SOLUTIONS TO PROBLEMS

P13.9 $a = \dfrac{MG}{(4R_E)^2} = \dfrac{9.80\ \text{m/s}^2}{16.0} = \boxed{0.613\ \text{m/s}^2}$ toward the Earth.

P13.10 $$g = \frac{GM}{R^2} = \frac{G\rho\left(\frac{4\pi R^3}{3}\right)}{R^2} = \frac{4}{3}\pi G\rho R$$

If $$\frac{g_M}{g_E} = \frac{1}{6} = \frac{\frac{4\pi G\rho_M R_M}{3}}{\frac{4\pi G\rho_E R_E}{3}}$$

then $$\frac{\rho_M}{\rho_E} = \left(\frac{g_M}{g_E}\right)\left(\frac{R_E}{R_M}\right) = \left(\frac{1}{6}\right)(4) = \boxed{\frac{2}{3}}.$$

P13.17 By Kepler's Third Law, $T^2 = ka^3$ ($a =$ semi-major axis)

For any object orbiting the Sun, with T in years and a in A.U., $k = 1.00$. Therefore, for Comet Halley

$$(75.6)^2 = (1.00)\left(\frac{0.570 + y}{2}\right)^3$$

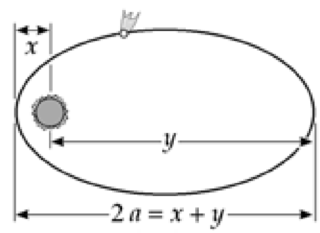

FIG. P13.17

The farthest distance the comet gets from the Sun is

$$y = 2(75.6)^{2/3} - 0.570 = \boxed{35.2\ \text{A.U.}}$$ (out around the orbit of Pluto)

P13.39 $$E_{\text{tot}} = -\frac{GMm}{2r}$$

$$\Delta E = \frac{GMm}{2}\left(\frac{1}{r_i} - \frac{1}{r_f}\right) = \frac{(6.67\times 10^{-11})(5.98\times 10^{24})}{2}\,\frac{10^3\ \text{kg}}{10^3\ \text{m}}\left(\frac{1}{6\ 370 + 100} - \frac{1}{6\ 370 + 200}\right)$$

$$\Delta E = 4.69\times 10^8\ \text{J} = \boxed{469\ \text{MJ}}$$

***P13.53** (a) Each bit of mass dm in the ring is at the same distance from the object at A. The separate contributions $-\dfrac{Gmdm}{r}$ to the system energy add up to $-\dfrac{GmM_{\text{ring}}}{r}$. When the object is at A, this is

$$\frac{-6.67\times 10^{-11}\ \text{N}\cdot\text{m}^2\,1\ 000\ \text{kg}\ 2.36\times 10^{20}\ \text{kg}}{\text{kg}^2\sqrt{(1\times 10^8\ \text{m})^2 + (2\times 10^8\ \text{m})^2}} = \boxed{-7.04\times 10^4\ \text{J}}.$$

(b) When the object is at the center of the ring, the potential energy is

$$-\frac{6.67\times 10^{-11}\ \text{N}\cdot\text{m}^2\ 1\ 000\ \text{kg}\ 2.36\times 10^{20}\ \text{kg}}{\text{kg}^2\,1\times 10^8\ \text{m}} = \boxed{-1.57\times 10^5\ \text{J}}.$$

continued on next page

(c) Total energy of the object-ring system is conserved:

$$\left(K+U_g\right)_A = \left(K+U_g\right)_B$$

$$0-7.04\times10^4\ \text{J} = \frac{1}{2}1\,000\ \text{kg}v_B^2 - 1.57\times10^5\ \text{J}$$

$$v_B = \left(\frac{2\times8.70\times10^4\ \text{J}}{1\,000\ \text{kg}}\right)^{1/2} = \boxed{13.2\ \text{m/s}}$$

P13.54 To approximate the height of the sulfur, set

$$\frac{mv^2}{2} = mg_{Io}h \qquad h = 70\,000\ \text{m} \qquad g_{Io} = \frac{GM}{r^2} = 1.79\ \text{m/s}^2$$

$$v = \sqrt{2g_{Io}h}$$

$$v = \sqrt{2(1.79)(70\,000)} \approx 500\ \text{m/s}\ \ (\text{over } 1\,000\ \text{mi/h})$$

