Halliday/Resnick/Walker 7e
Chapter 14

1. The air inside pushes outward with a force given by p_iA, where p_i is the pressure inside the room and A is the area of the window. Similarly, the air on the outside pushes inward with a force given by p_oA, where p_o is the pressure outside. The magnitude of the net force is $F = (p_i - p_o)A$. Since 1 atm = 1.013×10^5 Pa,

$$F = (1.0\text{ atm} - 0.96\text{ atm})(1.013\times10^5\text{ Pa/atm})(3.4\text{ m})(2.1\text{ m}) = 2.9\times10^4\text{ N}.$$

3. The pressure increase is the applied force divided by the area: $\Delta p = F/A = F/\pi r^2$, where r is the radius of the piston. Thus

$$\Delta p = (42\text{ N})/\pi(0.011\text{ m})^2 = 1.1\times10^5\text{ Pa}.$$

This is equivalent to 1.1 atm.

5. Let the volume of the expanded air sacs be V_a and that of the fish with its air sacs collapsed be V. Then

$$\rho_{\text{fish}} = \frac{m_{\text{fish}}}{V} = 1.08\text{ g/cm}^3 \quad\text{and}\quad \rho_w = \frac{m_{\text{fish}}}{V+V_a} = 1.00\text{ g/cm}^3$$

where ρ_w is the density of the water. This implies

$$\rho_{\text{fish}}V = \rho_w(V+V_a)\text{ or }(V+V_a)/V = 1.08/1.00,$$

which gives $V_a/(V+V_a) = 7.4\%$.

7. (a) The pressure difference results in forces applied as shown in the figure. We consider a team of horses pulling to the right. To pull the sphere apart, the team must exert a force at least as great as the horizontal component of the total force determined by "summing" (actually, integrating) these force vectors.

We consider a force vector at angle θ. Its leftward component is $\Delta p\cos\theta dA$, where dA is the area element for where the force is applied. We make use of the symmetry of the problem and let dA be that of a ring of constant θ on the surface. The radius of the ring is $r = R\sin\theta$, where R is the radius of the sphere. If the angular width of the ring is $d\theta$, in radians, then its width is $R\,d\theta$ and its area is $dA = 2\pi R^2\sin\theta\,d\theta$. Thus the net horizontal component of the force of the air is given by

$$F_h = 2\pi R^2\Delta p\int_0^{\pi/2}\sin\theta\cos\theta\,d\theta = \pi R^2\Delta p\,\sin^2\theta\Big|_0^{\pi/2} = \pi R^2\Delta p.$$

(b) We use 1 atm = 1.01×10^5 Pa to show that $\Delta p = 0.90$ atm $= 9.09\times10^4$ Pa. The sphere radius is $R = 0.30$ m, so

$$F_h = \pi(0.30\text{ m})^2(9.09 \times 10^4\text{ Pa}) = 2.6 \times 10^4\text{ N}.$$

(c) One team of horses could be used if one half of the sphere is attached to a sturdy wall. The force of the wall on the sphere would balance the force of the horses.

8. Note that 0.05 atm equals 5065 N/m^2. Application of Eq. 14-7 with the notation in this problem leads to

$$d_{\text{max}} = \frac{5065}{\rho_{\text{liquid}}\, g}$$

with SI units understood. Thus the difference of this quantity between fresh water (998 kg/m^3) and Dead Sea water (1500 kg/m^3) is

$$\Delta d_{\text{max}} = \frac{5065}{9.8}\left(\frac{1}{998} - \frac{1}{1500}\right) = 0.17\text{ m}.$$

10. Recalling that 1 atm = 1.01×10^5 Pa, Eq. 14-8 leads to

$$\rho gh = (1024\text{ kg/m}^3)\,(9.80\text{ m/s}^2)\,(10.9 \times 10^3\text{ m})\left(\frac{1\text{ atm}}{1.01 \times 10^5\text{ Pa}}\right) \approx 1.08 \times 10^3\text{ atm}.$$

