The pressure at a depth h in a liquid of constant density ρ is given by

$$P = \rho g h, \quad \textbf{(10–3a)}$$

where g is the acceleration due to gravity.

Pascal's principle says that an external pressure applied to a confined fluid is transmitted throughout the fluid.

Pressure is measured using a manometer or other type of gauge. A **barometer** is used to measure atmospheric pressure. Standard **atmospheric pressure** (average at sea level) is $1.013 \times 10^5\,\mathrm{N/m^2}$. **Gauge pressure** is the total (absolute) pressure less atmospheric pressure.

Archimedes' principle states that an object submerged wholly or partially in a fluid is buoyed up by a force equal to the weight of fluid it displaces ($F_B = m_F g = \rho_F V_{\mathrm{displ}} g$).

Fluid flow can be characterized either as **streamline** (sometimes called **laminar**), in which the layers of fluid move smoothly and regularly along paths called **streamlines**, or as **turbulent**, in which case the flow is not smooth and regular but is characterized by irregularly shaped whirlpools.

Fluid flow rate is the mass or volume of fluid that passes a given point per unit time. The **equation of continuity** states that for an incompressible fluid flowing in an enclosed tube, the product of the velocity of flow and the cross-sectional area of the tube remains constant:

$$Av = \text{constant}. \quad \textbf{(10–4)}$$

Bernoulli's principle tells us that where the velocity of a fluid is high, the pressure in it is low, and where the velocity is low, the pressure is high. For steady laminar flow of an incompressible and nonviscous fluid, **Bernoulli's equation**, which is based on the law of conservation of energy, is

$$P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2, \quad \textbf{(10–5)}$$

for two points along the flow.

[***Viscosity** refers to friction within a fluid and is essentially a frictional force between adjacent layers of fluid as they move past one another.]

[*Liquid surfaces hold together as if under tension (**surface tension**), allowing drops to form and objects like needles and insects to stay on the surface.]

Questions

1. If one material has a higher density than another, must the molecules of the first be heavier than those of the second? Explain.
2. Airplane travelers sometimes note that their cosmetics bottles and other containers have leaked during a flight. What might cause this?
3. The three containers in Fig. 10–44 are filled with water to the same height and have the same surface area at the base; hence the water pressure, and the total force on the base of each, is the same. Yet the total weight of water is different for each. Explain this "hydrostatic paradox."

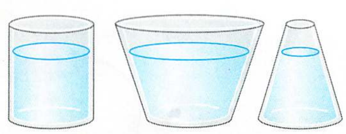

FIGURE 10–44 Question 3.

4. Consider what happens when you push both a pin and the blunt end of a pen against your skin with the same force. Decide what determines whether your skin is cut—the net force applied to it or the pressure.
5. A small amount of water is boiled in a 1-gallon metal can. The can is removed from the heat and the lid put on. Shortly thereafter the can collapses. Explain.
6. When blood pressure is measured, why must the jacket be held at the level of the heart?
7. An ice cube floats in a glass of water filled to the brim. What can you say about the density of ice? As the ice melts, will the water overflow? Explain.
8. Will an ice cube float in a glass of alcohol? Why or why not?
9. A submerged can of Coke® will sink, but a can of Diet Coke® will float. (Try it!) Explain.
10. Why don't ships made of iron sink?
11. Explain how the tube in Fig. 10–45, known as a **siphon**, can transfer liquid from one container to a lower one even though the liquid must flow uphill for part of its journey. (Note that the tube must be filled with liquid to start with.)

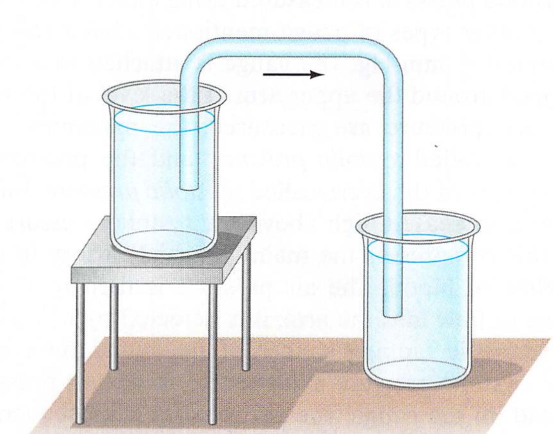

FIGURE 10–45 Question 11. A siphon.

