KMM2612 CHEMICAL ENGINEERING FLUID MECHANICS

PROBLEM SET 6

8–1C Consider the flow of air and water in pipes of the same diameter, at the same temperature, and at the same mean velocity. Which flow is more likely to be turbulent? Why?

8–2C Consider laminar flow in a circular pipe. Is the wall shear stress τ_w higher near the inlet of the pipe or near the exit? Why? What would your response be if the flow were turbulent?

8–3C What is hydraulic diameter? How is it defined? What is it equal to for a circular pipe of diameter D?

8–4C How is the hydrodynamic entry length defined for flow in a pipe? Is the entry length longer in laminar or turbulent flow?

8–8C Show that the Reynolds number for flow in a circular pipe of diameter D can be expressed as $\text{Re} = 4\dot{m}/(\pi D \mu)$.

8–31 The velocity profile for the fully developed laminar flow of a Newtonian fluid between two large parallel plates is given by

$$u(y) = \frac{3u_0}{2}\left[1 - \left(\frac{y}{h}\right)^2\right]$$

where $2h$ is the distance between the two plates, u_0 is the velocity at the center plane, and y is the vertical coordinate from the center plane. For a plate width of b, obtain a relation for the flow rate through the plates.

8–32 Water flows steadily through a reducing pipe section. The flow upstream with a radius of R_1 is laminar with a velocity profile of $u_1(r) = u_{01}(1 - r^2/R_1^2)$ while the flow downstream is turbulent with a velocity profile of $u_2(r) = u_{02}(1 - r/R_2)^{1/7}$. For incompressible flow with $R_2/R_1 = 4/7$, determine the ratio of centerline velocities u_{01}/u_{02}.

8–33 Water at 10°C (ρ = 999.7 kg/m^3 and μ = 1.307 × 10^{-3} kg/m·s) is flowing steadily in a 0.12-cm-diameter, 15-m-long pipe at an average velocity of 0.9 m/s. Determine (*a*) the pressure drop, (*b*) the head loss, and (*c*) the pumping power requirement to overcome this pressure drop. *Answers:* (*a*) 392 kPa, (*b*) 40.0 m, (*c*) 0.399 W

8–34 Consider an air solar collector that is 1 m wide and 5 m long and has a constant spacing of 3 cm between the glass cover and the collector plate. Air flows at an average temperature of 45°C at a rate of 0.15 m^3/s through the 1-m-wide edge of the collector along the 5-m-long passageway. Disregarding the entrance and roughness effects and the 90° bend, determine the pressure drop in the collector. *Answer:* 32.3 Pa

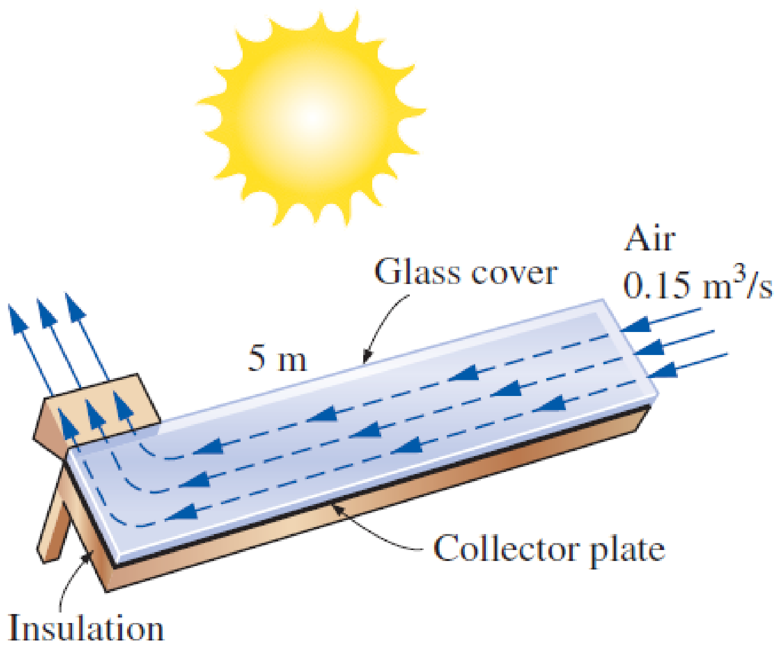
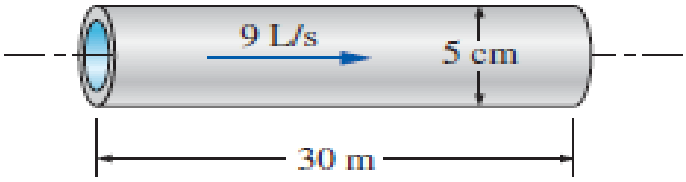


FIGURE P8–34

8–39 Water at 15°C (ρ = 999.1 kg/m^3 and μ = 1.138 × 10^{-3} kg/m·s) is flowing steadily in a 30-m-long and 5-cm-diameter horizontal pipe made of stainless steel at a rate of 9 L/s. Determine (*a*) the pressure drop, (*b*) the head loss, and (*c*) the pumping power requirement to overcome this pressure drop.



