5.04A

Orbital and Gravitation Problems

•$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$ •$M_E = 5.98 \times 10^{24}$ kg •$R_E = 6.38 \times 10^6$

1. What is the force of attraction between a 2kg mass and a 5 kg mass located 2 mm apart? What makes this problem unlikely to be physically achievable?

2. The gravitational force between two masses is found to be 10 μN at a separation of x meters. If the separation is doubled to 2x, what is the attractive force? If, at some later time, the same two masses are found to attract with a force of 90 μN, what is their required separation?

3. An Earth satellite has an orbital period of 2 hours. What is its orbital radius? What is its speed?

4. The moon orbits the Earth with an average orbital radius of 3.84×10^8 meters. Assuming the moon's orbit is circular, what is its orbital period?

5. Assuming the Earth orbits the sun in a circular path with a radius of 1.5×10^{11} meters, use what you know about the period of its orbit to find the mass of the sun.

6. Use Newton's Law of Universal Gravitation to determine the acceleration of gravity on the Earth. Show all your steps clearly.

7. Jupiter's mass is approximately 300 times that of the Earth and its radius is approximately 10 times that of the Earth. Use this information and the acceleration of gravity on the Earth (9.8 m/s/s) to find the acceleration of gravity on Jupiter. (Is Jupiter denser or less dense than the Earth based on this information?)

8. (Harder) Planet X has an acceleration of gravity of 5 m/s/s. Planet Y has sixteen times the mass of Planet X, but an equal density. What is the acceleration of gravity on Planet Y?

9. A satellite orbits the Earth with a speed of 4000 m/s in a circular orbit. What is the period of the orbit? What is the orbital radius?

10. Katherine Sheeleigh's mass is approximately 45 kg. How hard does the moon pull on her when she sits in a classroom here on Earth? How hard does the sun pull on her in the same situation? How hard does the Earth pull on her? What do you observe about the relative magnitudes of these three pulls?

11. Earth satellite A orbits at a radius of double the Earth's own radius, and satellite B orbits at quadruple the Earth's radius. Which satellite has the higher speed, and by what ratio? Which satellite has the longer period, and by what ratio?

Key

1. 1.67×10^{-4} N, the objects would need to be very dense to have masses of 2 and 5 kg and to get their centers 2mm apart
2. 2.5 μN, x/3 m
3. 8.06×10^{6} m, 7000 m/s
4. 2.37×10^{6} sec
5. 2.01×10^{30} kg
6. 9.80 m/s^2
7. 29.4 m/s^2, less dense
8. 12.5 m/s^2
9. 3.9×10^{4} sec, 2.5×10^{7} m
10. moon: 0.0015 N, sun: 0.27 N, earth: 441 N
11. satellite A $v_a / v_b = \sqrt{2}$, satellite B $T_b / T_a = 2^{3/2}$