Chapter 5. Fluid Mechanics

Think and Solve (Mathematica Application)

50. Suppose that you balance a 2-kg ball on the tip of your finger, which has an area of 1 cm^2. Show that the pressure on your finger is 20 N/cm^2, which is 200 kPa.

51. A 12-kg piece of metal displaces 2 L of water when submerged. Show that its density is 6000 kg/m^3. How does this compare with the density of water?

52. A 1-m-tall barrel is closed on top except for a thin pipe extending 5 m up from the top. When the barrel is filled with water up to the base of the pipe (1 m deep) the water pressure on the bottom of the barrel is 9.8 kPa. What is the pressure on the bottom when water is added to fill the pipe to its top?

53. A rectangular barge, 5 m long and 2 m wide, floats in fresh water. Suppose that a 400-kg crate of auto parts is loaded onto the barge. Show that the barge floats 4 cm deeper.

We can now set these two expressions for the buoyant force equal to each other and solve for the depth of the submerged portion of the barge: density_water x V = W density_water x 5m x 2m x d = 400 kg d = 400 kg / (density_water x 5m x 2m) The density of water is approximately 1000 kg/m^3, so: d = 400 kg / (1000 kg/m^3 x 5m x 2m) d = ***0.04 m*** *Therefore, the barge is submerged 0.04 meters (or 4 centimeters) deeper in the water due to the weight of the granite block.*

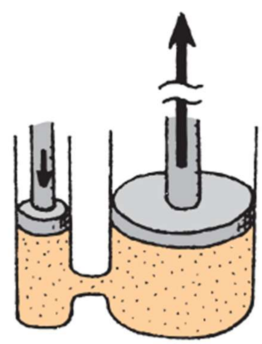
54. Suppose that the barge in the preceding problem can be pushed only 15 cm deeper into the water before the water overflows to sink it. Show that it could carry three, but not four, 400-kg crates.

55. A merchant in Kathmandu sells you a 1-kg solid gold statue for a very reasonable price. When you arrive home, you wonder whether you got a bargain, so you lower the statue into a container of water and measure the volume of displaced water. Show that for 1 kg of pure gold, the volume of water displaced is 51.8 cm^3.

56. A vacationer floats lazily in the ocean with 90% of her body below the surface. The density of the ocean water is 1025 kg/m^3. Show that the vacationer's average density is 923 kg/m^3.

57. Your friend of mass 100 kg can just barely float in fresh water. Calculate her approximate volume.

58. In the hydraulic pistons shown, the smaller piston has a diameter of 2 cm. The larger piston has a diameter of 6 cm. How much more force can the larger piston exert compared with the force applied to the smaller piston?



59. On a perfect fall day, you are hovering at rest at low altitude in a hot-air balloon. The total weight of the balloon, including its load and the hot air in it, is 20,000 N. Show that the volume of the displaced air is about 1700 m^3.

60. What change in pressure occurs in a party balloon that is squeezed to one-third its volume with no change in temperature?

61. A mountain climber of mass 80 kg ponders the idea of attaching a helium-filled balloon to himself to effectively reduce his weight by 25% when he climbs. He wonders what the approximate size of such a balloon would be. Hearing of your legendary physics skills, he asks you. Share with him your calculations that show the volume of the balloon to be about 17 m^3 (slightly more than 3 m in diameter for a spherical balloon).

62. The weight of the atmosphere above 1 square meter of Earth's surface is about 100,000 N. Density, of course, becomes less with altitude. But suppose the density of air were a constant 1.2 kg/m^3. Calculate where the top of the atmosphere would be. How does this compare with the nearly 40-km-high upper part of the atmosphere?

63. The wings of a certain airplane have a total bottom surface area of 100 m^2. At a particular speed, the difference in air pressure below and above the wings is 4% of atmospheric pressure. Show that the lift on the airplane is $4{\times}10^5$ N

Think and rank

64. Rank the following from **most to least**:

(a) The pressure at the bottom of a 20-cm-tall container of salt water.

(b) The pressure at the bottom of a 20-cm-tall container of fresh water.

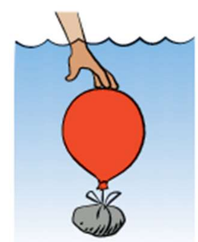
(c) The pressure at the bottom of a 5-cm tall container of mercury.

65. Rank, from **most to least**, the percentage of volume above the water line for:

(a) A basketball floating in fresh water.

(b) A basketball floating in salt water.

(c) A basket ball floating in mercury.



