REFERENCES

1. Hibbeler, R.C. *Dynamics.* Englewood Cliffs, NJ: Prentice Hall, 1995.

PROBLEMS

WILEY PLUS Problem available in *WileyPLUS* at instructor's discretion.

WILEY GO Guided Online (GO) Problem, available in *WileyPLUS* at instructor's discretion.

Newton's Second Law of Motion (§6.1)

6.1 Identify the surface and body forces acting on a glider in flight. Also, sketch a free body diagram and explain how Newton's laws of motion apply.

6.2 Newton's second law can be stated that the force is equal to the rate of change of momentum, $F = d(mv)/dt$. Taking the derivative by parts yields $F = m(dv)/(dt) + v(dm)/(dt)$. This does not correspond to $F = ma$. What is the source of the discrepancy?

The Linear Momentum Equation: Theory (§6.2)

6.3 WILEY PLUS Which of the following are correct with respect to the derivation of the momentum equation? (Select all that apply.)

- **a.** Reynold's transport theorem is applied to Fick's law.
- **b.** The extensive property is momentum.
- **c.** The intensive property is mass.
- **d.** The velocity is assumed to be uniformly distributed across each inlet and outlet.
- **e.** The net momentum flow is the "ins" minus the "outs."
- **f.** The net force is the sum of forces acting on the matter inside the CV

The Linear Momentum Equation: Application (§6.3)

6.4 WILEY PLUS When making a force diagram (FD) and its partner momentum diagram (MD) to set up the equations for a momentum equation problem (see Fig. 6.10 on p. 217 in §6.3), which of the following elements should be in the FD, and which should be in the MD? (Classify all below as either FD or MD.)

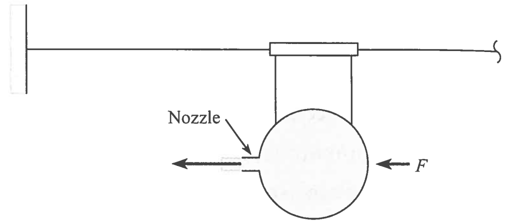
- **a.** Each mass stream with product $\dot{m}_o\mathbf{v}_o$ or product $\dot{m}_i\mathbf{v}_i$ crossing a control surface boundary.
- **b.** Reaction forces required to hold walls, vanes, or pipes in place.
- **c.** Weight of a solid body that contains or contacts the fluid.
- **d.** Weight of the fluid.
- **e.** Pressure force caused by a fluid flowing across a control surface boundary.

Applying the Momentum Equation to Fluid Jets (§6.4)

6.5 Give five examples of jets and how they are used in practice.

6.6 WILEY PLUS A "balloon rocket" is a balloon suspended from a taut wire by a hollow tube (drinking straw) and string. The nozzle is formed of a 0.8-cm-diameter tube, and an air jet exits the nozzle with a speed of 45 m/s and a density of 1.2 kg/m^3. Find the force F needed to hold the balloon stationary. Neglect friction.

6.7 WILEY PLUS The balloon rocket is held in place by a force F. The pressure inside the balloon is 20 cm-H_2O, the nozzle diameter is 1.0 cm, and the air density is 1.2 kg/m^3. Find the exit velocity v and the force F. Neglect friction and assume the air flow is inviscid and irrotational.

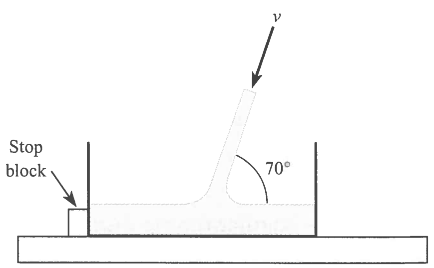


PROBLEMS 6.6, 6.7

6.8 WILEY PLUS For Example 6.2 in §6.4, the situation diagram shows concrete being "shot" at an angle into a cart that is tethered by a cable, and sitting on a scale. Determine whether the following two statements are "true" or "false."

- **a.** Mass is being accumulated in the cart.
- **b.** Momentum is being accumulated in the cart.

6.9 WILEY PLUS A water jet of diameter 30 mm and speed v = 25 m/s is filling a tank. The tank has a mass of 25 kg and contains 25 liters of water at the instant shown. The water temperature is 15°C. Find the force acting on the bottom of the tank and the force acting on the stop block. Neglect friction.



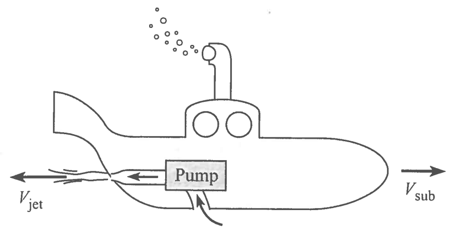
PROBLEMS 6.9, 6.10

6.10 WILEY GO A water jet of diameter 5 cm and speed v =18 m/s is filling a tank. The tank has a mass of 12 kg and contains 20 liters of water at the instant shown. The water temperature is 21°C. Find the minimum coefficient of friction such that the force acting on the stop block is zero.

6.11 A design contest features a submarine that will travel at a steady speed of V_{sub} = 1 m/s in 15°C water. The sub is powered by a water jet. This jet is created by drawing water from an inlet of diameter 25 mm, passing this water through a pump and then accelerating the water through a nozzle of diameter 5 mm to a speed of V_{jet}. The hydrodynamic drag force (F_D) can be calculated using

$$F_D = C_D\left(\frac{\rho V_{sub}^2}{2}\right)A_p$$

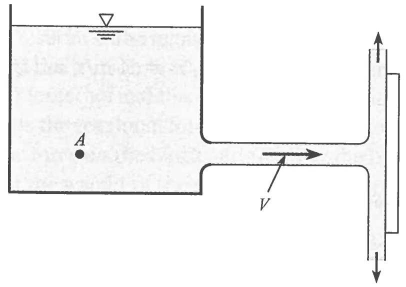
where the coefficient of drag is C_D = 0.3 and the projected area is A_p = 0.28 m^2. Specify an acceptable value of V_{jet}.



PROBLEM 6.11

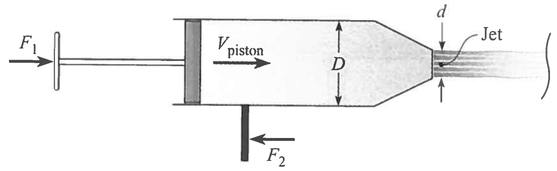
6.12 A horizontal water jet at 21°C impinges on a vertical-perpendicular plate. The discharge is 0.05 m^3/s. If the external force required to hold the plate in place is 900 N, what is the velocity of the water?

6.13 WILEY PLUS A horizontal water jet at 21°C issues from a circular orifice in a large tank. The jet strikes a vertical plate that is normal to the axis of the jet. A force of 2.7 kN is needed to hold the plate in place against the action of the jet. If the pressure in the tank is 170 kPa gage at point A, what is the diameter of the jet just downstream of the orifice?



PROBLEMS 6.12, 6.13

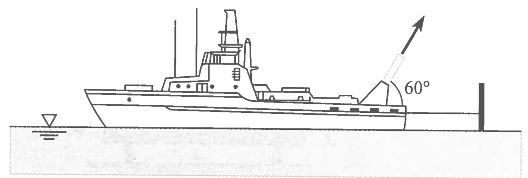
6.14 WILEY PLUS An engineer, who is designing a water toy, is making preliminary calculations. A user of the product will apply a force F_1 that moves a piston (D = 80 mm) at a speed of V_{piston} = 300 mm/s. Water at 20°C jets out of a converging nozzle of diameter d = 15 mm. To hold the toy stationary, the user applies a force F_2 to the handle. Which force (F_1 versus F_2) is larger? Explain your answer using concepts of the momentum principle. Then calculate F_1 and F_2. Neglect friction between the piston and the walls.



PROBLEM 6.14

6.15 A firehose on a boat is producing a 10 cm-diameter water jet with a speed of V =100 km/hr. The boat is held stationary by a cable attached to a pier, and the water temperature is 10°C. Calculate the tension in the cable.

6.16 WILEY PLUS A boat is held stationary by a cable attached to a pier. A firehose directs a spray of 5°C water at a speed of V = 50 m/s. If the allowable load on the cable is 5 kN, calculate the mass flow rate of the water jet. What is the corresponding diameter of the water jet?