12. A barge filled high with sand approaches a low bridge over the river and cannot quite pass under it. Should sand be added to, or removed from, the barge? [*Hint*: Consider Archimedes' principle.]
13. Will an empty balloon have precisely the same apparent weight on a scale as a balloon filled with air? Explain.
14. Explain why helium weather balloons, which are used to measure atmospheric conditions at high altitudes, are normally released while filled to only 10%–20% of their maximum volume.

15. A small wooden boat floats in a swimming pool, and the level of the water at the edge of the pool is marked. Consider the following situations and explain whether the level of the water will rise, fall, or stay the same. (*a*) The boat is removed from the water. (*b*) The boat in the water holds an iron anchor which is removed from the boat and placed on the shore. (*c*) The iron anchor is removed from the boat and dropped in the pool.

16. Why do you float higher in salt water than in fresh?

17. If you dangle two pieces of paper vertically, a few inches apart (Fig. 10–46), and blow between them, how do you think the papers will move? Try it and see. Explain.

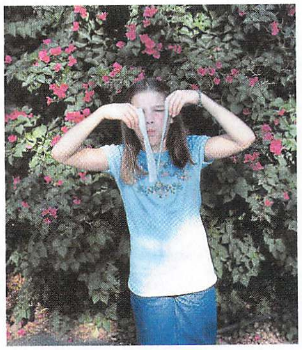

FIGURE 10–46 Question 17.

18. Why does the canvas top of a convertible bulge out when the car is traveling at high speed? [*Hint*: the windshield deflects air upward, pushing streamlines closer together.]

19. Roofs of houses are sometimes "blown" off (or are they pushed off?) during a tornado or hurricane. Explain, using Bernoulli's principle.

20. Children are told to avoid standing too close to a rapidly moving train because they might get sucked under it. Is this possible? Explain.

21. A tall Styrofoam cup is filled with water. Two holes are punched in the cup near the bottom, and water begins rushing out. If the cup is dropped so it falls freely, will the water continue to flow from the holes? Explain.

22. Why do airplanes normally take off into the wind?

23. Why does the stream of water from a faucet become narrower as it falls (Fig. 10–47)?

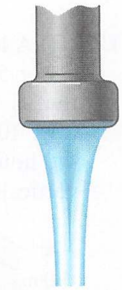

FIGURE 10–47 Question 23 and Problem 82. Water coming from a faucet.

24. Two ships moving in parallel paths close to one another risk colliding. Why?

Problems

10–2 Density and Specific Gravity

1. (I) The approximate volume of the granite monolith known as El Capitan in Yosemite National Park (Fig. 10–48) is about $10^8\,\text{m}^3$. What is its approximate mass?

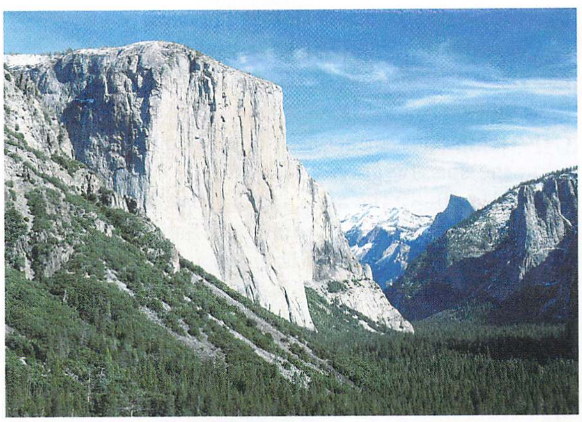

FIGURE 10–48 Problem 1.

2. (I) What is the approximate mass of air in a living room $4.8\,\text{m} \times 3.8\,\text{m} \times 2.8\,\text{m}$?
3. (I) If you tried to smuggle gold bricks by filling your backpack, whose dimensions are $60\,\text{cm} \times 28\,\text{cm} \times 18\,\text{cm}$, what would its mass be?
4. (I) State your mass and then estimate your volume. [*Hint*: Because you can swim on or just under the surface of the water in a swimming pool, you have a pretty good idea of your density.]
5. (II) A bottle has a mass of 35.00 g when empty and 98.44 g when filled with water. When filled with another fluid, the mass is 88.78 g. What is the specific gravity of this other fluid?
6. (II) If 5.0 L of antifreeze solution (specific gravity = 0.80) is added to 4.0 L of water to make a 9.0-L mixture, what is the specific gravity of the mixture?

