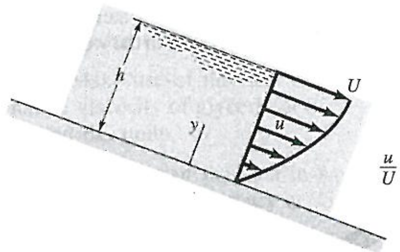
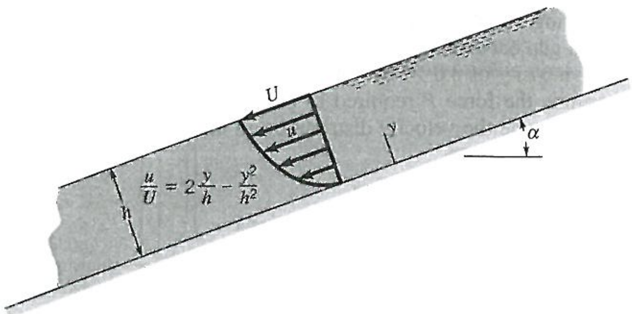


■ **Figure P1.81**

1.82 A thin layer of glycerin flows down an inclined, wide plate with the velocity distribution shown in Fig. P1.82. For $h = 0.3$ in. and $\alpha = 20°$, determine the surface velocity, U. Note that for equilibrium, the component of weight acting parallel to the plate surface must be balanced by the shearing force developed along the plate surface. In your analysis assume a unit plate width.



■ **Figure P1.82**

***1.83** Standard air flows past a flat surface, and velocity measurements near the surface indicate the following distribution:

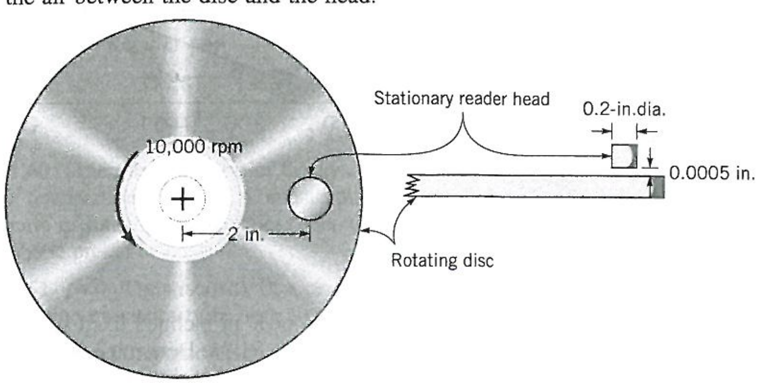
y (ft)	0.005	0.01	0.02	0.04	0.06	0.08
u (ft/s)	0.74	1.51	3.03	6.37	10.21	14.43

The coordinate y is measured normal to the surface and u is the velocity parallel to the surface. **(a)** Assume the velocity distribution is of the form

$$u = C_1 y + C_2 y^3$$

and use a standard curve-fitting technique to determine the constants C_1 and C_2. **(b)** Make use of the results of part (a) to determine the magnitude of the shearing stress at the wall ($y = 0$) and at $y = 0.05$ ft.

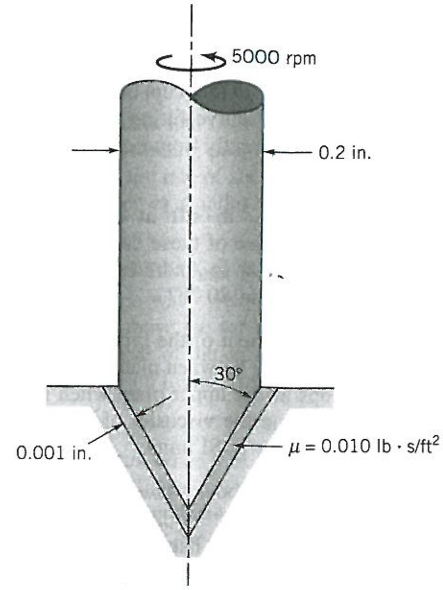
1.84 A new computer drive is proposed to have a disc, as shown in Fig. P1.84. The disc is to rotate at 10,000 rpm, and the reader head is to be positioned 0.0005 in. above the surface of the disc. Estimate the shearing force on the reader head as a result of the air between the disc and the head.



