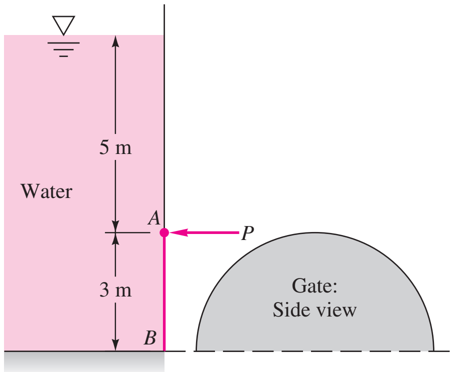
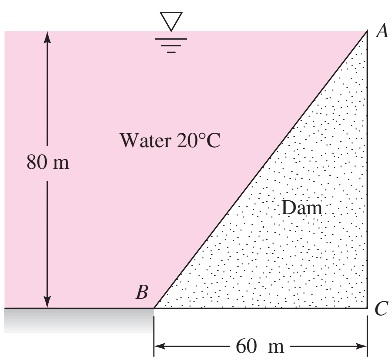
***P2.65** Gate *AB* in Fig. P2.65 is semicircular, hinged at *B*, and held by a horizontal force *P* at *A*. What force *P* is required for equilibrium?



P2.65

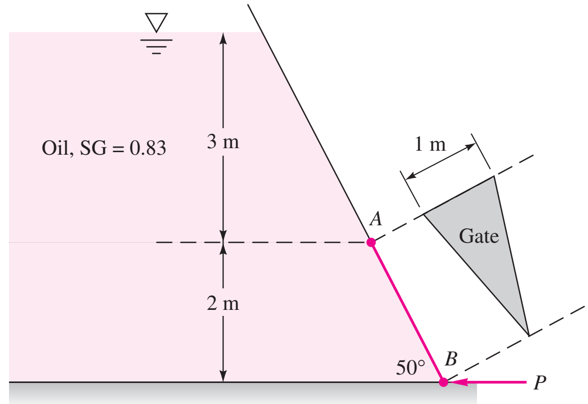
P2.66 Dam *ABC* in Fig. P2.66 is 30 m wide into the paper and made of concrete (SG = 2.4). Find the hydrostatic force on surface *AB* and its moment about *C*. Assuming no seepage of water under the dam, could this force tip the dam over? How does your argument change if there is seepage under the dam?



P2.66

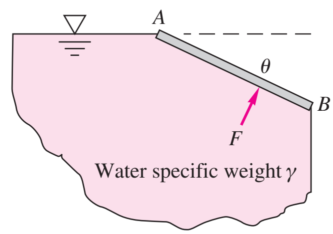
***P2.67** Generalize Prob. P2.66 as follows. Denote length *AB* as *H*, length *BC* as *L*, and angle *ABC* as θ. Let the dam material have specific gravity SG. The width of the dam is *b*. Assume no seepage of water under the dam. Find an analytic relation between SG and the critical angle θ_c for which the dam will just tip over to the right. Use your relation to compute θ_c for the special case SG = 2.4 (concrete).

P2.68 Isosceles triangle gate *AB* in Fig. P2.68 is hinged at *A* and weighs 1500 N. What horizontal force *P* is required at point *B* for equilibrium?



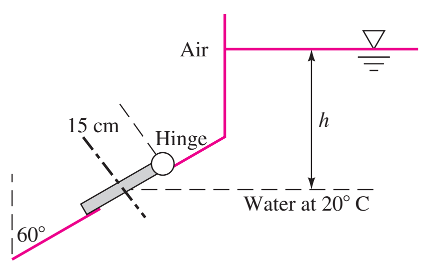
P2.68

P2.69 Consider the slanted plate *AB* of length *L* in Fig. P2.69. (*a*) Is the hydrostatic force *F* on the plate equal to the weight of the *missing water* above the plate? If not, correct this hypothesis. Neglect the atmosphere. (*b*) Can a "missing water" theory be generalized to *curved* surfaces of this type?



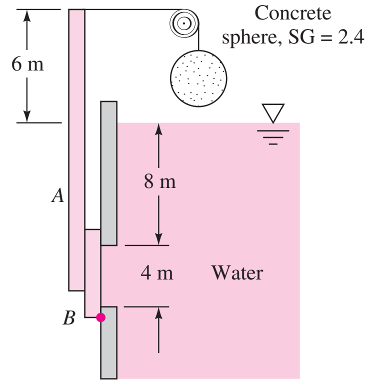
P2.69

P2.70 The swing-check valve in Fig. P2.70 covers a 22.86-cm diameter opening in the slanted wall. The hinge is 15 cm from the centerline, as shown. The valve will open when the hinge moment is 50 N · m. Find the value of *h* for the water to cause this condition.



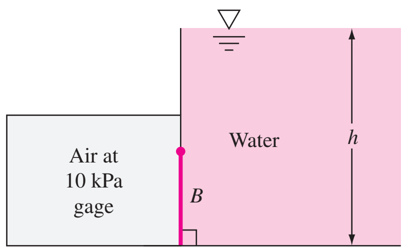
P2.70

***P2.71** In Fig. P2.71 gate *AB* is 3 m wide into the paper and is connected by a rod and pulley to a concrete sphere (SG = 2.40). What diameter of the sphere is just sufficient to keep the gate closed?



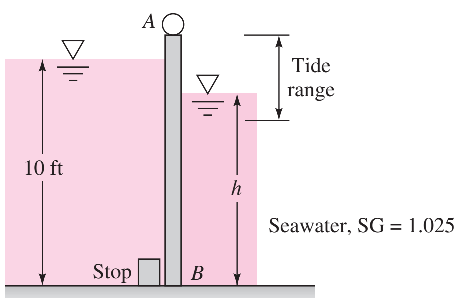
P2.71

P2.72 Gate B in Fig. P2.72 is 30 cm high, 60 cm wide into the paper, and hinged at the top. What water depth h will first cause the gate to open?



