Answers to Even Numbered Problems

2. (a) $3.14 \times 10^4$ N  
(b) $6.28 \times 10^4$ N

4. $1.65 \times 10^8$ Pa

6. 22 N directed down the page in the figure

8. $7.5 \times 10^6$ Pa

10. (a) 2.5 mm  
(b) 0.75 mm  
(c) $6.9 \times 10^3$ kg

12. The stress is $5.6 \times 10^7$ Pa, so the arm should survive.

14. $1.9 \times 10^4$ N

16. $1.2 \times 10^6$ Pa

18. (a) $-0.0538 \text{ m}^3$  
(b) $1.09 \times 10^3 \text{ kg/m}^3$  
(c) Yes, in most practical circumstances.

20. (a) 65.1 N  
(b) 275 N

22. 10.5 m; no, some alcohol and water evaporate.

24. 2.3 lb

26. 0.611 kg

28. 10.7% of the volume is exposed

30. (a) 1 017.9 N, 1 029.7 N  
(b) 86.2 N  
(c) 11.8 N for both

32. $1.28 \times 10^4 \text{ m}^2$

34. 16.5 cm

36. (a) $8.57 \times 10^3 \text{ kg/m}^3$  
(b) 714 kg/m$^3$

38. 78 kg

40. 154 in/s

42. (a) 11.0 m/s  
(b) $2.64 \times 10^4$ Pa
44. $4.4 \times 10^{-2} \text{ Pa}$

46. (a) $17.7 \text{ m/s}$  (b) $1.73 \text{ mm}$

48. (a) $15.1 \text{ MPa}$  (b) $2.95 \text{ m/s}$  (c) $4.34 \text{ kPa}$

50. $347 \text{ m/s}$

52. $7.32 \times 10^{-2} \text{ N/m}$

54. $5.6 \text{ m}$

56. $0.694 \text{ mm}$

58. $0.12 \text{ N}$

60. $1.5 \text{ m/s}$

62. $1.5 \times 10^5 \text{ Pa}$

64. $455 \text{ kPa}$

66. $8.0 \text{ cm/s}$

68. $9.5 \times 10^{-10} \text{ m}^2/\text{s}$

70. $1.02 \times 10^3 \text{ kg/m}^3$

72. (b) $1.25 \times 10^6 \text{ Pa}$

74. (a) $10.3 \text{ m}$  (b) zero

78. $1.9 \text{ m}$

80. (a) $1.25 \text{ cm}$  (b) $13.8 \text{ m/s}$

82. $0.72 \text{ mm}$

84. (b) $26 \text{ kN}$

86. (a) $18.3 \text{ mm}$  (b) $14.3 \text{ mm}$  (c) $8.56 \text{ mm}$

88. $1.71 \text{ cm}$

90. $0.86 \text{ mm}$
9.6 From \( Y = \frac{FL_0}{A(\Delta L)} \), the tension needed to stretch the wire by 0.10 mm is

\[
F = \frac{YA(\Delta L)}{L_0} = \frac{Y \left( \pi d^2 \right)(\Delta L)}{4L_0}
\]

\[
= \left( 18 \times 10^{10} \text{ Pa} \right) \pi \left( 0.22 \times 10^{-3} \text{ m} \right)^2 \left( 0.10 \times 10^{-3} \text{ m} \right) = 22 \text{ N}
\]

The tension in the wire exerts a force of magnitude \( F \) on the tooth in each direction along the length of the wire as shown in the above sketch. The resultant force exerted on the tooth has an \( x \)-component of \( R_x = \Sigma F_x = -F \cos 30^\circ + F \cos 30^\circ = 0 \), and a \( y \)-component of \( R_y = \Sigma F_y = -F \sin 30^\circ - F \sin 30^\circ = -F = -22 \text{ N} \).

