3/s$ $\therefore V_1 = \frac{Q}{\frac{\pi}{4}D_1^2} = \frac{4}{\frac{\pi}{4}(1ft)^2} = 5.09\ ft/s$

$$V_2 = \frac{Q}{\frac{\pi}{4}D_2^2} = \frac{4}{\frac{\pi}{4}(1/2 ft)^2} = 20.36\ ft/s$$

Now, $P_1 + \gamma_{oil} \cdot H + \gamma_{Hg} \cdot 3 - \gamma_{oil}(3 + H + h) = P_2$

$$\therefore \frac{P_1}{\gamma_{oil}} + \frac{3\gamma_{Hg}}{\gamma_{oil}} - 3 - h = \frac{P_2}{\gamma_{oil}}$$

Bernoulli becomes,

$$\frac{P_1}{\gamma_{oil}} + \frac{3\gamma_{Hg}}{\gamma_{oil}} - 3 - h + \frac{V_2^2}{2g} + z_2 = \frac{P_1}{\gamma_{oil}} + \frac{V_1^2}{2g} + z_1 + h_s$$

$\Rightarrow h_s = 50.38\ ft$

$$\dot{W}_{shaft} = \gamma_{oil} Q h_s = SG_{oil}\,\gamma_{H_2O} \cdot Q h_s$$
$$= 11581.5\ \frac{lb\,ft}{s} = 21\ hp.$$

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