P2.72

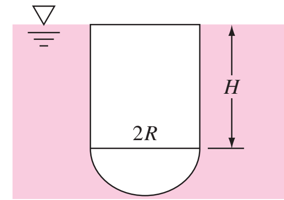
P2.73 Gate AB is 5 ft wide into the paper and opens to let fresh water out when the ocean tide is dropping. The hinge at A is 2 ft above the freshwater level. At what ocean level h will the gate first open? Neglect the gate weight.



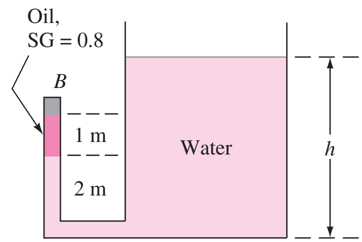
P2.73

P2.74 Find the height H in Fig. P2.74 for which the hydrostatic force on the rectangular panel is the same as the force on the semicircular panel below.

P2.75 The cap at point B on the 5-cm-diameter tube in Fig. P2.75 will be dislodged when the hydrostatic force on its base reaches 22 lbf. For what water depth h does this occur?

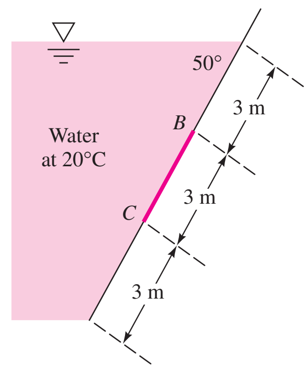


P2.74



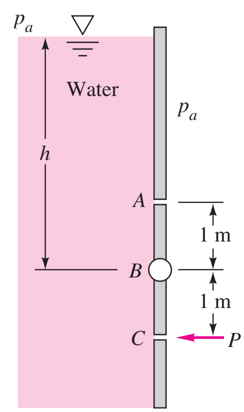
P2.75

P2.76 Panel BC in Fig. P2.76 is circular. Compute (a) the hydrostatic force of the water on the panel, (b) its center of pressure, and (c) the moment of this force about point B.



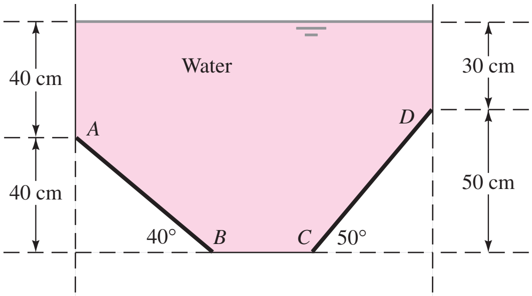
P2.76

P2.77 The circular gate ABC in Fig. P2.77 has a 1-m radius and is hinged at B. Compute the force P just sufficient to keep the gate from opening when $h = 8$ m. Neglect atmospheric pressure.



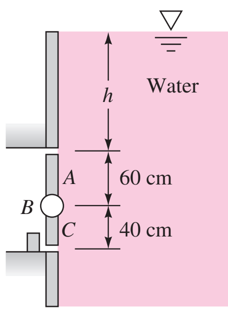
P2.77

P2.78 Panels AB and CD in Fig. P2.78 are each 120 cm wide into the paper. (*a*) Can you deduce, by inspection, which panel has the larger water force? (*b*) Even if your deduction is brilliant, calculate the panel forces anyway.



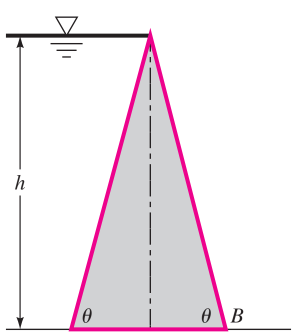
P2.78

P2.79 Gate *ABC* in Fig. P2.79 is 1 m square and is hinged at *B*. It will open automatically when the water level *h* becomes high enough. Determine the lowest height for which the gate will open. Neglect atmospheric pressure. Is this result independent of the liquid density?



P2.79

***P2.80** A concrete dam (SG = 2.5) is made in the shape of an isosceles triangle, as in Fig. P2.80. Analyze this geometry to find the range of angles θ for which the hydrostatic force will tend to tip the dam over at point *B*. The width into the paper is *b*.

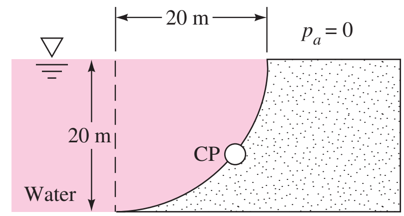


P2.80

Forces on curved surfaces

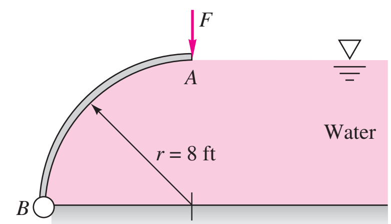
P2.81 For the semicircular cylinder *CDE* in Example 2.9, find the vertical hydrostatic force by integrating the vertical component of pressure around the surface from $\theta = 0$ to $\theta = \pi$.

***P2.82** The dam in Fig. P2.82 is a quarter circle 50 m wide into the paper. Determine the horizontal and vertical components of the hydrostatic force against the dam and the point CP where the resultant strikes the dam.



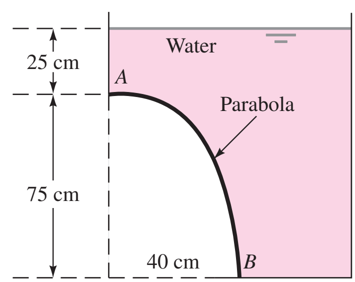
P2.82

***P2.83** Gate *AB* in Fig. P2.83 is a quarter circle 10 ft wide into the paper and hinged at *B*. Find the force *F* just sufficient to keep the gate from opening. The gate is uniform and weighs 3000 lbf.