11. The pressure p at the depth d of the hatch cover is $p_0 + \rho gd$, where ρ is the density of ocean water and p_0 is atmospheric pressure. The downward force of the water on the hatch cover is $(p_0 + \rho gd)A$, where A is the area of the cover. If the air in the submarine is at atmospheric pressure then it exerts an upward force of p_0A. The minimum force that must be applied by the crew to open the cover has magnitude

$$F = (p_0 + \rho gd)A - p_0A = \rho gdA = (1024\text{ kg/m}^3)(9.8\text{ m/s}^2)(100\text{ m})(1.2\text{ m})(0.60\text{ m})$$
$$= 7.2 \times 10^5\text{ N}.$$

12. In this case, Bernoulli's equation reduces to Eq. 14-10. Thus,

$$p_g = \rho g(-h) = -(1800\,\text{kg/m}^3)(9.8\text{ m/s}^2)(1.5\text{ m}) = -2.6 \times 10^4\text{ Pa}.$$

17. We can integrate the pressure (which varies linearly with depth according to Eq. 14-7) over the area of the wall to find out the net force on it, and the result turns out fairly intuitive (because of that linear dependence): the force is the "average" water pressure multiplied by the area of the wall (or at least the part of the wall that is exposed to the water), where "average" pressure is taken to mean $\frac{1}{2}$(pressure at surface + pressure at bottom). Assuming the pressure at the surface can be taken to be zero (in the gauge pressure sense explained in section 14-4), then this means the force on the wall is $\frac{1}{2}\rho gh$ multiplied by the appropriate area. In this problem the area is hw (where w is the 8.00 m width), so the force is $\frac{1}{2}\rho gh^2w$, and the change in force (as h is changed) is

$$\tfrac{1}{2}\rho g w\,(h_f^{\,2} - h_i^{\,2}) = \tfrac{1}{2}(998\text{ kg/m}^3)(9.80\text{ m/s}^2)(8.00\text{ m})(4.00^2 - 2.00^2)\text{m}^2 = 4.69\times 10^5\text{ N.}$$

20. The gauge pressure you can produce is

$$p = -\rho g h = -\frac{\left(1000\,\text{kg/m}^3\right)\left(9.8\,\text{m/s}^2\right)\left(4.0\times10^{-2}\,\text{m}\right)}{1.01\times10^5\ \text{Pa/atm}} = -3.9\times10^{-3}\text{atm}$$

where the minus sign indicates that the pressure inside your lung is less than the outside pressure.

22. (a) According to Pascal's principle $F/A = f/a \rightarrow F = (A/a)f$.

(b) We obtain

$$f = \frac{a}{A}F = \frac{(3.80\text{ cm})^2}{(53.0\text{ cm})^2}(20.0\times10^3\text{ N}) = 103\text{ N.}$$

The ratio of the squares of diameters is equivalent to the ratio of the areas. We also note that the area units cancel.

25. (a) The anchor is completely submerged in water of density ρ_w. Its effective weight is $W_{\text{eff}} = W - \rho_w gV$, where W is its actual weight (mg). Thus,

$$V = \frac{W - W_{\text{eff}}}{\rho_w g} = \frac{200\text{ N}}{\left(1000\text{ kg/m}^3\right)\left(9.8\text{ m/s}^2\right)} = 2.04\times10^{-2}\text{ m}^3\,.$$

(b) The mass of the anchor is $m = \rho V$, where ρ is the density of iron (found in Table 14-1). Its weight in air is

$$W = mg = \rho V g = \left(7870\text{ kg/m}^3\right)(2.04\times10^{-2}\text{ m}^3)\left(9.80\text{ m/s}^2\right) = 1.57\times10^3\text{ N}\,.$$

26. (a) The pressure (including the contribution from the atmosphere) at a depth of $h_{\text{top}} = L/2$ (corresponding to the top of the block) is

$$p_{\text{top}} = p_{\text{atm}} + \rho g h_{\text{top}} = \left[1.01\times10^5 + (1030)(9.8)(0.300)\right]\text{Pa} = 1.04\times10^5\text{ Pa}$$

where the unit Pa (Pascal) is equivalent to N/m^2. The force on the top surface (of area $A = L^2 = 0.36\text{ m}^2$) is $F_{\text{top}} = p_{\text{top}}A = 3.75\times10^4$ N.