■ **Figure P1.84**

1.85 The space between two 6-in.-long concentric cylinders is filled with glycerin (viscosity $= 8.5 \times 10^{-3}$ lb · s/ft²). The inner cylinder has a radius of 3 in. and the gap width between cylinders is 0.1 in. Determine the torque and the power required to rotate the inner cylinder at 180 rev/min. The outer cylinder is fixed. Assume the velocity distribution in the gap to be linear.

1.86 A pivot bearing used on the shaft of an electrical instrument is shown in Fig. P1.86. An oil with a viscosity of $\mu = 0.010$ lb · s/ft² fills the 0.001-in. gap between the rotating shaft and the stationary base. Determine the frictional torque on the shaft when it rotates at 5000 rpm.

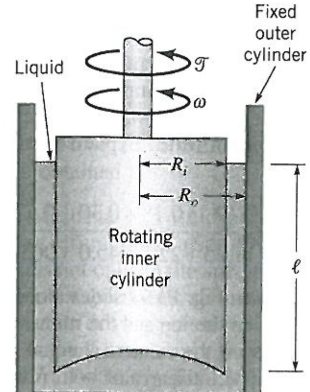


■ **Figure P1.86**

1.87 The viscosity of liquids can be measured through the use of a *rotating cylinder viscometer* of the type illustrated in Fig. P1.87. In this device the outer cylinder is fixed and the inner cylinder is rotated with an angular velocity, ω. The torque $\mathcal{T}$ required to develop ω is measured and the viscosity is calculated from these two measurements. **(a)** Develop an equation relating μ, ω, $\mathcal{T}$, ℓ, R_o, and R_i. Neglect end effects and assume the velocity distribution in the gap is linear. **(b)** The following torque-angular velocity data were obtained with a rotating cylinder viscometer of the type discussed in part (a).

Torque (ft · lb)	13.1	26.0	39.5	52.7	64.9	78.6
Angular velocity (rad/s)	1.0	2.0	3.0	4.0	5.0	6.0

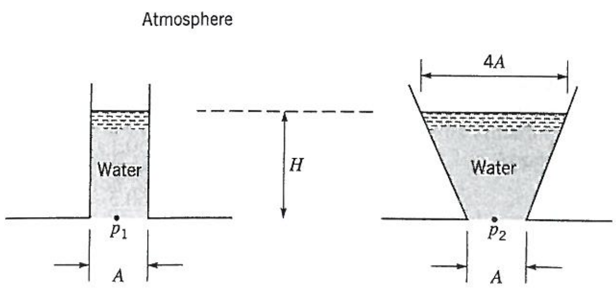
For this viscometer $R_o = 2.50$ in., $R_i = 2.45$ in., and $\ell = 5.00$ in. Make use of these data and a standard curve-fitting program to determine the viscosity of the liquid contained in the viscometer.



■ **Figure P1.87**

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.

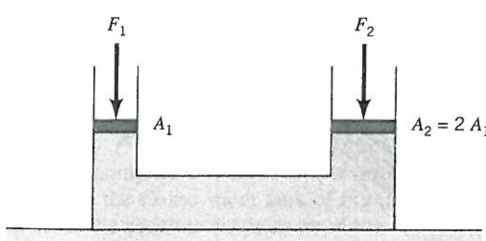


The relation between the pressures p_1 and p_2 at the base of the tubes is:

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:

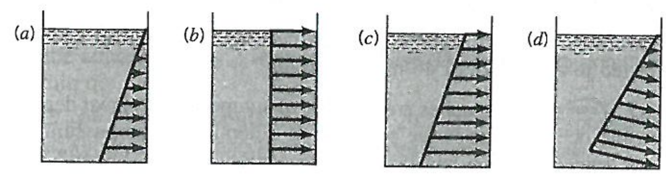
a) gravity, shear, and normal forces.

b) gravity and normal forces.

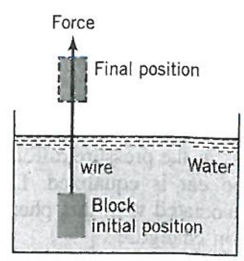
c) gravity and shear forces.

