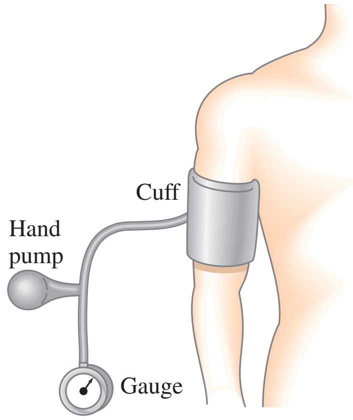
Blood pressure is measured using one of the types of gauge mentioned earlier (Section 10–6), and it is usually calibrated in mm-Hg. The gauge is attached to a closed, air-filled cuff that is wrapped around the upper arm at the level of the heart, Fig. 10–42. Two values of blood pressure are measured: the maximum pressure when the heart is pumping, called *systolic pressure*; and the pressure when the heart is in the resting part of the cycle, called *diastolic pressure*. Initially, the air pressure in the cuff is increased high above the systolic pressure by a pump, compressing the main (brachial) artery in the arm and briefly cutting off the flow of blood. The air pressure is then reduced slowly until blood again begins to flow into the arm; it can be detected by listening with a stethoscope to the characteristic tapping sound† of the blood returning to the forearm. At this point, systolic pressure is just equal to the air pressure in the arm cuff which can be read off the gauge. The air pressure is subsequently reduced further, and the tapping sound disappears when blood at low pressure can enter the artery. At this point, the gauge indicates the diastolic pressure. Normal systolic pressure is around 120 mm-Hg, whereas normal diastolic pressure is around 70 or 80 mm-Hg. Blood pressure is reported in the form 120/70.

PHYSICS APPLIED
Blood pressure

FIGURE 10–42 Device for measuring blood pressure.



†When the blood starts flowing through the constriction caused by the tight cuff, its velocity is high and the flow is turbulent. It is the turbulence that causes the tapping sound.

Summary

The three common phases of matter are **solid**, **liquid**, and **gas**. Liquids and gases are collectively called **fluids**, meaning they have the ability to flow. The **density** of a material is defined as its mass per unit volume:

$$\rho = \frac{m}{V}. \qquad \textbf{(10–1)}$$

Specific gravity (**SG**) is the ratio of the density of the material to the density of water (at 4°C).

Pressure is defined as force per unit area:

$$P = \frac{F}{A}. \qquad \textbf{(10–2)}$$

The pressure P at a depth h in a liquid of constant density ρ, due to the weight of the liquid, is given by

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

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 minus 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 ($F_B = m_F g = \rho_F V_{displ} g$).

Fluid flow can be characterized either as **streamline** (also 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:

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

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

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

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. 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.
3. 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. As the can cools, it collapses and looks crushed. Explain.
4. 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.
5. Will an ice cube float in a glass of alcohol? Why or why not?

6. A submerged can of Coke® will sink, but a can of Diet Coke® will float. (Try it!) Explain.

7. Why don't ships made of iron sink?

8. 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.]

9. 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.

10. Will an empty balloon have precisely the same apparent weight on a scale as a balloon filled with air? Explain.

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

12. Why does the stream of water from a faucet become narrower as it falls (Fig. 10–43)?

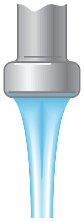


FIGURE 10–43 Question 12. Water coming from a faucet.

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

14. 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.

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

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

17. If you dangle two pieces of paper vertically, a few inches apart (Fig. 10–44), and blow between them, how do you think the papers will move? Try it and see. Explain.

FIGURE 10–44 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. 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.)

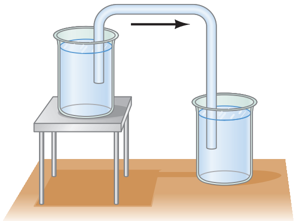


FIGURE 10–45 Question 20. A siphon.

*21. When blood pressure is measured, why must the arm cuff be held at the level of the heart?

