CHAPTER 10

1. When we use the density of granite, we have
   $m = \rho V = (2.7 \times 10^3\ \text{kg/m}^3)(1 \times 10^8\ \text{m}^3) =$ 2.7×10^{11} kg.

2. When we use the density of air, we have
   $m = \rho V = \rho LWH = (1.29\ \text{kg/m}^3)(5.8\ \text{m})(3.8\ \text{m})(2.8\ \text{m}) =$ 80 kg.

3. When we use the density of gold, we have
   $m = \rho V = \rho LWH = (19.3 \times 10^3\ \text{kg/m}^3)(0.60\ \text{m})(0.25\ \text{m})(0.15\ \text{m}) =$ 4.3×10^2 kg (≈ 950 lb!).

4. If we assume a mass of 65 kg with the density of water, we have
   $m = \rho V$;
   $65\ \text{kg} = (1.0 \times 10^3\ \text{kg/m}^3)V$, which gives $V =$ $6.5 \times 10^{-2}\ \text{m}^3$ (≈ 65 L).

5. From the masses we have
   $m_{\text{water}} = 98.44\ \text{g} - 35.00\ \text{g} = 63.44\ \text{g}$;
   $m_{\text{fluid}} = 88.78\ \text{g} - 35.00\ \text{g} = 53.78\ \text{g}$.
   Because the water and the fluid occupy the same volume, we have
   $\text{SG}_{\text{fluid}} = \rho_{\text{fluid}}/\rho_{\text{water}} = m_{\text{fluid}}/m_{\text{water}} = (53.78\ \text{g})/(63.44\ \text{g}) =$ 0.8477.

6. The definition of the specific gravity of the mixture is
   $\text{SG}_{\text{mixture}} = \rho_{\text{mixture}}/\rho_{\text{water}}$.
   The density of the mixture is
   $\rho_{\text{mixture}} = m_{\text{mixture}}/V = (\text{SG}_{\text{antifreeze}}\rho_{\text{water}}V_{\text{antifreeze}} + \text{SG}_{\text{water}}\rho_{\text{water}}V_{\text{water}})/V$, so we get
   $\text{SG}_{\text{mixture}} = (\text{SG}_{\text{antifreeze}}V_{\text{antifreeze}} + \text{SG}_{\text{water}}V_{\text{water}})/V$
   $= [(0.80)(5.0\ \text{L}) + (1.0)(4.0\ \text{L})]/(9.0\ \text{L}) =$ 0.89.

7. The difference in pressure is caused by the difference in elevation:
   $\text{Æ}P = \rho g\, \text{Æ}h = (1.05 \times 10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(1.60\ \text{m}) =$ $1.65 \times 10^4\ \text{N/m}^2$.

8. (*a*) The normal force on the heel must equal the weight. The pressure of the reaction to the normal force, which is exerted on the floor, is
   $P = F_{\text{N}}/A = mg/A = (50\ \text{kg})(9.80\ \text{m/s}^2)/(0.05 \times 10^{-4}\ \text{m}^2) =$ $9.8 \times 10^7\ \text{N/m}^2$.
   (*b*) For the elephant standing on one foot, we have
   $P = F_{\text{N}}/A = mg/A = (1500\ \text{kg})(9.80\ \text{m/s}^2)/(800 \times 10^{-4}\ \text{m}^2) =$ $1.8 \times 10^5\ \text{N/m}^2$.
   Note that this is a factor of ≈ 1000× less than that of the model!

9. (*a*) The force of the air on the table top is
   $F = PA = (1.013 \times 10^5\ \text{N/m}^2)(1.6\ \text{m})(1.9\ \text{m}) =$ 3.1×10^5 N (down).
   (*b*) Because the pressure is the same on the underside of the table, the upward force has the same magnitude: 3.1×10^5 N. This is why the table does not move!

10. The pressure difference on the lungs is the pressure change from the depth of water:

    $\text{Æ}P = \rho g\, \text{Æ}h$;

    (80 mm-Hg)(133 N/m^2 ·mm-Hg) = (1.00 × 10^3 kg/m^3)(9.80 m/s^2)$\text{Æ}h$, which gives $\text{Æ}h$ = 1.1 m.

11. There is atmospheric pressure outside the tire, so we find the net force from the gauge pressure. Because the reaction to the force from the pressure on the four footprints of the tires supports the automobile, we have

    $4PA = mg$;

    4(240 × 10^3 N/m^2)(200 × 10^{-4} m^2) = m(9.80 m/s^2), which gives m = 1.96 × 10^3 kg.

12. Because the force from the pressure on the cylinder supports the automobile, we have

    $PA = mg$;

    (18 atm)(1.013 × 10^5 N/m^2 ·atm)^1(11 × 10^{-2} m)^2 = m(9.8 m/s^2), which gives m = 7.1 × 10^3 kg.

    Note that we use gauge pressure because there is atmospheric pressure on the outside of the cylinder.

13. The pressure from the height of alcohol must balance the atmospheric pressure:

    $P = \rho gh$;

    1.013 × 10^5 N/m^2 = (0.79 × 10^3 kg/m^3)(9.80 m/s^2)h, which gives h = 13 m.

14. The pressure at a depth h is

    $P = P_0 + \rho gh$ = 1.013 × 10^5 N/m^2 + (1.00 × 10^3 kg/m^3)(9.80 m/s^2)(2.0 m) = 1.21 × 10^5 N/m^2.

    The force on the bottom is

    $F = PA$ = (1.21 × 10^5 N/m^2)(22.0 m)(12.0 m) = 3.2 × 10^7 N (down).

    The pressure depends only on depth, so it will be the same: 1.21 × 10^5 N/m^2.

15. The pressure is produced by a column of air:

    $P = \rho gh$;

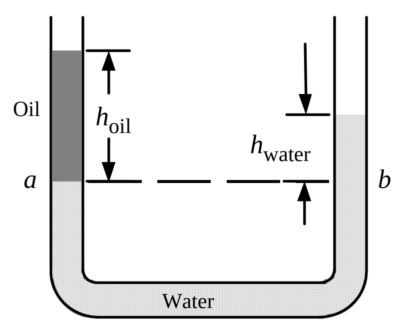
    1.013 × 10^5 N/m^2 = (1.29 kg/m^3)(9.80 m/s^2)h, which gives h = 8.0 × 10^3 m = 8.0 km.