66. Think about what happens to the volume of an air-filled balloon on top of water, and what happens to its volume beneath the water. Then rank, from **most to least**, the buoyant force on a weighted balloon in water when it is:

(a) Barely floating with its top at the surface.

(b) Pushed 1 m beneath the surface.

(c) 2 m beneath the surface.

67. Rank, from **greatest to least**, the volumes of air in the glass when it is held:

(a) Near the surface, as shown in the figure.

(b) 1 m beneath the surface.

(c) 2 m beneath the surface.

68. Rank, from greatest to least, the buoyant forces supplied by the atmosphere for:

(a) An elephant.

(b) A helium filled party balloon.

(c) A skydiver at terminal velocity.

69. Rank, from greatest to least, the amounts of lift on the fol lowing airplane wings.

(a) Area 1000 m^2 with atmospheric pressure difference of 2.0 N/m^2.

(b) Area 800 m^2 with atmospheric pressure difference of 2.4 N/m^2.

(c) Area 600 m^2 with atmospheric pressure difference of 3.8 N/m^2.

Readiness Assurance Test (RAT)

Choose the BEST answer to the question or the BEST way to complete the statement.

1. Water pressure at the bottom of a lake depends on the lake's

A. weight of water. **B.** surface area. **C.** depth. **D.** all of these

2. The buoyant force that acts on a 20,000-N ship is

A. somewhat less than 20,000 N. **B.** 20,000 N.

C. more than 20,000 N. **D.** dependent on whether it floats in salt or in fresh water.

3. A floating duck displaces its own

A. volume of water. **B.** weight of weight. **C.** both of these **D.** none of these

4. A rock suspended by a weighing scale weighs 15 N out of water and 10 N when submerged in water. What is the buoyant force on the rock?

A. 5 N **B.** 10 N **C.** 15 N **D.** none of these

5. The two caissons of the Falkirk Wheel in Scotland (the device that lifts and lowers ships) remain in balance when

A. both caissons are brim-filled with water. **B.** ships of different weights float in each.

C. both caissons are brim-filled with water and a ship floats in only one.

D. all of these

6. To what depth must an inverted drinking glass be pushed beneath the water surface to squeeze the enclosed air to half its volume?

A. 76 cm **B.** 10.3 m **C.** 14.7 m **D.** 20.6 m

7. Atmospheric pressure is caused by the atmosphere's

A. density. **B.** weight. **C.** temperature. **D.** relationship with solar energy.

8. A hydraulic device multiplies force by 100. This multiplication is done at the expense of

A. energy, which is divided by 100. **B.** the time during which the multiplied force acts.

C. the distance through which the multiplied force acts.

D. the mechanism providing the force.

9. The flight of a blimp best illustrates

A. Archimedes' principle. **B.** Pascal's principle.

C. Bernoulli's principle. **D.** Boyle's law.

10. As water in a confined pipe speeds up, the pressure it exerts against the inner walls of the pipe

A. increases. **B.** decreases. **C.** remains constant if flow rate is constant.

D. none of these

Chapter 6. Thermal Energy and Thermodynamics

Think and Solve (Mathematica Application)

The quantity of heat Q released or absorbed from a substance of specific heat c (which can be expressed in units of cal/g.°C or J/kg.°C) and mass m (in units of g or kg, undergoing a change in temperature ΔT *is* $Q = cm\Delta T$.

36. Will Maynez burns a 0.6-g peanut beneath 50 g of water, which increases in temperature from 22°C to 50°**C.** (The specific heat capacity of water is 1.0 cal/g # °C.)

(a) Assuming 40% efficiency, show that the peanut's food value is 3500 calories.

(b) Then show how the food value in calories per gram is 5.8 kcal/g (or 5.8 Cal/g).

37. Consider a 6.0-g steel nail 8.0 cm long and a hammer that exerts an average force of 600 N on the nail when it is being driven into a piece of wood. The nail becomes warmer. Show that the increase in the nail's temperature is 17.8°**C.** (Assume that the specific heat capacity of steel is 450 J/kg.°C.)

38. If you wish to warm 50 kg of water by 20°C for your bath, show that the amount of heat needed is 1000 kcal (1000 Cal). Then show that this rounds off to be about 4200 kJ.

39. The specific heat capacity of steel is 450 J/kg.°**C.** Show that the amount of heat needed to raise the temperature of a 10-kg piece of steel from 0°C to 100°C is 450,000 J. How does this compare with the heat needed to raise the temperature of the same mass of water through the same temperature difference? (For water, c = 4190 J/kg.°C.)