10–3 to 10–6 Pressure; Pascal's Principle

7. (I) Estimate the pressure exerted on a floor by (*a*) one pointed chair leg (60 kg on all four legs) of area = $0.020\,\text{cm}^2$, and (*b*) a 1500-kg elephant standing on one foot (area = $800\,\text{cm}^2$).
8. (I) What is the difference in blood pressure (mm-Hg) between the top of the head and bottom of the feet of a 1.60-m-tall person standing vertically?
9. (I) (*a*) Calculate the total force of the atmosphere acting on the top of a table that measures $1.6\,\text{m} \times 2.9\,\text{m}$. (*b*) What is the total force acting upward on the underside of the table?
10. (II) In a movie, Tarzan evades his captors by hiding underwater for many minutes while breathing through a long, thin reed. Assuming the maximum pressure difference his lungs can manage and still breathe is −85 mm-Hg, calculate the deepest he could have been.
11. (II) The gauge pressure in each of the four tires of an automobile is 240 kPa. If each tire has a "footprint" of $220\,\text{cm}^2$, estimate the mass of the car.
12. (II) The maximum gauge pressure in a hydraulic lift is 17.0 atm. What is the largest size vehicle (kg) it can lift if the diameter of the output line is 28.0 cm?
13. (II) How high would the level be in an alcohol barometer at normal atmospheric pressure?
14. (II) (*a*) What are the total force and the absolute pressure on the bottom of a swimming pool 22.0 m by 8.5 m whose uniform depth is 2.0 m? (*b*) What will be the pressure against the *side* of the pool near the bottom?

15. (II) How high would the atmosphere extend if it were of uniform density throughout, equal to half the present density at sea level?

16. (II) Water and then oil (which don't mix) are poured into a U-shaped tube, open at both ends. They come to equilibrium as shown in Fig. 10–49. What is the density of the oil? [*Hint*: Pressures at points a and b are equal. Why?]

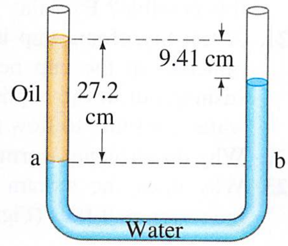

FIGURE 10–49 Problem 16.

17. (II) A house at the bottom of a hill is fed by a full tank of water 5.0 m deep and connected to the house by a pipe that is 110 m long at an angle of 58° from the horizontal (Fig. 10–50). (*a*) Determine the water gauge pressure at the house. (*b*) How high could the water shoot if it came vertically out of a broken pipe in front of the house?

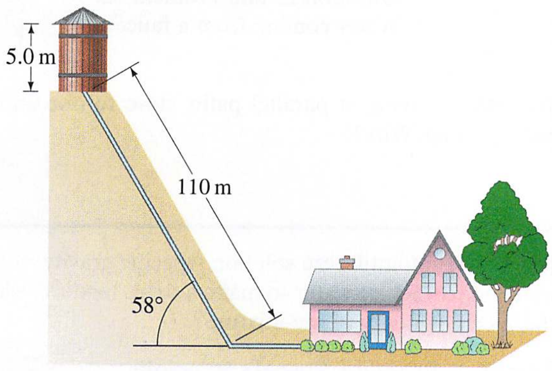

FIGURE 10–50 Problem 17.

18. (II) Determine the minimum gauge pressure needed in the water pipe leading into a building if water is to come out of a faucet on the twelfth floor, 38 m above that pipe.

19. (II) An open-tube mercury manometer is used to measure the pressure in an oxygen tank. When the atmospheric pressure is 1040 mbar, what is the absolute pressure (in Pa) in the tank if the height of the mercury in the open tube is (*a*) 28.0 cm higher, (*b*) 4.2 cm lower, than the mercury in the tube connected to the tank?