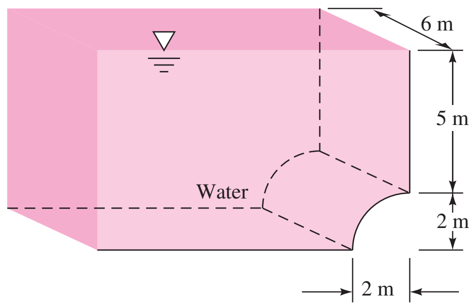
P2.83

P2.84 Panel AB in Fig. P2.84 is a parabola with its maximum at point *A*. It is 150 cm wide into the paper. Neglect atmospheric pressure. Find (*a*) the vertical and (*b*) the horizontal water forces on the panel.



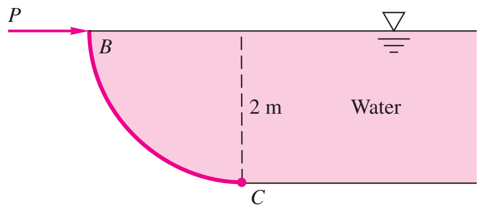
P2.84

P2.85 Compute the horizontal and vertical components of the hydrostatic force on the quarter-circle panel at the bottom of the water tank in Fig. P2.85.



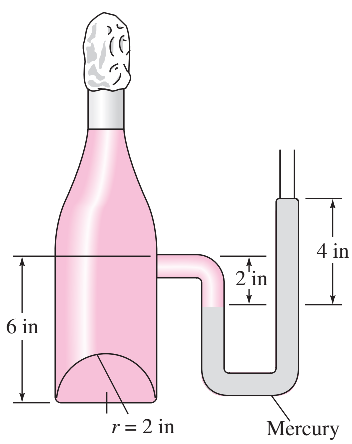
P2.85

P2.86 The quarter circle gate *BC* in Fig. P2.86 in hinged at *C*. Find the horizontal force *P* required to hold the gate stationary. Neglect the weight of the gate.



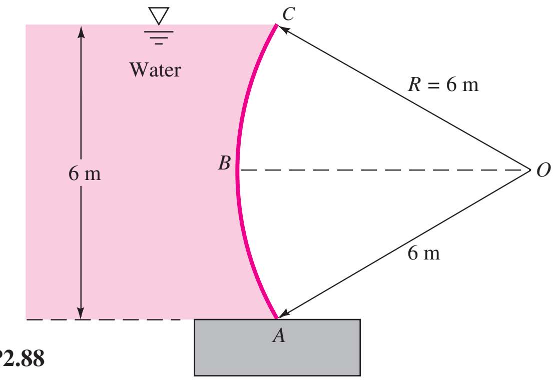
P2.86

P2.87 The bottle of champagne (SG = 0.96) in Fig. P2.87 is under pressure, as shown by the mercury-manometer reading. Compute the net force on the 2-in-radius hemispherical end cap at the bottom of the bottle.



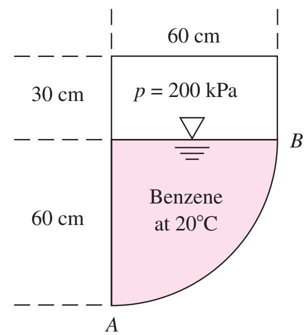
P2.87

***P2.88** Gate *ABC* is a circular arc, sometimes called a *Tainter gate*, which can be raised and lowered by pivoting about point *O*. See Fig. P2.88. For the position shown, determine (*a*) the hydrostatic force of the water on the gate and (*b*) its line of action. Does the force pass through point *O*?



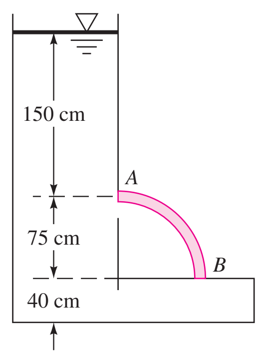
P2.88

P2.89 The tank in Fig. P2.89 contains benzene and is pressurized to 200 kPa (gage) in the air gap. Determine the vertical hydrostatic force on circular-arc section *AB* and its line of action.



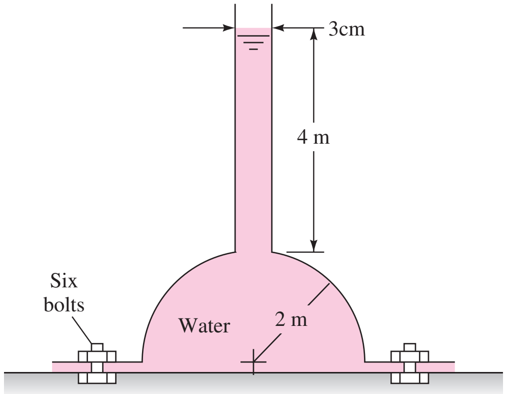
P2.89

P2.90 The tank in Fig. P2.90 is 120 cm long into the paper. Determine the horizontal and vertical hydrostatic forces on the quarter-circle panel *AB*. The fluid is water at 20°C. Neglect atmospheric pressure.



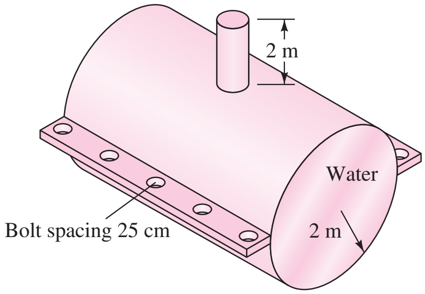
P2.90

P2.91 The hemispherical dome in Fig. P2.91 weighs 30 kN and is filled with water and attached to the floor by six equally spaced bolts. What is the force in each bolt required to hold down the dome?



