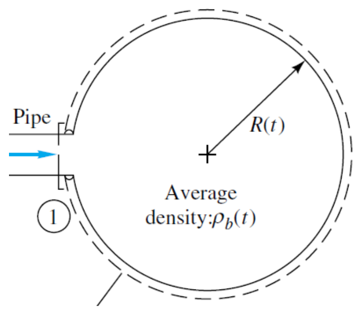
Problem Set – 3

ME 231A

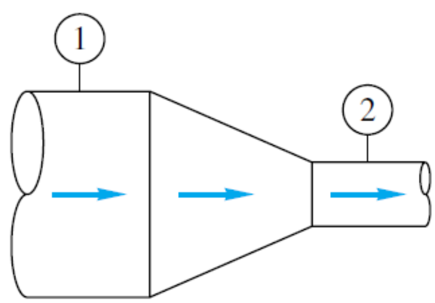
1. A laboratory test tank contains seawater of salinity S and density ρ. Water enters the tank at conditions (S_1, ρ_1, A_1, V_1) and is assumed to mix immediately in the tank. Tank water leaves through an outlet A_2 at velocity V_2. If salt is a "conservative" property (neither created nor destroyed), use the Reynolds transport theorem to find an expression for the rate of change of salt mass M_{salt} within the tank.

2. A room contains dust of uniform concentration C = ρ_{dust}/ρ. It is to be cleaned up by introducing fresh air at velocity V_i through a duct of area A_i on one wall and exhausting the room air at velocity V_0 through a duct A_0 on the opposite wall. Find an expression for the instantaneous rate of change of dust mass within the room.

3. The balloon in Fig. 3 is being filled through section 1, where the area is A_1, velocity is V_1, and fluid density is ρ_1. The average density within the balloon is ρ_b (t). Find an expression for the rate of change of system mass within the balloon at this instant.

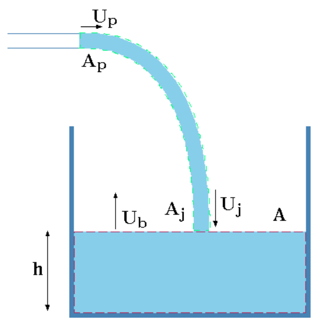


4. Water at 20°C flows steadily at 40 kg/s through the nozzle in Fig. 4. If D_1 18 cm and D_2 5 cm, compute the average velocity, in m/s, at (a) section 1 and (b) section 2.

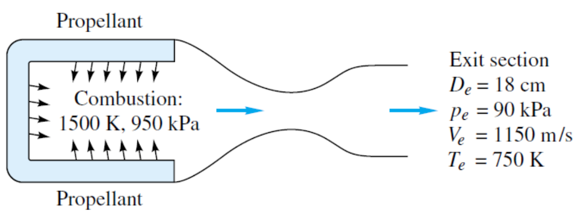


5. Liquid fills a bucket as shown in Fig. 5. The average velocity of the liquid at the exit of the filling pipe is *Up* and cross section of the pipe is *Ap*. The liquid fills a bucket with cross section area of **A** and instantaneous height is *h*. Find the height as a function of the other parameters. Assume that the density is constant and at the boundary interface *Aj*=0.7*Ap*. And where *Aj* is the

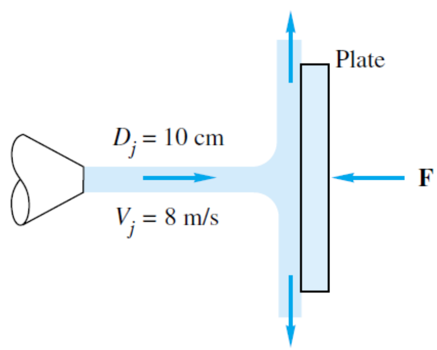
area of jet when touching the liquid boundary in bucket. The last assumption is result of the energy equation (with some influence of momentum equation). The relationship is function of the distance of the pipe from the boundary of the liquid. However, this effect can be neglected for this range which this problem. In reality, the ratio is determined by height of the pipe from the liquid surface in the bucket. Calculate the bucket liquid interface velocity.



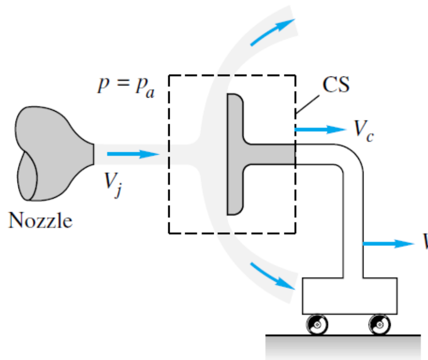
6. A solid propellant rocket in Fig. 6 is self-contained and has no entrance ducts. Using a control-volume analysis for the conditions shown in Fig. 6, compute the rate of mass loss of the propellant, assuming that the exit gas has a molecular weight of 28.