(b) The pressure at a depth of $h_{\text{bot}} = 3L/2$ (that of the bottom of the block) is

$$p_{\text{bot}} = p_{\text{atm}} + \rho g h_{\text{bot}} = \left[1.01\times10^5 + (1030)(9.8)(0.900)\right]\text{Pa} = 1.10\times10^5\text{ Pa}$$

where we recall that the unit Pa (Pascal) is equivalent to N/m^2. The force on the bottom surface is $F_{\text{bot}} = p_{\text{bot}} A = 3.96 \times 10^4$ N.

(c) Taking the difference $F_{\text{bot}} - F_{\text{top}}$ cancels the contribution from the atmosphere (including any numerical uncertainties associated with that value) and leads to

$$F_{\text{bot}} - F_{\text{top}} = \rho g\,(h_{\text{bot}} - h_{\text{top}})\; A = \rho g L^3 = 2.18\times 10^3 \text{ N}$$

which is to be expected on the basis of Archimedes' principle. Two other forces act on the block: an upward tension T and a downward pull of gravity mg. To remain stationary, the tension must be

$$T = mg - (F_{\text{bot}} - F_{\text{top}}) = (450 \text{ kg})(9.80 \text{ m/s}^2) - 2.18\times 10^3 \text{ N} = 2.23\times 10^3 \text{ N}.$$

(d) This has already been noted in the previous part: $F_b = 2.18\times 10^3$ N, and $T + F_b = mg$.

29. (a) Let V be the volume of the block. Then, the submerged volume is $V_s = 2V/3$. Since the block is floating, the weight of the displaced water is equal to the weight of the block, so $\rho_w V_s = \rho_b V$, where ρ_w is the density of water, and ρ_b is the density of the block. We substitute $V_s = 2V/3$ to obtain

$$\rho_b = 2\rho_w/3 = 2(1000 \text{ kg/m}^3)/3 \approx 6.7 \times 10^2 \text{ kg/m}^3.$$

(b) If ρ_o is the density of the oil, then Archimedes' principle yields $\rho_o V_s = \rho_b V$. We substitute $V_s = 0.90V$ to obtain $\rho_o = \rho_b/0.90 = 7.4 \times 10^2$ kg/m^3.

35. The volume V_{cav} of the cavities is the difference between the volume V_{cast} of the casting as a whole and the volume V_{iron} contained: $V_{\text{cav}} = V_{\text{cast}} - V_{\text{iron}}$. The volume of the iron is given by $V_{\text{iron}} = W/g\rho_{\text{iron}}$, where W is the weight of the casting and ρ_{iron} is the density of iron. The effective weight in water (of density ρ_w) is $W_{\text{eff}} = W - g\rho_w V_{\text{cast}}$. Thus, $V_{\text{cast}} = (W - W_{\text{eff}})/g\rho_w$ and

$$\begin{aligned} V_{\text{cav}} &= \frac{W - W_{\text{eff}}}{g\rho_w} - \frac{W}{g\rho_{\text{iron}}} = \frac{6000 \text{ N} - 4000 \text{ N}}{(9.8 \text{ m/s}^2)(1000 \text{ kg/m}^3)} - \frac{6000 \text{ N}}{(9.8 \text{ m/s}^2)(7.87\times 10^3 \text{ kg/m}^3)} \\ &= 0.126 \text{ m}^3 . \end{aligned}$$

41. We use the equation of continuity. Let v_1 be the speed of the water in the hose and v_2 be its speed as it leaves one of the holes. $A_1 = \pi R^2$ is the cross-sectional area of the hose. If there are N holes and A_2 is the area of a single hole, then the equation of continuity becomes

$$v_1 A_1 = v_2 \left(N A_2\right) \quad \Rightarrow \quad v_2 = \frac{A_1}{N A_2} v_1 = \frac{R^2}{N r^2} v_1$$

where R is the radius of the hose and r is the radius of a hole. Noting that $R/r = D/d$ (the ratio of diameters) we find

$$v_2 = \frac{D^2}{Nd^2} v_1 = \frac{(1.9\,\text{cm})^2}{24(0.13\,\text{cm})^2}(0.91\,\text{m/s}) = 8.1\,\text{m/s}.$$

42. We use the equation of continuity and denote the depth of the river as h. Then,

$$(8.2\,\text{m})(3.4\,\text{m})(2.3\,\text{m/s}) + (6.8\,\text{m})(3.2\,\text{m})(2.6\,\text{m/s}) = h(10.5\,\text{m})(2.9\,\text{m/s})$$

which leads to $h = 4.0$ m.