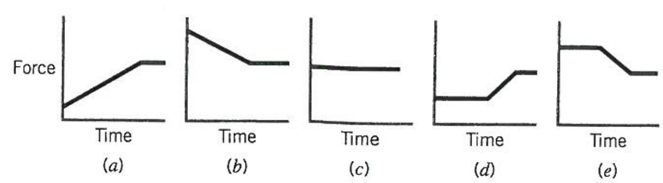
d) normal and shear forces.

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 web site, 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 6 lb/in.^{2} and the depth of glycerin is 10 ft, what is the pressure in lb/ft^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 WILEY 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 80 ft 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 psi.

2.7 WILEY 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 WILEY 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 and psi.

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 psi) associated with this phenomenon if it occurs during a 150-ft 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 (ft)	γ (lb/ft^3)
0	70
10	76
20	84
30	91
40	97
50	102
60	107
70	110
80	112
90	114
100	115

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 psf) versus depth (in feet).

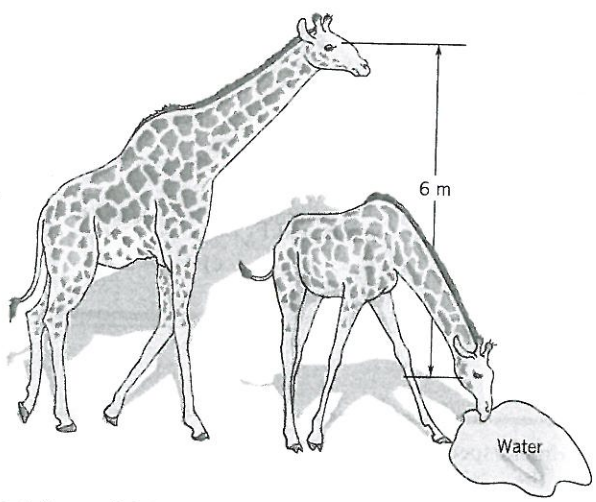
†2.14 Because of elevation differences, the water pressure in the second floor of your house is lower than it is in the first floor. For tall buildings this pressure difference can become unacceptable. Discuss possible ways to design the water distribution system in very tall buildings so that the hydrostatic 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 12.1 psia, determine by means of numerical integration the pressure at the top of the mountain.

Elevation (ft)	Temperature (°F)
5000	50.1 (base)
5500	55.2
6000	60.3
6400	62.6
7100	67.0
7400	68.4
8200	70.0
8600	69.5
9200	68.0
9900	67.1 (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 7 psia corresponds to what gage pressure for standard atmospheric pressure of 14.7 psia?

2.20 WILEY Assume that a person skiing high in the mountains at an altitude of 15,000 ft 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 Pikes Peak near Denver, Colorado, has an elevation of 14,110 ft. (**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 0.07647 lb/ft^3, what would the pressure be at this altitude? (**c**) If the air is assumed to have a constant temperature of 59 °F, 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 25.8 in. 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 29.97 in. of mercury. What would the barometer reading be when you carry it up to the observation deck 500 ft above the base of the monument?

2.26 Aneroid barometers can be used to measure changes in altitude. If a barometer reads 30.1 in. Hg at one elevation, what has been the change in altitude in meters when the barometer reading is 28.3 in. Hg? Assume a standard atmosphere and that Eq. 2.12 is applicable over the range of altitudes of interest.

2.27 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 5 psi. What is the absolute air pressure in the tank? Assume standard atmospheric pressure of 14.7 psi.

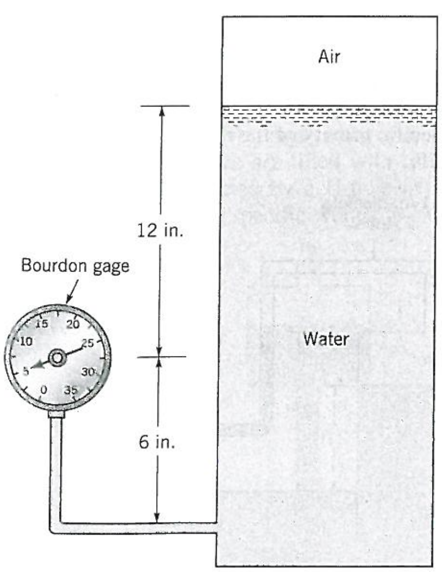


Figure P2.27

2.28 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 77.0 psi 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 5 ft above the base of the tank. The water level in the other side of the U-tube (which is open to the atmosphere) is 2 ft above the base. Determine the pressure within the tank.