8–40 Consider the flow of oil with $\rho = 894\ kg/m^3$ and $\mu = 2.33$ kg/m·s in a 28-cm-diameter pipeline at an average velocity of 0.5 m/s. A 330-m-long section of the pipeline passes through the icy waters of a lake. Disregarding the entrance effects, determine the pumping power required to overcome the pressure losses and to maintain the flow of oil in the pipe.

8–41 Consider laminar flow of a fluid through a square channel with smooth surfaces. Now the average velocity of the fluid is doubled. Determine the change in the head loss of the fluid. Assume the flow regime remains unchanged.

8–45 Oil with $\rho = 876\ kg/m^3$ and $\mu = 0.24$ kg/m·s is flowing through a 1.5-cm-diameter pipe that discharges into the atmosphere at 88 kPa. The absolute pressure 15 m before the exit is measured to be 135 kPa. Determine the flow rate of oil through the pipe if the pipe is (*a*) horizontal, (*b*) inclined 8° upward from the horizontal, and (*c*) inclined 8° downward from the horizontal.

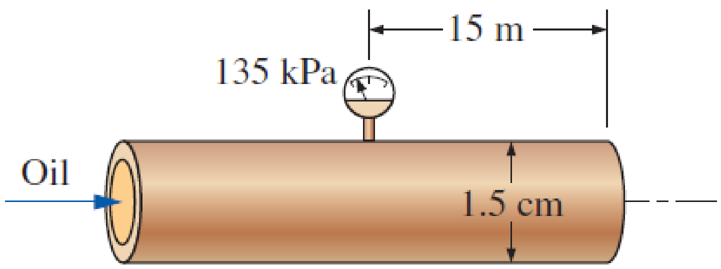


FIGURE P8–45

8–46 Glycerin at 40°C with $\rho = 1252\ kg/m^3$ and $\mu =$ 0.27 kg/m·s is flowing through a 2-cm-diameter, 25-m-long pipe that discharges into the atmosphere at 100 kPa. The flow rate through the pipe is 0.048 L/s. (*a*) Determine the absolute pressure 25 m before the pipe exit. (*b*) At what angle θ must the pipe be inclined downward from the horizontal for the pressure in the entire pipe to be atmospheric pressure and the flow rate to be maintained the same?

8–50 Oil with a density of 850 kg/m^3 and kinematic viscosity of 0.00062 m^2/s is being discharged by a 8-mm-diameter, 40-m-long horizontal pipe from a storage tank open to the atmosphere. The height of the liquid level above the center of the pipe is 4 m. Disregarding the minor losses, determine the flow rate of oil through the pipe.

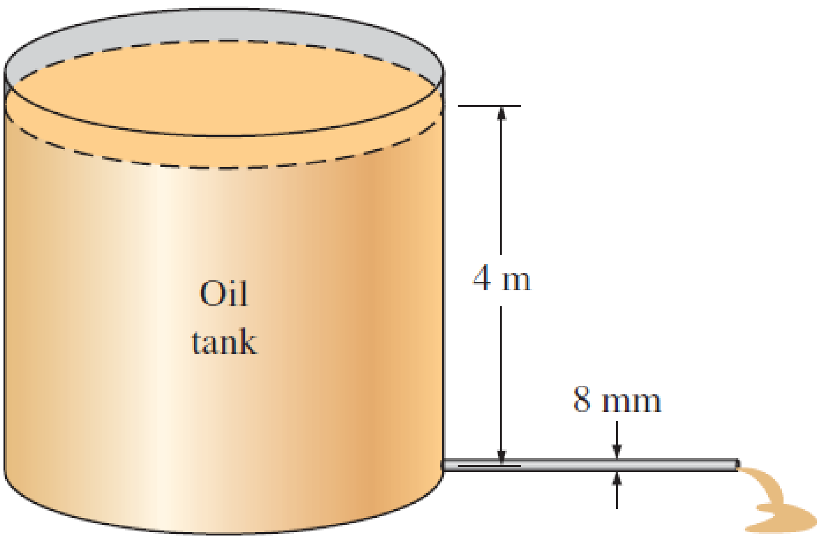
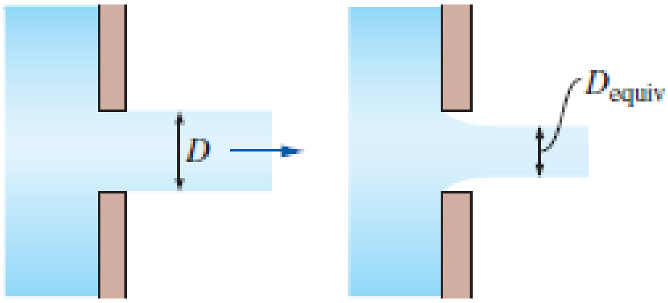