20. (II) In working out his principle, Pascal showed dramatically how force can be multiplied with fluid pressure. He placed a long, thin tube of radius $r = 0.30$ cm vertically into a wine barrel of radius $R = 21$ cm, Fig. 10–51. He found that when the barrel was filled with water and the tube filled to a height of 12 m, the barrel burst. Calculate (*a*) the mass of water in the tube, and (*b*) the net force exerted by the water in the barrel on the lid just before rupture.

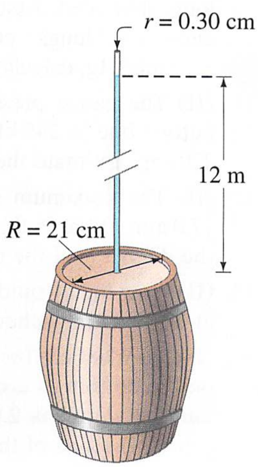

FIGURE 10–51 Problem 20 (not to scale).

* 21. (III) Estimate the density of the water 6.0 km deep in the sea. (See Table 9–1 and Section 9–5 regarding bulk modulus.) By what fraction does it differ from the density at the surface?

10–7 Buoyancy and Archimedes' Principle

22. (I) A geologist finds that a Moon rock whose mass is 9.28 kg has an apparent mass of 6.18 kg when submerged in water. What is the density of the rock?

23. (I) What fraction of a piece of aluminum will be submerged when it floats in mercury?

24. (II) A crane lifts the 18,000-kg steel hull of a ship out of the water. Determine (*a*) the tension in the crane's cable when the hull is submerged in the water, and (*b*) the tension when the hull is completely out of the water.

25. (II) A spherical balloon has a radius of 7.35 m and is filled with helium. How large a cargo can it lift, assuming that the skin and structure of the balloon have a mass of 930 kg? Neglect the buoyant force on the cargo volume itself.

26. (II) A 78-kg person has an apparent mass of 54 kg (because of buoyancy) when standing in water that comes up to the hips. Estimate the mass of each leg. Assume the body has SG = 1.00.

27. (II) What is the likely identity of a metal (see Table 10–1) if a sample has a mass of 63.5 g when measured in air and an apparent mass of 55.4 g when submerged in water?

28. (II) Calculate the true mass (in vacuum) of a piece of aluminum whose apparent mass is 2.0000 kg when weighed in air.

29. (II) An undersea research chamber is spherical with an external diameter of 5.20 m. The mass of the chamber, when occupied, is 74,400 kg. It is anchored to the sea bottom by a cable. What is (*a*) the buoyant force on the chamber, and (*b*) the tension in the cable?

30. (II) A scuba diver and her gear displace a volume of 65.0 L and have a total mass of 68.0 kg. (*a*) What is the buoyant force on the diver in sea water? (*b*) Will the diver sink or float?

31. (II) Archimedes' principle can be used not only to determine the specific gravity of a solid using a known liquid (Example 10–8); the reverse can be done as well. (*a*) As an example, a 3.40-kg aluminum ball has an apparent mass of 2.10 kg when submerged in a particular liquid: calculate the density of the liquid. (*b*) Derive a formula for determining the density of a liquid using this procedure.

32. (II) A 0.48-kg piece of wood floats in water but is found to sink in alcohol (SG = 0.79), in which it has an apparent mass of 0.047 kg. What is the SG of the wood?

33. (II) The specific gravity of ice is 0.917, whereas that of seawater is 1.025. What fraction of an iceberg is above the surface of the water?

34. (III) A 5.25-kg piece of wood (SG = 0.50) floats on water. What minimum mass of lead, hung from the wood by a string, will cause it to sink?

10–8 to 10–10 Fluid Flow; Bernoulli's Equation

35. (I) Using the data of Example 10–11, calculate the average speed of blood flow in the major arteries of the body, which have a total cross-sectional area of about 2.0 cm^2.

36. (I) A 15-cm-radius air duct is used to replenish the air of a room 9.2 m × 5.0 m × 4.5 m every 16 min. How fast does air flow in the duct?

37. (I) Show that Bernoulli's equation reduces to the hydrostatic variation of pressure with depth (Eq. 10–3b) when there is no flow $(v_1 = v_2 = 0)$.

38. (I) How fast does water flow from a hole at the bottom of a very wide, 4.6-m-deep storage tank filled with water? Ignore viscosity.