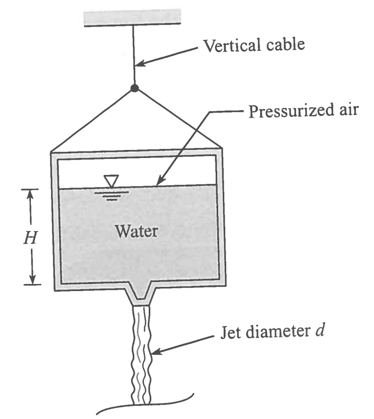


PROBLEMS 6.15, 6.16

6.17 WILEY GO A group of friends regularly enjoys white-water rafting, and they bring piston water guns to shoot water from one raft to another. One summer they notice that when on placid slack water (no current), after just a few volleys at each other, they are drifting apart. They wonder whether the jet being ejected out of a piston gun has enough momentum to force the shooter and raft backward. To answer this question,

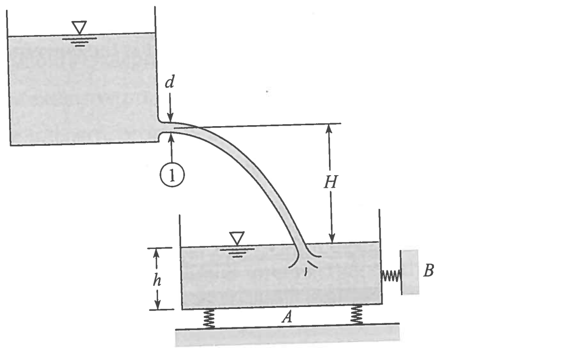
- **a.** Sketch a CV, an FD, and an MD for this system.
- **b.** Calculate the momentum flux (N) generated by ejecting water with a flow rate of 3.8 L/s from a cross section of 4 cm.

6.18 WILEY GO A tank of water (15°C) with a total weight of 200 N (water plus the container) is suspended by a vertical cable. Pressurized air drives a water jet (d = 12 mm) out the bottom of the tank such that the tension in the vertical cable is 10 N. If H = 425 mm, find the required air pressure in units of atmospheres (gage). Assume the flow of water is irrotational.



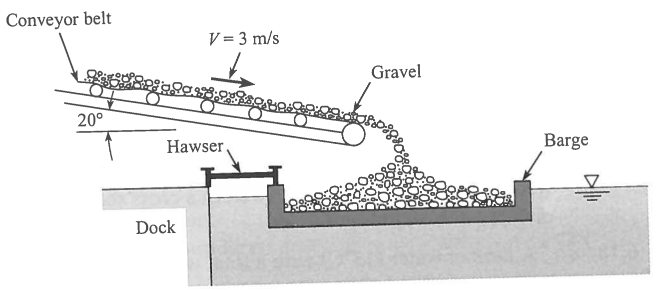
PROBLEM 6.18

6.19 WILEY PLUS A jet of water (15.5°C) is discharging at a constant rate of 0.05 m^3/s from the upper tank. If the jet diameter at section 1 is 10 cm, what forces will be measured by scales A and B? Assume the empty tank weighs 1.4 kN, the cross-sectional area of the tank is 0.37 m^2, $h = 0.3$ m, and $H = 2.7$ m.



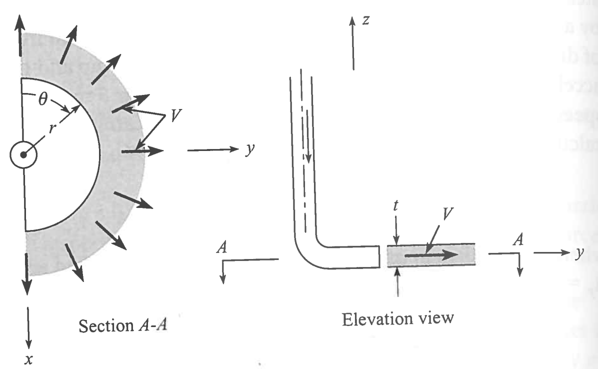
PROBLEM 6.19

6.20 A conveyor belt discharges gravel into a barge as shown at a rate of 38 m^3/min. If the gravel weighs 18.9 kN/m^3, what is the tension in the hawser that secures the barge to the dock?



PROBLEM 6.20

6.21 The semicircular nozzle sprays a sheet of liquid through 180° of arc as shown. The velocity is V at the efflux section where the sheet thickness is t. Derive a formula for the external force F (in the y-direction) required to hold the nozzle system in place. This force should be a function of ρ, V, r, and t.

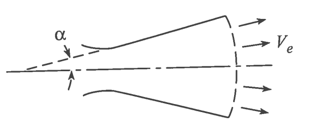


PROBLEM 6.21

6.22 The expansion section of a rocket nozzle is often conical in shape, and because the flow diverges, the thrust derived from the nozzle is less than it would be if the exit velocity were everywhere parallel to the nozzle axis. By considering the flow through the spherical section suspended by the cone and assuming that the exit pressure is equal to the atmospheric pressure, show that the thrust is given by

$$T = \dot{m}V_e \frac{(1 + \cos\alpha)}{2}$$

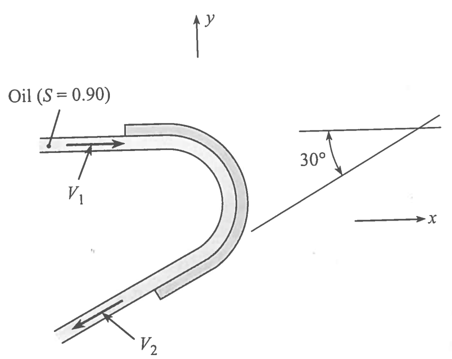
where $\dot{m}$ is the mass flow through the nozzle, V_e is the exit velocity, and α is the nozzle half-angle.



PROBLEM 6.22

Applying the Momentum Equation to Vanes (§6.4)

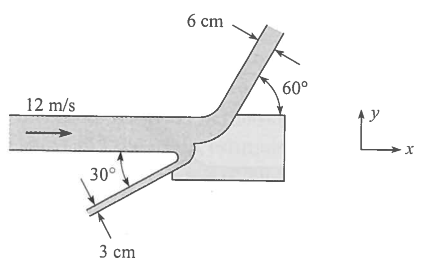
6.23 WILEY PLUS Determine the external reactions in the x- and y-directions needed to hold this fixed vane, which turns the oil jet ($S = 0.9$) in a horizontal plane. Here V_1 is 22 m/s, $V_2 = 21$ m/s, and $Q = 0.15$ m^3/s.



PROBLEMS 6.23, 6.24

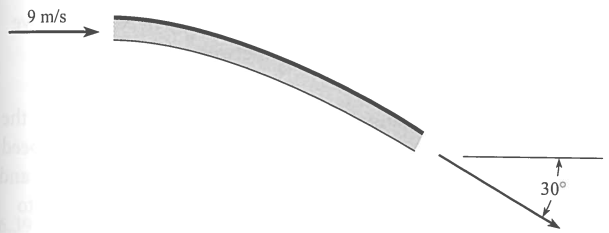
6.24 Solve Prob. 6.23 for $V_1 = 21$ m/s, $V_2 = 19.8$ m/s, and $Q = 0.043$ m^3/s.

6.25 WILEY PLUS This planar water jet (15.5°C) is deflected by a fixed vane. What are the x- and y-components of force per unit width needed to hold the vane stationary? Neglect gravity.



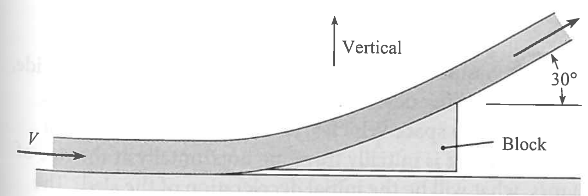
PROBLEM 6.25

6.26 WILEY PLUS A water jet with a speed of 9 m/s and a mass flow rate of 1.6 kg/s is turned 30° by a fixed vane. Find the force of the water jet on the vane. Neglect gravity.



PROBLEM 6.26

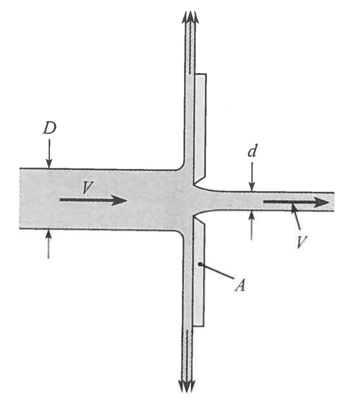
6.27 WILEY GO Water ($\rho = 1000$ kg/m^3) strikes a block as shown and is deflected 30°. The flow rate of the water is 1.5 kg/s, and the inlet velocity is $V = 10$ m/s. The mass of the block is 1 kg. The coefficient of static friction between the block and the surface is 0.1 (friction force/normal force). If the force parallel to the surface exceeds the frictional force, the block will move. Determine the force on the block and whether the block will move. Neglect the weight of the water.