16. Because points a and b are at the same elevation of water, the pressures must be the same. Each pressure is due to the atmospheric pressure at the top of the column and the height of the liquid, so we have

    $P_a = P_b$, or $P_0 + \rho_{oil} g h_{oil} = P_0 + \rho_{water} g h_{water}$;

    $\rho_{oil} g$(27.2 cm) = (1.00 × 10^3 kg/m^3)g(27.2 cm – 9.41 cm),

    which gives ρ_{oil} = 6.54 × 10^2 kg/m^3.



17. We find the gauge pressure from the water height:

    $P = \rho_{water} g h_{water}$ = (1.00 × 10^3 kg/m^3)(9.80 m/s^2)[5.0 m + (100 m) sin 60°] = 9.0 × 10^5 N/m^2 (gauge).

    If we neglect turbulence and frictional effects, we know from energy considerations that the water would rise to the elevation at which it started:

    h = [5.0 m + (100 m) sin 60°] = 92 m.

18. The minimum gauge pressure would cause the water to come out of the faucet with very little speed. This means the gauge pressure must be enough to hold the water at this elevation:

$P_{gauge} = \rho gh;$

$= (1.00 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(41 \text{ m}) =$ $4.0 \times 10^5 \text{ N/m}^2$.

19. (*a*) For the mass of water in the tube we have

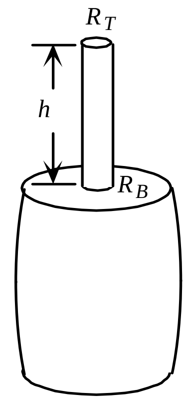
$m = \rho V = \rho^1 R_T^2 H = (1.00 \times 10^3 \text{ kg/m}^3)^1(0.0030 \text{ m})^2(12 \text{ m})$

$=$ 0.34 kg.

(*b*) The net force on the lid of the barrel is due to the gauge pressure of the water at the top of the barrel. Because this gauge pressure is from the mass of water in the tube, we have

$F = PA_B = (mg/A_T)A_B = mg(R_B/R_T)^2$

$= (0.34 \text{ kg})(9.80 \text{ m/s}^2)[(20 \text{ cm})/(0.30 \text{ cm})]^2 =$ $1.5 \times 10^4 \text{ N (up)}$.



20. We consider a mass of water m that occupies a volume V_0 at the surface. The pressure increase at a depth h will decrease the volume to V, where $m = \rho_0 V_0 = \rho V$. We use the bulk modulus to find the volume change:

$ÆV/V_0 = -ÆP/B = -\rho_0 gh/B = -(1.025 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(6.0 \times 10^3 \text{ m})/(2.0 \times 10^9 \text{ N/m}^2) = -0.030.$

The fact that this is small justifies using the surface density for the pressure calculation.
The volume at the depth h is

$V = V_0 + ÆV = (1 - 0.030)V_0 = 0.970 V_0,$

so the density is

$\rho = \rho_0(V_0/V) = (1.025 \times 10^3 \text{ kg/m}^3)(1/0.970) =$ $1.057 \times 10^3 \text{ kg/m}^3$.

For the fractional change in density, we have

$Æ\rho/\rho_0 = (V_0/V) - 1 = (1/0.970) - 1 = 1.030 - 1 =$ $+ 0.030$ (3%).

21. Because the mass of the displaced liquid is the mass of the hydrometer, we have

$m = \rho_{water} h_{water} A = \rho_{liquid} h_{liquid} A;$

$(1000 \text{ kg/m}^3)(22.5 \text{ cm}) = \rho_{liquid}$ (22.9), which gives $\rho_{liquid} =$ 983 kg/m^3.

22. Because the mass of the displaced water is the apparent change in mass of the rock, we have

$Æm = \rho_{water} V.$

For the density of the rock we have

$\rho_{rock} = m_{rock}/V = (m_{rock}/Æm)\rho_{water}$

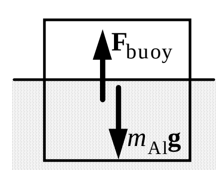
$= [(8.20 \text{ kg})/(8.20 \text{ kg} - 6.18 \text{ kg})](1.00 \times 10^3 \text{ kg/m}^3) =$ $4.06 \times 10^3 \text{ kg/m}^3$.

23. When the aluminum floats, the net force is zero. If the fraction of the aluminum that is submerged is f, we have

$F_{net} = 0 = F_{buoy} - m_{Al}g = \rho_{Hg} gfV - \rho_{Al} gV;$

$(13.6 \times 10^3 \text{ kg/m}^3)gfV = (2.70 \times 10^3 \text{ kg/m}^3)gV,$

which gives $f =$ 0.199.



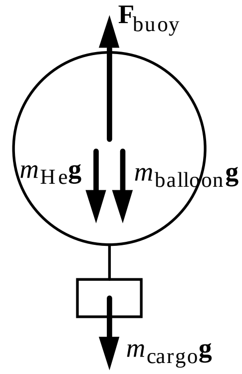
24. When the balloon and cargo float, the net force is zero, so we have

$F_{net} = 0 = F_{buoy} - m_{He}g - m_{balloon}g - m_{cargo}g;$

$0 = \rho_{air}gV_{balloon} - \rho_{He}gV_{balloon} - m_{balloon}g - m_{cargo}g;$

$0 = (1.29\ kg/m^3 - 0.179\ kg/m^3)\frac{4}{3}\pi(9.5\ m)^3 - (1000\ kg + m_{cargo}),$

which gives $m_{cargo} =$ 3.0×10^3 kg.



25. Because the mass of the displaced water is the apparent change in mass of the person, we have

$\Delta m = \rho_{water}V_{legs}.$

For the mass of one leg we have

$m_{leg} = SG_{body}\rho_{water} \times V_{legs} = SG_{body}\rho_{water} \times \Delta m/\rho_{water} = SG_{body} \times \Delta m$

$= (1.00) \times (78\ kg - 54\ kg) =$ 12 kg.

