9 Solids, Liquids, and Gases

9-1 Density

Vocabulary **Density:** A measure of how much mass occupies a given space.

$$\textbf{density} = \frac{\textbf{mass}}{\textbf{volume}} \quad \text{or} \quad D = \frac{m}{V}$$

The SI unit for density is the **kilogram per cubic meter (kg/m^3).**

Density is a characteristic property of a material. The density of an object does not change if the object is broken into smaller pieces. Although each piece now has less mass than the original object, it has less volume as well. Therefore, the density remains the same.

Think of density as describing how "compact" an object is. Remember, the density of a material can change with temperature because atoms and molecules move faster when they are heated, and thus usually occupy more space.

Solved Examples

Example 1: While doing dishes, Zvi drops his 3.00×10^{-3}-kg platinum wedding band into the dishwater, displacing a volume of $1.40 \times 10^{-7}\ m^3$ of water. What is the density of the plantinum band?

Given: $m = 3.00 \times 10^{-3}$ kg
$V = 1.40 \times 10^{-7}\ m^3$

Unknown: $D = ?$
Original equation: $D = \frac{m}{V}$

Solve: $D = \frac{m}{V} = \frac{3.00 \times 10^{-3}\ kg}{1.40 \times 10^{-7}\ m^3} = \mathbf{2.14 \times 10^4\ kg/m^3}$

Example 2: At a temperature of 4 °C, 5000. kg of water will fill a volume of $5.000\ m^3$. What is the density of water at 4 °C?

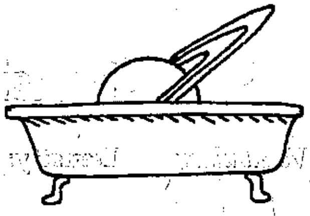
Given: $m = 5000.$ kg
$V = 5.000\ m^3$

Unknown: $D = ?$
Original equation: $D = \frac{m}{V}$

Solve: $D = \frac{m}{V} = \frac{5000.\ kg}{5.000\ m^3} = \mathbf{1000.\ kg/m^3}$

Practice Exercises

Exercise 1: The planet Saturn has a mass of 5.69×10^{26} kg and a volume of 8.01×10^{23} m^3. a) What is the density of Saturn? b) Would Saturn sink or float if you could place it in a gigantic bathtub filled with water?



Answer: **a.** ____________________

Answer: **b.** ____________________

Exercise 2: You are handed a 5.00×10^{-3}-kg coin and told that it is gold. You discover that the coin has a volume of 5.90×10^{-7} m^3. You know that the density of gold is 19 300 kg/m^3. Have you really been handed a gold coin, or simply a good imitation?

Answer: ____________________

Exercise 3: Diamond has a density of 3520 kg/m^3. During a physics lab, a diamond drops out of Virginia's necklace and falls into her graduated cylinder filled with 5.00×10^{-5} m^3 of water. This causes the water level to rise to the 5.05×10^{-5}–m^3 mark. What is the mass of Virginia's diamond?

Answer: ____________________

Exercise 4: You are given three different liquids—water, oil and glycerin—and asked to predict which will occupy the top, middle, and bottom layers when all three are poured into the same beaker. You take down the following data:

	mass (in kg)	**volume (in m^3)**
water	0.1000	1.00×10^{-4}
oil	0.0500	5.39×10^{-5}
glycerin	0.0400	3.17×10^{-5}

By finding the densities, determine how these liquids will layer themselves in the beaker from top to bottom.

Answer: ____________________

9-2 Solids

Compression and Stretching

Vocabulary **Elasticity:** A property of a body that causes it to deform when a force is exerted and return to its original shape when the deforming force is removed, within certain limits.

Vocabulary **Stress:** The force exerted on an area divided by the area.

$$\text{stress} = \frac{\text{force}}{\text{area}} = \frac{F}{A}$$

The SI unit of stress is the **newton per square meter (N/m^2).**

Vocabulary **Strain:** The ratio of change in dimension to original dimension.

Most often strain is used in describing the change in length of an object when a force is exerted.

$$\text{strain} = \frac{\text{change in length}}{\text{original length}} = \frac{\Delta L}{L}$$

Because strain is a ratio of lengths, it has no units.