PROBLEMS 6.27, 6.28

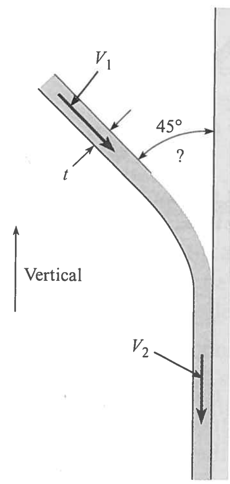
6.28 For the situation described in Prob. 6.27, find the maximum inlet velocity (V) such that the block will not slip.

6.29 WILEY PLUS Plate A is 50 cm in diameter and has a sharp-edged orifice at its center. A water jet (at 10°C) strikes the plate concentrically with a speed of 90 m/s. What external force is needed to hold the plate in place if the jet issuing from the orifice also has a speed of 90 m/s? The diameters of the jets are $D = 10$ cm and $d = 3.5$ cm.



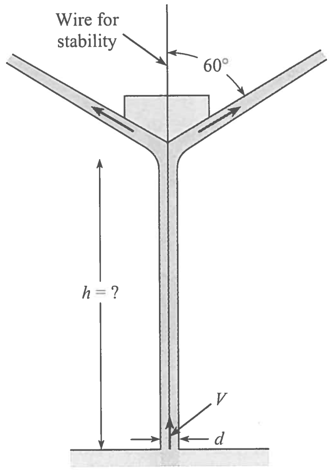
PROBLEM 6.29

6.30 A two-dimensional liquid jet impinges on a vertical wall. Assuming that the incoming jet speed is the same as the exiting jet speed ($V_1 = V_2$), derive an expression for the force per unit width of jet exerted on the wall. What form do you think the upper liquid surface will take next to the wall? Sketch the shape you think it will take, and explain your reasons for drawing it that way.



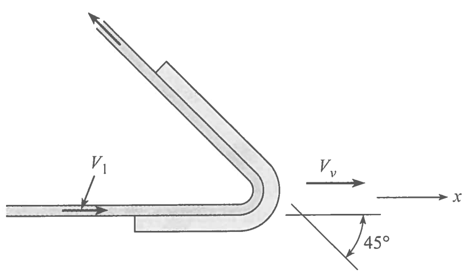
PROBLEM 6.30

6.31 WILEY PLUS A cone that is held stable by a wire is free to move in the vertical direction and has a jet of water (at 10°C) striking it from below. The cone weighs 30 N. The initial speed of the jet as it comes from the orifice is 15 m/s, and the initial jet diameter is 2 cm. Find the height to which the cone will rise and remain stationary. *Note:* The wire is only for stability and should not enter into your calculations.



PROBLEM 6.31

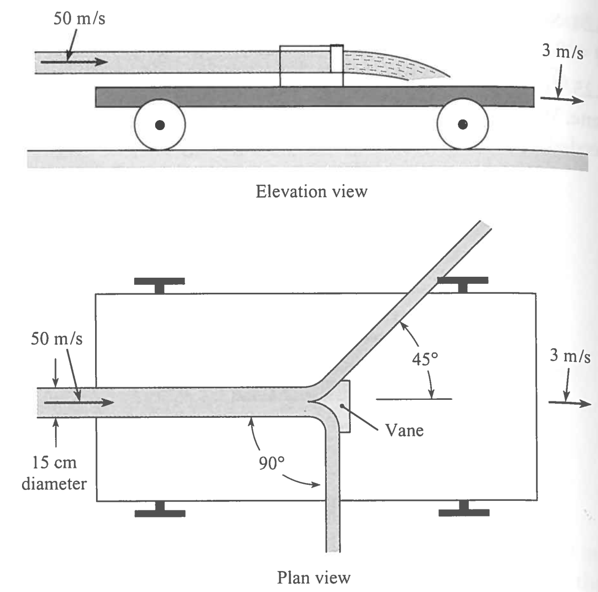
6.32 A horizontal jet of water (at 10°C) that is 6 cm in diameter and has a velocity of 20 m/s is deflected by the vane as shown. If the vane is moving at a rate of 7 m/s in the x-direction, what components of force are exerted on the vane by the water in the x- and y-directions? Assume negligible friction between the water and the vane.



PROBLEM 6.32

6.33 A vane on this moving cart deflects a 15-cm-diameter water (ρ = 1000 kg/m^3) jet as shown. The initial speed of the water in the jet is 50 m/s, and the cart moves at a speed of 3 m/s. If the vane splits the jet so that half goes one way and half the other, what force is exerted on the vane by the water?

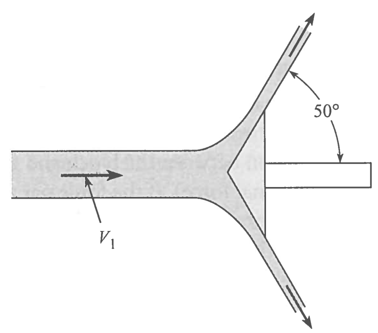
6.34 Refer to the cart of Prob. 6.33. If the cart speed is constant at 1.5 m/s, and if the initial jet speed is 18 m/s, and jet diameter = 45 mm, what is the rolling resistance of the cart? (ρ = 1000 kg/m^3)



PROBLEMS 6.33, 6.34

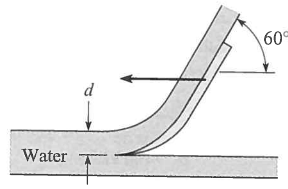
6.35 The water (ρ = 1000 kg/m^3) in this jet has a speed of 60 m/s to the right and is deflected by a cone that is moving to the left with a speed of 5 m/s. The diameter of the jet is 10 cm. Determine the external horizontal force needed to move the cone. Assume negligible friction between the water and the vane.

6.36 This two-dimensional water (at 10°C) jet is deflected by the two-dimensional vane, which is moving to the right with a speed of 18 m/s. The initial jet is 90 mm thick (vertical dimension), and its speed is 30 m/s. What power per meter of the jet (normal to the page) is transmitted to the vane?



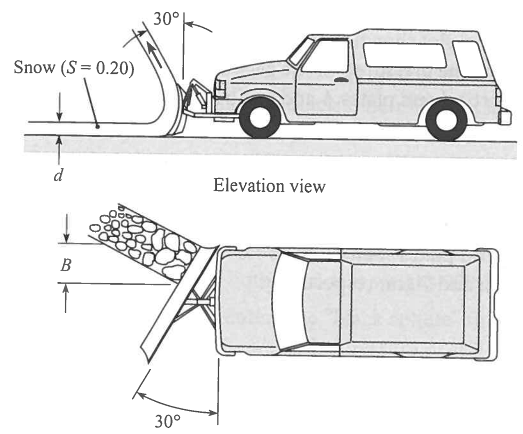
PROBLEMS 6.35, 6.36

6.37 Assume that the scoop shown, which is 20 cm wide, is used as a braking device for studying deceleration effects, such as those on space vehicles. If the scoop is attached to a 1000 kg sled that is initially traveling horizontally at the rate of 100 m/s, what will be the initial deceleration of the sled? The scoop dips into the water 8 cm (d = 8 cm). (T = 10°C.)



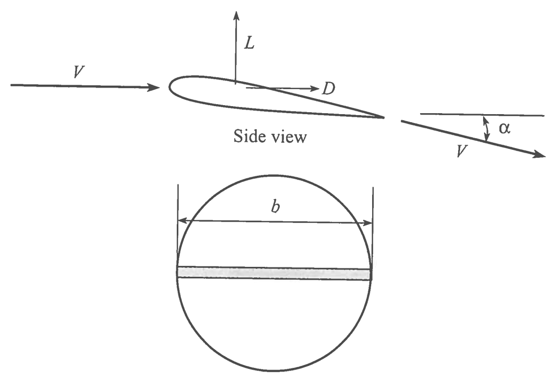
PROBLEM 6.37

6.38 This snowplow "cleans" a swath of snow that is 10 cm deep (d = 10 cm) and 0.6 m wide (B = 0.6 m). The snow leaves the blade in the direction indicated in the sketches. Neglecting friction between the snow and the blade, estimate the power required for just the snow removal if the speed of the snowplow is 12 m/s.



