1. The magnitude of the force of one particle on the other is given by $F = Gm_1m_2/r^2$, where m_1 and m_2 are the masses, r is their separation, and G is the universal gravitational constant. We solve for r:

$$r = \sqrt{\frac{Gm_1m_2}{F}} = \sqrt{\frac{(6.67 \times 10^{-11}\,\mathrm{N \cdot m^2/kg^2})(5.2\,\mathrm{kg})(2.4\,\mathrm{kg})}{2.3 \times 10^{-12}\,\mathrm{N}}} = 19 \text{ m} .$$

31. (a) The work done by you in moving the sphere of mass m_2 equals the change in the potential energy of the three-sphere system. The initial potential energy is

$$U_i = -\frac{Gm_1m_2}{d} - \frac{Gm_1m_3}{L} - \frac{Gm_2m_3}{L-d}$$

and the final potential energy is

$$U_f = -\frac{Gm_1m_2}{L-d} - \frac{Gm_1m_3}{L} - \frac{Gm_2m_3}{d} \; .$$

The work done is

$$\begin{aligned} W &= U_f - U_i = Gm_2\left(m_1\left(\frac{1}{d} - \frac{1}{L-d}\right) + m_3\left(\frac{1}{L-d} - \frac{1}{d}\right)\right) \\ &= (6.67\times10^{-11}\,\mathrm{m^3/s^2\cdot kg})(0.10\,\mathrm{kg})\left[(0.80\,\mathrm{kg})\left(\frac{1}{0.040\,\mathrm{m}} - \frac{1}{0.080\,\mathrm{m}}\right)\right. \\ &\qquad \left. + (0.20\,\mathrm{kg})\left(\frac{1}{0.080\,\mathrm{m}} - \frac{1}{0.040\,\mathrm{m}}\right)\right] \\ &= +5.0\times10^{-11}\ \mathrm{J}\; . \end{aligned}$$

(b) The work done by the force of gravity is $-(U_f - U_i) = -5.0\times10^{-11}$ J.

36. (a) We note that $height = R - R_{\text{Earth}}$ where $R_{\text{Earth}} = 6.37 \times 10^6$ m. With $M = 5.98 \times 10^{24}$ kg, $R_0 = 6.57 \times 10^6$ m and $R = 7.37 \times 10^6$ m, we have

$$K_i + U_i = K + U \implies \frac{1}{2} m \left(3.7 \times 10^3\right)^2 - \frac{GmM}{R_0} = K - \frac{GmM}{R}$$

Solving, we find $K = 3.8 \times 10^7$ J.

(b) Again, we use energy conservation.

$$K_i + U_i = K_f + U_f \implies \frac{1}{2} m \left(3.7 \times 10^3\right)^2 - \frac{GmM}{R_0} = 0 - \frac{GmM}{R_f}$$

Therefore, we find $R_f = 7.40 \times 10^6$ m. This corresponds to a distance of $1034.9 \approx 1.03 \times 10^3$ km above the earth's surface.

39. Energy conservation for this situation may be expressed as follows:

$$\begin{aligned} K_1 + U_1 &= K_2 + U_2 \\ \frac{1}{2}mv_1^2 - \frac{GmM}{r_1} &= \frac{1}{2}mv_2^2 - \frac{GmM}{r_2} \end{aligned}$$

where $M = 5.98 \times 10^{24}\,\text{kg}$, $r_1 = R = 6.37 \times 10^6\,\text{m}$ and $v_1 = 10000\,\text{m/s}$. Setting $v_2 = 0$ to find the maximum of its trajectory, we solve the above equation (noting that m cancels in the process) and obtain $r_2 = 3.2 \times 10^7$ m. This implies that its *altitude* is $r_2 - R = 2.5 \times 10^7$ m.

41. The period T and orbit radius r are related by the law of periods: $T^2 = (4\pi^2/GM)r^3$, where M is the mass of Mars. The period is 7 h 39 min, which is 2.754×10^4 s. We solve for M:

$$\begin{aligned} M &= \frac{4\pi^2 r^3}{GT^2} \\ &= \frac{4\pi^2(9.4 \times 10^6\,\mathrm{m})^3}{(6.67 \times 10^{-11}\,\mathrm{m^3/s^2\cdot kg})(2.754 \times 10^4\,\mathrm{s})^2} = 6.5 \times 10^{23}\ \mathrm{kg}\ . \end{aligned}$$

61. The energy required to raise a satellite of mass m to an altitude h (at rest) is given by

$$E_1 = \Delta U = GM_E m \left(\frac{1}{R_E} - \frac{1}{R_E + h} \right) ,$$

and the energy required to put it in circular orbit once it is there is

$$E_2 = \frac{1}{2} m v_{\rm orb}^2 = \frac{GM_E m}{2(R_E + h)} .$$

Consequently, the energy difference is

$$\Delta E = E_1 - E_2 = GM_E m \left[\frac{1}{R_E} - \frac{3}{2(R_E + h)} \right] .$$

(a) Since

$$\frac{1}{R_E} - \frac{3}{2(R_E + h)} = \frac{1}{6370\,\text{km}} - \frac{3}{2(6370\,\text{km} + 1500\,\text{km})} < 0$$

the answer is no ($E_1 < E_2$).

(b) Since

$$\frac{1}{R_E} - \frac{3}{2(R_E + h)} = \frac{1}{6370\,\text{km}} - \frac{3}{2(6370\,\text{km} + 3185\,\text{km})} = 0$$

we have $E_1 = E_2$.

(c) Since

$$\frac{1}{R_E} - \frac{3}{2(R_E + h)} = \frac{1}{6370\,\text{km}} - \frac{3}{2(6370\,\text{km} + 4500\,\text{km})} > 0$$

the answer is yes ($E_1 > E_2$).