Thus, the resultant force is

\[
\vec{R} = 22 \text{ N directed down the page in the diagram}.
\]

9.14 Let the weight of the car be \( W \). Then, each tire supports \( \frac{W}{4} \), and the gauge pressure is

\[
P = \frac{F}{A} = \frac{W}{4A}.
\]

Thus, \( W = 4AP = 4 \left( 0.024 \text{ m}^2 \right) \left( 2.0 \times 10^5 \text{ Pa} \right) = 1.9 \times 10^6 \text{ N} \)

9.17 The volume of concrete in a pillar of height \( h \) and cross-sectional area \( A \) is \( V = Ah \), and its weight is \( F_y = (Ah) \left( 5.0 \times 10^4 \text{ N/m}^3 \right) \). The pressure at the base of the pillar is then

\[
P = \frac{F_y}{A} = \frac{(Ah) \left( 5.0 \times 10^4 \text{ N/m}^3 \right)}{A} = h \left( 5.0 \times 10^4 \text{ N/m}^3 \right)
\]

Thus, if the maximum acceptable pressure is, \( P_{\text{max}} = 1.7 \times 10^7 \text{ Pa} \), the maximum allowable height is

\[
h_{\text{max}} = \frac{P_{\text{max}}}{5.0 \times 10^4 \text{ N/m}^3} = \frac{1.7 \times 10^7 \text{ Pa}}{5.0 \times 10^4 \text{ N/m}^3} = 34 \times 10^2 \text{ m}
\]

9.24 First, use Pascal’s principle, \( F_1/A_1 = F_2/A_2 \), to find the force piston 1 will exert on the handle when a 500-lb force pushes downward on piston 2.

Free-Body Diagram of Handle
$F_1 = \left( \frac{A_1}{A_2} \right) F_2^* = \left( \frac{\pi d_1^2 / 4}{\pi d_2^2 / 4} \right) F_2^* = \left( \frac{d_1^2}{d_2^2} \right) F_2^*$

$$= \left( \frac{0.25 \text{ in}}{1.5 \text{ in}} \right)^2 (500 \text{ lb}) = 14 \text{ lb}$$

Now, consider an axis perpendicular to the page, passing through the left end of the jack handle. \( \Sigma \tau = 0 \) yields

$$+(14 \text{ lb})(2.0 \text{ in}) - F \cdot (12 \text{ in}) = 0 \quad \text{or} \quad F = 2.3 \text{ lb}$$

9.25 Pascal’s principle, \( F_1/A_1 = F_2/A_2 \), gives

$$F_{\text{brake}} = \left( \frac{A_{\text{brake cylinder}}}{A_{\text{master cylinder}}} \right) F_{\text{pedal}} = \left( \frac{1.8 \text{ cm}^2}{6 \text{ cm}^2} \right) (44 \text{ N}) = 12.4 \text{ N}.$$

This is the normal force exerted on the brake shoe. The frictional force is

$$f = \mu_n n = 0.50 (12.4 \text{ N}) = 6.2 \text{ N},$$

and the torque is

$$\tau = f \cdot x_{\text{brake}} = (6.2 \text{ N})(0.34 \text{ m}) = 2.1 \text{ N} \cdot \text{m}$$

9.27 The boat sinks until the weight of the additional water displaced equals the weight of the truck. Thus,

$$W_{\text{truck}} = [\rho_{\text{water}} (\Delta V)] g$$

$$= \left( 10^3 \frac{\text{kg}}{\text{m}^3} \right) \left[ (4.00 \text{ m})(6.00 \text{ m})(4.00 \times 10^{-2} \text{ m}) \right] \left( 9.80 \frac{\text{m}}{\text{s}^2} \right),$$

or

$$W_{\text{truck}} = 9.41 \times 10^3 \text{ N} = 9.41 \text{ kN}$$

9.30 Note: We deliberately violate the rules of significant figures in this problem to illustrate a point.

(a) The absolute pressure at the level of the top of the block is

$$P_{\text{top}} = P_0 + \rho_{\text{water}} gh_{\text{top}}$$

$$= 1.0130 \times 10^5 \text{ Pa} + \left( 10^3 \frac{\text{kg}}{\text{m}^3} \right) \left( 9.80 \frac{\text{m}}{\text{s}^2} \right) (5.00 \times 10^{-2} \text{ m})$$