MisConceptual Questions

1. You hold a piece of wood in one hand and a piece of iron in the other. Both pieces have the same volume, and you hold them fully under water at the same depth. At the moment you let go of them, which one experiences the greater buoyancy force?
(*a*) The piece of wood.
(*b*) The piece of iron.
(*c*) They experience the same buoyancy force.
(*d*) More information is needed.

2. Three containers are filled with water to the same height and have the same surface area at the base, but the total weight of water is different for each (Fig. 10–46). In which container does the water exert the greatest force on the bottom of the container?
(*a*) Container A.
(*b*) Container B.
(*c*) Container C.
(*d*) All three are equal.

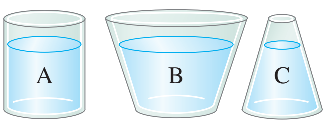


FIGURE 10–46 MisConceptual Question 2.

3. Beaker A is filled to the brim with water. Beaker B is the same size and contains a small block of wood which floats when the beaker is filled with water to the brim. Which beaker weighs more?
(*a*) Beaker A.
(*b*) Beaker B.
(*c*) The same for both.

4. Why does an ocean liner float?
(*a*) It is made of steel, which floats.
(*b*) Its very big size changes the way water supports it.
(*c*) It is held up in the water by large Styrofoam compartments.
(*d*) The average density of the ocean liner is less than that of seawater.
(*e*) Remember the *Titanic*—ocean liners do not float.

5. A rowboat floats in a swimming pool, and the level of the water at the edge of the pool is marked. Consider the following situations. (i) The boat is removed from the water. (ii) The boat in the water holds an iron anchor which is removed from the boat and placed on the shore. For each situation, the level of the water will
(*a*) rise. (*b*) fall. (*c*) stay the same.

6. You put two ice cubes in a glass and fill the glass to the rim with water. As the ice melts, the water level
   (*a*) drops below the rim.
   (*b*) rises and water spills out of the glass.
   (*c*) remains the same.
   (*d*) drops at first, then rises until a little water spills out.
7. Hot air is less dense than cold air. Could a hot-air balloon be flown on the Moon, where there is no atmosphere?
   (*a*) No, there is no cold air to displace, so no buoyancy force would exist.
   (*b*) Yes, warm air always rises, especially in a weak gravitational field like that of the Moon.
   (*c*) Yes, but the balloon would have to be filled with helium instead of hot air.
8. An object that can float in both water and in oil (whose density is less than that of water) experiences a buoyant force that is
   (*a*) greater when it is floating in oil than when floating in water.
   (*b*) greater when it is floating in water than when floating in oil.
   (*c*) the same when it is floating in water or in oil.
9. As water flows from a low elevation to a higher elevation through a pipe that changes in diameter,
   (*a*) the water pressure will increase.
   (*b*) the water pressure will decrease.
   (*c*) the water pressure will stay the same.
   (*d*) Need more information to determine how the water pressure changes.
10. Water flows in a horizontal pipe that is narrow but then widens and the speed of the water becomes less. The pressure in the water moving in the pipe is
   (*a*) greater in the wide part.
   (*b*) greater in the narrow part.
   (*c*) the same in both parts.
   (*d*) greater where the speed is higher.
   (*e*) greater where the speed is lower.
11. When a baseball curves to the right (a curveball), air is flowing
   (*a*) faster over the left side than over the right side.
   (*b*) faster over the right side than over the left side.
   (*c*) faster over the top than underneath.
   (*d*) at the same speed all around the baseball, but the ball curves as a result of the way the wind is blowing on the field.
12. How is the smoke drawn up a chimney affected when a wind is blowing outside?
   (*a*) Smoke rises more rapidly in the chimney.
   (*b*) Smoke rises more slowly in the chimney.
   (*c*) Smoke is forced back down the chimney.
   (*d*) Smoke is unaffected.

For assigned homework and other learning materials, go to the MasteringPhysics website.

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. 10–47) is about $10^8\ m^3$. What is its approximate mass?

FIGURE 10–47 Problem 1.