FIGURE P8–50

8–55 Liquid ammonia at −20°C is flowing through a 20-m-long section of a 5-mm-diameter copper tube at a rate of 0.09 kg/s. Determine the pressure drop, the head loss, and the pumping power required to overcome the frictional losses in the tube. *Answers:* 1240 kPa, 189 m, 0.167 kW

8–64 Consider flow from a water reservoir through a circular hole of diameter D at the side wall at a vertical distance H from the free surface. The flow rate through an actual hole with a sharp-edged entrance ($K_L = 0.5$) is considerably less than the flow rate calculated assuming "frictionless" flow and thus zero loss for the hole. Disregarding the effect of the kinetic energy correction factor, obtain a relation for the "equivalent diameter" of the sharp-edged hole for use in frictionless flow relations.



8–66 A horizontal pipe has an abrupt expansion from $D_1 = 8$ cm to $D_2 = 16$ cm. The water velocity in the smaller section is 10 m/s and the flow is turbulent. The pressure in the smaller section is $P_1 = 410$ kPa. Taking the kinetic energy correction factor to be 1.06 at both the inlet and the outlet, determine the downstream pressure P_2, and estimate the error that would have occurred if Bernoulli's equation had been used. *Answers:* 432 kPa, 25.4 kPa

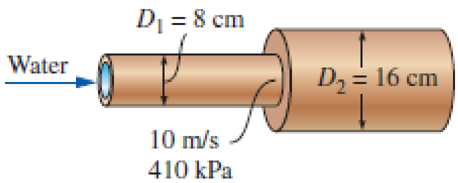


FIGURE P8–66

8–80 A 3-m-diameter tank is initially filled with water 2 m above the center of a sharp-edged 10-cm-diameter orifice. The tank water surface is open to the atmosphere, and the orifice drains to the atmosphere through a 100-m-long pipe. The friction coefficient of the pipe is taken to be 0.015 and the effect of the kinetic energy correction factor can be neglected. Determine (*a*) the initial velocity from the tank and (*b*) the time required to empty the tank.

8–89 A water tank filled with solar-heated water at 40°C is to be used for showers in a field using gravity-driven flow. The system includes 35 m of 1.5-cm-diameter galvanized iron piping with four miter bends (90°) without vanes and a wide-open globe valve. If water is to flow at a rate of 1.2 L/s through the shower head, determine how high the water level in the tank must be from the exit level of the shower. Disregard the losses at the entrance and at the shower head, and neglect the effect of the kinetic energy correction factor.

8–93 A certain part of cast iron piping of a water distribution system involves a parallel section. Both parallel pipes have a diameter of 30 cm, and the flow is fully turbulent. One of the branches (pipe *A*) is 1500 m long while the other branch (pipe *B*) is 2500 m long. If the flow rate through pipe *A* is 0.4 m^3/s, determine the flow rate through pipe *B*. Disregard minor losses and assume the water

temperature to be 15°C. Show that the flow is fully rough, and thus the friction factor is independent of Reynolds number.
Answer: 0.310 m^3/s

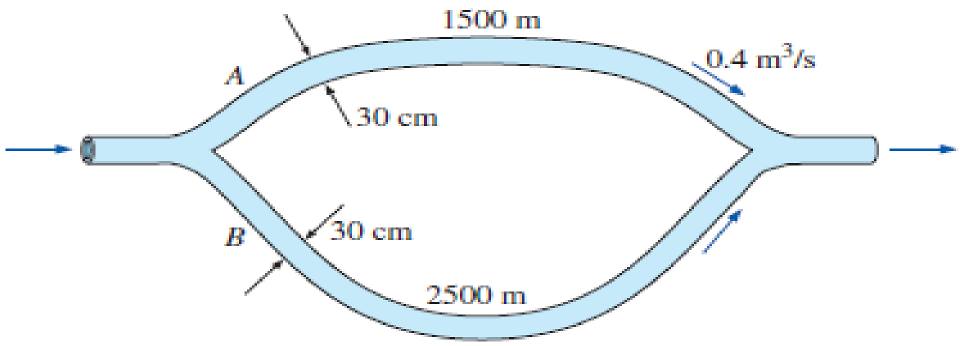


FIGURE P8–93

8–86 Water at 15°C is drained from a large reservoir using two horizontal plastic pipes connected in series. The first pipe is 20 m long and has a 10-cm diameter, while the second pipe is 35 m long and has a 4-cm diameter. The water level in the reservoir is 18 m above the centerline of the pipe. The pipe entrance is sharp-edged, and the contraction between the two pipes is sudden. Neglecting the effect of the kinetic energy correction factor, determine the discharge rate of water from the reservoir.

