

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

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

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 ( $E_1 > E_2$ ).