2.32 A barometric pressure of 29.4 in. Hg corresponds to what value of atmospheric pressure in psia, and in pascals?

2.33 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 5 ft long. The pressure gage on the tank reads 7 psi. 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 14.7 psia.

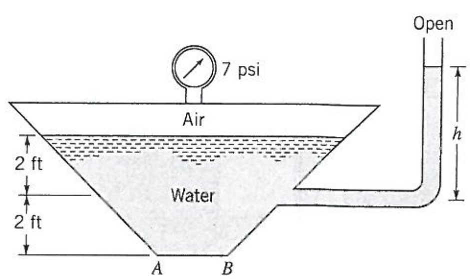


Figure P2.34

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.

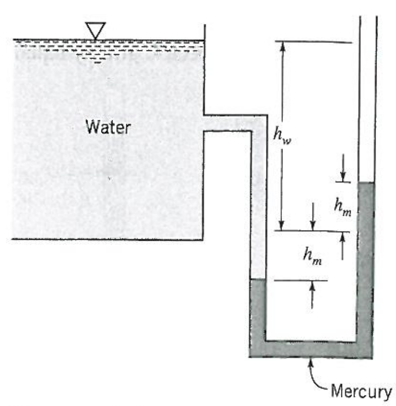
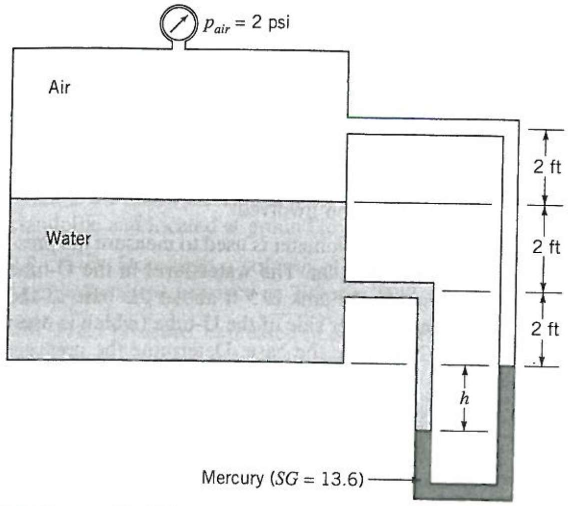


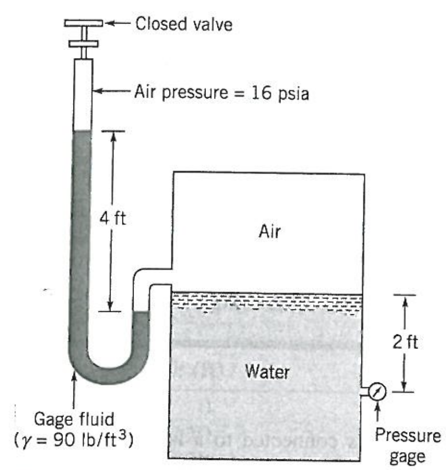
Figure P2.35

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 2 psi, determine the differential reading, h. The specific weight of the air is negligible.



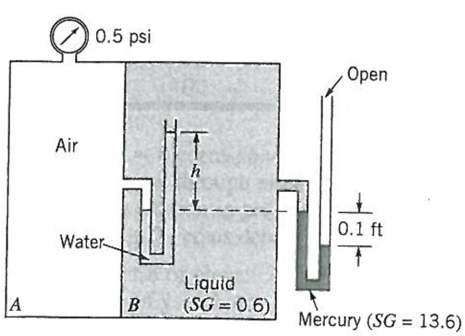
■ **Figure P2.36**

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 16 psia. Determine the reading on the pressure gage for a differential reading of 4 ft on the manometer. Express your answer in psi (gage). Assume standard atmospheric pressure and neglect the weight of the air columns in the manometer.



