PHYSICS 1a SOLUTIONS : CHAPTER 9

9.8

The molar mass of water is 18 g/mol. Thus the number of water molecules contained in 1.00 g of water is $[1.00\,\mathrm{g}/(18\,\mathrm{g/mol})]\,(6.02\times10^{23}/\mathrm{mol}) = 3.34\times10^{22}$. Since each H_2O molecule contains 3 atoms, the number of atoms in 1.00 g of H_2O is $3(3.34\times10^{22}) = 1.00\times10^{23}$, regardless of whether it is in liquid or solid state.

9.18

The volume of a proton of mass m and radius R is $V = 4\pi R^3/3 = 4\pi(1.35\times10^{-15}\,\mathrm{m})^3/3 = 1.031\times10^{-44}\,\mathrm{m}^3$, so its density is

$$\rho = \frac{m}{V} = \frac{1.673\times10^{-27}\,\mathrm{kg}}{1.031\times10^{-44}\,\mathrm{m}^3} = 1.62\times10^{17}\,\mathrm{kg/m^3}\,.$$

Use $1\,\mathrm{kg} = 1.102\times10^{-3}$ ton and $1\,\mathrm{m} = 39.37$ in. to convert this into ton/in.^{3}: $\rho = (1.62\times10^{17}\,\mathrm{kg/m^3})(1.102\times10^{-3}\,\mathrm{ton/kg})(1\,\mathrm{m}/39.37\,\mathrm{in.})^3 = 2.93\times10^9\,\mathrm{ton/in.^3}$.

9.27

Use Eq. (9.4) to find the pressure due to the water:

$$P_t = \rho g h = (1.00\times10^3\,\mathrm{kg/m^3})(9.81\,\mathrm{m/s^2})(3\,\mathrm{m}) = 3\times10^4\,\mathrm{Pa}\,.$$

9.32

With the previous problem in mind, the pressure in pascals is

$$P = (30\,\mathrm{lb/in.^2})\left(\frac{6.895\times10^4\,\mathrm{N/m^2}}{1.000\,\mathrm{lb/in.^2}}\right) = 2.1\times10^5\,\mathrm{Pa}\,.$$

Let the contact area between each tire and the road be A. Then the total contact area for all the four tires is $4A$, which supports the weight F_w of the car. So $F_w = P(4A)$, or

$$A = \frac{F_w}{4P} = \frac{8897\,\mathrm{N}}{4(2.1\times10^5\,\mathrm{Pa})} = 0.011\,\mathrm{m}^2\,.$$

9.33

Use Eq. (9.4) for the gauge pressure due to the sea water:

$$P_G = \rho g h = (1.025\,\mathrm{kg/m^3})(9.81\,\mathrm{m/s^2})(11\times10^3\,\mathrm{m}) = 1.1\times10^8\,\mathrm{Pa}\,.$$

With $1.000\,\mathrm{lb/in.^2} = 6.895\times10^4\,\mathrm{Pa}$, P_G may be converted to $1.6\times10^4\,\mathrm{lb/in.^2}$, i.e., 1.6×10^4 psi.

9.37

The density of mercury is $\rho = 13.6 \times 10^3\,\mathrm{kg/m^3}$. The air pressure P was indicated by the height h of the mercury column in his barometer, with $P = \rho g h$. Thus ΔP, the drop in air pressure corresponding to Δh, a change in the height of the mercury column, was

$$\begin{aligned}\Delta P &= \Delta(\rho g h) = \rho g \Delta h \\ &= (13.6 \times 10^3\,\mathrm{kg/m^3})(9.81\,\mathrm{m/s^2})\,[(3.0\,\mathrm{in.})(0.0254\,\mathrm{m/in.})] \\ &= 1.0 \times 10^4\,\mathrm{Pa}.\end{aligned}$$

9.45

The pressure P_l due to 40 cm of water is given by $P_l = \rho g h$, where $\rho = 1.00 \times 10^3\,\mathrm{kg/m^3}$ is the density of water, and $h = 40\,\mathrm{cm} = 0.40\,\mathrm{m}$. Thus

$$P = \rho g h = (1.00 \times 10^3\,\mathrm{kg/m^3})(9.81\,\mathrm{m/s^2})(0.40\,\mathrm{m}) = 3.9 \times 10^3\,\mathrm{Pa}.$$

