CHAPTER 10

FLUIDS

OBJECTIVES

After studying the material of this chapter, the student should be able to:

- distinguish between density, weight density, and specific gravity and given an object's mass and volume, calculate the object's density, weight density, and specific gravity.
- define pressure and calculate the pressure that an object of known weight exerts on a surface of known area, and express the magnitude of the pressure in psi, lb/ft^2, N/m^2, or pascals (Pa).
- calculate the pressure acting at a depth h below the surface of a liquid of density (ρ).
- distinguish between absolute pressure and gauge pressure and solve problems involving each type of pressure.
- state Pascal's principle and apply this principle to basic hydraulic systems.
- state Archimedes' principle and use this principle to solve problems related to buoyancy.
- explain what is meant by streamline flow, the equation of continuity, and the flow rate. Apply these concepts to word problems to solve for the velocity of water at a particular point in a closed pipe.
- use Bernoulli's equation and the concept of streamline flow to solve for the velocity of a fluid and/or the pressure exerted by a fluid at a particular point in a closed pipe.

KEY TERMS AND PHRASES

density (ρ) is the quantity of mass (m) per unit volume (V).

weight density is the ratio of the weight of a substance to its volume.

specific gravity (SG) is the ratio of the density of the substance to the density of pure water.

pressure is the ratio of the force acting perpendicular to a surface to the surface area (A) on which the force acts.

gauge pressure measures the difference in pressure between an unknown pressure and atmospheric pressure.

absolute pressure is the sum of the gauge pressure and the atmospheric pressure.

Pascal's principle states that pressure applied to a confined fluid is transmitted throughout the fluid and acts in all directions.

Archimedes' principle states that a body wholly or partly immersed in a fluid is buoyed up by a force equal to the weight of the fluid it displaces.

buoyant force is the force caused by the displaced fluid. The buoyant force is considered to be acting upward through the center of gravity of the displaced fluid.

streamline flow assumes that as each particle in the fluid passes a certain point it follows the same path as the particles that preceded it. There is no loss of energy due to internal friction in the fluid.

turbulent flow is the irregular movement of particles in a fluid and results in loss of energy due to internal friction in the fluid. Turbulent flow tends to increase as the velocity of a fluid increases.

flow rate is the mass (or volume) of fluid that passes a point per unit time.

Bernoulli's equation states that the quantity $P + \frac{1}{2} \rho v^2 + \rho g h$ is the same at every point in the moving fluid. This equation is derived through the use of the work-energy principle and ignores the effect of internal friction in a moving fluid. It should be noted that P, $\frac{1}{2} \rho v^2$, and $\rho g h$ all have dimensions of pressure.

SUMMARY OF MATHEMATICAL FORMULAS

density	$\rho = m/V$	Ratio of object's mass (m) to its volume (V).
specific gravity	$SG = \rho_{object} / \rho_{water}$	Ratio of the density of the substance to the density of pure water.
pressure	$P = F/A$	Ratio of the force acting perpendicular to a surface to the surface area (A) on which the force acts.
fluid pressure	$P = \rho g h$	Gauge pressure as a function of depth (h).
Archimedes' principle	$F_B = m_f g = \rho_f g V_f$	Buoyant force acting on an object placed in a fluid.
equation of continuity	$\rho A v =$ constant	Mass of fluid moving through any point is constant.
volume flow rate	$R = v A$	Volume of fluid that passes a point per unit time.
Bernoulli's equation	$P + \frac{1}{2} \rho v^2 + \rho g h$ = constant	Equation for the pressure at any point in a moving fluid.

CONCEPT SUMMARY

Density, Weight Density, and Specific Gravity

The **density** (ρ) of a substance is defined as the quantity of mass (m) per unit volume (V) and is given by

$\rho = m/V$

For solids and liquids, the density is usually expressed in grams per cm^3 (g/cm^3) or kilograms per cubic meter (kg/m^3). The density of gases is usually expressed in grams per liter (g/l).

The **weight density** of a substance is the ratio of the weight of a substance to its volume. weight density = weight/volume = $m\,g/V = \rho\,V\,g/V = \rho\,g$. Weight density is commonly used in problems involving English units. The weight density of distilled water at 39°F (4°C) is 62.4 lb/ft^3.