$$= 1.0179 \times 10^5 \text{ Pa}$$

and that at the level of the bottom of the block is
\[ F_{\text{bottom}} = P_0 + \rho_{\text{water}} gh_{\text{bottom}} \]
\[ = 1 \times 10^5 \text{ Pa} + \left( 1 \times 10^3 \frac{\text{kg}}{\text{m}^3} \right) \left( 9.80 \frac{\text{m}}{\text{s}^2} \right) \left( 1.70 \times 10^{-2} \text{ m} \right) \]
\[ = 1 \times 10^5 \text{ Pa} \]

Thus, the downward force exerted on the top by the water is
\[ F_{\text{top}} = P_{\text{top}} A = \left( 1 \times 10^5 \text{ Pa} \right) (0.100 \text{ m})^2 = 1017.9 \text{ N} \]
and the upward force the water exerts on the bottom of the block is
\[ F_{\text{bot}} = P_{\text{bot}} A = \left( 1 \times 10^5 \text{ Pa} \right) (0.100 \text{ m})^2 = 1029.7 \text{ N} \]

(b) The scale reading equals the tension, \( T \), in the cord supporting the block. Since the block is in equilibrium, \( \Sigma F_y = T + F_{\text{bot}} - F_{\text{top}} - mg = 0 \), or
\[ T = \left( 10 \lambda \text{ kg} \right) \left( 9.80 \frac{\text{m}}{\text{s}^2} \right) - (1029.7 - 1017.9) \text{ N} = 86.2 \text{ N} \]

(c) From Archimedes’ principle, the buoyant force on the block equals the weight of the displaced water. Thus,
\[ B = \left( \rho_{\text{water}} V_{\text{block}} \right) g \]
\[ = \left( 1 \times 10^3 \frac{\text{kg}}{\text{m}^3} \right) \left[ (0.100 \text{ m})^2 (0.120 \text{ m}) \right] (9.80 \frac{\text{m}}{\text{s}^2}) = 118 \text{ N} \]
From part (a), \( F_{\text{bot}} - F_{\text{top}} = (1029.7 - 1017.9) \text{ N} = 118 \text{ N} \), which is the same as the buoyant force found above.

9.33 The balloon is in equilibrium under the action of three forces. These are the buoyant force, \( B \), the total weight, \( W \), of the balloon and the helium, and the tension \( T \) in the string. Hence,
\[ \Sigma F_y = B - \left( m_{\text{balloon}} + m_{\text{helium}} \right) g - T = 0 \]
or \( T = B - \left( m_{\text{balloon}} + m_{\text{helium}} \right) g \)

The buoyant force is
\[ B = \left( \rho_{\text{air}} V_{\text{balloon}} \right) g \text{ and } m_{\text{helium}} = \rho_{\text{helium}} V_{\text{helium}} \), where \( V_{\text{helium}} = \frac{4\pi r^3}{3} \)

Thus, \( T = \left( \rho_{\text{air}} - \rho_{\text{helium}} \right) g \left( \frac{4\pi r^3}{3} \right) - m_{\text{balloon}} g \)
\[ = \left[ (1.29 - 0.181) \frac{\text{kg}}{\text{m}^3} \right] (9.80 \frac{\text{m}}{\text{s}^2}) \left( \frac{4\pi}{3} \right) (0.500 \text{ m})^3 - (0.0120 \text{ kg}) (9.80 \frac{\text{m}}{\text{s}^2}) \]

or \( T = 5.57 \text{ N} \)

9.34 At equilibrium, \( \Sigma F_y = B - F_{\text{spring}} - mg = 0 \) so the spring force is
\[ F_{\text{spring}} = B - mg = \left[ \left( \rho_{\text{water}} V_{\text{block}} \right) - m \right] g \]
where \( V_{\text{block}} = \frac{m}{\rho_{\text{wood}}} = \frac{5.00 \text{ kg}}{650 \text{ kg/m}^3} = 7.69 \times 10^{-3} \text{ m}^3 \). 

