End-of-Chapter Exercises

Exercises 1 – 12 are primarily conceptual questions that are designed to see if you have understood the main concepts of the chapter.

1. A particular block floats with 30% of its volume submerged in water, but with only 20% of its volume submerged in a second fluid. Which fluid exerts a larger buoyant force on the block? Briefly justify your answer.

2. A solid brick and a solid wooden block have exactly the same dimensions. When they are placed in a bucket of water, the brick sinks to the bottom but the block floats. Which object experiences a larger buoyant force?

3. An aluminum ball and a steel ball are exactly the same size, but the aluminum ball has less mass. Both balls sink to the bottom of a glass of water. (a) Briefly explain why the aluminum ball has less mass. (b) Which ball displaces more water in the glass?

4. When a block suspended from a spring scale is half submerged in Fluid A, the spring scale reads 8 N. When the block is half submerged in Fluid B, the spring scale reads 6 N. Which fluid has a higher density? Explain.

5. (a) Explain the physics behind a drinking straw. How is it possible to use a straw to drink through? (b) If you fill the straw partly with fluid and then seal the upper end of the straw with your thumb, you can get the column of fluid to remain in the straw. How does that work?

6. To crush a soda can with atmospheric pressure, start by placing a small amount of water into an empty soda can. Carefully heat the can until steam comes out of the can. It's important to let this process continue long enough for water vapor to drive most of the air out of the can. If you then quickly remove the can from the heat source and invert it into a bowl of cold water so that the opening to the can is under water, the can should almost instantly collapse. Do this all very carefully to make sure you don't burn yourself. Explain why the can collapses.

7. Three cubes of identical volume but different density are placed in a container of fluid. The blocks are in equilibrium when they are in the positions shown in Figure 9.27. If the strings connected to blocks A and C were cut, those blocks would not be in equilibrium. Rank the cubes based on the magnitude of (a) their densities; (b) the buoyant forces they experience.

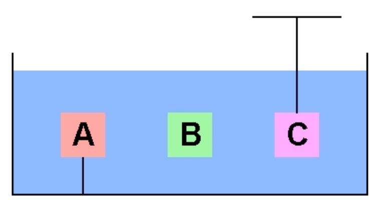
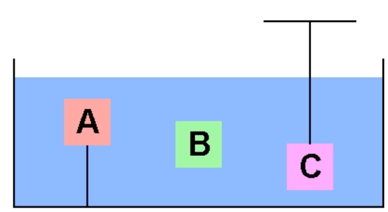


Figure 9.27: Three cubes of identical volume but different density at equilibrium in a container of fluid. For Exercise 7.

8. The two strings in Figure 9.27 are now lengthened, giving the situation shown in Figure 9.28. The cubes still have identical volumes but different densities. Rank the cubes based on the magnitude of (a) the force applied by the fluid on the top surface of the cube; (b) the force applied by the fluid on the bottom surface of the cube; (c) the buoyant force acting on the cube.

Figure 9.28: The same three cubes of identical volume but different density at equilibrium in a container of fluid as in Figure 9.27, but with longer strings. For Exercise 8.



9. A beaker of water is placed on a scale. If you dip your little finger into the water, making sure that you don't touch the beaker itself, does the scale reading increase, decrease, or stay the same? Explain.

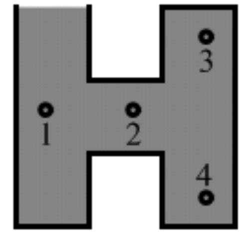


Figure 9.29: Four points are labeled in an H-shaped container of fluid, that is open to the atmosphere only at the top left. For Exercise 10.

10. Four points are labeled in a container shaped like the letter H, as shown in Figure 9.29. The container is filled with fluid, and open to the atmosphere only at the top left of the container. Rank the points based on their pressure, from largest to smallest. Use only > and/or = signs in your ranking (e.g., 2>1=3>4).

11. If you are careful when you lie down and get up again, it does not hurt to lie on a bed of nails. Supporting your weight on a single nail is a different story, however. Explain why you can lie comfortably on a bed of nails, but not with your weight supported by the point of a single nail.

12. Water is placed in a U-shaped tube, as shown in Figure 9.30. The tube is open to the atmosphere at the top left, but the tube is sealed with a rubber stopper at the top right. Can the water in the tube remain as shown, or must the level on the right drop and the level on the left rise? Explain.

