20. [II] What is the mass of a single water molecule, and how many of them are in 1.000 g of pure water? The atomic masses of hydrogen and oxygen are 1.008 u and 16.00 u, respectively.

21. [II] Ethyl alcohol, C_2H_5OH, has a density of 0.789×10^3 kg/m^3. Estimate the linear size of the molecule.

22. [II] Assume that a water molecule is a sphere of diameter 0.3 nm. Approximately how many of these spherical molecules will be in 18 cm^3 of water? How does this result compare with the correct answer? Why is it in error?

23. [III] What is the approximate separation between gas molecules at STP? How does this compare to the separation between molecules in a solid?

SECTION 9.4: HYDROSTATIC PRESSURE

24. [I] How high should a vertical pipe filled with water be if a gauge at its bottom is to read a pressure of 400 kPa due only to the liquid?

25. [I] A swimming pool 5-m wide by 10-m long is filled to a depth of 3-m. What is the pressure on the bottom due only to the water?

26. [I] A rectangular tank 2.0 m by 2.0 m by 3.5 m high contains gasoline, with a density of 0.68×10^3 kg/m^3, to a depth of 2.5 m. What is the gauge pressure anywhere 2.0 m below the surface of the gasoline?

27. [I] An oxygen tank sitting in the corner of a laboratory has an internal gauge pressure 5.00 times atmospheric pressure. What outward force is exerted per square centimeter on the inner wall of the tank?

28. [I] At about 10 miles up in the atmosphere, air pressure drops to roughly 2 lb/in.^{2} (down from 14.7 lb/in.^{2} at sea level). Using the fact that 1.000 lb = 4.448 N and 1.000 in. = 2.540 cm, what is the air pressure at that altitude in *atmospheres* and *pascals*?

29. [I] Prove that 1.000 lb/in.^{2} = 6.895×10^3 N/m^2, using the fact that 1.000 lb = 4.448 23 N.

30. [I] A typical automobile tire has a gauge pressure of around 30 lb/in.^{2} How much is that in pascals? If a car weighs 8897 N (i.e., 2000 lb), how much area (in SI units) on each tire is in contact with the road? See the previous problem.

31. [I] The U.S. Navy bathyscaphe *Trieste* in 1960 descended to a record depth of 10 920 m in the Pacific Ocean near the island of Guam. To two significant figures, determine the maximum gauge pressure (in both Pa and psi) it encountered. Assume the density of the sea is constant. [*Hint: The gauge pressure depends on the depth and the density of the fluid.*]

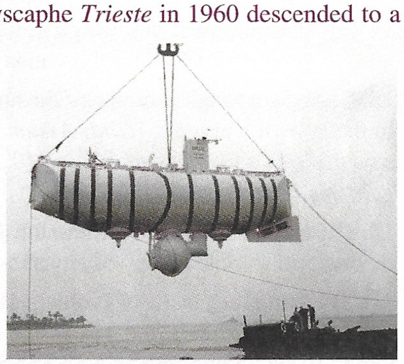

Figure P31

32. [I] In a large apartment house water is stored in a tank on the roof 30.5 m above a faucet in a first-floor kitchen. What is the gauge pressure at the faucet?

33. [I] How deep must you dive in fresh water before the gauge pressure equals 1.00 atmosphere (1.00 atm = 1.013×10^5 N/m^2)?

34. [I] A swimming pool 5.0-m wide by 10-m long is filled to a depth of 3.0 m. What is the absolute pressure on the bottom?

35. [I] When Pascal's brother-in-law climbed to the top of the 3200-ft-high Mont Puy-de-Dôme, the barometer he carried showed a drop in mercury of about 3.0 in. What was the corresponding pressure drop?

36. [I] A swimming pool 5.0-m wide by 10-m long is filled to a depth of 3.0 m. What is the total force exerted on the bottom due to the water?

37. [I] THIS PROBLEM WILL HELP US LEARN ABOUT THE HEIGHT DEPENDENCE OF HYDROSTATIC PRESSURE. A water tank is 310 m above the ground on top of a skyscraper, and a pipe runs straight from it all the way down to street level. (a) What is the meaning of the term *gauge pressure*? (b) Compute the gauge pressure at street level in the pipe. (c) If the pipe has a cross-sectional area of 0.50 m^2, what is the weight of the water in the pipe?

