- This hydrostatic force
  - Acts *at* the centroid of area for a uniform pressure distribution
  - Acts *below* the centroid of area for a hydrostatic pressure distibution. The slant distance between the center of pressure and the centroid of area is given by

$$y_{cp} - \bar{y} = \frac{\bar{I}}{\bar{y}A}$$

Hydrostatic Forces on a Curved Surface

- When a surface is curved, one can find the pressure force by applying force equilibrium to a free body comprised of the fluid in contact with the surface.

The Buoyant Force

- The *buoyant force* is the pressure force on a body that is partially or totally submerged in a fluid.
- The magnitude of the buoyant force is given by

$$\text{Buoyant force} = F_B = \text{Weight of the displaced fluid}$$

- The center of buoyancy is located at the center of gravity of the displaced fluid. The direction of the buoyant force is opposite the gravity vector.
- When the buoyant force is due to a single fluid with constant density, the magnitude of the buoyant force is:

$$F_B = \gamma \text{V}\!\!\!\!-_D$$

Hydrodynamic Stability

- Hydrodynamic stability means that if an object is displaced from equilibrium then there is a moment that causes the object to return to equilibrium.
- The criteria for stability are
  - *Immersed object.* The body is stable if the center of gravity is below the center of buoyancy.
  - *Floating object.* The body is stable if the metacentric height is positive.

REFERENCES

1. U.S. Standard Atmosphere Washington, DC: U.S. Government Printing Office, 1976.

2. Holman, J. P., and W. J. Gajda, Jr. *Experimental Methods for Engineers*. New York: McGraw-Hill, 1984.

3. Wikipedia contributors "Hydraulic machinery," Wikipedia, The Free Encyclopedia, http://en.wikipedia.org/w/index.php?title=Hydraulic_machinery&oldid=161288040 (accessed October 4, 2007).

PROBLEMS

PLUS Problem available in *WileyPLUS* at instructor's discretion.

GO Guided Online (GO) Problem, available in *WileyPLUS* at instructor's discretion.

Describing Pressure (§3.1)

3.1 PLUS A 100 mm diameter sphere contains an ideal gas at 20°C. Apply the grid method (§1.5 in Ch. 1) to calculate the density in units of kg/m^3.

a. Gas is helium. Gage pressure is 50.8 cm H_2O.

b. Gas is methane. Vacuum pressure is 20.7 kPa.

3.2 PLUS For the questions below, assume standard atmospheric pressure.

a. For a vacuum pressure of 30 kPa, what is the absolute pressure? Gage pressure?

b. For a pressure of 200 kPa gage, what is the absolute pressure in kPa?

3.3 PLUS The local atmospheric pressure is 99.0 kPa. A gage on an oxygen tank reads a pressure of 300 kPa gage. What is the pressure in the tank in kPa abs?

3.4 Using §3.1 and other resources, answer the following questions. Strive for depth, clarity, and accuracy while also combining sketches, words, and equations in ways that enhance the effectiveness of your communication.

a. What are five important facts that engineers need to know about pressure?

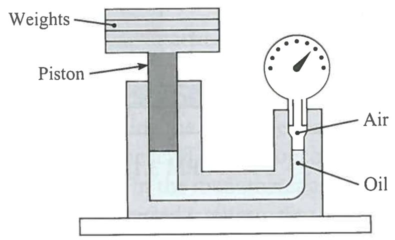
b. What are five common instances in which people use gage pressure?

c. What are the most common units for pressure?

d. Why is pressure defined using a derivative?

e. How is pressure similar to shear stress? How does pressure differ from shear stress?

3.5 GO The Crosby gage tester shown in the figure is used to calibrate or to test pressure gages. When the weights and the piston together weigh 140 N, the gage being tested indicates 200 kPa. If the piston diameter is 30 mm, what percentage of error exists in the gage?

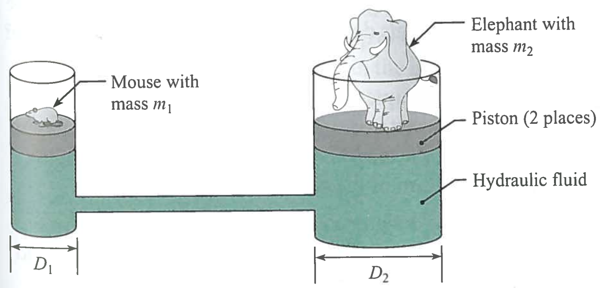


PROBLEM 3.5

3.6 PLUS As shown, a mouse can use the mechanical advantage provided by a hydraulic machine to lift up an elephant.

a. Derive an algebraic equation that gives the mechanical advantge of the hydraulic machine shown. Assume the pistons are frictionless and massless.

b. A mouse can have a mass of 25 g and an elephant a mass of 7500 kg. Determine a value of D_1 and D_2 so that the mouse can support the elephant.



PROBLEM 3.6

3.7 Find a parked automobile for which you have information on tire pressure and weight. Measure the area of tire contact with the pavement. Next, using the weight information and tire pressure, use engineering principles to calculate the contact area. Compare your measurement with your calculation and discuss.

Deriving and Applying the Hydrostatic Equation (§3.2)

3.8 PLUS To derive the hydrostatic equation, which of the following must be assumed? (Select all that are correct.)

a. the specific weight is constant

b. the fluid has no charged particles

c. the fluid is at equilibrium

3.9 Imagine two tanks. Tank A is filled to depth h with water. Tank B is filled to depth h with oil. Which tank has the largest pressure? Why? Where in the tank does the largest pressure occur?

3.10 Consider Figure 3.8 on p. 67 of §3.2.

a. Which fluid has the larger density?

b. If you graphed pressure as a function of z in these two layered liquids, in which fluid does the pressure change more with each incremental change in z?

3.11 PLUS Apply the grid method (§1.5 in Ch. 1) with the hydrostatic equation ($\Delta p = \gamma \Delta z$) to each of the following cases.

a. Predict the pressure change Δp in kPa for an elevation change Δz of 305 cm in a fluid with a density of 1.5 g/cm^3.

b. Predict the pressure change in kPa for a fluid with S = 0.8 and an elevation change of 22 m.

c. Predict pressure change in meter of water for a fluid with a density of 1.2 kg/m^3 and an elevation change of 305 m.

d. Predict the elevation change in millimeters for a fluid with S = 13 that corresponds to a change in pressure of 17 kPa.

3.12 PLUS Using §3.2 and other resources, answer the following questions. Strive for depth, clarity, and accuracy while also combining sketches, words, and equations in ways that enhance the effectiveness of your communication.

a. What does hydrostatic mean? How do engineers identify whether a fluid is hydrostatic?

b. What are the common forms on the hydrostatic equation? Are the forms equivalent or are they different?

c. What is a datum? How do engineers establish a datum?

d. What are the main ideas of Eq. (3.10) on p. 66 of §3.2? That is, what is the meaning of this equation?

e. What assumptions need to be satisfied to apply the hydrostatic equation?

3.13 GO Apply the grid method to each situation.

a. What is the change in air pressure in pascals between the floor and the ceiling of a room with walls that are 305 cm tall.

b. A diver in the ocean (S = 1.03) records a pressure of 253 kPa on her depth gage. How deep is she?

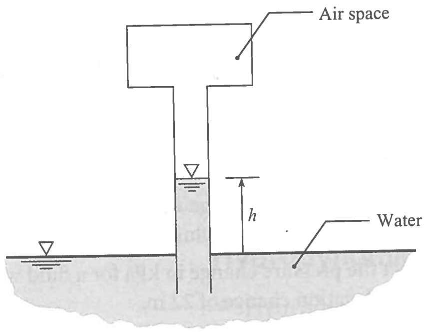
c. A hiker starts a hike at an elevation where the air pressure is 94 kPa, and he ascends 366 m to a mountain summit.

Assuming the density of air is constant, what is the pressure in kPa at the summit?

d. Lake Pend Oreille, in northern Idaho, is one of the deepest lakes in the world, with a depth of 350 m in some locations. This lake is used as a test facility for submarines. What is the maximum pressure that a submarine could experience in this lake?

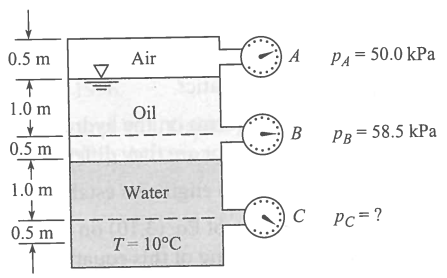
e. A 70 m tall standpipe (a standpipe is vertical pipe that is filled with water and open to the atmosphere) is used to supply water for fire fighting. What is the maximum pressure in the standpipe?

3.14 WILEY PLUS As shown, an air space above a long tube is pressurized to 50 kPa vacuum. Water (20°C) from a reservoir fills the tube to a height h. If the pressure in the air space is changed to 25 kPa vacuum, will h increase or descrease and by how much? Assume atmospheric pressure is 100 kPa.