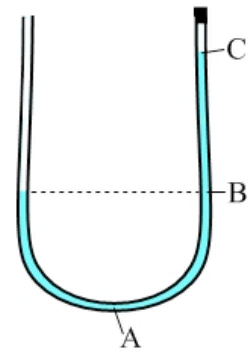


Figure 9.30: Fluid in a U-shaped tube that is open to the atmosphere on the left and sealed on the right. For Exercise 12.

Exercises 13 – 16 deal with buoyancy and/or density.

13. A particular block floats with 30% of its volume submerged in water, but with only 20% of its volume submerged in a second fluid. Taking the density of water to be 1000 kg/m^3, determine the density of (a) the block; (b) the second fluid.

14. You put some water into a glass and carefully mark the level of the top of the water. You then pour some of the water into one section of an ice cube tray and place the tray in the freezer to form a single ice cube. (a) Keeping in mind that water expands in volume by about 10% when it freezes, what will happen when the ice cube is placed back in the glass? Will the top of the water be higher, lower, or the same as it was before? (b) As the ice melts, will the water level rise, fall, or stay the same? Briefly explain your answers.

15. You have a glass of water with one or more ice cubes in it. Test your friends by asking them what will happen to the ice when you pour some oil on top of the water and ice. The density of the oil must be less than that of ice so the ice does not float to the top of the oil. Will the ice cube(s) float higher or lower in the water when the oil is poured on top, or will the level be unchanged? How will you explain the result to your friends?

16. When a block suspended from a spring scale is half submerged in Fluid A, the spring scale reads 8 N. When the block is half submerged in Fluid B, the spring scale reads 6 N. If the density of one fluid is twice as large as the density of the other, determine the buoyant force acting on the block when the block is half submerged in (a) Fluid A; (b) Fluid B. (c) What is the weight of the block?

Exercises 17 – 26 are designed to give you some practice with applying the general method of solving a typical buoyancy problem. For each exercise begin with the following parts: (a) Draw a diagram of the situation. (b) Sketch one of more free-body diagrams, including appropriate coordinate systems for each. (c) Apply Newton's Second Law.

17. A wooden block with a weight of 8.0 N floats with 60% of its volume submerged in oil. Parts (a) – (c) as described above. (d) What is the magnitude and direction of the buoyant force exerted on the block by the oil?

18. A metal ball with a weight of 12.0 N hangs from a string tied to a spring scale. When the ball is half-submerged in a particular fluid, the spring scale reads 7.0 N. The goal of this exercise is to find the buoyant force exerted on the block by the fluid when the fluid is both half-submerged and completely submerged, and to find the reading on the spring scale when the ball is completely submerged. Parts (a) – (c) as described above, making sure that you draw two sets of diagrams, one when the ball is half submerged and one when the ball is completely submerged. Find the buoyant force exerted on the ball by the fluid when the ball is (d) half submerged; (e) completely submerged. (f) What is the reading on the spring scale when the ball is completely submerged?

19. A basketball floats in a large tub of water with $1/11^{th}$ of its volume submerged. The mass of the basketball is 500 grams. The goal of this exercise is to find the radius of the ball, assuming the water has a density of 1000 kg/m^3. Parts (a) – (c) as described above. (d) What is the volume of water displaced by the ball? (e) What is the volume of the ball? (f) What is the equation for the volume of a sphere? (g) What is the radius of the basketball? (h) Did you use a particular value for g, the acceleration due to gravity? If so, what was it? Comment on the effect, if any, of you using a different value of g for the calculation.

20. Consider again the situation described in the previous exercise, with the basketball floating in the tub of water. Use $g = 9.80$ m/s^2. The goal of this exercise is to determine the force you need to apply to the ball to hold it below the surface of the water. Parts (a) – (c) as described above. You should have sketched diagrams for the floating ball in the previous exercise, so now draw a set of diagrams for the ball when you are holding it completely submerged below the water. What is the buoyant force applied to the ball by the water when the ball is (d) floating? (e) completely submerged? (f) What is the force you need to apply to the ball to hold it under the water?

21. A low-density block with a weight of 10 N is placed in a beaker of water and tied to the bottom of the beaker by a vertical string of fixed length. When the block is 25% submerged, the tension in the string is 15 N. The string will break if its tension exceeds 65 N. As water is steadily added to the beaker, the block becomes more and more submerged. Parts (a) – (c) as described above. (d) What fraction of the block is submerged at the instant the string breaks? (e) After the string breaks and the block comes to a new equilibrium position in the beaker, what fraction of the block's volume is submerged?