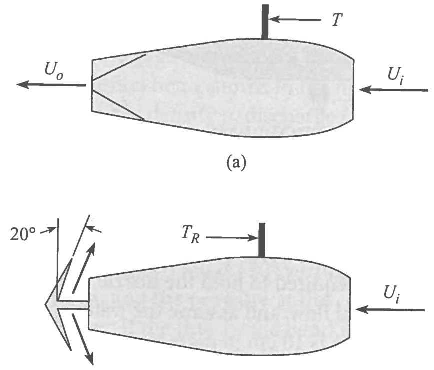
PROBLEM 6.38

6.39 A finite span airfoil can be regarded as a vane as shown in the figure. The cross section of air affected is equal to the circle with the diameter of the wing span, b. The wing deflects the air by an angle α and produces a force normal to the free-stream velocity, the lift L, and in the free-stream direction, the drag D. The airspeed is unchanged. Calculate the lift and drag for a 9 m wing span in a 90 m/s airstream at 101.3 kPa abs psia and 15.5°C for flow deflection of 2°.



PROBLEM 6.39

6.40 The "clam shell" thrust reverser sketched in the figure is often used to decelerate aircraft on landing. The sketch shows normal operation (a) and when deployed (b). The vanes are oriented 20° with respect to the vertical. The mass flow through the engine is 68 kg/s, the inlet velocity is 90 m/s, and the exit velocity is 425 m/s. Assume that when the thrust reverser is deployed, the exit velocity of the exhaust is unchanged. Assume the engine is stationary. Calculate the thrust under normal operation (N) and when the thrust reverser is deployed.



PROBLEM 6.40

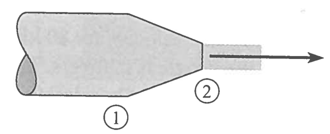
Applying the Momentum Equation to Nozzles (§6.4)

6.41 Firehoses are fitted with special nozzles. Use the Internet or contact your local fire department to find information on operational conditions and typical hose and nozzle sizes used.

6.42 High-speed water jets are used for speciality cutting applications. The pressure in the chamber is approximately 4.14 × 10^5 kPa gage. Using the Bernoulli equation, estimate the water speed exiting the nozzle exhausting to atmospheric pressure. Neglect compressibility effects and assume a water temperature of 15.5°C.

6.43 Water at 15.5°C flows through a nozzle that contracts from a diameter of 7.5 cm to 2.5 cm. The pressure at section 1 is 120 kPa, and atmospheric pressure prevails at the exit of the jet. Calculate the speed of the flow at the nozzle exit and the force required to hold the nozzle stationary. Neglect weight.

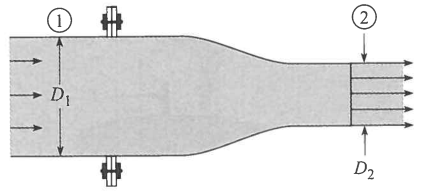
6.44 Water at 15°C flows through a nozzle that contracts from a diameter of 10 cm to 2 cm. The exit speed is v_2 = 25 m/s, and atmospheric pressure prevails at the exit of the jet. Calculate the pressure at section 1 and the force required to hold the nozzle stationary. Neglect weight.



PROBLEMS 6.43, 6.44

6.45 WILEY PLUS Water (at 10°C) flows through this nozzle at a rate of $0.56\ m^3/s$ and discharges into the atmosphere. $D_1 = 65$ cm, and $D_2 = 22.5$ cm. Determine the force required at the flange to hold the nozzle in place. Assume irrotational flow. Neglect gravitational forces.

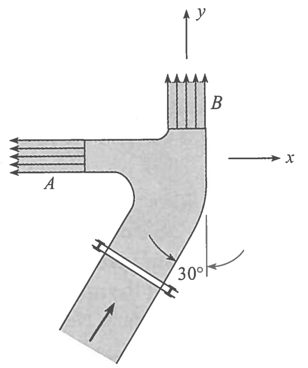
6.46 Solve Prob. 6.45 using the following values: $Q = 0.30\ m^3/s$, $D_1 = 30$ cm, and $D_2 = 10$ cm. ($\rho = 1000\ kg/m^3$.)



PROBLEMS 6.45, 6.46

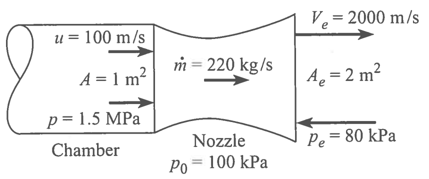
6.47 WILEY PLUS This "double" nozzle discharges water ($\rho = 1000\ kg/m^3$) into the atmosphere at a rate of $0.45\ m^3/s$. If the nozzle is lying in a horizontal plane, what x-component of force acting through the flange bolts is required to hold the nozzle in place? *Note:* Assume irrotational flow, and assume the water speed in each jet to be the same. Jet A is 10 cm in diameter, jet B is 12 cm in diameter, and the pipe is 0.3 m in diameter.

6.48 This "double" nozzle discharges water (at 10°C) into the atmosphere at a rate of $0.65\ m^3/s$. If the nozzle is lying in a horizontal plane, what x-component of force acting through the flange bolts is required to hold the nozzle in place? *Note:* Assume irrotational flow, and assume the water speed in each jet to be the same. Jet A is 8 cm in diameter, jet B is 9 cm in diameter, and the pipe is 30 cm in diameter.



PROBLEMS 6.47, 6.48

6.49 WILEY PLUS A rocket-nozzle designer is concerned about the force required to hold the nozzle section on the body of a rocket. The nozzle section is shaped as shown in the figure. The pressure and velocity at the entrance to the nozzle are 1.5 MPa and 100 m/s. The exit pressure and velocity are 80 kPa and 2000 m/s. The mass flow through the nozzle is 220 kg/s. The atmospheric pressure is 100 kPa. The rocket is not accelerating. Calculate the force on the nozzle-chamber connection. *Note:* The given pressures are absolute.

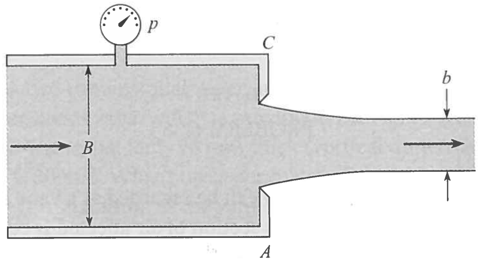


PROBLEM 6.49

6.50 A 15 cm nozzle is bolted with six bolts to the flange of a 30 cm pipe. If water ($\rho = 1000\ kg/m^3$) discharges from the nozzle into the atmosphere, calculate the tension load in each bolt when the pressure in the pipe is 200 kPa. Assume irrotational flow.

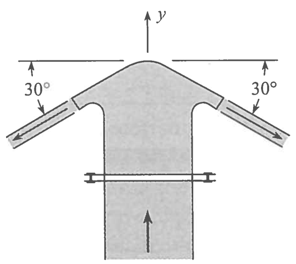
6.51 Water ($\rho = 1000\ kg/m^3$) is discharged from the two-dimensional slot shown at the rate of $0.23\ m^3/s$ per meter of slot. Determine the pressure p at the gage and the water force per meter on the vertical end plates A and C. The slot and jet dimensions B and b are 20 cm and 10 cm, respectively.

6.52 Water (at 10°C) is discharged from the two-dimensional slot shown at the rate of $0.40\ m^3/s$ per meter of slot. Determine the pressure p at the gage and the water force per meter on the vertical end plates A and C. The slot and jet dimensions B and b are 20 cm and 7 cm, respectively.



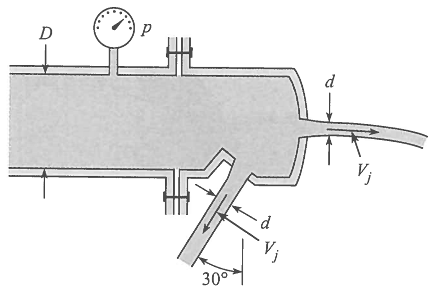
PROBLEMS 6.51, 6.52

6.53 This spray head discharges water ($\rho = 1000\ kg/m^3$) at a rate of $0.12\ m^3/s$. Assuming irrotational flow and an efflux speed of 20 m/s in the free jet, determine what force acting through the bolts of the flange is needed to keep the spray head on the 15 cm pipe. Neglect gravitational forces.



