Fluid Mechanics

Assignment-5 (Momentum Conservation)

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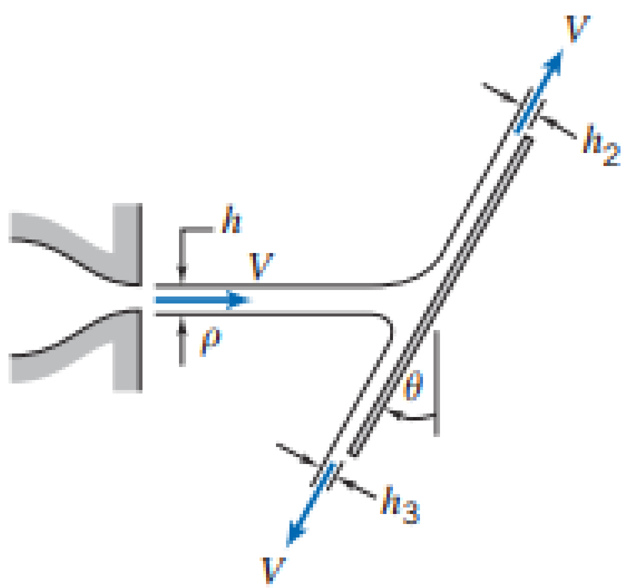
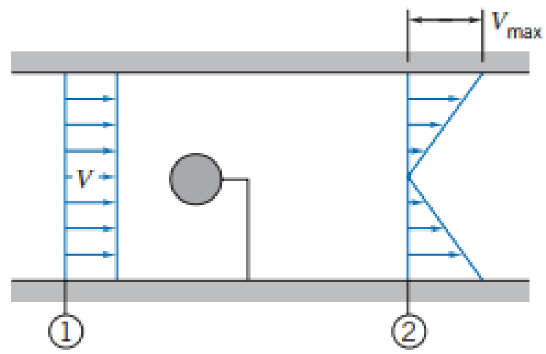
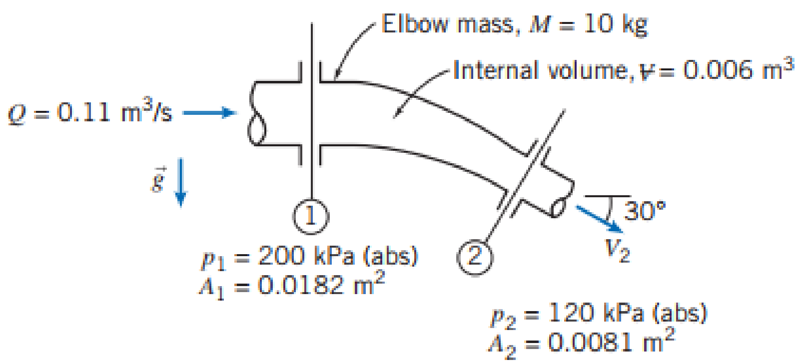
1. When a plane liquid jet strikes an inclined flat plate, it splits into two streams of equal speed but unequal thickness. For frictionless flow there can be no tangential force on the plate surface. Use this assumption to develop an expression for h_2/h as a function of plate angle, θ.



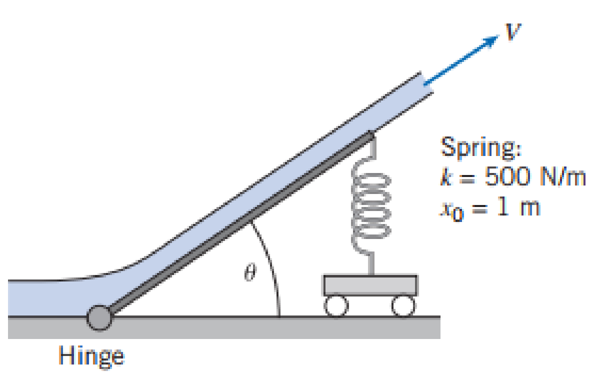
2. A small round object is tested in a 0.75 m diameter wind tunnel. The pressure is uniform across sections 1 and 2. The upstream pressure is 30 mm H_2O (gage), the downstream pressure is 15 mm H_2O (gage), and the mean air speed is 12.5 m/s. The velocity profile at section 2 is linear; it varies from zero at the tunnel centerline to a maximum at the tunnel wall. Calculate (a) the mass flow rate in the wind tunnel, (b) the maximum velocity at section 2, and (c) the drag of the object and its supporting vane. Neglect viscous resistance at the tunnel wall.



