Kepler's Laws of Planetary Motion

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Biography:

Johannes Kepler was born on December 27th, 1571, in modern-day SW Germany. At the age of 18, he earned a scholarship to the University of Tubingen, where he was introduced to Copernican theories. Due to his religious beliefs, he was alienated by both Catholics and Lutherans, leaving him without refuge during the Thirty-Years War. In 1600, he moved to Prague where he became Imperial mathematician after Tycho Brahe's death, and published Astronomia Nova on his first two laws of planetary motion in 1609. After a decade of loss and remarriage, Kepler returned to Wuttenberg, where, in 1619, he published Harmonices Mundi, outlining his third law. Kepler passed away in Regensburg, 1630, at the age of 58.

Portrait of Johannes Kepler

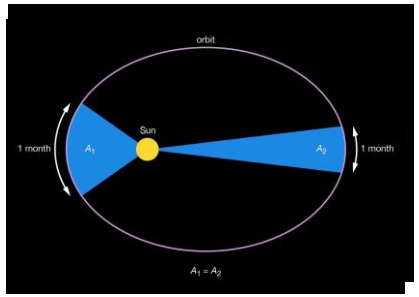

Figure 1 – Kepler's First and Second Laws.
On the right, the orbit is elliptical, and $A_1 = A_2$

$$\frac{T^2}{r^3} = \text{a constant}$$

Figure 2 – Kepler's Third Law

Planet	Mean distance to sun (AU)	Orbital Period (days)	T^2 / r^3 (10^3 day^2/AU^3)
Mercury	0.389	87.77	131
Venus	0.724	224.7	133
Earth	1	365.25	133
Mars	1.524	686.95	133
Jupiter	5.2	4332.62	134
Saturn	9.51	10759.2	135

Figure 3 – The data which Kepler would have had access to at the time when he derived his Third Law of Planetary Motion

What were his laws of planetary motion?

Kepler's laws of planetary motion were published between 1609 and 1619 and concerned planets in the Solar System orbiting the Sun. The laws modified Nicolaus Copernicus's heliocentric theory.

- Kepler's First Law: All the planets move around the Sun in elliptical orbits, with the Sun as one focus of the ellipse.
- Kepler's Second Law: the imaginary line joining any planet to the Sun will sweep out equal areas during lengths of time. (see Figure 1)
- Kepler's Third Law: the squares of the orbital periods of the planets are directly proportional to the cubes of their mean distances from the Sun. (see Figure 2 + 3)

All of Kepler's laws were derived from observations of our solar system. Using numerous highly meticulous measurements from his predecessor Tycho Brahe, he was able to show after many trials that the orbit of Mars was not circular, but rather elliptical. Thus, the distance between Mars and the Sun was constantly varied. He was also able to do the same of the other planets.

Kepler was also able to observe that Mars did not travel at a constant velocity. Since the orbits were elliptical, Mars would be travelling faster at its perihelion than at its aphelion, in such a way that an equal area would be swept out in equal lengths of time. Therefore, the planet's velocity was dependent on its distance from the Sun.

In 1619, Kepler was able to derive his Third Law by finding a pattern between the mean distance of the planets to the sun, and their orbital period. (see Figure 3)

References and Acknowledgements:
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