26. Because the mass of the displaced water is the apparent change in mass of the sample, we have

$\Delta m = \rho_{water}V.$

For the density of the sample we have

$\rho = m/V = (m/\Delta m)\rho_{water}$

$= [(63.5\ g)/(63.5\ g - 56.4\ g)](1.00 \times 10^3\ kg/m^3) = 8.94 \times 10^3\ kg/m^3.$

From the table of densities, the most likely metal is copper.

27. (*a*) Because the mass of the displaced liquid is the apparent change in mass of the ball, we have

$\Delta m = \rho_{liquid}V$, or

$\rho_{liquid} = \Delta m/V = (\Delta m/m)\rho_{ball}$;

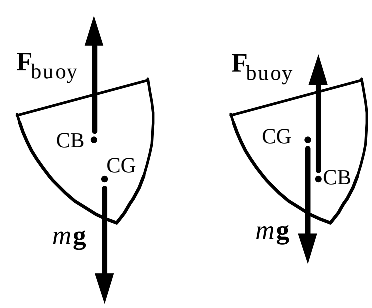
$= [(3.40\ kg - 2.10\ kg)/(3.40\ kg)](2.70 \times 10^3\ kg/m^3) =$ $1.03 \times 10^3\ kg/m^3$.

(*b*) For a submerged object, from part (*a*) we have

$\rho_{liquid} = [(m - m_{apparent})/m]\rho_{object}.$

28. (*a*) The buoyant force is a measure of the net force on the partially submerged object due to the pressure in the fluid. In order to remove the object and have no effect on the fluid, we would have to fill the submerged volume with an equal volume of fluid. As expected, the buoyant force on this fluid is the weight of the fluid. To have no net torque on the fluid, the buoyant force and the weight of the fluid would have to act at the same point, the center of gravity.

(*b*) From the diagram we see that, if the center of buoyancy is above the center of gravity, when the ship tilts, the net torque will tend to restore the ship's position. From the diagram we see that, if the center of buoyancy is below the center of gravity, when the ship tilts, the net torque will tend to continue the tilt. If the center of buoyancy is at the center of gravity, there will be no net torque from these forces, so other torques (from the wind and waves) would determine the motion of the ship. Thus stability is achieved when the center of buoyancy is above the center of gravity.



29. Because the mass of the displaced alcohol is the apparent change in mass of the wood, we have

$Æm = \rho_{alcohol} V$.

We find the specific gravity of the wood from

$SG_{wood}\rho_{water} = m_{wood}/V = (m_{wood}/Æm)\rho_{alcohol}$;

$SG_{wood}(1.00 \times 10^3 \text{ kg/m}^3) = [(0.48 \text{ kg})/(0.48 \text{ kg} – 0.035 \text{ kg})](0.79 \times 10^3 \text{ kg/m}^3)$, which gives

$SG_{wood} =$ 0.85.

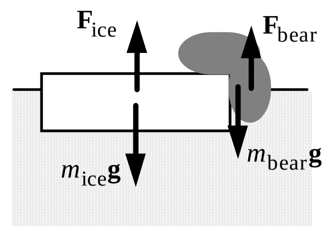
As expected, the specific gravity is less than 1, so the wood floats in water.

30. When the ice floats, the net force is zero. If the fraction of the ice that is above water is f, we have

$F_{net} = 0 = F_{buoy} – m_{ice}g = \rho_{sw}g(1 – f)V – \rho_{ice}gV$, or

$(1.025)\rho_w g(1 – f)V = (0.917)\rho_w gV$, which gives $f =$ 0.105 (10.5%).

31. From Problem 30, we know that the initial volume out of the water, without the bear on the ice, is



$V_1 = 0.105V_0 = 0.105(10 \text{ m}^3) = 1.05 \text{ m}^3$.

Thus we find the submerged volume of ice with the bear on the ice from

$V_2 = V_0 – !V_1 = 10 \text{ m}^3 – !(1.05 \text{ m}^3) = 9.48 \text{ m}^3$.

Because the net force is zero, we have

$F_{net} = 0 = F_{bear} + F_{ice} – m_{bear}g – m_{ice}g$, or

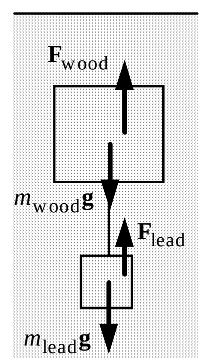
$\rho_{sea\ water}g(0.30)V_{bear} + \rho_{sea\ water}gV_2 = m_{bear}g + \rho_{ice}gV_0$;

$\rho_{sea\ water}g(0.30)(m_{bear}/\rho_{bear}) + \rho_{sea\ water}gV_2 = m_{bear}g + \rho_{ice}gV_0$;

$(1.025)\rho_w(0.30)[m_{bear}/(1.00)\rho_w] + (1.025 \times 10^3 \text{ kg/m}^3)(9.48 \text{ m}^3) = m_{bear} + (0.917)(1.00 \times 10^3 \text{ kg/m}^3)(10 \text{ m}^3)$,

which gives $m_{bear} =$ 7.9×10^2 kg.

32. The minimum mass of lead will suspend it under water.



Because the net force is zero, we have

$F_{net} = 0 = F_{lead} + F_{wood} – m_{lead}g – m_{wood}g$, or

$\rho_{water}gV_{lead} + \rho_{water}gV_{wood} = m_{bear}g + m_{wood}g$;

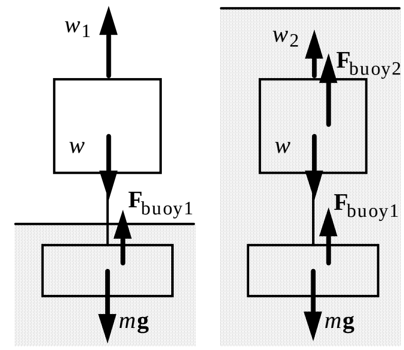
$\rho_{water}g(m_{lead}/\rho_{lead}) + \rho_{water}g(m_{wood}/\rho_{wood}) = m_{bear}g + m_{wood}g$.

