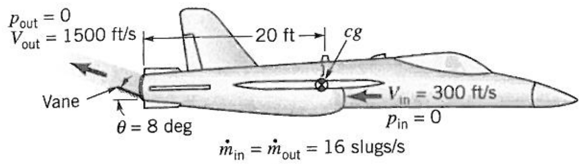
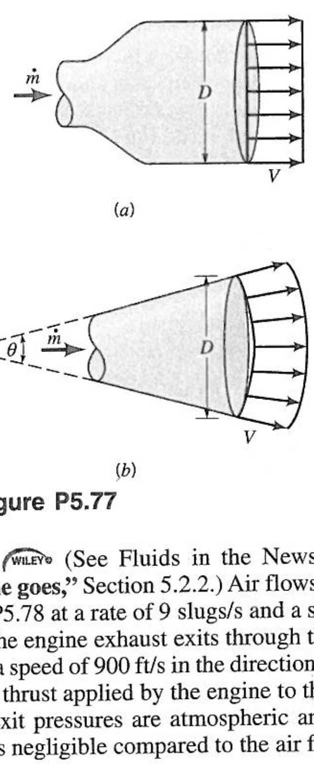


■ **Figure P5.76**

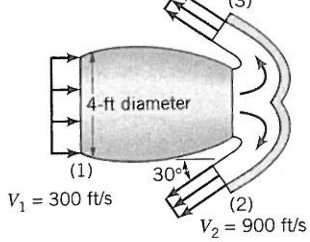
up) about the aircraft's mass center (cg) for the conditions indicated in the figure. **(b)** By how much is the thrust (force along the centerline of the aircraft) reduced for the case indicated compared to normal flight when the exhaust is parallel to the centerline?

5.77 The exhaust gas from the rocket shown in Fig. P5.77*a* leaves the nozzle with a uniform velocity parallel to the x axis. The gas is assumed to be discharged from the nozzle as a free jet. **(a)** Show that the thrust that is developed is equal to ρAV^2, where $A = \pi D^2/4$. **(b)** The exhaust gas from the rocket nozzle shown in Fig. P5.77*b* is also uniform, but rather than being directed along the x axis, it is directed along rays from point 0 as indicated. Determine the thrust for this rocket.



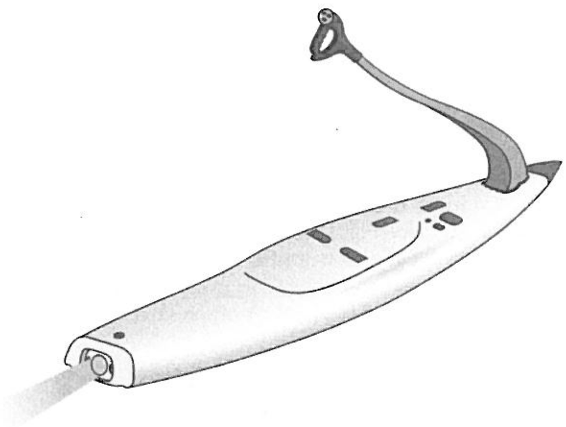
■ **Figure P5.77**

5.78 WILEY (See Fluids in the News article titled **"Where the Plume goes,"** Section 5.2.2.) Air flows into the jet engine shown in Fig. P5.78 at a rate of 9 slugs/s and a speed of 300 ft/s. Upon landing, the engine exhaust exits through the reverse thrust mechanism with a speed of 900 ft/s in the direction indicated. Determine the reverse thrust applied by the engine to the airplane. Assume the inlet and exit pressures are atmospheric and that the mass flowrate of fuel is negligible compared to the air flowrate through the engine.



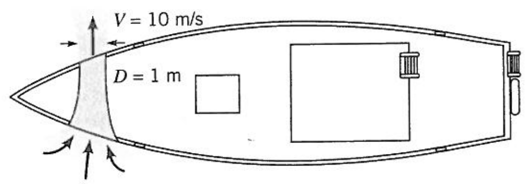
■ **Figure P5.78**

5.79 WILEY (See Fluids in the News article titled **"Motorized Surfboard,"** Section 5.2.2.) The thrust to propel the powered surfboard shown in Fig. P5.79 is a result of water pumped through the board that exits as a high-speed 2.75-in.-diameter jet. Determine the flowrate and the velocity of the exiting jet if the thrust is to be 300 lb. Neglect the momentum of the water entering the pump.