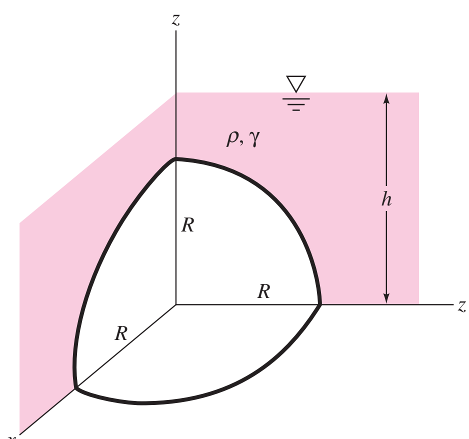
P2.91

P2.92 A 4-m-diameter water tank consists of two half cylinders, each weighing 4.5 kN/m, bolted together as shown in Fig. P2.92. If the support of the end caps is neglected, determine the force induced in each bolt.



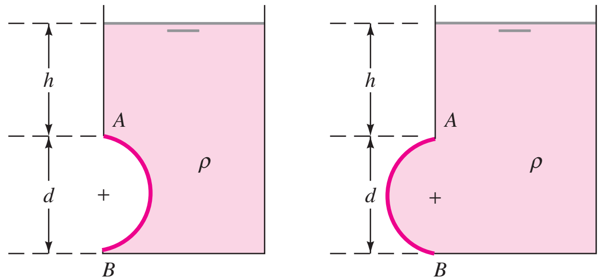
P2.92

***P2.93** In Fig. P2.93, a one-quadrant spherical shell of radius R is submerged in liquid of specific weight γ and depth $h > R$. Find an analytic expression for the resultant hydrostatic force, and its line of action, on the shell surface.



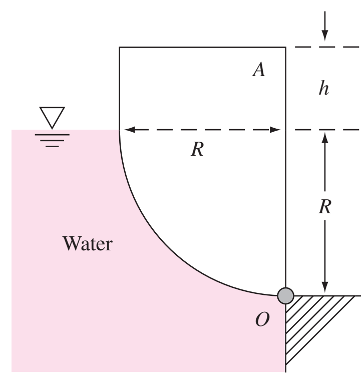
P2.93

P2.94 Find an analytic formula for the vertical and horizontal forces on each of the semicircular panels AB in Fig. P2.94. The width into the paper is b. Which force is larger? Why?



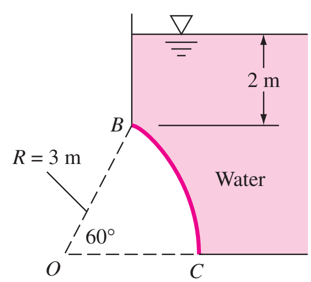
P2.94

***P2.95** The uniform body A in Fig. P2.95 has width b into the paper and is in static equilibrium when pivoted about hinge O. What is the specific gravity of this body if (*a*) $h = 0$ and (*b*) $h = R$?



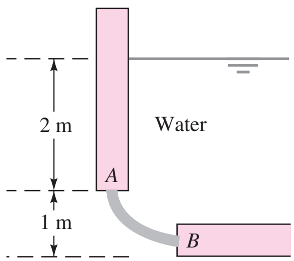
P2.95

P2.96 Curved panel BC in Fig. P2.96 is a 60° arc, perpendicular to the bottom at C. If the panel is 4 m wide into the paper, estimate the resultant hydrostatic force of the water on the panel.



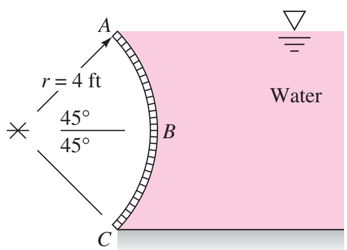
P2.96

P2.97 The contractor ran out of gunite mixture and finished the deep corner, of a 5-m-wide swimming pool, with a quarter-circle piece of PVC pipe, labeled *AB* in Fig. P2.97. Compute the horizontal and vertical water forces on the curved panel *AB*.



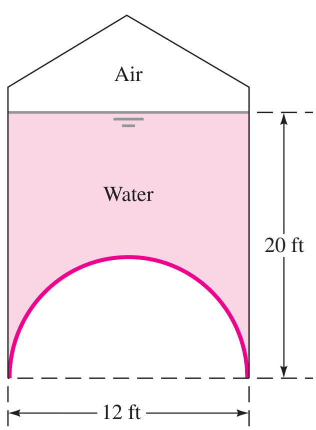
P2.97

P2.98 Gate *ABC* in Fig. P2.98 is a quarter circle 8 ft wide into the paper. Compute the horizontal and vertical hydrostatic forces on the gate and the line of action of the resultant force.



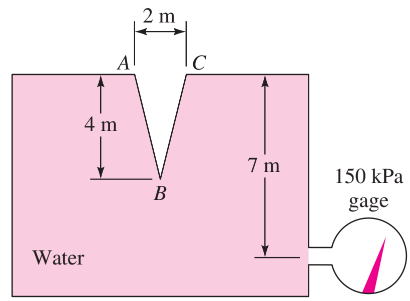
P2.98

P2.99 The mega-magnum cylinder in Fig. P2.99 has a hemispherical bottom and is pressurized with air to 75 kPa (gage) at the top. Determine (*a*) the horizontal and (*b*) the vertical hydrostatic forces on the hemisphere, in lbf.



