Homework 4

Ch En 374 – Fluid Mechanics

Due date: 4 Oct. 2019

Survey Question

Please report how long it took you to complete this assignment (in hours) in the "Notes" section when you turn your assignment in on Learning Suite.

Practice Problems

1. [Exam Review Questions]. Try and answer the following True/False questions from memory without looking at your book. Then use your book or a friend and fix your answers.

   (a) __________ All else being equal, an object at a low Reynolds number will fall faster in a high viscosity fluid than in a low viscosity fluid.

   (b) __________ Fully developed flow in a pipe means the velocity profile does not change along the length of the pipe.

   (c) __________ Surface tension resists the creation of new interfacial area.

   (d) __________ Even though fluids are made of molecules, at large enough length scales we can typically treat them as a continuum.

   (e) __________ A non-Newtonian fluid obeys the relation $\tau = \mu s$.

   (f) __________ In general, changing the pressure of a *gas* significantly affects its density.

   (g) __________ In general, changing the pressure of a *liquid* significantly affects its density.

   (h) __________ In the equation $\tau = \mu s$, τ is a shear stress and s is a strain, $\dfrac{\Delta x}{D}$.

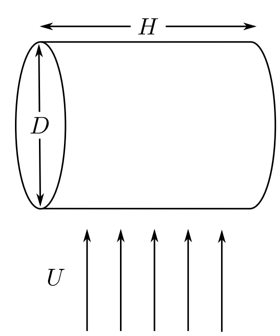
   (i) __________ The drop in pressure along a horizontal pipe occurs because of a loss of energy due to friction.

   (j) __________ Laminar flow is characterized by fluid that flows in straight lines.

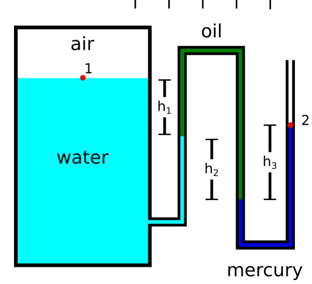
   (k) __________ Form drag is important when the Reynolds number is high.

   (l) __________ The unit for force (N) in the SI unit system is a fundamental dimension.

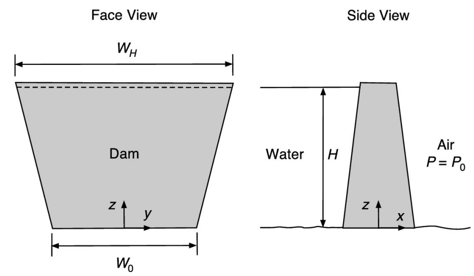
2. [Lecture 11 – Drag II: Flat Plates & Terminal Velocity]. After watching the recent news of hurricanes in the Carolinas, you wonder how strong wind has to be to pick up a person. Modeling a human being as a (long) cylinder with $D = 0.25$ m, $H = 1.8$ m and $\rho = 985\,\text{kg/m}^3$ find the speed (in m/s) where the cylinder's weight is just balanced by the drag force from the wind ($\rho_{\text{air}} = 1.18$ kg/m^3, $\mu_{\text{air}} = 1.86 \times 10^{-5}$ Pa·s). Justify any assumptions you make.



3. [Lecture 12 – Fluid Statics I: Pressure & Manometers]. The water in a tank is pressurized by air, and the pressure is measured by a multifluid manometer as shown in the figure below. Determine the gauge pressure of air in the tank if $h_1 = 0.2\,\text{m}$, $h_2 = 0.3\,\text{m}$, $h_3 = 0.46\,\text{m}$. Take the densities of water, oil and mercury to be $1000\,\text{kg/m}^3$, $850\,\text{kg/m}^3$, and $13,600\,\text{kg/m}^3$, respectively.



4. [Lecture 13 – Fluid Statics II: Pressure Forces]. When viewed from downstream, the Hoover Dam in the US is roughly trapezoidal, as in the figure below. The width at the top is $W_H = 1244\,\text{ft}$; the width at the bottom is about 2/3 of that, or $W_0 = 830\,\text{ft}$; the height of the reservoir, assumed here to reach almost to the top, is $H = 576\,\text{ft}$. The dam contains 4,400,000 cubic yards of concrete, which has a specific gravity of 2.4.

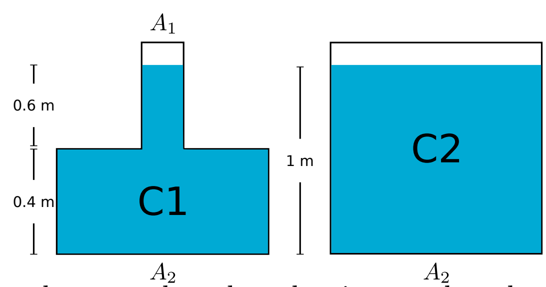


   (a) Derive an expression for the net pressure force acting horizontally on the dam (with coordinates as in the figure below, that is F_{Px}.

   (b) How does the horizontal force (in N) compare with the weight of the concrete?

Challenge Problems

5. You and two friends are trying to calculate the pressure force on the bottom of containers C1 and C2 filled with water to the same height. The cross-sectional areas of the bottom of the containers are the same and are given by $A_2 = 0.5\,\text{m}^2$, but the top of container $C1$ has an area given by by $A_1 = 0.005\,\text{m}^2$.



   One of your friends is convinced that the forces are the same, but the other is sure that they are different. What is the force on the bottom of C1 and C2? Are they the same? Why or why not? (For simplicity, assume that $P_{atm} = 0$).

6. Water flows past a flat plate that is oriented parallel to the flow with an upstream velocity of 0.5 m/s. Determine the approximate location downstream from the leading edge where the boundary layer becomes turbulent. What is the boundary layer thickness at this location?

7. Particles may aggregate in water as a result of their hydrophobicity or Van der Waals attractions. Such aggregates are called *flocs* and the process is termed *flocculation*. (Aerosols can also flocculate.) The objective is to explore how this affects gravitational settling. Suppose that an individual particle is a sphere with diameter $d = 10\,\mu\text{m}$ and density $\rho_0 = 2000\,\text{kg/m}^3$.

   (a) Evaluate the terminal velocity u of an individual particle

   (b) Suppose that 1000 particles form a nearly spherical floc of diameter d_{floc}. If the floc has a void fraction of $\epsilon = 0.50$, then $d_{\text{floc}} = 126\ \mu\text{m}$ and $\rho_{\text{floc}} = 1.5 \times 10^3\ \text{kg/m}^3$. If the floc behaves as an impermeable sphere (which is a good assumption by the way), what will its terminal velocity u_{floc} be? How does u_{floc} compare with u?

8. Use a differential balance to derive the static pressure equation in Cartesian coordinates. Note that detailed derivations of this equation are available to you in Section 4.2 of your textbook and notes and a YouTube video posted on the course website. (*It is important to understand differential balances, because we will use them several times over the next few weeks as we try to understand the the origin and meaning of the Navier-Stokes equation.*)