43. Suppose that a mass Δm of water is pumped in time Δt. The pump increases the potential energy of the water by Δmgh, where h is the vertical distance through which it is lifted, and increases its kinetic energy by $\frac{1}{2}\Delta mv^2$, where v is its final speed. The work it does is $\Delta W = \Delta mgh + \frac{1}{2}\Delta mv^2$ and its power is

$$P = \frac{\Delta W}{\Delta t} = \frac{\Delta m}{\Delta t}\left(gh + \frac{1}{2}v^2\right).$$

Now the rate of mass flow is $\Delta m/\Delta t = \rho_w Av$, where ρ_w is the density of water and A is the area of the hose. The area of the hose is $A = \pi r^2 = \pi(0.010\text{ m})^2 = 3.14 \times 10^{-4}\text{ m}^2$ and

$$\rho_w Av = (1000\text{ kg/m}^3)(3.14 \times 10^{-4}\text{ m}^2)(5.00\text{ m/s}) = 1.57\text{ kg/s}.$$

Thus,

$$P = \rho Av\left(gh + \frac{1}{2}v^2\right) = (1.57\,\text{kg/s})\left((9.8\,\text{m/s}^2)(3.0\,\text{m}) + \frac{(5.0\,\text{m/s})^2}{2}\right) = 66\,\text{W}.$$

45. (a) We use the equation of continuity: $A_1v_1 = A_2v_2$. Here A_1 is the area of the pipe at the top and v_1 is the speed of the water there; A_2 is the area of the pipe at the bottom and v_2 is the speed of the water there. Thus

$$v_2 = (A_1/A_2)v_1 = [(4.0\text{ cm}^2)/(8.0\text{ cm}^2)]\,(5.0\text{ m/s}) = 2.5\text{m/s}.$$

(b) We use the Bernoulli equation: $p_1 + \frac{1}{2}\rho v_1^2 + \rho gh_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho gh_2$, where ρ is the density of water, h_1 is its initial altitude, and h_2 is its final altitude. Thus

$$\begin{aligned} p_2 &= p_1 + \frac{1}{2}\rho\left(v_1^2 - v_2^2\right) + \rho g\left(h_1 - h_2\right) \\ &= 1.5\times10^5\,\text{Pa} + \frac{1}{2}(1000\,\text{kg/m}^3)\left[(5.0\,\text{m/s})^2 - (2.5\,\text{m/s})^2\right] + (1000\,\text{kg/m}^3)(9.8\,\text{m/s}^2)(10\text{ m}) \\ &= 2.6\times10^5\text{ Pa}. \end{aligned}$$

46. We use Bernoulli's equation:

$$p_2 - p_i = \rho g D + \frac{1}{2}\rho\left(v_1^2 - v_2^2\right)$$

where ρ = 1000 kg/m^3, D = 180 m, v_1 = 0.40 m/s and v_2 = 9.5 m/s. Therefore, we find Δp = 1.7 × 10^6 Pa, or 1.7 MPa. The SI unit for pressure is the Pascal (Pa) and is equivalent to N/m^2.

47. (a) The equation of continuity leads to

$$v_2 A_2 = v_1 A_1 \quad \Rightarrow \quad v_2 = v_1\left(\frac{r_1^2}{r_2^2}\right)$$

which gives v_2 = 3.9 m/s.

(b) With h = 7.6 m and p_1 = 1.7 × 10^5 Pa, Bernoulli's equation reduces to

$$p_2 = p_1 - \rho g h + \frac{1}{2}\rho\left(v_1^2 - v_2^2\right) = 8.8\times10^4\,\text{Pa}.$$

54. (a) The volume of water (during 10 minutes) is

$$V = (v_1 t)\,A_1 = (15\,\text{m/s})(10\,\text{min})(60\,\text{s/min})\left(\frac{\pi}{4}\right)(0.03\,\text{m})^2 = 6.4\,\text{m}^3.$$

(b) The speed in the left section of pipe is

$$v_2 = v_1\left(\frac{A_1}{A_2}\right) = v_1\left(\frac{d_1}{d_2}\right)^2 = (15\,\text{m/s})\left(\frac{3.0\,\text{cm}}{5.0\,\text{cm}}\right)^2 = 5.4\,\text{m/s}.$$

