

SECTION OBJECTIVES

- Describe Kepler's laws of planetary motion.
- Relate Newton's mathematical analysis of gravitational force to the elliptical planetary orbits proposed by Kepler.
- Solve problems involving orbital speed and period.

KEPLER'S LAWS

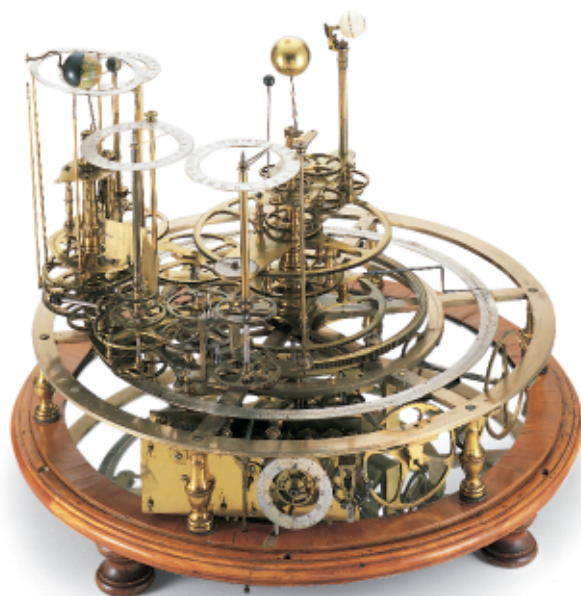
People have studied the motions of the planets since ancient times. Until the middle of the 16th century, most people believed that Earth was at the center of the universe. Originally, it was believed that the sun and other planets orbited Earth in perfect circles. However, this model did not account for all of the observations of planetary motion.

In the second century CE, Claudius Ptolemy developed an elaborate theory of planetary motion. Ptolemy's theory attempted to reconcile observation with theory and to keep Earth at the center of the universe. In this theory, planets travel in small circles called *epicycles* while simultaneously traveling in larger circular orbits. Even Ptolemy's complex model did not fully agree with observation, although the model did explain more than previous theories.

In 1543, the Polish astronomer Nicolaus Copernicus (1473–1543) published *On the Revolutions of the Heavenly Spheres*, in which he proposed that Earth and other planets orbit the sun in perfect circles. **Figure 11** shows a sun-centered planetary model that is believed to have been made for King George III of England. The idea of a sun-centered universe was not completely new in the 16th century. A Greek named Aristarchus theorized 1700 years before Copernicus did that Earth revolved around the sun, but most other scientists did not accept his theory.

Kepler's three laws describe the motion of the planets

The astronomer Tycho Brahe (1546–1601) made many precise observations of the planets and stars. However, some of Brahe's data did not agree with the Copernican model. The astronomer Johannes Kepler (1571–1630) worked for many years to reconcile Copernican theory with Brahe's data. Kepler's analysis led to three laws of planetary motion, which were developed a generation before Newton's law of universal gravitation. Kepler's three laws can be summarized as shown on the next page.

**Figure 11**

This elaborate planetary model—called an *orrery*—shows the motions of Mercury, Venus, and Earth around the sun. The model also shows the moon's inclined orbit around Earth.