22. A large hot-air balloon has a mass of 300 kg, including the shell of the balloon, the basket, and the passengers, but not including the air inside the balloon itself. The goal of the exercise is to determine the volume of the balloon, assuming the air inside the balloon has a density that is 90% of the density of the air outside, that the density of the air outside the balloon is 1.30 kg/m^3, and that the balloon is floating in equilibrium above the ground. Parts (a) – (c) as described above. (d) What is the volume of the balloon?

23. You are designing a pair of Styrofoam (density 1.30 kg/m^3) shoes that you can wear to walk on water. Your mass is 50 kg, and you want the shoes to be 30% submerged in the water. Parts (a) – (c) as described above. (d) What volume of Styrofoam do you need for each shoe? (e) Estimate the volume of a typical shoebox, and compare the volume of one of the Styrofoam shoes to the volume of a shoebox.

24. You, Archimedes, suspect that the king's crown is not solid gold but is instead gold-plated lead. To test your theory, you weigh the crown, and find it to weigh 60.0 N and to have an apparent weight of 56.2 N when it is completely submerged in water. Parts (a) – (c) as described above. (d) What is the average density of the crown? (e) Is it solid gold? If not, find what fraction (by weight) is gold and what fraction is lead.

25. A square raft at the local beach is made from five 2.0-meter wooden boards that have a square cross-section measuring 40 cm x 40 cm. The goal of the exercise is to determine the largest number of children that can stand on the raft without the raft being completely submerged if the boards have a density of 500 kg/m^3. Assume that each child has a mass of 35 kg. Parts (a) – (c) as described above. (d) How many children can stand on the raft without the raft being completely submerged, assuming each child is completely out of the water?

26. After heavy rains have stopped, you go out in a boat to check the level of the water in a reservoir behind a dam (your boat is in the reservoir). You notice that the water is dangerously close to spilling over the top of the dam, and when you look up at the sky you see more dark clouds approaching. Your boat has a very heavy anchor in it, so the goal of the exercise is to determine how throwing the anchor overboard would affect the level of the water in the reservoir (assuming the boat displaces a reasonable fraction of the water in the reservoir). Parts (a) – (c) as described above, where you should draw two sets of diagrams, one when the anchor is in the boat and the other when the anchor is resting at the bottom of the reservoir. (d) Using your diagrams to help you, determine whether the water level in the reservoir rises, falls, or stays the same when you toss the anchor overboard.

Exercises 27 – 30 deal with pressure.

27. A cylindrical barrel is completely full of water and sealed at the top except for a narrow tube extending vertically through the lid. The barrel has a diameter of 80 cm, while the tube has a diameter of 1 cm. You can actually cause the lid to pop off by pouring a relatively small amount of water into the tube. To what height do you need to add water to the tube to get the lid to pop off the barrel? The lid pops off when the vector sum of the force of the atmosphere pushing down on the top of the lid and the force of the water pushing up on the bottom of the lid is 250 N up.

28. Before the negative environmental impact of mercury was fully understood, many barometers utilized a column of mercury to measure atmospheric pressure. This was first done by Evangelista Torricelli in 1643. A design for a simple barometer is shown in Figure 9.31, where there is negligible pressure at the top of the inverted column. (a) What is the height of a column of mercury that produces a pressure at its base equal to standard atmospheric pressure? (b) If water was used instead, what is the height of the column of water required? (c) Does this help explain why mercury was chosen as the working fluid in many barometers? Are there any other advantages mercury offers over water in this application?

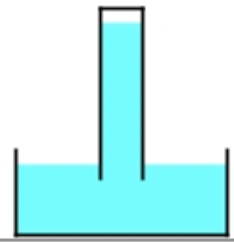


Figure 9.31: A simple liquid barometer, with an inverted column of fluid in a reservoir of that same fluid. The reservoir is open to the atmosphere, but the column is not. For Exercises 28 and 29.

29. Consider again the liquid barometer described in Exercise 28 and shown in Figure 9.31. Because of an approaching storm system, the local atmospheric pressure drops from 101.3 kPa to 99.7 kPa. (a) Does this cause the liquid to rise or fall in the tube? Determine the change in height of the column of liquid if the liquid is (b) mercury; (c) water.