40. In the lab, you submerge 100 g of 40°C nails in 200 g of 20°C water. (The specific heat of iron is 0.12 cal/g.°C.) Equate the heat gained by the water to the heat lost by the nails, and show that the final temperature of the water is about 21°**C.**

*To solve the problems that follow, you will need knowledge of the average coefficient of linear expansion, α, which differs for different materials. We define a to be the change in length (L) per unit length—or the fractional change in length—for a temperature change of 1°**C.** That is, $\alpha = \Delta L/L$ per °**C.** For aluminum, $\alpha = 24\times10^{-6}$ /°C, and for steel, $\alpha = 11\times10^{-6}$ /°**C.** The change in length ΔL of a material is given by $\Delta L = \alpha L \Delta T$.*

41. Consider a 1-m bar that expands 0.6 cm when heated. Show that when similarly heated, a 100-m bar of the same material becomes 100.6 m long.

42. Suppose that the 1.3-km main span of steel for the Golden Gate Bridge had no expansion joints. Show that for an increase in temperature of 20°C, the bridge would be nearly 0.3 m longer.

43. Imagine people breathing on the length of a 40,000-km steel pipe that forms a ring to fit snugly entirely around the circumference of Earth so as to raise its temperature by 1°**C.** The pipe gets longer—and is no longer snug. How high does it then stand above ground level? Show that the answer is an astounding 70 m higher! (To simplify, consider only the expansion of its radial distance from the center of Earth, and apply the geometry formula that relates circumference C and radius r—that is, $C = 2\pi r$)

Think and rank

44. Rank, from greatest to least, the magnitudes of these units of thermal energy: (a) 1 calorie. (b) 1 Calorie. (c) 1 joule.

45. Three blocks of metal at the same temperature are placed on a hot stove. Their specific heat capacities are given, after their identities, in the list that follows. Rank these blocks of metal, from greatest to least, in terms of how quickly they warm up:

(a) Steel, 450 J/kg. °C. (b) Aluminum, 910 J/kg.°C. (c) Copper, 390 J/kg .°C.

46. How much the lengths of various substances change with temperature changes is given by their coefficients of lin ear expansion, α. The greater the value of α, the greater the change in length for a given change in temperature. Three kinds of metal wires are stretched between distant telephone poles. Rank these wires, from greatest to least, in terms of how much they will sag on a hot summer day:

(a) Copper, $\alpha = 17\times10^{-6}/°C$.

(b) Aluminum, $\alpha = 24\times10^{-6}/°C$.

(c) Steel, $\alpha = 11\times10^{-6}/°C$.

47. The precise volume of 200 grams of water in a beaker depends on the temperature of the water. Rank the fol lowing temperatures from greatest volume of 200 grams of water to least volume of 200 grams of water: (a) 0°C. (b) 4°C. (c) 10°C

Readiness Assurance Test (RAT)

Choose the BEST answer to the question or the BEST way to complete the statement.

1. The motion of molecules that most affects temperature is

A. translational motion. **B.** rotational motion.

C. internal vibrational motion. **D.** simple harmonic motion.

2. Heat energy travels from

A. an object that has a greater amount of thermal energy to an object with lower thermal energy.

B. an object that has a higher temperature to an object with a lower temperature.

C. both of these

D. none of these

3. Absolute zero corresponds to a temperature of

A. 0 K. **B.** –273° C. **C.** both of these **D.** neither of these

4. Thermal energy is normally measured in units of

A. calories. **B.** joules. **C.** both of these **D.** neither of these

5. Which two laws of thermodynamics are statements of what doesn't happen?

A. The first and the second **B.** The first and the third

C. The second and the third **D.** None of these; that is, they all state what does happen.

6. Your garage gets messier day by day. In this case, entropy is

A. decreasing. **B.** increasing. **C.** hanging steady. **D.** none of these

7. The specific heat capacity for aluminum is more than twice that of copper. If equal quantities of heat are given to equal masses of aluminum and copper, the metal that more rapidly increases in temperature is

A. aluminum. **B.** copper.

C. neither of these; that is, both will increase in temperature at the same rate.

D. none of these

8. A bimetallic strip used in thermostats relies on the fact that different metals have different

A. specific heat capacities. **B.** thermal energies at different temperatures.

C. rates of thermal expansion. **D.** all of these

9. Water at 4°C will expand when it is slightly

A. cooled. **B.** warmed. **C.** both of these **D.** neither of these

10. Microscopic slush in water tends to make the water

A. slipperier. **B.** warmer. **C.** more dense. **D.** less dense.