Thus, \( F_{\text{spring}} = \left[ \left( 10^3 \text{ kg/m}^3 \right) \left( 7.69 \times 10^{-3} \text{ m}^3 \right) - 5.00 \text{ kg} \right] \left( 9.80 \text{ m/s}^2 \right) = 264 \text{ N} \)

The elongation of the spring is then
\[
\Delta x = \frac{F_{\text{spring}}}{k} = \frac{264 \text{ N}}{160 \text{ N/m}} = 0.165 \text{ m} = 16.5 \text{ cm}
\]

9.39 The volume of the iron block is
\[
V = \frac{m_{\text{iron}}}{\rho_{\text{iron}}} = \frac{2.00 \text{ kg}}{7.86 \times 10^3 \text{ kg/m}^3} = 2.54 \times 10^{-4} \text{ m}^3
\]

and the buoyant force exerted on the iron by the oil is
\[
B = \rho_{\text{oil}} V = \left( 916 \text{ kg/m}^3 \right) \left( 2.54 \times 10^{-4} \text{ m}^3 \right) \left( 9.80 \text{ m/s}^2 \right) = 2.28 \text{ N}
\]

Applying \( \Sigma F_y = 0 \) to the iron block gives the support force exerted by the upper scale
and hence the reading on that scale as
\[
F_{\text{upper}} = m_{\text{iron}} g - B = 19.6 \text{ N} - 2.28 \text{ N} = 17.3 \text{ N}
\]

From Newton’s third law, the iron exerts force \( B \) downward on the oil (and hence the beaker). Applying \( \Sigma F_y = 0 \) to the system consisting of the beaker and the oil gives
\[
F_{\text{lower}} - B - (m_{\text{oil}} + m_{\text{beaker}}) g = 0
\]

The support force exerted by the lower scale (and the lower scale reading) is then
\[
F_{\text{lower}} = B + (m_{\text{oil}} + m_{\text{beaker}}) g = 2.28 \text{ N} + \left[ \left( 2.00 + 1.00 \right) \text{ kg} \right] \left( 9.80 \text{ m/s}^2 \right) = 31.7 \text{ N}
\]

9.43 From Bernoulli’s equation, choosing \( y = 0 \) at the level of the syringe and needle,
\[
P_2 + \frac{1}{2} \rho v_2^2 = P_1 + \frac{1}{2} \rho v_1^2
\]

so the flow speed in the needle is
\[
v_2 = \sqrt{v_1^2 + \frac{2(P_1 - P_2)}{\rho}}
\]

In this situation,
\[
P_1 - P_2 = P_1 - P_{\text{atm}} = (P_i)_{\text{gauge}} = \frac{F}{A_i} = \frac{2.00 \text{ N}}{2.50 \times 10^{-5} \text{ m}^2} = 8.00 \times 10^4 \text{ Pa}
\]

Thus, assuming \( v_1 \approx 0 \),
\[
v_2 = \sqrt{0 + \frac{2 \left( 8.00 \times 10^4 \text{ Pa} \right)}{1.00 \times 10^3 \text{ kg/m}^3}} = 12.6 \text{ m/s}
\]

9.45 First, consider the path from the viewpoint of projectile motion to find the speed at which the water emerges from the tank. From \( \Delta y = v_{y0} t + \frac{1}{2} a_y t^2 \) with \( v_{y0} = 0 \), we find the time of flight as
From the horizontal motion, the speed of the water coming out of the hole is
\[ v_2 = v_{ox} = \frac{\Delta x}{t} = \frac{0.600 \text{ m}}{0.452 \text{ s}} = 1.33 \text{ m/s} \]