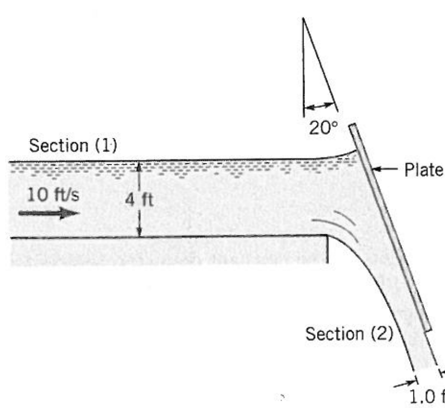
■ **Figure P5.79**

5.80 WILEY (See Fluids in the News article titled **"Bow Thrusters,"** Section 5.2.2.) The bow thruster on the boat shown in Fig. P5.80 is used to turn the boat. The thruster produces a 1-m-diameter jet of water with a velocity of 10 m/s. Determine the force produced by the thruster. Assume that the inlet and outlet pressures are zero and that the momentum of the water entering the thruster is negligible.



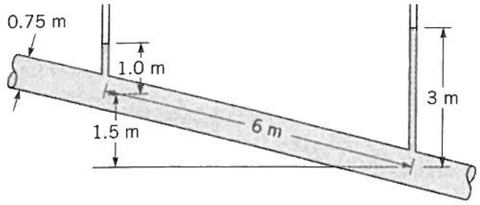
■ **Figure P5.80**

5.81 Water flows from a two-dimensional open channel and is diverted by an inclined plate as illustrated in Fig. P5.81. When the velocity at section (1) is 10 ft/s, what horizontal force (per unit width) is required to hold the plate in position? At section (1) the pressure distribution is hydrostatic, and the fluid acts as a free jet at section (2). Neglect friction.



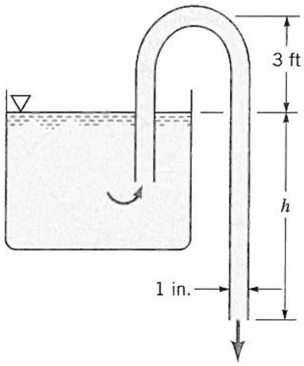
■ **Figure P5.81**

†**5.82** If a valve in a pipe is suddenly closed, a large pressure surge may develop. For example, when the electrically operated shutoff valve in a dishwasher closes quickly, the pipes supplying the dishwasher may rattle or "bang" because of this large pressure pulse. Explain the physical mechanism for this "water hammer" phenomenon. How could this phenomenon be analyzed?



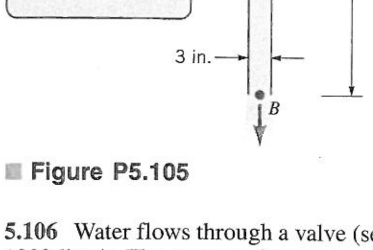
■ **Figure P5.103**

5.104 A siphon is used to draw water at 70 °F from a large container as indicated in Fig. P5.104. The inside diameter of the siphon line is 1 in. and the pipe centerline rises 3 ft above the essentially constant water level in the tank. Show that by varying the length of the siphon below the water level, h, the rate of flow through the siphon can be changed. Assuming frictionless flow, determine the maximum flowrate possible through the siphon. The limiting condition is the occurrence of cavitation in the siphon. Will the actual maximum flow be more or less than the frictionless value? Explain.



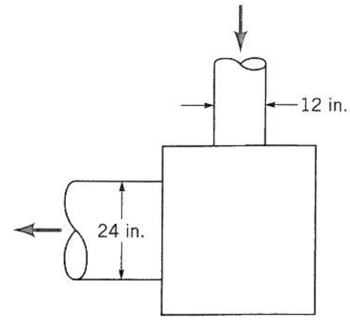
■ **Figure P5.104**

5.105 WILEY A water siphon having a constant inside diameter of 3 in. is arranged as shown in Fig. P5.105. If the friction loss between A and B is $0.8V^2/2$, where V is the velocity of flow in the siphon, determine the flowrate involved.