39. (II) A $\frac{5}{8}$-inch (inside) diameter garden hose is used to fill a round swimming pool 6.1 m in diameter. How long will it take to fill the pool to a depth of 1.2 m if water issues from the hose at a speed of 0.40 m/s?

40. (II) What gauge pressure in the water mains is necessary if a firehose is to spray water to a height of 15 m?

41. (II) A 6.0-cm-diameter horizontal pipe gradually narrows to 4.0 cm. When water flows through this pipe at a certain rate, the gauge pressure in these two sections is 32.0 kPa and 24.0 kPa, respectively. What is the volume rate of flow?

42. (II) What is the volume rate of flow of water from a 1.85-cm-diameter faucet if the pressure head is 15.0 m?

43. (II) If wind blows at 35 m/s over a house, what is the net force on the roof if its area is 240 m^2 and is flat?

44. (II) What is the lift (in newtons) due to Bernoulli's principle on a wing of area 78 m^2 if the air passes over the top and bottom surfaces at speeds of 260 m/s and 150 m/s, respectively?

45. (II) Estimate the air pressure inside a category 5 hurricane, where the wind speed is 300 km/h (Fig. 10–52).

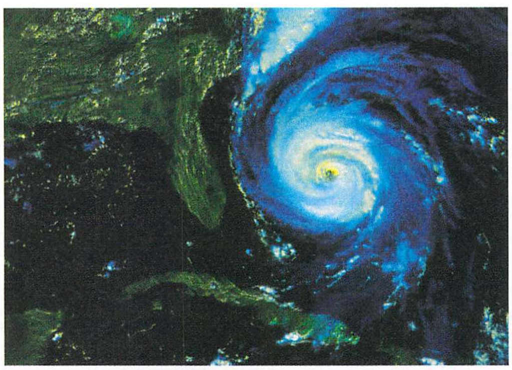

FIGURE 10–52 Problem 45.

46. (II) Water at a gauge pressure of 3.8 atm at street level flows into an office building at a speed of 0.60 m/s through a pipe 5.0 cm in diameter. The pipe tapers down to 2.6 cm in diameter by the top floor, 18 m above (Fig. 10–53), where the faucet has been left open. Calculate the flow velocity and the gauge pressure in such a pipe on the top floor. Assume no branch pipes and ignore viscosity.

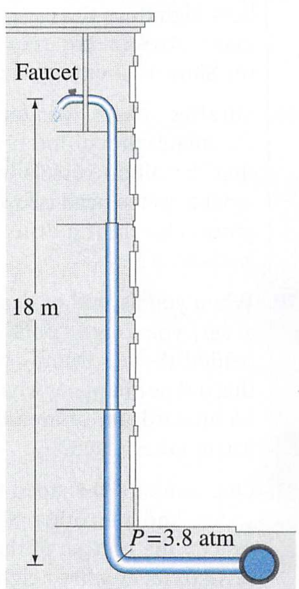

FIGURE 10–53 Problem 46.

47. (III) (*a*) Show that the flow velocity measured by a venturi meter (see Fig. 10–30) is given by the relation

$$v_1 = A_2\sqrt{\frac{2(P_1 - P_2)}{\rho(A_1^2 - A_2^2)}}.$$

(*b*) A venturi tube is measuring the flow of water; it has a main diameter of 3.0 cm tapering down to a throat diameter of 1.0 cm. If the pressure difference is measured to be 18 mm-Hg, what is the velocity of the water?

48. (III) In Fig. 10–54, take into account the speed of the top surface of the tank and show that the speed of fluid leaving the opening at the bottom is

$$v_1 = \sqrt{\frac{2gh}{(1 - A_1^2/A_2^2)}},$$

where $h = y_2 - y_1$, and A_1 and A_2 are the areas of the opening and of the top surface, respectively. Assume $A_1 \ll A_2$ so that the flow remains nearly steady and laminar.

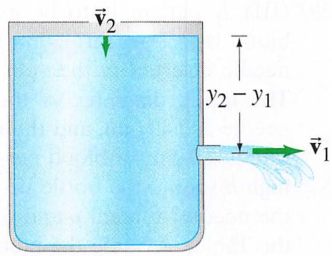

FIGURE 10–54 Problems 48 and 49.

