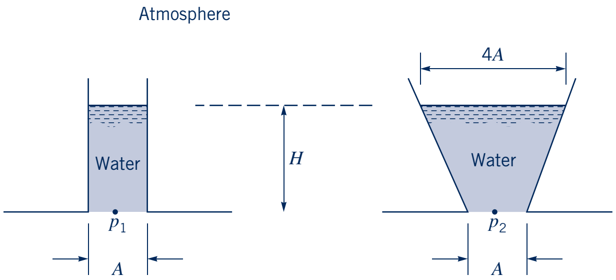
Conceptual Questions

2.1C Two tubes connected to two water reservoirs are as shown below. The tube on the left is straight, and that on the right is a cone with the top area four times that of the base. The bottom area of the cone equals that of the straight tube. The height of the water is the same for both cases.

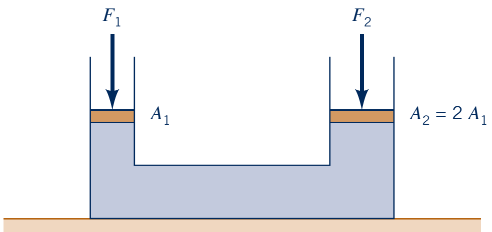


The relation between the pressures p_1 and p_2 at the base of the tubes is:

a) $p_2 = 4\ p_1$. b) $p_2 = 2\ p_1$. c) $p_2 = \frac{1}{2}\ p_1$.

d) $p_2 = p_1$. e) $p_2 = \frac{1}{3}\ p_1$.

2.2C A system filled with a liquid is shown below. On the left there is a piston in a tube of cross-sectional area A_1 with a force F_1 applied to it, and on the right there is a piston in a tube of cross-sectional area A_2 that is twice that of A_1 and a force F_2. The pistons are weightless. The two liquid levels are the same.



The relation between the force F_2 and F_1 is

a) $F_2 = F_1$ b) $F_2 = 4\ F_1$ c) $F_2 = 2\ F_1$

d) $F_2 = F_1/2$ e) $F_2 = F_1/4$

2.3C For a fluid element at rest, the forces acting on the element are:

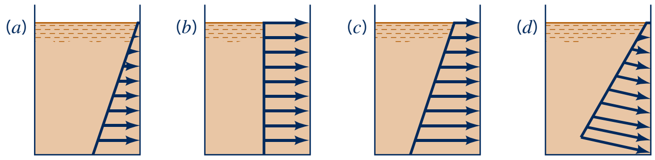
a) gravity, shear, and normal forces.

b) gravity and normal forces.

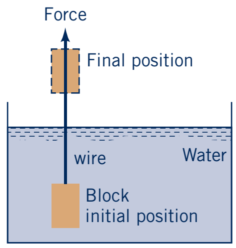
c) gravity and shear forces.

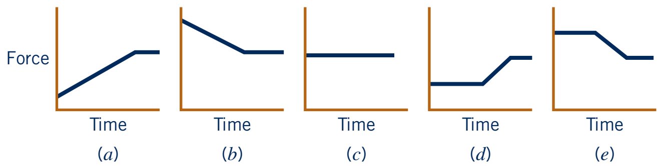
d) normal and shear forces.

2.4C A tank is filled with a liquid, and the surface is exposed to the atmosphere. Which of the following accurately represents the absolute pressure distribution on the right-hand side of the tank?



2.5C A wire is attached to a block of metal that is submerged in a tank of water as shown below. The graph that most correctly describes the relation between the force in the wire and time as the block is pulled slowly out of the water is





Additional conceptual questions are available in *WileyPLUS* at the instructor's discretion.

Problems

Note: Unless specific values of required fluid properties are given in the problem statement, use the values found in the tables on the inside of the front cover. Answers to the even-numbered problems are listed at the end of the book. The Lab Problems as well as the videos that accompany problems can be accessed in *WileyPLUS* or the book's website, www.wiley.com/college/munson.

Section 2.3 Pressure Variation in a Fluid at Rest

2.1 Obtain a photograph/image of a situation in which the fact that in a static fluid the pressure increases with depth is important. Print this photo and write a brief paragraph that describes the situation involved.

2.2 A closed, 5 m tall tank is filled with water to a depth of 4 m. The top portion of the tank is filled with air which, as indicated by a pressure gage at the top of the tank, is at a pressure of 20 kPa. Determine the pressure that the water exerts on the bottom of the tank.

2.3 WILEY GO A closed tank is partially filled with glycerin. If the air pressure in the tank is 4.1 kN/m^2 and the depth of glycerin is 3.0 m what is the pressure in N/m^2 at the bottom of the tank?

2.4 Blood pressure is usually given as a ratio of the maximum pressure (systolic pressure) to the minimum pressure (diastolic pressure). As shown in **Video V2.3**, such pressures are commonly measured with a mercury manometer. A typical value for this ratio for a human would be 120/70, where the pressures are in mm Hg. (**a**) What would these pressures be in pascals? (**b**) If your car tire was inflated to 120 mm Hg, would it be sufficient for normal driving?

2.5 An unknown immiscible liquid seeps into the bottom of an open oil tank. Some measurements indicate that the depth of the unknown liquid is 1.5 m and the depth of the oil (specific weight = 8.5 kN/m^3) floating on top is 5.0 m. A pressure gage connected to the bottom of the tank reads 65 kPa. What is the specific gravity of the unknown liquid?

2.6 The water level in an open standpipe is 24.4 m above the ground. What is the static pressure at a fire hydrant that is connected to the standpipe and located at ground level? Express your answer in kPa.

2.7 How high a column of SAE 30 oil would be required to give the same pressure as 700 mm Hg?

2.8 What pressure, expressed in pascals, will a skin diver be subjected to at a depth of 40 m in seawater?

2.9 Bathyscaphes are capable of submerging to great depths in the ocean. What is the pressure at a depth of 5 km, assuming that seawater has a constant specific weight of 10.1 kN/m^3? Express your answer in pascals.

2.10 For the great depths that may be encountered in the ocean the compressibility of seawater may become an important consideration. (a) Assume that the bulk modulus for seawater is constant and derive a relationship between pressure and depth which takes into account the change in fluid density with depth. (b) Make use of part (a) to determine the pressure at a depth of 6 km assuming seawater has a bulk modulus of 2.3×10^9 Pa and a density of 1030 kg/m^3 at the surface. Compare this result with that obtained by assuming a constant density of 1030 kg/m^3.

2.11 Sometimes when riding an elevator or driving up or down a hilly road a person's ears "pop" as the pressure difference between the inside and outside of the ear is equalized. Determine the pressure difference (in kPa) associated with this phenomenon if it occurs during a 46 m elevation change.

2.12 Develop an expression for the pressure variation in a liquid in which the specific weight increases with depth, h, as $\gamma = Kh + \gamma_0$, where K is a constant and γ_0 is the specific weight at the free surface.

***2.13** In a certain liquid at rest, measurements of the specific weight at various depths show the following variation:

h (m)	γ (kN/m^3)
0	10.9
3	11.9
6	13.2
9	14.2
12	15.2
15	16
18	16.8
21	17.2
24	17.5
27	17.9
30	18.1

The depth $h = 0$ corresponds to a free surface at atmospheric pressure. Determine, through numerical integration of Eq. 2.4, the corresponding variation in pressure and show the results on a plot of pressure (in kPa) versus depth (in meter).

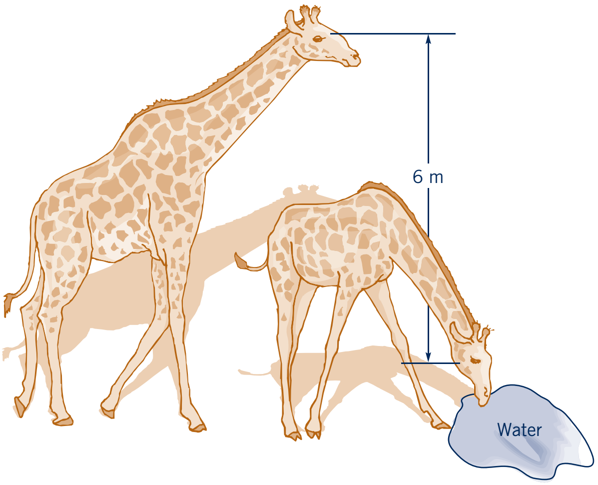
†2.14 Because of elevation differences, the water pressure in the second floor of your house is lower than it is in the first floor. For tall buildings this pressure difference can become unacceptable. Discuss possible ways to design the water distribution system in very tall buildings so that the hydrostatic pressure difference is within acceptable limits.

***2.15** Under normal conditions the temperature of the atmosphere decreases with increasing elevation. In some situations, however, a temperature inversion may exist so that the air temperature increases with elevation. A series of temperature probes on a mountain give the elevation–temperature data shown in the table below. If the barometric pressure at the base of the mountain is 83.4 kPa, determine by means of numerical integration the pressure at the top of the mountain.

Elevation (m)	Temperature (°C)
1524	10.1 (base)
1676	12.9
1829	15.7
1951	17.0
2164	19.4
2256	20.2
2500	21.1
2621	20.8
2804	20.0
3018	19.5 (top)

†2.16 Although it is difficult to compress water, the density of water at the bottom of the ocean is greater than that at the surface because of the higher pressure at depth. Estimate how much higher the ocean's surface would be if the density of seawater were instantly changed to a uniform density equal to that at the surface.

2.17 (See Fluids in the News article titled **"Giraffe's blood pressure,"** Section 2.3.1.) **(a)** Determine the change in hydrostatic pressure in a giraffe's head as it lowers its head from eating leaves 6 m above the ground to getting a drink of water at ground level as shown in Fig. P2.17. Assume the specific gravity of blood is $SG = 1$. **(b)** Compare the pressure change calculated in part **(a)** to the normal 120 mm of mercury pressure in a human's heart.



■ **Figure P2.17**

Section 2.4 Standard Atmosphere

2.18 What would be the barometric pressure reading, in mm Hg, at an elevation of 4 km in the U.S. standard atmosphere? (Refer to Table C.2 in Appendix C.)

2.19 An absolute pressure of 49 kPa corresponds to what gage pressure for standard atmospheric pressure of 101.3 kPa?

2.20 Assume that a person skiing high in the mountains at an altitude of 4500 m takes in the same volume of air with each breath as she does while walking at sea level. Determine the ratio of the mass of oxygen inhaled for each breath at this high altitude compared to that at sea level.

2.21 WILEY Pikes Peak near Denver, Colorado, has an elevation of 4300 m. (**a**) Determine the pressure at this elevation, based on Eq. 2.12. (**b**) If the air is assumed to have a constant specific weight of 12 N/m^3, what would the pressure be at this altitude? (**c**) If the air is assumed to have a constant temperature of 15 °C, what would the pressure be at this elevation? For all three cases assume standard atmospheric conditions at sea level (see Table 2.1).

2.22 Equation 2.12 provides the relationship between pressure and elevation in the atmosphere for those regions in which the temperature varies linearly with elevation. Derive this equation and verify the value of the pressure given in Table C.2 in Appendix C for an elevation of 5 km.

2.23 As shown in Fig. 2.6 for the U.S. standard atmosphere, the troposphere extends to an altitude of 11 km where the pressure is 22.6 kPa (abs). In the next layer, called the stratosphere, the temperature remains constant at −56.5 °C. Determine the pressure and density in this layer at an altitude of 15 km. Assume $g = 9.77\ m/s^2$ in your calculations. Compare your results with those given in Table C.2 in Appendix C.

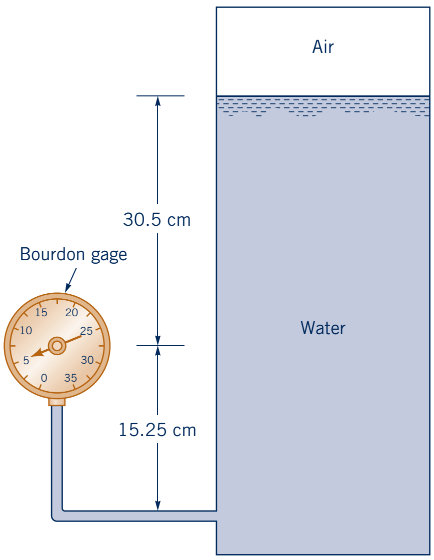
2.24 (See Fluids in the News article titled **"Weather, barometers, and bars,"** Section 2.5.) The record low sea-level barometric pressure ever recorded is 65.5 cm of mercury. At what altitude in the standard atmosphere is the pressure equal to this value?

Section 2.5 Measurement of Pressure

2.25 On a given day, a barometer at the base of the Washington Monument reads 76.12 cm of mercury. What would the barometer reading be when you carry it up to the observation deck 152 m above the base of the monument?