30. In 2002, Tanya Streeter of the USA set a world record of 160 m for the deepest dive without breathing assistance (such as SCUBA gear). At that depth, what is the absolute pressure?

Exercises 31 – 35 address issues in fluid dynamics.

31. If you turn on a water faucet so that the water flows smoothly, you should observe that the cross-sectional area of the water stream decreases as the stream drops. (a) Explain why the water stream narrows. At a particular point, the flow speed is 10 cm/s and the stream has a cross-sectional area of 2.0 cm^2. At a point 20 cm below this point, determine (b) the flow speed, and (c) the cross-sectional area of the stream.

32. Take a bottle of water, filled to a depth of 25 cm, and carefully poke a small hole in the bottom of the bottle with a nail. (a) When you remove the cap from the bottle, what is the speed of the water emerging from the hole? (b) When you screw the cap back on the bottle, the water should stop coming out of the hole. Explain why.

33. A cylinder of height H sits on the floor. The cylinder is completely full of water, but a stream of water is emerging horizontally from the side of the cylinder at a distance h from the top. In terms of H, h, and g, determine: (a) the speed with which the water is emerging from the cylinder; (b) the time it takes the water to travel from the hole to the floor; (c) the horizontal distance traveled by the water as it falls.

34. Consider again the cylinder described in Exercise 33, but this time let's say there are three holes in the side of the cylinder. The holes are at distances of $H/4$, $H/2$, and $3H/4$ from the top of the cylinder. (a) Make a prediction – which stream of water travels furthest horizontally before reaching the floor? What do you base your prediction on? (b) Check your prediction using $H = 1.0$ m. Calculate the horizontal distance traveled, before reaching the floor, by the water from each hole.

35. While washing your hands at a sink, you determine that the water emerges from the faucet, which has a diameter of 1.0 cm, with a speed of 1.8 m/s. If the water comes from a pump located 1.5 m below the faucet, what is the absolute pressure at the pump if the pipe leading from the pump has a diameter of (a) 1.0 cm; (b) 8.0 cm?

General problems and conceptual questions

36. Consider the situation shown in Figure 9.32. (a) In figure A, what is the tension in the string? In figure B, what is the (b) buoyant force on the ball? (c) scale reading? In figure C, what is the (d) buoyant force on the ball? (e) tension in the string? (f) scale reading? In figure D, what is the (g) buoyant force on the ball? (h) scale reading?

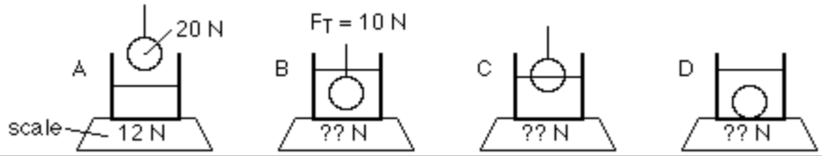


Figure 9.32: In figure A, a 20 N ball is supported by a string. It hangs over a beaker of fluid that sits on a scale. The scale reading is 12 N. In figure B the ball is completely submerged in the fluid. In figure C the ball is exactly half submerged. In figure D the string has been cut and the ball rests on the bottom of the beaker.

37. As shown in Figure 9.33, a wooden cube measuring 20.0 cm on each side floats in water with 80.0% of its volume submerged. Suspended by a string below the wooden cube is a metal cube. The metal cube measures 10.0 cm on each side and has a specific gravity of 5.00. (a) Which cube has a larger buoyant force acting on it? (b) Taking the density of water to be 1000 kg/m^3, what is the density of the wooden cube? (c) What is the tension in the string between the cubes? Assume the string itself has negligible mass and volume. (d) The pair of blocks is now placed in a different liquid. When the blocks are at equilibrium in this new liquid, the buoyant force acting on the wooden cube is exactly the same as the buoyant force acting on the metal cube. What is the density of this new liquid?

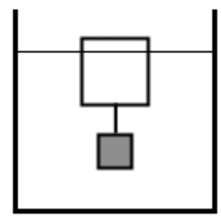


Figure 9.33: A metal cube suspended from a wooden cube, for Exercises 37 – 39.

38. Consider the situation shown in Figure 9.33, in which a wooden cube measuring 20.0 cm on each side floats in a fluid with 80.0% of its volume submerged. Suspended by a string below the wooden cube is a metal cube. The metal cube measures 10.0 cm on each side. If the wooden cube has a density of 800 kg/m^3 and the metal cube has a density of 1600 kg/m^3 what is the density of the fluid?