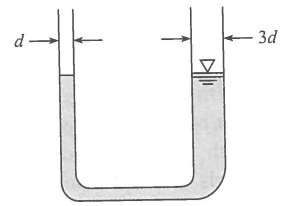
PROBLEM 3.14

3.15 WILEY PLUS For the closed tank with Bourdon-tube gages tapped into it, what is the specific gravity of the oil and the pressure reading on gage C?



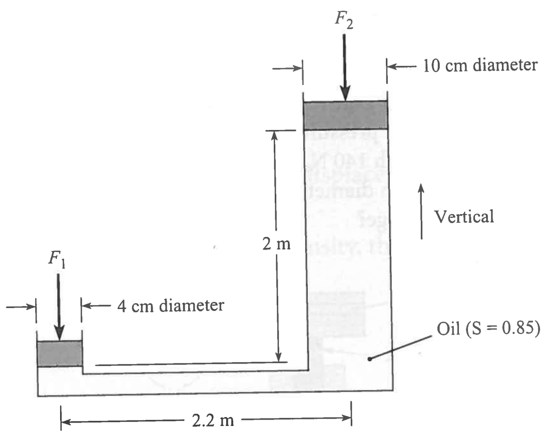
PROBLEM 3.15

3.16 This manometer contains water at room temperature. The glass tube on the left has an inside diameter of 1 mm (d = 1.0 mm). The glass tube on the right is three times as large. For these conditions, the water surface level in the left tube will be (a) higher than the water surface level in the right tube, (b) equal to the water surface level in the right tube, or (c) less than the water surface level in the right tube. State your main reason or assumption for making your choice.



PROBLEM 3.16

3.17 WILEY PLUS If a 200 N force F_1 is applied to the piston with the 4 cm diameter, what is the magnitude of the force F_2 that can be resisted by the piston with the 10 cm diameter? Neglect the weights of the pistons.



PROBLEM 3.17

3.18 Regarding the hydraulic jack in Problem 3.17, which ideas were used to analyze the jack? (select all that apply)

a. pressure = (force)(area)

b. pressure increases linearly with depth in a hydrostatic fluid

c. the pressure at the very bottom of the 4-cm chamber is larger than the pressure at the very bottom of the 10-cm chamber

d. when a body is stationary, the sum of forces on the object is zero

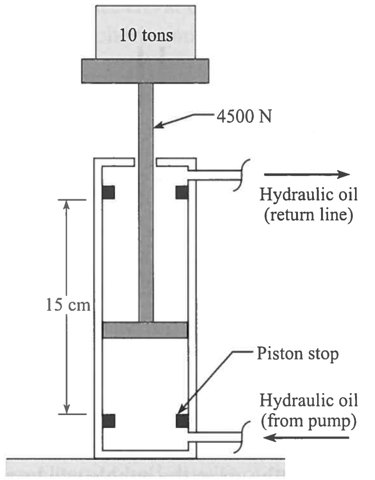
e. when a body is stationary, the sum of moments on the object is zero

f. pressure = (weight/volume)(change in elevation)

3.19 Some skin divers go as deep as 50 m. What is the gage pressure at this depth in fresh water, and what is the ratio of the absolute pressure at this depth to normal atmospheric pressure? Assume T = 20°C.

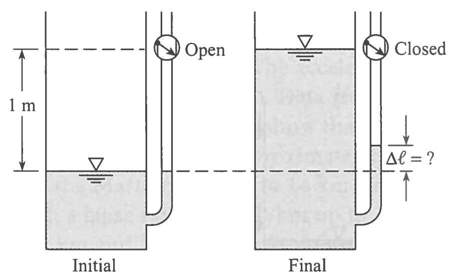
3.20 WILEY PLUS Water occupies the bottom 0.8 m of a cylindrical tank. On top of the water is 0.3 m of kerosene, which is open to the atmosphere. If the temperature is 20°C, what is the gage pressure at the bottom of the tank?

3.21 An engineer is designing a hydraulic lift with a capacity of 10 tons. The moving parts of this lift weigh 4500 N. The lift should raise the load to a height of 15 cm in 20 seconds. This will be accomplished with a hydraulic pump that delivers fluid to a cylinder. Hydraulic cylinders with a stroke of 200 cm are available with bore sizes from 5 to 20 cm. Hydraulic piston pumps with an operating pressure range from 1380 to 20,700 kPa gage are available with pumping capacities of 20, 38, and 56 liters per minute. Select a hydraulic pump size and a hydraulic cylinder size that can be used for this application.



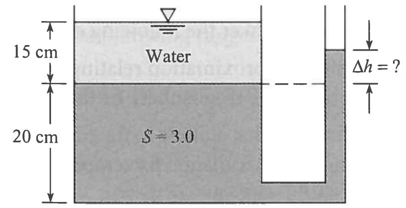
PROBLEM 3.21

3.22 WILEY GO A tank with an attached manometer contains water at 20°C. The atmospheric pressure is 100 kPa. There is a stopcock located 1 m from the surface of the water in the manometer. The stopcock is closed, trapping the air in the manometer, and water is added to the tank to the level of the stopcock. Find the increase in elevation of the water in the manometer assuming the air in the manometer is compressed isothermally.



PROBLEM 3.22

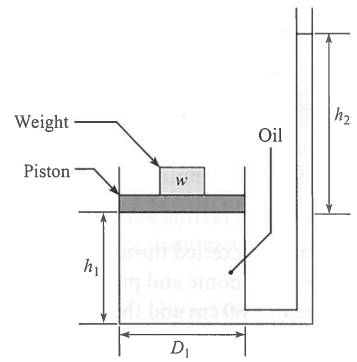
3.23 WILEY PLUS A tank is fitted with a manometer on the side, as shown. The liquid in the bottom of the tank and in the manometer has a specific gravity (S) of 3.0. The depth of this bottom liquid is 20 cm. A 15 cm layer of water lies on top of the bottom liquid. Find the position of the liquid surface in the manometer.



PROBLEM 3.23

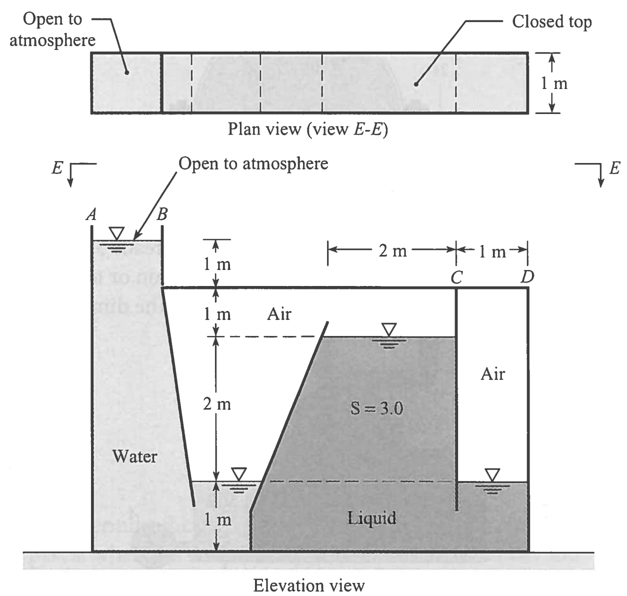
3.24 WILEY PLUS As shown, a load acts on a piston of diameter D_1. The piston rides on a reservoir of oil of depth h_1 and specific gravity S. The reservoir is connected to a round tube of diameter D_2 and oil rises in the tube to height h_2. The oil in the tube is open to atmosphere. Derive an equation for the height h_2 in terms of the weight W of the load and other relevant variables. Neglect the weight of the piston.

3.25 As shown, a load of mass 5 kg is situated on a piston of diameter D_1 = 120 mm. The piston rides on a reservoir of oil of depth h_1 = 42 mm and specific gravity S = 0.8. The reservoir is connected to a round tube of diameter D_2 = 5 mm and oil rises in the tube to height h_2. Find h_2. Assume the oil in the tube is open to atmosphere and neglect the weight of the piston.



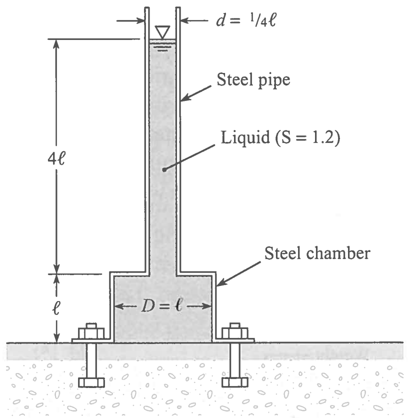
PROBLEMS 3.24, 3.25

3.26 WILEY GO What is the maximum gage pressure in the odd tank shown in the figure? Where will the maximum pressure occur? What is the hydrostatic force acting on the top (CD) of the last chamber on the right-hand side of the tank? Assume T = 10°C.