We can rearrange this:

$m_{lead}[1 – (1/SG_{lead})] = m_{wood}[(1/SG_{wood}) – 1]$;

$m_{lead}[1 – (1/11.3)] = (2.52 \text{ kg})[(1/0.50) – 1]$, which gives

$m_{lead} =$ 2.76 kg.



33. The apparent weight is the force required to hold the system, so the net force is zero. When only the sinker is submerged, we have

$F_{\text{net}} = 0 = w_1 + F_{\text{buoy1}} - w - mg$, or

$w_1 + \rho_{\text{water}} g V_{\text{sinker}} = w + mg$.

When the sinker and object are submerged, we have

$F_{\text{net}} = 0 = w_2 + F_{\text{buoy1}} + F_{\text{buoy2}} - w - mg$, or

$w_2 + \rho_{\text{water}} g V_{\text{sinker}} + \rho_{\text{water}} g V_{\text{object}} = w + mg$.

If we subtract the two results, we get

$w_1 - w_2 - \rho_{\text{water}} g V_{\text{object}} = 0$, or

$\rho_{\text{water}} g (m_{\text{object}}/\rho_{\text{object}}) = w/\text{SG}_{\text{object}} = w_1 - w_2$, so $\text{SG}_{\text{object}} = w/(w_1 - w_2)$.

34. The flow rate in the major arteries must be the flow rate in the aorta:

    $\rho v_1 A_1 = \rho v_2 A_2$;

    (30 cm/s)¹(1.0 cm)^2 = v_2(2.0 cm^2), which gives v_2 = 47 cm/s.

35. From the equation of continuity we have

    Flow rate = Av;

    (9.2 m)(5.0 m)(4.5 m)/(10 min)(60 s/min) = ¹(0.17 cm)$^2 v$, which gives v = 3.8 m/s.

36. From the equation of continuity we have

    Flow rate = $A_{pool}h/t = A_{hose}v$;

    (¹(7.2 m)^2(1.5 m)/t = (¹[(0.625 in)(0.0254 m/in)]^2(0.28 m/s), which gives $t = 1.10 \times 10^6$ s = 13 days.

37. If we choose the initial point at the water main where the water is not moving and the final point at the top of the spray, where the water also is not moving, from Bernoulli's equation we have

    P_1 + !$\rho v_1^2 + \rho g h_1 = P_2$ + !$\rho v_2^2 + \rho g h_2$;

    $P_1 + 0 + 0 = P_{atm} + 0 + (1.00 \times 10^3$ kg/m^3)(9.80 m/s^2)(12 m), which gives

    $P_1 - P_{atm} = P_{gauge}$ = 1.2×10^5 N/m^2 = 1.2 atm.

38. If we choose the initial point at the pressure head where the water is not moving and the final point at the faucet, from Bernoulli's equation we have

    P_1 + !$\rho v_1^2 + \rho g h_1 = P_2$ + !$\rho v_2^2 + \rho g h_2$;

    $P_{atm} + 0 + (1.00 \times 10^3$ kg/m^3)(9.80 m/s^2)(12.0 m) = P_{atm} + !(1.00×10^3 kg/m^3)v_2^2, which gives

    v_2 = 15.3 m/s.

    For the flow rate we have

    Flow rate = Av = (¹(0.016 m)^2 (15.3 m/s) = 3.1×10^{-3} m^3/s.

39. The pressure under the roof will be atmospheric. If we choose the initial point where the air is not moving and the final point above the roof, from Bernoulli's equation we have

    P_1 + !$\rho v_1^2 + \rho g h_1 = P_2$ + !$\rho v_2^2 + \rho g h_2$;

    $P_{atm} + 0 + 0 = P$ + !(1.29 kg/m^3)(30 m/s)^2, which gives $P - P_{atm} = 5.8 \times 10^2$ N/m^2.

    The net upward force on the roof is

    $F = (P - P_{atm})A = (5.8 \times 10^2$ N/m^2)(240 m^2) = 1.4×10^5 N.

40. If we consider the points at the top and bottom surfaces of the wing compared to the air flow in front of the wing, from Bernoulli's equation we have

    P_0 + !$\rho v_0^2 + \rho g h_0 = P_1$ + !$\rho v_1^2 + \rho g h_1 = P_2$ + !$\rho v_2^2 + \rho g h_2$;

    P_1 + !(1.29 kg/m^3)(340 m/s)^2 + 0 = P_2 + !(1.29 kg/m^3)(290 m/s)^2, which gives $P_2 - P_1 = 2.03 \times 10^4$ N/m^2.

    The net upward force on the wing is

    $F = (P_2 - P_1)A = (2.03 \times 10^4$ N/m^2)(80 m^2) = 1.6×10^6 N.

41. If we consider the points far away from the center of the hurricane and at the center of the hurricane, from Bernoulli's equation we have

$P_1 + !\rho v_1^2 + \rho g h_1 = P_2 + !\rho v_2^2 + \rho g h_2;$

$1.013 \times 10^5\text{ N/m}^2 + 0 + 0 = P_2 + !(1.29\text{ kg/m}^3)[(300\text{ km/h})/(3.6\text{ ks/h})]^2 + 0,$

which gives $P_2 =$ $9.7 \times 10^4\text{ N/m}^2$.

42. If we consider a volume of fluid, at each end of the pipe there is a force toward the fluid of PA. If the area of the pipe is constant, the net force on the fluid is

$F_{\text{net}} = (P_1 - P_2)A.$

The required power is

$\text{Power} = F_{\text{net}}v = (P_1 - P_2)Av = (P_1 - P_2)Q.$

43. The flow rate in the pipe at street level must be the flow rate at the top floor:

$v_1A_1 = v_2A_2;$

$(0.60\text{ m/s})(^1(5.0\text{ cm})^2 = v_2(^1(2.6\text{ cm})^2$, which gives $v_2 =$ 2.22 m/s.