Stress and strain are proportional to each other, and their ratio is equal to the elasticity of the material. The elasticity of a material is called the stretch modulus or **Young's modulus, Y.**

$$\textbf{Young's modulus} = \frac{\textbf{stress}}{\textbf{strain}} \quad \text{or} \quad Y = \frac{F/A}{\Delta L/L} = \frac{FL}{A\Delta L}$$

The SI unit for Young's modulus is the **newton per square meter (N/m^2).**

Shearing

Shearing is another way of applying stress to an object to cause a distortion. However, this type of distortion is not one of dimension, but one of shape. For example, the book in Figure A will look like the one in Figure B when it is sheared.

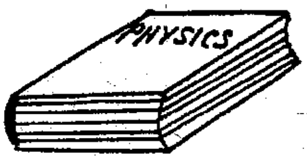


Figure A

Figure B

In this case, the shearing stress is the force exerted on the area of one of the pages and the strain is the ratio of the horizontal distance the book moves, ΔL, to the original width of the book, L. The ratio of stress to strain is equal to the elastic modulus or the **shearing modulus, S.**

$$\textbf{shearing modulus} = \frac{\textbf{shearing stress}}{\textbf{shearing strain}} \quad \text{or} \quad S = \frac{F/A}{\Delta L/L} = \frac{FL}{A\Delta L}$$

Solved Examples

Example 3: Jason, the piano tuner, is tuning a 0.50-m-long steel piano wire of cross-sectional area 0.18 cm^2 by stretching it with a force of 1200 N. By how much does this lengthen the wire? ($Y_{steel} = 2.0 \times 10^{11}$ N/m^2)

Solution: First, convert cm^2 to m^2. $0.18\ cm^2 = 1.8 \times 10^{-5}\ m^2$

Given: $L = 0.50$ m
$F = 1200$ N
$A = 1.8 \times 10^{-5}\ m^2$
$Y = 2.0 \times 10^{11}\ N/m^2$

Unknown: $\Delta L = ?$
Original equation: $Y = \dfrac{FL}{A\Delta L}$

$$\textit{Solve: } \Delta L = \frac{FL}{YA} = \frac{(1200\ \text{N})(0.50\ \text{m})}{(2.0 \times 10^{11}\ \text{N/m}^2)(1.8 \times 10^{-5}\ \text{m}^2)} = \mathbf{1.7 \times 10^{-4}\ m}$$

Example 4: While writing his history research paper, Brent reaches across the library table for his dictionary and pulls it toward himself by the edge of the top cover with a force of 16 N, displacing the cover by 0.02 m. The top of the 0.05-m-thick dictionary measures 0.05 m^2. What is the shear modulus of the dictionary?

Given: $F = 16$ N
$A = 0.05\ \text{m}^2$
$L = 0.05$ m
$\Delta L = 0.02$ m

Unknown: $S = ?$
Original equation: $S = \dfrac{FL}{A\Delta L}$

$$\textit{Solve: } S = \frac{FL}{A\Delta L} = \frac{(16\ \text{N})(0.05\ \text{m})}{(0.05\ \text{m}^2)(0.02\ \text{m})} = \mathbf{800\ N/m^2}$$

Practice Exercises

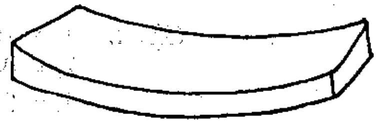
Exercise 5: Two leopards are fighting over a piece of meat they caught while hunting. The leopards pull on the meat muscle with a force of 100. N, stretching the 0.10-m-long tendon by 0.0080 m. If the cross-sectional area of the tendon is $1.0 \times 10^{-5}\ \text{m}^2$, what is its stretch modulus?

Answer: ____________________

Exercise 6: Before heading out on her big date, Ling stands in front of the bathroom mirror brushing her 0.25-m-long hair with a force of 2.0 N. If the cross-sectional area of a piece of hair is $1.0 \times 10^{-7}\ \text{m}^2$, by how much does the hair stretch when it is brushed? ($Y_{hair} = 2.0 \times 10^9$ N)

Answer: ____________________

Exercise 7: When a piece of wood is distorted by a karate chop, the top of the board is compressed while the bottom is stretched as shown. Therefore, you must first consider the change in length of the bottom of the board where the break begins. Chantal is a black belt in karate and she breaks a 30.0-cm piece of wood with a force of 70.0 N, changing it in length by 4.0×10^{-4} cm. What is the cross-sectional area of the piece of wood? ($Y_{wood} = 1.0 \times 10^9\ N/m^2$)



Answer: ____________________

Exercise 8: While Miss Levesque is erasing the blackboard with her 9.0×10^{-3}-m^2 eraser, the eraser is subjected to a great amount of shearing force. If a 2.0-cm-thick eraser is pushed with a horizontal force of 1.5 N, displacing the top of the eraser by 5.0 mm, what is the shear modulus of the eraser?