39. Consider the situation described in Exercise 38. (a) Describe qualitatively what will happen if the string is cut. (b) What is the magnitude and direction of the acceleration of each block immediately after the string is cut? (c) After a long time, where will the blocks be?

40. Three cubes of identical volume but different density are placed in a container of fluid. The blocks are in equilibrium when they are in the positions shown in Figure 9.34. If the strings connected to blocks A and C were cut, those blocks would not be in equilibrium. If the densities of the cubes have a 1:2:3 ratio and the magnitude of the tension in the string attached to block A is F_T, what is the magnitude of the tension in the string attached to block C? Express your answer in terms of F_T.

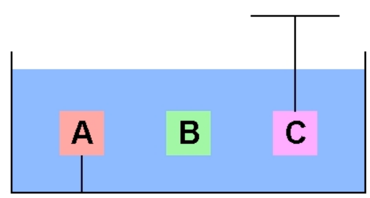


Figure 9.34: Three cubes of identical volume but different density at equilibrium in a container of fluid. For Exercise 40.

41. A toy balloon, which has a mass of 3.5 g before it is inflated, is filled with helium (with a density of 0.18 kg/m^3) to a volume of 8000 cm^3. What is the minimum mass that should be hung from the balloon to prevent it from rising up into the air?

42. Who was Archimedes? When did he live, and what else is he known for aside from buoyancy? Do some background reading and write a couple of paragraphs about him.

43. Use equation 9.7 to estimate the height of the atmosphere. Do you expect this to be a reasonably accurate measure of the height? Would your calculated value represent a lower limit or an upper limit of the true height of the atmosphere? Explain.

44. A popular demonstration about atmospheric pressure is called the Magdeburg hemispheres. Two hemispheres are held together while air is pumped out from between them. As long as there is a good seal between the hemispheres, it is extremely hard to separate them. (a) Explain why. (b) If the hemispheres are 20 cm in diameter, determine the force required to separate them, assuming all the air is evacuated from inside. This demonstration was first done by Otto von Guericke in the German town of Magdeburg around 1656, where two teams of horses tried unsuccessfully to pull the hemispheres apart.

45. Standard atmospheric pressure, which is 1 atm or 101.3 kPa, can be quoted in many different units. State atmospheric pressure in three other units, at least two of which are not SI units.

46. Pour your favorite carbonated beverage into a tall glass and watch the bubbles rise. What should happen to the size of the bubbles as they rise? Why? Can you observe the bubbles changing size as they rise?

47. A brick with a density of 4200 kg/m^3 measures 8 cm by 15 cm by 30 cm. It can be placed with any of its six faces against the floor. (a) Find the maximum and minimum values of the normal force exerted by the floor on the block when the block is resting on the floor in its various orientations. (b) Find the maximum and minimum values of the pressure associated with the block resting on the floor in its various orientations. Neglect any contribution from atmospheric pressure.

48. What are “the bends”, in reference to deep-sea diving? Write a paragraph or two on what causes the bends, how to prevent them, and how to treat a diver who has the bends.

49. Mountain climbers, and people who live at high altitudes, have difficulty making a good cup of tea or coffee, despite the fact that they follow the usual procedure of heating water until it boils, and bringing the tea or coffee together with the water. What is the problem?

50. As an engineer at a mine, you are in charge of pumping water out of a flooded mine shaft that extends 20 m down from the surface. You consider two different configurations, one in which the pump is placed at the surface and it essentially sucks water out of the shaft in the same manner that a drinking straw works, and another in which the pump is placed at the bottom of the shaft and pumps water up to the surface. Assuming the pump is fully submersible (i.e., that it will work when completely submerged in water at the bottom of the shaft), which of these configurations is more appropriate for this situation? Why?

51. Water is placed in a U-shaped tube, as shown in Figure 9.35. The tube is open to the atmosphere at the top left, but the tube is sealed with a rubber stopper at the top right. Point A is 20 cm below point B, and point C is 30 cm above point B. Determine the gauge pressure at (a) point A; (b) point B; (c) point C.

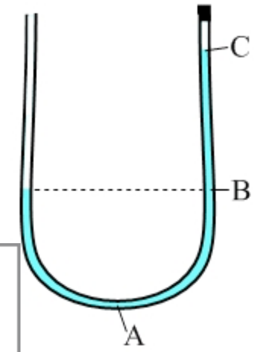


Figure 9.35: Fluid in a U-shaped tube that is open to the atmosphere on the left and sealed on the right. For Exercise 51.