38. [I] THIS PROBLEM EXAMINES HYDROSTATIC PRESSURE AND FORCE. The *Titanic* sunk on its maiden voyage from Southampton, England to New York on April 14, 1912. It rests in the North Atlantic in water 3.0 km deep. (a) What is the density of seawater? (b) What is the meaning of absolute pressure? (c) Neglecting variations in water density, what was the maximum external pressure (both gauge and absolute) that the craft experienced? (d) What was the value of the force exerted by the sea on every square centimeter of the hull?

39. [II] The medical literature uses yet another pressure unit: the cm of water (water columns are convenient for measuring modest gauge pressures). Thus, one reads that a newborn baby is capable of developing a "momentary intrathoracic negative pressure of the order of 40 cm of water." How much is that in pascals?

40. [II] To remove unwanted fluids from the body, an aspirator such as that shown in Fig. P40 is used. A small electric pump provides the suction (typically at gauge pressure levels of −90 to −120 mm Hg), while the bottle containing water provides the control. Explain how the depth beneath the water surface of the control tube establishes the pressure in the drain tube. What happens to the suction pressure as the drain tube in the bottle becomes submerged in liquid aspirated from the patient? When will the system shut itself off? Suppose the procedure starts with the control tube 10 cm into the water—what is the suction pressure to the patient?

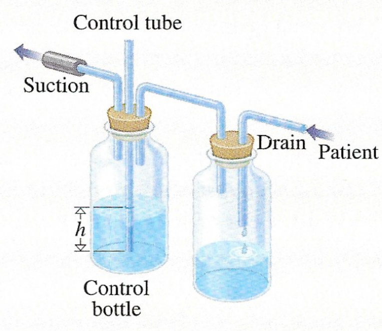

Figure P40

41. [II] Given that most people cannot "suck" water up a straw any higher than about 1.1 m, what's the lowest gauge pressure they can create in the lungs?

42. [II] The gauge pressure in a basement water pipe supplying a tall building is 3.00×10^5 Pa. In an apartment several floors up, the pressure is half this value. How high up is the apartment?

43. [II] A rubber pipe is attached to one end of an open U-tube water-filled manometer (such as the one in Fig. 9.13). A patient exhales strongly into the rubber pipe, and a difference in height between the two columns of 61 cm results. What absolute pressure was developed by the lungs?

44. [II] The piston in equilibrium, shown in Fig. P44, has a face area of 0.10 m^2 and experiences a downward force of 1.00 kN. The mercury in the vessel is 10.0-cm deep. What is the gauge pressure at the very bottom of the chamber?

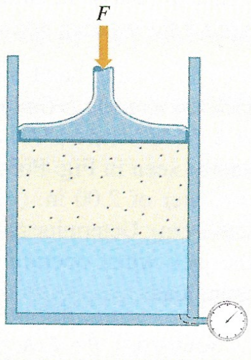

Figure P44

45. [II] THIS PROBLEM EXPLORES HYDROSTATIC PRESSURE DUE TO A COMBINATION OF LIQUIDS. Suppose you take a tall vertical tube, sealed at the bottom, and pour in water to a height of 24 cm, and then gently add another 12 cm of olive oil (with a density of 0.92 g/cm^3). (a) What is the gauge pressure on the bottom before the oil is added to the water? (b) Does the oil float on the water? How do you know? (c) What is the gauge pressure at the water-oil interface? (d) What is the gauge pressure on the bottom of the tube after the oil is added?

46. [II] THIS PROBLEM TREATS HYDROSTATIC PRESSURE DUE TO A COMBINATION OF FACTORS. A tank 10 m by 5.0 m is filled with lubricating oil (having a density of 0.91 g/cm^3) to a height of 4.0 m. A 10 000 lb mahogany boat is then floated on the oil. (a) What is the weight of the oil in the tank? (b) What is the area of the bottom of the tank? (c) What is the gauge pressure on the bottom before the boat arrives? (d) How much does the boat weigh in newtons? (e) After the boat arrives, what's the total weight, of oil and boat, acting on the bottom of the tank? (f) What is then the gauge pressure at the bottom?

47. [II] A submarine rests in 20.0 m of water. How much force must a diver exert against the pressure of the sea in order to pull open a hatch 1.0 m × 0.50 m, assuming the internal pressure in the boat is 90% of atmospheric?