P2.99

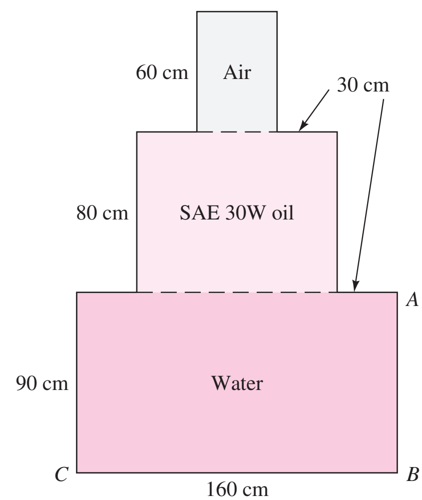
P2.100 Pressurized water fills the tank in Fig. P2.100. Compute the net hydrostatic force on the conical surface *ABC*.



P2.100

Forces on layered surfaces

P2.101 The closed layered box in Fig. P2.101 has square horizontal cross sections everywhere. All fluids are at 20°C. Estimate the gage pressure of the air if (*a*) the hydrostatic force on panel *AB* is 48 kN or (*b*) the hydrostatic force on the bottom panel *BC* is 97 kN.



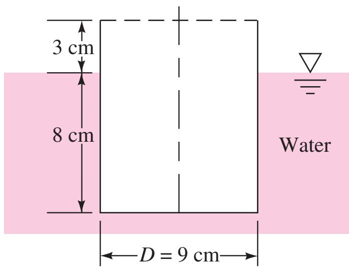
P2.101

P2.102 A cubical tank is 3 × 3 × 3 m and is layered with 1 meter of fluid of specific gravity 1.0, 1 meter of fluid with SG = 0.9, and 1 meter of fluid with SG = 0.8. Neglect atmospheric pressure. Find (*a*) the hydrostatic force on the bottom and (*b*) the force on a side panel.

Buoyancy; Archimedes'principles

P2.103 A solid block, of specific gravity 0.9, floats such that 75 percent of its volume is in water and 25 percent of its volume is in fluid *X*, which is layered above the water. What is the specific gravity of fluid *X*?

P2.104 The can in Fig. P2.104 floats in the position shown. What is its weight in N?



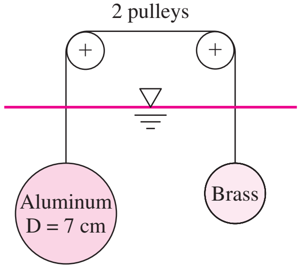
P2.104

P2.105 It is said that Archimedes discovered the buoyancy laws when asked by King Hiero of Syracuse to determine whether his new crown was pure gold (SG = 19.3). Archimedes measured the weight of the crown in air to be 11.8 N and its weight in water to be 10.9 N. Was it pure gold?

P2.106 A spherical helium balloon is 2.5 m in diameter and has a total mass of 6.7 kg. When released into the U.S. standard atmosphere, at what altitude will it settle?

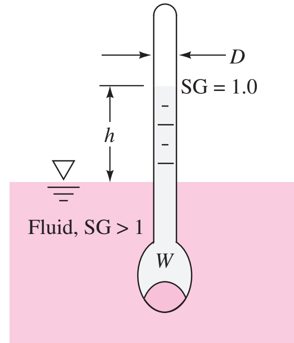
P2.107 Repeat Prob. 2.62, assuming that the 10,000-lbf weight is aluminum (SG = 2.71) and is hanging submerged in the water.

P2.108 A 7-cm-diameter solid aluminum ball (SG = 2.7) and a solid brass ball (SG = 8.5) balance nicely when submerged in a liquid, as in Fig. P2.108. (*a*) If the fluid is water at 20°C, what is the diameter of the brass ball? (*b*) If the brass ball has a diameter of 3.8 cm, what is the density of the fluid?



P2.108

P2.109 A *hydrometer* floats at a level that is a measure of the specific gravity of the liquid. The stem is of constant diameter D, and a weight in the bottom stabilizes the body to float vertically, as shown in Fig. P2.109. If the position $h = 0$ is pure water (SG = 1.0), derive a formula for h as a function of total weight W, D, SG, and the specific weight γ_0 of water.

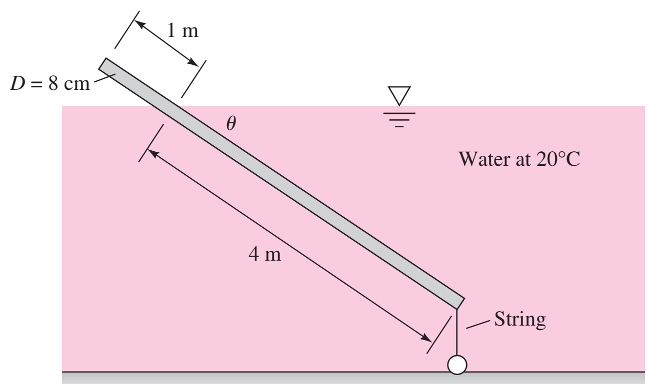


P2.109

P2.110 A solid sphere, of diameter 18 cm, floats in 20°C water with 1,527 cubic centimeters exposed above the surface. (*a*) What are the weight and specific gravity of this sphere? (*b*) Will it float in 20°C gasoline? If so, how many cubic centimeters will be exposed?

P2.111 A hot-air balloon must be designed to support basket, cords, and one person for a total weight of 1300 N. The balloon material has a mass of 60 g/m^2. Ambient air is at 25°C and 1 atm. The hot air inside the balloon is at 70°C and 1 atm. What diameter spherical balloon will just support the total weight? Neglect the size of the hot-air inlet vent.

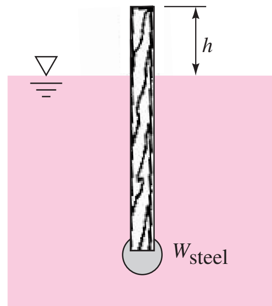
P2.112 The uniform 5-m-long round wooden rod in Fig. P2.112 is tied to the bottom by a string. Determine (*a*) the tension in the string and (*b*) the specific gravity of the wood. Is it possible for the given information to determine the inclination angle θ? Explain.