(c) Since $p_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$ and $h_1 = h_2,\ p_1 = p_0$, which is the atmospheric pressure,

$$\begin{aligned} p_2 &= p_0 + \frac{1}{2}\rho\left(v_1^2 - v_2^2\right) = 1.01\times10^5\,\text{Pa} + \frac{1}{2}\left(1.0\times10^3\,\text{kg/m}^3\right)\left[(15\,\text{m/s})^2 - (5.4\,\text{m/s})^2\right] \\ &= 1.99\times10^5\,\text{Pa} = 1.97\,\text{atm}. \end{aligned}$$

Thus the gauge pressure is (1.97 atm – 1.00 atm) = 0.97 atm = 9.8 × 10^4 Pa.

66. The normal force $\vec{F}_N$ exerted (upward) on the glass ball of mass m has magnitude 0.0948 N. The buoyant force exerted by the milk (upward) on the ball has magnitude

$$F_b = \rho_{\text{milk}}\, g\, V$$

where $V = \frac{4}{3}\pi r^3$ is the volume of the ball. Its radius is r = 0.0200 m. The milk density is ρ_{milk} = 1030 kg/m^3. The (actual) weight of the ball is, of course, downward, and has magnitude $F_g = m_{\text{glass}}\, g$. Application of Newton's second law (in the case of zero acceleration) yields

$$F_N + \rho_{\text{milk}}\, g\, V - m_{\text{glass}}\, g = 0$$

which leads to m_{glass} = 0.0442 kg. We note the above equation is equivalent to Eq.14-19 in the textbook.

70. To be as general as possible, we denote the ratio of body density to water density as f (so that $f = \rho/\rho_w$ = 0.95 in this problem). Floating involves an equilibrium of vertical forces acting on the body (Earth's gravity pulls down and the buoyant force pushes up). Thus,

$$F_b = F_g \Rightarrow \rho_w g V_w = \rho g V$$

where V is the total volume of the body and V_w is the portion of it which is submerged.

(a) We rearrange the above equation to yield

$$\frac{V_w}{V} = \frac{\rho}{\rho_w} = f$$

which means that 95% of the body is submerged and therefore 5% is above the water surface.

(b) We replace ρ_w with $1.6\rho_w$ in the above equilibrium of forces relationship, and find

$$\frac{V_w}{V} = \frac{\rho}{1.6\rho_w} = \frac{f}{1.6}$$

which means that 59% of the body is submerged and thus 41% is above the quicksand surface.

(c) The answer to part (b) suggests that a person in that situation is able to breathe.

76. The downward force on the balloon is mg and the upward force is $F_b = \rho_{\text{out}}Vg$. Newton's second law (with $m = \rho_{\text{in}}V$) leads to

$$\rho_{\text{out}} Vg - \rho_{\text{in}} Vg = \rho_{\text{in}} Va \quad \Rightarrow \left(\frac{\rho_{\text{out}}}{\rho_{\text{in}}} - 1\right) g = a.$$

The problem specifies $\rho_{\text{out}} / \rho_{\text{in}}$ = 1.39 (the outside air is cooler and thus more dense than the hot air inside the balloon). Thus, the upward acceleration is (1.39 – 1.00)(9.80 m/s^2) = 3.82 m/s^2.

79. (a) From Bernoulli equation $p_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$, the height of the water extended up into the standpipe for section B is related to that for section D by

$$h_B = h_D + \frac{1}{2g}\left(v_D^2 - v_B^2\right)$$

Equation of continuity further implies that $v_D A_D = v_B A_B$, or

$$v_B = \left(\frac{A_D}{A_B}\right) v_D = \left(\frac{2R_B}{R_B}\right)^2 v_D = 4v_D$$

where

$$v_D = R_V / (\pi R_D^2) = (2.0\times10^{-3}\,\text{m}^3/\text{s})/(\pi(0.040\text{ m})^2) = 0.40\text{ m/s}.$$

With $h_D = 0.50\text{ m}$, we have

$$h_B = 0.50\text{ m} + \frac{1}{2(9.8\text{ m/s}^2)}(-15)(0.40\text{ m/s})^2 = 0.38\text{ m}.$$

(b) From the above result, we see that the greater the radius of the cross-sectional area, the greater the height. Thus, $h_C > h_D > h_B > h_A$.