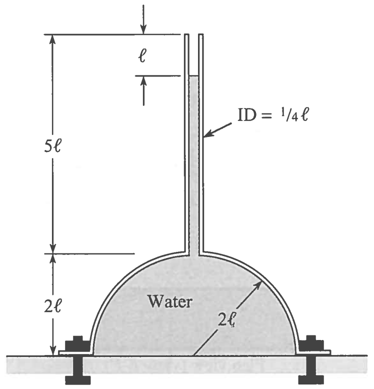
PROBLEM 3.26

3.27 The steel pipe and steel chamber shown in the figure together weigh 2700 N. What force will have to be exerted on the chamber by all the bolts to hold it in place? The dimension ℓ is equal to 75 cm. *Note:* There is no bottom on the chamber—only a flange bolted to the floor.



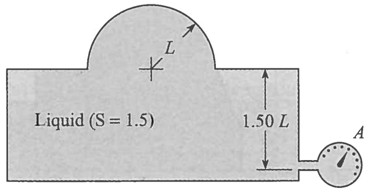
PROBLEM 3.27

3.28 What force must be exerted through the bolts to hold the dome in place? The metal dome and pipe weigh 6 kN. The dome has no bottom. Here ℓ = 80 cm and the specific weight of the water is γ = 9810 N/m^3.



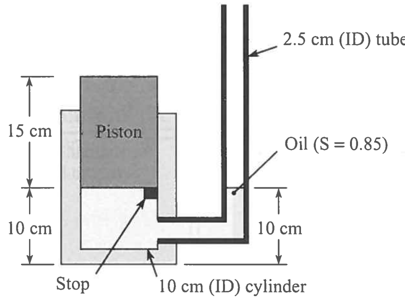
PROBLEM 3.28

3.29 Find the vertical component of force in the metal at the base of the spherical dome shown when gage *A* reads 35 kPa gage. Indicate whether the metal is in compression or tension. The specific gravity of the enclosed fluid is 1.5. The dimension *L* is 60 cm. Assume the dome weighs 4450 N.



PROBLEM 3.29

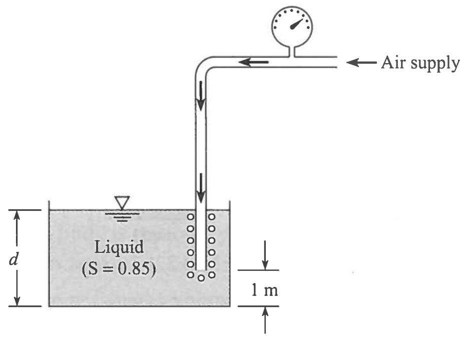
3.30 The piston shown weighs 45 N. In its initial position, the piston is restrained from moving to the bottom of the cylinder by means of the metal stop. Assuming there is neither friction nor leakage between piston and cylinder, what volume of oil (S = 0.85) would have to be added to the 2.5 cm tube to cause the piston to rise 2.5 cm from its initial position?



PROBLEM 3.30

3.31 Consider an air bubble rising from the bottom of a lake. Neglecting surface tension, determine approximately what the ratio of the density of the air in the bubble will be at a depth of 10 m to its density at a depth of 2.5 m.

3.32 One means of determining the surface level of liquid in a tank is by discharging a small amount of air through a small tube, the end of which is submerged in the tank, and reading the pressure on the gage that is tapped into the tube. Then the level of the liquid surface in the tank can be calculated. If the pressure on the gage is 15 kPa, what is the depth *d* of liquid in the tank?



PROBLEM 3.32

Calculating Pressure in the Atmosphere (§3.2)

3.33 For Fig. 3.9 on p. 70 of §3.2 that describes temperature variation with altitude, answer the following questions.

a. Does the linear approximation relating temperature to altitude apply in the troposphere or the stratosphere?

b. At approximately what altitude in the earth's atmosphere does the linear approximation for temperature variation fail?

3.34 The boiling point of water decreases with elevation because of the pressure change. What is the boiling point of water at an elevation of 2000 m and at an elevation of 4000 m for standard atmospheric conditions?

3.35 From a depth of 10 m in a lake to an elevation of 4000 m in the atmosphere, plot the variation of absolute pressure. Assume that the lake water surface elevation is at mean sea level and assume standard atmospheric conditions.

3.36 Assume that a woman must breathe a constant mass rate of air to maintain her metabolic processes. If she inhales and exhales 16 times per minute at sea level, where the temperature is 15°C and the pressure is 101 kPa, what would you expect her rate of breathing at 5486 m to be? Use standard atmospheric conditions.

3.37 A pressure gage in an airplane indicates a pressure of 95 kPa at takeoff, where the airport elevation is 1 km and the temperature is 10°C. If the standard lapse rate of 5.87°C/km is assumed, at what elevation is the plane when a pressure of 75 kPa is read? What is the temperature for that condition?

3.38 Denver, Colorado, is called the "mile-high" city. What are the pressure, temperature, and density of the air when standard atmospheric conditions prevail?

3.39 An airplane is flying at 10 km altitude in a U.S. standard atmosphere. If the internal pressure of the aircraft interior is 100 kPa, what is the outward force on a window? The window is flat and has an elliptical shape with lengths of 300 mm along the major axis and 200 mm along the minor axis.

3.40 The mean atmospheric pressure on the surface of Mars is 0.7 kPa, and the mean surface temperature is −63°C. The atmosphere consists primarily of CO_2 (95.3%) with small amounts of nitrogen and argon. The acceleration due to gravity on the surface is 3.72 m/s^2. Data from probes entering the Martian atmosphere show that the temperature variation with altitude can be approximated as constant at −63°C from the Martian surface to 14 km, and then a linear decrease with a lapse rate of 1.5°C/km up to 34 km. Find the pressure at 8 km and 30 km altitude. Assume the atmosphere is pure carbon dioxide. Note that the temperature distribution in the atmosphere of Mars differs from that of Earth because the region of constant temperature is adjacent to the surface and the region of decreasing temperature starts at an altitude of 14 km.

3.41 Design a computer program that calculates the pressure and density for the U.S. standard atmosphere from 0 to 30 km altitude. Assume the temperature profiles are linear and are approximated by the following ranges, where *z* is the altitude in kilometers:

0–13.72 km	$T = 23.1 - 5.87z$ (°C)
13.7–16.8 km	$T = -57.5$°C
16.8–30 km	$T = -57.5 + 1.387(z - 16.8)$°C

Measuring Pressure (§3.3)

3.42 Match the following pressure-measuring devices with the correct name. The device names are: barometer, Bourdon gage, piezometer, manometer, and pressure transducer.

a. A vertical or U-shaped tube where changes in pressure are documented by changes in relative elevation of a liquid that is usually denser than the fluid in the system measured; can be used to measure vacuum.

b. Typically contains a diaphragm, a sensing element, and conversion to an electric signal.

c. A round face with a scale to measure needle deflection, where the needle is deflected by changes in extension of a coiled hollow tube.

d. A vertical tube where a liquid rises in response to a positive gage pressure.

e. An instrument used to measure atmospheric pressure; of various designs.

Applying the Manometer Equations (§3.3)

3.43 Which is the more correct way to describe the two summation (Σ) terms of the manometer equation, Eq (3.21) on p. 74 of §3.3?

a. Add the downs and subtract the ups.

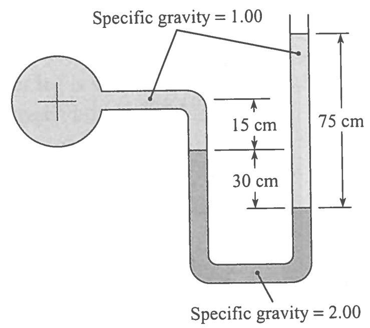
b. Subtract the downs and add the ups.

3.44 Using the Internet and other resources, answer the following questions:

a. What are three common types of manometers? For each type, make a sketch and give a brief description.

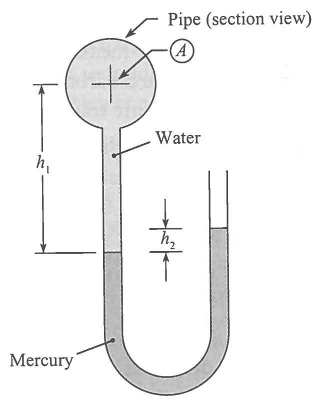
b. How would you build a manometer from materials that are commonly available? Sketch your design concept.

3.45 Is the gage pressure at the center of the pipe (a) negative, (b) zero, or (c) positive? Neglect surface tension effects and state your rationale.