■ **Figure P5.105**

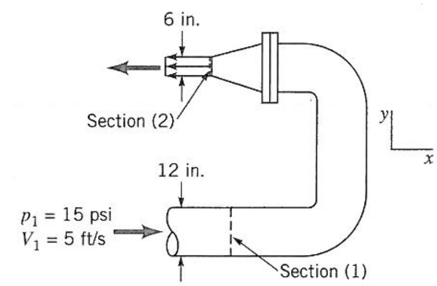
5.106 Water flows through a valve (see Fig. P5.106) at the rate of 1000 lbm/s. The pressure just upstream of the valve is 90 psi and the pressure drop across the valve is 50 psi. The inside diameters of the valve inlet and exit pipes are 12 and 24 in. If the flow through the valve occurs in a horizontal plane, determine the loss in available energy across the valve.



■ **Figure P5.106**

5.107 A gas expands through a nozzle from a pressure of 300 psia to a pressure of 5 psia. The enthalpy change involved, $\check{h}_1 - \check{h}_2$, is 150 Btu/lbm. If the expansion is adiabatic but with frictional effects and the inlet gas speed is negligibly small, determine the exit gas velocity.

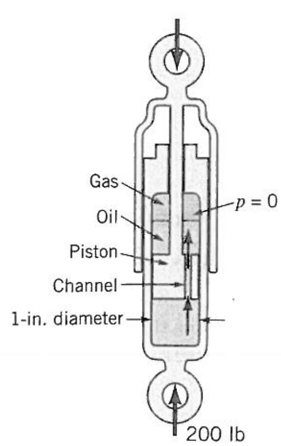
5.108 WILEY For the 180° elbow and nozzle flow shown in Fig. P5.108, determine the loss in available energy from section (1) to section (2). How much additional available energy is lost from section (2) to where the water comes to rest?



■ **Figure P5.108**

5.109 An automobile engine will work best when the back pressure at the interface of the exhaust manifold and the engine block is minimized. Show how reduction of losses in the exhaust manifold, piping, and muffler will also reduce the back pressure. How could losses in the exhaust system be reduced? What primarily limits the minimization of exhaust system losses?

5.110 WILEY (See Fluids in the News article titled **"Smart Shocks,"** Section 5.3.3.) A 200-lb force applied to the end of the piston of the shock absorber shown in Fig. P5.110 causes the two ends of the shock absorber to move toward each other with a speed of 5 ft/s. Determine the head loss associated with the flow of the oil through the channel. Neglect gravity and any friction force between the piston and cylinder walls.

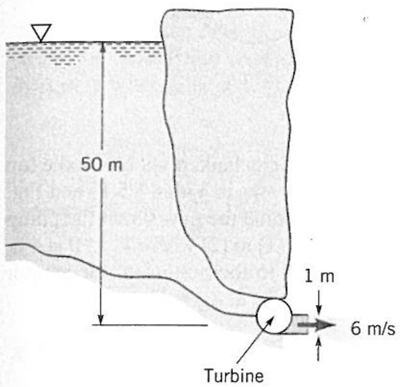


■ **Figure P5.110**

Section 5.3.2 Application of the Energy Equation—With Shaft Work

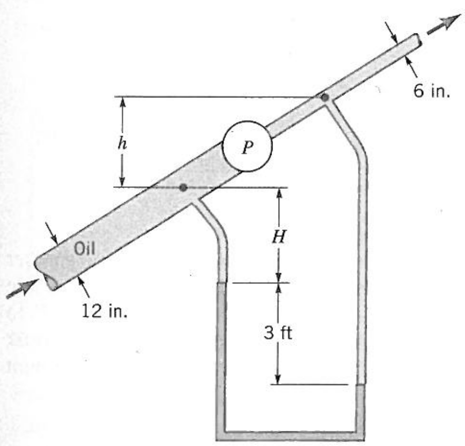
†**5.111** Based on flowrate and pressure rise information, estimate the power output of a human heart.

