OpenStax Astronomy, Ch.3: WS Solutions (Apr-2021)

Solutions

1. State Kepler's three laws in your own words.

   Kepler's first law says that all planetary orbits are ellipses with the Sun at one focus. Kepler's second law says that planets sweep out equal areas of their orbits in equal amounts of time. Kepler's third law says that the square of the average distance a planet is from the Sun is proportional to the period of its orbit cubed.

2. Why did Kepler need Tycho Brahe's data to formulate his laws?

   In science, laws of nature are often developed by carefully analyzing data collected from observations of various phenomena. In this case, Kepler used Brahe's data regarding the observed positions of the planet Mars in order to determine that Mars moved in an elliptical, not circular, orbit.

3. Why do we say that Neptune was the first planet to be discovered through the use of mathematics?

   Careful observations of Uranus showed that the planet was not exactly where Newton's laws predicted it to be in the night sky from day to day. Using mathematics, Kepler's laws, and Newton's laws, mathematicians were able to calculate that the gravitational influence of a planet outside the orbit of Uranus could account for Uranus' observed orbital discrepancies and predict where this planet should be located. Johann Galle discovered the planet Neptune in just that location.

4. Why was Brahe reluctant to provide Kepler with all his data at one time?

   Brahe didn't want Kepler to discover the general rules of how the planets moved, thereby robbing Brahe of the glory.

5. According to Kepler's second law, where in a planet's orbit would it be moving fastest? Where would it be moving slowest?

   The planet would move fastest when it is closest to the Sun (at perihelion) and slowest when farthest from the Sun (at aphelion).

6. What was the great insight Newton had regarding Earth's gravity that allowed him to develop the universal law of gravitation?

   Newton speculated that Earth's gravity might extend out into space to help keep the Moon in its orbit around Earth. On a deeper level, he was able to see that the same rules of nature developed on Earth could also apply in the heavens (beyond Earth).

7. Pluto's orbit is more eccentric than any of the major planets. What does that mean?

   Pluto's orbit is less circular (or more elongated) than the others planets' orbital paths.

8. Why is Tycho Brahe often called "the greatest naked-eye astronomer" of all time?

   Tycho Brahe made large and elaborate measurement devices on his island, but none of them were telescopes (Tycho was "pre-telescopic"). He and his helpers used equipment to make precise measurements of the positions of planets moving through space, but the equipment did not have lenses.

9. Is it possible to escape the force of gravity by going into orbit around Earth? How does the force of gravity in the International Space Station (orbiting an average of 400 km above Earth's surface) compare with that on the ground?

It is not possible to escape the force of gravity by going into orbit. The space station is about 6800 km from the center of Earth, only about 86% farther away than the surface of our planet. The force of gravity in the International Space Station (ISS) is only slightly less than the gravity at the surface of Earth. People (and sandwiches) “float” in the ISS because they, and the station itself, are falling around Earth.

10. A body moves in a perfectly circular path at constant speed. Are there forces acting in such a system? How do you know?

Yes; there must be a force pulling toward the center of the circle. According to Newton’s first law, there must a force present to keep the object moving in a circle rather than a straight line.

11. Two asteroids begin to gravitationally attract one another. If one asteroid has twice the mass of the other, which one experiences the greater force? Which one experiences the greater acceleration?

Since Newton’s law of gravity says the force is proportional to the product of the two masses, both masses experience the same force. This is also consistent with Newton’s third law of motion. But the asteroid with the lesser mass would feel the greater acceleration, according to Newton’s second law.

12. How does the mass of an astronaut change when she travels from Earth to the Moon? How does her weight change?

Her mass does not change because that measures the amount of “stuff” that makes up her body. Her weight will decrease because that is a measure of the amount of gravitational force she is experiencing; on the Moon, her weight would be about 1/6 what it is on Earth.

13. If there is gravity where the International Space Station (ISS) is located above Earth, why doesn’t the space station get pulled back down to Earth?

If the space station were not moving, it would do just that, but when the space station was first assembled at a certain height above Earth, it was provided an appropriate speed for that height in a direction parallel to the surface of Earth. As such, instead of falling *toward* Earth, it is continuously falling *around* Earth. Since friction with Earth’s atmosphere slows down the ISS, it requires occasional upward pushes, or boosts, to stay in orbit.

14. By what factor would a person’s weight be increased if Earth had 10 times its present mass, but the same volume?

Since the force is directly proportional to mass, the person would weigh 10 times his or her present weight. If the volume is the same, the distance of the person from Earth’s center would not change.

15. Suppose astronomers find an earthlike planet that is twice the size of Earth (that is, its radius is twice that of Earth’s). What must be the mass of this planet such that the gravitational force (F_{gravity}) at the surface would be identical to Earth’s?

Gravitational force at the surface is inversely proportional to the square of the radius of the planet and directly proportional to the mass of the planet; therefore, the planet must have a mass of 2^2 or 4 times that of Earth.

16. What is the average distance from the Sun (in astronomical units) of an asteroid with an orbital period of 8 years?

$$a = \sqrt[3]{8 \times 8} = 4 \text{ AU}$$

17. In 1996, astronomers discovered an icy object beyond Pluto that was given the designation 1996 TL 66. It has a semimajor axis of 84 AU. What is its orbital period according to Kepler's third law?

$$P = \sqrt{84 \times 84 \times 84} = 770 \text{ years}$$