2. (I) What is the approximate mass of air in a living room $5.6\ m \times 3.6\ m \times 2.4\ m$?
3. (I) If you tried to smuggle gold bricks by filling your backpack, whose dimensions are $54\ cm \times 31\ cm \times 22\ cm$, 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 89.22 g. What is the specific gravity of this other fluid?
6. (II) If 4.0 L of antifreeze solution (specific gravity = 0.80) is added to 5.0 L of water to make a 9.0-L mixture, what is the specific gravity of the mixture?
7. (III) The Earth is not a uniform sphere, but has regions of varying density. Consider a simple model of the Earth divided into three regions—inner core, outer core, and mantle. Each region is taken to have a unique constant density (the average density of that region in the real Earth):

Region	Radius (km)	Density (kg/m^3)
Inner Core	0–1220	13,000
Outer Core	1220–3480	11,100
Mantle	3480–6380	4400

(*a*) Use this model to predict the average density of the entire Earth. (*b*) If the radius of the Earth is 6380 km and its mass is 5.98×10^{24} kg, determine the actual average density of the Earth and compare it (as a percent difference) with the one you determined in (*a*).

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

8. (I) Estimate the pressure needed to raise a column of water to the same height as a 46-m-tall pine tree.

9. (I) Estimate the pressure exerted on a floor by (*a*) one pointed heel of area = 0.45 cm^2, and (*b*) one wide heel of area 16 cm^2, Fig. 10–48. The person wearing the shoes has a mass of 56 kg.

FIGURE 10–48 Problem 9.

10. (I) What is the difference in blood pressure (mm-Hg) between the top of the head and bottom of the feet of a 1.75-m-tall person standing vertically?

11. (I) (*a*) Calculate the total force of the atmosphere acting on the top of a table that measures 1.7 m × 2.6 m. (*b*) What is the total force acting upward on the underside of the table?

12. (II) How high would the level be in an alcohol barometer at normal atmospheric pressure?

13. (II) In a movie, Tarzan evades his captors by hiding under water 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.

14. (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 25.5 cm?

15. (II) The gauge pressure in each of the four tires of an automobile is 240 kPa. If each tire has a "footprint" of 190 cm^2 (area touching the ground), estimate the mass of the car.

16. (II) (*a*) Determine the total force and the absolute pressure on the bottom of a swimming pool 28.0 m by 8.5 m whose uniform depth is 1.8 m. (*b*) What will be the pressure against the *side* of the pool near the bottom?

17. (II) A house at the bottom of a hill is fed by a full tank of water 6.0 m deep and connected to the house by a pipe that is 75 m long at an angle of 61° from the horizontal (Fig. 10–49). (*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?

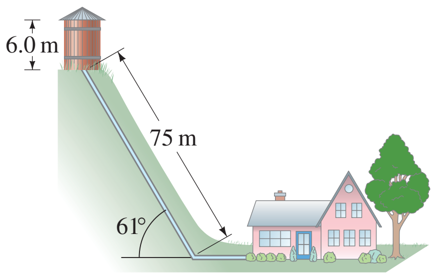


FIGURE 10–49 Problem 17.

18. (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. 10–50. What is the density of the oil? [*Hint*: Pressures at points a and b are equal. Why?]

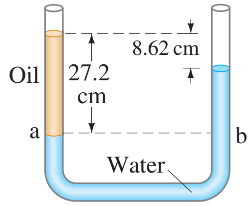


FIGURE 10–50 Problem 18.

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

20. (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 fourteenth floor, 44 m above that pipe.

21. (II) A **hydraulic press** for compacting powdered samples has a large cylinder which is 10.0 cm in diameter, and a small cylinder with a diameter of 2.0 cm (Fig. 10–51). A lever is attached to the small cylinder as shown. The sample, which is placed on the large cylinder, has an area of 4.0 cm^2. What is the pressure on the sample if 320 N is applied to the lever?

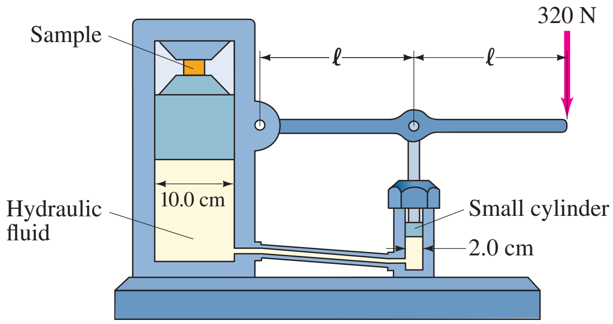


FIGURE 10–51 Problem 21.