5.112 What is the maximum possible power output of the hydroelectric turbine shown in Fig. P5.112?



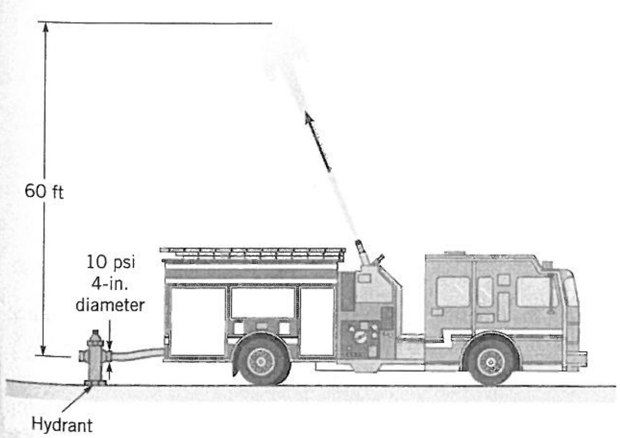
■ **Figure P5.112**

5.113 Oil ($SG = 0.88$) flows in an inclined pipe at a rate of 5 ft^3/s as shown in Fig. P5.113. If the differential reading in the mercury manometer is 3 ft, calculate the power that the pump supplies to the oil if head losses are negligible.



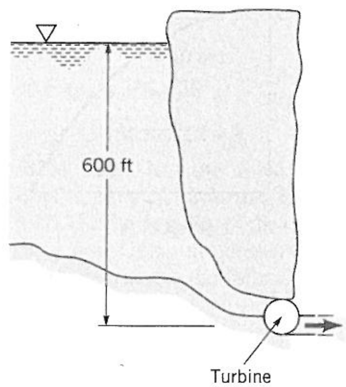
■ **Figure P5.113**

5.114 The pumper truck shown in Fig. P5.114 is to deliver 1.5 ft^3/s to a maximum elevation of 60 ft above the hydrant. The pressure at the 4-in.-diameter outlet of the hydrant is 10 psi. If head losses are negligibly small, determine the power that the pump must add to the water.



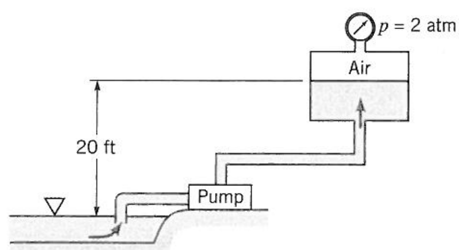
■ **Figure P5.114**

5.115 The hydroelectric turbine shown in Fig. P5.115 passes 8 million gal/min across a head of 600 ft. What is the maximum amount of power output possible? Why will the actual amount be less?



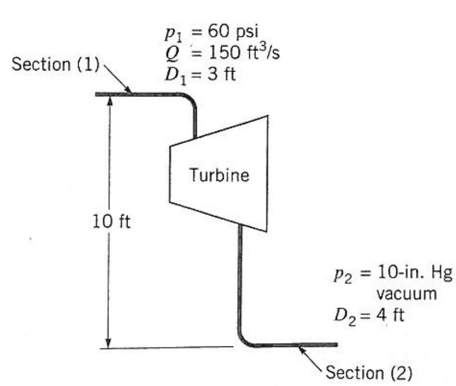
■ **Figure P5.115**

5.116 A pump is to move water from a lake into a large, pressurized tank as shown in Fig. P5.116 at a rate of 1000 gal in 10 min or less. Will a pump that adds 3 hp to the water work for this purpose? Support your answer with appropriate calculations. Repeat the problem if the tank were pressurized to 3, rather than 2, atmospheres.



■ **Figure P5.116**

5.117 Water is supplied at 150 ft^3/s and 60 psi to a hydraulic turbine through a 3-ft inside-diameter inlet pipe as indicated in Fig. P5.117. The turbine discharge pipe has a 4-ft inside diameter. The static pressure at section (2), 10 ft below the turbine inlet, is 10-in. Hg vacuum. If the turbine develops 2500 hp, determine the power lost between sections (1) and (2).