9.47

From the problem statement we know that P_G, the lowest gauge pressure most people can create in their lungs, is equal to that due to a water column of height $h = 1.1\,\mathrm{m}$. Thus

$$P_G = -\rho_W g h = -(1.00 \times 10^3\,\mathrm{kg/m^3})(9.81\,\mathrm{m/s^2})(1.1\,\mathrm{m}) = -1.1 \times 10^4\,\mathrm{Pa}.$$

Here the minus sign indicates that the pressure inside the lung is lower than that outside.

9.51

Let the pressure difference between the two sides of the hatch be ΔP and the surface area of either side of the hatch be A. Then the force F needed to open the hatch is $F = A\Delta P$. Note

that the pressure outside the sub is $P_{out} = P_A + \rho_W g h$, where $h = 20.0\,\mathrm{m}$ is the depth of the water; while that inside the sub is $P_{in} = 90\% P_A$. So $\Delta P = P_{out} - P_{in} = P_A + \rho_W g h - 90\% P_A = 0.10 P_A + \rho_W g h$, and

$$\begin{aligned}F &= A\Delta P = A(0.10 P_A + \rho_W g h) \\ &= (1.0 \times 0.5\,\mathrm{m})\left[0.10(1.013 \times 10^5\,\mathrm{Pa}) + (1.00 \times 10^3\,\mathrm{kg/m^3})(9.81\,\mathrm{m/s^2})(20.0\,\mathrm{m})\right] \\ &= 1.1 \times 10^5\,\mathrm{N},\end{aligned}$$

which is about 24×10^3 lb, or 12 tons.

9.70

Use Eq. (9.7): $F_o/F_i = A_o/A_i$. Here $F_o = (900\,\mathrm{kg})(9.81\,\mathrm{m/s^2}) = 8829\,\mathrm{N}$, $A_i = 64.0\,\mathrm{cm^2}$, and $A_o = 3200\,\mathrm{cm^2}$; so

$$F_i = F_o\left(\frac{A_i}{A_o}\right) = \frac{(8829\,\mathrm{N})(64.0\,\mathrm{cm^2})}{3200\,\mathrm{cm^2}} = 177\,\mathrm{N}.$$

The displacement of the piston, y_i, is related to that of the car, y_o (= 2.00 m), by Eq. (9.8), $A_o/A_i = y_i/y_o$, which we combine with Eq. (9.7) to solve for y_i:

$$y_i = y_o\left(\frac{F_o}{F_i}\right) = \frac{(2.00\,\mathrm{m})(8829\,\mathrm{N})}{176.58\,\mathrm{N}} = 100\,\mathrm{m}.$$

9.84

Since she floats around in the swimming pool, the woman must be receiving a buoyant force equal to her weight ($F_W = 500\,\text{N}$), meaning that she must have displaced an amount of water which weighs 500 N. The corresponding volume of the water she displaces is $V = F_W/\rho_W g = 500\,\text{N}/[(1.000\,\text{kg/m}^3)(9.81\,\text{m/s}^2)] = 0.050\,97\,\text{m}^3$. If the water level in the pool of surface area A rises by h as a result of her arrival, then $Ah = V$, or

$$h = \frac{V}{A} = \frac{0.050\,97\,\text{m}^3}{10\,\text{m} \times 10\,\text{m}} = 5.1 \times 10^{-4}\,\text{m} = 0.51\,\text{mm}.$$

9.87

Let the required volume of the balloon be V, then the weight of the helium (He) is $\rho_{He} gV$, and the buoyant force exerted by the air on the balloon is $F_B = \rho_{air} gV$. For the balloon to be in equilibrium, its total weight F_W must be equal to F_B:

$$F_W = \rho_{He} gV + F_{WL} = F_B = \rho_{air} gV,$$

where $F_{WL} = (454\,\text{kg})g$ is the weight of the load. Solve for V:

$$V = \frac{F_{WL}}{(\rho_{air} - \rho_{He})g} = \frac{(454\,\text{kg})g}{(1.29\,\text{kg/m}^3 - 0.178\,\text{kg/m}^3)g} = 408.3\,\text{m}^3.$$

The corresponding mass m_{He} of the helium is $m_{He} = \rho_{He} V = (0.178\,\text{kg/m}^3)(408.3\,\text{m}^3) = 72.7\,\text{kg}$.