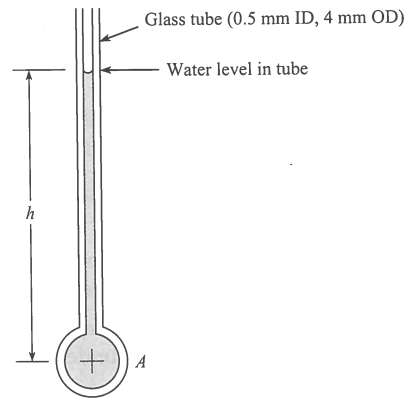
PROBLEM 3.45

3.46 Determine the gage pressure at the center of the pipe (point *A*) in pascal when the temperature is 21°C with h_1 = 40 cm and h_2 = 5 cm.



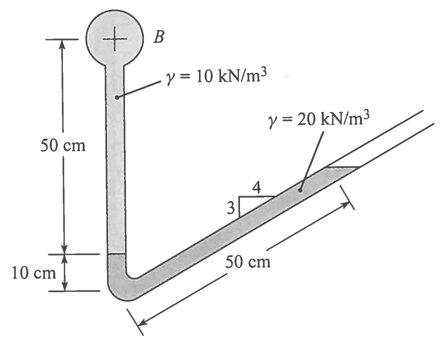
PROBLEM 3.46

3.47 Considering the effects of surface tension, estimate the gage pressure at the center of pipe A for $h = 120$ mm and $T = 20°C$.



PROBLEM 3.47

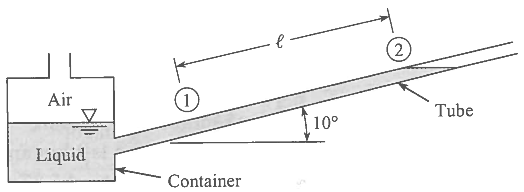
3.48 What is the pressure at the center of pipe B?



PROBLEM 3.48

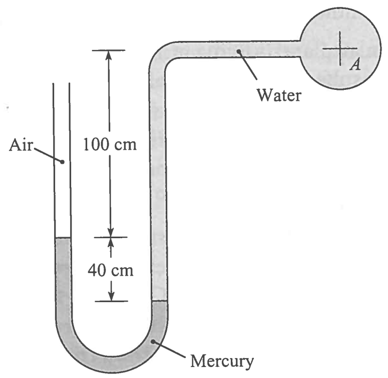
3.49 The ratio of container diameter to tube diameter is 8. When air in the container is at atmospheric pressure, the free surface in the tube is at position 1. When the container is pressurized, the liquid in the tube moves 40 cm up the tube from position 1 to position 2. What is the container pressure that causes this deflection? The liquid density is 1200 kg/m³.

3.50 The ratio of container diameter to tube diameter is 10. When air in the container is at atmospheric pressure, the free surface in the tube is at position 1. When the container is pressurized, the liquid in the tube moves 1 m up the tube from position 1 to position 2. What is the container pressure that causes this deflection? The specific weight of the liquid is 7850 N/m³.



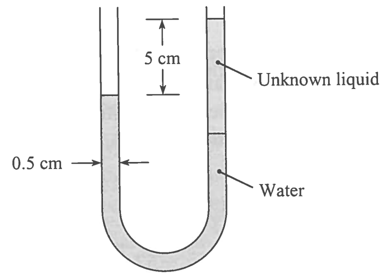
PROBLEMS 3.49, 3.50

3.51 Determine the gage pressure at the center of pipe A in kilopascals.



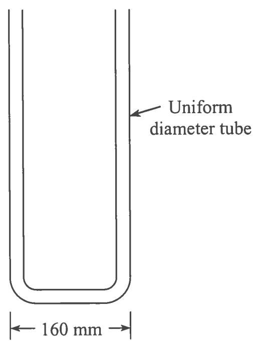
PROBLEM 3.51

3.52 A device for measuring the specific weight of a liquid consists of a U-tube manometer as shown. The manometer tube has an internal diameter of 0.5 cm and originally has water in it. Exactly 2 cm³ of unknown liquid is then poured into one leg of the manometer, and a displacement of 5 cm is measured between the surfaces as shown. What is the specific weight of the unknown liquid?



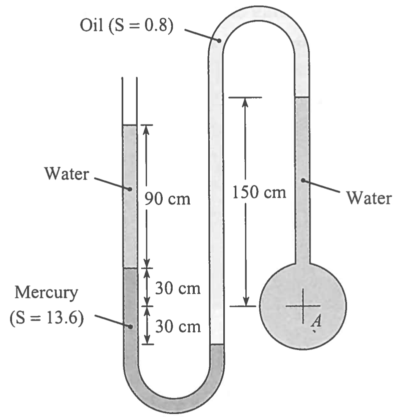
PROBLEM 3.52

3.53 Mercury is poured into the tube in the figure until the mercury occupies 375 mm of the tube's length. An equal volume of water is then poured into the left leg. Locate the water and mercury surfaces. Also determine the maximum pressure in the tube.



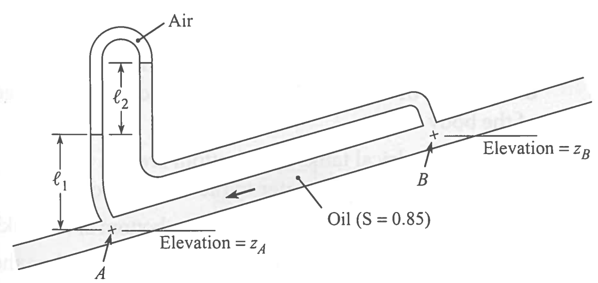
PROBLEM 3.53

3.54 Find the pressure at the center of pipe A. $T = 10°C$.



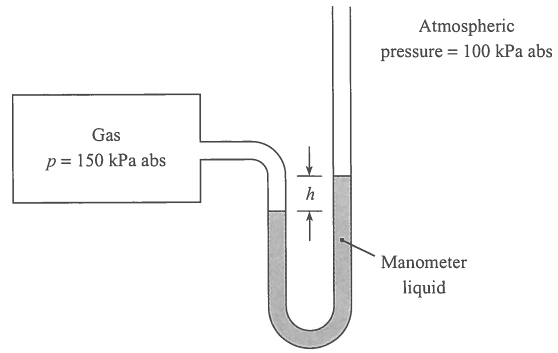
PROBLEM 3.54

3.55 Determine (a) the difference in pressure and (b) the difference in piezometric head between points A and B. The elevations z_A and z_B are 10 m and 11 m, respectively, $\ell_1 = 1$ m, and the manometer deflection ℓ_2 is 50 cm.



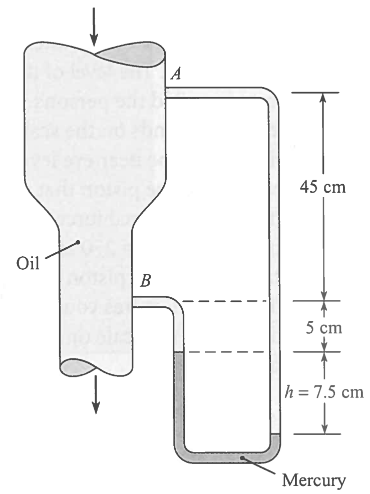
PROBLEM 3.55

3.56 The deflection on the manometer is h meters when the pressure in the tank is 150 kPa absolute. If the absolute pressure in the tank is doubled, what will the deflection on the manometer be?



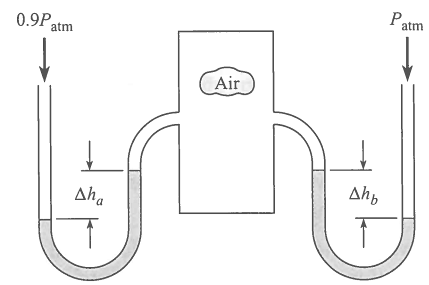
PROBLEM 3.56

3.57 A vertical conduit is carrying oil (S = 0.95). A differential mercury manometer is tapped into the conduit at points A and B. Determine the difference in pressure between A and B when $h = 7.5$ cm. What is the difference in piezometric head between A and B?



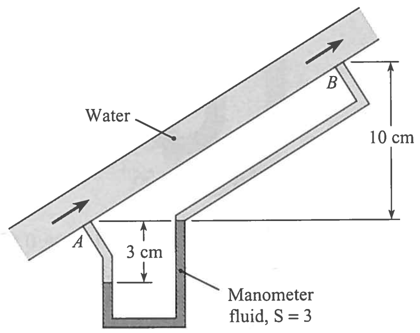
PROBLEM 3.57

3.58 Two water manometers are connected to a tank of air. One leg of the manometer is open to 100 kPa pressure (absolute) while the other leg is subjected to 90 kPa. Find the difference in deflection between both manometers, $\Delta h_a - \Delta h_b$.



