AP Physics Problem Set: Newton & Kepler

Multiple Choice
Identify the choice that best completes the statement or answers the question.

___ 1. Kepler’s first law states that
   a. the orbits of the planets are elliptical.
   b. the speed of a planet’s orbit varies depending on which part of the ellipse it is occupying.
   c. the square of the ratio of the periods of any two planets revolving around the Sun is equal to the cube of the ratio of their average distance from the Sun.
   d. objects attract other objects with a force that is directly proportional to the product of their masses, and inversely proportional to the square of the distance between them.

___ 2. Kepler’s second law states that
   a. the orbits of the planets are elliptical.
   b. the speed of a planet’s orbit varies depending on which part of the ellipse it is occupying.
   c. the square of the ratio of the periods of any two planets revolving around the Sun is equal to the cube of the ratio of their average distance from the Sun.
   d. objects attract other objects with a force that is directly proportional to the product of their masses, and inversely proportional to the square of the distance between them.

___ 3. Kepler’s third law states that
   a. the orbits of the planets are elliptical.
   b. the speed of a planet’s orbit varies depending on which part of the ellipse it is occupying.
   c. the square of the ratio of the periods of any two planets revolving around the Sun is equal to the cube of the ratio of their average distance from the Sun.
   d. objects attract other objects with a force that is directly proportional to the product of their masses, and inversely proportional to the square of the distance between them.

___ 4. Newton’s law of universal gravitation states that
   a. the orbits of the planets are elliptical.
   b. the speed of a planet’s orbit varies depending on which part of the ellipse it is occupying.
   c. the square of the ratio of the periods of any two planets revolving around the Sun is equal to the cube of the ratio of their average distance from the Sun.
   d. objects attract other objects with a force that is directly proportional to the product of their masses, and inversely proportional to the square of the distance between them.

___ 6. Gravity is what type of force?
   a. field force  
   b. contact force  
   c. normal force  
   d. frictional force

___ 7. A space probe is directly between two moons of a planet. If it is twice as far from moon A as it is from moon B, but the net force on the probe is zero, what can be said about the relative masses of the moons?
   a. Moon A is twice as massive as moon B.
   b. Moon A has the same mass as moon B.
   c. Moon A is four times as massive as moon B.
   d. Moon A is half as massive as moon B.
Problem

8. If Earth shrinks in size such that its shape and mass remain the same, but the radius decreases to 0.21 times its original value, find the acceleration due to gravity on its surface.

9. A satellite orbits Jupiter $6.40 \times 10^3$ km above its surface. Given that the mass of Jupiter is $1.90 \times 10^{27}$ kg and the radius of Jupiter is $7.15 \times 10^7$ m, calculate the period of orbit of the satellite.
10. Mars has two very small elliptical-shaped moons, Deimos and Phobos. They were discovered in August 1877 by the American astronomer Asaph Hall (1829–1907) of the U.S. Naval Observatory in Washington, DC.

The inner moon, Phobos, is 27 km long, and it revolves around the planet in 7.6 hours. Phobos is closer to its planet than any other moon in the solar system, orbiting Mars with an orbital radius of only 9378 km. The outer moon, Deimos, is 15 km long and it circles the planet in 30.35 hours. How far away from Mars’s center is Deimos?

11. What is the orbital period, T, of Phobos in seconds?

12. What is the orbital period, T, of Deimos in seconds?
13. The orbital period for Saturn is 10,832.327 days. The average distance between Saturn and the Sun is 1,400,000,000 km. If \( G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2 \), estimate the mass of the Sun.

14. The units for the gravitational constant, \( G \), are \( \text{N} \cdot \text{m}^2/\text{kg}^2 \). Simplify this set of units.
15. You have been hired to do calculations for a consortium that plans to place a space station in orbit around Mars. The mass of Mars is $6.42 \times 10^{23}$ kg and its radius is $3.40 \times 10^6$ m. In order for the space station to appear to remain over the same spot on Mars at all times, its orbital period must be equal to the length of a day on Mars: $8.86 \times 10^4$ s. At what height above the surface of Mars should the space station be located in order to maintain this orbit? Use Newton’s version of Kepler’s third law.
16. The Moon is receding from Earth by approximately 3.8 cm per year. Earth’s mass is $5.98 \times 10^{24}$ kg, and its radius is $6.38 \times 10^6$ m. The Moon’s mass is $7.3 \times 10^{22}$ kg, its radius is $1.79 \times 10^6$ m, and its orbital period around Earth is 27.3 days. The current average distance between the two surfaces is $3.85 \times 10^8$ m. Assume that neither body gains or loses mass and that the recession continues at a rate of $3.8 \times 10^8$ m per year.
   a. Approximately how much will the gravitational attraction between the Moon and Earth change between now and 499 million years from now?
   b. Approximately how long, in present Earth-days, will it take the Moon to orbit Earth 499 million years from now?
17. The mean distance of the planet Neptune from the Sun is 30.05 times the mean distance of Earth from the Sun.
   a. Determine how many Earth-years it takes Neptune to orbit the Sun.
   b. The mass of the Sun is $1.99 \times 10^{30}$ kg, and the closest distance of Neptune from the Sun is $4.44 \times 10^9$ km. What is the orbital speed of Neptune in km/s at this point?
   c. Without doing any numerical calculations, answer the following. Is the orbital speed of Earth less than, equal to, or greater than the orbital speed of Neptune? Explain your reasoning.
   d. The radius of Neptune is 3.883 times that of Earth, and the mass of Neptune is 17.147 times that of Earth. From the surface of which planet (Earth or Neptune) would it be easier to launch a satellite? Explain your reasoning.