We now use Bernoulli’s equation, with point 1 at the top of the tank and point 2 at the level of the hole. With \( P_1 = P_2 = P_{atm} \) and \( v_1 \approx 0 \), this gives
\[ \rho g y_1 = \frac{1}{2} \rho v_2^2 + \rho g y_2 \], or
\[ h = y_1 - y_2 = \frac{v_2^2}{2g} = \frac{(1.33 \text{ m/s})^2}{2(9.80 \text{ m/s}^2)} = 9.00 \times 10^{-2} \text{ m} = 9.00 \text{ cm} \]

9.47 First, determine the flow speed inside the larger portions from
\[ v_i = \frac{\text{flow rate}}{A_1} = \frac{1.80 \times 10^{-4} \text{ m}^3/\text{s}}{\pi (2.50 \times 10^{-2} \text{ m})^2/4} = 0.367 \text{ m/s} \]

The absolute pressure inside the large section on the left is \( P_1 = P_0 + \rho gh_1 \), where \( h_1 \) is the height of the water in the leftmost standpipe. The absolute pressure in the constriction is \( P_2 = P_0 + \rho gh_2 \), so
\[ P_1 - P_2 = \rho g (h_1 - h_2) = \rho g (5.00 \text{ cm}) \]

The flow speed inside the constriction is found from Bernoulli’s equation with \( y_1 = y_2 \).
This gives \( v_2^2 = v_i^2 + 2(\rho h_1) = v_i^2 + 2g(h_1 - h_2) \), or
\[ v_2 = \sqrt{(0.367 \text{ m/s})^2 + 2(9.80 \text{ m/s}^2)(5.00 \times 10^{-2} \text{ m})} = 1.06 \text{ m/s} \]

The cross-sectional area of the constriction is then
\[ A_2 = \frac{\text{flow rate}}{v_2} = \frac{1.80 \times 10^{-4} \text{ m}^3/\text{s}}{1.06 \text{ m/s}} = 1.71 \times 10^{-4} \text{ m}^2 \]

and the diameter is
\[ d_2 = \sqrt{\frac{4A_2}{\pi}} = \sqrt{\frac{4(1.71 \times 10^{-4} \text{ m}^2)}{\pi}} = 1.47 \times 10^{-2} \text{ m} = 1.47 \text{ cm} \]
9.71  (a) Both iron and aluminum are denser than water, so both blocks will be fully submerged. Since the two blocks have the same volume, they displace equal amounts of water and the buoyant forces acting on the two blocks are equal.

(b) Since the block is held in equilibrium, the force diagram at the right shows that

\[ \sum F_y = 0 \Rightarrow T = m g - B \]

The buoyant force \( \mathbf{B} \) is the same for the two blocks, so the spring scale reading \( T \) is largest for the iron block which has a higher density, and hence weight, than the aluminum block.

(c) The buoyant force in each case is

\[ B = (\rho \text{ water}) g = \left( 1.0 \times 10^3 \text{ kg/m}^3 \right) \left( 0.20 \text{ m} \right) \left( 9.8 \text{ m/s}^2 \right) = 2.0 \times 10^3 \text{ N} \]

For the iron block:

\[ T_{\text{iron}} = (\rho_{\text{iron}}) g - B = \left( 7.86 \times 10^3 \text{ kg/m}^3 \right) \left( 0.20 \text{ m} \right) \left( 9.8 \text{ m/s}^2 \right) - B \]

or \( T_{\text{iron}} = 1.5 \times 10^4 \text{ N} - 2.0 \times 10^3 \text{ N} = 1.3 \times 10^4 \text{ N} \)

For the aluminum block:

\[ T_{\text{aluminum}} = (\rho_{\text{aluminum}}) g - B = \left( 2.70 \times 10^3 \text{ kg/m}^3 \right) \left( 0.20 \text{ m} \right) \left( 9.8 \text{ m/s}^2 \right) - B \]

or \( T_{\text{aluminum}} = 5.2 \times 10^3 \text{ N} - 2.0 \times 10^3 \text{ N} = 3.3 \times 10^3 \text{ N} \)