A more precise answer is given by

$$\frac{1}{2}mv^2 - \frac{GMm}{r_1} = -\frac{GMm}{r_2}$$

$$\frac{1}{2}v^2 = \left(6.67\times10^{-11}\right)\left(8.90\times10^{22}\right)\left(\frac{1}{1.82\times10^6} - \frac{1}{1.89\times10^6}\right) \qquad v = \boxed{492\ \text{m/s}}$$

P13.62 (a) The net torque exerted on the Earth is zero. Therefore, the angular momentum of the Earth is conserved;

$$mr_a v_a = mr_p v_p \text{ and } v_a = v_p\left(\frac{r_p}{r_a}\right) = \left(3.027\times10^4\ \text{m/s}\right)\left(\frac{1.471}{1.521}\right) = \boxed{2.93\times10^4\ \text{m/s}}$$

(b) $$K_p = \frac{1}{2}mv_p^2 = \frac{1}{2}\left(5.98\times10^{24}\right)\left(3.027\times10^4\right)^2 = \boxed{2.74\times10^{33}\ \text{J}}$$

$$U_p = -\frac{GmM}{r_p} = -\frac{\left(6.673\times10^{-11}\right)\left(5.98\times10^{24}\right)\left(1.99\times10^{30}\right)}{1.471\times10^{11}} = \boxed{-5.40\times10^{33}\ \text{J}}$$

(c) Using the same form as in part (b), $K_a = \boxed{2.57\times10^{33}\ \text{J}}$ and $U_a = \boxed{-5.22\times10^{33}\ \text{J}}$.

Compare to find that $K_p + U_p = \boxed{-2.66\times10^{33}\ \text{J}}$ and $K_a + U_a = \boxed{-2.65\times10^{33}\ \text{J}}$. They agree.

SOLUTIONS TO PROBLEMS

P14.10 (a) Suppose the "vacuum cleaner" functions as a high–vacuum pump. The air below the brick will exert on it a lifting force

$$F = PA = 1.013\times10^5\ \text{Pa}\left[\pi\left(1.43\times10^{-2}\ \text{m}\right)^2\right] = \boxed{65.1\ \text{N}}.$$

(b) The octopus can pull the bottom away from the top shell with a force that could be no larger than

$$F = PA = \left(P_0 + \rho gh\right)A = \left[1.013\times10^5\ \text{Pa} + \left(1\,030\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)\left(32.3\ \text{m}\right)\right]\left[\pi\left(1.43\times10^{-2}\ \text{m}\right)^2\right]$$

$$F = \boxed{275\ \text{N}}$$

14.12 The pressure on the bottom due to the water is $P_b = \rho gz = 1.96\times10^4\ \text{Pa}$

So, $F_b = P_bA = \boxed{5.88\times10^6\ \text{N}}$

On each end, $F = \overline{P}A = 9.80\times10^3\ \text{Pa}\left(20.0\ \text{m}^2\right) = \boxed{196\ \text{kN}}$

On the side, $F = \overline{P}A = 9.80\times10^3\ \text{Pa}\left(60.0\ \text{m}^2\right) = \boxed{588\ \text{kN}}$

P14.20 Let h be the height of the water column added to the right side of the U–tube. Then when equilibrium is reached, the situation is as shown in the sketch at right. Now consider two points, A and B shown in the sketch, at the level of the water–mercury interface. By Pascal's Principle, the absolute pressure at B is the same as that at A. But,

$$P_A = P_0 + \rho_w gh + \rho_{\text{Hg}} gh_2 \text{ and}$$
$$P_B = P_0 + \rho_w g\left(h_1 + h + h_2\right).$$

Thus, from $P_A = P_B$, $\rho_w h_1 + \rho_w h + \rho_w h_2 = \rho_w h + \rho_{\text{Hg}} h_2$, or

$$h_1 = \left[\frac{\rho_{\text{Hg}}}{\rho_w} - 1\right]h_2 = \left(13.6 - 1\right)\left(1.00\ \text{cm}\right) = \boxed{12.6\ \text{cm}}.$$

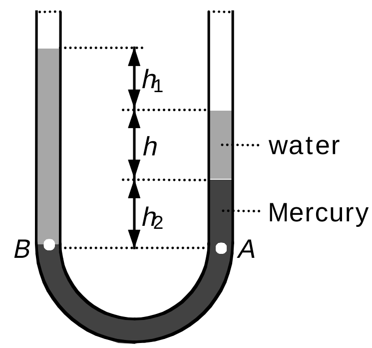

FIG. P14.20