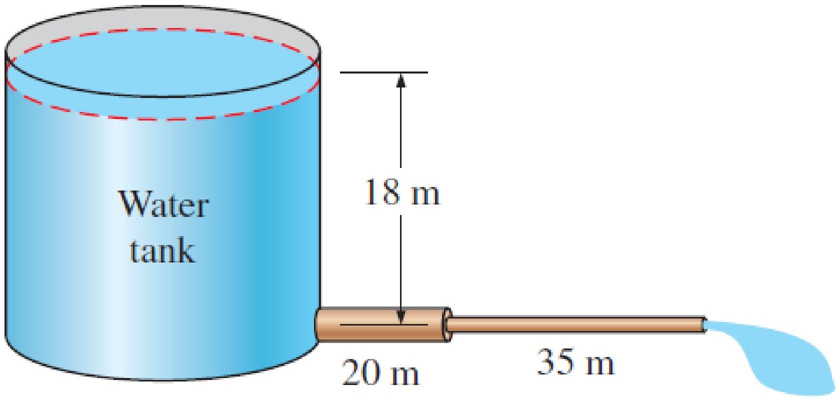


FIGURE P8–86

8–116 A flow nozzle equipped with a differential pressure gage is used to measure the flow rate of water at 10°C (ρ = 999.7 kg/m^3 and μ = 1.307 × 10^{-3} kg/m·s) through a 3-cm-diameter horizontal pipe. The nozzle exit diameter is 1.5 cm, and the measured pressure drop is 3 kPa. Determine the volume flow rate of water, the average velocity through the pipe, and the head loss.

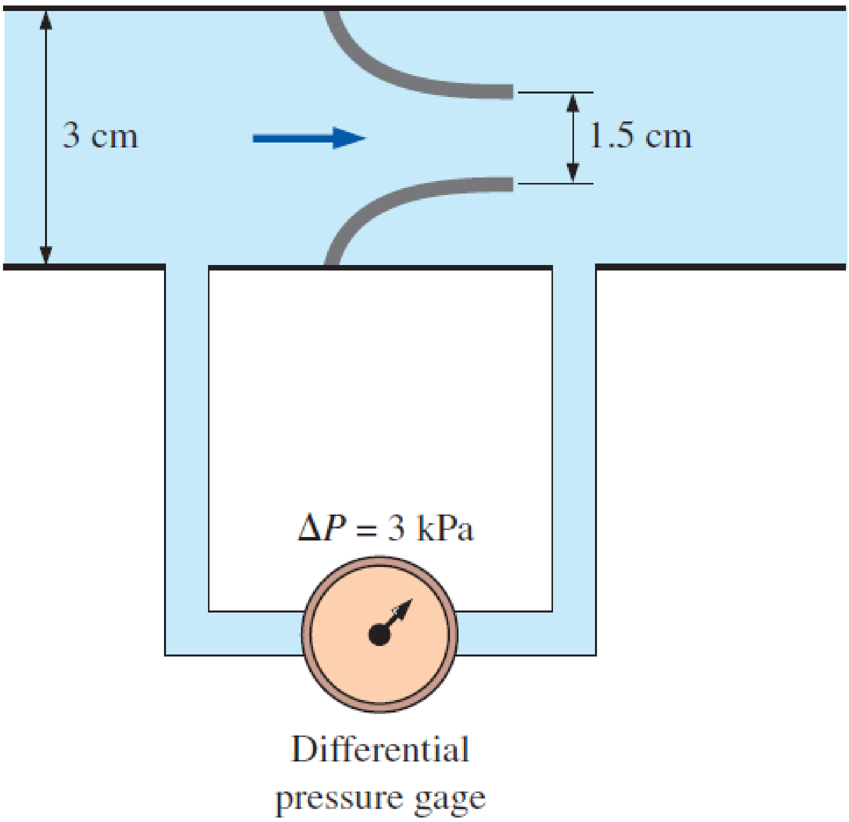


FIGURE P8–116