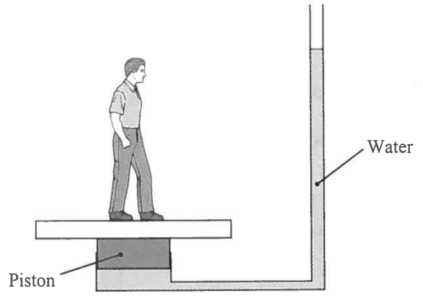
PROBLEM 3.58

3.59 A manometer is used to measure the pressure difference between points A and B in a pipe as shown. Water flows in the pipe, and the specific gravity of the manometer fluid is 2.8. The distances and manometer deflection are indicated on the figure. Find (a) the pressure differences $p_A - p_B$, and (b) the difference in piezometric pressure, $p_{z,A} - p_{z,B}$. Express both answers in kPa.



PROBLEM 3.59

3.60 A novelty scale for measuring a person's weight by having the person stand on a piston connected to a water reservoir and stand pipe is shown in the diagram. The level of the water in the stand pipe is to be calibrated to yield the person's weight in pounds force. When the person stands on the scale, the height of the water in the stand pipe should be near eye level so the person can read it. There is a seal around the piston that prevents leaks but does not cause a significant frictional force. The scale should function for people who weigh between 270 and 1110 N and are between 1.2 and 1.8 m tall. Choose the piston size and standpipe diameter. Clearly state the design features you considered. Indicate how you would calibrate the scale on the standpipe. Would the scale be linear?



PROBLEM 3.60

Applying the Panel Force Equations (§3.4)

3.61 Using §3.4 and other resources, answer the questions below. Strive for depth, clarity, and accuracy while also combining sketches, words, and equations in ways that enhance the effectiveness of your communication.

a. For hydrostatic conditions, what do typical pressure distributions on a panel look like? Sketch three examples that correspond to different situations.

b. What is a center of pressure (CP)? What is a centroid of area?

c. In Eq. (3.28) on p. 80 of §3.4, what does $\bar{p}$ mean? What factors influence the value of $\bar{p}$?

d. What is the relationship between the pressure distribution on a panel and the resultant force?

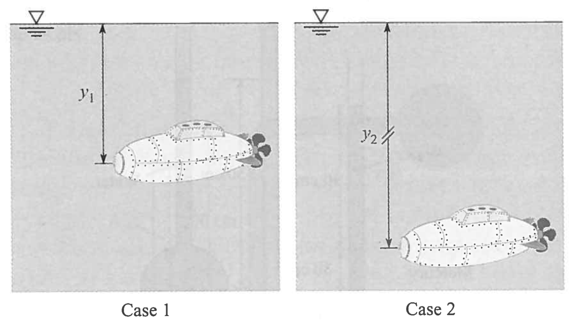
e. How far is the CP from the centroid of area? What factors influence this distance?

3.62 WILEY GO Part 1. Consider the equation for the distance between the CP and the centroid of a submerged panel (Eq. (3.33) on p. 81 of §3.4). In that equation, y_{cp} is

a. the vertical distance from the water surface to the CP.

b. the slant distance from the water surface to the CP.

Part 2. Consider the figure shown. For Case 1 as shown, the viewing window on the front of a submersible exploration vehicle is at a depth of y_1. For Case 2, the submersible has moved deeper in the ocean, to y_2. As a result of this increased overall depth of the submersible and its window, does the spacing between the CP and centroid (a) get larger, (b) stay the same, or (c) get smaller?



PROBLEM 3.62

3.63 Which of these assumptions and/or limitations must be known when using Eq. (3.33) on p. 81 of §3.4 for a submerged surface or panel to calculate the distance between the centroid of the panel and the center of pressure of the hydrostatic force (select all that apply):

a. The equation only applies to a single fluid of constant density

b. The pressure at the surface must be p = 0 gage

c. The panel must be vertical

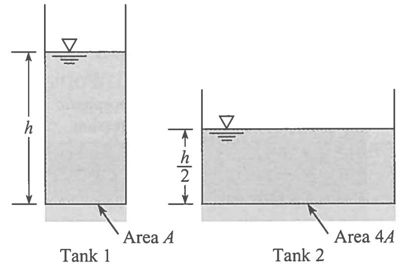
d. The equation gives only the vertical location (as a slant distance) to the CP, not the lateral distance from the edge of the body

3.64 WILEY PLUS Two cylindrical tanks have bottom areas A and $4A$ respectively, and are filled with water to the depths shown.

a. Which tank has the higher pressure at the bottom of the tank?

b. Which tank has the greater force acting downward on the bottom circular surface?

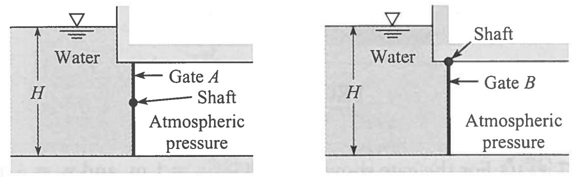
3.65 WILEY PLUS What is the force acting on the gate of an irrigation ditch if the ditch and gate are 1.2 m wide, 1.2 m deep, and the ditch is competely full of water? There is no water on the other side of the gate. The weather has been hot for weeks, so the water is 21°C.



PROBLEM 3.64

3.66 WILEY PLUS Consider the two rectangular gates shown in the figure. They are both the same size, but gate A is held in place by a horizontal shaft through its midpoint and gate B is cantilevered to a shaft at its top. Now consider the torque T required to hold the gates in place as H is increased. Choose the valid statement(s): (a) T_A increases with H. (b) T_B increases with H. (c) T_A does not change with H. (d) T_B does not change with H.

3.67 WILEY PLUS For gate A, choose the statements that are valid: (a) The hydrostatic force acting on the gate increases as H increases. (b) The distance between the CP on the gate and the centroid of the gate decreases as H increases. (c) The distance between the CP on the gate and the centroid of the gate remains constant as H increases. (d) The torque applied to the shaft to prevent the gate from turning must be increased as H increases. (e) The torque applied to the shaft to prevent the gate from turning remains constant as H increases.



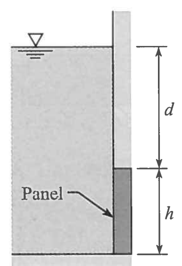
PROBLEMS 3.66, 3.67

3.68 WILEY PLUS As shown, water (15°C) is in contact with a square panel; $d = 1$ m and $h = 2$ m.

a. Calculate the depth of the centroid

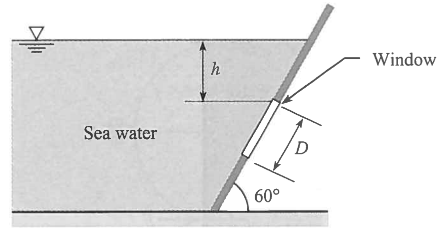
b. Calculate the resultant force on the panel

c. Calculate the distance from the centroid to the CP.



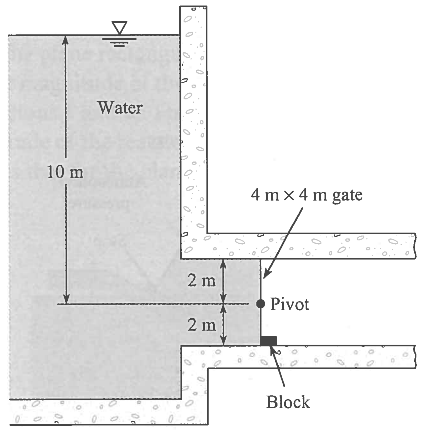
PROBLEM 3.68

3.69 WILEY GO As shown, a round viewing window of diameter $D = 0.5$ m is situated in a large tank of seawater ($S = 1.03$). The top of the window is 1.5 m below the water surface, and the window is angled at 60° with respect to the horizontal. Find the hydrostatic force acting on the window and locate the corresponding CP.



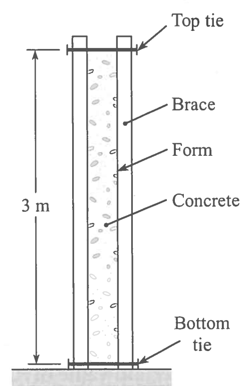
PROBLEM 3.69

3.70 WILEY PLUS Find the force of the gate on the block. See sketch.



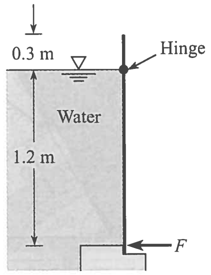
PROBLEM 3.70

3.71 Assume that wet concrete ($\gamma = 23{,}600$ N/m^3) behaves as a liquid. Determine the force per meter of length exerted on the forms. If the forms are held in place as shown, with ties between vertical braces spaced every 60 cm, what force is exerted on the bottom tie?



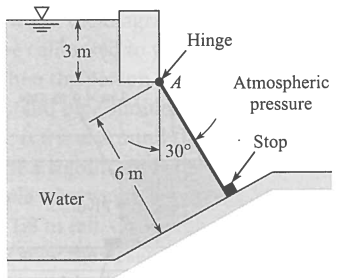
PROBLEM 3.71

3.72 WILEY PLUS A rectangular gate is hinged at the water line, as shown. The gate is 1.2 m high and 1.8 m wide. The specific weight of water is 9810 N/m^3. Find the necessary force applied at the bottom of the gate to keep it closed.



