Solution

The rate of flow of blood is found from equation 13H.4, where η, the viscosity of blood, is 4.00×10^{-3} Ns/m². Let us assume that the total pressure differential is obtained by the effects of gravity from the hydrostatic equation, equation 13.7. The density of blood is about 1050 kg/m³. Thus,

$$\Delta p = \rho g h$$
$$= (1050 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(0.750 \text{ m})$$
$$= 7.72 \times 10^3 \text{ Pa}$$

The blood flow rate now obtained is

$$\frac{\Delta V}{\Delta t} = \frac{(\Delta p)\pi R^4}{8\eta L} \tag{13H.4}$$
$$= \frac{(7.72 \times 10^3 \text{ N/m}^2)(\pi)(0.250 \times 10^{-3} \text{ m})^4}{8(4.00 \times 10^{-3} \text{ Ns/m}^2)(0.0400 \text{ m})}$$
$$= 7.40 \times 10^{-8} \text{ m}^3\text{/s}$$

The Language of Physics

Fluids
A fluid is any substance that can flow. Hence, liquids and gases are both considered to be fluids (p. 367).

Fluid statics or hydrostatics
The study of fluids at rest (p. 367).

Fluid dynamics or hydrodynamics
The study of fluids in motion (p. 367).

Density
The amount of mass in a unit volume of a substance (p. 367).

Pressure
The magnitude of the normal force acting per unit surface area (p. 368).

The hydrostatic equation
An equation that gives the pressure of a fluid at a particular depth (p. 370).

Barometer
An instrument that measures atmospheric pressure (p. 371).

Gauge pressure
The pressure indicated on a pressure measuring gauge. It is equal to the absolute pressure minus normal atmospheric pressure (p. 375).

Pascal's principle
If the pressure at any point in an enclosed fluid at rest is changed, the pressure changes by an equal amount at all points in the fluid (p. 376).

Archimedes' principle
A body immersed in a fluid is buoyed up by a force that is equal to the weight of the fluid displaced. A body floats when the weight of the body is equal to the weight of the fluid displaced (p. 378).

Law of conservation of mass
In any ordinary mechanical or chemical process, mass is neither created nor destroyed (p. 384).

The equation of continuity
An equation based on the law of conservation of mass, that indicates that when the cross-sectional area of a pipe gets smaller, the velocity of the fluid must become greater. Conversely, when the cross-sectional area increases, the velocity of the fluid must decrease (p. 384).

Bernoulli's theorem
The sum of the pressure, the potential energy per unit volume, and the kinetic energy per unit volume at any one location of the fluid is equal to the sum of the pressure, the potential energy per unit volume, and the kinetic energy per unit volume at any other location in the fluid, for a nonviscous, incompressible fluid in streamlined flow (p. 387).

Venturi effect
The effect of the decrease in pressure with the increase in speed of the fluid in a horizontal pipe (p. 389).

Venturi meter
A device that uses the Venturi effect to measure the velocity of fluids in pipes (p. 389).

Summary of Important Equations

Density
$$\rho = \frac{m}{V} \quad (13.1)$$

Mass
$$m = \rho V \quad (13.2)$$

Pressure
$$p = \frac{F}{A} \quad (13.3)$$

Hydrostatic equation
$$p = \rho g h \quad (13.7)$$

Force
$$F = pA \quad (13.12)$$

Absolute and gauge pressure
$$p_{abs} = p_{gauge} + p_0 \quad (13.15)$$

Hydraulic lift
$$F = \frac{A}{a} f \quad (13.18)$$

$$y_1 = \frac{A}{a} y_2 \quad (13.23)$$

Archimedes' principle
$$\text{Buoyant force} = \text{Weight of water displaced} \quad (13.30)$$

Mass flow rate
$$\frac{\Delta m}{\Delta t} = \rho A v \quad (13.38)$$

Equation of continuity
$$A_1 v_1 = A_2 v_2 \quad (13.47)$$
$$Av = \text{constant} \quad (13.49)$$