■ **Figure P5.117**

is 30 mm, the pressure is 400 kPa. If the loss in energy across the pump due to fluid friction effects is 170 N · m/kg, determine the hydraulic efficiency of the pump.

5.126 WILEY Water is to be pumped from the large tank shown in Fig. P5.126 with an exit velocity of 6 m/s. It was determined that the original pump (pump 1) that supplies 1 kW of power to the water did not produce the desired velocity. Hence, it is proposed that an additional pump (pump 2) be installed as indicated to increase the flowrate to the desired value. How much power must pump 2 add to the water? The head loss for this flow is $h_L = 250\,Q^2$, where h_L is in m when Q is in m^3/s.

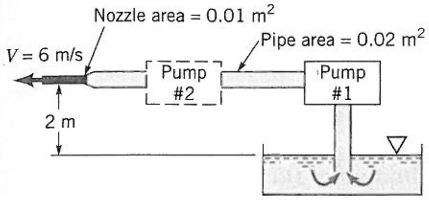


Figure P5.126

5.127 WILEY (See Fluids in the News article titled **"Curtain of Air,"** Section 5.3.3.) The fan shown in Fig. P5.127 produces an air curtain to separate a loading dock from a cold storage room. The air curtain is a jet of air 10 ft wide, 0.5 ft thick moving with speed $V = 30$ ft/s. The loss associated with this flow is loss $= K_L V^2/2$, where $K_L = 5$. How much power must the fan supply to the air to produce this flow?

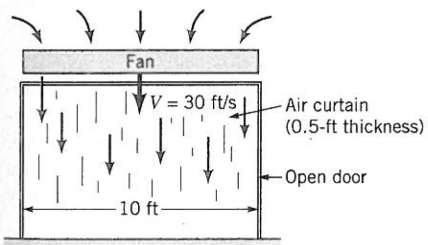


Figure P5.127

Section 5.3.3 Application of the Energy Equation—Combined with Linear Momentum

5.128 If a $\frac{3}{4}$-hp motor is required by a ventilating fan to produce a 24-in. stream of air having a velocity of 40 ft/s as shown in Fig. P5.128, estimate **(a)** the efficiency of the fan and **(b)** the thrust of the supporting member on the conduit enclosing the fan.

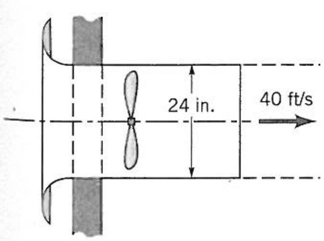


Figure P5.128

5.129 WILEY Air flows past an object in a pipe of 2-m diameter and exits as a free jet as shown in Fig. P5.129. The velocity and pressure upstream are uniform at 10 m/s and 50 N/m^2, respectively. At the pipe exit the velocity is nonuniform as indicated. The shear stress along the pipe wall is negligible. **(a)** Determine the head loss associated with a particle as it flows from the uniform velocity upstream of the object to a location in the wake at the exit plane of the pipe. **(b)** Determine the force that the air exerts on the object.

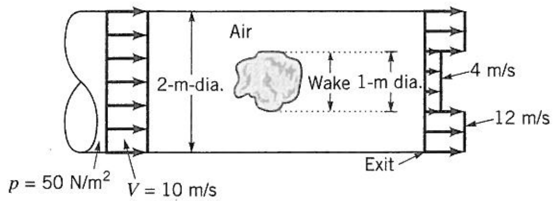


Figure P5.129

5.130 Near the downstream end of a river spillway, a hydraulic jump often forms, as illustrated in Fig. P5.130 and **Video V10.11.** The velocity of the channel flow is reduced abruptly across the jump. Using the conservation of mass and linear momentum principles, derive the following expression for h_2,

$$h_2 = -\frac{h_1}{2} + \sqrt{\left(\frac{h_1}{2}\right)^2 + \frac{2V_1^2 h_1}{g}}$$