Answer: ____________________

Exercise 9: Jorge is running down the newly-waxed school hallway and tries to slide across the floor in his sneakers. The 2.0-cm thick rubber soles each have a cross-sectional area of 0.020 m^2 and are sheared with a force of 15 000 N. a) How much are the shoes displaced horizontally? b) Why does Jorge fall forward? ($S_{rubber} = 5.0 \times 10^9\ N/m^2$)

Answer: a. ____________________

Answer: b. ____________________

9-3 Liquids

Vocabulary **Hydrostatic Pressure:** The pressure exerted on an object by a column of fluid.

The hydrostatic pressure depends upon the original atmospheric pressure pushing on the surface of the fluid, and upon the fluid's density and height.

The farther an object is located below the surface of the fluid, the greater the pressure acting on it.

hydrostatic pressure =
atmospheric pressure + (density)(acceleration due to gravity)(height)

$$P_h = P_a + Dgh$$

For these exercises, assume that normal atmospheric pressure is 1.01×10^5 Pa.

Recall from Chapter 3 that a pascal (Pa) is equivalent to a newton per square meter (N/m^2).

Archimedes' Principle

According to **Archimedes' principle**, an object completely or partially immersed in a fluid is pushed up by a force that is equal to the weight of the displaced fluid.

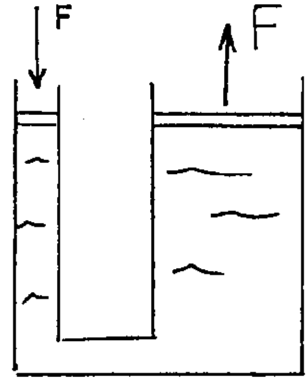
buoyant force = (density)(acceleration due to gravity)(volume)

$$F_b = DgV$$

Here the density and volume are those of the displaced fluid. This equation can be used whether the object sinks or floats. However, if the object is only partially submerged, the volume used in the calculation is that of the submerged portion. Therefore, for a floating object, the buoyant force is equal to the weight of the object itself.

Pascal's Principle

According to **Pascal's principle**, the change in pressure on one part of a confined fluid is equal to the change in pressure on any other part of the confined fluid.



$$\Delta P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Therefore, a small force exerted over a small area will result in a large force exerted over a large area. An application of Pascal's principle is found in hydraulic lifts, which are used to raise automobiles off the ground. In a hydraulic lift, the force exerted on a smaller piston provides a pressure that is applied, undiminished, to the larger piston, enabling it to lift the car.

Solved Examples

Example 5: Wanda watches the fish in her fish tank and notices that the angel fish like to feed at the water's surface, while the catfish feed 0.300 m below at the bottom of the tank. If the average density of the water in the tank is 1000. kg/m^3, what is the pressure on the catfish?

Solution: Solve this exercise using the equation for hydrostatic pressure.

Given: $P_a = 1.01 \times 10^5$ Pa
$D = 1000.$ kg/m^3
$g = 10.0$ m/s^2
$h = 0.300$ m

Unknown: $P_h = ?$
Original equation: $P_h = P_a + Dgh$

Solve: $P_h = P_a + Dgh = (1.01 \times 10^5\ \text{Pa}) + (1000.\ \text{kg/m}^3)(10.0\ \text{m/s}^2)(0.300\ \text{m})$
$= 1.01 \times 10^5\ \text{Pa} + 3.00 \times 10^3\ \text{Pa} = \mathbf{1.04 \times 10^5\ Pa}$

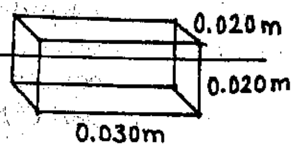
Example 6: Phyllis is being fed intravenously in her hospital bed from a bottle 0.400 m above her arm that contains a nutrient solution whose density is 1025 kg/m^3. What is the pressure of the fluid that is going into Phyllis' arm?