2.26 Aneroid barometers can be used to measure changes in altitude. If a barometer reads 76 cm Hg at one elevation, what has been the change in altitude in meters when the barometer reading is 72 cm Hg? Assume a standard atmosphere and that Eq. 2.12 is applicable over the range of altitudes of interest.

2.27 WILEY Bourdon gages (see **Video V2.4** and Fig. 2.13) are commonly used to measure pressure. When such a gage is attached to the closed water tank of Fig. P2.27 the gage reads 34.5 kPa. What is the absolute air pressure in the tank? Assume standard atmospheric pressure of 101.3 kPa.



■ **Figure P2.27**

2.28 WILEY On the suction side of a pump, a Bourdon pressure gage reads 40 kPa vacuum. What is the corresponding absolute pressure if the local atmospheric pressure is 100 kPa (abs)?

2.29 A Bourdon pressure gage attached to the outside of a tank containing air reads 530.9 kPa when the local atmospheric pressure is 760 mm Hg. What will be the gage reading if the atmospheric pressure increases to 773 mm Hg?

Section 2.6 Manometry

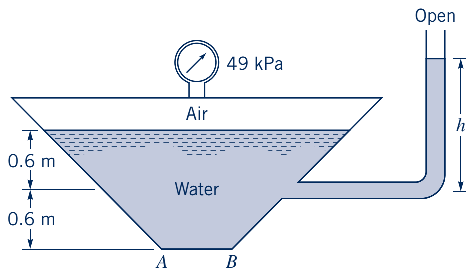
2.30 Obtain a photograph/image of a situation in which the use of a manometer is important. Print this photo and write a brief paragraph that describes the situation involved.

2.31 A water-filled U-tube manometer is used to measure the pressure inside a tank that contains air. The water level in the U-tube on the side that connects to the tank is 1.5 m above the base of the tank. The water level in the other side of the U-tube (which is open to the atmosphere) is 0.6 m above the base. Determine the pressure within the tank.

2.32 WILEY A barometric pressure of 74.7 cm Hg corresponds to what value of atmospheric pressure in pascals?

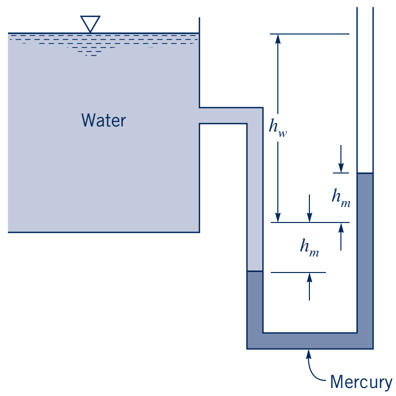
2.33 WILEY For an atmospheric pressure of 101 kPa (abs) determine the heights of the fluid columns in barometers containing one of the following liquids: (**a**) mercury, (**b**) water, and (**c**) ethyl alcohol. Calculate the heights including the effect of vapor pressure and compare the results with those obtained neglecting vapor pressure. Do these results support the widespread use of mercury for barometers? Why?

2.34 The closed tank of Fig. P.2.34 is filled with water and is 1.5 m long. The pressure gage on the tank reads 49 kPa. Determine: (**a**) the height, h, in the open water column, (**b**) the gage pressure acting on the bottom tank surface AB, and (**c**) the absolute pressure of the air in the top of the tank if the local atmospheric pressure is 101.3 kPa.



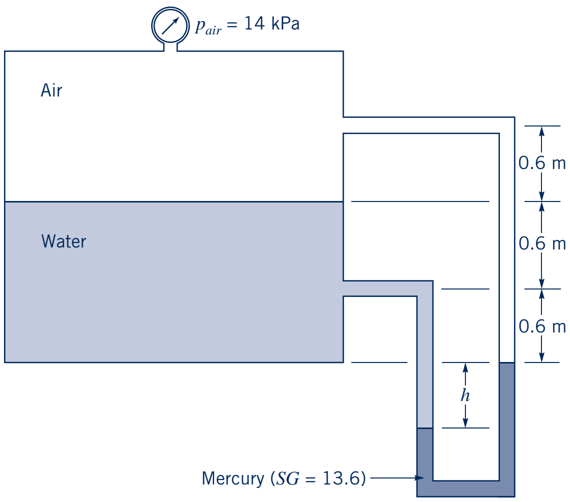
■ **Figure P2.34**

2.35 A mercury manometer is connected to a large reservoir of water as shown in Fig. P2.35. Determine the ratio, h_w/h_m, of the distances h_w and h_m indicated in the figure.



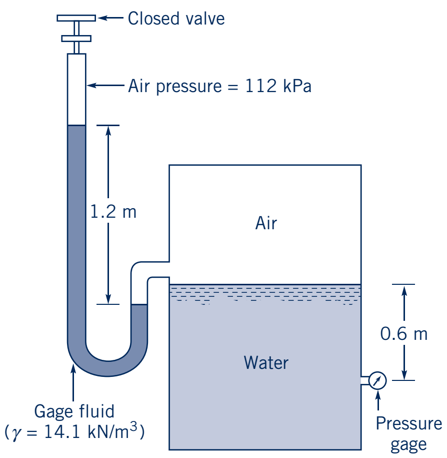
■ **Figure P2.35**

2.36 A U-tube mercury manometer is connected to a closed pressurized tank as illustrated in Fig. P2.36. If the air pressure is 14 kPa, determine the differential reading, h. The specific weight of the air is negligible.



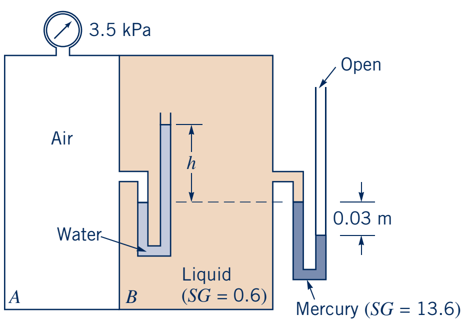
■ **Figure P2.36**

2.37 A U-tube manometer is connected to a closed tank containing air and water as shown in Fig. P2.37. At the closed end of the manometer the air pressure is 112 kPa. Determine the reading on the pressure gage for a differential reading of 1.2 m on the manometer. Express your answer in Pascal (gage). Assume standard atmospheric pressure and neglect the weight of the air columns in the manometer.



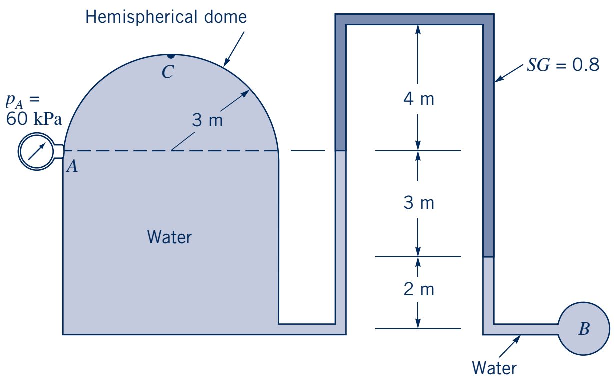
■ **Figure P2.37**

2.38 Compartments A and B of the tank shown in Fig. P2.38 are closed and filled with air and a liquid with a specific gravity equal to 0.6. Determine the manometer reading, h, if the barometric pressure is 101.3 kPa and the pressure gage reads 3.4 kPa. The effect of the weight of the air is negligible.



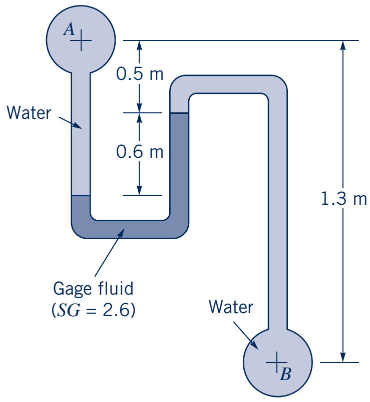
■ **Figure P2.38**

2.39 A closed cylindrical tank filled with water has a hemispherical dome and is connected to an inverted piping system as shown in Fig. P2.39. The liquid in the top part of the piping system has a specific gravity of 0.8, and the remaining parts of the system are filled with water. If the pressure gage reading at A is 60 kPa, determine (**a**) the pressure in pipe B, and (**b**) the pressure head, in millimeters of mercury, at the top of the dome (point C).



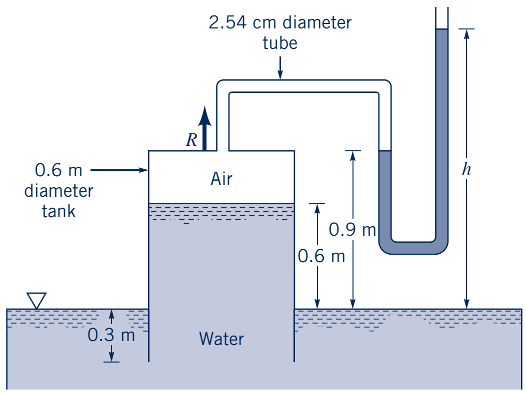
■ **Figure P2.39**

2.40 Two pipes are connected by a manometer as shown in Fig. P2.40. Determine the pressure difference, $p_A - p_B$, between the pipes.



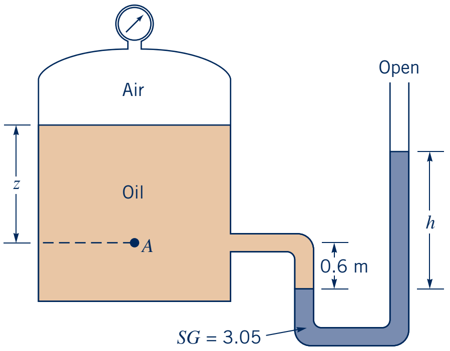
■ **Figure P2.40**

2.41 An inverted open tank is held in place by a force R as shown in Fig. P2.41. If the specific gravity of the manometer fluid is 2.5, determine the value of h.



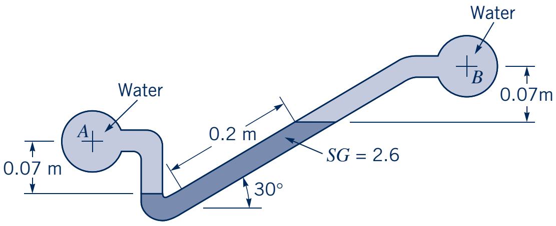
■ **Figure P2.41**

2.42 A U-tube manometer is connected to a closed tank as shown in Fig. P2.42. The air pressure in the tank is 3.4 kPa and the liquid in the tank is oil ($\gamma = 8.5 \text{ kN/m}^3$). The pressure at point A is 13.78 kPa. Determine: (**a**) the depth of oil, z, and (**b**) the differential reading, h, on the manometer.



■ **Figure P2.42**

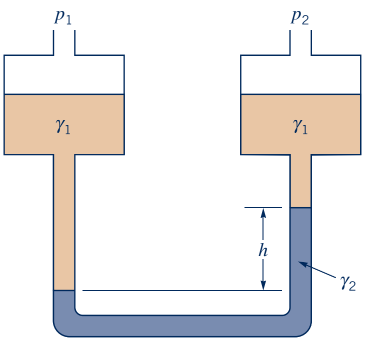
2.43 For the inclined-tube manometer of Fig. P2.43, the pressure in pipe A is 4.1 kPa. The fluid in both pipes A and B is water, and the gage fluid in the manometer has a specific gravity of 2.6. What is the pressure in pipe B corresponding to the differential reading shown?



■ **Figure P2.43**

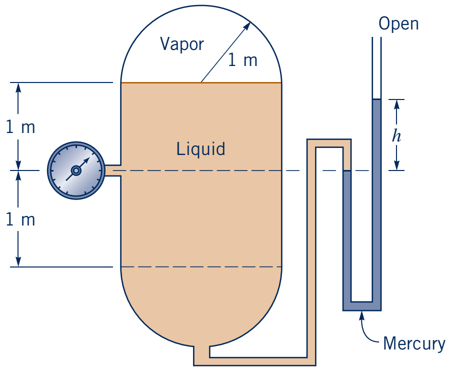
2.44 A flowrate measuring device is installed in a horizontal pipe through which water is flowing. A U-tube manometer is connected to the pipe through pressure taps located 0.07 m on either side of the device. The gage fluid in the manometer has a specific weight of 17.69 kN/m^3. Determine the differential reading of the manometer corresponding to a pressure drop between the taps of 3.4 kPa.

