Halliday ♦ Resnick ♦ Walker

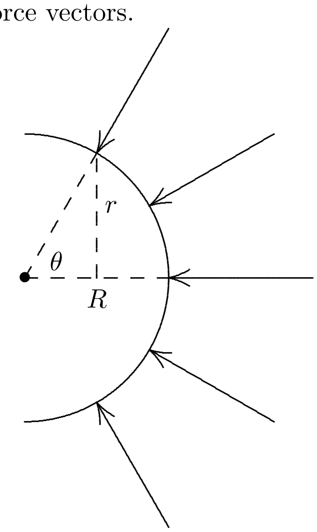
FUNDAMENTALS OF PHYSICS
SIXTH EDITION

Selected Solutions

Chapter 15

15.7
15.17
15.29
15.55

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

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

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

17. We assume that the pressure is the same at all points that are the distance $d = 20\,\text{km}$ below the surface. For points on the left side of Fig. 15-31, this pressure is given by $p = p_0 + \rho_o g d_o + \rho_c g d_c + \rho_m g d_m$, where p_0 is atmospheric pressure, ρ_o and d_o are the density and depth of the ocean, ρ_c and d_c are the density and thickness of the crust, and ρ_m and d_m are the density and thickness of the mantle (to a depth of 20 km). For points on the right side of the figure p is given by $p = p_0 + \rho_c g d$. We equate the two expressions for p and note that g cancels to obtain $\rho_c d = \rho_o d_o + \rho_c d_c + \rho_m d_m$. We substitute $d_m = d - d_o - d_c$ to obtain

$$\rho_c d = \rho_o d_o + \rho_c d_c + \rho_m d - \rho_m d_o - \rho_m d_c \ .$$

We solve for d_o:

$$\begin{aligned} d_o &= \frac{\rho_c d_c - \rho_c d + \rho_m d - \rho_m d_c}{\rho_m - \rho_o} = \frac{(\rho_m - \rho_c)(d - d_c)}{\rho_m - \rho_o} \\ &= \frac{\left(3.3\,\text{g/cm}^3 - 2.8\,\text{g/cm}^3\right)(20\,\text{km} - 12\,\text{km})}{3.3\,\text{g/cm}^3 - 1.0\,\text{g/cm}^3} = 1.7\ \text{km} \ . \end{aligned}$$

29. (a) The downward force of gravity mg is balanced by the upward buoyant force of the liquid: $mg = \rho g V_s$. Here m is the mass of the sphere, ρ is the density of the liquid, and V_s is the submerged volume. Thus $m = \rho V_s$. The submerged volume is half the total volume of the sphere, so $V_s = \frac{1}{2}(4\pi/3)r_o^3$, where r_o is the outer radius. Therefore,

$$m = \frac{2\pi}{3}\rho r_o^3 = \left(\frac{2\pi}{3}\right)\left(800\,\mathrm{kg/m^3}\right)(0.090\,\mathrm{m})^3 = 1.22\ \mathrm{kg}\ .$$

(b) The density ρ_m of the material, assumed to be uniform, is given by $\rho_m = m/V$, where m is the mass of the sphere and V is its volume. If r_i is the inner radius, the volume is

$$V = \frac{4\pi}{3}\left(r_o^3 - r_i^3\right) = \frac{4\pi}{3}\left((0.090\,\mathrm{m})^3 - (0.080\,\mathrm{m})^3\right) = 9.09\times 10^{-4}\ \mathrm{m}^3\ .$$

The density is

$$\rho_m = \frac{1.22\,\mathrm{kg}}{9.09\times 10^{-4}\,\mathrm{m}^3} = 1.3\times 10^3\ \mathrm{kg/m^3}\ .$$

55. (a) The continuity equation yields $Av = aV$, and Bernoulli's equation yields $\Delta p + \frac{1}{2}\rho v^2 = \frac{1}{2}\rho V^2$, where $\Delta p = p_1 - p_2$. The first equation gives $V = (A/a)v$. We use this to substitute for V in the second equation, and obtain $\Delta p + \frac{1}{2}\rho v^2 = \frac{1}{2}\rho (A/a)^2 v^2$. We solve for v. The result is

$$v = \sqrt{\frac{2\,\Delta p}{\rho\left(\frac{A^2}{a^2} - 1\right)}} = \sqrt{\frac{2a^2\,\Delta p}{\rho(A^2 - a^2)}}\ .$$

(b) We substitute values to obtain

$$v = \sqrt{\frac{2(32\times 10^{-4}\,\mathrm{m}^2)^2(55\times 10^3\,\mathrm{Pa} - 41\times 10^3\,\mathrm{Pa})}{(1000\,\mathrm{kg/m}^3)\left((64\times 10^{-4}\,\mathrm{m}^2)^2 - (32\times 10^{-4}\,\mathrm{m}^2)^2\right)}} = 3.06\ \mathrm{m/s}\ .$$

Consequently, the flow rate is

$$Av = \left(64\times 10^{-4}\,\mathrm{m}^2\right)(3.06\,\mathrm{m/s}) = 2.0\times 10^{-2}\ \mathrm{m}^3/\mathrm{s}\ .$$