Homework 9

Ch En 374 – Fluid Mechanics

Due date: *Monday* 18 Nov. 2019

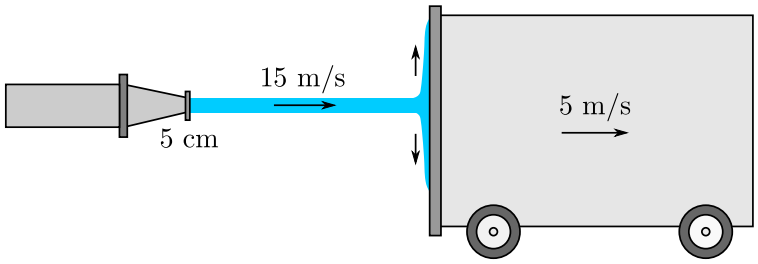
Survey Question

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.

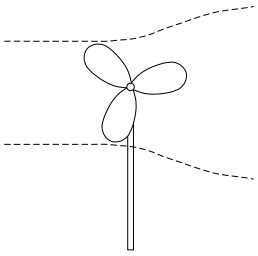
Practice Problems

1. [Lecture 25 – Integral Mass Balance]. The minimum fresh air requirement of a residential building is specified to be 0.35 air change per hour. That is 35 percent of the entire air contained in a residence should be replaced by fresh outdoor air every hour. If the ventilation requirement of a 2.7-m-high, 200-m^2 residence is to be met entirely by a fan, determine the flow capacity in L/min of the fan that needs to be installed. Also determine the diameter of the duct if the average air velocity is not to exceed 6 m/s.

2. [Lecture 26 – Integral and Engineering Momentum Balance]. Water exits a jet ($D = 5$ cm) at 15 m/s and strikes the vertical back surface of a cart splattering in all directions in the plane of that surface. After a brief period, the cart begins moving at a constant speed of 5 m/s. Determine the force that is being applied by the friction of the wheels that is keeping the cart from accelerating.



3. [Lecture 27 – Integral and Engineering Mechanical Energy Balance]. At a certain location, wind is blowing steadily at 12 m/s on a wind turbine with 50-m-diameter blades. Downstream from the turbine, the kinetic energy is reduced and the breeze is now only 3 m/s. Calculate the net power that the wind turbine produces, assuming that the air density is 1.25 kg/m^3.



Challenge Problems

4. Answer the following conceptual questions:

   (a) What is the main benefit of using an integral balance instead of a differential balance?

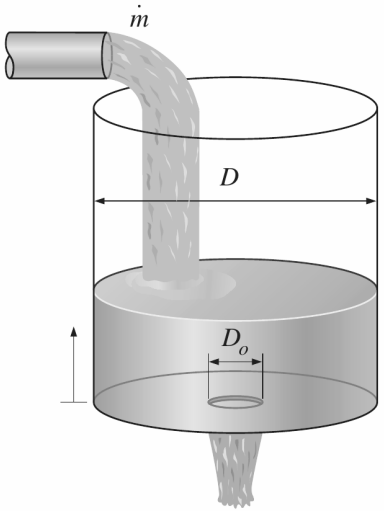
   (b) List the assumptions that are needed to obtain the engineering mass balance from the general integral mass balance.

(c) List the assumptions that are needed to obtain the engineering momentum balance from the general integral momentum balance

(d) List the assumptions that are needed to obtain the engineering mechanical energy balance from the general integral mechanical energy balance.

(e) Write down both "Bernoulli's equation" and "Bernoulli's engineering equation". What assumptions does "Bernoulli's equation" contain that the "engineering" equation does not?

5. Water enters a tank of diameter D steadily at a constant mass flow rate of $\dot{m}$. An orifice at the bottom with diameter $D_o \ll D$ that allows water to escape. The orifice has a rounded entrance, so the frictional losses are negligible. In this problem, we are going to find the maximum height, $h_{\max}$ that the water will reach in the tank.

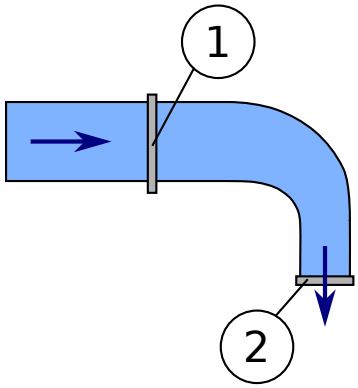


   (a) Use a mass balance to find an expression for dh/dt in terms of the variables above and the mass flow rate out of the orifice, $\dot{m}_o$.

   (b) Use a mechanical energy balance to find an expression for $\dot{m}_o$ in terms of the variables given and the height h. (*Hint: Because $D \gg D_o$ the liquid level changes very slowly compared to the velocity of the fluid leaving the orifice.*)

   (c) Combine your expressions to determine the maximum height that the water will reach in the tank. You may assume that the tank is initially empty.

6. Suppose water (with a density ρ) enters the nozzle with a 90° bend shown to the right with a mean velocity U and a pressure P_1 and exits at the atmospheric pressure, P_0. The inlet diameter of the nozzle is D_1 and the outlet diameter is D_2. We would like to calculate the net force exerted on the nozzle. In this problem, you may assume that the flow is turbulent.



   (a) First, determine the net force exerted on a 90° bend with no diameter change (i.e. $D_1 = D_2$).

   (b) Now, calculate the net force exerted on the nozzle in the figure for the case that $D_1 \neq D_2$.