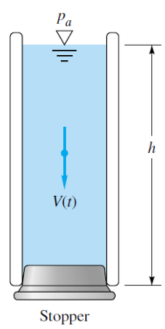
7. The water jet in Fig. 7 strikes normal to a fixed plate. Neglect gravity and friction, and compute the force F in Newtons required to hold the plate fixed.



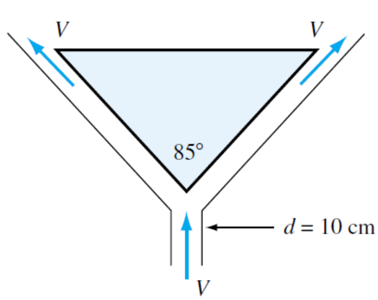
8. A water jet of velocity V_j impinges normal to a flat plate which moves to the right at velocity V_c, as shown in Fig. 8. Find the force required to keep the plate moving at constant velocity if the jet density is 1000 kg/m^3, the jet area is 3 cm^2, and V_j and V_c are 20 and 15 m/s, respectively. Neglect the weight of the jet and plate, and assume steady flow with respect to the moving plate with the jet splitting into an equal upward and downward half-jet.



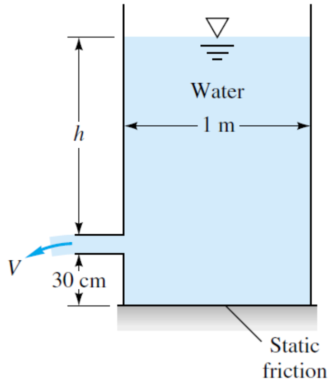
9. As shown in Fig. 9, a liquid column of height h is confined in a vertical tube of cross-sectional area A by a stopper. At t = 0 the stopper is suddenly removed, exposing the bottom of the liquid to atmospheric pressure. Using a control-volume analysis of mass and vertical momentum, derive the differential equation for the downward motion V(t) of the liquid. Assume one-dimensional, incompressible, frictionless flow.



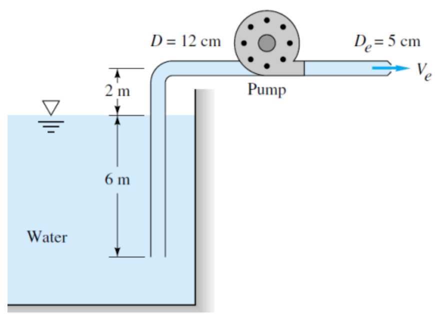
10. Air at 20°C and 1 atm enters the bottom of an 85° conical flowmeter duct at a mass flow of 0.3 kg/s, as shown in Fig. 10. It is able to support a centered conical body by steady annular flow around the cone, as shown. The air velocity at the upper edge of the body equals the entering velocity. Estimate the weight of the body, in newtons.



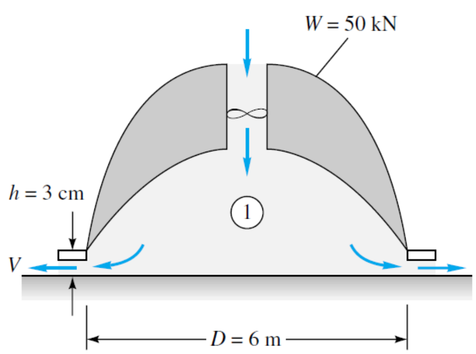
11. Torricelli's idealization of efflux from a hole in the side of a tank is $v = \sqrt{2gh}$, as shown in Fig. 11. The cylindrical tank weighs 150 N when empty and contains water at 20°C. The tank bottom is on very smooth ice (static friction coefficient 0.01). The hole diameter is 9 cm. For what water depth h will the tank just begin to move to the right?



12. When the pump in Fig. 12 draws 220 m^3/h of water at 20°C from the reservoir, the total friction head loss is 5 m. The flow discharges through a nozzle to the atmosphere. Estimate the pump power in kW delivered to the water.



13. The air-cushion vehicle in Fig. 13 brings in sea-level standard air through a fan and discharges it at high velocity through an annular skirt of 3-cm clearance. If the vehicle weighs 50 kN, estimate (a) the required airflow rate and (b) the fan power in kW.



14. A liquid jet of velocity V_j and area A_j strikes a single 180° bucket on a turbine wheel rotating at angular velocity Ω , as in Fig. 14. Derive an expression for the power P delivered to this wheel at this instant as a function of the system parameters. At what angular velocity is the maximum power delivered? How would your analysis differ if there were many, many buckets on the wheel, so that the jet was continually striking at least one bucket?