The **specific gravity** (SG) of a substance is the ratio of the density of the substance to the density of another substance which is taken as a standard. The density of pure water at 4°C is usually taken as the standard and this has been defined to be exactly 1.000 g/cm^3 or 1.000×10^3 kg/m^3.

Specific gravity is a dimensionless quantity. This is because it is the ratio of the density of one substance to the density of another. The specific gravity of an object is the same in any system of measurement.

SG = density of substance/density of water

For example, the density of aluminum is 2.7×10^3 kg/m^3; therefore, the SG of aluminum is SG = $2.7 \times 10^3\ kg/m^3 / 1.0 \times 10^3\ kg/m^3 = 2.7$.

EXAMPLE PROBLEM 1. A solid sphere made of wood has a radius of 0.100 m. The mass of the sphere is 1.0 kg. Determine the a) density and b) specific gravity of the wood.

Part a. Step 1. Determine the volume of the sphere.	Solution: (Section 10-1) $V = 4/3\ \pi\ r^3$ $V = 4/3\ \pi\ (0.100\ m)^3 = 4.18 \times 10^{-3}\ m^3$
Part a. Step 2. Apply the formula for density.	$\rho = m/V$ $\rho = (1.00\ kg)/(4.18 \times 10^{-3}\ m^3) = 239\ kg/m^3$
Part b. Step 1. Apply the formula for specific gravity.	SG = density of wood/density of water SG = $(239\ kg/m^3)/(1000\ kg/m^{3)} = 0.239$

Pressure

Pressure (P) is defined as the ratio of the force acting perpendicular to a surface to the surface area (A) over which the force acts.

$P = F/A$

The SI unit of pressure is N/m^2 or pascal (Pa) while the English unit is lb/ft^2. A number of other units are used, e.g., lb/in^2 (or psi) and atmospheres. One atmosphere is the average pressure exerted by the Earth's atmosphere at sea level.

$1.00 \text{ atm} = 14.7 \text{ lb/in}^2 = 1.01 \times 10^5 \text{ N/m}^2 = 101.3 \text{ kPa}$

TEXTBOOK QUESTION 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.

ANSWER: When the lid is placed on the can, the internal pressure exerted by the hot gases, water vapor, and air inside the can balances the external atmospheric pressure acting on the can. As the gases inside the can cool, the pressure they exert on the side walls of the can decreases while the external atmospheric pressure remains constant. Eventually, the difference in pressure becomes large enough that the can collapses.

Pressure in Fluids

The pressure (P) produced by a column of fluid of height h and density ρ is given by

$P = \rho g h$

The density of liquids and solids is considered to be constant. In reality, the density of a liquid will increase slightly with increasing depth. The variation in density is usually negligible and can be ignored.

Gauge Pressure and Absolute Pressure

Ordinary pressure gauges measure the difference in pressure between an unknown pressure and atmospheric pressure. The pressure measured is called the **gauge pressure** and the unknown pressure is referred to as the **absolute pressure.**

$P_{absolute} = P_{gauge} + P_{atmosphere}$

Thus, if a tire gauge registers 193 kPa, the absolute pressure would be approximately 193 kPa + 101 kPa = 294 kPa.

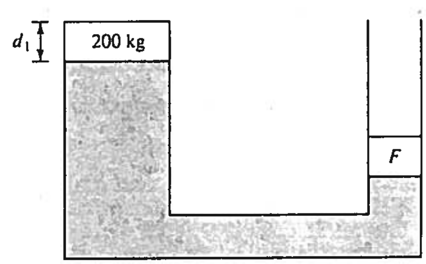
EXAMPLE PROBLEM 2. A submerged wreck is located 18.3 m (i.e., 60 feet) beneath the surface of the ocean off the coast of South Florida. Determine the a) gauge pressure and b) absolute pressure on a scuba diver who is exploring the wreck. Note: the density of seawater is 1025 kg/m^3.