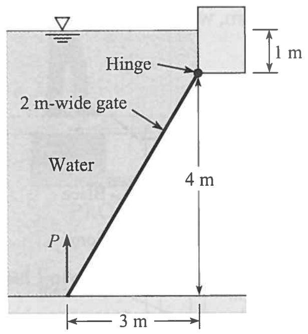
PROBLEM 3.72

3.73 The gate shown is rectangular and has dimensions 6 m by 4 m. What is the reaction at point A? Neglect the weight of the gate.



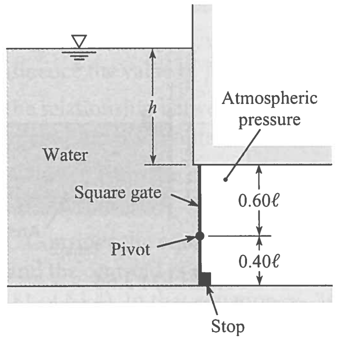
PROBLEM 3.73

3.74 WILEY PLUS Determine P necessary to just start opening the 2 m–wide gate.



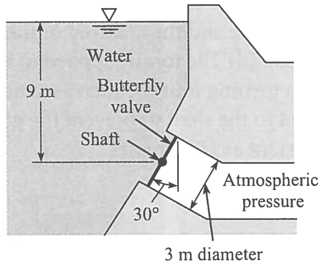
PROBLEM 3.74

3.75 WILEY PLUS The square gate shown is eccentrically pivoted so that it automatically opens at a certain value of h. What is that value in terms of ℓ?



PROBLEM 3.75

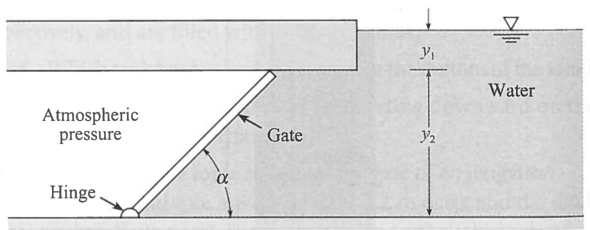
3.76 WILEY GO This 3 m–diameter butterfly valve is used to control the flow in a 3 m–diameter outlet pipe in a dam. In the position shown, it is closed. The valve is supported by a horizontal shaft through its center. What torque would have to be applied to the shaft to hold the valve in the position shown?



PROBLEM 3.76

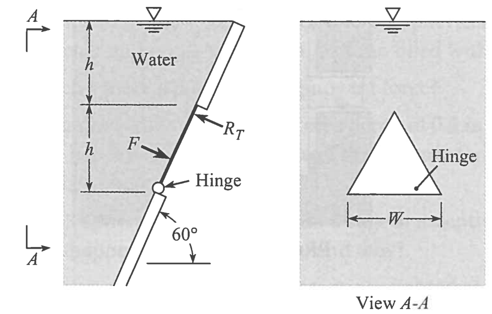
3.77 WILEY PLUS For the gate shown, $\alpha = 45°$, $y_1 = 1$ m, and $y_2 = 4$ m. Will the gate fall or stay in position under the action of the hydrostatic and gravity forces if the gate itself weighs 150 kN and is 1.0 m wide? Assume $T = 10°$C. Use calculations to justify your answer.

3.78 WILEY PLUS For this gate, $\alpha = 45°$, $y_1 = 1$ m, and $y_2 = 2$ m. Will the gate fall or stay in position under the action of the hydrostatic and gravity forces if the gate itself weighs 80,000 N and is 1 m wide? Assume $T = 10°$C. Use calculations to justify your answer.



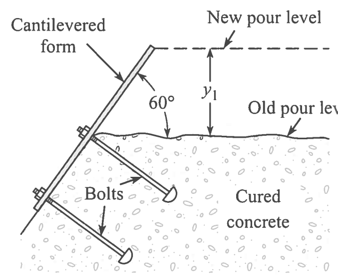
PROBLEMS 3.77, 3.78

3.79 Determine the hydrostatic force F on the triangular gate, which is hinged at the bottom edge and held by the reaction R_T at the upper corner. Express F in terms of γ, h, and W. Also determine the ratio R_T/F. Neglect the weight of the gate.



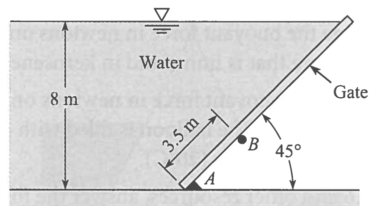
PROBLEM 3.79

3.80 WILEY PLUS In constructing dams, the concrete is poured in lifts of approximately 1.5 m ($y_1 = 1.5$ m). The forms for the face of the dam are reused from one lift to the next. The figure shows one such form, which is bolted to the already cured concrete. For the new pour, what moment will occur at the base of the form per meter of length (normal to the page)? Assume that concrete acts as a liquid when it is first poured and has a specific weight of 24 kN/m^3.



PROBLEM 3.80

3.81 The plane rectangular gate can pivot about the support at B. For the conditions given, is it stable or unstable? Neglect the weight of the gate. Justify your answer with calculations.

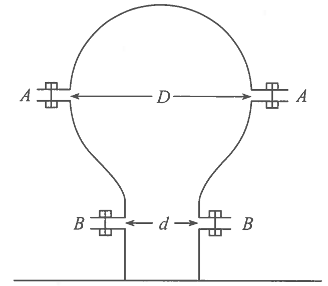


PROBLEM 3.81

Calculating Pressure on Curved Surfaces (§3.5)

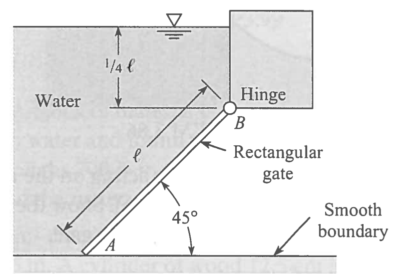
3.82 WILEY PLUS Two hemispheric shells are perfectly sealed together, and the internal pressure is reduced to 25% of atmospheric pressure. The inner radius is 10.5 cm, and the outer radius is 10.75 cm. The seal is located halfway between the inner and outer radius. If the atmospheric pressure is 101.3 kPa, what force is required to pull the shells apart?

3.83 If exactly 20 bolts of 2.5 cm diameter are needed to hold the air chamber together at A-A as a result of the high pressure within, how many bolts will be needed at B-B? Here $D = 40$ cm and $d = 20$ cm.

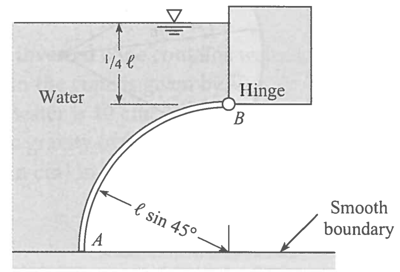


PROBLEM 3.83

3.84 For the plane rectangular gate ($\ell \times w$ in size), figure (*a*), what is the magnitude of the reaction at A in terms of γ_w and the dimensions ℓ and w? For the cylindrical gate, figure (*b*), will the magnitude of the reaction at A be greater than, less than, or the same as that for the plane gate? Neglect the weight of the gates.



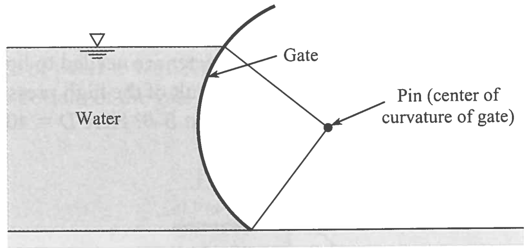
(a) Plane gate



(b) Curved gate

PROBLEM 3.84

3.85 Water is held back by this radial gate. Does the resultant of the pressure forces acting on the gate pass above the pin, through the pin, or below the pin?



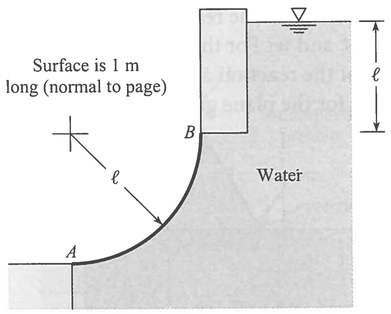
PROBLEM 3.85

3.86 For the curved surface AB:

a. Determine the magnitude, direction, and line of action of the vertical component of hydrostatic force acting on the surface. Here $\ell = 1$ m.

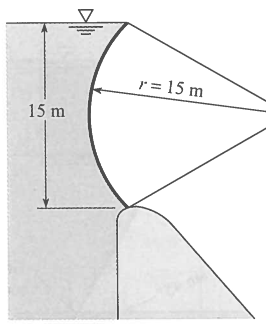
b. Determine the magnitude, direction, and line of action of the horizontal component of hydrostatic force acting on the surface.

c. Determine the resultant hydrostatic force acting on the surface.