P2.112

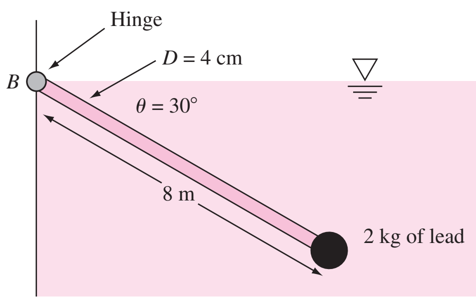
P2.113 A *spar buoy* is a buoyant rod weighted to float and protrude vertically, as in Fig. P2.113. It can be used for measurements or markers. Suppose that the buoy is maple wood (SG = 0.6), 2 in by 2 in by 12 ft, floating in seawater

(SG = 1.025). How many pounds of steel (SG = 7.85) should be added to the bottom end so that h = 18 in?



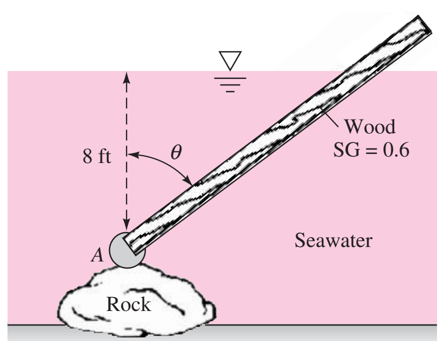
P2.113

P2.114 The uniform rod in Fig. P2.114 is hinged at point B on the waterline and is in static equilibrium as shown when 2 kg of lead (SG = 11.4) are attached to its end. What is the specific gravity of the rod material? What is peculiar about the rest angle θ = 30°?



P2.114

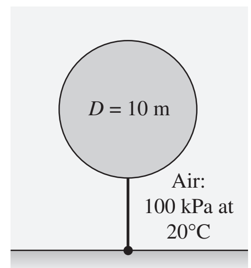
P2.115 The 2-in by 2-in by 12-ft spar buoy from Fig. P2.113 has 5 lbm of steel attached and has gone aground on a rock, as in Fig. P2.115. Compute the angle θ at which the buoy will lean, assuming that the rock exerts no moments on the spar.



P2.115

P2.116 The deep submersible vehicle ALVIN in the chapter-opener photo has a hollow titanium (SG = 4.50) spherical passenger compartment with an inside diameter of 78.08 in and a wall thickness of 1.93 in. (*a*) Would the empty sphere float in seawater? (*b*) Would it float if it contained 1000 lbm of people and equipment inside? (*c*) What wall thickness would cause the empty sphere to be neutrally buoyant?

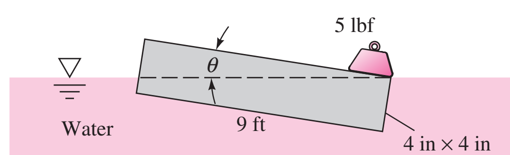
P2.117 The balloon in Fig. P2.117 is filled with helium and pressurized to 135 kPa and 20°C. The balloon material has a mass of 85 g/m^2. Estimate (*a*) the tension in the mooring line and (*b*) the height in the standard atmosphere to which the balloon will rise if the mooring line is cut.



P2.117

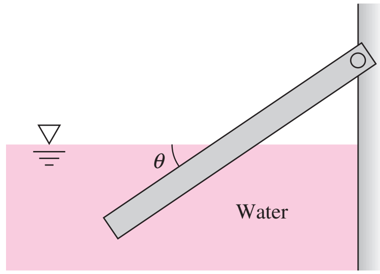
P2.118 An intrepid treasure-salvage group has discovered a steel box, containing gold doubloons and other valuables, resting in 80 ft of seawater. They estimate the weight of the box and treasure (in air) at 7000 lbf. Their plan is to attach the box to a sturdy balloon, inflated with air to 3 atm pressure. The empty balloon weighs 250 lbf. The box is 2 ft wide, 5 ft long, and 18 in high. What is the proper diameter of the balloon to ensure an upward lift force on the box that is 20 percent more than required?

P2.119 When a 5-lbf weight is placed on the end of the uniform floating wooden beam in Fig. P2.119, the beam tilts at an angle θ with its upper right corner at the surface, as shown. Determine (*a*) the angle θ and (*b*) the specific gravity of the wood. *Hint:* Both the vertical forces and the moments about the beam centroid must be balanced.



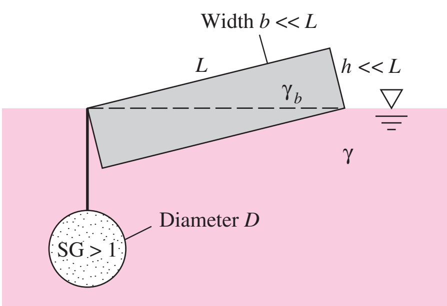
P2.119

P2.120 A uniform wooden beam (SG = 0.65) is 10 cm by 10 cm by 3 m and is hinged at A, as in Fig. P2.120. At what angle θ will the beam float in the 20°C water?



P2.120

P2.121 The uniform beam in Fig. P2.121, of size L by h by b and with specific weight γ_b, floats exactly on its diagonal when a heavy uniform sphere is tied to the left corner, as

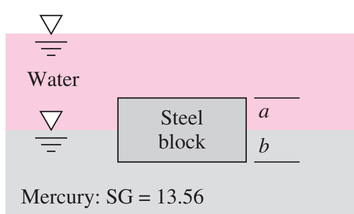


P2.121

shown. Show that this can happen only (*a*) when $\gamma_b = \gamma/3$ and (*b*) when the sphere has size

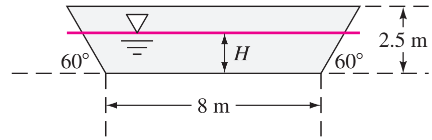
$$D = \left[\frac{Lhb}{\pi(\text{SG} - 1)}\right]^{1/3}$$

P2.122 A uniform block of steel (SG = 7.85) will "float" at a mercury–water interface as in Fig. P2.122. What is the ratio of the distances a and b for this condition?