PROBLEM 6.53

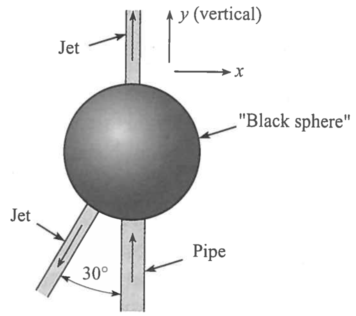
6.54 Two circular water ($\rho = 1000\ kg/m^3$) jets of 12 mm diameter ($d = 12$ mm) issue from this unusual nozzle. If the efflux speed is 25 m/s, what force is required at the flange to hold the nozzle in place? The pressure in the 10 cm pipe ($D = 9$ cm) is 345 kPa gage.



PROBLEM 6.54

6.55 Liquid (S = 1.2) enters the "black sphere" through a 5 cm pipe with velocity of 15 m/s and a pressure of 400 kPa gage. It leaves the sphere through two jets as shown. The velocity in the vertical jet is 30 m/s, and its diameter is 2.5 cm. The other jet's diameter is also 2.5 cm. What force through the 5 cm pipe wall is required in the x- and y-directions to hold the sphere in place? Assume the sphere plus the liquid inside it weighs 900 N.

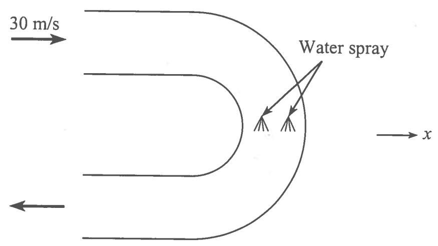
6.56 WILEY GO Liquid (S = 1.5) enters the "black sphere" through a 5 cm pipe with a velocity of 10 m/s and a pressure of 400 kPa. It leaves the sphere through two jets as shown. The velocity in the vertical jet is 30 m/s, and its diameter is 25 mm. The other jet's diameter is also 25 mm. What force through the 5 cm pipe wall is required in the x- and y-directions to hold the sphere in place? Assume the sphere plus the liquid inside it weighs 600 N.



PROBLEMS 6.55, 6.56

Applying the Momentum Equation to Pipe Bends (§6.4)

6.57 WILEY PLUS A hot gas stream enters a uniform-diameter return bend as shown. The entrance velocity is 90 m/s, the gas density is $0.32\ kg/m^3$, and the mass flow rate is 0.45 kg/s. Water is sprayed into the duct to cool the gas down. The gas exits with a density of $1\ kg/m^3$. The mass flow of water into the gas is negligible. The pressures at the entrance and exit are the same and equal to the atmospheric pressure. Find the force required to hold the bend.



PROBLEM 6.57

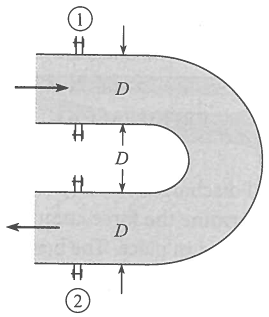
6.58 Assume that the gage pressure p is the same at sections 1 and 5 cm the horizontal bend shown in the figure. The fluid flowing in the bend has density ρ, discharge Q, and velocity V. The cross-sectional area of the pipe is A. Then the magnitude of the force (neglecting gravity) required at the flanges to hold the bend in place will be (a) pA, (b) $pA + \rho QV$, (c) $2pA + \rho QV$, or (d) $2pA + 2\rho QV$.

6.59 WILEY PLUS The pipe shown has a 180° vertical bend in it. The diameter D is 0.3m, and the pressure at the center of the upper pipe is 105 kPa gage. If the flow in the bend is $0.6\ m^3/s$, what external force will be required to hold the bend in place against the action of the water? The bend weighs 900 N, and the volume of the bend is $0.085\ m^3$. Assume the Bernoulli equation applies. ($\rho = 1000\ kg/m^3$)

6.60 The pipe shown has a 180° horizontal bend in it as shown, and D is 20 cm. The discharge of water ($\rho = 1000\ kg/m^3$) in the pipe and bend is $0.35\ m^3/s$, and the pressure in the pipe and bend is 100 kPa gage. If the bend volume is $0.10\ m^3$, and the bend itself weighs 400 N, what force must be applied at the flanges to hold the bend in place?

6.61 Set up the solution for Problem 6.60, and answer the following questions:

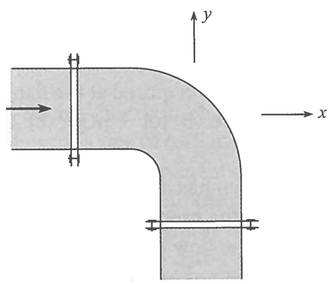
- **a.** Do the two pressure forces from the inlet and exit act in the same direction, or in opposite directions?
- **b.** For the data given, which term has the larger magnitude (in N), the pressure force term, or the net momentum flux term?



PROBLEMS 6.58, 6.59, 6.60, 6.61

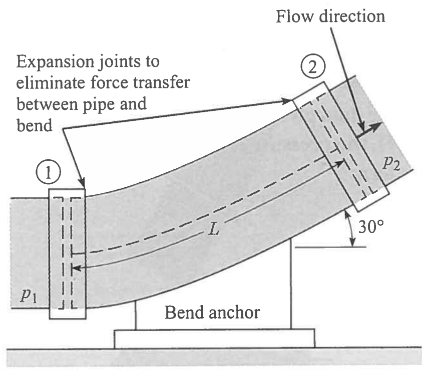
6.62 Water (at 10°C) flows in the 90° horizontal bend at a rate of 0.34 m^3/s and discharges into the atmosphere past the downstream flange. The pipe diameter is 0.3 m. What force must be applied at the upstream flange to hold the bend in place? Assume that the volume of water downstream of the upstream flange is 0.1 m^3 and that the bend and pipe weigh 445 N. Assume the pressure at the inlet section is 28 kPa gage.

6.63 WILEY PLUS The gage pressure throughout the horizontal 90° pipe bend is 300 kPa. If the pipe diameter is 1 m and the water (at 10°C) flow rate is 10 m^3/s, what x-component of force must be applied to the bend to hold it in place against the water action?



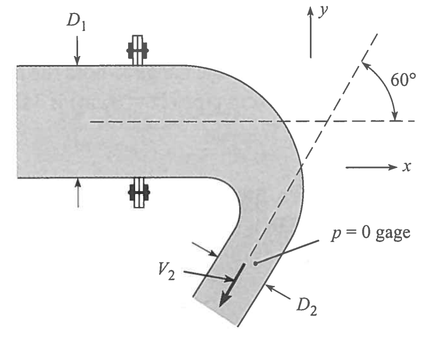
PROBLEMS 6.62, 6.63

6.64 This 30° vertical bend in a pipe with a 0.6 m diameter carries water ($\rho = 1000$ kg/m^3) at a rate of 0.9 m^3/s. If the pressure p_1 is 70 kPa at the lower end of the bend, where the elevation is 30 m, and p_2 is 60 kPa at the upper end, where the elevation is 31 m, what will be the vertical component of force that must be exerted by the "anchor" on the bend to hold it in position? The bend itself weighs 1350 N, and the length L is 1.2 m.



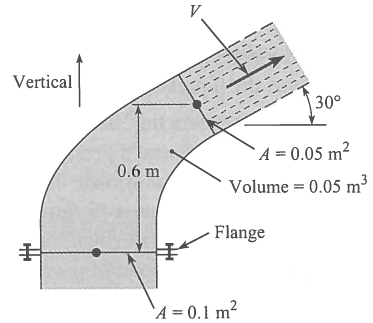
PROBLEM 6.64

6.65 WILEY GO This bend discharges water ($\rho = 1000$ kg/m^3) into the atmosphere. Determine the force components at the flange required to hold the bend in place. The bend lies in a horizontal plane. Assume viscous forces are negligible. The interior volume of the bend is 0.25 m^3, $D_1 = 60$ cm, $D_2 = 30$ cm, and $V_2 = 10$ m/s. The mass of the bend material is 250 kg.



