3. 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:

$$r = \sqrt{\frac{Gm_1m_2}{F}} = \sqrt{\frac{(6.67\times10^{-11}\,\text{N}\cdot\text{m}^2/\text{kg}^2)(5.2\text{kg})(2.4\text{kg})}{2.3\times10^{-12}\,\text{N}}} = 19\,\text{m}.$$

17. (a) The gravitational acceleration at the surface of the Moon is $g_{moon} = 1.67$ m/s^2 (see Appendix C). The ratio of weights (for a given mass) is the ratio of g-values, so

$$W_{moon} = (100\text{ N})(1.67/9.8) = 17\text{ N}.$$

(b) For the force on that object caused by Earth's gravity to equal 17 N, then the free-fall acceleration at its location must be $a_g = 1.67$ m/s^2. Thus,

$$a_g = \frac{Gm_E}{r^2} \Rightarrow r = \sqrt{\frac{Gm_E}{a_g}} = 1.5\times10^7\,\text{m}$$

so the object would need to be a distance of $r/R_E = 2.4$ "radii" from Earth's center.

19. The acceleration due to gravity is given by $a_g = GM/r^2$, where M is the mass of Earth and r is the distance from Earth's center. We substitute $r = R + h$, where R is the radius of Earth and h is the altitude, to obtain

$$a_g = \frac{GM}{r^2} = \frac{GM}{(R_E+h)^2}.$$

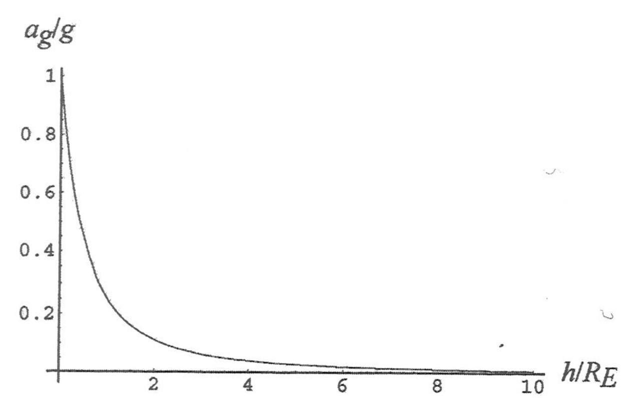
We solve for h and obtain $h = \sqrt{GM/a_g} - R_E$. From Appendix C, $R_E = 6.37\times10^6$ m and $M = 5.98\times10^{24}$ kg, so

$$h = \sqrt{\frac{(6.67\times10^{-11}\,\text{m}^3/\text{s}^2\cdot\text{kg})(5.98\times10^{24}\,\text{kg})}{(4.9\,\text{m/s}^2)}} - 6.37\times10^6\,\text{m} = 2.6\times10^6\,\text{m}.$$

Note: We may rewrite a_g as

$$a_g = \frac{GM}{r^2} = \frac{GM/R_E^2}{(1+h/R_E)^2} = \frac{g}{(1+h/R_E)^2}$$

where $g = 9.83\,\text{m/s}^2$ is the gravitational acceleration on the surface of the Earth. The plot below depicts how a_g decreases with increasing altitude.



24. (a) What contributes to the GmM/r^2 force on m is the (spherically distributed) mass M contained within r (where r is measured from the center of M). At point A we see that $M_1 + M_2$ is at a smaller radius than $r = a$ and thus contributes to the force:

$$\left|F_{\text{on } m}\right| = \frac{G(M_1 + M_2)m}{a^2}.$$

(b) In the case $r = b$, only M_1 is contained within that radius, so the force on m becomes GM_1m/b^2.

(c) If the particle is at C, then no other mass is at smaller radius and the gravitational force on it is zero.

31. The density of a uniform sphere is given by $\rho = 3M/4\pi R^3$, where M is its mass and R is its radius. On the other hand, the value of gravitational acceleration a_g at the surface of a planet is given by $a_g = GM/R^2$. For a particle of mass m, its escape speed is given by

$$\frac{1}{2}mv^2 = G\frac{mM}{R} \quad \Rightarrow \quad v = \sqrt{\frac{2GM}{R}}.$$

(a) From the definition of density above, we find the ratio of the density of Mars to the density of Earth to be

$$\frac{\rho_M}{\rho_E} = \frac{M_M}{M_E}\frac{R_E^3}{R_M^3} = 0.11\left(\frac{0.65\times10^4\text{ km}}{3.45\times10^3\text{ km}}\right)^3 = 0.74.$$

(b) The value of gravitational acceleration for Mars is

$$a_{gM} = \frac{GM_M}{R_M^2} = \frac{M_M}{R_M^2}\cdot\frac{R_E^2}{M_E}\cdot\frac{GM_E}{R_E^2} = \frac{M_M}{M_E}\frac{R_E^2}{R_M^2}a_{gE}$$

$$= 0.11\left(\frac{0.65\times10^4\text{ km}}{3.45\times10^3\text{ km}}\right)^2\left(9.8\text{ m/s}^2\right) = 3.8\text{ m/s}^2.$$

(c) For Mars, the escape speed is

$$v_M = \sqrt{\frac{2GM_M}{R_M}} = \sqrt{\frac{2(6.67\times10^{-11}\text{ m}^3/\text{s}^2\cdot\text{kg})(0.11)(5.98\times10^{24}\text{ kg})}{3.45\times10^6\text{ m}}} = 5.0\times10^3\text{ m/s}.$$

Note: The ratio of the escape speeds on Mars and on Earth is

$$\frac{v_M}{v_E} = \frac{\sqrt{2GM_M/R_M}}{\sqrt{2GM_E/R_E}} = \sqrt{\frac{M_M}{M_E}\cdot\frac{R_E}{R_M}} = \sqrt{(0.11)\cdot\frac{6.5\times10^3\text{ km}}{3.45\times10^3\text{ km}}} = 0.455.$$

44. Kepler's law of periods, expressed as a ratio, is

$$\left(\frac{r_s}{r_m}\right)^3 = \left(\frac{T_s}{T_m}\right)^2 \Rightarrow \left(\frac{1}{2}\right)^3 = \left(\frac{T_s}{1\text{ lunar month}}\right)^2$$

which yields $T_s = 0.35$ lunar month for the period of the satellite.