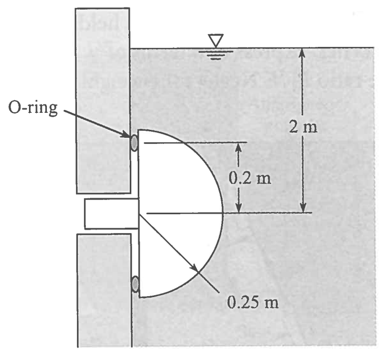
PROBLEM 3.86

3.87 Determine the hydrostatic force acting on the radial gate if the gate is 12 m long (normal to the page). Show the line of action of the hydrostatic force acting on the gate.



PROBLEM 3.87

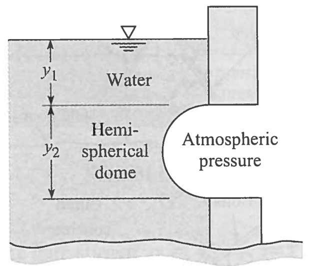
3.88 WILEY PLUS A plug in the shape of a hemisphere is inserted in a hole in the side of a tank as shown in the figure. The plug is sealed by an O-ring with a radius of 0.2 m. The radius of the hemispherical plug is 0.25 m. The depth of the center of the plug is 2 m in fresh water. Find the horizontal and vertical forces on the plug due to hydrostatic pressure.



PROBLEM 3.88

3.89 WILEY PLUS This dome (hemisphere) is located below the water surface as shown. Determine the magnitude and sign of the force components needed to hold the dome in place and the line of action of the horizontal component of force. Here $y_1 = 1$ m and $y_2 = 2$ m. Assume $T = 10°C$.

3.90 Consider the dome shown. This dome is 3 m in diameter, but now the dome is not submerged. The water surface is at the level of the center of curvature of the dome. For these conditions, determine the magnitude and direction of the resultant hydrostatic force acting on the dome.



PROBLEM 3.89, 3.90

Calculating Buoyant Forces (§3.6)

3.91 Apply the grid method (§1.5 in Ch. 1) to each situation below.

a. Determine the buoyant force in newtons on a basketball that is floating in a lake (10°C).

b. Determine the buoyant force in newtons on a 1 mm copper sphere that is immersed in kerosene.

c. Determine the buoyant force in newtons on a 30 cm–diameter balloon. The balloon is filled with helium and situated in ambient air (20°C).

3.92 Using §3.6 and other resources, answer the following questions. Strive for depth, clarity, and accuracy while also combining sketches, words, and equations in ways that enhance the effectiveness of your communication.

a. Why learn about buoyancy? That is, what are important technical problems that involve buoyant forces?

b. For a buoyant force, where is the CP? Where is the line of action?

c. What is displaced volume? Why is it important?

d. What is the relationship between pressure distribution and buoyant force?

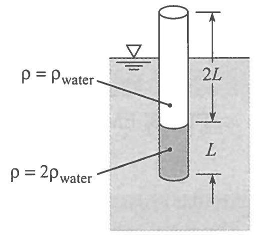
3.93 Three spheres of the same diameter are submerged in the same body of water. One sphere is steel, one is a spherical balloon filled with water, and one is a spherical balloon filled with air.

a. Which sphere has the largest buoyant force?

b. If you move the steel sphere from a depth of 0.3 m to 3.0 m, what happens to the magnitude of the buoyant force acting on that sphere?

c. If all 3 spheres are released from a cage at a depth of 1 m, what happens to the 3 spheres, and why?

3.94 As shown, a uniform-diameter rod is weighted at one end and is floating in a liquid. The liquid (a) is lighter than water, (b) must be water, or (c) is heavier than water. Show your work.

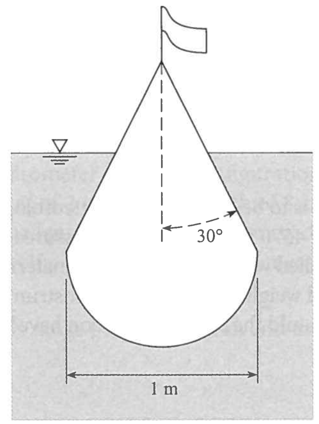


PROBLEM 3.94

3.95 WILEY PLUS A 245-m ship has a displacement of 3.4×10^8 N, and the area defined by the waterline is 3500 m^2. Will the ship take more or less draft when steaming from salt water to fresh water? How much will it settle or rise?

3.96 WILEY PLUS A submerged spherical steel buoy that is 1.2 m in diameter and weighs 1200 N is to be anchored in salt water 20 m below the surface. Find the weight of scrap iron that should be sealed inside the buoy in order that the force on its anchor chain will not exceed 4.5 kN.

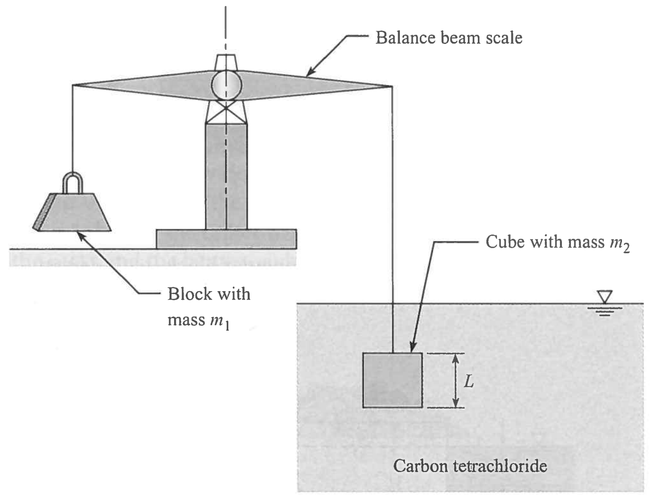
3.97 A buoy is designed with a hemispherical bottom and conical top as shown in the figure. The diameter of the hemisphere is 1 m, and the half angle of the cone is 30°. The buoy has a mass of 460 kg. Find the location of the water line on the buoy floating in sea water ($\rho = 1010$ kg/m^3).



PROBLEM 3.97

3.98 WILEY PLUS A rock weighs 925 N in air and 781 N in water. Find its volume.

3.99 WILEY PLUS As shown, a cube ($L = 60$ mm) suspended in carbon tetracloride is exactly balanced by an object of mass $m_1 = 700$ g. Find the mass m_2 of the cube.

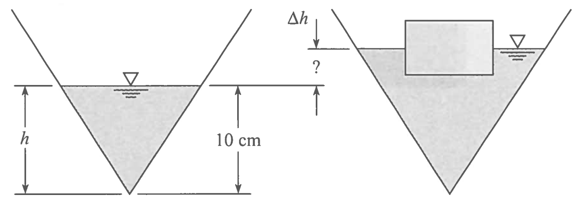


PROBLEM 3.99

3.100 WILEY PLUS A block of material of unknown volume is submerged in water and found to weigh 300 N (in water). The same block weighs 700 N in air. Determine the specific weight and volume of the material.

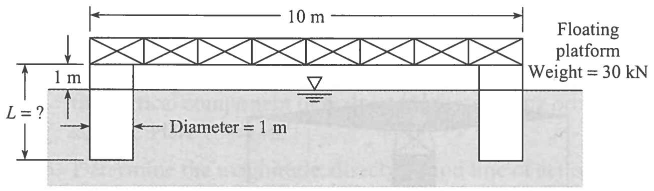
3.101 A 0.3 m–diameter cylindrical tank is filled with water to a depth of 0.6 m. A cylinder of wood 12.5 cm in diameter and 6.25 cm long is set afloat on the water. The weight of the wood cylinder is 9 N. Determine the change (if any) in the depth of the water in the tank.

3.102 A 90° inverted cone contains water as shown. The volume of the water in the cone is given by $\forall = (\pi/3)h^3$. The original depth of the water is 10 cm. A block with a volume of 200 cm^3 and a specific gravity of 0.6 is floated in the water. What will be the change (in cm) in water surface height in the cone?



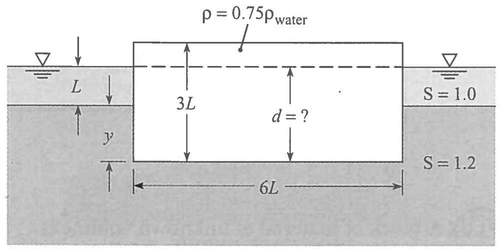
PROBLEM 3.102

3.103 The floating platform shown is supported at each corner by a hollow sealed cylinder 1 m in diameter. The platform itself weighs 30 kN in air, and each cylinder weighs 1.0 kN per meter of length. What total cylinder length L is required for the platform to float 1 m above the water surface? Assume that the specific weight of the water (brackish) is 10,000 N/m^3. The platform is square in plan view.