SOLUTION: Outside the sub $P_{out} = P_A + \rho_W g h$; inside the sub $P_{in} = 90\% P_A$; the difference in pressure is $P_{out} - P_{in} = (0.10P_A + \rho_W g h)$. Thus $F = A(0.10P_A + \rho_W g h) = (0.50\ m^2)(0.10P_A + \rho_W g h) = 1.0 \times 10^5$ N.

48. [II] The open U-tube in Fig. P48 contained some water before a less dense liquid was poured in on the right side. If the density of the unknown liquid is ρ_x, show that

$$\rho_x = \frac{\rho_w h_w}{h_x}$$

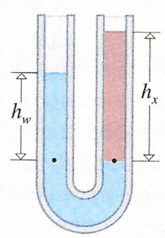

Figure P48

49. [II] Return to the manometer in Fig. 9.13, but this time suppose it's filled with mercury and the level on the right is 4.0 cm lower than the level on the left. What is the pressure in the chamber, taking atmospheric pressure to be 0.101 MPa?

50. [III] A glass plate 0.12 m × 0.20 m is mounted on the top of a submerged camera box to make an angle of 30° with the horizontal. The uppermost 0.12-m edge is 0.20 m below the surface of the water. The box is sealed, and there is air inside at atmospheric pressure. Please compute the net force acting on the plate due to the water.

51. [III] Figure P51 deals with the problem of showing that the pressure within a fluid is independent of orientation. Shown is the end of a wedge-shaped volume of fluid where the average pressure on each of its faces is P_a, P_b, and P_c. The lengths of the sides of the top face are both L, and it makes an angle of ϕ with the bottom. Find the net force on each face, and show that the fluid wedge is in equilibrium when

$$P_a L^2 \sin\phi = P_c L^2 \sin\phi$$

and

$$P_b L^2 \cos\phi = P_c L^2 \cos\phi + \tfrac{1}{2}\rho g L^3 \sin\phi \cos\phi$$

Now, let the wedge shrink and show that $P_a = P_b = P_c$ in the limit as $L \to 0$.

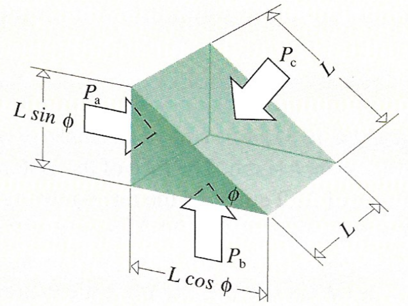

Figure P51

52. [III] The diving bell shown in Fig. P52 allows swimmers to comfortably remain under water for long intervals. Show that

$$d = \frac{P_A h}{(H - h)\rho g} + h$$

where P_A is the original pressure in the bell (usually atmospheric). [*Hint: Don't forget atmospheric pressure on the water.*]

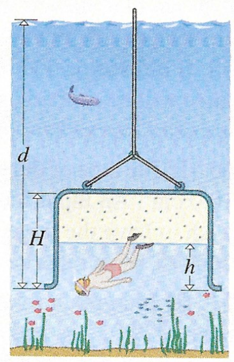

Figure P52

53. [III] A swimming pool 5-m wide by 10-m long is filled to a depth of 3 m. What is the total force on either narrow wall due only to the water?

SECTION 9.5: PASCAL'S PRINCIPLE

54. [I] Consider a narrow horizontal cylindrical chamber permanently sealed at one end and closed off at the other end with a tightly fitted movable piston having an area of 0.050 m^2. The chamber is filled with oil, and a compressive force of 1000 N is applied to the liquid via the piston. Determine the pressure read by a sensor (a) at the flat far end and (b) halfway in along the wall.

55. [I] The digging bucket on a large mechanical excavator is moved by a piston sliding within a single hydraulic cylinder. According to the manufacturer, the hydraulic fluid in the cylinder is pressurized to 1000 psi (6.895 × 10^6 Pa or 68 atm) by a pump. The cylinder has a diameter of 0.165 m and a stroke of 1.36 m. Determine the maximum force that can be exerted by the cylinder.

SOLUTION: $F = PA = (6.895 \times 10^6\ \text{Pa})(\tfrac{1}{4}\pi D^2) = 147$ kN.

56. [I] The pressure that operates a hydraulic elevator is provided by an electric pump. If the elevator and its cargo have a combined mass of 4200 kg and the piston diameter is 22.0 cm, what pressure must be maintained on the fluid?