Part a. Step 1. Calculate the gauge pressure at 18.3 m.	$P = \rho g h$ $P = (1025\ kg/m^3)(9.80\ m/s^2)(18.3\ m)$ $P = 1.83 \times 10^5\ N/m^2$ or 182 kPa
Part b. Step 1. Calculate the absolute pressure on the diver.	$P_{absolute} = P_{gauge} + P_{atmosphere}$ where $1.0\ atm = 1.013 \times 10^5\ N/m^2$ $= 1.83 \times 10^5\ N/m^2 + 1.013 \times 10^5\ N/m^2$ $P_{absolute} = 2.84 \times 10^5\ N/m^2$ or 284 kPa

Pascal's Principle

Pascal's principle states that pressure applied to a confined fluid is transmitted throughout the fluid and acts in all directions. The principle means that if the pressure on any part of a confined fluid is changed, then the pressure on every other part of the fluid must be changed by the same amount. This principle is basic to all hydraulic systems.

EXAMPLE PROBLEM 3. In the hydraulic system shown in the diagram, the 200 kg cylinder has a cross-sectional area of 50.0 cm². The cylinder on the right has a cross-sectional area of 2.50 cm². a) Determine the weight (F) required to hold the system in equilibrium. b) If the left-hand cylinder is pushed down 10.0 cm, determine through what distance F will move.



Part a. Step 1. Apply Pascal's principle and solve for F.	Solution: (Section 10-4) $(F_1)/(A_1) = (F_2)/(A_2)$ $[(200\ kg)(9.80\ m/s^2)]/(50.0\ cm^2) = (F_2)/(2.50\ cm^2)$ $F = 98.0\ N$
Part b. Step 1. Determine the distance that the right-hand cylinder rises.	The volume of fluid displaced by the 50.0 cm² cylinder equals the change in the volume of fluid in the right-hand cylinder. Note: the volume of the displaced fluid equals the product of the cross-sectional area of the piston and the distance that the piston moves. $V = A\ d$ $A_1\ d_1 = A_2\ d_2$

$(50.0\ cm^2)(10.0\ cm) = (2.50\ cm^2)\ d_2$

$d_2 = 2.00 \times 10^2\ cm$

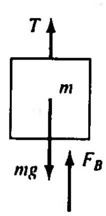
Buoyancy and Archimedes' Principle

Archimedes' principle states that a body wholly or partly immersed in a fluid is buoyed up by a force equal to the weight of the fluid it displaces. This upward force is called the **buoyant force**. As a result, objects lowered into a fluid "appear" to lose weight. The buoyant force is considered to be acting upward through the center of gravity of the displaced fluid.

TEXTBOOK QUESTION 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.

ANSWER. A weather balloon will rise as long as the buoyant force exerted by the air is slightly greater than the balloon's weight. As the balloon rises the external air pressure will decrease and the balloon's volume will increase as the inside pressure matches the outside pressure. If the balloon were to be fully inflated at ground level, the balloon would prematurely expand at a lower altitude, the material would be overstretched and it would burst and fall back to the ground. If the balloon is only partially inflated, the balloon's volume would gradually increase as it rises and the balloon would reach a much higher altitude. At that point, the balloon's weight equals the buoyant force. Eventually, helium molecules will diffuse out of the balloon and the balloon will gradually descend to the ground.

EXAMPLE PROBLEM 4. An aluminum object has a mass of 13.5 kg and a density of $2.70 \times 10^3\ kg/m^3$. The object is attached to a string and immersed in a tank of water. Determine the a) volume of the object and b) tension in the string when it is completely immersed.

Part a. Step 1. Determine the volume of the object.	Solution: (Sections 10-1 and 10-6) $\rho = m/V$ and $V = m/\rho = 13.5\ kg/2.70 \times 10^3\ kg/m^3 = 5.00 \times 10^{-3}\ m^3$
Part b. Step 1. Draw an accurate diagram and locate all of the forces acting on the object.	 T is the tension in the string, mg is the object's weight, and the buoyant force is F_b.