Given: $D = 1025$ kg/m^3
$h = 0.400$ m
$g = 10.0$ m/s^2
$P_a = 1.01 \times 10^5$ Pa

Unknown: $P_a = ?$
Original equation: $P_h + P_a + Dgh$

Solve: $P_h = P_a + Dgh = (1.01 \times 10^5\ \text{Pa}) + (1025\ \text{kg/m}^3)(10.0\ \text{m/s}^2)(0.400\ \text{m})$
$= 1.01 \times 10^5\ \text{Pa} + 4.10 \times 10^3\ \text{Pa} = \mathbf{1.05 \times 10^5\ Pa}$

Example 7: Palmer drops an ice cube into his glass of water. The ice, whose density is 917 kg/m^3, has dimensions of 0.030 m × 0.020 m × 0.020 m, as shown in the diagram. What is the buoyant force acting on the ice?



Solution: Solve this exercise using Archimedes' principle.

The dimensions of the ice provide you with the ice cube's volume.

$$0.030\ \text{m} \times 0.020\ \text{m} \times 0.020\ \text{m} = 1.2 \times 10^{-5}\ \text{m}^3$$

Because the density of the water is less than the ice, the ice will float so that part of it is above the surface. Therefore,

buoyant force = weight of water displaced = weight of ice

Given: $D_{ice} = 917\ kg/m^3$
$g = 10.0\ m/^2$
$V = 1.2 \times 10^{-5}\ m^3$

Unknown: $F_b = ?$
Original equation: $F_b = DgV$

Solve: $F_b = D_{ice}gV = (917\ kg/m^3)(10.0\ m/s^2)(1.2 \times 10^{-5}\ m^3) = \mathbf{0.11\ N}$

Therefore, the water pushes the ice cube up with a force of 0.11 N.

Example 8: Every Sunday morning, Dad takes the family trash to the trash compactor in the basement. When he presses the button on the front of the compactor, a force of 350 N pushes down on the 1.3-cm^2 input piston, causing a force of 22 076 N to crush the trash. What is the area of the output piston that crushes the trash?

Solution: Solve this exercise using Pascal's principle.

Given: $F_1 = 350\ N$
$A_1 = 1.3\ cm^2$
$F_2 = 22\ 076\ N$

Unknown: $A_2 = ?$
Original equation: $\frac{F_1}{A_1} = \frac{F_2}{A_2}$

Solve: $A_2 = \frac{F_2 A_1}{F_1} = \frac{(22\ 076\ N)(1.3\ cm^2)}{350\ N} = \mathbf{82\ cm^2}$

Practice Exercises

Exercise 10: The head of a giraffe is 2.0 m above its heart and the density of the blood is $1.05 \times 10^3\ kg/m^3$. What is the difference in pressure between the giraffe's heart and head? (Fortunately, a giraffe's neck has a special circulatory system to adapt to this neck length, producing an even flow of blood to the head.)

Answer: ______________________

Exercise 11: How much pressure is needed in ground-based water pipes to pump water up to the restaurant on the top floor of the World Trade Center, 410 m above the ground?

Answer: ______________________

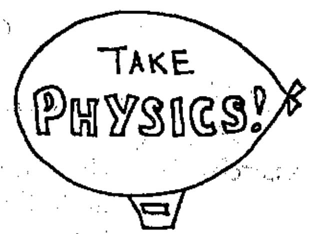
Exercise 12: The difference in pressure between the atmosphere and the human lungs is 1.05×10^5 Pa. What is the longest straw you could use to draw up milk whose density is 1030 kg/m^3?

Answer: ____________________

Exercise 13: Cadir is basting a roast turkey with a meat baster that creates a pressure of 9.980×10^4 Pa when the plastic bulb is squeezed and released. If turkey juice rises 0.0900 m up the tube of the baster, what is the density of the juice?

Answer: ____________________

Exercise 14: A 5450-m^3 blimp circles Fenway Park during the World Series, suspended in Earth's 1.21-kg/m^3 atmosphere. The density of the helium in the blimp is 0.178 kg/m^3. a) What is the buoyant force that suspends the blimp in the air? b) How does this buoyant force compare to the blimp's weight? c) How much weight, in addition to the helium, can the blimp carry and still continue to maintain a constant altitude?