57. [I] THIS PROBLEM HELPS US BETTER UNDERSTAND THE TRANSMISSION OF FORCE THROUGH A CONFINED INCOMPRESSIBLE LIQUID. The face of the piston on the left in Fig. P57 has an area of 21.2 cm^2, and the one on the right has an area of 63.6 cm^2 (a) What is the ratio of the areas of the two piston faces? (b) If the mass on the left is 26.2 kg, how much mass should be placed on the right to balance the system?

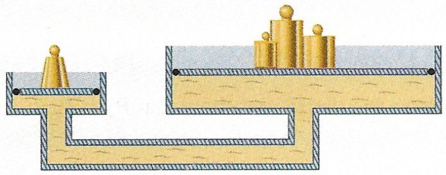

Figure P57

58. [I] THIS PROBLEM EXAMINES THE TRANSMISSION OF FORCE IN A CONFINED INCOMPRESSIBLE FLUID. The face of the piston on the left in Fig. P57 has an area of 21.2 cm^2, and the one on the right has an area of 63.6 cm^2. The mass on the left is 24.0 kg. (a) What is the force acting on the piston on the left? (b) What is the pressure on the piston on the left? (c) What is the pressure on the piston on the right?

59. [I] A hydraulic press consists of two connected cylinders—one 8.00 cm in diameter, the other 20.00 cm in diameter. The cylinders are sealed with movable pistons, and the whole system is filled with oil. If a force of 600 N is then applied to the smaller piston, what force will be exerted on the larger piston? Ignore friction. [*Hint: The pressure everywhere in the sealed system is equal.*]

60. [I] The area of the face of the small piston of a hydraulic press is 10.0 cm^2. An input force of 100 N is applied to that piston, and we wish to have the large piston exert a corresponding output force of 9600 N. What must be the area in cm^2 of the face of the large piston?

61. [I] Imagine a hydraulically operated dentist's chair having a mass of 200.0 kg, and in it is sitting a 54.8-kg patient. The large piston beneath the chair has a diameter of 5.00 cm, whereas the small piston, moved by a pedal on which the dentist steps, has a diameter of 1.00 cm. What is the pressure in the interconnecting fluid when the dentist operates the chair? How much force must he exert on the small piston?

62. [I] Figure P62 is a simplified drawing of a brake arrangement on a car; the master cylinder actually connects to all four brakes via two separate systems. Suppose a force of 100 N is applied to the piston in the master cylinder as a result of someone stepping on the brake. That cylinder has a face area of 6.45 cm^2 as compared to the 19.35-cm^2 face area of the brake cylinder. How much force will be transmitted to each brake shoe pushing the two stationary linings outward against the rotating drum?

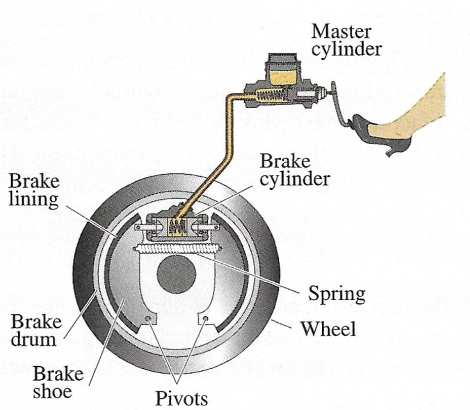

Figure P62

63. [II] A small hand-operated hydraulic jack has a rated maximum lifting capacity of 4500 lb (where 1.000 lb = 4.448 N). As can be seen in Fig. P63, the piston has a diameter of 2.00 in. (where 1.000 in. = 2.540 cm). Determine the fluid pressure in the jack when operating under a maximum load.

SOLUTION: $P = F/A = (4500 \times 4.448\text{ N})/(\frac{1}{4}\pi D^2) = (4500 \times 4.448\text{ N})/\frac{1}{4}\pi(0.050\,8\text{ m})^2 = 9.88\text{ MPa}$.