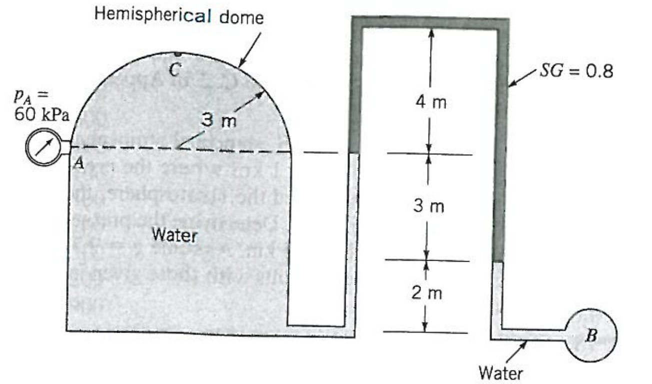
■ **Figure P2.37**

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 14.7 psia and the pressure gage reads 0.5 psi. The effect of the weight of the air is negligible.



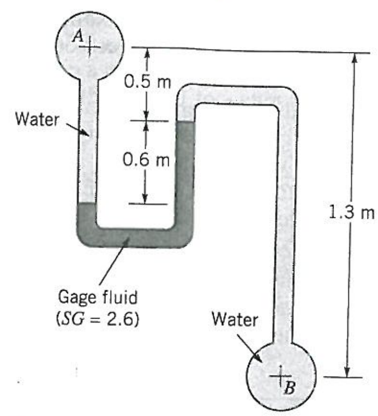
■ **Figure P2.38**

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).



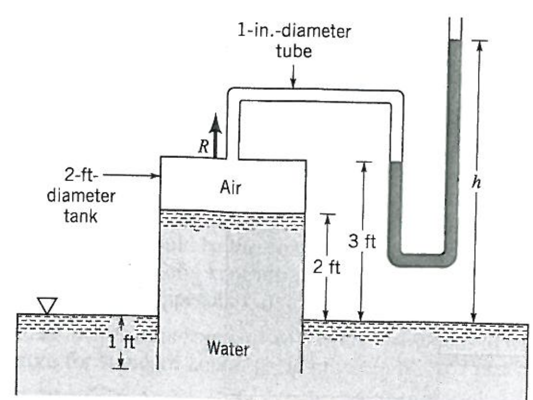
■ **Figure P2.39**

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.



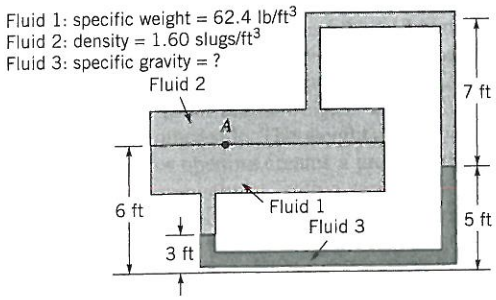
■ **Figure P2.40**

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.



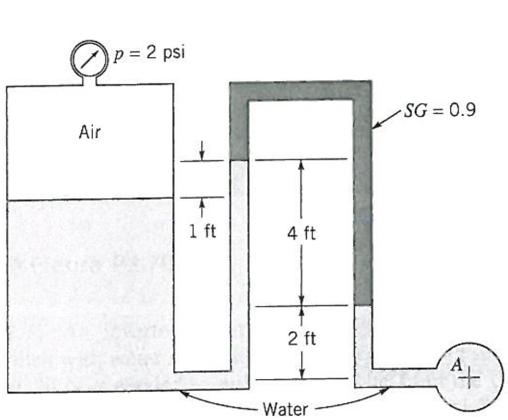
■ **Figure P2.41**

2.55 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.



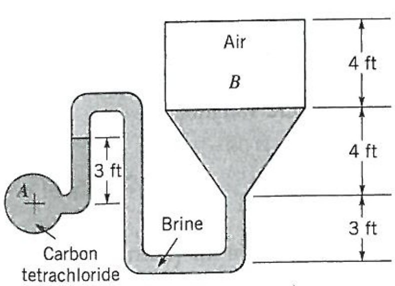
■ **Figure P2.55**

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 2 psi.



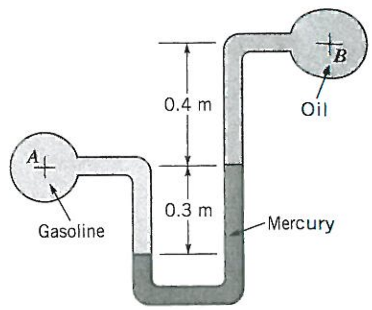
■ **Figure P2.56**

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 25 psi.