Part b. Step 2. Determine the volume of water displaced by the object.	Since the object is completely submerged, the volume of the water displaced equals the volume of the aluminum object. $V_{water} = 5.00 \times 10^{-3}\ m^3$
Part b. Step 3. Determine the weight of the water displaced by the submerged object.	The weight of the water displaced can be determined since both the density and the volume of the water displaced are known. $weight_{water\ displaced} = \rho_w V g$ $= (1.00 \times 10^3\ kg/m^3)(5.00 \times 10^{-3}\ m^3)(9.80\ m/s^2)$ $weight_{water\ displaced} = 49.0\ N$
Part b. Step 4. Use Archimedes' principle to determine the buoyant force.	Archimedes' principle states that the buoyant force equals the weight of the fluid displaced; therefore, $F_B = 49.0\ N$
Part b. Step 5. Apply Newton's second law and solve for the tension in the string.	$\Sigma F = m a$ but $a = 0\ m/s^2$ $T + F_B - mg = 0$ $T + 49.0\ N - (13.5\ kg)(9.80\ m/s^2) = 0$ $T = 83.3\ N$

Fluids in Motion

The equations that follow are applied when a moving fluid exhibits **streamline flow.** Streamline flow assumes that as each particle in the fluid passes a certain point it follows the same path as the particles that preceded it. There is no loss of energy due to internal friction in the fluid.

In reality, particles in a fluid exhibit **turbulent flow,** which is the irregular movement of particles in a fluid and results in loss of energy due to internal friction in the fluid. Turbulent flow tends to increase as the velocity of a fluid increases.

Flow Rate

The **flow rate** is the mass of fluid that passes a point per unit time (m/t). The formula for flow rate is

$$m/t = \rho A v$$

where ρ is the density of the fluid, A is the cross-sectional area of the tube of fluid at the particular point in question, and v is the velocity of the fluid at the point in question.

Since fluid cannot accumulate at any point, the flow rate is constant. This is expressed as the **equation of continuity.**

$\rho \, A \, v$ = constant

In streamline flow, the fluid is considered to be incompressible and the density is the same throughout. The equation of continuity can then be written in terms of the volume rate of flow (R) which is constant throughout the fluid: $R = Av$ = constant.

Bernoulli's Equation

A fluid in streamline flow follows **Bernoulli's equation**:

$P + \frac{1}{2} \rho v^2 + \rho g h$ = constant

P, ρ, and h are the absolute pressure, density, and height at a particular point in a fluid. The equation states that the quantity $P + \frac{1}{2} \rho v^2 + \rho g h$ is the same at every point in the stream. This equation is derived through the use of the work-energy principle and ignores the effect of internal friction in a moving fluid. It should be noted that P, $\frac{1}{2} \rho v^2$, and $\rho g h$ all have dimensions of pressure.

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

ANSWER: Initially the papers move toward each other. Moving air between the pieces causes a decrease in the air pressure between the pieces. The pressure outside the gap is greater than the air pressure on the inside forcing the pieces together.

The air flow momentarily stops when the pieces of paper meet. At this point, there is no difference in the air pressure between the pieces as compared to outside the pieces and the pieces begin to move apart. However, as the pieces move apart air again flows between the pieces and the pieces again move together. The result is that the pieces tend to flutter.

TEXTBOOK QUESTION 18. Why does the canvas top of a convertible bulge out when the car is traveling at high speed?

ANSWER: Air moving over the top of the canvas causes a decrease in the downward pressure (P_2). Inside the car the speed of the air is much less and therefore the upward pressure (P_1) on the canvas is greater than the downward pressure. The pressure difference ($P_1 - P_2$) causes the canvas top to bulge out. Using Bernoulli's equation, and setting point 2 above the canvas while point 1 is a point below the canvas, then

$$P_1 + \frac{1}{2} \rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g h_2$$

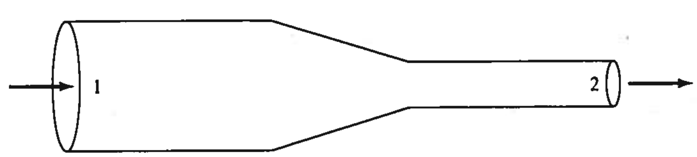
but $h_1 \approx h_2$ and $v_1 = 0$. Then $P_1 - P_2 = \frac{1}{2} \rho v_2^2$.