Work done in moving a fluid
$$W = p\Delta V \quad (13.50)$$

Bernoulli's theorem
$$p_1 + \rho g h_1 + \tfrac{1}{2}\rho v_1^2 = p_2 + \rho g h_2 + \tfrac{1}{2}\rho v_2^2 \quad (13.63)$$

and
$$p + \rho g h + \tfrac{1}{2}\rho v^2 = \text{constant} \quad (13.64)$$

Questions for Chapter 13

1. Discuss the differences between solids, liquids, and gases.
†2. Hieron II, King of Syracuse in ancient Greece, asked his relative Archimedes to determine if the gold crown made for him by the local goldsmith, was solid gold or a mixture of gold and silver. How did Archimedes, or how could you, determine whether or not the crown was pure gold?
3. When you fly in an airplane you find that your ears keep "popping" when the plane is ascending or descending. Explain why.
4. Using a barometer and the direction of the wind, describe how you could make a reasonable weather forecast.
†5. A pilot uses an aneroid barometer as an altimeter that is calibrated to a standard atmosphere. What happens to the aircraft if the temperature of the atmosphere does not coincide with the standard atmosphere?
†6. Does a sphygmomanometer measure gauge pressure or absolute pressure?
7. How would you define a mechanical advantage for the hydraulic lift?
8. In example 13.13, could the iron block sink to a depth of 39.4 cm in a pool of water 100 cm deep and then float at that point? Why or why not?
†9. How does eating foods very high in cholesterol have an effect on the arteries and hence the flow of blood in the body?
†10. Why is an intravenous bottle placed at a height h above the arm of a patient?

Problems for Chapter 13

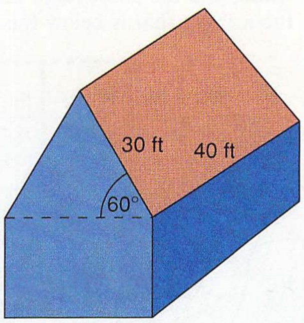
13.2 Density

1. A cylinder 3.00 cm in diameter and 3.00 cm high has a mass of 15.0 g. What is its density?
2. Find the mass of a cube of iron 10.0 cm on a side.
3. A gold ingot is 50.0 cm by 20.0 cm by 10.0 cm. Find (a) its mass and (b) its weight.
4. Find the mass of the air in a room 6.00 m by 8.00 m by 3.00 m.
5. Assume that the earth is a sphere. Compute the average density of the earth.
6. Find the weight of 1.00 liter of air.
7. A crown, supposedly made of gold, has a mass of 8.00 kg. When it is placed in a full container of water, 691 cm^3 of water overflows. Is the crown made of pure gold or is it mixed with some other materials?
8. A solid brass cylinder 10.0 cm in diameter and 25.0 cm long is soldered to a solid iron cylinder 10.0 cm in diameter and 50.0 cm long. Find the weight of the combined cylinder.
9. An annular cylinder of 2.50-cm inside radius and 4.55-cm outside radius is 10.5 cm high. If the cylinder has a mass of 5.35 kg, find its density.

13.3 Pressure

10. As mentioned in the text, a non-SI unit of pressure is the torr, named after Torricelli, which is equal to the pressure exerted by a column of mercury 1 mm high. Express a pressure of 2.53×10^5 Pa in torrs.
†11. From the knowledge of normal atmospheric pressure at the surface of the earth, compute the approximate mass of the atmosphere.
12. A barometer reads a height of 72.0 cm of Hg. Express this atmospheric pressure in terms of (a) in. of Hg, (b) mb, (c) lb/in.^{2}, and (d) Pa.
13. (a) A "high" pressure area of 1030 mb moves into an area. What is this pressure expressed in lb/in.^{2}? (b) A "low" pressure area of 980 mb moves into an area. What is this pressure expressed in lb/in.^{2}?
14. Normal systolic blood pressure is approximately 120 mm of Hg and normal diastolic pressure is 80 mm of Hg. Express these pressures in terms of Pa and lb/in.^{2}.

15. The point of a 10-penny nail has a diameter of 1.00 mm. If the nail is driven into a piece of wood with a force of 150 N, find the pressure that the tip of the nail exerts on the wood.
16. The gauge pressure in the tires of your car is 30.0 lb/in.^{2}. What is the absolute pressure of the air in the tires?
17. The gauge pressure in the tires of your car is 2.42×10^5 N/m^2. What is the absolute pressure of the air in the tires?
18. What is the water pressure and the absolute pressure in a swimming pool at depths of (a) 1.00 m, (b) 2.00 m, (c) 3.00 m, and (d) 4.00 m?
19. Find the force exerted by normal atmospheric pressure on the top of a table 1.00 m high, 1.00 m long, 0.75 m wide, and 0.10 m thick. What is the force on the underside of the table top exerted by normal atmospheric pressure?
20. What force is exerted on the top of the roof by normal atmospheric pressure?