9.73  The cross-sectional area of the aorta is \( A_1 = \pi d_1^2 / 4 \) and that of a single capillary is \( A_c = \pi d_c^2 / 4 \). If the circulatory system has \( N \) such capillaries, the total cross-sectional area carrying blood from the aorta is

\[ A_2 = N A_c = \frac{N \pi d_c^2}{4} \]

From the equation of continuity,

\[ A_2 = \left( \frac{v_1}{v_2} \right) A_1, \text{ or } \frac{N \pi d_c^2}{4} = \left( \frac{v_1}{v_2} \right) \pi d_1^2 / 4, \]

which gives
\[ N = \left( \frac{v_1}{v_2} \right) \left( \frac{d_1}{d_2} \right)^2 = \left( \frac{1.0 \, \text{m/s}}{1.0 \times 10^{-2} \, \text{m/s}} \right) \left( \frac{0.50 \times 10^{-2} \, \text{m}}{10 \times 10^{-6} \, \text{m}} \right)^2 = 2.5 \times 10^7 \]

9.78 When the balloon comes into equilibrium, the weight of the displaced air equals the weight of the filled balloon plus the weight of string that is above ground level. If \( m_s \) and \( L \) are the total mass and length of the string, the mass of string that is above ground level is \( \left( \frac{h}{L} \right) m_s \). Thus,

\[ \rho_{\text{air}} g V_{\text{balloon}} = m_{\text{balloon}} g + \rho_{\text{helium}} g V_{\text{balloon}} + \left( \frac{h}{L} \right) m_s g, \]

which reduces to

\[ h = \left( \frac{\rho_{\text{air}} - \rho_{\text{helium}}}{m_s} \right) V_{\text{balloon}} - \frac{m_{\text{balloon}}}{m_s} L. \]

This yields

\[ h = \left( 1.29 \, \text{kg/m}^3 - 0.179 \, \text{kg/m}^3 \right) \left[ 4\pi \left( 0.40 \, \text{m} \right)^3 / 3 \right] - 0.25 \, \text{kg} / 0.050 \, \text{kg} = \frac{2.0 \, \text{m}}{2.0 \, \text{m}} = 1.9 \, \text{m} \]

9.81 Consider the diagram and apply Bernoulli’s equation to points A and B, taking \( y = 0 \) at the level of point B, and recognizing that \( v_A \approx 0 \). This gives

\[ P_A + 0 + \rho_w g (h - L \sin \theta) = P_B + \frac{1}{2} \rho_w v_B^2 + 0 \]

Recognize that \( P_A = P_B = P_{\text{atm}} \) since both points are open to the atmosphere. Thus, we obtain

\[ v_A = \sqrt{2g(h - L \sin \theta)} = \sqrt{2(9.80 \, \text{m/s}) \left[ 10.0 \, \text{m} - (2.00 \, \text{m}) \sin 30.0^\circ \right]} = 13.3 \, \text{m/s} \]

Now the problem reduces to one of projectile motion with

\[ v_{0y} = v_B \sin 30.0^\circ = 6.64 \, \text{m/s} \]

At the top of the arc, \( v_y = 0 \), and \( y = y_{\text{max}} \).
Then, \( v_y^2 = v_{oy}^2 + 2a_y(\Delta y) \) gives \( 0 = (6.64 \, \text{m} / \text{s})^2 + 2(-9.80 \, \text{m} / \text{s}^2)(y_{mx} - 0) \),

or \( y_{mx} = 2.25 \, \text{m} \) above the level of point B.

9.87 A water droplet emerging from one of the holes becomes a projectile with \( v_{oy} = 0 \) and \( v_{ox} = v \).

The time for this droplet to fall distance \( h \) to the floor is found from \( \Delta y = v_{oy}t + \frac{1}{2}a_y t^2 \) to be

\[
t = \sqrt{\frac{2h}{g}}
\]

The horizontal range is \( R = vt = v\sqrt{\frac{2h}{g}} \).