PROBLEM 6.65

6.66 WILEY PLUS This nozzle bends the flow from vertically upward to 30° with the horizontal and discharges water ($\gamma = 9810$ N/m^3) at a speed of $V = 40$ m/s. The volume within the nozzle itself is 0.05 m^3, and the weight of the nozzle is 445 N. For these conditions, what *vertical* force must be applied to the nozzle at the flange to hold it in place?



PROBLEM 6.66

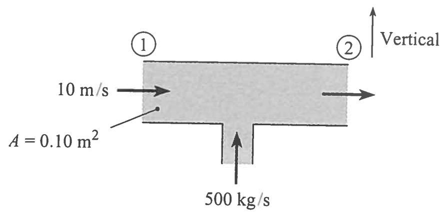
6.67 A pipe 0.3 m in diameter bends through an angle of 135°. The velocity of flow of gasoline (S = 0.8) is 6 m/s, and the pressure is 70 kPa gage in the bend. What external force is required to hold the bend against the action of the gasoline? Neglect the gravitational force.

6.68 WILEY PLUS A 15 cm horizontal pipe has a 180° bend in it. If the rate of flow of water (15.5°C) in the bend is 0.06 m^3/s and the pressure therein is 140 kPa gage, what external force in the original direction of flow is required to hold the bend in place?

6.69 A pipe 15 cm in diameter bends through 135°. The velocity of flow of gasoline (S = 0.8) is 8 m/s, and the pressure is 100 kPa gage throughout the bend. Neglecting gravitational force, determine the external force required to hold the bend against the action of the gasoline.

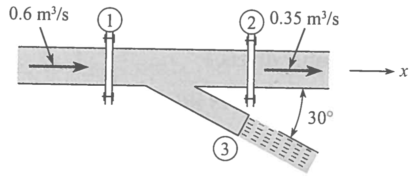
6.70 A horizontal reducing bend turns the flow of water ($\rho = 1000$ kg/m^3) through 60°. The inlet area is 0.001 m^2, and the outlet area is 0.0001 m^2. The water from the outlet discharges into the atmosphere with a velocity of 50 m/s. What horizontal force (parallel to the initial flow direction) acting through the metal of the bend at the inlet is required to hold the bend in place?

6.71 Water (at 10°C) flows in a duct as shown. The inlet water velocity is 10 m/s. The cross-sectional area of the duct is 0.1 m^2. Water is injected normal to the duct wall at the rate of 500 kg/s midway between stations 1 and 2. Neglect frictional forces on the duct wall. Calculate the pressure difference ($p_1 - p_2$) between stations 1 and 2.



PROBLEM 6.71

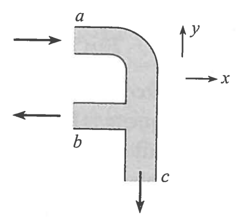
6.72 WILEY PLUS For this wye fitting, which lies in a horizontal plane, the cross-sectional areas at sections 1, 2, and 3 are 0.1 m^2, 0.1 m^2, and 0.025 m^2, respectively. At these same respective sections the pressures are 48 kPa gage, 43 kPa gage, and 0 kPa gage, and the water discharges are 0.6 m^3/s to the right, 0.35 m^3/s to the right, and exits to atmosphere at 0.23 m^3/s. What x-component of force would have to be applied to the wye to hold it in place?



PROBLEM 6.72

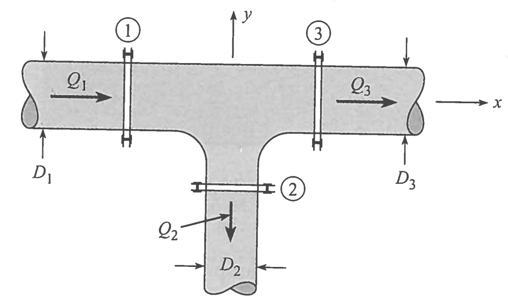
6.73 Water (ρ =1000 kg/m^3) flows through a horizontal bend and T section as shown. The mass flow rate entering at section a is 6 kg/s, and those exiting at sections b and c are 3 kg/s each. The pressure at section a is 35 kPa gage. The pressure at the two outlets is atmospheric. The cross-sectional areas of the pipes are the same: 32 cm^2. Find the x-component of force necessary to restrain the section.

6.74 Water ($\rho = 1000$ kg/m^3) flows through a horizontal bend and T section as shown. At section a the flow enters with a velocity of 6 m/s, and the pressure is 4.8 kPa. At both sections b and c the flow exits the device with a velocity of 3 m/s, and the pressure at these sections is atmospheric ($p = 0$). The cross-sectional areas at a, b, and c are all the same: 0.20 m^2. Find the x- and y-components of force necessary to restrain the section.



PROBLEMS 6.73, 6.74

6.75 For this horizontal T through which water ($\rho = 1000$ kg/m^3) is flowing, the following data are given: $Q_1 = 0.25$ m^3/s, $Q_2 = 0.10$ m^3/s, $p_1 = 100$ kPa, $p_2 = 70$ kPa, $p_3 = 80$ kPa, $D_1 = 15$ cm, $D_2 = 7$ cm, and $D_3 = 15$ cm. For these conditions, what external force in the x–y plane (through the bolts or other supporting devices) is needed to hold the T in place?

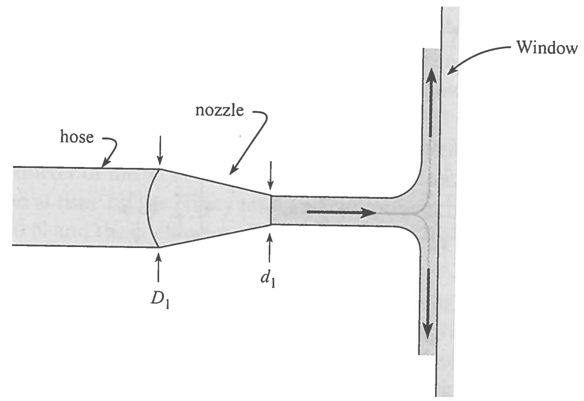


PROBLEM 6.75

Applying Momentum Equation: Other Situations (§6.4)

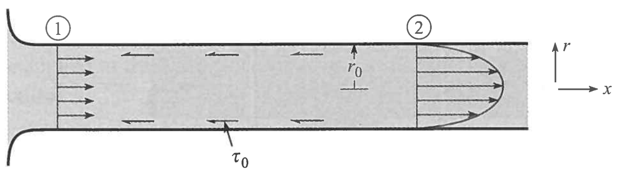
6.76 WILEY GO Firehoses can break windows. A 0.2-m diameter (D_1) firehose is attached to a nozzle with a 0.1 m diameter (d_2) outlet. The free jet from the nozzle is deflected by 90° when it hits the window as shown. Find the force the window must withstand due to the impact of the jet when water flows through the firehose at a rate of 0.15 m^3/s.

6.77 WILEY PLUS A fireman is soaking a home that is dangerously close to a burning building. To prevent water damage to the inside of the neighboring home, he throttles down his flow rate so that it will not break windows. Assuming the typical window should be able to withstand a force up to 110 N, what is the largest volumetric flow rate he should allow (liter/min.), given a 20-cm diameter (D_1) firehose discharging through a nozzle with 10 cm diameter (d_2) outlet. The free jet from the nozzle is deflected by 90° when it hits the window as shown.



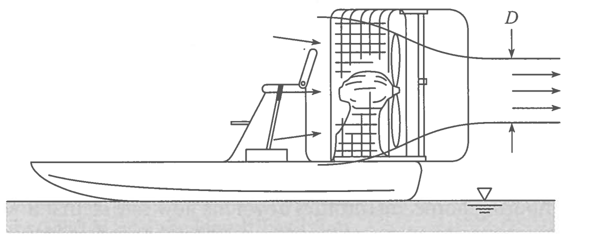
PROBLEMS 6.76, 6.77

6.78 For laminar flow in a pipe, wall shear stress (τ_0) causes the velocity distribution to change from uniform to parabolic as shown. At the fully developed section (section 2), the velocity is distributed as follows: $u = u_{max}[1 - (r/r_0)^2]$. Derive a formula for the force on the wall due to shear stress, F_τ, between 1 and 2 as a function of U (the mean velocity in the pipe), ρ, p_1, p_2, and D (the pipe diameter).



