

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
2.06 Fluid Dynamics

PROBLEM SET #3, Spring Term 2013

Issued: Thursday, April 25, 2013

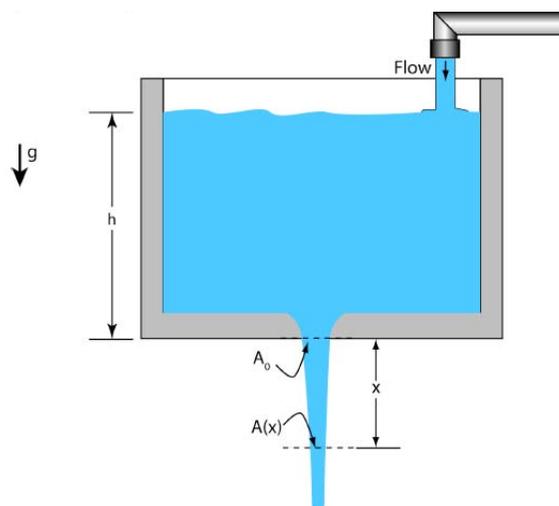
Due: Thursday, May 2, 2013, 1:05 PM

Topics: Mass Conservation, Momentum Equation

Readings: White Chapter 3

Problem 1 – Shorter problems

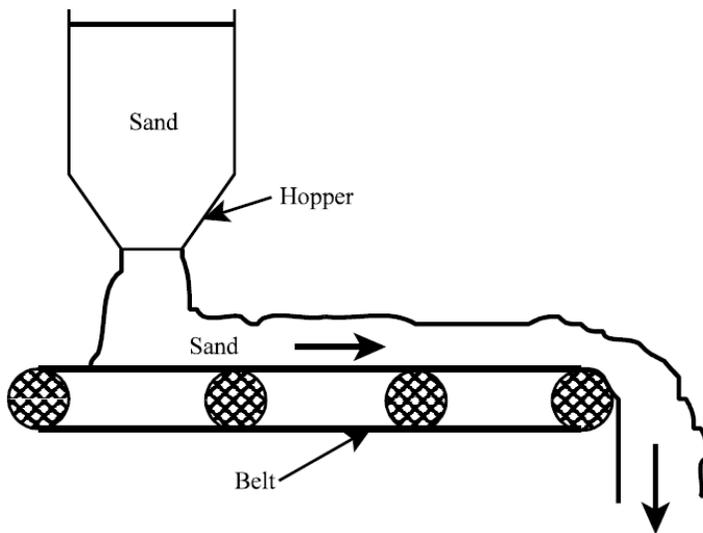
- a) If a device has one inlet and one outlet, do the mass flow rates have to be equal? Explain.
- b) Air, modeled as an ideal gas ($R=287 \text{ J/kg K}$), flows at a steady rate through a horizontal pipe of constant circular cross-sectional area. The temperature of the air is constant at $T_{air} = 25^\circ\text{C}$ all along the flow direction. At point A, the pressure is $P_A = 3 \times 10^5 \text{ N/m}^2$ and the bulk mean velocity is $V_A = 100 \text{ m/sec}$. At point B the pressure is $P_B = 2 \times 10^5 \text{ N/m}^2$. What is the bulk mean velocity at B?
- c) A large water tank has a small orifice on its bottom. The cross-sectional area of the jet emerging from the orifice (at $x=0$) is A_0 . The level of the water in the tank is kept at a constant level (h) by continuously filling the tank. Please find an expression for the cross-sectional area A as a function of the distance away from the bottom surface of the tank x and explain this qualitatively. Please assume that water is inviscid and that surface tension effects may be neglected.



Problem 2 – Shorter problems

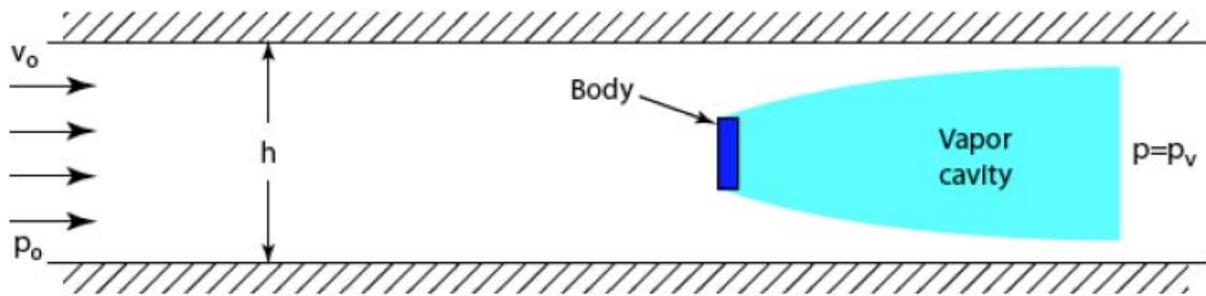
a) A fire hose ejects water ($\rho=1000 \text{ kg/m}^3$) through the nozzle of diameter 3 cm at a velocity of 30 m/s. The stream is directed at a stationary wall. Please determine the net force felt by the wall due to the stream. (Note that without the stream the wall would still feel a force due to atmospheric pressure.)

b) As shown in the sketch below, a hopper dumps sand on to a moving belt at the rate of 65 kg/s. The belt carries the sand a short distance and then drops it off the end of the belt and into a waiting truck. The drive wheels are 80 cm in diameter and rotate clockwise at 150 rev/min. Neglecting friction and air drag, estimate the power required to drive the belt.



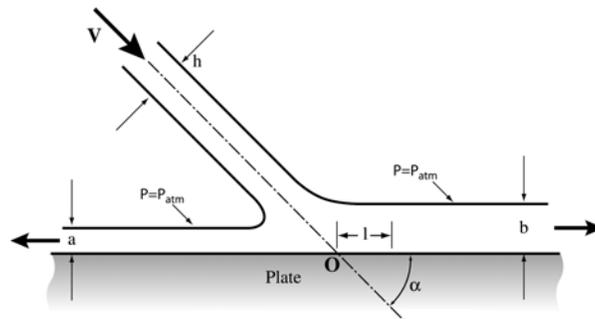
c) Two firefighters are fighting a fire with identical water hoses and nozzles, except that one is holding the hose straight so that the water leaves the nozzle in the same direction it enters the hose, while the other holds it backward so that the water makes a U turn before being discharged. Which firefighter (if any) will experience a greater reaction force? Explain.

Problem 3



A two dimensional body is mounted in a two dimensional water tunnel of breadth h . The velocity v_o far upstream is fixed. It is observed when the upstream pressure p_o is lowered sufficiently, the liquid behind the body boils and forms a very long cavity at the vapor pressure p_v ($p_v < p_o$). The velocity across the liquid jets forming the boundary of the cavity can be assumed to be uniform far downstream. Also assume there is no friction and that the density of the vapor and the effect of gravity are negligible. What is the drag force per unit width in terms of v_o , p_o , p_v , h , and the constant density of the liquid, ρ ?

Problem 4



A steady, incompressible, frictionless, two dimensional jet of fluid with density ρ , breadth h , velocity V , and unit width impinges on a flat plate held at angle α to its axis. Gravitational forces can be neglected. Please determine the total force on the plate, and the breadths a and b of the two branches.

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