21. If normal atmospheric pressure can support a column of Hg 76.0 cm high, how high a column will it support of (a) water, (b) benzene, (c) alcohol, and (d) glycerine?
22. What is the minimum pressure of water entering a building if the pressure at the second floor faucet, 16.0 ft above the ground, is to be 5.00 lb/in.^{2}?
23. The water main pressure entering a house is 31.0 N/cm^2. What is the pressure at the second floor faucet, 6.00 m above the ground? What is the maximum height of any faucet such that water will still flow from it?
24. A barometer reads 76.0 cm of Hg at the base of a tall building. The barometer is carried to the roof of the building and now reads 75.6 cm of Hg. If the average density of the air is 1.28 kg/m^3, what is the height of the building?
25. The hatch of a submarine is 100 cm by 50.0 cm. What force is exerted on this hatch by the water when the submarine is 50.0 m below the surface?

13.4 Pascal's Principle

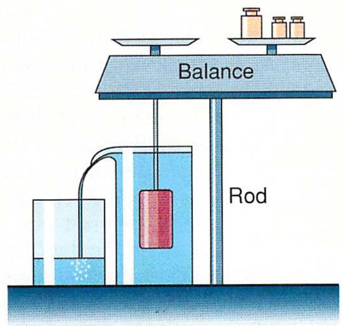
26. In the hydraulic lift of figure 13.5, the diameter $d_1 = 10.0$ cm and $d_2 = 50.0$ cm. If a force of 10.0 N is applied at the small piston, (a) what force will appear at the large piston? (b) If the large piston is to move through a height of 2.00 m, what must the total displacement of the small piston be?
27. In a hydraulic lift, the large piston exerts a force of 25.0 N when a force of 3.50 N is applied to the smaller piston. If the smaller piston has a radius of 12.5 cm, and the lift is 65.0% efficient, what must be the radius of the larger piston?
28. The theoretical mechanical advantage (TMA) of a hydraulic lift is equal to the ratio of the force that you get out of the lift to the force that you must put into the lift. Show that the theoretical mechanical advantage of the hydraulic lift is given by

$$\text{TMA} = \frac{F_{\text{out}}}{F_{\text{in}}} = \frac{A_{\text{out}}}{A_{\text{in}}} = \frac{y_{\text{in}}}{y_{\text{out}}}$$

where A_{out} is the area of the output piston, A_{in} is the area of the input piston, y_{in} is the distance that the input piston moves, and y_{out} is the distance that the output piston moves.

13.5 Archimedes' Principle

29. Find the weight of a cubic block of iron 5.00 cm on a side. This block is now hung from a spring scale such that the block is totally submerged in water. What would the scale indicate for the weight (called the apparent weight) of the block?



30. A copper cylinder 5.00 cm high and 3.00 cm in diameter is hung from a spring scale such that the cylinder is totally submerged in ethyl alcohol. Find the apparent weight of the block.
31. Find the buoyant force on a brass block 10.5 cm long by 12.3 cm wide by 15.0 cm high when placed in (a) water, (b) glycerine, and (c) mercury.
32. If the iron block in example 13.13 were placed in a pool of mercury instead of the water would it float or sink? If it floats, to what depth does it sink before it floats?
†33. A block of wood sinks 8.00 cm in pure water. How far will it sink in salt water?
34. A weather balloon contains 33.5 m^3 of helium at the surface of the earth. Find the largest load this balloon is capable of lifting. The density of helium is 0.1785 kg/m^3.

13.6 The Equation of Continuity

35. A 3/4-in. pipe is connected to a 1/2-in. pipe. If the velocity of the fluid in the 3/4-in. pipe is 2.00 ft/s, what is the velocity in the 1/2-in. pipe? How much water flows per second from the 1/2-in. pipe?

36. A 2.50-cm pipe is connected to a 0.900-cm pipe. If the velocity of the fluid in the 2.50-cm pipe is 1.50 m/s, what is the velocity in the 0.900-cm pipe? How much water flows per second from the 0.900-cm pipe?