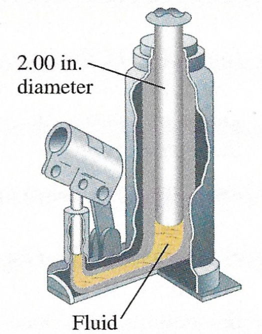

Figure P63

64. [II] THIS PROBLEM TAKES INTO ACCOUNT HYDROSTATIC PRESSURE EVEN THOUGH THE SYSTEM IS SEALED. Figure P64 shows two pistons (small and large, with masses m_S and m_L, and areas A_S and A_L) in equilibrium. The connecting liquid is oil having a density ρ_o. The mass of the small piston is unknown, so we want an equation for m_S in terms of the other parameters, including h, the column height. (a) Write an expression for the absolute pressure just below the large piston. (b) Write an expression for the absolute pressure at that same level, but below the small piston. Do not neglect the weight of the oil. (c) What can be said about these two pressures? (d) Write an expression for m_S in terms of M, m_L, A_S, A_L, ρ_o and h.

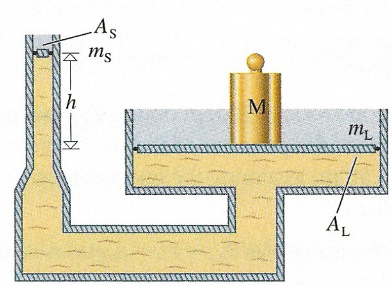

Figure P64

65. [II] THIS PROBLEM TREATS THE TRANSMISSION OF FORCE IN A CONFINED INCOMPRESSIBLE LIQUID. We want to study the forces (input and output) indicated in the cross-sectional view shown in Fig. P65, keeping in mind that the large piston has a substantial mass m_L. The system, which supports an external load equal to F_o, is in equilibrium. (a) Write an expression for the gauge pressure just below the large piston. (b) Neglecting the weight of the fluid, write an expression for the gauge pressure just above the small piston. (c) What can be said about these two pressures? (d) Write an expression for F_o in terms of F_i, m_L, A_S, and A_L.

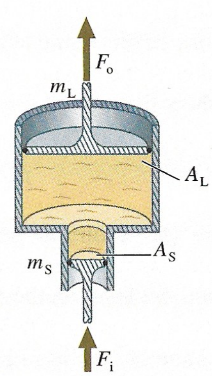

Figure P65

66. [II] A hydraulic lift consists of two interconnected pistons filled with a common working liquid. If the areas of the piston faces are 64.0 cm^2 and 3200 cm^2 and if a 900-kg car rests on the latter, how

much force must be exerted to raise the vehicle very slowly? If the car is to be raised 2.00 m, how far must the input piston be depressed?

67. [II] A hydraulic cylinder on a large machine operates at a pressure of 1000 psi (i.e., 6.895×10^6 Pa), and has a diameter of 0.20 m and a stroke length of 1.36 m. What's the maximum amount of power that it can deliver if a complete stroke takes 6.0 s?

68. [II] Emergency rescue teams often carry small hydraulic devices (like the one in Fig. P68) to cut or bend debris in order to remove victims from wreckage. Compute the output force exerted by the device when a force of 360 N is applied to the handle, which is pivoted at the far right. The small piston has a diameter of 2.00 cm; the large one has a diameter of 6.00 cm.

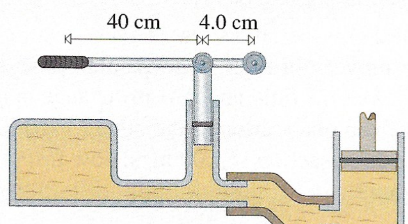

Figure P68

SECTION 9.6: BUOYANT FORCE

69. [I] What is the buoyant force exerted on a sunken treasure chest that has come to rest on a few small rocks at the bottom of a freshwater lake? The chest is 1.00-m long, 0.50-m wide, and 0.60-m high and contains 10 kg of pure gold.

70. [I] The density of uranium is 18.7×10^3 kg/m^3. What is its specific gravity? How much more dense than water is uranium?

71. [I] The fluid in a lead storage battery for a car has a specific gravity of 1.30 when it's fully charged and 1.15 when it's discharged. By how much does the density of the fluid change when the battery is completely run down?

72. [I] Imagine a rectangular solid having a height of 1.50 cm and a density of 10.5×10^3 kg/m^3 floating in an unknown liquid. Given that the block is submerged to a depth of 1.16 cm, find the density of the liquid.

73. [I] An ancient coin, which X-rays show is solid and homogeneous, has a mass of 0.010 0 kg. When submerged, it displaces 0.952 g of water. What is its specific gravity, and what is it probably made of? [*Hint: Use the definition of specific gravity,* ρ/ρ_W.]

74. [I] Determine the specific gravity of a statue if its mass is 25.0 kg in air and appears to be only 15.0 kg when measured while submerged in water.

75. [I] A metal object is hung from a scale and found to weigh 10.0 N. It is then lowered into a tank of water and its "weight," measured while it's submerged, is found to be 8.00 N. What is its specific gravity?

76. [I] Envision a thin-walled jar having a mass of 10.0 g containing 0.100 g of hydrogen at atmospheric pressure. Estimate the difference we can expect to observe if we weigh the filled jar in dry air at 0°C as opposed to weighing it in vacuum. The density of hydrogen is 90×10^{-6} g/cm^3.

77. [II] THIS PROBLEM EXAMINES THE DENSITY OF NUCLEAR MATTER. The nucleus of a hydrogen atom has a diameter of about 2.4 fm = 2.4×10^{-15} m and a mass of 1.673×10^{-27} kg. (a) Determine the volume of the nucleus. (b) What is the density of the nucleus? (c) What is the specific gravity of nuclear matter?

78. [II] THIS PROBLEM DEALS WITH THE SPECIFIC GRAVITY OF AN UNKNOWN LIQUID. The measured mass of a chunk of material in air is 60.0 g, in water it's 34.0 g, and in the unknown liquid it's 14.0 g. (a) What is the reduced mass of the chunk in water? (b) What is the mass of the water displaced? (c) What is the volume of water displaced? (d) What is the volume of the chunk of material? (e) What is the mass of the unknown liquid displaced? (f) What is the density of the unknown liquid? (g) What is the specific gravity of the unknown liquid?

79. [II] The buoyant force may be thought of as acting upward at a point sometimes called the center-of-volume (Fig. P79). For a person, because the lungs are light and yet voluminous, the center-of-volume is usually above the center-of-gravity. On allowing the body to descend fully into the water, a net torque will initially exist and the floating person will rotate until the line-of-action of the buoyant force passes through the *c.g.* Studies show that the average density of a young woman with her lungs inflated is about 980 kg/m^3. What percentage of her body will remain in the air when she's floating in fresh water ($\rho_W = 1.000 \times 10^3$ kg/m^3)?

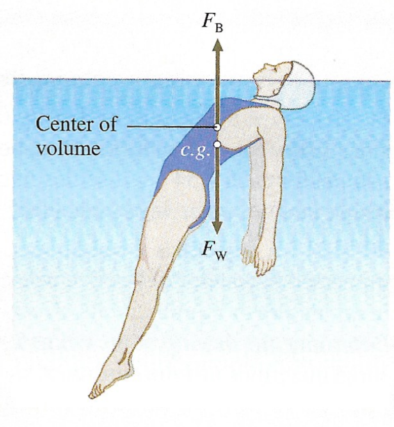

Figure P79

80. [II] A 227-kg block of cement, of density 2.8×10^3 kg/m^3, rests on a pedestal in front of the Al Capone Memorial Library. How much did it weigh submerged while being hauled out of the river (freshwater)?

SOLUTION: $F'_W = F_W - F_B = m_c g - g\rho_W V_c = m_c g - g\rho_W m_c/\rho_c = m_c g(1 - \rho_W/\rho_c) = (227 \text{ kg})(9.81 \text{ m/s}^2)(1 - 1/2.8) = 1.4 \text{ kN}$.

81. [II] A ring weighs 6.327×10^{-3} N when measured in air and 6.033×10^{-3} N when submerged in water. What is its volume (to three significant figures)? What is it likely made of? What is its relative density (to three significant figures)?

82. [II] A woman weighing 500 N jumps into a swimming pool 10 m × 10 m by 5 m deep and floats around. By how much does the water level change as a result of her arrival?

83. [II] Icebergs float in the ocean with much of their huge volumes hidden below the surface. What fraction is visible above the water? What portion of an ice cube floats above the surface of a glass of tap water?

84. [II] A person floats on the Great Salt Lake, which has a density of 1.15×10^3 kg/m^3. Approximately how much of the swimmer's body is above the water?

85. [II] THIS PROBLEM EXPLORES FLOATING IN SEAWATER. A steel can has a mass of 390 g and a capacity of 1000 cm^3. (a) What's the average density of the can as a whole? (b) Will it float when empty? (c) How much does it weigh? (d) What's the value of the