22. (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*) 18.5 cm higher, (*b*) 5.6 cm lower, than the mercury in the tube connected to the tank? See Fig. 10–7a.

10–7 Buoyancy and Archimedes' Principle

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

24. (II) 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?

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

26. (II) A spherical balloon has a radius of 7.15 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.

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 4.0000 kg when weighed in air.

29. (II) Because gasoline is less dense than water, drums containing gasoline will float in water. Suppose a 210-L steel drum is completely full of gasoline. What total volume of steel can be used in making the drum if the gasoline-filled drum is to float in fresh water?

30. (II) A scuba diver and her gear displace a volume of 69.6 L and have a total mass of 72.8 kg. (*a*) What is the buoyant force on the diver in seawater? (*b*) Will the diver sink or float?

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

32. (II) Archimedes' principle can be used 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 3.80-kg aluminum ball has an apparent mass of 2.10 kg when submerged in a particular liquid: calculate the density of the liquid. (*b*) Determine a formula for finding the density of a liquid using this procedure.

33. (II) A 32-kg child decides to make a raft out of empty 1.0-L soda bottles and duct tape. Neglecting the mass of the duct tape and plastic in the bottles, what minimum number of soda bottles will the child need to be able stay dry on the raft?

34. (II) A two-component model used to determine percent body fat in a human body assumes that a fraction $f\ (< 1)$ of the body's total mass m is composed of fat with a density of $0.90\ \mathrm{g/cm^3}$, and that the remaining mass of the body is composed of fat-free tissue with a density of $1.10\ \mathrm{g/cm^3}$. If the specific gravity of the entire body's density is X, show that the percent body fat $(= f \times 100)$ is given by

$$\%\ \text{Body fat} = \frac{495}{X} - 450.$$

35. (II) On dry land, an athlete weighs 70.2 kg. The same athlete, when submerged in a swimming pool and hanging from a scale, has an "apparent weight" of 3.4 kg. Using Example 10–8 as a guide, (*a*) find the total volume V of the submerged athlete. (*b*) Assume that when submerged, the athlete's body contains a residual volume $V_R = 1.3 \times 10^{-3}\ \mathrm{m^3}$ of air (mainly in the lungs). Taking $V - V_R$ to be the actual volume of the athlete's body, find the body's specific gravity, SG. (*c*) What is the athlete's percent body fat assuming it is given by the formula $(495/\mathrm{SG}) - 450$?

36. (III) A 3.65-kg block of wood $(\mathrm{SG} = 0.50)$ floats on water. What minimum mass of lead, hung from the wood by a string, will cause the block to sink?

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

37. (I) A 12-cm-radius air duct is used to replenish the air of a room 8.2 m × 5.0 m × 3.5 m every 12 min. How fast does the air flow in the duct?

38. (I) Calculate the average speed of blood flow in the major arteries of the body, which have a total cross-sectional area of about $2.0\ \mathrm{cm^2}$. Use the data of Example 10–12.

39. (I) How fast does water flow from a hole at the bottom of a very wide, 4.7-m-deep storage tank filled with water? Ignore viscosity.

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

41. (II) What is the volume rate of flow of water from a 1.85-cm-diameter faucet if the pressure head is 12.0 m?

42. (II) A fish tank has dimensions 36 cm wide by 1.0 m long by 0.60 m high. If the filter should process all the water in the tank once every 3.0 h, what should the flow speed be in the 3.0-cm-diameter input tube for the filter?

43. (II) What gauge pressure in the water pipes is necessary if a fire hose is to spray water to a height of 16 m?

44. (II) A 180-km/h wind blowing over the flat roof of a house causes the roof to lift off the house. If the house is 6.2 m × 12.4 m in size, estimate the weight of the roof. Assume the roof is not nailed down.