52. A flexible tube can be used as a simple siphon to transfer fluid from one container to a lower container. This is shown in Figure 9.36. The fluid has a density of 800 kg/m^3. If the tube has a cross-sectional area that is much smaller than the cross-sectional area of the higher container, what is the speed of the fluid at (a) point Z? (b) point Y? (c) What is the absolute pressure at point Y? See the dimensions given in Figure 9.35, and take atmospheric pressure to be 101.3 kPa.

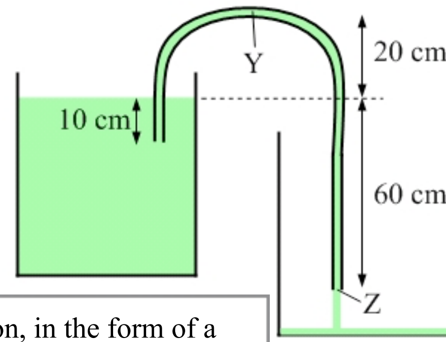


Figure 9.36: A siphon, in the form of a flexible tube, being used to transfer fluid from the container on the left to the container on the right.

53. A venturi tube is a tube with a constriction in it. Pressure in a venturi tube can be measured by attaching a U-shaped fluid-filled device to the venturi tube as shown in Figure 9.37. (a) If the fluid in the U is water, and there is a 10 cm difference between the water levels on the two sides, what is the pressure difference between points 1 and 2 in the venturi tube? (b) The venturi tube has air flowing through it. If the cross-sectional area of the venturi tube is 6 times larger at point 1 than it is at point 2, what is the air speed at point 2?

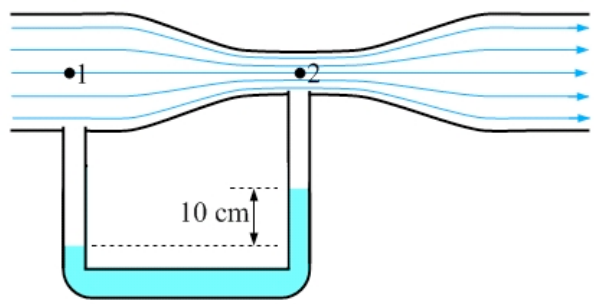


Figure 9.37: A venturi tube with a water-filled U-tube to measure pressure, for Exercise 53.

54. Your town supplies water with the aid of a tall water tower that is on top of the highest hill in town. The top surface of the water in the tank is open to the atmosphere. (a) Explain why it makes sense to use such a water tower in the water-distribution system. (b) Would you expect the water pressure to be highest in homes at higher elevations or at lower elevations in the town, all other factors being equal?

55. Consider the water tower described in the previous exercise. Opening a valve at the base of the tower allows water to flow out a pipe that bends up, projecting water straight up into the air. If the water reaches a maximum height of 8.5 m above the base of the tower, to what depth is the water tower filled with water?

56. As you wash your car, you are using an ordinary garden hose to spray water over the car. You notice that, if you cover most of the open end of the hose with your hand, the water sprays out with a higher speed. Explain how this works.

57. About once every 30 minutes, a geyser known as Old Faceful projects water 15 m straight up into the air. (a) What is the speed of the water when it emerges from the ground? (b) Assuming the water travels to the surface through a narrow crack that extends 10 m below the surface, and that the water comes from a chamber with a large cross-sectional area, what is the pressure in the chamber?

58. A drinking fountain projects water at a 45˚ angle with respect to the horizontal. The water reaches a maximum height of 10 cm above the opening of the fountain. With what speed was it projected into the air?

59. While taking a shower, you notice that the shower head is made up of 40 small round openings, each with a radius of 1.5 mm. You also determine that it takes 8.0 s for the shower to completely fill a 1-liter container you hold in the water stream. The water in your house is pumped by a pump in the basement, 7.2 m below the level of the shower head. If the pump maintains an absolute pressure of 1.5 atm., what is the cross-sectional area of the pipe connected to the pump?

60. There were many famous members of the Bernoulli family, and they did not all get along. Do some background reading on the Bernoullis and write a paragraph or two about them, making sure that you identify the member of the family credited with the Bernoulli equation we used in this chapter.

61. Three students are having a conversation. Explain what you think is correct about what they say, and what you think is incorrect.

