The National Academy of Science, in order to gather information on deforestation, wishes to place a 520 kg infrared–sensing satellite in a polar orbit around the earth. The radius of the earth is approximately $6.38 \times 10^3$ km, and the acceleration of gravity at the orbital altitude of 160 km is very nearly the same as it is at the surface of the earth.

1. Construct a force diagram for the satellite described in the statement above.
2. What is the agent of the centripetal force for the satellite?
3. How much work is done on the satellite during one complete orbit of the earth? Explain your answer.
4. Determine how long it would take for the satellite to make one complete revolution around the earth.

The earth’s orbit around the sun is very nearly circular, with an average radius of 1.5 x 10^8 km. Assume the mass of the earth is 6.0 x 10^24 kg.

5. What is the average speed of the earth in its orbit around the sun?
6. What is the magnitude of the earth's average acceleration in its orbit around the sun? Show your work.
7. With what force does the sun attract the earth?

The gravitational field strength on the moon, which has a radius of $1.74 \times 10^6$ m, is approximately 0.17 as large as the gravitational field strength at the surface of the earth. Assume that the diagram below represents the orbit of the satellite around the moon at an altitude of 100 km.

8. How much would a 1500 kg satellite weigh at the surface of the moon?
9. Construct a force diagram of the satellite in orbit.
10. Demonstrate the direction of the acceleration, if any, by means of a motion map.
11. What is the radius of the orbit of the satellite?
12. What is the orbital speed of the satellite?
13. What would be the orbital period of the satellite (in hours)?
14. If the satellite were to change its orbit so that it was now at an altitude of 50 km, would it have to speed up or slow down? By what factor is the velocity changed? Explain.
1. The only force is gravity always pointing to the center of the Earth.
2. The centripetal force is gravity.
3. No work is done since there is no change in energy.
4. 
   \[ a_c = \frac{v^2}{r} \]
   
   \[ gr = \left( \frac{2\pi r}{T} \right)^2 \]
   
   \[ gr = \frac{4\pi^2 r^2}{T^2} \]
   
   \[ T^2 = \frac{4\pi^2 r^2}{gr} \]
   
   \[ T = \sqrt{\frac{4\pi^2 r}{g}} \]
   
   \[ T = \frac{4\pi^2 (6380000 m + 160000 m)}{9.8 \text{ m/s}^2} \]
   
   \[ T = 5100 \text{ s} \]
   
   \[ T = 86 \text{ min} \]

5. 
   
   \[ v = \frac{2\pi r}{T} \]
   
   \[ v = \frac{2\pi(1.5 \times 10^{11} \text{ m})}{31556736 \text{ s}} \]
   
   \[ v = 30000 \text{ m/s} \]

6. 
   
   \[ a_c = \frac{v^2}{r} \]
   
   \[ a_c = \frac{(30000 \text{ m/s})^2}{1.5 \times 10^{11} \text{ m}} \]
   
   \[ F_c = \frac{0.0059 \text{ m/s}^2}{1.5 \times 10^{11} \text{ m}} \]

7. 
   
   \[ F_c = \frac{mv^2}{r} \]
   
   \[ F_c = \frac{(6.0 \times 10^{24} \text{ kg})(30000 \text{ m/s})^2}{1.5 \times 10^{11} \text{ m}} \]
   
   \[ F_c = 3.6 \times 10^{22} \text{ N} \]

8. 
   
   \[ g_M = 0.17g_E \]
   
   \[ g_M = 0.17(9.8 \text{ m/s}^2) \]
   
   \[ g_M = 1.67 \text{ m/s}^2 \]

   \[ F_g = mg_M \]
   
   \[ F_g = (1500 \text{ kg})(1.67 \text{ m/s}^2) \]
   
   \[ F_g = 2500 \text{ N} \]

9. The only force is gravity which always points to the center of the moon.

10. 

11. 
   
   \[ r = 1.74 \times 10^6 \text{ m} + 100000 \text{ m} \]
   
   \[ r = 1.84 \times 10^6 \text{ m} \]

12. 
   
   \[ a_c = \frac{v^2}{r} \]
   
   \[ v = \sqrt{a_c r} \]
   
   \[ v = \sqrt{(1.67 \text{ m/s}^2)(1.84 \times 10^6 \text{ m})} \]
   
   \[ v = 1750 \text{ m/s} \]

13. 
   
   \[ v = \frac{2\pi r}{T} \]
   
   \[ T = \frac{2\pi r}{v} \]
   
   \[ r = 2\pi(1.84 \times 10^6 \text{ m}) \]
   
   \[ T = 6600 \text{ s} \]
   
   \[ T = 1.8 \text{ h} \]

14. 
   
   \[ v = \sqrt{a_c r} \]
   
   As \( r \) decreases so will \( v \). The radius decreases by \( \frac{1.835 \times 10^6 \text{ m}}{1.84 \times 10^6 \text{ m}} = 0.997 \) then the speed will decrease by \( \sqrt{0.997} = 0.998 \).