2.45 Small differences in gas pressures are commonly measured with a *micromanometer* of the type illustrated in Fig. P2.45. This device consists of two large reservoirs each having a cross-sectional area A_r which are filled with a liquid having a specific weight γ_1 and connected by a U-tube of cross-sectional area A_t containing a liquid of specific weight γ_2. When a differential gas pressure $p_1 - p_2$, is applied, a differential reading, h, develops. It is desired to have this reading sufficiently large (so that it can be easily read) for small pressure differentials. Determine the relationship between h and $p_1 - p_2$ when the area ratio A_t/A_r is small, and show that the differential reading, h, can be magnified by making the difference in specific weights, $\gamma_2 - \gamma_1$, small. Assume that initially (with $p_1 = p_2$) the fluid levels in the two reservoirs are equal.



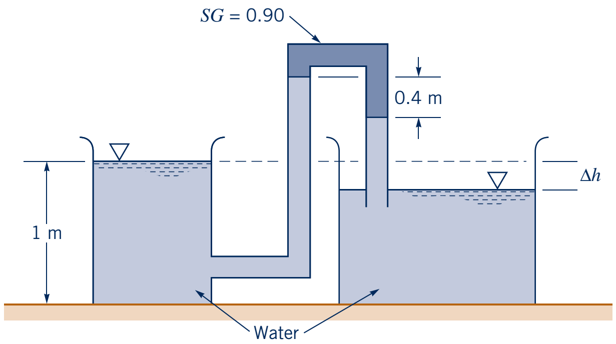
■ **Figure P2.45**

2.46 The cylindrical tank with hemispherical ends shown in Fig. P2.46 contains a volatile liquid and its vapor. The liquid density is 800 kg/m^3, and its vapor density is negligible. The pressure in the vapor is 120 kPa (abs) and the atmospheric pressure is 101 kPa (abs). Determine: (**a**) the gage pressure reading on the pressure gage, and (**b**) the height, h, of the mercury, manometer.



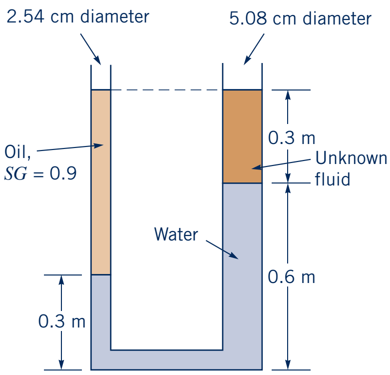
■ **Figure P2.46**

2.47 Determine the elevation difference, Δh, between the water levels in the two open tanks shown in Fig. P2.47.



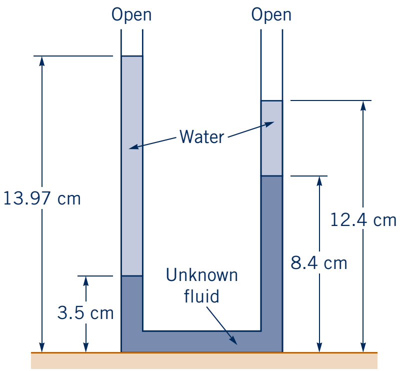
■ **Figure P2.47**

2.48 Water, oil, and an unknown fluid are contained in the vertical tubes shown in Fig. P2.48. Determine the density of the unknown fluid.



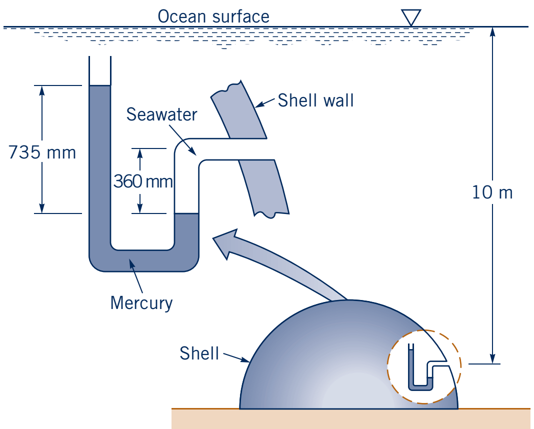
■ **Figure P2.48**

2.49 WILEY For the configuration shown in Fig. P2.49 what must be the value of the specific weight of the unknown fluid? Express your answer in N/m^3.



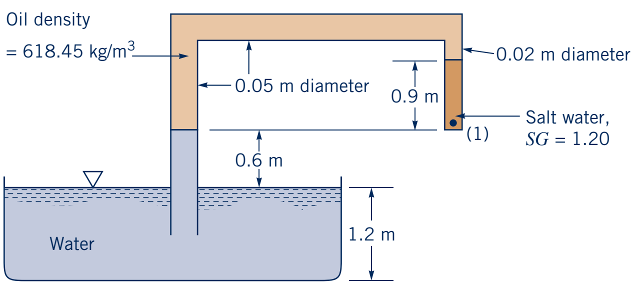
■ **Figure P2.49**

2.50 WILEY An air-filled, hemispherical shell is attached to the ocean floor at a depth of 10 m as shown in Fig. P2.50. A mercury barometer located inside the shell reads 765 mm Hg, and a mercury U-tube manometer designed to give the outside water pressure indicates differential reading of 735 mm Hg as illustrated. Based on these data, what is the atmospheric pressure at the ocean surface?



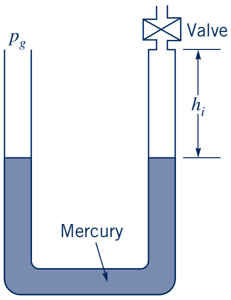
■ **Figure P2.50**

2.51 Water, oil, and salt water fill a tube as shown in Fig. P2.51. Determine the pressure at point 1 (inside the closed tube).



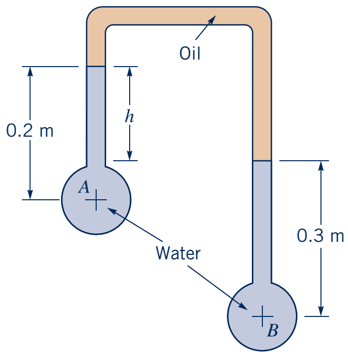
■ **Figure P2.51**

***2.52** Both ends of the U-tube mercury manometer of Fig. P2.52 are initially open to the atmosphere and under standard atmospheric pressure. When the valve at the top of the right leg is open, the level of mercury below the valve is h_i. After the valve is closed, air pressure is applied to the left leg. Determine the relationship between the differential reading on the manometer and the applied gage pressure, p_g. Show on a plot how the differential reading varies with p_g for $h_i = 25$, 50, 75, and 100 mm over the range $0 \leq p_g \leq 300$ kPa. Assume that the temperature of the trapped air remains constant.



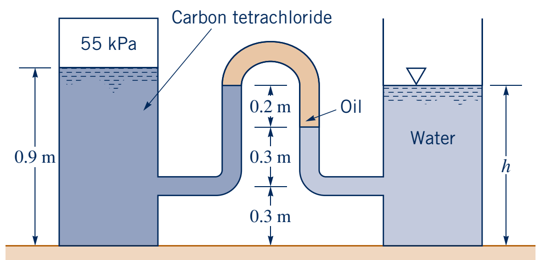
■ **Figure P2.52**

2.53 The inverted U-tube manometer of Fig. P2.53 contains oil ($SG = 0.9$) and water as shown. The pressure differential between pipes A and B, $p_A - p_B$, is -5 kPa. Determine the differential reading h.



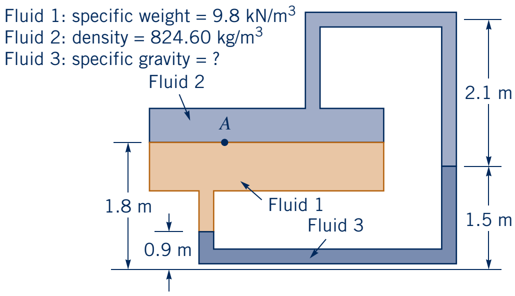
■ **Figure P2.53**

2.54 An inverted U-tube manometer containing oil ($SG = 0.8$) is located between two reservoirs as shown in Fig. P2.54. The reservoir on the left, which contains carbon tetrachloride, is closed and pressurized to 55 kPa. The reservoir on the right contains water and is open to the atmosphere. With the given data, determine the depth of water, h, in the right reservoir.



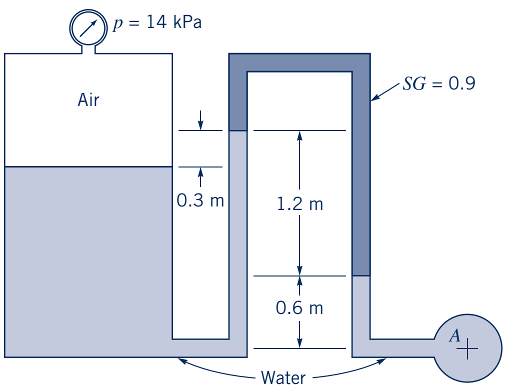
■ **Figure P2.54**

2.55 Three different liquids with properties as indicated fill the tank and manometer tubes as shown in Fig. P2.55. Determine the specific gravity of Fluid 3.



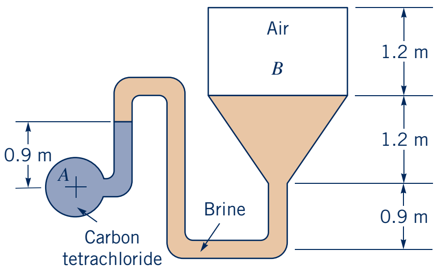
■ **Figure P2.55**

2.56 Determine the pressure of the water in pipe *A* shown in Fig. P2.56 if the gage pressure of the air in the tank is 14 kPa.



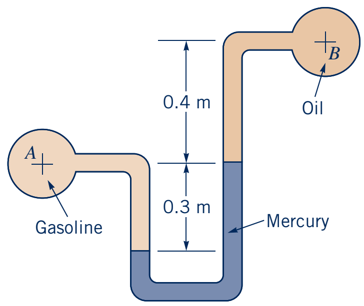
■ **Figure P2.56**

2.57 In Fig. P2.57 pipe *A* contains carbon tetrachloride (SG = 1.60) and the closed storage tank *B* contains a salt brine (SG = 1.15). Determine the air pressure in tank *B* if the pressure in pipe *A* is 172 kPa.



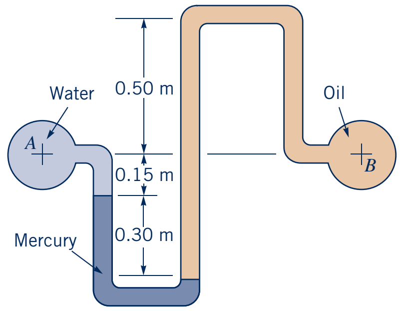
■ **Figure P2.57**

2.58 In Fig. P2.58 pipe *A* contains gasoline ($SG = 0.7$), pipe *B* contains oil ($SG = 0.9$), and the manometer fluid is mercury. Determine the new differential reading if the pressure in pipe *A* is decreased 25 kPa, and the pressure in pipe *B* remains constant. The initial differential reading is 0.30 m as shown.



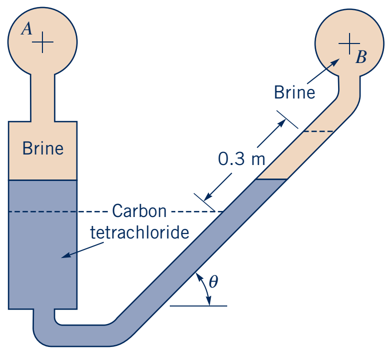
■ **Figure P2.58**

2.59 The mercury manometer of Fig. P2.59 indicates a differential reading of 0.30 m when the pressure in pipe *A* is 30 mm Hg vacuum. Determine the pressure in pipe *B*.



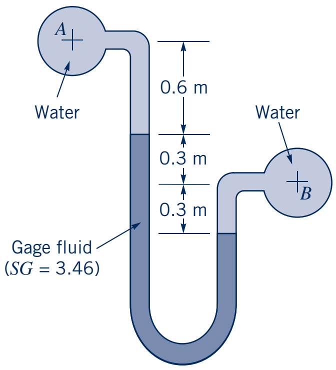
■ **Figure P2.59**

2.60 The inclined differential manometer of Fig. P2.60 contains carbon tetrachloride. Initially the pressure differential between pipes *A* and *B*, which contain a brine ($SG = 1.1$), is zero as illustrated in the figure. It is desired that the manometer give a differential reading of 0.3 m (measured along the inclined tube) for a pressure differential of 0.7 kPa. Determine the required angle of inclination, θ.