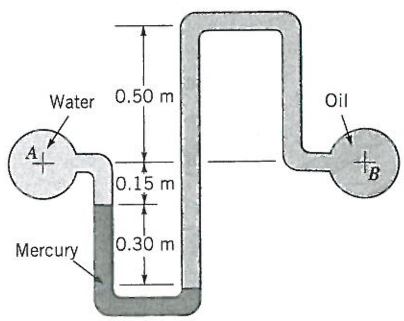
■ **Figure P2.57**

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.



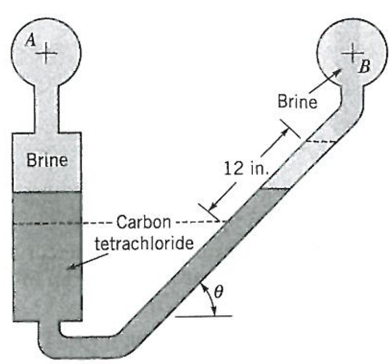
■ **Figure P2.58**

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 12 in. (measured along the inclined tube) for a pressure differential of 0.1 psi. Determine the required angle of inclination, θ.



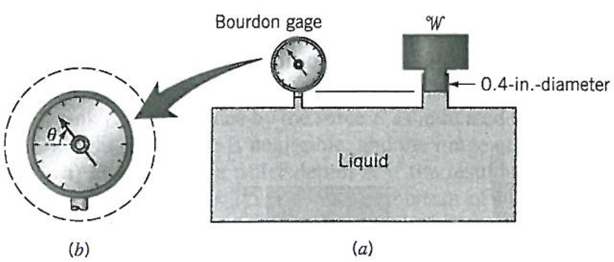
■ **Figure P2.60**

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 1.3 psi and the pressure in pipe B increases by 0.9 psi, determine the new differential reading of the manometer.

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.

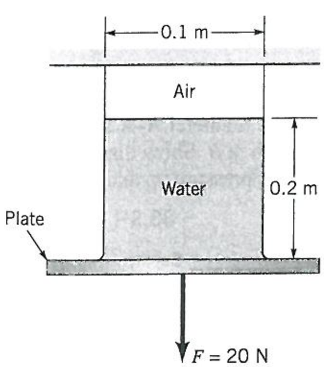
*2.70 A Bourdon gage (see Fig. 2.13 and **Video V2.4**) is often used to measure pressure. One way to calibrate this type of gage is to use the arrangement shown in Fig. P2.70*a*. The container is filled with a liquid and a weight, $\mathcal{W}$, placed on one side with the gage on the other side. The weight acting on the liquid through a 0.4-in.-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 psi.

$\mathcal{W}$ (lb)	0	1.04	2.00	3.23	4.05	5.24	6.31
θ (deg.)	0	20	40	60	80	100	120



■ Figure P2.70

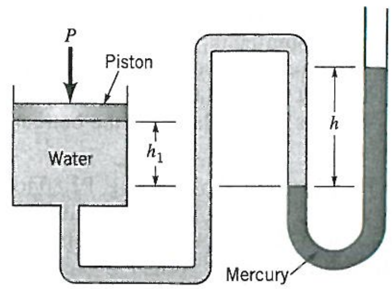
2.71 An inverted 0.1-m-diameter circular cylinder is partially filled with water and held in place as shown in Fig. P2.71. A force of 20 N is needed to pull the flat plate from the cylinder. Determine the air pressure within the cylinder. The plate is not fastened to the cylinder and has negligible mass.



■ Figure P2.71

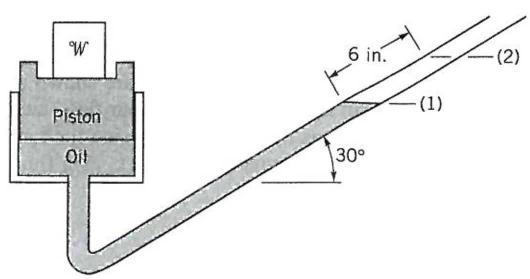
2.72 You partially fill a glass with water, place an index card on top of the glass, and then turn the glass upside down while holding the card in place. You can then remove your hand from the card and the card remains in place, holding the water in the glass. Explain how this works.