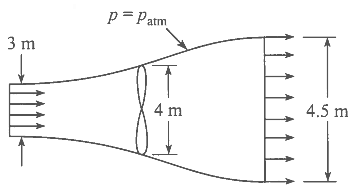
PROBLEM 6.78

6.79 WILEY PLUS The propeller on a swamp boat produces a slipstream 0.9 m in diameter with a velocity relative to the boat of 90 m/s. If the air temperature is 27°C, what is the propulsive force when the boat is not moving and also when its forward speed is 9 m/s? *Hint:* Assume that the pressure, except in the immediate vicinity of the propeller, is atmospheric.



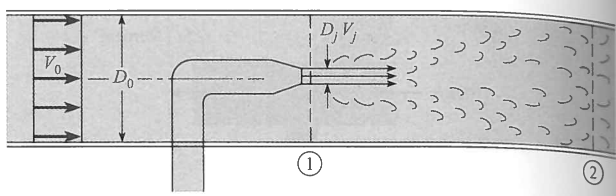
PROBLEM 6.79

6.80 WILEY PLUS A wind turbine is operating in a 12 m/s wind that has a density of 1.2 kg/m³. The diameter of the turbine silhouette is 4 m. The constant-pressure (atmospheric) streamline has a diameter of 3 m upstream of the windmill and 4.5 m downstream. Assume that the velocity distributions are uniform and the air is incompressible. Determine the thrust on the wind turbine.



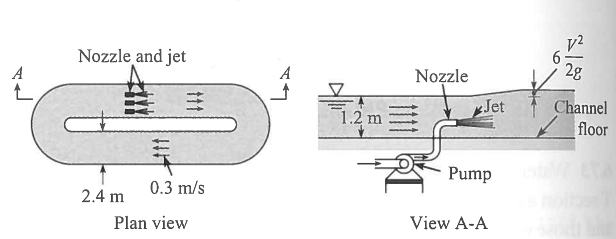
PROBLEM 6.80

6.81 WILEY PLUS The figure illustrates the principle of the jet pump. Derive a formula for $p_2 - p_1$ as a function of D_j, V_j, D_0, V_0, and ρ. Assume that the fluid from the jet and the fluid initially flowing in the pipe are the same, and assume that they are completely mixed at section 2, so that the velocity is uniform across that section. Also assume that the pressures are uniform across both sections 1 and 2. What is $p_2 - p_1$ if the fluid is water, $A_j/A_0 = 1/3$, $V_j = 15$ m/s, and $V_0 = 2$ m/s? Neglect shear stress.



PROBLEM 6.81

6.82 Jet-type pumps are sometimes used to circulate the flow in basins in which fish are being reared. The use of a jet-type pump eliminates the need for mechanical machinery that might be injurious to the fish. The accompanying figure shows the basic concept for this type of application. For this type of basin the jets would have to increase the water surface elevation by an amount equal to $6V^2/2g$, where V is the average velocity in the basin (0.3 m/s as shown in this example). Propose a basic design for a jet system that would make such a recirculating system work for a channel 2.4 m wide and 1.2 m deep. That is, determine the speed, size, and number of jets.



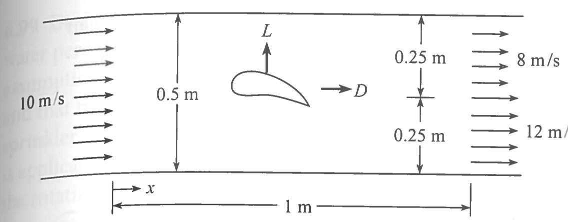
PROBLEM 6.82

6.83 An engineer is measuring the lift and drag on a wind turbine blade section mounted in a two-dimensional wind tunnel. The wind tunnel is 0.5 m high and 0.5 m deep (into the paper). The upstream wind velocity is uniform at 10 m/s, and the downstream velocity is 12 m/s and 8 m/s as shown. The vertical component of velocity is zero at both stations. The test section is 1 m long. The engineer measures the pressure distribution in the tunnel along the upper and lower walls and finds

$$p_u = 100 - 10x - 20x(1 - x)\text{(Pa gage)}$$

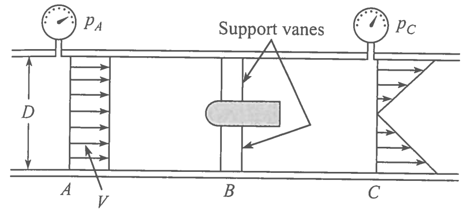
$$p_l = 100 - 10x + 20x(1 - x)\text{(Pa gage)}$$

where x is the distance in meters measured from the beginning of the test section. The gas density is homogeneous throughout and equal to 1.2 kg/m³. The lift and drag are the vectors indicated on the figure. The forces acting on the fluid are in the opposite direction to these vectors. Find the lift and drag forces acting on the wind turbine blade section.



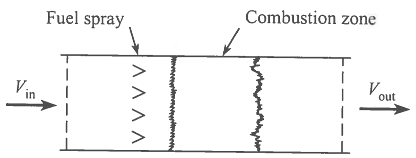
PROBLEM 6.83

6.84 WILEY PLUS A torpedolike device is tested in a wind tunnel with an air density of 1.35 kg/m³. The tunnel is 0.9 m in diameter, the upstream pressure is 1.65 kPa gage, and the downstream pressure is 0.7 kPa gage. If the mean air velocity V is 36 m/s, what are the mass rate of flow and the maximum velocity at the downstream section at C? If the pressure is assumed to be uniform across the sections at A and C, what is the drag of the device and support vanes? Assume viscous resistance at the walls is negligible.



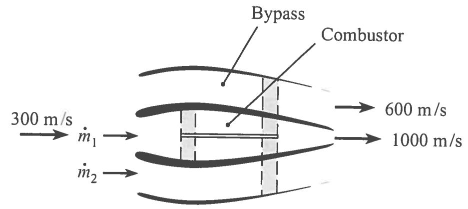
PROBLEM 6.84

6.85 A ramjet operates by taking in air at the inlet, providing fuel for combustion, and exhausting the hot air through the exit. The mass flow at the inlet and outlet of the ramjet is 60 kg/s (the mass flow rate of fuel is negligible). The inlet velocity is 225 m/s. The density of the gases at the exit is 0.25 kg/m³, and the exit area is 0.5 m². Calculate the thrust delivered by the ramjet. The ramjet is not accelerating, and the flow within the ramjet is steady.



PROBLEM 6.85

6.86 WILEY PLUS A modern turbofan engine in a commercial jet takes in air, part of which passes through the compressors, combustion chambers, and turbine, and the rest of which bypasses the compressor and is accelerated by the fans. The mass flow rate of bypass air to the mass flow rate through the compressor-combustor-turbine path is called the "bypass ratio." The total flow rate of air entering a turbofan is 300 kg/s with a velocity of 300 m/s. The engine has a bypass ratio of 2.5. The bypass air exits at 600 m/s, whereas the air through the compressor–combustor–turbine path exits at 1000 m/s. What is the thrust of the turbofan engine? Clearly show your control volume and application of momentum equation.



PROBLEM 6.86

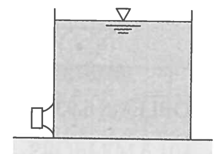
Applying Momentum Equation to Moving CVs (§6.5)

6.87 Using the Internet or some other source as reference, define in your own words the meaning of "inertial reference frame."

6.88 The surface of the earth is not a true inertial reference frame because there is a centripetal acceleration due to the earth's rotation. The earth rotates once every 24 hours and has a diameter of 12,900 kilometers. What is the centripetal acceleration on the surface of the earth, and how does it compare to the gravitational acceleration?

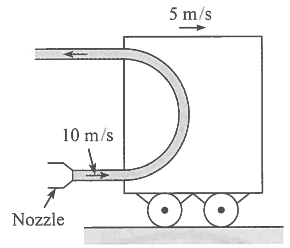
6.89 A large tank of liquid is resting on a frictionless plane as shown. Explain in a qualitative way what will happen after the cap is removed from the short pipe.

6.90 WILEY PLUS The open water tank shown is resting on a frictionless plane. The capped orifice on the side has a 4-cm diameter exit pipe that is located 3 m below the surface of the water. Ignore all friction effects, and determine the force necessary to keep the tank from moving when the cap is removed.


PROBLEMS 6.89, 6.90

6.91 Consider a tank of water ($\rho = 1000$ kg/m³) in a container that rests on a sled. A high pressure is maintained by a compressor so that a jet of water leaving the tank horizontally from an orifice does so at a constant speed of 25 m/s relative to the tank. If there is 0.10 m³ of water in the tank at time t and the diameter of the jet is 15 mm, what will be the acceleration of the sled at time t if the empty tank and compressor have a weight of 350 N and the coefficient of friction between the sled and the ice is 0.05?