The loss of available energy across the jump can also be determined if energy conservation is considered. Derive the loss expression

$$\text{jump loss} = \frac{g(h_2 - h_1)^3}{4h_1h_2}.$$

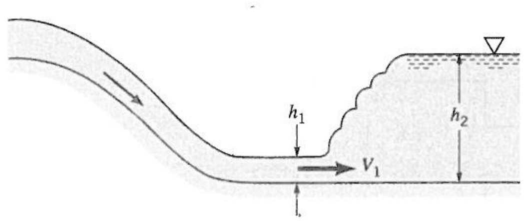


Figure P5.130

5.131 WILEY Water flows steadily down the inclined pipe as indicated in Fig P5.131. Determine the following: **(a)** the difference in pressure $p_1 - p_2$, **(b)** the loss between sections (1) and (2), **(c)** the net axial force exerted by the pipe wall on the flowing water between sections (1) and (2).

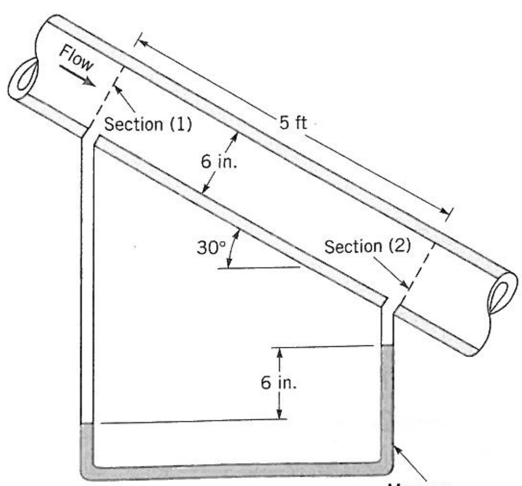


Figure P5.131

30 mm, the pressure is 400 kPa. If the loss in energy across the ımp due to fluid friction effects is 170 N · m/kg, determine the 'draulic efficiency of the pump.

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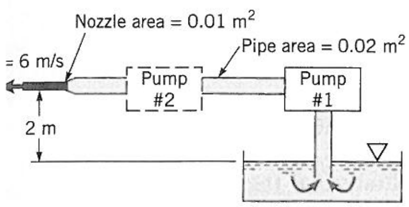

Figure P5.126

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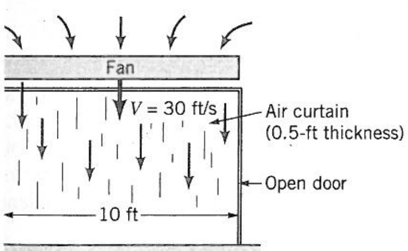


Figure P5.127

:ction 5.3.3 Application of the Energy Equation— ombined with Linear Momentum

128 If a $\frac{3}{4}$-hp motor is required by a ventilating fan to produce a -in. stream of air having a velocity of 40 ft/s as shown in Fig. .128, estimate **(a)** the efficiency of the fan and **(b)** the thrust of ɜ supporting member on the conduit enclosing the fan.

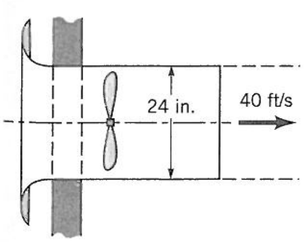


Figure P5.128

129 Air flows past an object in a pipe of 2-m diameter and its as a free jet as shown in Fig. P5.129. The velocity and pressure stream are uniform at 10 m/s and 50 N/m², respectively. At the ɔe exit the velocity is nonuniform as indicated. The shear stress ɔng the pipe wall is negligible. **(a)** Determine the head loss asso- ıted with a particle as it flows from the uniform velocity upstream of the object to a location in the wake at the exit plane of the pipe. **(b)** Determine the force that the air exerts on the object.