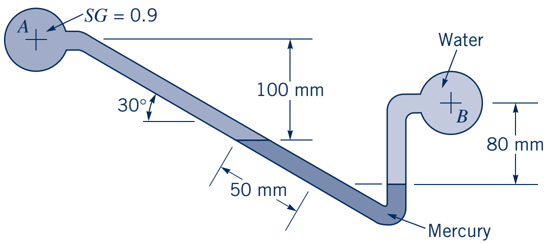
■ **Figure P2.60**

2.61 The manometer fluid in the manometer of Fig. P2.61 has a specific gravity of 3.46. Pipes *A* and *B* both contain water. If the pressure in pipe *A* is decreased by 8.9 kPa and the pressure in pipe *B* increases by 6.2 kPa determine the new differential reading of the manometer.



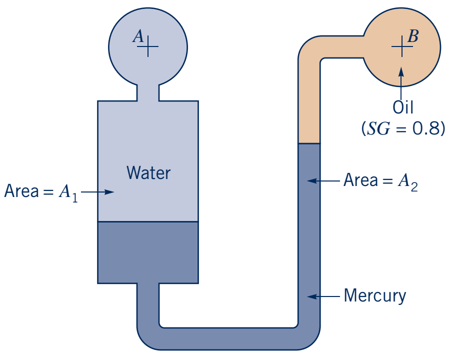
■ **Figure P2.61**

2.62 WILEY Determine the new differential reading along the inclined leg of the mercury manometer of Fig. P2.62, if the pressure in pipe *A* is decreased 10 kPa and the pressure in pipe *B* remains unchanged. The fluid in *A* has a specific gravity of 0.9 and the fluid in *B* is water.



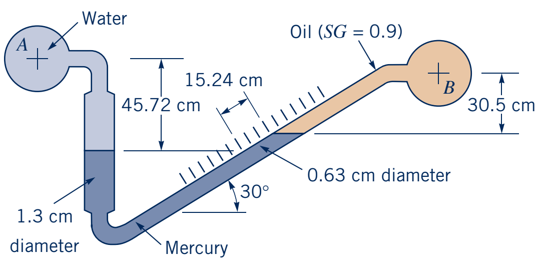
■ **Figure P2.62**

2.63 Determine the ratio of areas, A_1/A_2, of the two manometer legs of Fig. P2.63 if a change in pressure in pipe *B* of 3.4 kPa gives a corresponding change of 2.5 cm in the level of the mercury in the right leg. The pressure in pipe *A* does not change.



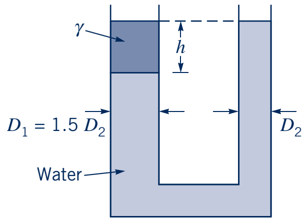
■ **Figure P2.63**

2.64 WILEY Determine the change in the elevation of the mercury in the left leg of the manometer of Fig. P2.64 as a result of an increase in pressure of 34.5 kPa in pipe *A* while the pressure in pipe *B* remains constant.



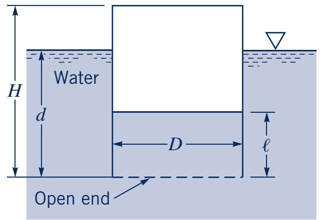
■ **Figure P2.64**

2.65 The U-shaped tube shown in Fig. 2.65 initially contains water only. A second liquid with specific weight, γ, less than water is placed on top of the water with no mixing occurring. Can the height, *h*, of the second liquid be adjusted so that the left and right levels are at the same height? Provide proof of your answer.



■ **Figure P2.65**

***2.66** An inverted hollow cylinder is pushed into the water as shown in Fig. P2.66. Determine the distance, ℓ, that the water rises in the cylinder as a function of the depth, *d*, of the lower edge of the cylinder. Plot the results for $0 \le d \le H$, when *H* is equal to 1 m. Assume the temperature of the air within the cylinder remains constant.

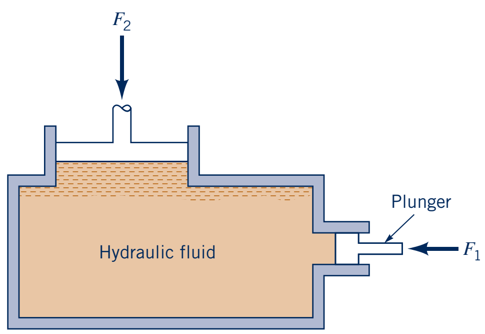


■ **Figure P2.66**

Section 2.8 Hydrostatic Force on a Plane Surface (also see Lab Problems 2.1LP, 2.2LP, 2.3LP, and 2.4LP)

2.67 Obtain a photograph/image of a situation in which the hydrostatic force on a plane surface is important. Print this photo and write a brief paragraph that describes the situation involved.

2.68 WILEY The basic elements of a hydraulic press are shown in Fig. P2.68. The plunger has an area of 6.45 cm^2, and a force, F_1, can be applied to the plunger through a lever mechanism having a mechanical advantage of 8 to 1. If the large piston has an area of 967 cm^2, what load, F_2, can be raised by a force of 133 N applied to the lever? Neglect the hydrostatic pressure variation.

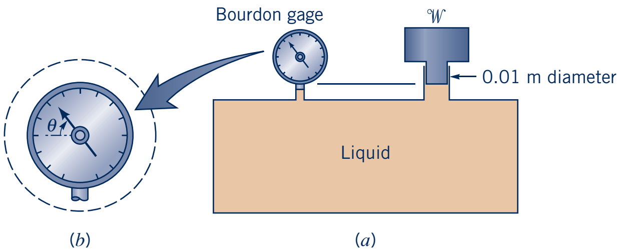


■ **Figure P2.68**

2.69 A 0.3 m diameter pipe is connected to a 0.02 m diameter pipe, and both are rigidly held in place. Both pipes are horizontal with pistons at each end. If the space between the pistons is filled with water, what force will have to be applied to the larger piston to balance a force of 90 N applied to the smaller piston? Neglect friction.

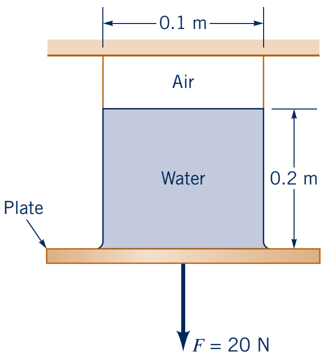
***2.70** A Bourdon gage (see Fig. 2.13 and **Video V2.4**) is often used to measure pressure. One way to calibrate this type of gage is to use the arrangement shown in Fig. P2.70*a*. The container is filled with a liquid and a weight, $\mathcal{W}$, placed on one side with the gage on the other side. The weight acting on the liquid through a 1 cm diameter opening creates a pressure that is transmitted to the gage. This arrangement, with a series of weights, can be used to determine what a change in the dial movement, θ, in Fig. P2.70*b*, corresponds to in terms of a change in pressure. For a particular gage, some data are given below. Based on a plot of these data, determine the relationship between θ and the pressure, p, where p is measured in kPa.

$\mathcal{W}$ (N)	0	4.62	8.89	14.36	18.01	23.30	28.06
θ (deg.)	0	20	40	60	80	100	120



■ **Figure P2.70**

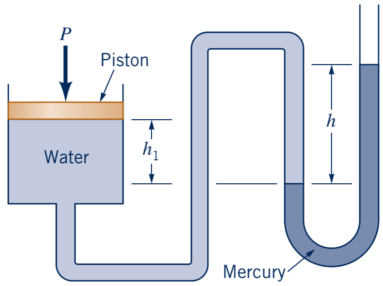
2.71 An inverted 0.1 m diameter circular cylinder is partially filled with water and held in place as shown in Fig. P2.71. A force of 20 N is needed to pull the flat plate from the cylinder. Determine the air pressure within the cylinder. The plate is not fastened to the cylinder and has negligible mass.



■ **Figure P2.71**

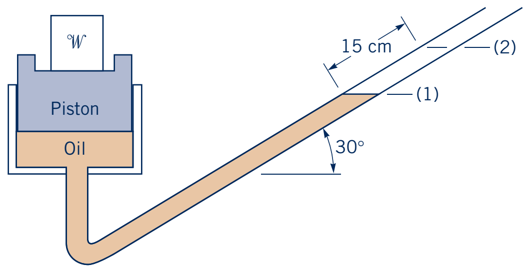
2.72 You partially fill a glass with water, place an index card on top of the glass, and then turn the glass upside down while holding the card in place. You can then remove your hand from the card and the card remains in place, holding the water in the glass. Explain how this works.

2.73 WILEY A piston having a cross-sectional area of 0.07 m^2 is located in a cylinder containing water as shown in Fig. P2.73. An open U-tube manometer is connected to the cylinder as shown. For h_1 = 60 mm and h = 100 mm, what is the value of the applied force, P, acting on the piston? The weight of the piston is negligible.



■ **Figure P2.73**

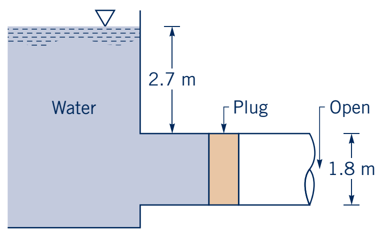
2.74 WILEY A 15.24 cm diameter piston is located within a cylinder that is connected to a 1.3 cm diameter inclined-tube manometer as shown in Fig. P2.74. The fluid in the cylinder and the manometer is oil (specific weight = 9.3 kN/m^3). When a weight, $\mathcal{W}$, is placed on the top of the cylinder, the fluid level in the manometer tube rises from point (1) to (2). How heavy is the weight? Assume that the change in position of the piston is negligible.



■ **Figure P2.74**

2.75 A square gate (4 m by 4 m) is located on the 45° face of a dam. The top edge of the gate lies 8 m below the water surface. Determine the force of the water on the gate and the point through which it acts.

2.76 A large, open tank contains water and is connected to a 1.8 m diameter conduit as shown in Fig. P2.76. A circular plug is used to seal the conduit. Determine the magnitude, direction, and location of the force of the water on the plug.



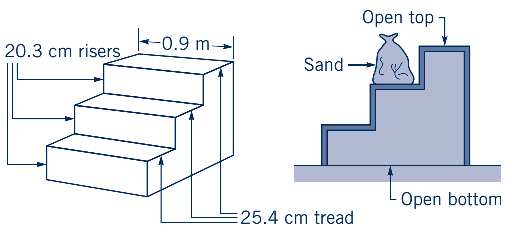
■ **Figure P2.76**

2.77 A circular 2 m diameter gate is located on the sloping side of a swimming pool. The side of the pool is oriented 60° relative to the horizontal bottom, and the center of the gate is located 3 m below the water surface. Determine the magnitude of the water force acting on the gate and the point through which it acts.

2.78 A vertical rectangular gate is 2.4 m wide and 3.0 m long and weighs 26,688 N. The gate slides in vertical slots in the side of a reservoir containing water. The coefficient of friction between the slots and the gate is 0.03. Determine the minimum vertical force required to lift the gate when the water level is 1.2 m above the top edge of the gate.

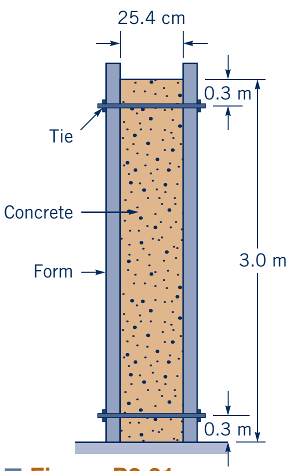
2.79 A horizontal 2 m diameter conduit is half filled with a liquid (SG = 1.6) and is capped at both ends with plane vertical surfaces. The air pressure in the conduit above the liquid surface is 200 kPa. Determine the resultant force of the fluid acting on one of the end caps, and locate this force relative to the bottom of the conduit.

2.80 Concrete is poured into the forms as shown in Fig. P2.80 to produce a set of steps. Determine the weight of the sandbag needed to keep the bottomless forms from lifting off the ground. The weight of the forms is 378 kN and the specific weight of the concrete is 23.7 kN/m^3.



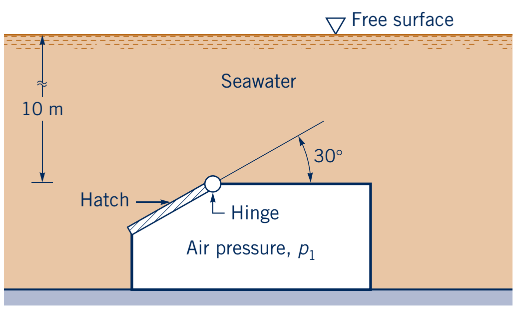
■ **Figure P2.80**

2.81 Forms used to make a concrete basement wall are shown in Fig. P2.81. Each 1.2 m long form is held together by four ties—two at the top and two at the bottom as indicated. Determine the tension in the upper and lower ties. Assume concrete acts as a fluid with a weight of 23.7 kN/m^3.