As the car's speed increases, the difference in pressure increases and the canvas bulges out.

EXAMPLE PROBLEM 5. During the early morning hours of August 24, 1992, the winds of Hurricane Andrew visited the home of the author of this study guide. It is estimated that wind gusts in excess of 150 mph (67 m/s) passed over the roof of the author's house. Calculate the a) difference in pressure between the air in the attic and the air passing over the roof and b) upward force exerted on the roof if area of the roof is 275 m^2. Assume that the air inside the attic was not moving and that the thickness of the roof was negligible. Note: assume that the density of air is 1.29 kg/m^3.

Part a. Step 1.	Solution: (Section 10-8)
Use Bernoulli's equation to determine the pressure.	$P_1 + ½ \rho v_1^2 + \rho g h_1 = P_2 + ½ \rho v_2^2 + \rho g h_2$ But $h_1 = h_2$ while $v_1 = 0$. Therefore, the equation becomes
Let P_1 represent the pressure inside the attic and $v_1 = 0$. Also, since the thickness of the roof is negligible $h_1 = h_2$.	$P_1 = P_2 + ½ \rho v_2^2$ $P_1 - P_2 = ½ \rho v_2^2 = ½ (1.29 kg/m^3)(67 m/s)^2$ $P_1 - P_2 = 2.9 \times 10^3 N/m^2$
Part b. Step 1.	pressure = force/area and force = pressure x area
Calculate the upward force (lift) exerted by the moving air on the roof.	$F = (2.9 \times 10^3 N/m^2)(275 m^2) = 8.0 \times 10^5 N$ Note: this upward force is approximately equal to 90 tons of lift. According to the Miami-Dade County building code all roof trusses must be attached to the tie beam of the building by metal straps. The tile on the author's roof needed to be replaced but the roof did stay on the house.

EXAMPLE PROBLEM 6. A horizontal pipe has a diameter of 0.150 m at point 1 and 0.0500 m at point 2. The velocity of water at point 1 is 0.800 m/s and the pressure is 1.01 x 10^5 N/m^2. Determine the a) volume flow rate, b) velocity of the water at point 2, and c) pressure at point 2.



Part a. Step 1.	Solution: (Sections 10-7 and 10-8)
Calculate the volume flow rate.	$R = A_1 v_1 = [\pi(0.150 m/2)^2](0.800 m/s) = 1.41 \times 10^{-2} m^3/s$

Part b. Step 1. Apply the rate flow equation and determine the velocity of the water at point 2.	Water cannot accumulate at any point in the hose, the rate of volume flow (R) must be the same throughout. $R = A_1 v_1 = A_2 v_2$ where $A = \pi(\text{diameter}/2)^2$ $[\pi(0.150 \text{ m}/2)^2](0.800 \text{ m/s}) = [\pi(0.0500 \text{ m}/2)^2] v_2$ $v_2 = 7.20 \text{ m/s}$
Part c. Step 1. Use Bernoulli's equation to determine the pressure. Note: the pipe is horizontal; therefore, $h_1 = h_2$.	$P_1 + \frac{1}{2} \rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g h_2$ but $h_1 = h_2$, $P_1 + \frac{1}{2} \rho v_1^2 = P_2 + \frac{1}{2} \rho v_2^2$ $1.01 \times 10^5 \text{ N/m}^2 + \frac{1}{2} (1000 \text{ kg/m}^3)(0.800 \text{ m/s})^2 = P_2 + \frac{1}{2} (1000 \text{ kg/m}^3)(7.20 \text{ m/s})^2$ $1.01 \times 10^5 \text{ N/m}^2 + 320 \text{ N/m}^2 = P_2 + 2.59 \times 10^4 \text{ N/m}^2$ $P_2 = 7.54 \times 10^4 \text{ N/m}^2$

PROBLEM SOLVING SKILLS

For problems involving density and specific gravity:

1. If necessary, use information given in the problem to calculate the object's mass and volume.
2. Determine the object's density ($\rho = m/V$).
3. Determine the object's specific gravity by dividing the object's density by the density of water.