45. (II) A 6.0-cm-diameter horizontal pipe gradually narrows to 4.5 cm. When water flows through this pipe at a certain rate, the gauge pressure in these two sections is 33.5 kPa and 22.6 kPa, respectively. What is the volume rate of flow?

46. (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 46.

47. (II) What is the lift (in newtons) due to Bernoulli's principle on a wing of area $88\ m^2$ if the air passes over the top and bottom surfaces at speeds of 280 m/s and 150 m/s, respectively?

48. (II) Water at a gauge pressure of 3.8 atm at street level flows into an office building at a speed of 0.78 m/s through a pipe 5.0 cm in diameter. The pipe tapers down to 2.8 cm in diameter by the top floor, 16 m above (Fig. 10–53), where the faucet has been left open. Calculate the flow velocity and the gauge pressure in the pipe on the top floor. Assume no branch pipes and ignore viscosity.

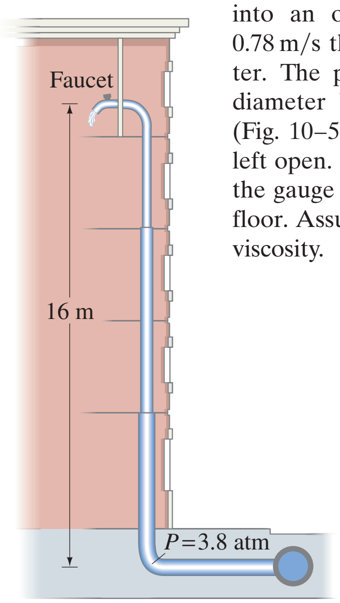


FIGURE 10–53 Problem 48.

49. (II) Show that the power needed to drive a fluid through a pipe with uniform cross-section is equal to the volume rate of flow, Q, times the pressure difference, $P_1 - P_2$. Ignore viscosity.

50. (III) (*a*) Show that the flow speed measured by a venturi meter (see Fig. 10–29) 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 meter is measuring the flow of water; it has a main diameter of 3.5 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 speed of the water entering the venturi throat?

51. (III) A fire hose exerts a force on the person holding it. This is because the water accelerates as it goes from the hose through the nozzle. How much force is required to hold a 7.0-cm-diameter hose delivering 420 L/min through a 0.75-cm-diameter nozzle?

*10–11 Viscosity

***52.** (II) A viscometer consists of two concentric cylinders, 10.20 cm and 10.60 cm in diameter. A liquid fills the space between them to a depth of 12.0 cm. The outer cylinder is fixed, and a torque of $0.024\ m \cdot N$ keeps the inner cylinder turning at a steady rotational speed of 57 rev/min. What is the viscosity of the liquid?

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

***53.** (I) Engine oil (assume SAE 10, Table 10–3) passes through a fine 1.80-mm-diameter tube that is 10.2 cm long. What pressure difference is needed to maintain a flow rate of 6.2 mL/min?

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

***55.** (II) What diameter must a 15.5-m-long air duct have if the ventilation and heating system is to replenish the air in a room $8.0\ m \times 14.0\ m \times 4.0\ m$ every 15.0 min? Assume the pump can exert a gauge pressure of 0.710×10^{-3} atm.

***56.** (II) What must be the pressure difference between the two ends of a 1.6-km section of pipe, 29 cm in diameter, if it is to transport oil $(\rho = 950\ kg/m^3,\ \eta = 0.20\ Pa \cdot s)$ at a rate of $650\ cm^3/s$?

***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 ($r = 0.80$ cm) during the resting part of the heart's cycle is about 35 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.** (II) Assuming a constant pressure gradient, if blood flow is reduced by 65%, by what factor is the radius of a blood vessel decreased?

***59.** (II) Calculate the pressure drop per cm along the aorta using the data of Example 10–12 and Table 10–3.

***60.** (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. 10–54). The inside diameter of the 25-mm-long needle is 0.80 mm, and the required flow rate is $2.0\ cm^3$ 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 78 torr above atmospheric pressure.