■ **Figure P2.81**

2.82 A structure is attached to the ocean floor as shown in Fig. P2.82. A 2 m diameter hatch is located in an inclined wall and hinged on one edge. Determine the minimum air pressure, p_1, within the container that will open the hatch. Neglect the weight of the hatch and friction in the hinge.

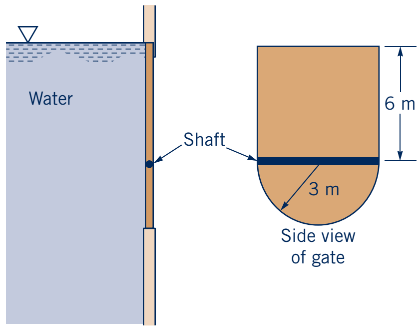


■ **Figure P2.82**

2.83 An open rectangular container contains a liquid that has a specific weight that varies according to the equation $\gamma = c_1 + c_2 h$, where c_1 and c_2 are constants and h is a vertical coordinate measured downward from the free surface. Derive an equation for the magnitude of the liquid force exerted on one wall of the container having a width b and height H and an equation that gives the vertical coordinate of this force.

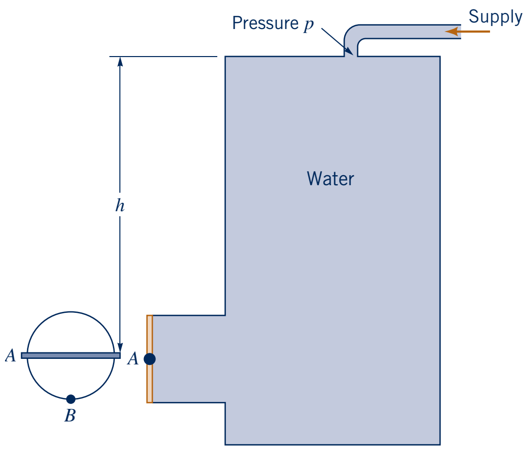
2.84 A long, vertical wall separates seawater from fresh water. If the seawater stands at a depth of 7 m, what depth of freshwater is required to give a zero resultant force on the wall? When the resultant force is zero, will the moment due to the fluid forces be zero? Explain.

2.85 A gate having the shape shown in Fig. P2.85 is located in the vertical side of an open tank containing water. The gate is mounted on a horizontal shaft. (**a**) When the water level is at the top of the gate, determine the magnitude of the fluid force on the rectangular portion of the gate above the shaft and the magnitude of the fluid force on the semicircular portion of the gate below the shaft. (**b**) For this same fluid depth, determine the moment of the force acting on the semicircular portion of the gate with respect to an axis that coincides with the shaft.



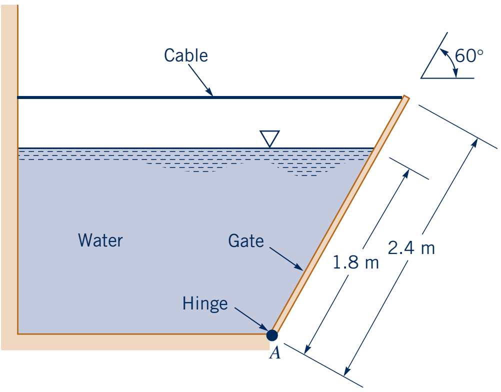
■ **Figure P2.85**

2.86 A pump supplies water under pressure to a large tank as shown in Fig. P2.86. The circular-plate valve fitted in the short discharge pipe on the tank pivots about its diameter A–A and is held shut against the water pressure by a latch at B. Show that the force on the latch is independent of the supply pressure, p, and the height of the tank, h.



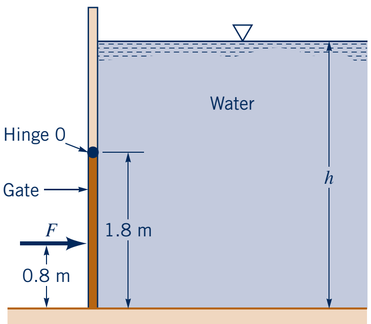
■ **Figure P2.86**

2.87 A homogeneous, 1.2 m wide, 9.6 m long rectangular gate weighing 3.6 kN is held in place by a horizontal flexible cable as shown in Fig. P2.87. Water acts against the gate, which is hinged at point *A*. Friction in the hinge is negligible. Determine the tension in the cable.



■ **Figure P2.87**

2.88 A rectangular gate 1.8 m tall and 1.5 m wide in the side of an open tank is held in place by the force *F* as indicated in Fig. P.2.88. The weight of the gate is negligible, and the hinge at O is frictionless. (**a**) Determine the water depth, *h*, if the resultant hydrostatic force of the water acts 0.8 m above the bottom of the gate, i.e., it is collinear with the applied force *F*. (**b**) For the depth of part (a), determine the magnitude of the resultant hydrostatic force. (**c**) Determine the force that the hinge puts on the gate under the above conditions.



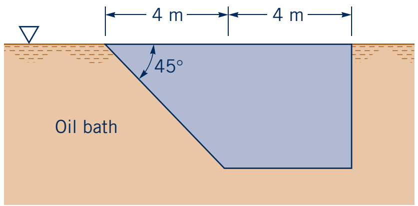
■ **Figure P2.88**

†**2.89** Sometimes it is difficult to open an exterior door of a building because the air distribution system maintains a pressure difference between the inside and outside of the building. Estimate how big this pressure difference can be if it is "not too difficult" for an average person to open the door.

2.90 An area in the form of an isosceles triangle with a base width of 1.8 m and an attitude of 2.4 m lies in the plane forming one wall of a tank that contains a liquid having a specific weight of 12.60 kN/m^3. The side slopes upward, making an angle of 60° with the horizontal. The base of the triangle is horizontal, and the vertex is above the base. Determine the resultant force the fluid exerts on the area when the fluid depth is 6.1 m above the base of the triangular area. Show, with the aid of a sketch, where the center of pressure is located.

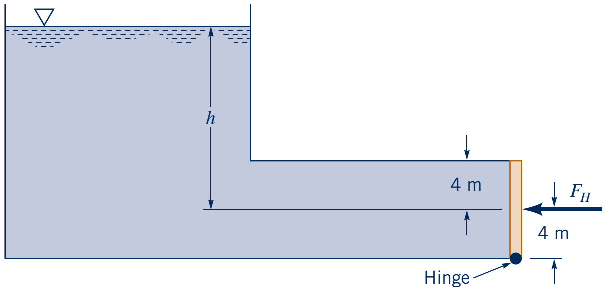
2.91 Solve Problem 2.90 if the isosceles triangle is replaced with a right triangle having the same base width and altitude as the isosceles triangle.

2.92 A vertical plane area having the shape shown in Fig. P2.92 is immersed in an oil bath (specific weight = 8.75 kN/m^3). Determine the magnitude of the resultant force acting on one side of the area as a result of the oil.



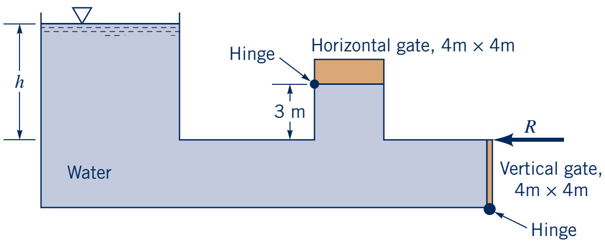
■ **Figure P2.92**

2.93 A 3 m wide, 8 m high rectangular gate is located at the end of a rectangular passage that is connected to a large open tank filled with water as shown in Fig. P2.93. The gate is hinged at its bottom and held closed by a horizontal force, F_H, located at the center of the gate. The maximum value for F_H is 3500 kN. (**a**) Determine the maximum water depth, *h*, above the center of the gate that can exist without the gate opening. (**b**) Is the answer the same if the gate is hinged at the top? Explain your answer.



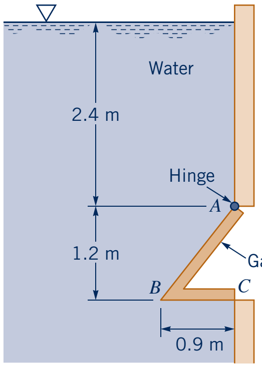
■ **Figure P2.93**

2.94 Two square gates close two openings in a conduit connected to an open tank of water as shown in Fig. P2.94. When the water depth, *h*, reaches 5 m it is desired that both gates open at the same time. Determine the weight of the homogeneous horizontal gate and the horizontal force, *R*, acting on the vertical gate that is required to keep the gates closed until this depth is reached. The weight of the vertical gate is negligible, and both gates are hinged at one end as shown. Friction in the hinges is negligible.



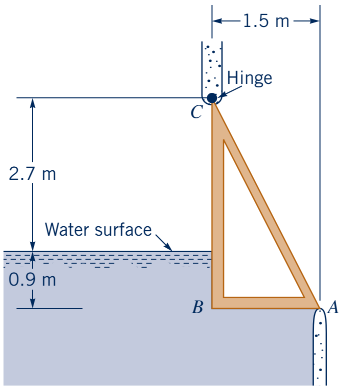
■ **Figure P2.94**

2.95 A gate having the cross section shown in Fig. 2.95 closes an opening 1.5 m wide and 1.2 m high in a water reservoir. The gate weighs 2224 N, and its center of gravity is 0.3 m to the left of *AC* and 0.6 m above *BC*. Determine the horizontal reaction that is developed on the gate at *C*.



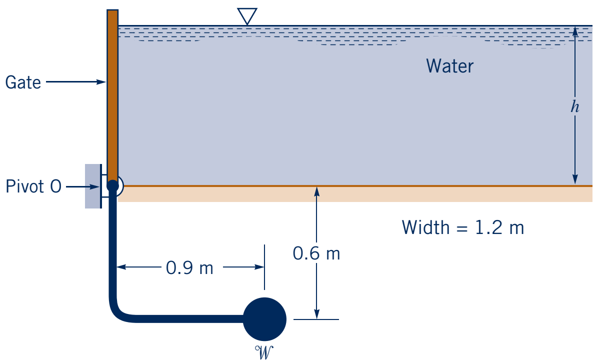
■ **Figure P2.95**

2.96 A gate having the cross section shown in Fig. P2.96 is 1.2 m wide and is hinged at *C*. The gate weighs 80.0 kN, and its mass center is 0.5 m to the right of the plane *BC*. Determine the vertical reaction at *A* on the gate when the water level is 0.9 m above the base. All contact surfaces are smooth.



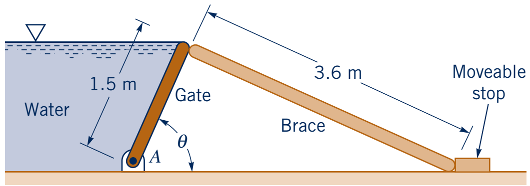
■ **Figure P2.96**

2.97 The massless, 1.2 m wide gate shown in Fig. P2.97 pivots about the frictionless hinge O. It is held in place by the 8896 N counterweight, $\mathscr{W}$. Determine the water depth, *h*.



■ **Figure P2.97**

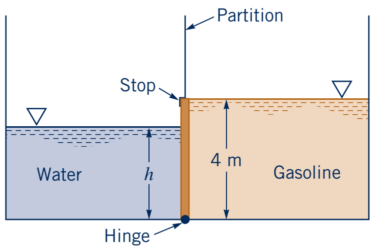
***2.98** A 890 N homogeneous gate 3.0 m wide and 1.5 m long is hinged at point *A* and held in place by a 3.6 m long brace as shown in Fig. P2.98. As the bottom of the brace is moved to the right, the water level remains at the top of the gate. The line of action of the



■ **Figure P2.98**

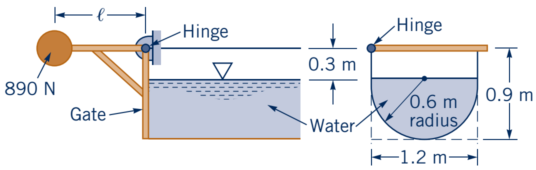
force that the brace exerts on the gate is along the brace. (**a**) Plot the magnitude of the force exerted on the gate by the brace as a function of the angle of the gate, θ, for $0 \leq \theta \leq 90°$. (**b**) Repeat the calculations for the case in which the weight of the gate is negligible. Common on the result as $\theta \to 0$.

2.99 An open tank has a vertical partition and on one side contains gasoline with a density $\rho = 700$ kg/m^3 at a depth of 4 m, as shown in Fig. P2.99. A rectangular gate that is 4 m high and 2 m wide and hinged at one end is located in the partition. Water is slowly added to the empty side of the tank. At what depth, *h*, will the gate start to open?