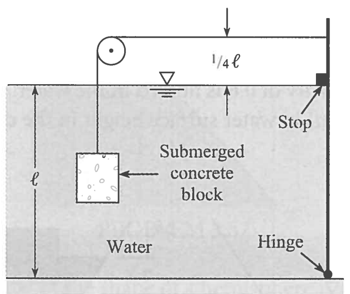
PROBLEM 3.103

3.104 To what depth d will this rectangular block (with density 0.75 times that of water) float in the two-liquid reservoir?



PROBLEM 3.104

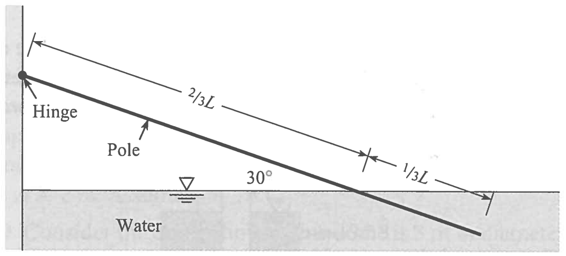
3.105 Determine the minimum volume of concrete (γ = 23.6 kN/m^3) needed to keep the gate (1 m wide) in a closed position, with ℓ = 2 m. Note the hinge at the bottom of the gate.



PROBLEM 3.105

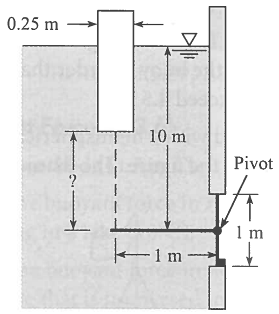
3.106 A cylindrical container 1.2 m high and 0.6 m in diameter holds water to a depth of 0.6 m. How much does the level of the water in the tank change when a 22 N block of ice is placed in the container? Is there any change in the water level in the tank when the block of ice melts? Does it depend on the specific gravity of the ice? Explain all the processes.

3.107 The partially submerged wood pole is attached to the wall by a hinge as shown. The pole is in equilibrium under the action of the weight and buoyant forces. Determine the density of the wood.



PROBLEM 3.107

3.108 A gate with a circular cross section is held closed by a lever 1 m long attached to a buoyant cylinder. The cylinder is 25 cm in diameter and weighs 200 N. The gate is attached to a horizontal shaft so it can pivot about its center. The liquid is water. The chain and lever attached to the gate have negligible weight. Find the length of the chain such that the gate is just on the verge of opening when the water depth above the gate hinge is 10 m.



PROBLEM 3.108

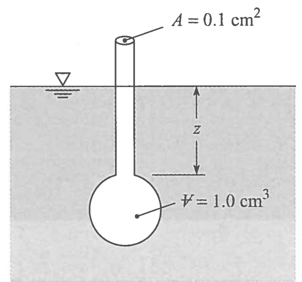
3.109 A balloon is to be used to carry meteorological instruments to an elevation of 4570 m where the air pressure is 56 kPa abs. The balloon is to be filled with helium, and the material from which it is to be fabricated weighs 0.5 N/m^2. If the instruments weigh 35 N, what diameter should the spherical balloon have?

3.110 A weather balloon is constructed of a flexible material such that the internal pressure of the balloon is always 10 kPa higher than the local atmospheric pressure. At sea level the diameter of the balloon is 1 m, and it is filled with helium. The balloon material, structure, and instruments have a mass of 100 g. This does not include the mass of the helium. As the balloon rises, it will expand. The temperature of the helium is always equal to the local atmospheric temperature, so it decreases as the balloon gains altitude. Calculate the maximum altitude of the balloon in a standard atmosphere.

Measuring ρ, γ, and S with Hydrometers (§3.6)

3.111 The hydrometer shown weighs 0.015 N. If the stem sinks 6.0 cm in oil (z = 6.0 cm), what is the specific gravity of the oil?

3.112 The hydrometer shown sinks 5.3 cm (z = 5.3 cm) in water (15°C). The bulb displaces 1.0 cm^3, and the stem area is 0.1 cm^2. Find the weight of the hydrometer.

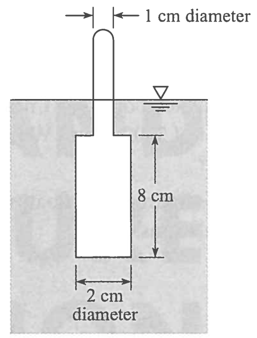


PROBLEMS 3.111, 3.112

3.113 A common commercial hydrometer for measuring the amount of antifreeze in the coolant system of an automobile engine consists of a chamber with differently colored balls. The system is calibrated to give the range of specific gravity by distinguishing between the balls that sink and those that float. The specific gravity of an ethylene glycol-water mixture varies from 1.012 to 1.065 for 10% to 50% by weight of ethylene glycol. Assume there are six balls, 1 cm in diameter each, in the chamber. What should the weight of each ball be to provide a range of specific gravities between 1.01 and 1.06 with 0.01 intervals?

3.114 A hydrometer with the configuration shown has a bulb diameter of 2 cm, a bulb length of 8 cm, a stem diameter of 1 cm, a length of 8 cm, and a mass of 40 g. What is the range of specific gravities that can be measured with this hydrometer?

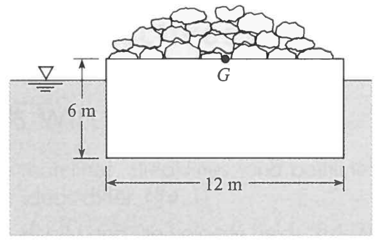
(*Hint:* Liquid levels range between bottom and top of stem.)



PROBLEM 3.114

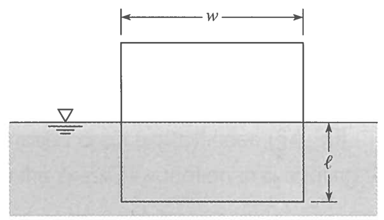
Predicting Stability (§3.7)

3.115 A barge 6 m wide and 12 m long is loaded with rocks as shown. Assume that the center of gravity of the rocks and barge is located along the centerline at the top surface of the barge. If the rocks and the barge weigh 1780 kN, will the barge float upright or tip over?



PROBLEM 3.115

3.116 A floating body has a square cross section with side w as shown in the figure. The center of gravity is at the centroid of the cross section. Find the location of the water line, ℓ/w, where the body would be neutrally stable (GM = 0). If the body is floating in water, what would be the specific gravity of the body material?

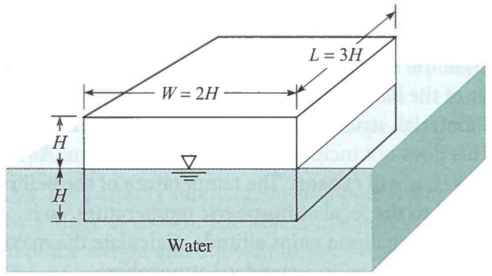


PROBLEM 3.116

3.117 A cylindrical block of wood 1 m in diameter and 1 m long has a specific weight of 7500 N/m^3. Will it float in water with its axis vertical?

3.118 PLUS A cylindrical block of wood 1 m in diameter and 1 m long has a specific weight of 5000 N/m^3. Will it float in water with the ends horizontal?

3.119 Is the block in this figure stable floating in the position shown? Show your calculations.



PROBLEM 3.119

THE BERNOULLI EQUATION AND PRESSURE VARIATION

4

FIGURE 4.1

This photo shows flow over a model truck in a wind-tunnel. The purpose of the study was to compare the drag force on various designs of tonneau covers. The study was done by Stephen Lyda while he was an undergraduate engineering student. (Photo by Stephen Lyda)

Chapter Road Map

This chapter describes flowing fluids, introduces the Bernoulli equation, and describes pressure variations in flowing fluids.

Learning Objectives

STUDENTS WILL BE ABLE TO

- Describe streamlines, streaklines, and pathlines. Explain how these ideas differ. (§4.1)
- Describe velocity and the velocity field. (§4.2)
- Describe the Eulerian and Lagrangian approaches. (§4.2)
- Describe flowing fluids using the concepts introduced in section §4.3.
- Define acceleration. Sketch the direction of the acceleration vector of a fluid particle. Define local acceleration and convective acceleration. (§4.4)
- Apply Euler's equation to describe pressure variations. (§4.5)
- Apply the Bernoulli equation along a streamline. (§4.6)
- Define static pressure and kinetic pressure. Explain how to measure velocity using a Pitot-static tube. (§4.7)
- Define the rate-of-rotation and vorticity. Define an irrotational flow. (§4.8)
- Apply the Bernoulli equation in an irrotational flow. (§4.9)
- Define the pressure coefficient. Sketch the pressure variation for flow around a circular cylinder. (§4.10)
- Calculate the pressure variation in a rotating flow. (§4.11)