If we use Bernoulli's equation between the street level and the top floor, we have

$P_1 + P_{\text{atm}} + !\rho v_1^2 + \rho g h_1 = P_2 + P_{\text{atm}} + !\rho v_2^2 + \rho g h_2;$

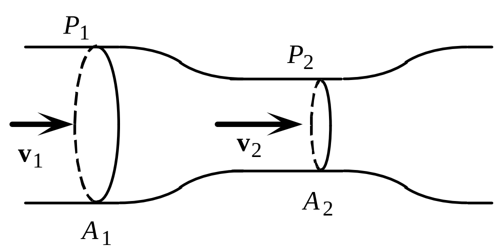
$3.8\text{ atm} + P_{\text{atm}} + !(1.00 \times 10^3\text{ kg/m}^3)(0.60\text{ m/s})^2 + 0 =$

$P_2 + P_{\text{atm}} + !(1.00 \times 10^3\text{ kg/m}^3)(2.22\text{ m/s})^2 + (1.00 \times 10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)(20\text{ m}),$

which gives $P_2 =$ 1.8 atm (gauge).

44. (*a*) The flow rate through the venturi meter is constant:

$v_1A_1 = v_2A_2.$



If we use Bernoulli's equation between the segments of the meter, we have

$P_1 + !\rho v_1^2 + \rho g h_1 = P_2 + !\rho v_2^2 + \rho g h_2;$

$P_1 + !\rho v_1^2 + 0 = P_2 + !\rho v_2^2 + 0$, or $P_1 - P_2 = !\rho(v_2^2 - v_1^2).$

When we substitute for v_2 from the flow rate, we get

$P_1 - P_2 = !\rho[(v_1A_1/A_2)^2 - v_1^2] = !\rho v_1^2[(A_1^2 - A_2^2)/A_2^2],$

which gives

$v_1 = A_2[2(P_1 - P_2)/\rho(A_1^2 - A_2^2)]^{1/2}.$

(*b*) With the given data, we have

$v_1 = A_2[2(P_1 - P_2)/\rho(A_1^2 - A_2^2)]^{1/2} = D_1^2[2(P_1 - P_2)/\rho(D_1^4 - D_2^4)]^{1/2}$

$= (1.0\text{ cm})^2\{2(18\text{ mm-Hg})(133\text{ N/m}^2 \cdot\text{mm-Hg})/(1.00 \times 10^3\text{ kg/m}^3)[(3.0\text{ cm})^4 - (1.0\text{ cm})^4]\}^{1/2}$

$=$ 0.24 m/s.

45. The torque corresponds to a tangential force on the inner cylinder:

$F = \tau/R_1.$

The layer of fluid has a thickness $R_2 - R_1$, the fluid next to the outer cylinder is at rest, and the fluid next to the inner cylinder has a speed $v = R_1\omega$, where

$\omega = (62\text{ rev/min})(2^1\text{ rad/rev})/(60\text{ s/min}) = 6.49\text{ rad/s}.$

If we use the average radius for the area over which the torque acts in the definition of viscosity, we have

$\eta = FL/Av = \tau(R_2 - R_1)/R_1[2^1!(R_1 + R_2)H]R_1\omega = \tau(R_2 - R_1)/^1R_1^2(R_1 + R_2)H\omega$

$= (0.024\text{ m}\cdot\text{N})(0.0530\text{ m} - 0.0510\text{ m})/^1(0.0510\text{ m})^2(0.0510\text{ m} + 0.0530\text{ m})(0.120\text{ m})(6.49\text{ rad/s})$

= $0.072\ \text{Pa}\cdot\text{s}$.

46. The same volume of water is used, so the time is inversely proportional to the flow rate. Taking into account the viscosity of the water, with the only change the diameter of the hose, we have

$t \propto 1/Q \propto 1/r^4 \propto 1/d^4$.

For the two hoses we have.

$t_2/t_1 = (d_1/d_2)^4 = (3/5)^4 =$ 1/7.7 = 0.13.

47. From Poiseuille's equation we have

$Q = \pi r^4(P_1 - P_2)/8\eta L$;

$450 \times 10^{-6}\ \text{m}^3/\text{s} = \pi(0.145\ \text{m})^4(P_1 - P_2)/8(0.20\ \text{Pa}\cdot\text{s})(1.9 \times 10^3\ \text{m})$,

which gives $P_1 - P_2 =$ $9.9 \times 10^2\ \text{N/m}^2$.

48. The pressure forcing the blood through the needle is produced from the elevation of the bottle:

$\Delta P = \rho g h$.

From Poiseuille's equation we have

$Q = \pi r^4(P_1 - P_2)/8\eta L = \pi r^4 \rho g h/8\eta L$;

$(4.1 \times 10^{-6}\ \text{m}^3/\text{min})/(60\ \text{s/min}) = \pi(0.20 \times 10^{-3}\ \text{m})^4(1.05 \times 10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(1.70\ \text{m})/8\eta(0.038\ \text{m})$,

which gives $\eta =$ $4.2 \times 10^{-3}\ \text{Pa}\cdot\text{s}$.

49. From Poiseuille's equation we have

$Q = V/t = \pi r^4(P_1 - P_2)/8\eta L$;

$(9.0\ \text{m})(14\ \text{m})(4.0\ \text{m})/(10\ \text{min})(60\ \text{s/min}) =$

$\pi r^4(0.71 \times 10^{-3}\ \text{atm})(1.013 \times 10^5\ \text{N/m}^2\cdot\text{atm})/8(0.018 \times 10^{-3}\ \text{Pa}\cdot\text{s})(21\ \text{m})$,

which gives $r = 0.058$ m.

Thus the diameter needed is 0.12 m.

50. For the viscous flow of the blood, we have

$Q \propto r^4$.

For the two flows we have.

$Q_2/Q_1 = (r_2/r_1)^4$;

$0.25 = (r_2/r_1)^4$, which gives $r_2/r_1 =$ 0.71 (reduced by 29%).

51. From Poiseuille's equation we have

$Q = Av = \pi r^4\,\Delta P/8\eta L$;

$\pi(0.010\ \text{m})^2(0.30\ \text{m/s}) = \pi(0.010\ \text{m})^4\,\Delta P/8(4 \times 10^{-3}\ \text{Pa}\cdot\text{s})L$,

which gives $\Delta P/L = 96\ \text{N/m}^2/\text{m} =$ $0.96\ \text{N/m}^2/\text{cm}$.