■ **Figure P2.99**

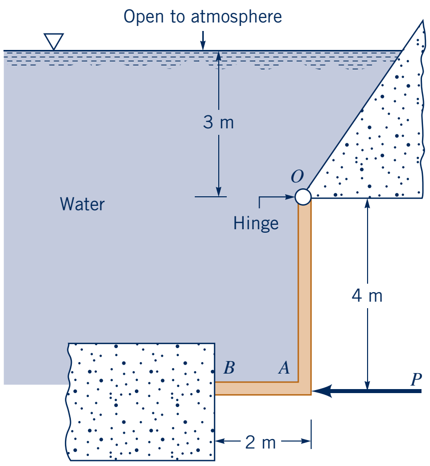
2.100 A 1.2 m by 0.9 m massless rectangular gate is used to close the end of the water tank shown in Fig. P2.100. A 890 N weight attached to the arm of the gate at a distance ℓ from the frictionless hinge is just sufficient to keep the gate closed when the water depth is 0.6 m that is, when the water fills the semicircular lower portion of the tank. If the water were deeper, the gate would open. Determine the distance ℓ.



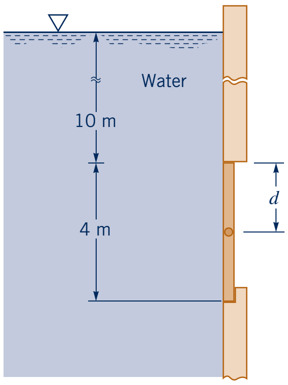
■ **Figure P2.100**

2.101 The rigid gate, *OAB*, of Fig. P2.101 is hinged at *O* and rests against a rigid support at *B*. What minimum horizontal force, *P*, is required to hold the gate closed if its width is 3 m? Neglect the weight of the gate and friction in the hinge. The back of the gate is exposed to the atmosphere.

2.102 A rectangular gate that is 2 m wide is located in the vertical wall of a tank containing water as shown in Fig. P2.102. It is desired to have the gate open automatically when the depth of water above the top of the gate reaches 10 m. (**a**) At what distance, *d*, should the frictionless horizontal shaft be located? (**b**) What is the magnitude of the force on the gate when it opens?

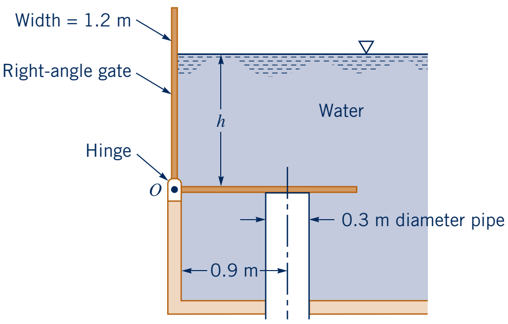


■ **Figure P2.101**



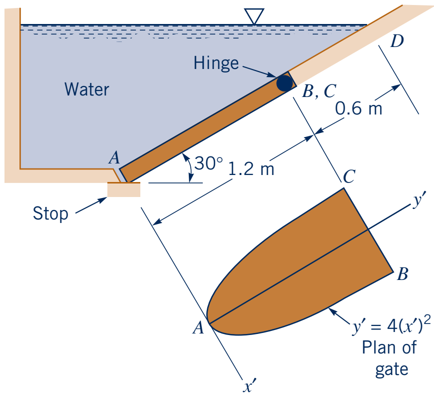
■ **Figure P2.102**

2.103 A thin 1.2 m wide, right-angle gate with negligible mass is free to pivot about a frictionless hinge at point *O*, as shown in Fig. P2.103. The horizontal portion of the gate covers a 0.3 m diameter drain pipe that contains air at atmospheric pressure. Determine the minimum water depth, *h*, at which the gate will pivot to allow water to flow into the pipe.



■ **Figure P2.103**

2.104 The inclined face *AD* of the tank of Fig. P2.104 is a plane surface containing a gate *ABC*, which is hinged along line *BC*. The shape of the gate is shown in the plan view. If the tank contains water, determine the magnitude of the force that the water exerts on the gate.



■ **Figure P2.104**

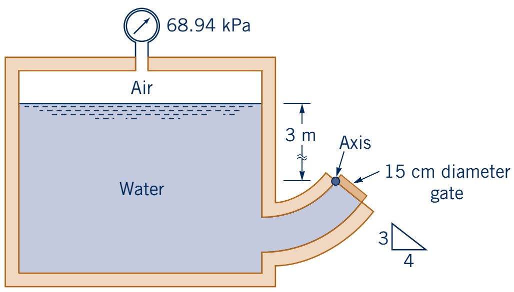
2.105 An open rectangular tank is 2 m wide and 4 m long. The tank contains water to a depth of 2 m and oil ($SG = 0.8$) on top of the water to a depth of 1 m. Determine the magnitude and location of the resultant fluid force acting on one end of the tank.

***2.106** An open rectangular settling tank contains a liquid suspension that at a given time has a specific weight that varies approximately with depth according to the following data:

h (m)	γ (N/m^3)
0	10.0
0.4	10.1
0.8	10.2
1.2	10.6
1.6	11.3
2.0	12.3
2.4	12.7
2.8	12.9
3.2	13.0
3.6	13.1

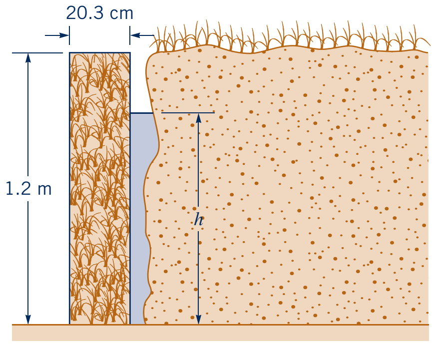
The depth $h = 0$ corresponds to the free surface. Determine, by means of numerical integration, the magnitude and location of the resultant force that the liquid suspension exerts on a vertical wall of the tank that is 6 m wide. The depth of fluid in the tank is 3.6 m.

2.107 The closed vessel of Fig. P2.107 contains water with an air pressure of 68.94 kPa at the water surface. One side of the vessel contains a spout that is closed by a 15 cm diameter circular gate that is hinged along one side as illustrated. The horizontal axis of the hinge is located 3 m below the water surface. Determine the minimum torque that must be applied at the hinge to hold the gate shut. Neglect the weight of the gate and friction at the hinge.



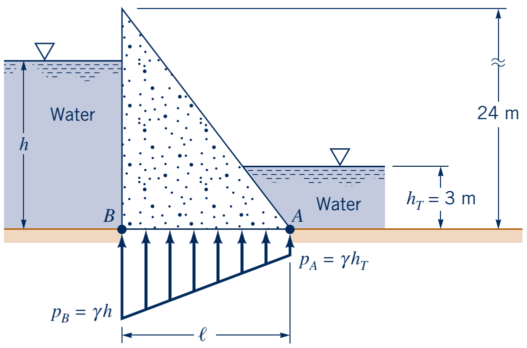
■ **Figure P2.107**

2.108 A 1.2 m tall, 20.3 cm wide concrete 23.7 kN/m^3 retaining wall is built as shown in Fig. P2.108. During a heavy rain, water fills the space between the wall and the earth behind it to a depth h. Determine the maximum depth of water possible without the wall tipping over. The wall simply rests on the ground without being anchored to it.



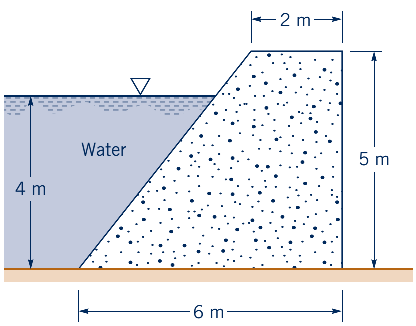
■ **Figure P2.108**

2.109 Water backs up behind a concrete dam as shown in Fig. 2.109. Leakage under the foundation gives a pressure distribution under the dam as indicated. If the water depth, h, is too great, the dam will topple over about its toe (point A). For the dimensions given, determine the maximum water depth for the following widths of the dam, ℓ = 6, 9, 12, 15, and 18 m. Base your analysis on a unit length of the dam. The specific weight of the concrete is 23.7 kN/m^3.



■ **Figure P2.109**

2.110 (WILEY) The concrete dam of Fig. P2.110 weighs 23.6 kN/m^3 and rests on a solid foundation. Determine the minimum coefficient of friction between the dam and the foundation required to keep the dam from sliding at the water depth shown. Assume no fluid uplift pressure along the base. Base your analysis on a unit length of the dam.



■ **Figure P2.110**

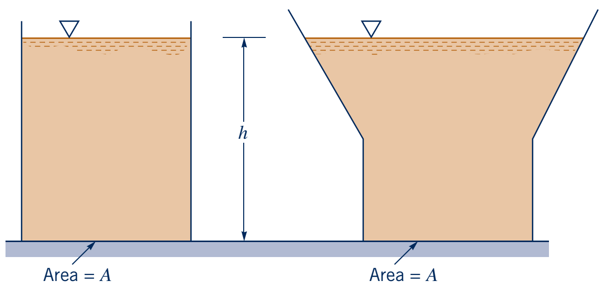
2.111 (See Fluids in the News article titled **"The Three Gorges Dam,"** Section 2.8.) (**a**) Determine the horizontal hydrostatic force on the 2309 m long Three Gorges Dam when the average depth of the water against it is 175 m. (**b**) If all of the 6.4 billion people on Earth were to push horizontally against the Three Gorges Dam, could they generate enough force to hold it in place? Support your answer with appropriate calculations.

Section 2.10 Hydrostatic Force on a Curved Surface

2.112 Obtain a photograph/image of a situation in which the hydrostatic force on a curved surface is important. Print this photo and write a brief paragraph that describes the situation involved.

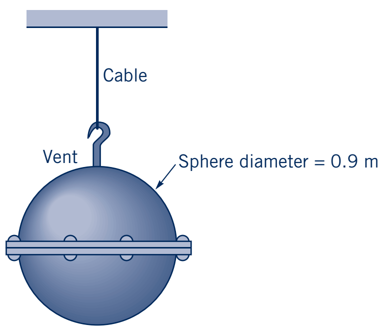
2.113 (WILEY) A 0.6 m diameter hemispherical plexiglass "bubble" is to be used as a special window on the side of an above-ground swimming pool. The window is to be bolted onto the vertical wall of the pool and faces outward, covering a 0.6 m diameter opening in the wall. The center of the opening is 1.2 m below the surface. Determine the horizontal and vertical components of the force of the water on the hemisphere.

2.114 Two round, open tanks containing the same type of fluid rest on a table top as shown in Fig. P2.114. They have the same bottom area, A, but different shapes. When the depth, h, of the liquid in the two tanks is the same, the pressure force of the liquids on the bottom of the two tanks is the same. However, the force that the table exerts on the two tanks is different because the weight in each of the tanks is different. How do you account for this apparent paradox?



■ **Figure P2.114**

2.115 Two hemispherical shells are bolted together as shown in Fig. P2.115. The resulting spherical container, which weighs 1334 N, is filled with mercury and supported by a cable as shown. The container is vented at the top. If eight bolts are symmetrically located around the circumference, what is the vertical force that each bolt must carry?



■ **Figure P2.115**

2.116 A 4 m long curved gate is located in the side of a reservoir containing water as shown in Fig. P2.116. Determine the magnitude of the horizontal and vertical components of the force of the water on the gate. Will this force pass through point *A*? Explain.

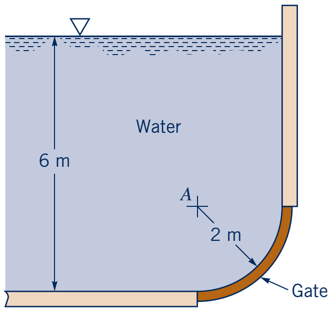


Figure P2.116

2.117 WILEY The 5.5 m long lightweight gate of Fig. P2.117 is a quarter circle and is hinged at *H*. Determine the horizontal force, *P*, required to hold the gate in place. Neglect friction at the hinge and the weight of the gate.

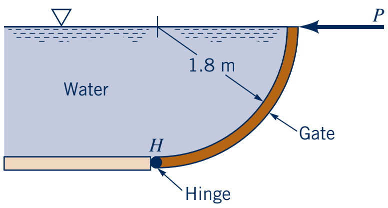


Figure P2.117

2.118 The air pressure in the top of the 2 liter pop bottle shown in **Video V2.6** and Fig. P2.118 is 276 kPa, and the pop depth is 25.4 cm. The bottom of the bottle has an irregular shape with a diameter of 10.9 cm. (**a**) If the bottle cap has a diameter of 2.5 cm what is the magnitude of the axial force required to hold the cap in place? (**b**) Determine the force needed to secure the bottom 5.0 cm of the bottle to its cylindrical sides. For this calculation assume the effect of the weight of the pop is negligible. (**c**) By how much does the weight of the pop increase the pressure 5.0 cm above the bottom? Assume the pop has the same specific weight as that of water.