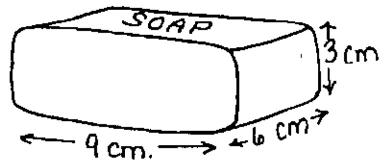


Answer: **a.** ____________________

Answer: **b.** ____________________

Answer: **c.** ____________________

Exercise 15: Ivory soap will float when placed in water so that most of the soap is suspended below the surface, and only a small fraction sticks up above the water line. A bar of soap has dimensions of 9.00 cm × 6.00 cm × 3.00 cm, as shown, and a density of 994 kg/m^3. What is the buoyant force acting on the soap?



Answer: ____________________

Exercise 16: Eliza, the auto mechanic, is raising a 1200.-kg car on her hydraulic lift so that she can work underneath. If the area of the input piston is 12.0 cm^2, while the output piston has an area of 700. cm^2, what force must be exerted on the input piston to lift the car?

Answer: ____________________

Exercise 17: Allegra's favorite ride at the Barrel-O-Fun Amusement Park is the Flying Umbrella, which is lifted by a hydraulic jack. The operator activates the ride by applying a force of 72 N to a 3.0-cm-wide cylindrical piston, which holds the 20 000.-N ride off the ground. What is the diameter of the piston that holds the ride?

Answer: ____________________

9-4 Gases

The **ideal gas law** expresses the relationship between the pressure, volume, and temperature of a gas.

In the exercises in this chapter, the mass of the gas remains constant. You will be examining relationships between changes in pressure, volume, or temperature, using a combined form of the law that reads:

$$\frac{(\textbf{Pressure}_1)(\textbf{Volume}_1)}{\textbf{Temperature}_1} = \frac{(\textbf{Pressure}_2)(\textbf{Volume}_2)}{\textbf{Temperature}_2} \quad \text{or} \quad \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

where the subscript "1" signifies the initial conditions and the subscript "2" signifies the final conditions.

When you do calculations with the ideal gas law, use the correct SI units. Temperature is measured in **kelvins (K)**, pressure is measured in **pascals (Pa)**, and volume is measured in **cubic meters (m^3)**. See Chapter 10 for an explanation of the Kelvin temperature scale.

If the temperature remains constant, the relationship between changes in pressure and volume is known as **Boyle's law.** Boyle's law says that volume decreases as the pressure increases. If the pressure remains constant, the relationship between changes in volume and temperature is known as **Charles' law.** Charles' law says that volume increases as the temperature increases.

Solved Examples

Example 9: To capture its prey, a whale will create a cylindrical wall of bubbles beneath the surface of the water, trapping confused fish inside. If an air bubble has a volume of 5.0 cm^3 at a depth where the water pressure is 2.00×10^5 Pa, what is the volume of the bubble just before it breaks the surface of the water?

Solution: In this exercise, the temperature remains the same. Remove it from both sides of the equation.

Given: $P_1 = 2.00 \times 10^5$ Pa
$V_1 = 5.00\ cm^3$
$P_2 = 1.01 \times 10^5$ Pa

Unknown: $V_2 = ?$
Original equation: $P_1V_1 = P_2V_2$

Solve: $V_2 = \dfrac{P_1V_1}{P_2} = \dfrac{(2.00 \times 10^5\ \text{Pa})(5.00\ \text{cm}^3)}{1.01 \times 10^5\ \text{Pa}} = \mathbf{9.90\ cm^3}$

Example 10: Tootie, a clown, carries a 2.00×10^{-3}-m^3 helium-filled mylar balloon from the 295-K heated circus tent to the cold outdoors, where the temperature is 273 K. How much does the volume of the balloon decrease?

Solution: In this exercise the pressure remains constant. Therefore, remove it from both sides of the equation.

Given: $V_1 = 2.00 \times 10^{-3}\ \text{m}^3$
$T_1 = 295\ \text{K}$
$T_2 = 273\ \text{K}$

Unknown: $V_2 = ?$
Original equation: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Solve: $V_2 = \frac{V_1 T_2}{T_1} = \frac{(2.00 \times 10^{-3}\ \text{m}^3)(273\ \text{K})}{295\ \text{K}} = 1.85 \times 10^{-3}\ \text{m}^3$

$V_1 - V_2 = (2.00 \times 10^{-3}\ \text{m}^3) - (1.85 \times 10^{-3}\ \text{m}^3) = \mathbf{0.15 \times 10^{-3}\ m^3}$

Example 11: Taylor is cooking a pot roast for dinner in a pressure cooker. Water will normally boil at a temperature of 373 K and an atmospheric pressure of 1.01×10^5 Pa. What is the boiling temperature inside the pot, when the pressure is increased to 1.28×10^5 Pa? The pot maintains a constant volume.