For problems involving Pascal's principle:

1. Identify which quantities are related to the input and which relate to the output and complete a data table based on information given and implied in the problem.
2. Use the concept of pressure in a fluid and Pascal's principle to solve the problem.

For problems where Archimedes' principle is used to calculate the buoyant force on an object completely immersed in a fluid:

1. If the mass and density of the object are known, then the volume of the object can be determined.
2. The volume of the object equals the volume of the fluid the object displaces.
3. Use Archimedes' principle to determine the buoyant force.

For problems where Archimedes' principle is used to calculate the buoyant force on an object that floats in the fluid:

1. For a floating object the buoyant force equals the object's weight.
2. The weight of the fluid displaced equals the buoyant force.

For problems involving the rate flow equation and the equation of continuity:

1. Complete a data table listing the cross-sectional area of the closed pipe at each point, as well as the velocity and density of the fluid at the each point in question.

2. Use the rate flow equation and equation of continuity to solve the problem.

For problems involving Bernoulli's equation:

1. Complete a data table listing the pressure, velocity of the fluid, and height of the fluid above a reference point for each point in question. If the problem involves a fluid moving through a closed pipe, then determine the cross-sectional area of the closed pipe at each point in question.
2. If necessary, use the equation of continuity to determine the velocity of the fluid at a particular point.
3. Use Bernoulli's equation to solve the problem.

SOLUTIONS TO SELECTED TEXTBOOK PROBLEMS

TEXTBOOK PROBLEM 3. If you tried to smuggle gold bricks by filling your backpack, whose dimensions are 60 cm x 28 cm x 18 cm, what would its mass be?

Part a. Step 1. Determine the volume of the gold in cubic meters (m^3).	Solution: (Section 10-2) Volume = (length)(width)(height) $V = (0.60\ m)(0.28\ m)(0.18\ m)$ $V = 3.0 \times 10^{-2}\ m^3$
Part a. Step 2. Determine the gold's mass. Note: the density of gold is $19.3 \times 10^3\ kg/m^3$.	density = mass/volume mass = (density)(volume) mass = $(19.3 \times 10^3\ kg/m^3)(3.0 \times 10^{-2}\ m^3) = 5.8 \times 10^2\ kg \approx 1300$ lbs.

TEXTBOOK PROBLEM 7. Estimate the pressure exerted on a floor by (a) a pointed chair leg (60 kg on all four legs) of area = 0.020 cm^2, and (b) a 1500 kg elephant standing on one foot (area = 800 cm^2).

Part a. Step 1. Convert the area from cm^2 to m^2.	Solution: (Section 10-3) chair $(4\ \text{legs})(0.020\ cm^2)(1\ m^2/10^4\ cm^2) = 8.0 \times 10^{-6}\ m^2$ elephant $(800\ cm^2)(1\ m^2/10^4\ cm^2) = 8.0 \times 10^{-2}\ m^2$
Part a. Step 2. Determine the pressure exerted by one chair leg and the elephant.	$P_{leg} = (F_{chair})/(A_{legs})$ $= [(60\ kg)(9.8\ m/s^2)]/(8.0 \times 10^{-6}\ m^2)$ $P_{leg} \approx 7 \times 10^7\ N/m^2$ $P_{elephant} = (F_{elephant})/(A_{elephant})$

	$= [(1500\ kg)(9.8\ m/s^2)]/(8.0 \times 10^{-2}\ m^2)$ $P_{elephant} = 1.8 \times 10^5\ N/m^2 \approx 2 \times 10^5\ N/m^2$
Part a. Step 3. Determine the ratio of the pressures.	$P_{chair\ leg}/P_{elephant} \approx (7 \times 10^7\ N/m^2)/(2 \times 10^5\ N/m^2) \approx 400$ One chair leg exerts a pressure approximately 400 times greater than that of the elephant placing its weight on one foot.