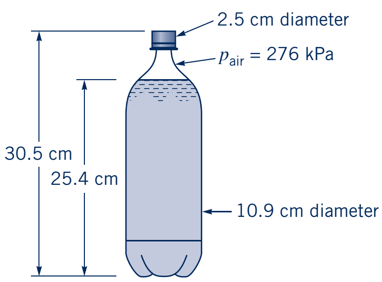


Figure P2.118

2.119 A tank wall has the shape shown in Fig. P2.119. Determine the horizontal and vertical components of the force of the water on a 1.2 m length of the curved section *AB*.

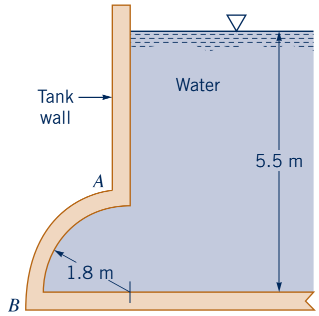


Figure P2.119

2.120 Hoover Dam (see **Video 2.5**) is the highest arch-gravity type of dam in the United States. A cross section of the dam is shown in Fig. P2.120(*a*). The walls of the canyon in which the dam is located are sloped, and just upstream of the dam the vertical plane shown in Figure P2.120(*b*) approximately represents the cross section of the water acting on the dam. Use this vertical cross section to estimate the resultant horizontal force of the water on the dam, and show where this force acts.

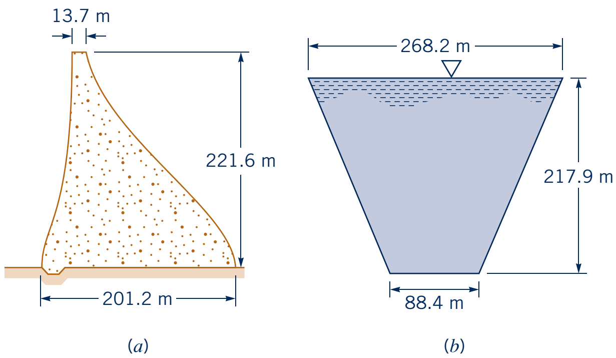


Figure P2.120

2.121 WILEY A plug in the bottom of a pressurized tank is conical in shape, as shown in Fig. P2.121. The air pressure is 40 kPa, and the liquid in the tank has a specific weight of 27 kN/m^3. Determine the magnitude, direction, and line of action of the force exerted on the curved surface of the cone within the tank due to the 40-kPa pressure and the liquid.

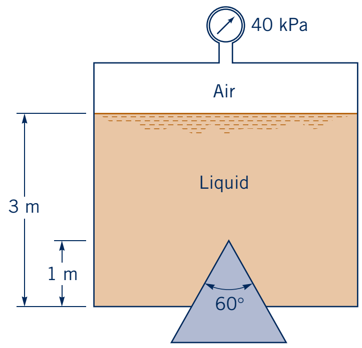
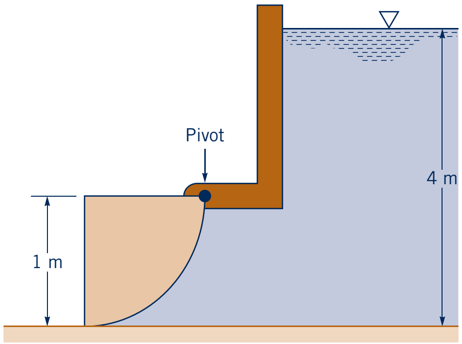
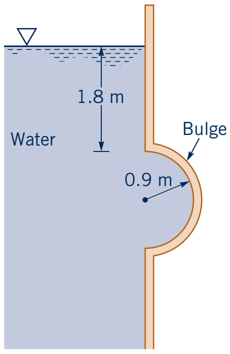


Figure P2.121

2.122 WILEY The homogeneous gate shown in Fig. P2.122 consists of one quarter of a circular cylinder and is used to maintain a water depth of 4 m. That is, when the water depth exceeds 4 m, the gate



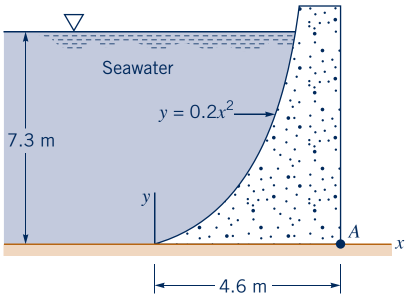
■ Figure P2.122



■ Figure P2.128

opens slightly and lets the water flow under it. Determine the weight of the gate per meter of length.

2.123 The concrete (specific weight = 23.7 kN/m^3) seawall of Fig. P2.123 has a curved surface and restrains seawater at a depth of 7.3 m. The trace of the surface is a parabola as illustrated. Determine the moment of the fluid force (per unit length) with respect to an axis through the toe (point *A*).



■ Figure P2.123

2.124 A 30.5 cm diameter pipe contains a gas under a pressure of 965 kPa. If the pipe wall thickness is 0.6 cm, what is the average circumferential stress developed in the pipe wall?

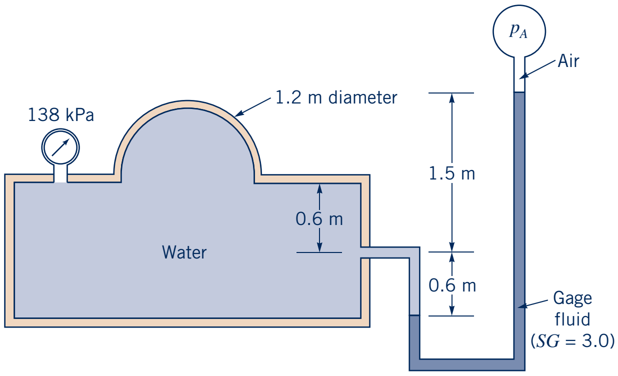
2.125 A cylindrical tank with its axis horizontal has a diameter of 2.0 m and a length of 4.0 m. The ends of the tank are vertical planes. A vertical 0.1 m diameter pipe is connected to the top of the tank. The tank and the pipe are filled with ethyl alcohol to a level of 1.5 m above the top of the tank. Determine the resultant force of the alcohol on one end of the tank and show where it acts.

2.126 Imagine the tank of Problem 2.125 split by a horizontal plane. Determine the magnitude of the resultant force of the alcohol on the bottom half of the tank.

2.127 If the tank ends in Problem 2.125 are hemispherical, what is the magnitude of the resultant horizontal force of the alcohol on one of the curved ends?

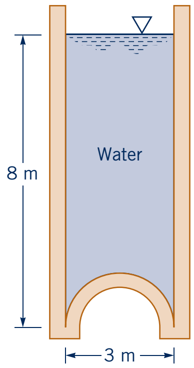
2.128 An open tank containing water has a bulge in its vertical side that is semicircular in shape as shown in Fig. P2.128. Determine the horizontal and vertical components of the force that the water exerts on the bulge. Base your analysis on a 0.3 m length of the bulge.

2.129 A closed tank is filled with water and has a 1.2 m diameter hemispherical dome as shown in Fig. 2.129. A U-tube manometer is connected to the tank. Determine the vertical force of the water on the dome if the differential manometer reading is 2.1 m and the air pressure at the upper end of the manometer is 86.9 kPa.



■ Figure P2.129

2.130 A 3 m diameter open cylindrical tank contains water and has a hemispherical bottom as shown in Fig. P2.130. Determine the magnitude, line of action, and direction of the force of the water on the curved bottom.



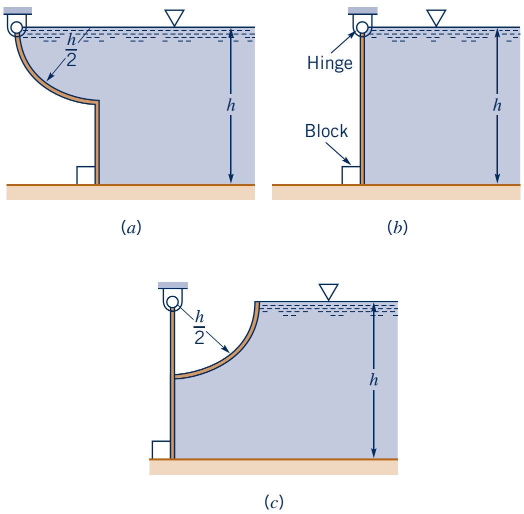
■ Figure P2.130

2.131 Three gates of negligible weight are used to hold back water in a channel of width *b* as shown in Fig. P2.131. The force of the gate against the block for gate (*b*) is *R*. Determine (in terms of *R*) the force against the blocks for the other two gates.

Section 2.11 Buoyancy, Flotation, and Stability

2.132 Obtain a photograph/image of a situation in which Archimede's principle is important. Print this photo and write a brief paragraph that describes the situation involved.

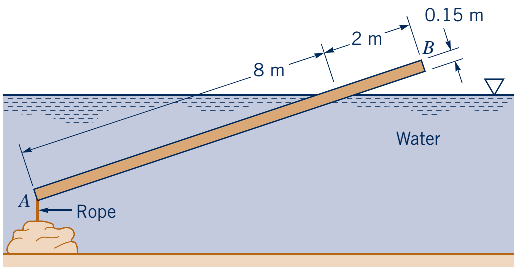
2.133 A freshly cut log floats with one fourth of its volume protruding above the water surface. Determine the specific weight of the log.



■ **Figure P2.131**

2.134 A 0.9 m × 0.9 m × 0.9 m wooden cube (specific weight = 5.8 kN/m^3) floats in a tank of water. How much of the cube extends above the water surface? If the tank were pressurized so that the air pressure at the water surface was increased by 6.9 kPa, how much of the cube would extend above the water surface? Explain how you arrived at your answer.

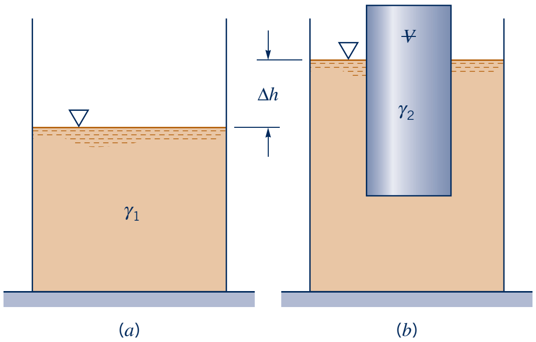
2.135 The homogeneous timber *AB* of Fig. P2.135 is 0.15 m by 0.35 m in cross section. Determine the specific weight of the timber and the tension in the rope.



■ **Figure P2.135**

2.136 A river barge, whose cross section is approximately rectangular, carries a load of grain. The barge is 8.5 m wide and 27.4 m long. When unloaded, its draft (depth of submergence) is 1.5 m and with the load of grain the draft is 2.1 m. Determine (**a**) the unloaded weight of the barge and (**b**) the weight of the grain.

2.137 A tank of cross-sectional area *A* is filled with a liquid of specific weight γ_1 as shown in Fig. P2.137*a*. Show that when a cylinder of specific weight γ_2 and volume $\mathcal{V}$ is floated in the liquid (see Fig. P2.137*b*), the liquid level rises by an amount $\Delta h = (\gamma_2/\gamma_1)\,\mathcal{V}/A$.

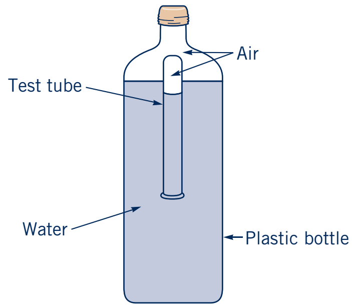


■ **Figure P2.137**

2.138 When the Tucurui Dam was constructed in northern Brazil, the lake that was created covered a large forest of valuable hardwood trees. It was found that even after 15 years underwater the trees were perfectly preserved and underwater logging was started. During the logging process a tree is selected, trimmed, and anchored with ropes to prevent it from shooting to the surface like a missile when cut. Assume that a typical large tree can be approximated as a truncated cone with a base diameter of 2.4 m a top diameter of 0.6 m and a height of 30.5 m. Determine the resultant vertical force that the ropes must resist when the completely submerged tree is cut. The specific gravity of the wood is approximately 0.6.