Jenna: OK, so here's the question. "A block floats 60% submerged in Fluid A, and only 40% submerged in Fluid B. Which fluid applies a larger buoyant force to the block?" That should be easy, right? The buoyant force is proportional to the volume displaced, so Fluid A exerts the larger force.

Jaime: I think they give the same buoyant force. In both cases, the fluid has to support the full weight of the block. So, the buoyant force equals mg in both cases.

Jenna: Is it the full mg, though? Or is it 60% of mg in the first case and 40% in the second?

Michael: What if we think about densities? Fluid B has a bigger density, and the buoyant force is proportional to the fluid density, so it should really be B that exerts the bigger force.

Jaime: That's actually why it works out to be equal. The buoyant force depends on both the volume displaced and the density, so B has less volume displaced but more density, and it balances out.

62. In Essential Question 9.10, we analyzed what would happen to the flow rate if the radius of a blood vessel decreased by 5%. For that same situation, if the heart adjusted to maintain the original flow rate, by what factor would the pressure difference between the ends of the blood vessel increase?

63. By what factor would the cross-sectional area of a blood vessel have to change (all other factors being unchanged) for the flow rate to be reduced by 50%?

64. If the radius of a blood vessel drops to 80% of its original radius because of the buildup of plaque, and the body responds by increasing the pressure difference across the blood vessel by 10%, what will have happened to the flow rate?

65. A patient in the hospital is receiving a saline solution through a needle in their arm. The needle is 3.0 cm long, horizontal, with one end in a vein in the arm, and the other end attached to a wide tube that extends down from the bag of solution, which hangs from a pole so that the fluid level is 90 cm above the needle. The inner radius of the needle is 0.20 mm. The top of the fluid is exposed to the atmosphere, and the flow rate of the fluid (which has a density of 1025 kg/m^3 and a viscosity of 0.0010 Pa s) through the needle is 0.30 L/h. What is the average gauge pressure inside the vein where the needle is?

66. At 20˚C, honey has a viscosity about 4000 times larger than that of water. For a particular tube, 400 mL/s of water will flow through for a particular pressure difference. (a) If the same tube, with the same pressure difference, is used for honey, what will the flow rate be? (b) If you want the flow rate for honey to be the same as that for water, with the same pressure difference, by what factor should you increase the radius of the tube?

67. In Example 9.11, we discussed an ultracentrifuge with an angular speed of 5000 rpm, producing a centripetal acceleration of 5000 *g*. (a) What is the angular speed, in rad/s? (b) What is the average radius of the circle through which the sample spins, to produce 5000 *g?*

68. A particular ultracentrifuge operates at two different angular speeds, one twice the other, and has two different places where sample tubes can be loaded into the device, one twice as far from the center as the other. If the smallest centripetal acceleration you can obtain with this centrifuge is 2000 *g*, what are the other values you can obtain for the centripetal acceleration?

69. Section 9.11, which discussed the terminal speed of an object falling through a viscous fluid, included the following statement: “In general, the smaller the object, the smaller the magnitude of the terminal velocity.” In Example 9.11, we also derived an equation for the terminal speed, which was:

$$v_t = \left(1 - \frac{\rho_{fluid}}{\rho_{object}}\right)\frac{mg}{6\pi\eta r}$$

Note the factor of *r* in the denominator on the right side of the equation. You have two balls, made from identical material, so they have the same density, but one has twice the radius of the other. The smaller ball has a terminal speed of 4.0 mm/s in a particular viscous fluid. Predict the terminal speed of the larger ball in this same fluid. Is your prediction consistent with the statement that smaller objects have smaller terminal speeds? Explain why or why not.

70. Find a clear plastic shampoo bottle, almost full of shampoo. Make sure the bottle is tightly capped! Shake the bottle to get some air bubbles, with a good mixture of bubble sizes. When you invert the bottle, what do you observe? Which bubbles rise fastest? Is this consistent with what we learned about objects moving through a viscous fluid, or not?

71. You drop a steel ball bearing, with a radius of 2.0 mm, into a beaker of honey. Note that honey has a viscosity of 4.0 Pa s and a density of 1360 kg/m^3, and steel has a density of 7800 kg/m^3. (a) What is the terminal speed of the ball bearing? (b) Aluminum has a density of 2700 kg/m^3. What radius should an aluminum ball have to have the same terminal speed in honey that the steel ball has?