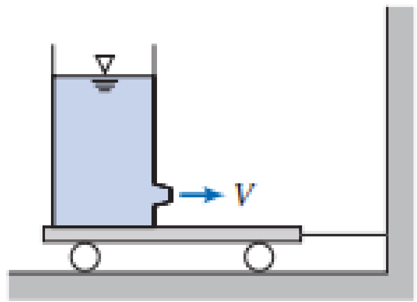
3. A 30^0 reducing elbow is shown. The fluid is water. Evaluate the components of force that must be provided by the adjacent pipes to keep the elbow from moving.



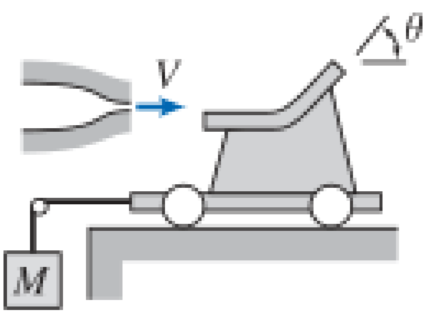
4. A free jet of water with constant cross-section area 0.01 m^2 is deflected by a hinged plate of length 2 m supported by a spring with spring constant $k = 500\,\mathrm{N/m}$ and uncompressed length $x_0 = 1$ m. (a) Find the deflection angle θ as a function of jet speed V. (b) What jet speed has a deflection of $\theta = 5^0$?



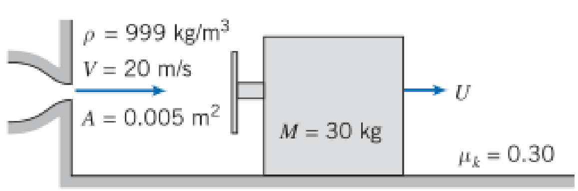
5. A large tank of height $h = 1$ m and diameter $D = 0.75$ m is affixed to a cart as shown. Water issues from the tank through a nozzle of diameter $d = 15$ mm. The speed of the liquid leaving the tank is approximately $V = \sqrt{2gy}$, where y is the height from the nozzle to the free surface. Determine the tension in the wire when $y = 0.9$ m.



6. A jet of water issuing from a stationary nozzle at $10\,\mathrm{m\,s^{-1}}$, with jet area $0.1\,\mathrm{m}^2$, strikes a turning vane mounted on a cart as shown. The vane turns the jet through angle $\theta = 40^0$. Determine the value of mass M required to hold the cart stationary.



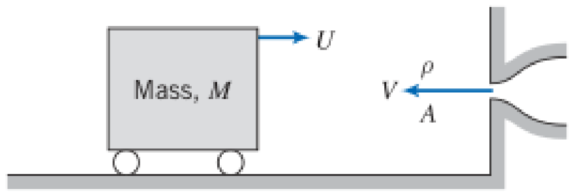
7. A vane/slider assembly moves under the influence of a liquid jet as shown. The coefficient of kinetic friction for motion of the slider along the surface is $\mu_k = 0.30$. Calculate the terminal speed of the slider.



8. A rectangular block of mass M, with vertical faces, rolls without resistance along a smooth horizontal plane as shown. The block travels initially at speed U_0. At $t = 0$ the block is struck by a liquid jet and its speed begins to slow.

   (a) Obtain an algebraic expression for the acceleration of the block for $t > 0$.

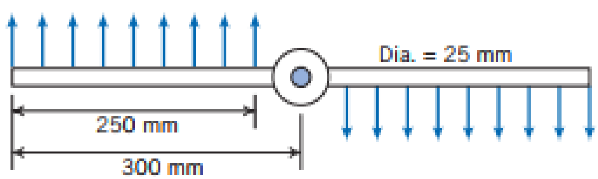
   (b) Solve the equation to determine the time at which $U = 0$.



9. Water flows in a uniform flow out of the 2.5 mm slots of the rotating spray system, as shown. The flow rate is 3 L/s. Find

   (a) the torque required to hold the system stationary and

   (b) the steady-state speed of rotation after it is released.



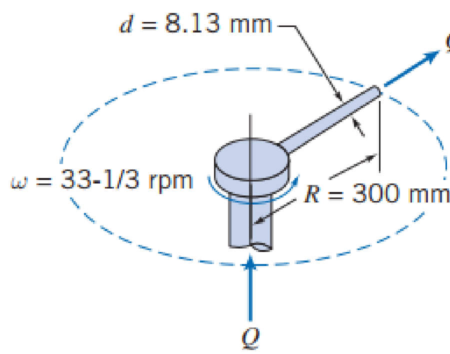
10. A single tube carrying water rotates at constant angular speed, as shown. Water is pumped through the tube at volume flow rate $Q = 13.8$ L/min.