†2.139 Estimate the minimum water depth needed to float a canoe carrying two people and their camping gear. List all assumptions and show all calculations.

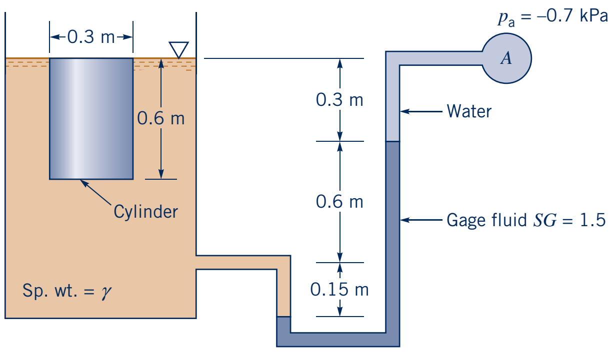
2.140 An inverted test tube partially filled with air floats in a plastic water-filled soft drink bottle as shown in **Video V2.7** and Fig. P2.140. The amount of air in the tube has been adjusted so that it just floats. The bottle cap is securely fastened. A slight squeezing of the plastic bottle will cause the test tube to sink to the bottom of the bottle. Explain this phenomenon.



■ **Figure P2.140**

2.141 An irregularly shaped piece of a solid material weighs 35.8 N in air and 23.4 N when completely submerged in water. Determine the density of the material.

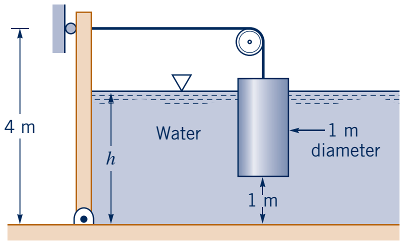
2.142 A 0.3 m diameter, 0.6 m long cylinder floats in an open tank containing a liquid having a specific weight γ. A U-tube manometer is connected to the tank as shown in Fig. P2.142. When the



■ **Figure P2.142**

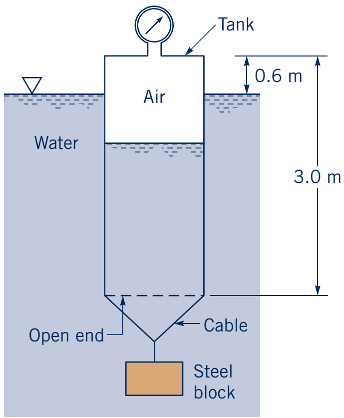
pressure in pipe *A* is 0.7 kPa below atmospheric pressure, the various fluid levels are as shown. Determine the weight of the cylinder. Note that the top of the cylinder is flush with the fluid surface.

2.143 A 1 m diameter cylindrical mass, *M*, is connected to a 2 m wide rectangular gate as shown in Fig. P2.143. The gate is to open when the water level, *h*, drops below 2.5 m. Determine the required value for *M*. Neglect friction at the gate hinge and the pulley.



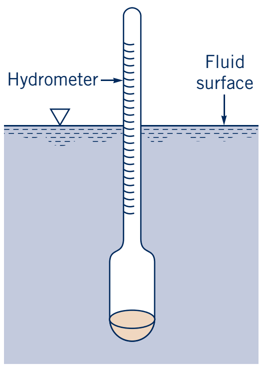
■ **Figure P2.143**

2.144 The thin-walled, 1 m diameter tank of Fig. P2.144 is closed at one end and has a mass of 90 kg. The open end of the tank is lowered into the water and held in the position shown by a steel block having a density of 7840 kg/m^3. Assume that the air that is trapped in the tank is compressed at a constant temperature. Determine: (**a**) the reading on the pressure gage at the top of the tank, and (**b**) the volume of the steel block.



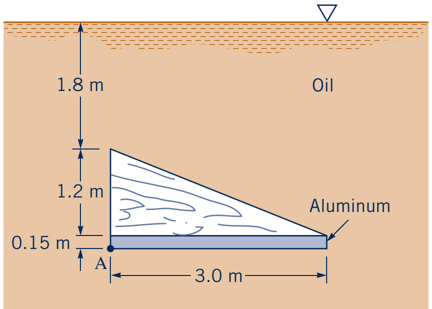
■ **Figure P2.144**

2.145 When a hydrometer (see Fig. P2.145 and **Video V2.8**) having a stem diameter of 0.8 cm is placed in water, the stem protrudes 8 cm above the water surface. If the water is replaced with a liquid having a specific gravity of 1.10, how much of the stem would protrude above the liquid surface? The hydrometer weighs 0.187 N.



■ **Figure P2.145**

2.146 A 0.6 m thick block constructed of wood (*SG* = 0.6) is submerged in oil (*SG* = 0.8) and has a 0.6 m thick aluminum (specific weight = 26.54 kN/m^3) plate attached to the bottom as indicated in Fig. P2.146. Determine completely the force required to hold the block in the position shown. Locate the force with respect to point *A*.



■ **Figure P2.146**

2.147 (See Fluids in the News article titled **"Concrete canoes,"** Section 2.11.1.) How much extra water does a 654 N concrete canoe displace compared to an ultralightweight 169 N Kevlar canoe of the same size carrying the same load?

2.148 An iceberg (specific gravity 0.917) floats in the ocean (specific gravity 1.025). What percent of the volume of the iceberg is under water?

Section 2.12 Pressure Variation in a Fluid with Rigid-Body Motion

2.149 Obtain a photograph/image of a situation in which the pressure variation in a fluid with rigid-body motion is involved. Print this photo and write a brief paragraph that describes the situation involved.

2.150 It is noted that while stopping, the water surface in a glass of water sitting in the cup holder of a car is slanted at an angle of 15° relative to the horizontal street. Determine the rate at which the car is decelerating.

2.151 An open container of oil rests on the flatbed of a truck that is traveling along a horizontal road at 24.6 m/s. As the truck slows uniformly to a complete stop in 5 s, what will be the slope of the oil surface during the period of constant deceleration?

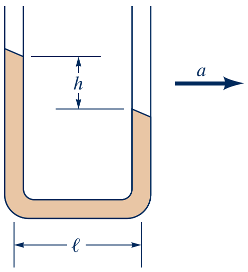
2.152 A 19 L, cylindrical open container with a bottom area of 7.5 $\times$ 10^{-2}m^2 is filled with glycerin and rests on the floor of an elevator. (**a**) Determine the fluid pressure at the bottom of the container when the elevator has an upward acceleration of 0.9 m/s^2. (**b**) What resultant force does the container exert on the floor of the elevator during this acceleration? The weight of the container is negligible. (Note: 1 L = 0.001 m^3)

2.153 An open rectangular tank 1 m wide and 2 m long contains gasoline to a depth of 1 m. If the height of the tank sides is 1.5 m, what is the maximum horizontal acceleration (along the long axis of the tank) that can develop before the gasoline would begin to spill?

2.154 If the tank of Problem 2.153 slides down a frictionless plane that is inclined at 30° with the horizontal, determine the angle the free surface makes with the horizontal.

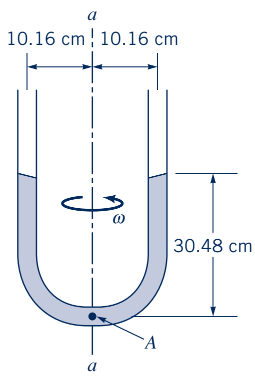
2.155 A closed cylindrical tank that is 2.4 m in diameter and 7.3 m long is completely filled with gasoline. The tank, with its long axis horizontal, is pulled by a truck along a horizontal surface. Determine the pressure difference between the ends (along the long axis of the tank) when the truck undergoes an acceleration of 1.5 m/s^2.

2.156 The open U-tube of Fig. P2.156 is partially filled with a liquid. When this device is accelerated with a horizontal acceleration a, a differential reading h develops between the manometer legs which are spaced a distance ℓ apart. Determine the relationship between a, ℓ, and h.



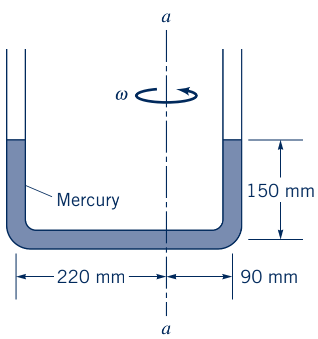
■ **Figure P2.156**

2.157 The U-tube of Fig. P2.157 is partially filled with water and rotates around the axis a–a. Determine the angular velocity that will cause the water to start to vaporize at the bottom of the tube (point A).



■ **Figure P2.157**

2.158 The U-tube of Fig. P2.158 contains mercury and rotates about the off-center axis a–a. At rest, the depth of mercury in each leg is 150 mm as illustrated. Determine the angular velocity for which the difference in heights between the two legs is 75 mm.



■ **Figure P2.158**

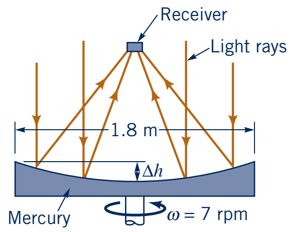
2.159 An open 1 m diameter tank contains water at a depth of 0.7 m when at rest. As the tank is rotated about its vertical axis the center of the fluid surface is depressed. At what angular velocity will the bottom of the tank first be exposed? No water is spilled from the tank.

2.160 An open, 0.6 m diameter tank contains water to a depth of 0.9 m when at rest. If the tank is rotated about its vertical axis with an angular velocity of 180 rev/min, what is the minimum height of the tank walls to prevent water from spilling over the sides?

2.161 A child riding in a car holds a string attached to a floating, helium-filled balloon. As the car decelerates to a stop, the balloon tilts backwards. As the car makes a right-hand turn, the balloon tilts to the right. On the other hand, the child tends to be forced forward as the car decelerates and to the left as the car makes a right-hand turn. Explain these observed effects on the balloon and child.

2.162 A closed, 0.4 m diameter cylindrical tank is completely filled with oil ($SG = 0.9$) and rotates about its vertical longitudinal axis with an angular velocity of 40 rad/s. Determine the difference in pressure just under the vessel cover between a point on the circumference and a point on the axis.

2.163 (See Fluids in the News article titled **"Rotating mercury mirror telescope,"** Section 2.12.2.) The largest liquid mirror telescope uses a 1.8 m diameter tank of mercury rotating at 7 rpm to produce its parabolic-shaped mirror as shown in Fig. P2.163. Determine the difference in elevation of the mercury, Δh, between the edge and the center of the mirror.



■ **Figure P2.163**

■ Lab Problems

2.1 LP This problem involves the force needed to open a gate that covers an opening in the side of a water-filled tank. To proceed with this problem, go to Appendix H which is located in WileyPLUS or on the book's website, www.wiley.com/college/munson.

2.2 LP This problem involves the use of a cleverly designed apparatus to investigate the hydrostatic, pressure force on a submerged rectangle. To proceed with this problem, go to Appendix H which is located in *WileyPLUS* or on the book's website, www.wiley.com/college/munson.

2.3 LP This problem involves determining the weight needed to hold down an open-bottom box that has slanted sides when the box is filled with water. To proceed with this problem, go to Appendix H which is located in *WileyPLUS* or on the book's website, www.wiley.com/college/munson.

2.4 LP This problem involves the use of a pressurized air pad to provide the vertical force to support a given load. To proceed with this problem, go to Appendix H which is located in *WileyPLUS* or on the book's website, www.wiley.com/college/munson.

■ Lifelong Learning Problems

2.1 LL Although it is relatively easy to calculate the net hydrostatic pressure force on a dam, it is not necessarily easy to design and construct an appropriate, long-lasting, inexpensive dam. In fact, inspection of older dams has revealed that many of them are in peril of collapse unless corrective action is soon taken. Obtain information about the severity of the poor conditions of older dams throughout the country. Summarize your findings in a brief report.

2.2 LL Over the years the demand for high-quality, first-growth timber has increased dramatically. Unfortunately, most of the trees that supply such lumber have already been harvested. Recently, however, several companies have started to reclaim the numerous high-quality logs that sank in lakes and oceans during the logging boom times many years ago. Many of these logs are still in excellent condition. Obtain information about the use of fluid mechanics concepts in harvesting sunken logs. Summarize your findings in a brief report.

2.3 LL Liquid-filled manometers and Bourdon tube pressure gages have been the mainstay for measuring pressure for many, many years. However, for many modern applications these tried-and-true devices are not sufficient. For example, various new uses need small, accurate, inexpensive pressure transducers with digital outputs. Obtain information about some of the new concepts used for pressure measurement. Summarize your findings in a brief report.

■ FE Exam Problems

Sample FE (Fundamentals of Engineering) exam questions for fluid mechanics are provided in *WileyPLUS* or on the book's website, www.wiley.com/college/munson.