49. (III) Suppose the opening in the tank of Fig. 10–54 is a height h_1 above the base and the liquid surface is a height h_2 above the base. The tank rests on level ground. (*a*) At what horizontal distance from the base of the tank will the fluid strike the ground? (*b*) At what other height, h_1', can a hole be placed so that the emerging liquid will have the same "range"? Assume $v_2 \approx 0$.

* 10–11 Viscosity

* 50. (II) A *viscometer* consists of two concentric cylinders, 10.20 cm and 10.60 cm in diameter. A particular liquid fills the space between them to a depth of 12.0 cm. The outer cylinder is fixed, and a torque of 0.024 m·N keeps the inner cylinder turning at a steady rotational speed of 62 rev/min. What is the viscosity of the liquid?

* 10–12 Flow in Tubes; Poiseuille's Equation

* 51. (I) A gardener feels it is taking him too long to water a garden with a $\frac{3}{8}$-in.-diameter hose. By what factor will his time be cut if he uses a $\frac{5}{8}$-in.-diameter hose? Assume nothing else is changed.

* 52. (II) Engine oil (assume SAE 10, Table 10–3) passes through a 1.80-mm-diameter tube in a prototype engine. The tube is 5.5 cm long. What pressure difference is needed to maintain a flow rate of 5.6 mL/min?

* 53. (II) What must be the pressure difference between the two ends of a 1.9-km section of pipe, 29 cm in diameter, if it is to transport oil $(\rho = 950\ \text{kg/m}^3, \eta = 0.20\ \text{Pa}\cdot\text{s})$ at a rate of 450 cm^3/s?

* 54. (II) What diameter must a 21.0-m-long air duct have if the ventilation and heating system is to replenish the air in a room 9.0 m × 12.0 m × 4.0 m every 10 min? Assume the pump can exert a gauge pressure of 0.71×10^{-3} atm.

* 55. (II) Calculate the pressure drop per cm along the aorta using the data of Example 10–11 and Table 10–3.

* 56. (II) Assuming a constant pressure gradient, if blood flow is reduced by 75%, by what factor is a blood vessel decreased in radius?

* 57. (II) Poiseuille's equation does not hold if the flow velocity is high enough that turbulence sets in. The onset of turbulence occurs when the **Reynolds number**, *Re*, exceeds approximately 2000. *Re* is defined as

$$Re = \frac{2\bar{v}r\rho}{\eta},$$

where $\bar{v}$ is the average speed of the fluid, ρ is its density, η is its viscosity, and r is the radius of the tube in which the fluid is flowing. (*a*) Determine if blood flow through the aorta is laminar or turbulent when the average speed of blood in the aorta $(r = 1.2\ \text{cm})$ during the resting part of the heart's cycle is about 40 cm/s. (*b*) During exercise, the blood-flow speed approximately doubles. Calculate the Reynolds number in this case, and determine if the flow is laminar or turbulent.

* 58. (III) A patient is to be given a blood transfusion. The blood is to flow through a tube from a raised bottle to a needle inserted in the vein (Fig. 10–55). The inside diameter of the 4.0-cm-long needle is 0.40 mm, and the required flow rate is 4.0 cm^3 of blood per minute. How high h should the bottle be placed above the needle? Obtain ρ and η from the Tables. Assume the blood pressure is 18 torr above atmospheric pressure.

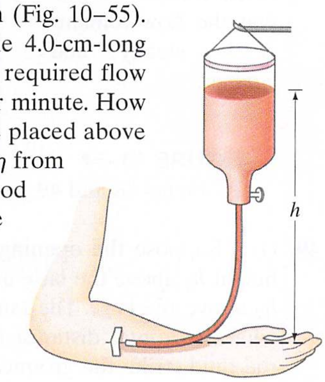

FIGURE 10–55 Problems 58 and 63.

* 10–13 Surface Tension and Capillarity

* 59. (I) If the force F needed to move the wire in Fig. 10–35 is 5.1×10^{-3} N, calculate the surface tension γ of the enclosed fluid. Assume $L = 0.070$ m.

* 60. (I) Calculate the force needed to move the wire in Fig. 10–35 if it is immersed in a soapy solution and the wire is 18.2 cm long.