    Find the torque that must be applied to maintain the steady rotation of the tube using two methods of analysis:

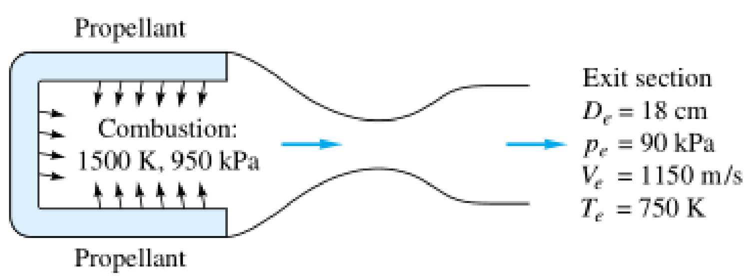
    (a) a rotating control volume

    and

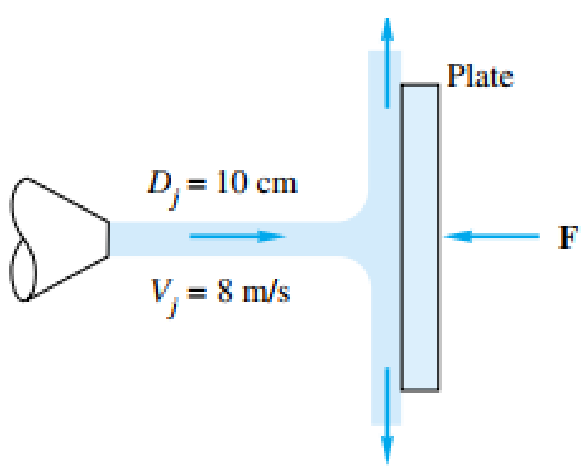
    (b) a fixed control volume.



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



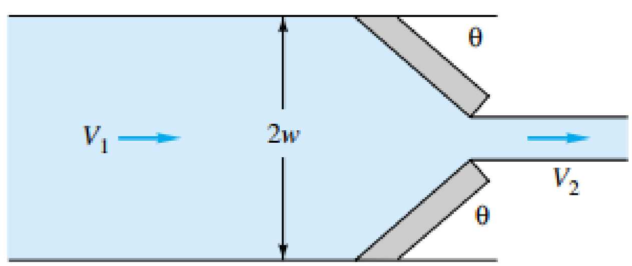
12. The water jet in the below figure strikes normal to a fixed plate. Neglect gravity and friction, and compute the force F in Newtons required to hold the plate fixed.



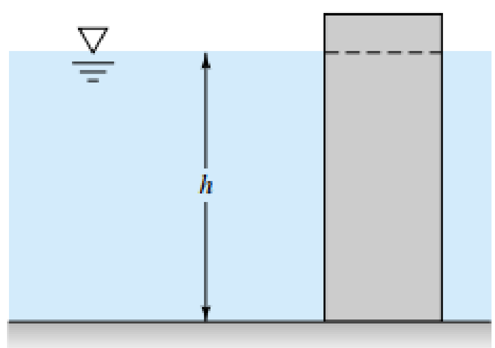
13. The vertical gate in a water channel is partially open, as in the figure below. Assuming no change in water level and a hydrostatic pressure distribution,

(a) derive an expression for the streamwise force F_x on one-half of the gate as a function of $(\rho, h, w, \theta, V_1)$.

(b) Apply your result to the case of water at $20^0 C$, $V_1 = 0.8\,\mathrm{m\,s^{-1}}, h = 2\,\mathrm{m}, w = 1.5\,\mathrm{m}$, and $\theta = 50^0$.