Solution: In this example the volume remains constant. Therefore, remove it from both sides of the equation.

Given: $P_1 = 1.01 \times 10^5\ \text{Pa}$
$T_1 = 373\ \text{K}$
$P_2 = 1.28 \times 10^5\ \text{Pa}$

Unknown: $T_2 = ?$
Original equation: $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

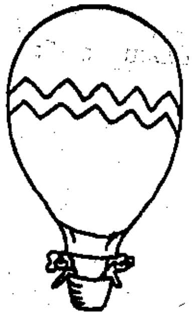
Solve: $T_2 = \frac{P_2 T_1}{P_1} = \frac{(1.28 \times 10^5\ \text{Pa})(373\ \text{K})}{1.01 \times 10^5\ \text{Pa}} = \mathbf{473\ K}$

Practice Exercises

Exercise 18: The Caloric value of food is measured with a device called a bomb calorimeter. Oxygen is forced into this sealed container and kept at a constant volume. Once the internal pressure is increased to 1.50×10^5 Pa, a small piece of food inside the calorimeter is ignited with a spark. As the food burns, the temperature inside the sealed vessel rapidly increases from 293 K to 523 K. What is the new pressure of the gas inside the chamber when the temperature rises?

Answer: ______________________

rcise 19: Brandon takes Yvonne on a surprise hot-air balloon ride for her birthday. However, once the pair is airborne, Yvonne announces that she is afraid of heights. The 2200.-m^3 balloon is filled to capacity with 350.0 K air at a height where the surrounding air presure is 1.01×10^5 Pa. When Brandon turns off the heating unit, the air in the balloon begins to cool and the balloon descends. a) Why do both the pressure and volume of the air in the balloon remain constant, even though the balloon's air cools to a temperature of 300.0 K? b) Hot-air balloons are always made so that the bottom remains open throughout the flight. By how much would the balloon's volume change if the balloon could be manually closed as the temperature dropped to 300.0 K? (Assume atmospheric pressure remains constant.)



Answer: **a.** ______________________

Answer: **b.** ______________________

Exercise 20: During Annette's first airplane ride, her plane ascends from sea level, where cabin pressure is 1.01×10^5 Pa, to flying altitude, where the cabin pressure drops slightly to 1.00×10^5 Pa despite pressurized conditions. Annette feels a sensation in her middle ear, whose volume is 6.0×10^{-7} m^3. a) What is the new volume of air inside Annette's middle ear? b) What could Annette do to compensate for this change in volume?

Answer: **a.** ______________________

Answer: **b.** ______________________

Exercise 21: Theo has won a a new car on a game show, and when his shiny new vehicle arrives on a warm 301-K (28°C) fall day, the 0.016-m^3 tires have an air pressure of 2.02×10^5 Pa. However, two weeks later, when the temperature drops to 273 K (0°C), Theo's pressure gauge reads only 1.90×10^5 Pa. What is the new volume of the car tires?

Answer: ______________________

Additional Exercises

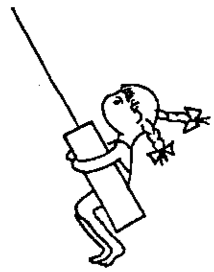
A-1: A 1.9–kg piece of wood from a sunken pirate ship has a volume of 2.16×10^{-3} m^3. Will this piece of wood float to the surface of the water or remain submerged with the ship?

A-2: Ursula drops a 0.0330-kg ice cube into her glass of soda water. The ice cube has dimensions of 3.0 cm $\times$ 3.0 cm $\times$ 4.0 cm. Does the ice cube float or sink in Ursula's drink?

A-3: Which is more dense, a 20.0-g silver bullet that occupies a volume of 1.9 cm^3, or the 5.98×10^{24}-kg Earth, that occupies a volume of 1.08×10^{21} m^3?