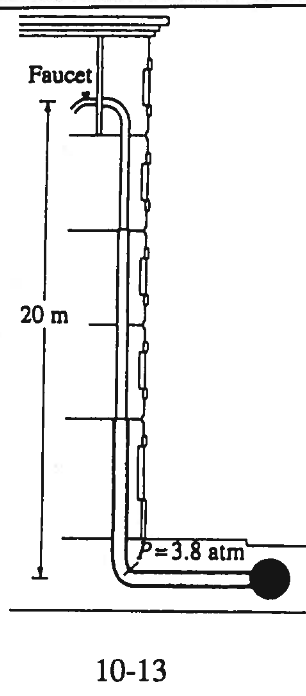
TEXTBOOK PROBLEM 33. The specific gravity of ice is 0.917, whereas for seawater is 1.025. What fraction of an iceberg is above the water?

Part a. Step 1. Determine the density of ice and seawater.	Solution: (Section 10-6) $SG = (\rho_{ice})/(\rho_{water})$ $\rho_{ice} = (SG_{ice})(\rho_{water}) = (0.917)(1000\ kg/m^3) = 917\ kg/m^3$ $SG = (\rho_{seawater})/(\rho_{water})$ $\rho_{seawater} = (SG_{seawater})(\rho_{water}) = (1.025)(1000\ kg/m^3) = 1025\ kg/m^3$
Part a. Step 2. Use Archimedes determine the fraction of an iceberg's volume is above the water.	According to Archimedes' principle, the buoyant force equals the weight of the water displaced. Since iceberg floats, the buoyant force equals the weight of the iceberg. $F_B = m_{seawater}\ g$ and $F_B = m_{iceberg}\ g$ $m_{seawater}\ g = m_{iceberg}\ g$ Note: g cancels $m_{seawater} = m_{iceberg}$ and $m = \rho V$ $\rho_{seawater} V_{seawater} = \rho_{iceberg} V_{iceberg}$ $(1025\ kg/m^3)V_{seawater} = (917\ kg/m^3)V_{iceberg}$ $V_{seawater} = [(917\ kg/m^3)V_{iceberg}]/(1025\ kg/m^3)$ $V_{seawater} = 0.895\ V_{iceberg}$ The amount of water displaced by the iceberg is 0.895, i.e. 89.5%, of the iceberg's volume. Therefore, 89.5% of the iceberg's volume is below the ocean's surface while 0.105 or 10.5% is visible above the surface.

TEXTBOOK PROBLEM 44. 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.

Part a. Step 1. Complete a data table using information both given and implied.	Solution: (Section 10-8) Let P_1 represent the pressure below the wing while P_2 represents the pressure above the wing. Also, the thickness of the wing is negligible $h_1 \approx h_2$. $P_1 = ?$ $P_2 = ?$ $v_1 = 360$ m/s $v_2 = 150$ m/s $\rho = 1.29$ kg/m^3 $h_1 \approx h_2$
Part a. Step 2. Use the Bernoulli equation to determine the difference in pressure.	$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$ Rearranging the equation gives $P_1 - P_2 = \frac{1}{2}\rho (v_2^2 - v_1^2) + \rho g (h_2 - h_1)$ but $\rho g (h_2 - h_1) \approx 0$ $P_1 - P_2 = \frac{1}{2}(1.29 \text{ kg/m}^3)[(260 \text{ m/s})^2 - (150 \text{ m/s})^2]$ $P_1 - P_2 = 2.9 \times 10^3 \text{ N/m}^2$
Part b. Step 1. Calculate the upward force (lift) exerted by the moving air on the wing.	pressure = force/area and force = pressure x area $F = (2.9 \times 10^3 \text{ N/m}^2)(78 \text{ m}^2) = 2.3 \times 10^6$ N Note: this upward force is approximately equal to 258 tons of lift.

TEXTBOOK PROBLEM 46. 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 at the top floor. Assume no branch pipes and ignore viscosity.