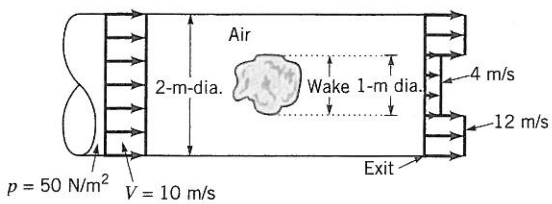


Figure P5.129

5.130 Near the downstream end of a river spillway, a hydraulic jump often forms, as illustrated in Fig. P5.130 and **Video V10.11.** The velocity of the channel flow is reduced abruptly across the jump. Using the conservation of mass and linear momentum principles, derive the following expression for h_2,

$$h_2 = -\frac{h_1}{2} + \sqrt{\left(\frac{h_1}{2}\right)^2 + \frac{2V_1^2 h_1}{g}}$$

The loss of available energy across the jump can also be determined if energy conservation is considered. Derive the loss expression

$$\text{jump loss} = \frac{g(h_2 - h_1)^3}{4h_1 h_2}$$

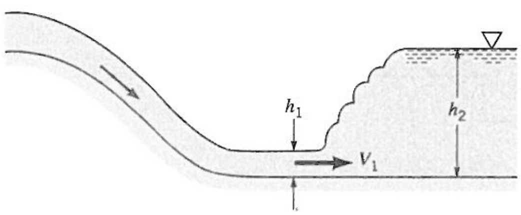


Figure P5.130

5.131 Water flows steadily down the inclined pipe as indicated in Fig P5.131. Determine the following: **(a)** the difference in pressure $p_1 - p_2$, **(b)** the loss between sections (1) and (2), **(c)** the net axial force exerted by the pipe wall on the flowing water between sections (1) and (2).

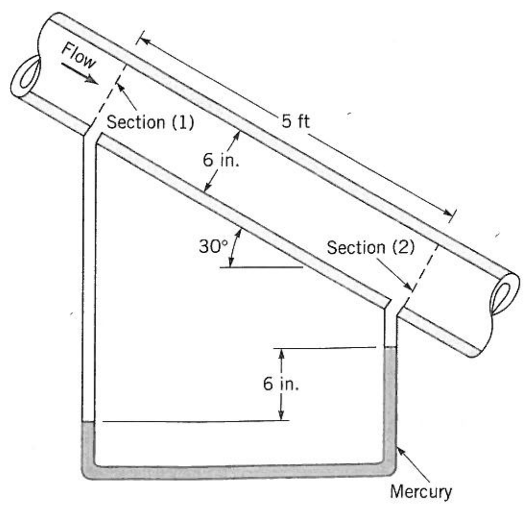
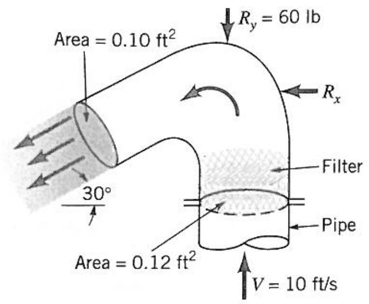


Figure P5.131

5.132 Water flows steadily in a pipe and exits as a free jet through an end cap that contains a filter as shown in Fig. P5.132. The flow is in a horizontal plane. The axial component, R_y, of the anchoring force needed to keep the end cap stationary is 60 lb. Determine the head loss for the flow through the end cap.

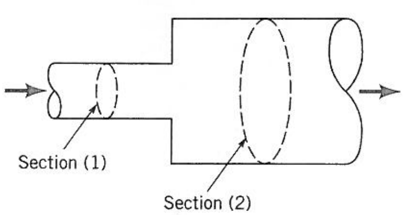


■ **Figure P5.132**

5.133 When fluid flows through an abrupt expansion as indicated in Fig. P5.133, the loss in available energy across the expansion, loss_{ex}, is often expressed as

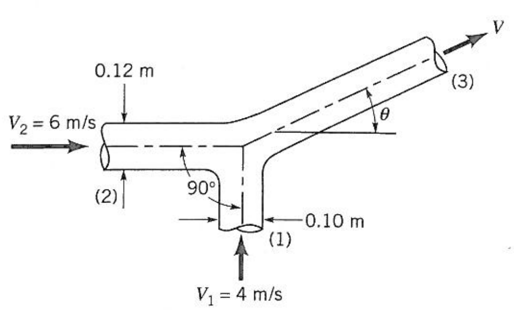
$$\text{loss}_{ex} = \left(1 - \frac{A_1}{A_2}\right)^2 \frac{V_1^2}{2}$$

where A_1 = cross-sectional area upstream of expansion, A_2 = cross-sectional area downstream of expansion, and V_1 = velocity of flow upstream of expansion. Derive this relationship.