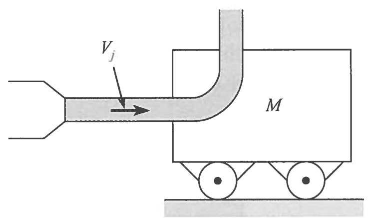
6.92 WILEY PLUS A cart is moving along a railroad track at a constant velocity of 5 m/s as shown. Water ($\rho = 1000$ kg/m³) issues from a nozzle at 10 m/s and is deflected through 180° by a vane on the cart. The cross-sectional area of the nozzle is 0.002 m². Calculate the resistive force on the cart.



PROBLEM 6.92

6.93 A water jet is used to accelerate a cart as shown. The discharge (Q) from the jet is 0.1 m^3/s, and the velocity of the jet (V_j) is 10 m/s. When the water hits the cart, it is deflected normally as shown. The mass of the cart (M) is 10 kg. The density of water (ρ) is 1000 kg/m^3. There is no resistance on the cart, and the initial velocity of the cart is zero. The mass of the water in the jet is much less than the mass of the cart. Derive an equation for the acceleration of the cart as a function of Q, ρ, V_c, M, and V_j. Evaluate the acceleration of the cart when the velocity is 5 m/s.

6.94 WILEY PLUS A water jet strikes a cart as shown. After striking the cart, the water is deflected vertically with respect to the cart. The cart is initially at rest and is accelerated by the water jet. The mass in the water jet is much less than that of the cart. There is no resistance on the cart. The mass flow rate from the jet is 45 kg/s. The mass of the cart is 100 kg. Find the time required for the cart to achieve a speed one-half of the jet speed.



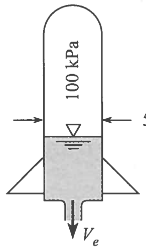
PROBLEMS 6.93, 6.94

6.95 It is common practice in rocket trajectory analyses to neglect the body-force term and drag, so the velocity at burnout is given by

$$v_{bo} = \frac{T}{\lambda}\ln\frac{M_0}{M_f}$$

Assuming a thrust-to-mass-flow ratio of 3000 N · s/kg and a final mass of 50 kg, calculate the initial mass needed to establish the rocket in an earth orbit at a velocity of 7200 m/s.

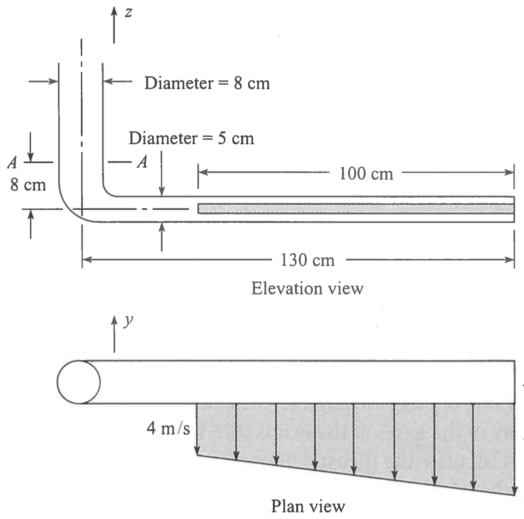
6.96 A very popular toy on the market several years ago was the water rocket. Water (at 10°C) was loaded into a plastic rocket and pressurized with a hand pump. The rocket was released and would travel a considerable distance in the air. Assume that a water rocket has a mass of 50 g and is charged with 100 g of water. The pressure inside the rocket is 100 kPa gage. The exit area is one-tenth of the chamber cross-sectional area. The inside diameter of the rocket is 5 cm. Assume that Bernoulli's equation is valid for the water flow inside the rocket. Neglecting air friction, calculate the maximum velocity it will attain.



PROBLEM 6.96

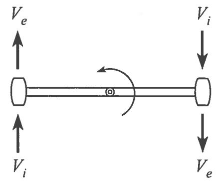
The Angular Momentum Equation (§6.6)

6.97 WILEY PLUS Water (ρ = 1000 kg/m^3) is discharged from the slot in the pipe as shown. If the resulting two-dimensional jet is 100 cm long and 15 mm thick, and if the pressure at section A-A is 30 kPa, what is the reaction at section A-A? In this calculation, do not consider the weight of the pipe.



PROBLEM 6.97

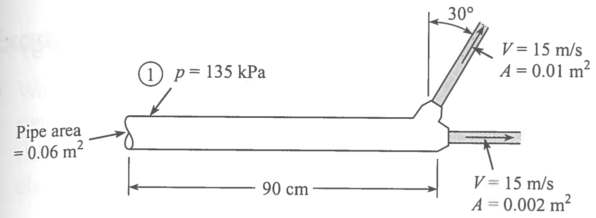
6.98 Two small liquid-propellant rocket motors are mounted at the tips of a helicopter rotor to augment power under emergency conditions. The diameter of the helicopter rotor is 7 m, and it rotates at 1 rev/s. The air enters at the tip speed of the rotor, and exhaust gases exit at 500 m/s with respect to the rocket motor. The intake area of each motor is 20 cm^2, and the air density is 1.2 kg/m^3. Calculate the power provided by the rocket motors. Neglect the mass rate of flow of fuel in this calculation.



PROBLEM 6.98

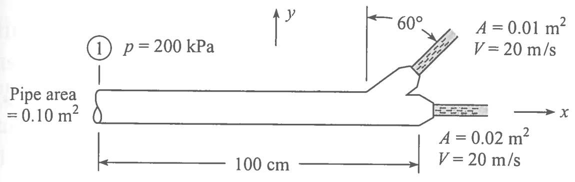
6.99 Design a rotating lawn sprinkler to deliver 0.625 m of water per hour over a circle of 15 m radius. Make the simplifying assumptions that the pressure to the sprinkler is 350 kPa gage and that frictional effects involving the flow of water through the sprinkler flow passages are negligible (the Bernoulli equation is applicable). However, do not neglect the friction between the rotating element and the fixed base of the sprinkler.

6.100 WILEY PLUS What is the force and moment reaction at section 1? Water (at 10°C) is flowing in the system. Neglect gravitational forces.



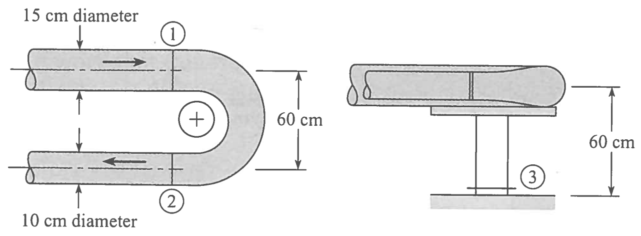
PROBLEM 6.100

6.101 What is the reaction at section 1? Water (ρ = 1000 kg/m^3) is flowing, and the axes of the two jets lie in a vertical plane. The pipe and nozzle system weighs 90 N.



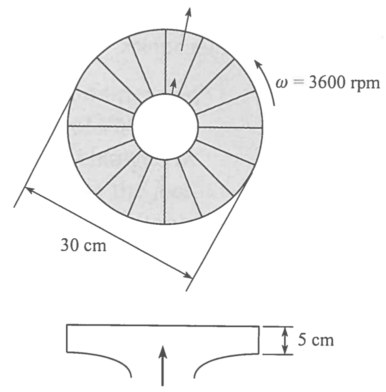
PROBLEM 6.101

6.102 A reducing pipe bend is held in place by a pedestal as shown. There are expansion joints at sections 1 and 2, so no force is transmitted through the pipe past these sections. The pressure at section 1 is 140 kPa gage, and the rate of flow of water (ρ = 1000 kg/m^3) is 0.06 m^3/s. Find the force and moment that must be applied at section 3 to hold the bend stationary. Assume the flow is irrotational, and neglect the influence of gravity.



PROBLEM 6.102

6.103 A centrifugal fan is used to pump air. The fan rotor is 0.3 m in diameter, and the blade spacing is 5 cm. The air enters with no angular momentum and exits radially with respect to the fan rotor. The discharge is 0.7 m^3/s. The rotor spins at 3600 rev/min. The air is at atmospheric pressure and a temperature of 15.5°C. Neglect the compressibility of the air. Calculate the power (kW) required to operate the fan.



PROBLEM 6.103