37. A duct for a home air conditioning unit is 10.0 in. in diameter. If the duct is to remove the air in a room 20.0 ft by 24.0 ft by 8.00 ft high every 20.0 min, what must the velocity of the air in the duct be?

38. A duct for a home air-conditioning unit is 35.0 cm in diameter. If the duct is to remove the air in a room 9.00 m by 6.00 m by 3.00 m high every 15.0 min, what must the velocity of the air in the duct be?

13.7 Bernoulli's Theorem

39. Water enters the house from a main at a pressure of 1.5×10^5 Pa at a speed of 40.0 cm/s in a pipe 4.00 cm in diameter. What will be the pressure in a 2.00-cm pipe located on the second floor 6.00 m high when no water is flowing from the upstairs pipe? When the water starts flowing, at what velocity will it emerge from the upstairs pipe?

40. A can of water 30.0 cm high sits on a table 80.0 cm high. If the can develops a leak 5.00 cm from the bottom, how far away from the table will the water hit the floor?

41. Water rises to a height $h_{01} = 35.0$ cm, and $h_{02} = 10.0$ cm, in a Venturi meter, figure 13.11(b). The diameter of the first pipe is 4.00 cm, whereas the diameter of the second pipe is 2.00 cm. What is the velocity of the water in the first and second pipe? What is the mass flow rate and the volume flow rate?

Additional Problems

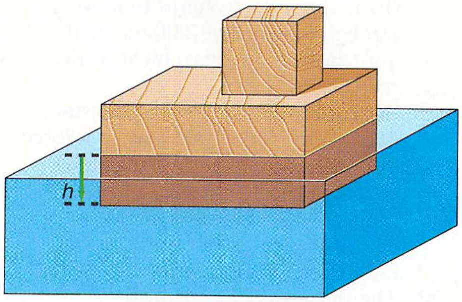
42. A car weighs 2890 lb and the gauge pressure of the air in each tire is 30 lb/in.^{2}. Assuming that the weight of the car is evenly distributed over the four tires, (a) find the area of each tire that is flat on the ground and (b) if the width of the tire is 5.00 inches, find the length of the tire that is in contact with the ground.

43. A certain portion of a rectangular, concrete flood wall is 12.0 m high and 30.0 m long. During severe flooding of the river, the water level rises to a height of 10.0 m. Find (a) the water pressure at the base of the flood wall, (b) the average water pressure exerted on the flood wall, and (c) the average force exerted on the flood wall by the water.

44. The Vehicle Assembly Building at the Kennedy Space Center is 160 m high. Assuming the density of air to be a constant, find the difference in atmospheric pressure between the ground floor and the ceiling of the building.

45. If the height of a water tower is 20.0 m, what is the pressure of the water as it comes out of a pipe at the ground?

†46. A 20.0-g block of wood floats in water to a depth of 5.00 cm. A 10.0-g block is now placed on top of the first block, but it does not touch the water. How far does the combination sink?



†47. An iron ball, 4.00 cm in diameter, is dropped into a tank of water. Assuming that the only forces acting on the ball are gravity and the buoyant force, determine the acceleration of the ball. Discuss the assumption made in this problem.

†48. If 80% of a floating cylinder is beneath the water, what is the density of the cylinder?

†49. From knowing that the density of an ice cube is 920 kg/m^3 can you determine what percentage of the ice cube will be submerged when in a glass of water?

†50. Find the equation for the length of the side of a cube of material that will give the same buoyant force as (a) a sphere of radius r and (b) a cylinder of radius r and height h, if both objects are completely submerged.

†51. Find the radius of a solid cylinder that will experience the same buoyant force as an annular cylinder of radii $r_2 = 4.00$ cm and $r_1 = 3.00$ cm. Both cylinders have the same height h.