A-4: In her gymnastics routine, Regina dismounts from the uneven–parallel bars and lands straight-legged on the ground, compressing her 0.250–m–long femur by 2.10×10^{-5} m. If the femur has a cross-sectional area of 3.00×10^{-4} m^2 and the stress modulus of bone is 2.00×10^{10} N/m^2, with how much force does Regina hit the ground?

A-5: When they go swimming in their favorite water hole, Jeb and Dixie like to swing over the water on an old tire attached to a tree branch with a 3.0-m nylon rope. If the diameter of the rope is 2.00 cm, by how much does the rope stretch when 60.0-kg Dixie swings from it? ($Y_{nylon} = 3.7 \times 10^9$ N/m^2)



A-6: Lucy is going skin diving to see coral off the coast of Mexico in sea water with a density of 1025 kg/m^3. a) How great is the pressure pushing on Lucy at a depth of 20.0 m? b) How will the pressure change if Lucy swims deeper?

A-7: A water tower sits on the top of a hill and supplies water to the citizens below. The difference in pressure between the water tower and the Daileys' house is 1.1×10^5 Pa, while the difference in pressure between the tower and the Stearns' house is 3.2×10^5 Pa. a) Which house sits at a higher elevation, the Daileys' or the Stearns'? b) What is the difference in elevation between the two houses?

A-8: Eileen is floating on her back in the beautiful blue Caribbean during her spring vacation. If Eileen's density is 980 kg/m^3 and she has a volume of 0.060 m^3, what is the buoyant force that supports her in the sea water of density 1025 kg/m^3?

A-9: While swimming in her backyard pool, Nicole attempts to hold a 0.9000-m^3 inner tube completely submerged under the water. a) What buoyant force will be exerted on the inner tube as Nicole attempts to force it under the water? b) When Nicole lets go of the inner tube, it pops up to the surface with a force of 8990. N. What is the weight of the inner tube?

A-10: Irene is testing the strength of her model balsa wood bridge with a hydraulic press before the National Contest in Denver. Irene exerts a force of 3.0 N on a 1-cm-radius input piston, and a force is exerted on the 10.0-cm-radius output piston. If the bridge can withstand a force of 350 N before breaking, will the bridge survive the test and make it into the contest?

A-11: In exercise A-6, if Lucy were to foolishly hold her breath as she ascends to the water's surface, a) by how many times would the volume of her lungs change (assuming the water temperature remains constant)? b) Would her lungs be crushed or would they blow up like a balloon? c) What is the best way to ascend after diving?

A-12: Dong-Jae is bottling his own root beer in his basement where the air temperature is 315 K. The pressure inside each root beer bottle is 1.20×10^5 Pa, but the caps will pop off the bottles if the pressure inside exceeds 1.35×10^5 Pa. After the bottles are sealed and labeled, Dong-Jae stores them in his attic, which heats up to 364 K on a hot summer day. What happens to the pressure inside the bottles?

Challenge Exercises for Further Study

B-1: A 40.0-m-long steel elevator cable has a cross-sectional area of 4.0×10^{-4} m^2 and is able to stretch 1.0 cm before breaking. If the elevator itself has a mass of 1000. kg, how many 70.0-kg people can safely ride in the elevator? ($Y_{steel} = 2.0 \times 10^{11}$ N/m^2)

B-2: A can of soda displaces 3.79×10^{-4} m^3 of water when completely submerged. Each 0.018-kg can contains 3.54×10^{-4} m^3 of soda. a) Compare the buoyant force on a can of diet soda of density 1001 kg/m^3 to the force on a can of regular soda of density 1060. kg/m^3. b) If many cans of diet and regular soda are in a large tub of water and ice, how can you easily pick out the diet soda?

B-3: Saul ascends from the city of Tucson, Arizona, to the top of Kitt Peak, 2900 m above sea level. Usually Saul will feel his ears "pop" as the pressure inside his ears attempts to maintain equilibrium with the surrounding air. However, on this day Saul has a cold and his Eustachian tube is clogged, causing a tremendous pressure behind his 4.0×10^{-5}-m^2 ear drum. a) What force does Saul feel pushing on his ears? b) Is this pressure pushing in or out of his ear as he ascends? ($D_{air} = 1.20$ kg/m^3)

B-4: Hannah and her friends go fishing in her 1.20-m^3 rowboat, which has a mass of 100. kg. How many 60.0-kg people can get into the boat before the boat sinks?