52. (*a*) We find the Reynolds number for the blood flow:

$Re = 2\bar{v}r\rho/\eta = 2(0.30\ \text{m/s})(0.010\ \text{m})(1.05 \times 10^3\ \text{kg/m}^3)/(4.0 \times 10^{-3}\ \text{Pa}\cdot\text{s}) = 1600$.

Thus the flow is laminar but close to turbulent.

(*b*) If the only change is in the average speed, we have

$Re_2/Re_1 = \bar{v}_2/\bar{v}_1$;

$Re_2/1600 = 2$, or $Re_2 =$ 3200, so the flow is turbulent.

53. Although the flow is not through a pipe, we approximate the thickness as the diameter. For the Reynolds number we have

$Re = 2\text{æ}r\rho/\eta = 2[(50 \times 10^{-3}\text{ m/yr})/(3.16 \times 10^{7}\text{ s/yr})]!(100 \times 10^{3}\text{ m})(3200\text{ kg/m}^3)/(4 \times 10^{19}\text{ Pa}\cdot\text{s})$

$\approx 1 \times 10^{-20}$.

This is definitely laminar flow.

54. We find the pressure difference required across the needle from Poiseuille's equation:

$Q = \pi r^4(P_1 - P_2)/8\eta L$;

$(4.0 \times 10^{-6}\text{ m}^3/\text{min})/(60\text{ s/min}) = \pi(0.20 \times 10^{-3}\text{ m})^4(P_1 - P_2)/8(4.0 \times 10^{-3}\text{ Pa}\cdot\text{s})(0.040\text{ m})$,

which gives $P_1 - P_2 = 1.70 \times 10^4\text{ N/m}^2$.

The pressure P_2 is the pressure in the vein. The pressure P_1 is produced from the elevation of the bottle:

$P_1 = P_{atm} + \rho gh$.

Thus we have

$P_{atm} + \rho gh - P_2 = 1.70 \times 10^4\text{ N/m}^2$, or

$\rho gh = P_2 - P_{atm} + 1.70 \times 10^4\text{ N/m}^2$;

$(1.05 \times 10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)h = (18\text{ torr})(133\text{ N/m}^2\cdot\text{torr}) + 1.70 \times 10^4\text{ N/m}^2$, which gives $h =$ 1.9 m.

55. For the two surfaces, top and bottom, we have

$\gamma = F/2¬ = (5.1 \times 10^{-3}\text{ N})/2(0.070\text{ m}) =$ 0.036 N/m.

56. For the two surfaces, top and bottom, we have

$F = \gamma 2¬ = (0.025\text{ N/m})2(0.182\text{ m}) =$ 9.1×10^{-3} N.

57. From Example 10–14, the six upward surface tension forces must balance the weight. We find the required angle from

$6(2\pi r\gamma \cos\theta) \approx w$;

$6(2)\pi(3.0 \times 10^{-5}\text{ m})(0.072\text{ N/m})\cos\theta \approx (0.016 \times 10^{-3}\text{ kg})(9.80\text{ m/s}^2)$, which gives $\cos\theta \approx 1.9$.

Because the maximum possible value of $\cos\theta$ is 1, the insect would not remain on the surface.

58. (*a*) We assume that the net force from the weight and the buoyant force is much smaller than the surface tension. For the two surfaces, inner and outer circumferences, we have

$F = \gamma 2L = \gamma 2(2\pi r)$, or $\gamma = F/4\pi r$.

(*b*) For the given data we have

$\gamma = F/4\pi r = (840 \times 10^{-3}\text{ N})/4\pi(0.028\text{ m}) =$ 2.4 N/m.

59. The volume of water must remain the same. We find the surface area of the pool from

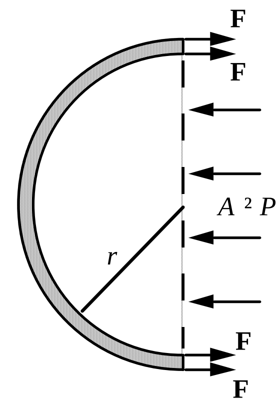
$V = A_{pool}h = 100(!)(9\pi h^3)$, which gives $A_{pool} = 100(\%\pi h^2)$.

The surface energy is equal to the work necessary to form the surface: $W = \gamma A$. For the ratio we have

$W_{droplets}/W_{pool} = A_{droplets}/A_{pool} = 100(!)(4\pi h^2)/100(\%\pi h^2) =$ 3.

60. We consider half of the soap bubble. The forces on the hemisphere will be the surface tensions on the two circles and the net force from the excess pressure between the inside and the outside of the bubble. This net force is the sum of all of the forces perpendicular to the surface of the hemisphere, but must be parallel to the surface tension. Therefore we can find it by finding the force on the circle that is the base of the hemisphere. The total force must be zero, so we have

$2(2\pi r)\gamma = (\pi r^2)\,\Delta P$, which gives $\Delta P = 4\gamma/r$.



61. The liquid pressure is produced from the elevation of the bottle:

$\Delta P = \rho g h$.

(*a*) $(65\text{ mm-Hg})(133\text{ N/m}^2\cdot\text{mm-Hg}) = (1.00\times10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)h$, which gives $h =$ 0.88 m.

(*b*) $(550\text{ mm-H}_2\text{O})(9.81\text{ N/m}^2\cdot\text{mm-H}_2\text{O}) = (1.00\times10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)h$, which gives $h =$ 0.55 m.

(*c*) If we neglect viscous effects, we must produce a pressure to balance the blood pressure:

$(18\text{ mm-Hg})(133\text{ N/m}^2\cdot\text{mm-Hg}) = (1.00\times10^{-3}\text{ kg/m}^3)(9.80\text{ m/s}^2)h$, which gives $h =$ 0.24 m.

62. (*a*) If the fluid is incompressible, the pressure must be constant, so we have

$P = F_{\text{needle}}/A_{\text{needle}} = F_{\text{plunger}}/A_{\text{plunger}}$;

$F_{\text{needle}}/(\pi(0.020\text{ cm})^2 = (2.4\text{ N})/(\pi(1.3\text{ cm})^2$, which gives $F_{\text{needle}} =$ 5.7×10^{-4} N.