2.73 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

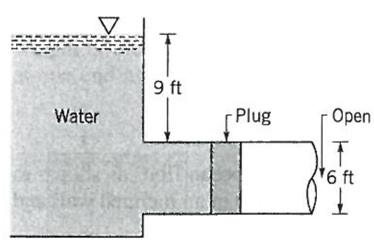
2.74 A 6-in.-diameter piston is located within a cylinder that is connected to a $\frac{1}{2}$-in.-diameter inclined-tube manometer as shown in Fig. P2.74. The fluid in the cylinder and the manometer is oil (specific weight = 59 lb/ft^3). When a weight, $\mathcal{W}$, is placed on the top of the cylinder, 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 6-ft-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.

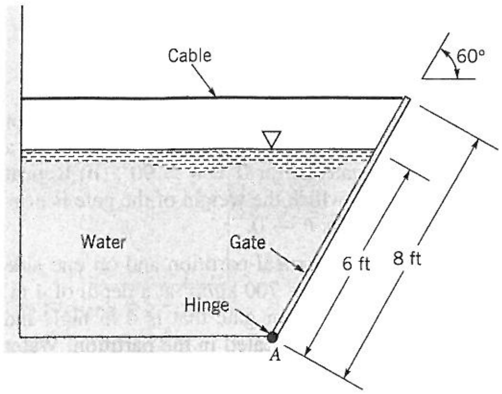


■ Figure P2.76

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.

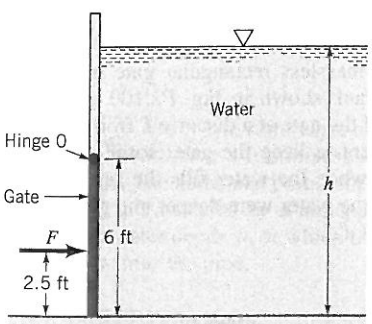
2.78 A vertical rectangular gate is 8 ft wide and 10 ft long and weighs 6000 lb. The gate slides in vertical slots in the side of a reservoir containing water. The coefficient of friction between the slots and the gate is 0.03. Determine the minimum vertical force required to lift the gate when the water level is 4 ft above the top edge of the gate.

2.87 A homogeneous, 4-ft-wide, 8-ft-long rectangular gate weighing 800 lb 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 6 ft tall and 5 ft 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 2.5 ft 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.



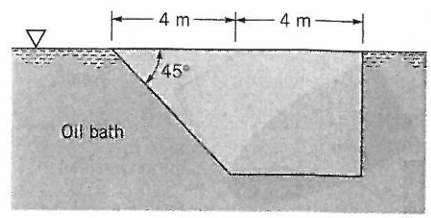
■ **Figure P2.88**

†**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 6 ft and an attitude of 8 ft lies in the plane forming one wall of a tank that contains a liquid having a specific weight of 79.8 lb/ft^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 20 ft above the base of the triangular area. Show, with the aid of a sketch, where the center of pressure is located.

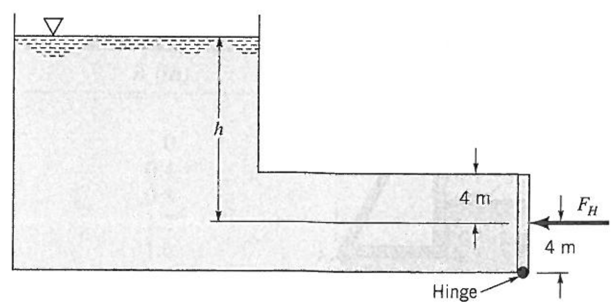
2.91 Solve Problem 2.90 if the isosceles triangle is replaced with a right triangle having the same base width and altitude as the isosceles triangle.

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.



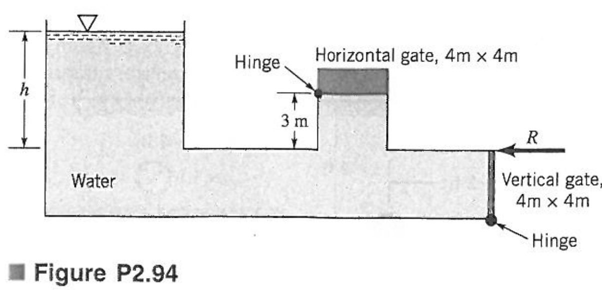
■ **Figure P2.92**

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.