* 61. (II) If the base of an insect's leg has a radius of about 3.0×10^{-5} m and the insect's mass is 0.016 g, would you expect the six-legged insect to remain on top of the water? Why or why not?

* 62. (II) The surface tension of a liquid can be determined by measuring the force F needed to just lift a circular platinum ring of radius r from the surface of the liquid. (*a*) Find a formula for γ in terms of F and r. (*b*) At 30°C, if $F = 8.40 \times 10^{-3}$ N and $r = 2.8$ cm, calculate γ for the tested liquid.

General Problems

63. Intravenous infusions are often made under gravity, as shown in Fig. 10–55. Assuming the fluid has a density of 1.00 g/cm^3, at what height h should the bottle be placed so the liquid pressure is (*a*) 55 mm-Hg, and (*b*) 650 mm-H_2O? (*c*) If the blood pressure is 18 mm-Hg above atmospheric pressure, how high should the bottle be placed so that the fluid just barely enters the vein?

64. A 2.4-N force is applied to the plunger of a hypodermic needle. If the diameter of the plunger is 1.3 cm and that of the needle 0.20 mm, (*a*) with what force does the fluid leave the needle? (*b*) What force on the plunger would be needed to push fluid into a vein where the gauge pressure is 18 mm-Hg? Answer for the instant just before the fluid starts to move.

65. A bicycle pump is used to inflate a tire. The initial tire (gauge) pressure is 210 kPa (30 psi). At the end of the pumping process, the final pressure is 310 kPa (45 psi). If the diameter of the plunger in the cylinder of the pump is 3.0 cm, what is the range of the force that needs to be applied to the pump handle from beginning to end?

66. Estimate the pressure on the mountains underneath the Antarctic ice sheet, which is typically 3 km thick.

67. What is the approximate difference in air pressure between the top and the bottom of the Empire State building in New York City? It is 380 m tall and is located at sea level. Express as a fraction of atmospheric pressure at sea level.

68. A hydraulic lift is used to jack a 970-kg car 12 cm off the floor. The diameter of the output piston is 18 cm, and the input force is 250 N. (*a*) What is the area of the input piston? (*b*) What is the work done in lifting the car 12 cm? (*c*) If the input piston moves 13 cm in each stroke, how high does the car move up for each stroke? (*d*) How many strokes are required to jack the car up 12 cm? (*e*) Show that energy is conserved.

69. Giraffes are a wonder of cardiovascular engineering. Calculate the difference in pressure (in atmospheres) that the blood vessels in a giraffe's head have to accommodate as the head is lowered from a full upright position to ground level for a drink. The height of an average giraffe is about 6 m.

70. When you ascend or descend a great deal when driving in a car, your ears "pop," which means that the pressure behind the eardrum is being equalized to that outside. If this did not happen, what would be the approximate force on an eardrum of area 0.50 cm^2 if a change in altitude of 950 m takes place?

71. One arm of a U-shaped tube (open at both ends) contains water, and the other alcohol. If the two fluids meet at exactly the bottom of the U, and the alcohol is at a height of 18.0 cm, at what height will the water be?

72. A simple model (Fig. 10–56) considers a continent as a block (density $\approx$ 2800 kg/m^3) floating in the mantle rock around it (density $\approx$ 3300 kg/m^3). Assuming the continent is 35 km thick (the average thickness of the Earth's continental crust), estimate the height of the continent above the surrounding rock.

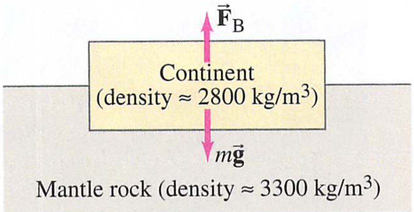

FIGURE 10–56 Problem 72.

73. The contraction of the left ventricle (chamber) of the heart pumps blood to the body. Assuming that the inner surface of the left ventricle has an area of 82 cm^2 and the maximum pressure in the blood is 120 mm-Hg, estimate the force exerted by that ventricle at maximum pressure.

74. Estimate the total mass of the Earth's atmosphere, using the known value of atmospheric pressure at sea level.

75. Suppose a person can reduce the pressure in his lungs to −80 mm-Hg gauge pressure. How high can water then be sucked up a straw?