9.92

The volume of fluid passing through a certain cross-sectional area per unit time is J. If the density of the fluid is ρ, then the mass of the fluid passing through per unit time is ρJ, which by definition is the mass-flow rate (called J_m). With the previous problem in mind, the flow rate J is found to be $J = \frac{1}{4}\pi D^2 v$. The mass-flow rate is then

$$J_m = \rho J = \frac{\pi}{4}\rho D^2 v = \frac{\pi}{4}(0.68 \times 10^3\,\text{kg/m}^3)(0.050\,\text{m})^2(2.5\,\text{m/s}) = 3.3\,\text{kg/s}.$$

9.96

The pressure change due to the change in the cross-sectional area of the pipe is obtained by solving the combination of Bernoulli's Equation, $P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$, and the Equation of Continuity, $A_1 v_1 = A_2 v_2$. Here the subscripts 1 and 2 denote the high- and low-pressure sides, respectively. The result is $P_1 - P_2 = \frac{1}{2}\rho v_2^2 (A_1^2 - A_2^2)/A_1^2$. Solve for v_2, the flow speed at the low-pressure side, from this equation, then substitute the result into the formula for the flow rate, $J = A_2 v_2$:

$$\begin{aligned} J = A_2 v_2 &= A_2 \sqrt{\frac{2(P_1 - P_2)A_1^2}{A_1^2 - A_2^2}} \\ &= (50 \times 10^{-4}\,\text{m}^2)\sqrt{\frac{2(80 \times 10^3\,\text{Pa})(200\,\text{cm}^2)^2}{(200\,\text{cm}^2)^2 - (50\,\text{cm}^2)^2}} \\ &= 6.5 \times 10^{-2}\,\text{m}^3/\text{s}. \end{aligned}$$

9.107

Apply Bernoulli's Equation to the flow at the pipe (p) and the throat (t): $P_p + \frac{1}{2}\rho v_p^2 + \rho g y_p = P_t + \frac{1}{2}\rho v_t^2 + \rho g y_t$. Note that $y_p = y_t$, and $A_p v_p = A_t v_t$ (the Continuity Equation), or $v_p = v_t(A_t/A_p)$. Thus the equation above reduces to

$$\Delta P = P_p - P_t = \frac{1}{2}\rho(v_t^2 - v_p^2) = \frac{1}{2}\rho v_t^2\left(1 - \frac{A_t^2}{A_p^2}\right).$$

Now, the pressure difference ΔP between the pipe and the throat is responsible for the difference in the height of the two liquid columns, so $\Delta P = \rho g \Delta y$. Substitute this into the expression for ΔP above and solve for v_p:

$$v_p = \sqrt{\frac{2g\Delta y}{A_p^2/A_t^2 - 1}}$$

9.109

When the vaccine fluid is inside the gun, its speed v_1 is zero while its pressure is $P_1 = (550\,\text{psi})(6.895\times10^4\,\text{Pa/psi}) = 3.792\times10^6\,\text{Pa}$, where we used the conversion factor $1.000\,\text{psi} = 6.895\times10^3\,\text{Pa}$ found in Problem (9.31). As the fluid is ejected into the air, its speed is v_2 and its pressure is $P_2 = P_A = 1.013\times10^5\,\text{Pa}$, since it is exposed to the air. For convenience, set $y_1 = y_2 = 0$ and apply Bernoulli's Equation:

$$P_1 + \frac{1}{2}\rho v_1^2 = P_1 = P_2 + \frac{1}{2}\rho v_2^2 = P_A + \frac{1}{2}\rho v_2^2,$$

which we solve for v_2:

$$v_2 = \sqrt{\frac{2(P_1 - P_A)}{\rho}} = \sqrt{\frac{2(3.792\times10^6\,\text{Pa} - 1.013\times10^5\,\text{Pa})}{1.1\times10^3\,\text{kg/m}^3}} = 82\,\text{m/s},$$

which amounts to about 180 mph.