P2.122

P2.123 A barge has the trapezoidal shape shown in Fig. P2.123 and is 22 m long into the paper. If the total weight of barge and cargo is 350 tons, what is the draft H of the barge when floating in seawater?

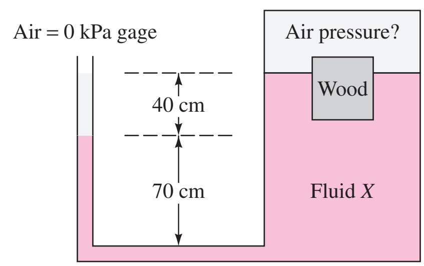


P2.123

P2.124 A balloon weighing 3.5 lbf is 6 ft in diameter. It is filled with hydrogen at 18 lbf/in^2 absolute and 60°F and is released. At what altitude in the U.S. standard atmosphere will this balloon be neutrally buoyant?

P2.125 A solid sphere, of diameter 20 cm, has a specific gravity of 0.7. (*a*) Will this sphere float in 20°C SAE 10W oil? If so, (*b*) how many cubic centimeters are exposed, and (*c*) how high will a spherical cap protrude above the surface? *Note:* If your knowledge of offbeat sphere formulas is lacking, you can "Ask Dr. Math" at Drexel University, **<http://mathforum.org/dr.math/>** EES is recommended for the solution.

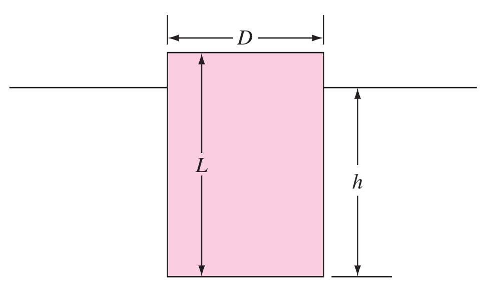
P2.126 A block of wood (SG = 0.6) floats in fluid X in Fig. P2.126 such that 75 percent of its volume is submerged in fluid X. Estimate the vacuum pressure of the air in the tank.



P2.126

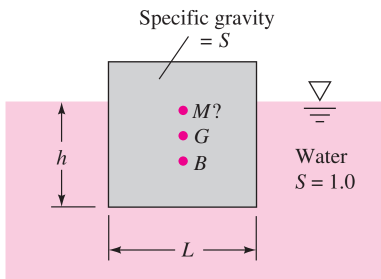
Stability of floating bodies

***P2.127** Consider a cylinder of specific gravity $S < 1$ floating vertically in water ($S = 1$), as in Fig. P2.127. Derive a formula for the stable values of D/L as a function of S and apply it to the case $D/L = 1.2$.



P2.127

P2.128 An iceberg can be idealized as a cube of side length L, as in Fig. P2.128. If seawater is denoted by $S = 1.0$, then glacier ice (which forms icebergs) has $S = 0.88$. Determine if this "cubic" iceberg is stable for the position shown in Fig. P2.128.



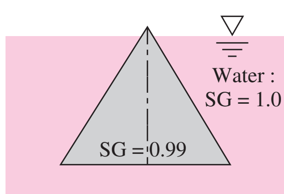
P2.128

P2.129 The iceberg idealization in Prob. P2.128 may become unstable if its sides melt and its height exceeds its width. In Fig. P2.128 suppose that the height is L and the depth into the paper is L, but the width in the plane of the paper is $H < L$. Assuming $S = 0.88$ for the iceberg, find the ratio H/L for which it becomes neutrally stable (about to overturn).

P2.130 Consider a wooden cylinder (SG = 0.6) 1 m in diameter and 0.8 m long. Would this cylinder be stable if placed to float with its axis vertical in oil (SG = 0.8)?

P2.131 A barge is 15 ft wide and 40 ft long and floats with a draft of 4 ft. It is piled so high with gravel that its center of gravity is 3 ft above the waterline. Is it stable?

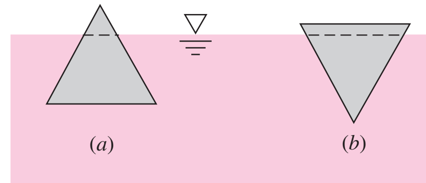
P2.132 A solid right circular cone has SG = 0.99 and floats vertically as in Fig. P2.132. Is this a stable position for the cone?



P2.132

P2.133 Consider a uniform right circular cone of specific gravity $S < 1$, floating with its vertex *down* in water ($S = 1$). The base radius is R *and* the cone height is H. Calculate and plot the stability MG of this cone, in dimensionless form, versus H/R for a range of $S < 1$.

P2.134 When floating in water (SG = 1.0), an equilateral triangular body (SG = 0.9) might take one of the two positions shown in Fig. P2.134. Which is the more stable position? Assume large width into the paper.



P2.134

P2.135 Consider a homogeneous right circular cylinder of length L, radius R, and specific gravity SG, floating in water (SG = 1). Show that the body will be stable with its axis vertical if

$$\frac{R}{L} > [2\mathrm{SG}(1 - \mathrm{SG})]^{1/2}$$

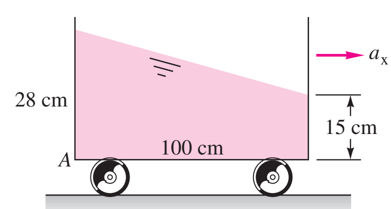
P2.136 Consider a homogeneous right circular cylinder of length L, radius R, and specific gravity SG = 0.5, floating in water (SG = 1). Show that the body will be stable with its axis horizontal if $L/R > 2.0$.