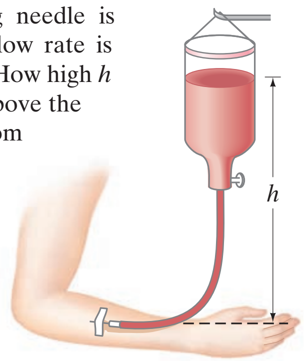


FIGURE 10–54 Problem 60.

*10–13 Surface Tension and Capillarity

*61. (I) If the force F needed to move the wire in Fig. 10–34 is 3.4×10^{-3} N, calculate the surface tension γ of the enclosed fluid. Assume $\ell = 0.070$ m.

*62. (I) Calculate the force needed to move the wire in Fig. 10–34 if it holds a soapy solution (Table 10–4) and the wire is 21.5 cm long.

*63. (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 $F = 6.20 \times 10^{-3}$ N and $r = 2.9$ cm, calculate γ for the tested liquid.

*64. (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?

*65. (III) Estimate the diameter of a steel needle that can just barely remain on top of water due to surface tension.

*10–14 Pumps; the Heart

*66. (II) A physician judges the health of a heart by measuring the pressure with which it pumps blood. If the physician mistakenly attaches the pressurized cuff around a standing patient's calf (about 1 m below the heart) instead of the arm (Fig. 10–42), what error (in Pa) would be introduced in the heart's blood pressure measurement?

General Problems

67. A 3.2-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 is 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 75 mm-Hg? Answer for the instant just before the fluid starts to move.

68. A beaker of water rests on an electronic balance that reads 975.0 g. A 2.6-cm-diameter solid copper ball attached to a string is submerged in the water, but does not touch the bottom. What are the tension in the string and the new balance reading?

69. Estimate the 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.

70. A hydraulic lift is used to jack a 960-kg car 42 cm off the floor. The diameter of the output piston is 18 cm, and the input force is 380 N. (*a*) What is the area of the input piston? (*b*) What is the work done in lifting the car 42 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 42 cm? (*e*) Show that energy is conserved.

71. 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 $0.20\ \text{cm}^2$ if a change in altitude of 1250 m takes place?

72. Giraffes are a wonder of cardiovascular engineering. Calculate the difference in pressure (in atmospheres) that the blood vessels in a giraffe's head must 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.

73. How high should the pressure head be if water is to come from a faucet at a speed of 9.2 m/s? Ignore viscosity.

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

75. 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 2.5 cm, what is the range of the force that needs to be applied to the pump handle from beginning to end?

76. Estimate the pressure on the mountains underneath the Antarctic ice sheet, which is typically 2 km thick.

77. A simple model (Fig. 10–55) considers a continent as a block (density $\approx 2800\ \text{kg/m}^3$) floating in the mantle rock around it (density $\approx 3300\ \text{kg/m}^3$). 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 mantle rock.

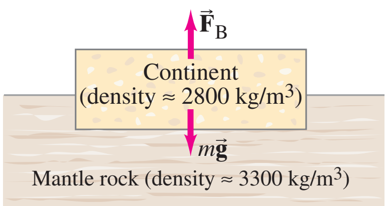


FIGURE 10–55 Problem 77.

78. A ship, carrying fresh water to a desert island in the Caribbean, has a horizontal cross-sectional area of $2240\ \text{m}^2$ at the waterline. When unloaded, the ship rises 8.25 m higher in the sea. How much water (m^3) was delivered?

79. During each heartbeat, approximately $70\,\text{cm}^3$ 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. 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° above the horizontal and covers a radius of 6.0 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?

81. 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 $82\,\text{cm}^2$ and the maximum pressure in the blood is 120 mm-Hg, estimate the force exerted by that ventricle at maximum pressure.

82. An airplane has a mass of $1.7 \times 10^6\,\text{kg}$, and the air flows past the lower surface of the wings at 95 m/s. If the wings have a surface area of $1200\,\text{m}^2$, how fast must the air flow over the upper surface of the wing if the plane is to stay in the air?

83. A hurricane-force wind of 180 km/h blows across the face of a storefront window. Estimate the force on the $2.0\,\text{m} \times 3.0\,\text{m}$ window due to the difference in air pressure inside and outside the window. Assume the store is airtight so the inside pressure remains at 1.0 atm. (This is why you should not tightly seal a building in preparation for a hurricane.)