If the two streams hit the floor at the same spot, it is necessary that \( R_1 = R_2 \), or

\[
v_y = \sqrt{\frac{2h}{g}} = v_y' = \sqrt{\frac{2h_2}{g}}
\]

With \( h_1 = 5.00 \, \text{cm} \) and \( h_2 = 12.0 \, \text{cm} \), this reduces to

\[
y_1 = v_y = \sqrt{\frac{h_2}{h_1}} = v_y', \quad \text{or} \quad v_1 = v_y'\sqrt{\frac{12.0 \, \text{cm}}{5.00 \, \text{cm}}}
\]

Apply Bernoulli’s equation to points 1 (the lower hole) and 3 (the surface of the water). The pressure is atmospheric pressure at both points and, if the tank is large in comparison to the size of the holes, \( v_1 \approx 0 \). Thus, we obtain

\[
P_{am} + \frac{1}{2} \rho v_1^2 + \rho gh_1 = P_{am} + 0 + \rho gh_3, \quad \text{or} \quad v_1^2 = 2g(h_3 - h_1).
\]

Similarly, applying Bernoulli’s equation to point 2 (the upper hole) and point 3 gives

\[
P_{am} + \frac{1}{2} \rho v_2^2 + \rho gh_2 = P_{am} + 0 + \rho gh_3, \quad \text{or} \quad v_2^2 = 2g(h_3 - h_2).
\]

Square equation (1) and substitute from equations (2) and (3) to obtain

\[
2g(h_3 - h_1) = 2.40 \left[ 2g(h_3 - h_2) \right]
\]

Solving for \( h_3 \) yields

\[
h_3 = \frac{2.40h_2 - h_1}{1.40} = \frac{2.40(12.0 \, \text{cm}) - 5.00 \, \text{cm}}{1.40} = 17.0 \, \text{cm}
\]

so the surface of the water in the tank is \( 17.0 \, \text{cm} \) above floor level.
9.88 Since the block is floating, the total buoyant force must equal the weight of the block. Thus,

\[
\rho_{oil} \left[ A (4.00 \text{ cm} \ - x) \right] g + \rho_{water} \left[ A \cdot x \right] g = \rho_{wood} \left[ A (4.00 \text{ cm}) \right] g
\]

where \( A \) is the surface area of the top or bottom of the rectangular block.

Solving for the distance \( x \) gives

\[
x = \left( \frac{\rho_{water} - \rho_{oil}}{\rho_{wood} - \rho_{oil}} \right) (4.00 \text{ cm}) = \left( \frac{960 - 930}{1000 - 930} \right) (4.00 \text{ cm}) = 1.71 \text{ cm}
\]

9.89 In order for the object to float fully submerged in the fluid, its average density must be the same as that of the fluid. Therefore, we must add ethanol to the water until the density of the mixture is 900 kg/m\(^3\) = 0.900 g/cm\(^3\). The mass of the mixture will be

\[M = \rho V = (0.900 \text{ g/cm}^3) V\]

where \( V \) is the total volume of the mixture.

The mass of water in the mixture is

\[m_w = \rho_w V_w = (1.00 \text{ g/cm}^3)(500 \text{ cm}^3) = 500 \text{ g}\]

and the mass of ethanol added is

\[m_e = \rho_e V_e = (0.806 \text{ g/cm}^3) V_e\]

where \( V_e \) is the volume of ethanol added.

The total mass is

\[M = m_w + m_e = 500 \text{ g} + (0.806 \text{ g/cm}^3) V_e\]

and the total volume is \( V = V_w + V_e = 500 \text{ cm}^3 + V_e \)

Substituting these into \( M = (0.900 \text{ g/cm}^3) V \) from above gives

\[500 \text{ g} + (0.806 \text{ g/cm}^3) V_e = (0.900 \text{ g/cm}^3)(500 \text{ cm}^3 + V_e)\]

Solving for the volume of the added ethanol yields

\[V_e = \frac{500 \text{ g} - (0.900 \text{ g/cm}^3)(500 \text{ cm}^3)}{(0.900 - 0.806) \text{ g/cm}^3} = 532 \text{ cm}^3\]