Uniform acceleration

P2.137 A tank of water 4 m deep receives a constant upward acceleration a_z. Determine (*a*) the gage pressure at the tank bottom if $a_z = 5\ \mathrm{m^2/s}$ and (*b*) the value of a_z that causes the gage pressure at the tank bottom to be 1 atm.

P2.138 A 12-fl-oz glass, of 3-in diameter, partly full of water, is attached to the edge of an 8-ft-diameter merry-go-round, which is rotated at 12 r/min. How full can the glass be before water spills? *Hint:* Assume that the glass is much smaller than the radius of the merry-go-round.

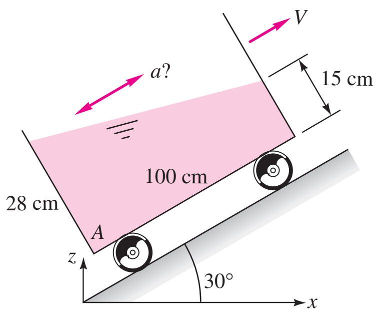
P2.139 The tank of liquid in Fig. P2.139 accelerates to the right with the fluid in rigid-body motion. (*a*) Compute a_x in $\mathrm{m/s^2}$. (*b*) Why doesn't the solution to part (*a*) depend on the density of the fluid? (*c*) Determine the gage pressure at point A if the fluid is glycerin at 20°C.



P2.139

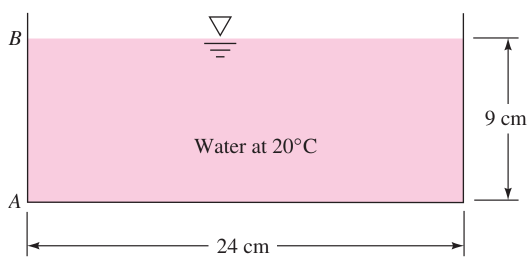
P2.140 Suppose an elliptical-end fuel tank that is 10 m long and has a 3-m horizontal major axis and 2-m vertical major axis is filled completely with fuel oil ($\rho = 890\ \mathrm{kg/m^3}$). Let the tank be pulled along a horizontal road. For rigid-body motion, find the acceleration, and its direction, for which (*a*) a constant-pressure surface extends from the top of the front end wall to the bottom of the back end and (*b*) the top of the back end is at a pressure 0.5 atm lower than the top of the front end.

P2.141 The same tank from Prob. P2.139 is now moving with constant acceleration up a 30° inclined plane, as in Fig. P2.141. Assuming rigid-body motion, compute (*a*) the value of the acceleration *a*, (*b*) whether the acceleration is up or down, and (*c*) the gage pressure at point *A* if the fluid is mercury at 20°C.



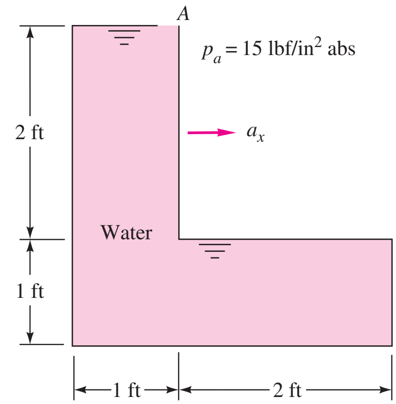
P2.141

P2.142 The tank of water in Fig. P2.142 is 12 cm wide into the paper. If the tank is accelerated to the right in rigid-body motion at 6.0 m/s^2, compute (*a*) the water depth on side *AB* and (*b*) the water-pressure force on panel *AB*. Assume no spilling.



P2.142

P2.143 The tank of water in Fig. P2.143 is full and open to the atmosphere at point *A*. For what acceleration a_x in ft/s^2 will the pressure at point *B* be (*a*) atmospheric and (*b*) zero absolute?

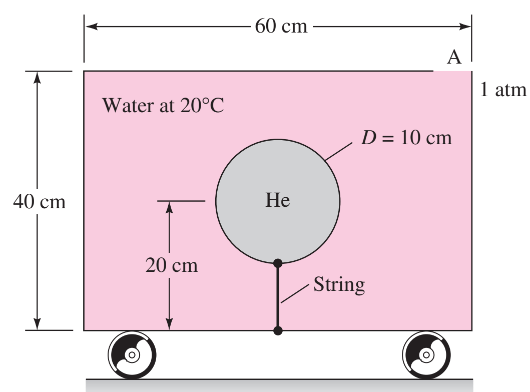


P2.143

P2.144 Consider a hollow cube of side length 22 cm, filled completely with water at 20°C. The top surface of the cube is horizontal. One top corner, point *A*, is open through a small hole to a pressure of 1 atm. Diagonally opposite to point *A* is top corner *B*. Determine and discuss the various rigid-body accelerations for which the water at point *B* begins to cavitate, for (*a*) horizontal motion and (*b*) vertical motion.

P2.145 A fish tank 14 in deep by 16 by 27 in is to be carried in a car that may experience accelerations as high as 6 m/s^2. What is the maximum water depth that will avoid spilling in rigid-body motion? What is the proper alignment of the tank with respect to the car motion?

P2.146 The tank in Fig. P2.146 is filled with water and has a vent hole at point *A*. The tank is 1 m wide into the paper. Inside the tank, a 10-cm balloon, filled with helium at 130 kPa, is tethered centrally by a string. If the tank accelerates to the right at 5 m/s^2 in rigid-body motion, at what angle will the balloon lean? Will it lean to the right or to the left?



P2.146