84. 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 16.0 cm, at what height will the water be?

85. Blood is placed in a bottle 1.40 m above a 3.8-cm-long needle, of inside diameter 0.40 mm, from which it flows at a rate of $4.1\,\text{cm}^3/\text{min}$. What is the viscosity of this blood?

86. You are watering your lawn with a hose when you put your finger over the hose opening to increase the distance the water reaches. If you are holding the hose horizontally, and the distance the water reaches increases by a factor of 4, what fraction of the hose opening did you block?

87. A copper (Cu) weight is placed on top of a 0.40-kg block of wood $\left(\text{density} = 0.60 \times 10^3\,\text{kg/m}^3\right)$ floating in water, as shown in Fig. 10–56. What is the mass of the copper if the top of the wood block is exactly at the water's surface?

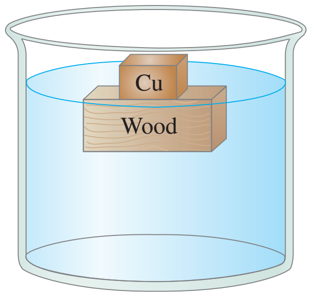


FIGURE 10–56 Problem 87.

***88.** If cholesterol buildup reduces the diameter of an artery by 25%, by what % will the blood flow rate be reduced, assuming the same pressure difference?

Search and Learn

1. A 5.0-kg block and 4.0 kg of water in a 0.50-kg container are placed symmetrically on a board that can balance at the center (Fig. 10–57). A solid aluminum cube of sides 10.0 cm is lowered into the water. How much of the aluminum must be under water to make this system balance? How would your answer change for a lead cube of the same size? Explain. (See Sections 10–7 and 9–1.)

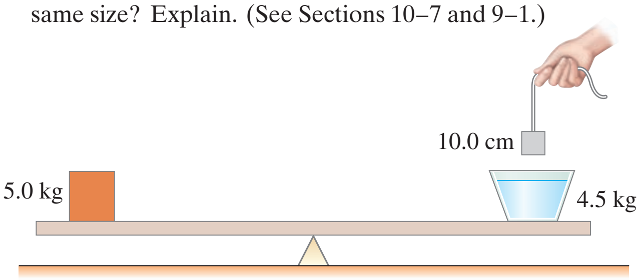


FIGURE 10–57 Search and Learn 1.

2. (*a*) Show that the buoyant force F_B on a partially submerged object such as a ship acts at the center of gravity of the fluid before it is displaced, Fig. 10–58. This point is called the **center of buoyancy**. (*b*) To ensure that a ship is in stable equilibrium, would it be better if its center of buoyancy was above, below, or at the same point as its center of gravity? Explain. (See Section 10–7 and Chapter 9.)

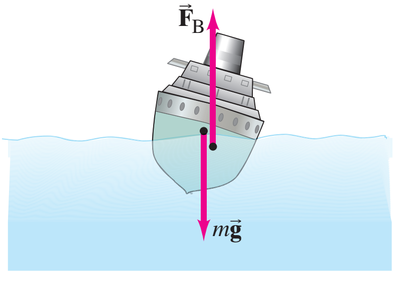


FIGURE 10–58
Search and Learn 2.

3. (*a*) When submerged in water, two objects with different volumes have the same *apparent* weight. When taken out of water, compare their weights in air. (*b*) Which object has the greater density?

4. What approximations are made in the derivation of Bernoulli's equation? Qualitatively, how do you think Bernoulli's equation would change if each of these approximations was not made? (See Sections 10–8, 10–9, 10–11, and 10–12.)

*5. Estimate the density of the water 5.4 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?

ANSWERS TO EXERCISES

A: (*d*).
B: The same. Pressure depends on depth, not on length.
C: (*a*).
D: (*e*).
E: The rowboat is shaped to have a lot of empty, air-filled space, so its "average" density is much lower than that of water (unless the boat becomes full of water, in which case it sinks). Steel ships float for the same reason.
F: Increases.
G: (*b*).