■ **Figure P5.133**

5.134 Two water jets collide and form one homogeneous jet as shown in Fig. P5.134. **(a)** Determine the speed, V, and direction, θ, of the combined jet. **(b)** Determine the loss for a fluid particle flowing from (1) to (3), from (2) to (3). Gravity is negligible.



■ **Figure P5.134**

Section 5.3.4 Application of the Energy Equation to Nonuniform Flows

5.135 Water flows vertically upward in a circular cross-sectional pipe. At section (1), the velocity profile over the cross-sectional area is uniform. At section (2), the velocity profile is

$$\mathbf{V} = w_c\left(\frac{R - r}{R}\right)^{1/7} \hat{\mathbf{k}}$$

where $\mathbf{V}$ = local velocity vector, w_c = centerline velocity in the axial direction, R = pipe inside radius, and r = radius from pipe axis. Develop an expression for the loss in available energy between sections (1) and (2).

5.136 A small fan moves air at a mass flowrate of 0.004 lbm/s. Upstream of the fan, the pipe diameter is 2.5 in., the flow is laminar, the velocity distribution is parabolic, and the kinetic energy coefficient, α_1, is equal to 2.0. Downstream of the fan, the pipe diameter is 1 in., the flow is turbulent, the velocity profile is quite flat, and the kinetic energy coefficient, α_2, is equal to 1.08. If the rise in static pressure across the fan is 0.015 psi and the fan shaft draws 0.00024 hp, compare the value of loss calculated: **(a)** assuming uniform velocity distributions, **(b)** considering actual velocity distributions.

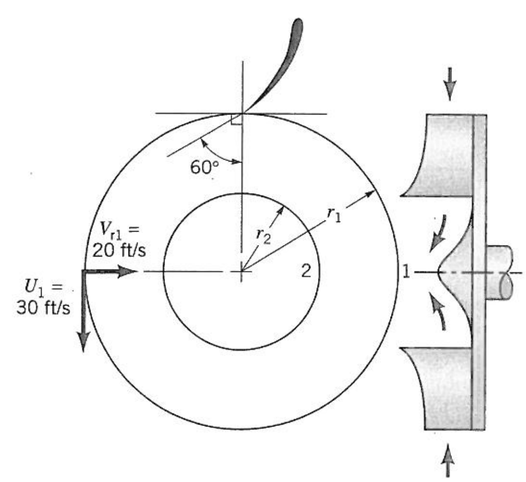
Section 5.3.5 Combination of the Energy Equation and the Moment-of-Momentum Equation

5.137 Air enters a radial blower with zero angular momentum. It leaves with an absolute tangential velocity, V_θ, of 200 ft/s. The rotor blade speed at rotor exit is 170 ft/s. If the stagnation pressure rise across the rotor is 0.4 psi, calculate the loss of available energy across the rotor and the rotor efficiency.

5.138 Water enters a pump impeller radially. It leaves the impeller with a tangential component of absolute velocity of 10 m/s. The impeller exit diameter is 60 mm, and the impeller speed is 1800 rpm. If the stagnation pressure rise across the impeller is 45 kPa, determine the loss of available energy across the impeller and the hydraulic efficiency of the pump.

5.139 Water enters an axial-flow turbine rotor with an absolute velocity tangential component, V_θ, of 15 ft/s. The corresponding blade velocity, U, is 50 ft/s. The water leaves the rotor blade row with no angular momentum. If the stagnation pressure drop across the turbine is 12 psi, determine the hydraulic efficiency of the turbine.

5.140 An inward flow radial turbine (see Fig. P5.140) involves a nozzle angle, α_1, of 60° and an inlet rotor tip speed, U_1, of 30 ft/s. The ratio of rotor inlet to outlet diameters is 2.0. The radial component of velocity remains constant at 20 ft/s through the rotor, and the flow leaving the rotor at section (2) is without angular momentum. If the flowing fluid is water and the stagnation pressure drop across the rotor is 16 psi, determine the loss of available energy across the rotor and the hydraulic efficiency involved.



■ **Figure P5.140**