(*b*) Just before the fluid starts to move, the pressure must be the gauge pressure in the vein:

$P = F_{\text{plunger}}/A_{\text{plunger}}$;

$(18\text{ mm-Hg})(133\text{ N/m}^2\cdot\text{mm-Hg}) = F_{\text{plunger}}/(\pi(1.3\times10^{-2}\text{ cm})^2$, which gives $F_{\text{plunger}} =$ 0.32 N.

63. If the motion is such that we can consider the air to be in equilibrium, we find the applied force from

$F = PA$;

$F_i = P_iA = (210\times10^3\text{ N/m}^2)(\pi(0.030\text{ m})^2 = 1.5\times10^2\text{ N}$;

$F_f = P_fA = (310\times10^3\text{ N/m}^2)(\pi(0.030\text{ m})^2 = 2.2\times10^2\text{ N}$.

Thus the range of the applied force is $1.5\times10^2\text{ N} \le F \le 2.2\times10^2\text{ N}$.

64. The pressure difference is produced from the elevation:

$\Delta P = \rho g h$

$= (1.29\text{ kg/m}^3)(9.80\text{ m/s}^2)(410\text{ m})/(1.013\times10^5\text{ N/m}^2\cdot\text{atm}) =$ 0.051 atm.

65. The pressure is

$P = P_{\text{atm}} + \rho g h$

$= 1\text{ atm} + (917\text{ kg/m}^3)(9.80\text{ m/s}^2)(4\times10^3\text{ m})/(1.013\times10^5\text{ N/m}^2\cdot\text{atm}) \approx$ 4×10^2 atm.

66. The pressure difference in the blood is produced by the elevation change:

$\Delta P = \rho g\,\Delta h$

$= (1.05\times10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)(6\text{ m})/(1.013\times10^5\text{ N/m}^2\cdot\text{atm}) =$ 0.6 atm.

67. The pressure difference on the ear drum is the change produced by the elevation change:

$\Delta P = \rho g\, \Delta h$.

The net force is

$F = A\, \Delta P = A\rho g\, \Delta h$.

$= (0.50 \times 10^{-4}\ \text{m}^2)(1.29\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(1000\ \text{m}) =$ 0.63 N.

68. Because the animal is suspended in the mixture, the mass of the animal is the mass of the displaced mixture, and the volume of the animal is the volume of the mixture:

$m_{\text{animal}} = m_{\text{disp}}$;

$V = V_{\text{alcohol}} + V_{\text{water}}$.

We are given that

$m_{\text{alcohol}} = \rho_{\text{alcohol}} V_{\text{alcohol}} = 0.180 m_{\text{disp}}$, and $m_{\text{water}} = \rho_{\text{water}} V_{\text{water}} = 0.820 m_{\text{disp}}$.

For the density of the animal we have

$\rho_{\text{animal}} = m_{\text{animal}}/V = m_{\text{disp}}/(V_{\text{alcohol}} + V_{\text{water}}) = m_{\text{disp}}/[(0.180 m_{\text{disp}}/\rho_{\text{alcohol}}) + (0.820 m_{\text{disp}}/\rho_{\text{water}})]$

$= \rho_{\text{water}}\rho_{\text{alcohol}}/(0.180\rho_{\text{water}} + 0.820\rho_{\text{alcohol}})$

$= (1.00 \times 10^3\ \text{kg/m}^3)(0.79 \times 10^3\ \text{kg/m}^3)/[0.180(1.00 \times 10^3\ \text{kg/m}^3) + 0.820(0.79 \times 10^3\ \text{kg/m}^3)]$

$=$ 954 kg/m^3.

69. The sum of the magnitudes of the forces on the ventricle wall is

$F = A\, \Delta P$;

$= (85 \times 10^{-4}\ \text{m}^2)(120\ \text{mm-Hg})(133\ \text{N/m}^2 \cdot \text{mm-Hg}) =$ 1.4×10^2 N.

Note that the forces on the wall are not all parallel, so this is not the vector sum.

70. We assume that ρ and g are constant. The pressure on a small area of the Earth's surface is produced by the weight of the air above it:

$P = mg/A = m_{\text{total}}g/A_{\text{total}} = m_{\text{total}}g/4\pi R_{\text{Earth}}^2$;

$1.013 \times 10^5\ \text{N/m}^2 = m_{\text{total}}(9.80\ \text{m/s}^2)/4\pi(6.37 \times 10^6\ \text{m})^2$, which gives $m_{\text{total}} =$ 5.3×10^{18} kg.

71. The pressure difference on the water in the straw produces the elevation change:

$\Delta P = \rho g\, \Delta h$

$(80\ \text{mm-Hg})(133\ \text{N/m}^2 \cdot \text{mm-Hg}) = (1.00 \times 10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)h$, which gives $h =$ 1.1 m.

72. If we choose the initial point at the pressure head, where the water is not moving, and the final point at the faucet, from Bernoulli's equation we have

$P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g h_2$;

$P_{\text{atm}} + 0 + (1.00 \times 10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)h_1 = P_{\text{atm}} + \tfrac{1}{2}(1.00 \times 10^3\ \text{kg/m}^3)(7.2\ \text{m/s})^2 + 0$, which gives

$h_1 =$ 2.6 m.

73. The mass of the unloaded water must equal the mass of the displaced sea water:

$m = \rho_{\text{sea water}}Ah = (1.025 \times 10^3\ \text{kg/m}^3)(2800\ \text{m}^2)(8.50\ \text{m}) =$ 2.44×10^7 kg.

Note that this is a volume of

$V = m/\rho_{\text{water}} = (2.44 \times 10^7\ \text{kg})/(1.00 \times 10^3\ \text{kg/m}^3) = 2.44 \times 10^4\ \text{m}^3$,

which is greater than the volume change of the sea water.

74. We assume that for the maximum number of people, the logs are completely in the water and the people are not. Because the net force is zero, we have

$F_{buoy} = m_{people}g + m_{logs}g;$

$\rho_{water}g(\pi r^2)N_{logs}L = N_{people}mg + N_{logs}\rho_{logs}g(\pi r^2)L.$

Because the specific gravity is the ratio of the density to the density of water, this can be written

$(1 - SG_{logs})N_{logs}\rho_{water}\pi r^2 L = N_{people}m;$

$(1 - 0.60)(10)(1.00 \times 10^3 \text{ kg/m}^3)\pi(0.165 \text{ m})^2(6.1 \text{ m}) = N_{people}(70 \text{ kg})$, which gives $N_{people} = 29.8$.