Part a. Step 1. Complete a data table using information both given and implied.	Solution: (Sections 10-8 and 10-9) Assume that point 1 is at $h_1 = 0$ and that $h_2 = 20$ m. $P_1 = (3.8 \text{ atm})[(1.01 \times 10^5 \text{ N/m}^2)/(1 \text{ atm}) = 3.84 \times 10^5 \text{ N/m}^2$ $\rho_{water} = 1.0 \times 10^3 \text{ kg/m}^3$ $g = 9.8 \text{ m/s}^2$ $v_1 = 0.60 \text{ m/s}$ $h_1 = 0$ m $A_1 = \pi(0.050 \text{ m})^2 = 7.8 \times 10^{-3} \text{ m}^2$ $A_2 = \pi(0.026 \text{ m})^2 = 2.1 \times 10^{-3} \text{ m}^2$ $h_2 = 18$ m $v_2 = ?$ $P_2 = ?$
Part a. Step 2. Use the rate flow equation to solve for the velocity at point 2.	The volume rate flow remains constant throughout the pipe. Determine v_2 using the rate flow equation. $A_1 v_1 = A_2 v_2$ $(7.8 \times 10^{-3} \text{ m}^2)(0.60 \text{ m/s}) = (2.1 \times 10^{-3} \text{ m}^2) v_2$ $v_2 = 2.2$ m/s
Part a. Step 3. Use Bernoulli's equation to determine the gauge pressure at point 2.	$P_1 + ½ \rho v_1^2 + \rho g h_1 = P_2 + ½ \rho v_2^2 + \rho g h_2$ but $h_1 = 0$, then $\rho g h_1 = 0$ $P_1 + ½ \rho v_1^2 = P_2 + ½ \rho v_2^2 + \rho g h_2$ $3.8 \times 10^5 \text{ N/m}^2 + ½ (1000 \text{ kg/m}^3)(0.60 \text{ m/s})^2 =$ $P_2 + ½ (1000 \text{ kg/m}^3)(2.2 \text{ m/s})^2 + (1000 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(18 \text{ m})$ $3.8 \times 10^5 \text{ N/m}^2 + 180 \text{ N/m}^2 = P_2 + 2.5 \times 10^3 \text{ N/m}^2 + 1.76 \times 10^5 \text{ N/m}^2$ $P_2 = 2.0 \times 10^5 \text{ N/m}^2 \approx 2.0$ atm

TEXTBOOK PROBLEM 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 that the average person has a mass of 68 kg? Do not neglect the weight of the logs. Assume that the specific gravity of wood is 0.60.

Part a. Step 1. Determine the density of the wood.	Solution: (Section 10-6) $SG = (\rho_{wood})/(\rho_{water})$ $\rho_{wood} = (SG)(\rho_{water}) = (0.60)(1000 \text{ kg/m}^3) = 600 \text{ kg/m}^3$

Part a. Step 2. Calculate the total volume of the raft and the volume of the water displaced.	The raft is made of cylindrical logs. The radius of a log = ½ (56 cm) = 28 cm = 0.28 m. The volume of a log given by $V = \pi\ r^2\ h = \pi\ (0.28\ m)^2(6.1\ m) = 1.5\ m^2$ The raft is made up of 10 logs. The total volume of the raft is $V_{raft} = (10)(1.5\ m^3) = 15\ m^3$ According to the statement of the problem, the raft is "just" submerged. Therefore, the volume of the water displaced equals the volume of the raft, i.e., $V_{water} = 15\ m^3$
Part a. Step 3. Use Archimedes' principle to determine the maximum number of people who can stand on the raft without getting their feet wet.	According to Archimedes' principle, the buoyant force equals the weight of the water displaced. The top of the raft is just at the water line, the buoyant force of the water equals the weight of the raft + people. $F_B = m_{water}\ g$ and $F_B = m_{raft}\ g + m_{people}\ g$ $m_{water}\ g = m_{raft}\ g + m_{people}\ g$ Note: g cancels $m_{water} = m_{raft} + m_{people}$ and $m = \rho V$ $\rho_{water}\ V_{water} = \rho_{wood}\ V_{wood} + m_{people}$ $(1000\ kg/m^3)(15\ m^3) = (600\ kg/m^3)(15\ m^3) + m_{people}$ $15000\ kg = 9000\ kg + m_{people}$ $m_{people} = 6000\ kg$ Each person has a mass of 68 kg; therefore, maximum number of people = (6000 kg)/(68 kg) ≈ 88