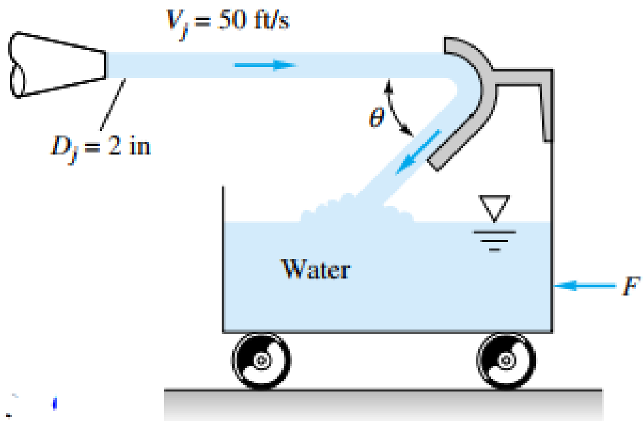


Top view

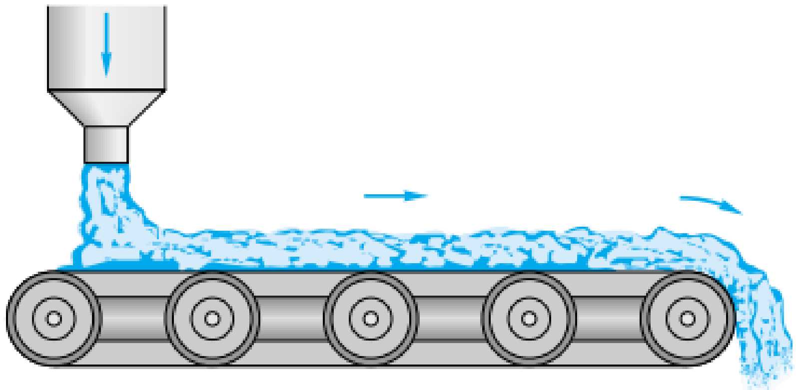


Side view

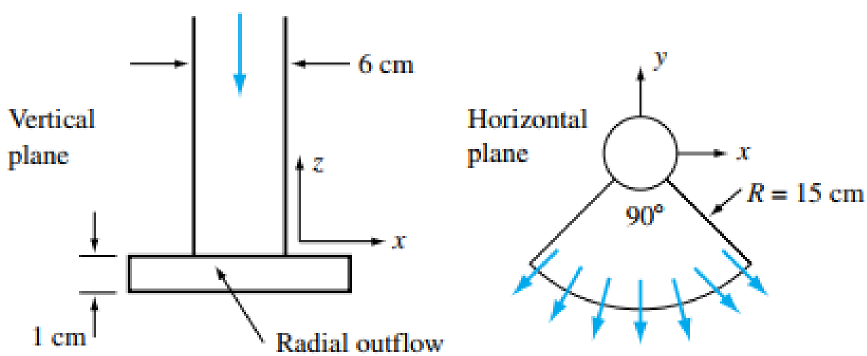
14. A $20^0 C$ water jet strikes a vane on a tank with frictionless wheels, as shown. The jet turns and falls into the tank without spilling. If $\theta = 30^0$, estimate the horizontal force F (in Newtons) needed to hold the tank stationary.



15. Gravel is dumped from a hopper, at a rate of 650 N/s, onto a moving belt, as in the figure below. The gravel then passes off the end of the belt. The drive wheels are 80 cm in diameter and rotate clockwise at 150 r/min. Neglecting system friction and air drag, estimate the power required to drive this belt.



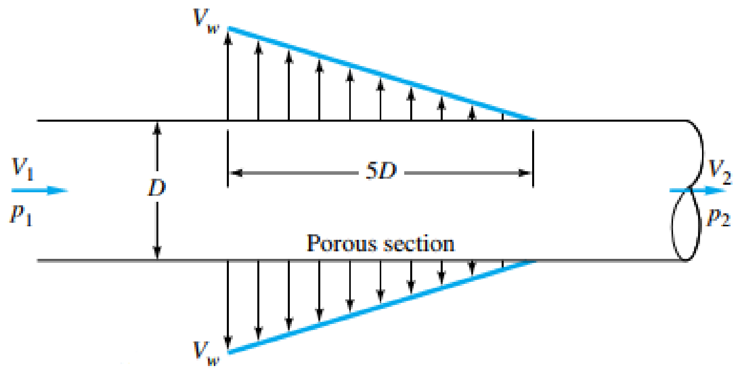
16. Water at 20^0C flows down a vertical 6-cm-diameter tube at 300 gal/min, as in the figure. The flow then turns horizontally and exits through a 90^0 radial duct segment 1 cm thick, as shown. If the radial outflow is uniform and steady, estimate the forces (F_x, F_y, F_z) required to support this system against fluid momentum changes.



17. The below figure simulates a manifold flow, with fluid removed from a porous wall or perforated section of pipe. Assume incompressible flow with negligible wall friction and small suction $V_w \ll V_1$. If (p_1, V_1, V_w, ρ, D) are known, derive expressions for

    (a) V_2 and

    (b) p_2.


V_w
V_1
p_1
D
$5D$
Porous section
V_2
p_2
V_w