Thus the raft can hold a maximum of 29 people.

75. The work done in each heartbeat is

$W = Fd = PAd = PV.$

If n is the heart rate, the power output is

Power $= nW = nPV$

$= [(70 \text{ beats/min})/(60 \text{ s/min})](105 \text{ mm-Hg})(133 \text{ N/m}^2 \cdot\text{mm-Hg})(70 \times 10^{-6} \text{ m}^3) =$ 1.1 W.

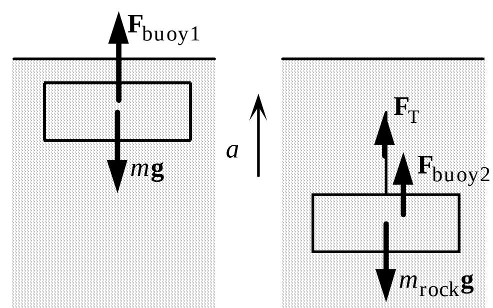
76. We find the effective g by considering a volume of the water.

The net force must produce the acceleration:

$F_{buoy1} - mg = ma;$

$\rho_{water}g' V_{water} - \rho_{water}V_{water}g = \rho_{water}V_{water}a;$

$g' = g + a = g + 3.5g = 4.5g.$



The buoyant force on the rock is

$F_{buoy2} = \rho_{water}g' V_{rock} = \rho_{water}g'(m_{rock}/\rho_{rock}) = g' m_{rock}/SG_{rock}$

$= (4.5)(9.80 \text{ m/s}^2)(3.0 \text{ kg})/(2.7)$

$=$ 49 N.

To see if the rock will float, we find the tension required to accelerate the rock:

$F_T + F_{buoy2} = m_{rock}a;$

$F_T + 49 \text{ N} = (3.0 \text{ kg})(3.5)(9.80 \text{ m/s}^2)$, which gives $F_T = 54$ N.

Because the result is positive, tension is required, so the rock will not float.

77. We choose the reference level at the nozzle. If we apply Bernoulli's equation from the exit of the nozzle to the top of the spray, we have

$P_1 + !\rho v_1^2 + \rho g h_1 = P_2 + !\rho v_2^2 + \rho g h_2;$

$P_{atm} + !\rho v_1^2 + 0 = P_{atm} + 0 + \rho g h_2$, which gives $v_1^2 = 2gh_2$.

If we use the equation of continuity from the pump to the nozzle, we have

Flow rate $= A_3 v_3 = A_1 v_1$, or $v_3 = (A_1/A_3)v_1 = (D_1/D_3)^2 v_1$.

If we apply Bernoulli's equation from the pump to the exit of the nozzle, we have

$P_3 + !\rho v_3^2 + \rho g h_3 = P_1 + !\rho v_1^2 + \rho g h_1;$

$P_{pump} + !\rho[(D_1/D_3)^2 v_1]^2 + \rho g h_3 = P_{atm} + !\rho v_1^2 + 0$, or

$P_{pump} - P_{atm} = !\rho v_1^2[1 - (D_1/D_3)^4] - \rho g h_3 = \rho g\{h_2[1 - (D_1/D_3)^4] - h_3\}$

$= (1.00 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)\{(0.12 \text{ m})[1 - (0.060 \text{ cm}/0.12 \text{ cm})^4] - (- 1.1 \text{ m})\}$

$=$ $1.13 \times 10^4 \text{ N/m}^2$.

78. We let d represent the diameter of the stream a distance y below the faucet. If we use the equation of continuity, we have

Flow rate = $A_0v_0 = A_1v_1$, or $v_1 = (A_0/A_1)v_0 = (D/d)^2v_0$.

We choose the reference level at the faucet. If we apply Bernoulli's equation to the stream, we have

$P_0 + !\rho v_0^2 + \rho gh_0 = P_1 + !\rho v_1^2 + \rho gh_1$;

$P_{atm} + !\rho v_0^2 + 0 = P_{atm} + !\rho v_1^2 + \rho g(-y)$;

$v_1^2 = v_0^2 + 2gy = (D/d)^4v_0^2$, which gives $d = D[v_0^2/(v_0^2 + 2gy)]^{1/4}$.

79. (*a*) We use the flow rate to find the speed in an injector:

$Q = Av = N_{cylinders}N_{injectors}{}^1r^2v$;

$(7.5 \times 10^{-3}\ m^3/rev)(3000\ rev/min)/(60\ s/min) = (12)(4)^1(3.0 \times 10^{-3}\ m)^2v$,

which gives $v =$ 2.8×10^2 m/s.

(*b*) If we apply Bernoulli's equation to the flow through the injectors, we have

$P_0 + !\rho v_0^2 + \rho gh_0 = P_1 + !\rho v_1^2 + \rho gh_1$;

$(1.5\ atm)(1.013 \times 10^5\ N/m^2 \cdot atm) + 0 + 0 = P_{injector} + !(1.29\ kg/m^3)(2.8 \times 10^2\ m/s)^2 + 0$,

which gives

$P_{injector} =$ 1.03×10^5 N/m^2 (1.01 atm).

80. (*a*) We choose the reference level at the bottom of the sink. If we apply Bernoulli's equation to the flow from the average depth of water in the sink to the pail, we have

$P_0 + !\rho v_0^2 + \rho gh_0 = P_1 + !\rho v_1^2 + \rho gh_1$;

$P_{atm} + 0 + + \rho gh_0 = P_{atm} + !\rho v_1^2 + \rho gh_1$, or

$v_1 = [2g(h_0 - h_1)]^{1/2} = \{-2(9.80\ m/s^2)[0.020\ m - (-0.50\ m)]\}^{1/2} =$ 3.1 m/s.

(*b*) We use the flow rate to find the time:

$Q = Av = V/t$;

${}^1(0.010\ cm)^2(3.07\ m/s) = (0.375\ m^2)(0.04\ 0m)/t$, which gives $t =$ 16 s.