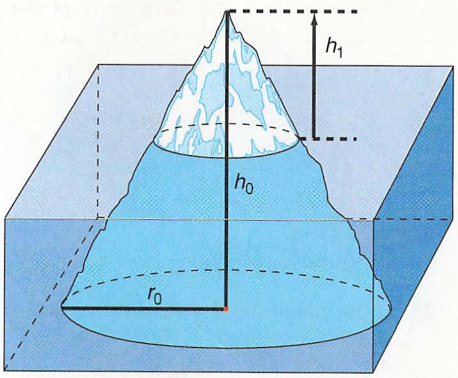
†52. A cone of maximum radius r_0 and height h_0, is placed in a fluid, as shown in the diagram. The volume of a right circular cone is given by

$$V_{\text{cone}} = \tfrac{1}{3}\pi r^2 h$$

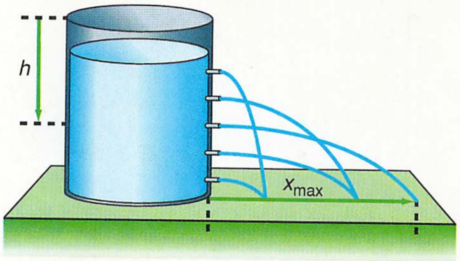
(a) Find the equation for the weight of the cone. (b) If the cone sinks so that a height h_1 remains out of the fluid, find the equation for the volume of the cone that is immersed in the fluid. (c) Find the equation for the buoyant force acting on the cone. (d) Show that the height h_1 that remains out of the fluid is given by

$$h_1 = \sqrt[3]{1 - (\rho_c/\rho_f)}\,h_0$$

where ρ_c is the density of the cone and ρ_f is the density of the fluid. (e) If we approximate an iceberg by a cone, find the percentage height of the iceberg that sticks out of the salt water, and the percentage volume of the iceberg that is below the water.



†53. A can 30.0 cm high is filled to the top with water. Where should a hole be made in the side of the can such that the escaping water reaches the maximum distance x in the horizontal direction? (*Hint:* calculate the distance x for values of h from 0 to 30.0 cm in steps of 5.00 cm.)



54. In the flow of fluid from an orifice in figure 13.12, it was assumed that the vertical motion of the water at the top of the tank was very small, and hence v_1 was set equal to zero. Show that if this assumption does not hold, the velocity of the fluid from the orifice v_2 can be given by

$$v_2 = \sqrt{\frac{2gh}{1 - (d_2^4/d_1^4)}}$$

where d_1 is the diameter of the tank and d_2 is the diameter of the orifice.

†55. A wind blows over the roof of your house at 100 mph. What is the difference in pressure acting on the roof because of this velocity? (*Hint:* the air inside the attic is still, that is, $v = 0$ inside the house.)

56. A wind blows over the roof of a house at 136 km/hr. What is the difference in pressure acting on the roof because of this velocity? (*Hint:* the air inside the attic is still, that is, $v = 0$ inside the house.)

†57. If air moves over the top of an airplane wing at 150 m/s and 120 m/s across the bottom of the wing, find the difference in pressure between the top of the wing and the bottom of the wing. If the area of the wing is 15.0 m², find the force acting upward on the wing.

Interactive Tutorials

58. Find the buoyant force BF and apparent weight AW of a solid sphere of radius $r = 0.500$ m and density $\rho = 7.86 \times 10^3$ kg/m³, when immersed in a fluid whose density is $\rho_f = 1.00 \times 10^3$ kg/m³.

59. Archimedes' principle. A solid block of wood of length $L = 15.0$ cm, width $W = 20.0$ cm, and height $h_0 = 10.0$ cm, is placed into a pool of water. The density of the block is 680 kg/m³. (a) Will the block sink or float? (b) If it floats, how deep will the block be submerged when it floats? (c) What percentage of the original volume is submerged?

60. The equation of continuity and flow rate. Water flows in a pipe of diameter $d_1 = 4.00$ cm at a velocity of 35.0 cm/s, as shown in figure 13.9. The diameter of the tapered part of the pipe is $d_2 = 2.55$ cm. Find (a) the velocity of the fluid in the tapered part of the pipe, (b) the mass flow rate, and (c) the volume flow rate of the fluid.

61. Bernoulli's theorem. Water flows in an elevated, tapered pipe, as shown in figure 13.10. The first part of the pipe is at a height $h_1 = 3.58$ m above the ground and the water is at a pressure $p_1 = 5000$ N/m², the diameter $d_1 = 25.0$ cm, and the velocity of the water is $v_1 = 0.553$ m/s. If the diameter of the tapered part of the pipe is $d_2 = 10.0$ cm and the height of the pipe above the ground is $h_2 = 1.25$ m, find (a) the velocity v_2 of the fluid in the tapered part of the pipe and (b) the pressure p_2 of the water in the tapered part of the pipe.