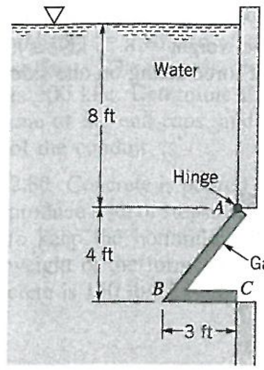
■ **Figure P2.93**

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.



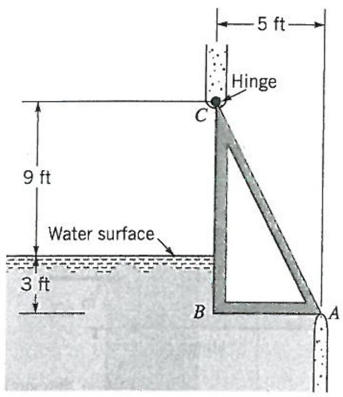
■ **Figure P2.94**

2.95 A gate having the cross section shown in Fig. 2.95 closes an opening 5 ft wide and 4 ft high in a water reservoir. The gate weighs 500 lb, and its center of gravity is 1 ft to the left of *AC* and 2 ft above *BC*. Determine the horizontal reaction that is developed on the gate at *C*.



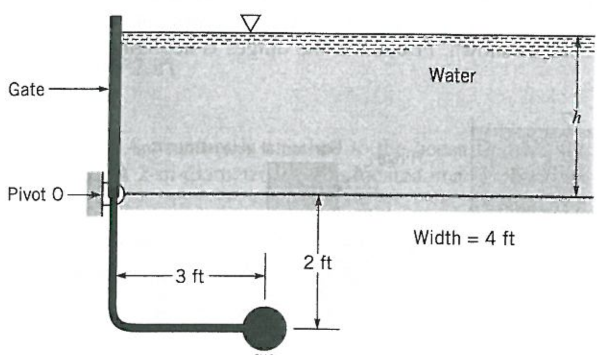
■ **Figure P2.95**

2.96 A gate having the cross section shown in Fig. P2.96 is 4 ft wide and is hinged at C. The gate weighs 18,000 lb, and its mass center is 1.67 ft to the right of the plane BC. Determine the vertical reaction at A on the gate when the water level is 3 ft above the base. All contact surfaces are smooth.



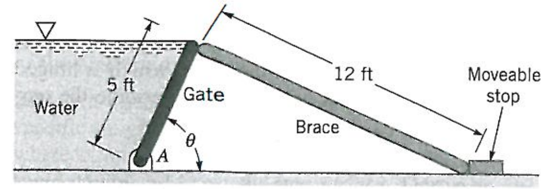
■ **Figure P2.96**

2.97 The massless, 4-ft-wide gate shown in Fig. P2.97 pivots about the frictionless hinge O. It is held in place by the 2000 lb counterweight, $\mathcal{W}$. Determine the water depth, h.



■ **Figure P2.97**

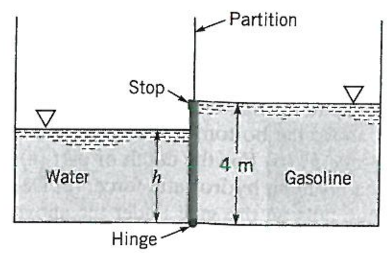
***2.98** A 200-lb homogeneous gate 10 ft wide and 5 ft long is hinged at point A and held in place by a 12-ft-long brace as shown in Fig. P2.98. As the bottom of the brace is moved to the right, the water level remains at the top of the gate. The line of action of the



■ **Figure P2.98**

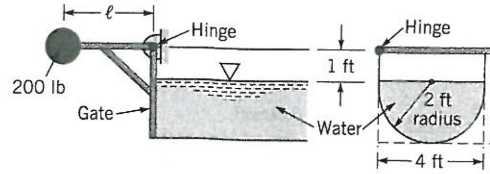
force that the brace exerts on the gate is along the brace. **(a)** Plot the magnitude of the force exerted on the gate by the brace as a function of the angle of the gate, θ, for $0 \leq \theta \leq 90°$. **(b)** Repeat the calculations for the case in which the weight of the gate is negligible. Common 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 4-ft by 3-ft massless rectangular gate is used to close the end of the water tank shown in Fig. P2.100. A 200-lb 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 2 ft, 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?