76. A ship, carrying fresh water to a desert island in the Caribbean, has a horizontal cross-sectional area of 2650 m^2 at the waterline. When unloaded, the ship rises 8.50 m higher in the sea. How much water was delivered?

77. A copper (Cu) weight is placed on top of a 0.50-kg block of wood (density = 0.60×10^3 kg/m^3) floating in water, as shown in Fig. 10–57. What is the mass of the copper if the top of the wood block is exactly at the water's surface?

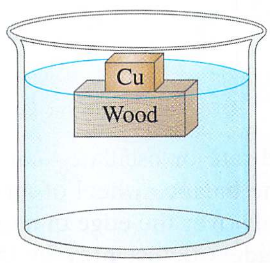

FIGURE 10–57 Problem 77.

78. A raft is made of 10 logs lashed together. Each is 56 cm in diameter and has a length of 6.1 m. How many people can the raft hold before they start getting their feet wet, assuming the average person has a mass of 68 kg? Do *not* neglect the weight of the logs. Assume the specific gravity of wood is 0.60.

79. During each heartbeat, approximately 70 cm^3 of blood is pushed from the heart at an average pressure of 105 mm-Hg. Calculate the power output of the heart, in watts, assuming 70 beats per minute.

80. A bucket of water is accelerated upward at 2.4*g*. What is the buoyant force on a 3.0-kg granite rock (SG = 2.7) submerged in the water? Will the rock float? Why or why not?

81. How high should the pressure head be if water is to come from a faucet at a speed of 9.5 m/s? Ignore viscosity.

82. The stream of water from a faucet decreases in diameter as it falls (Fig. 10–47). Derive an equation for the diameter of the stream as a function of the distance y below the faucet, given that the water has speed v_0 when it leaves the faucet, whose diameter is d.

83. Four lawn sprinkler heads are fed by a 1.9-cm-diameter pipe. The water comes out of the heads at an angle of 35° to the horizontal and covers a radius of 8.0 m. (*a*) What is the velocity of the water coming out of each sprinkler head? (Assume zero air resistance.) (*b*) If the output diameter of each head is 3.0 mm, how many liters of water do the four heads deliver per second? (*c*) How fast is the water flowing inside the 1.9-cm-diameter pipe?

84. You need to siphon water from a clogged sink. The sink has an area of 0.48 m^2 and is filled to a height of 4.0 cm. Your siphon tube rises 50 cm above the bottom of the sink and then descends 100 cm to a pail as shown in Fig. 10–58. The siphon tube has a diameter of 2.0 cm. (*a*) Assuming that the water enters the siphon tube with almost zero velocity, calculate its velocity when it enters the pail. (*b*) Estimate how long it will take to empty the sink.

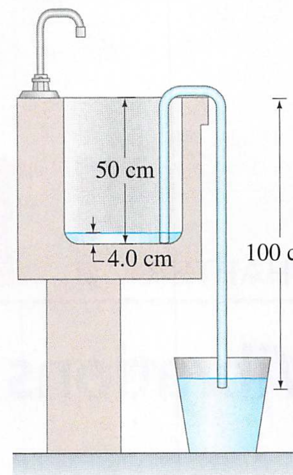

FIGURE 10–58 Problems 84 and 85.

85. Consider a siphon which transfers water from one vessel to a second (lower) one, as in Fig. 10–58. Determine the rate of flow if the tube has a diameter of 1.2 cm and the difference in water levels of the two containers is 64 cm.

86. An airplane has a mass of 2.0×10^6 kg, and the air flows past the lower surface of the wings at 95 m/s. If the wings have a surface area of 1200 m^2, how fast must the air flow over the upper surface of the wing if the plane is to stay in the air? Consider only the Bernoulli effect.

* 87. Blood from an animal is placed in a bottle 1.70 m above a 3.8-cm-long needle, of inside diameter 0.40 mm, from which it flows at a rate of 4.1 cm^3/min. What is the viscosity of this blood?

* 88. If cholesterol build-up reduces the diameter of an artery by 15%, what will be the effect on blood flow?

Answers to Exercises

A: The same. Pressure depends on depth, not on length.
B: Lower.
C: Increases.