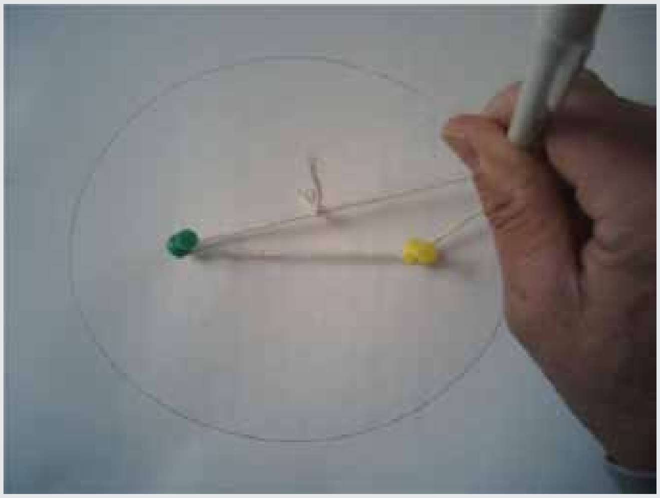
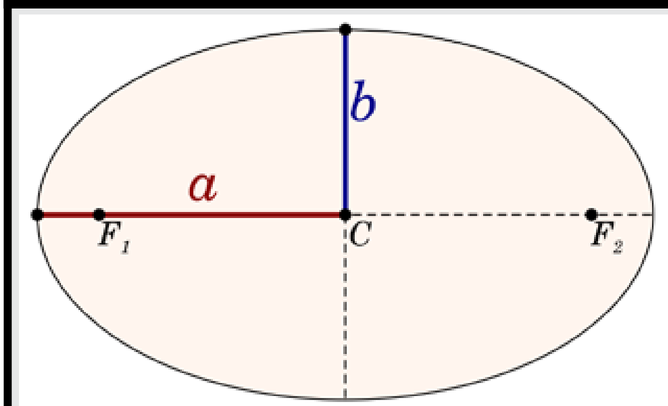
FIGURE 1-4[5]



An ellipse can be drawn by stretching a loop of string between two tacks and the tip of a pencil and tracing the pencil to create a smooth curve.

The **eccentricity** of an elliptical orbit is defined to be half the distance between the foci (F_1 and F_2 in Figure 1-5) divided by the length of the semimajor axis (*a* in Figure 1-5). The eccentricity of a perfect circle is zero, and as the eccentricity increases from zero, the ellipse becomes less circular in shape.

FIGURE 1-5[6]

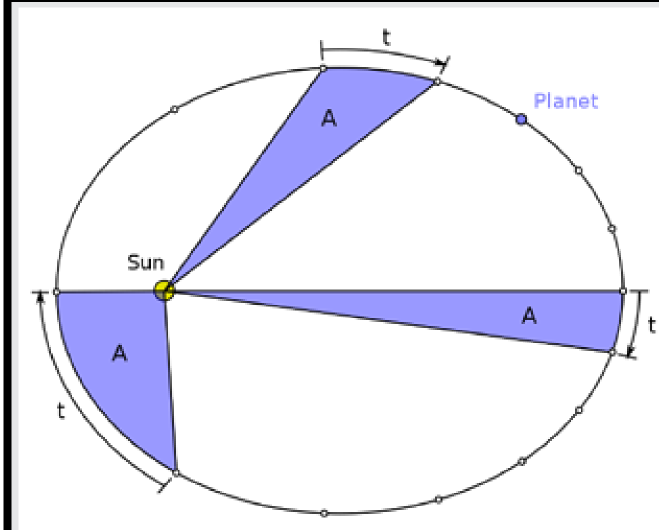


The general form of an ellipse. The two foci are labeled F_1 *and* F_2. *The semimajor axis is labeled* a *and the semiminor axis is labeled* b.

2. *An imaginary line connecting a planet to the Sun sweeps out equal areas in equal times.*

This law describes how the orbital speed of a planet changes depending on its distance from the Sun. When a planet is closer to the Sun, it moves faster, thereby traveling a further distance along its orbit in a given amount of time (Figure 1-6).

FIGURE 1-6[7]



An illustration of Kepler's Second Law. Over the course of its orbit, the planet will sweep out equal areas A *over the three equal time intervals* t.

3. *The square of a planet's orbital period is proportional to the cube of its semimajor axis.*

This law can be expressed mathematically as $P_{yr}^{\ 2} = a_{AU}^{\ 3}$, where P_{yr} is the orbital period in Earth years and a_{AU} is the length of the semimajor axis, measured in astronomical units (AU). (One astronomical unit is defined to be the semimajor axis of Earth's orbit.) For example, as seen in Table 1-1, the semimajor axis of Jupiter's orbit is $a = 5.203$ AU. By cubing this value and taking the square root, we obtain the value of its orbital period *P*, which is 11.86 years. Using Table 1-1, you can verify that the data for the other planets are related in the same way.

Kepler's laws of planetary motion are **empirical**. That is, they accurately describe a phenomenon (in this case planetary motion) but do not suggest an explanation for *why* it occurs. Although Kepler did not propose a theory for why the planets behaved as they did, that insight would arrive within the century through the work of Galileo Galilei and Sir Isaac Newton.