Kepler's Laws of Planetary Motion

Unit: Gravitation

NGSS Standards/MA Curriculum Frameworks (2016): N/A

AP® Physics 1 Learning Objectives/Essential Knowledge (2024): 2.9.B, 2.9.B.1

Mastery Objective(s): (Students will be able to…)

- Set up and solve problems involving Kepler's Laws.

Success Criteria:

- All variables are identified and substituted correctly.
- Algebra is correct and rounding to appropriate number of significant figures is reasonable.

Language Objectives:

- Explain how the speed that a planet is moving changes as it revolves around the sun.

Tier 2 Vocabulary: focus

Notes:

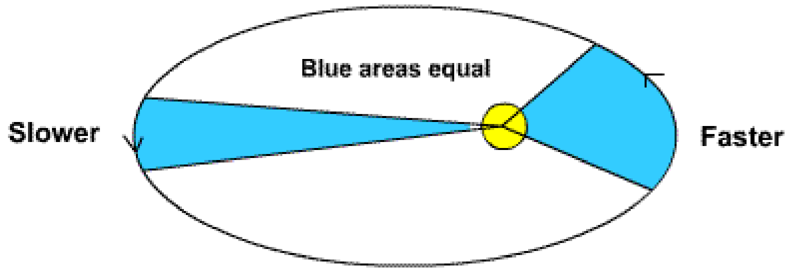
The German mathematician and astronomer Johannes Kepler lived about 100 years after Copernicus. Kepler derived three laws and equations that govern planetary motion, which were published in three volumes between 1617 and 1621.

Kepler's First Law

The orbit of a planet is an ellipse, with the sun at one focus.

Kepler's Second Law

A line that joins a planet with the sun will sweep out equal areas in equal amounts of time.



I.e., the planet moves faster as it moves closer to the sun and slows down as it gets farther away. If the planet takes exactly 30 days to sweep out one of the blue areas above, then it will take exactly 30 days to sweep out the other blue area, and any other such area in its orbit.

While we now know that the planet's change in speed is caused by the force of gravity, Kepler's Laws were published fifty years before Isaac Newton published his theory of gravity.

Use this space for summary and/or additional notes:

Kepler's Third Law

If T is the period of time that a planet takes to revolve around a sun and $r_{ave.}$ is the average radius of the planet from the sun (the length of the semi-major axis of its elliptical orbit) then:

$$\frac{T^2}{r_{ave.}^3} = \text{constant} \text{ for every planet in that solar system}$$

We now know that, $\frac{T^2}{r_{ave.}^3} = \frac{4\pi^2}{GM}$, where G is the universal gravitational constant and M is the mass of the star in question, which means this ratio is different for every planetary system. For our solar system, the value of $\frac{T^2}{r_{ave.}^3}$ is approximately $9.5\times10^{-27}\ \frac{\text{s}^2}{\text{m}^3}$ or $3\times10^{-34}\ \frac{\text{years}^2}{\text{m}^3}$.

Kepler's third law allows us to estimate the mass of a planet in some distant solar system, based on the mass of its sun and the time it takes for the planet to make one revolution.

Use this space for summary and/or additional notes: