Acadiana Sky

Calculating the Orbital Speeds of Planets

Originally developed for the Lafayette Science Museum

Teacher Information

It is surprisingly easy for students with limited mathematical skill to calculate how fast planets go around the sun, and there are two ways to do it.

Older students can use Kepler's 3rd Law of Planetary Motion. It requires being familiar with equations, multiplication of large numbers, multiplication and division with decimals, squaring and cubing numbers, and taking square roots.

Kepler's 3rd Law of Planetary Motion was published by Johannes Kepler around 1619. Briefly, it states that there is a very specific mathematical relationship between the time a planet takes to orbit the sun (its sidereal period) and the planet's average distance from the sun: the square of the period is equal to the cube of the distance, when both are expressed in terms of Earth's values.

Younger students who can do multiplication and division with decimals can skip using Kepler's 3rd Law if they are given the radius of the planet's orbit. That information is provided in a table near the end of this activity, or the students can look it up themselves as an exercise in doing research.

Students can work in either the metric or English systems of measurement.

Both ways of doing this exercise assume that planetary orbits are perfect circles. Although not exactly true, this is a good approximation that works very well. The actual average speeds of the planets around the sun are given in a table at the end of this activity. Answers calculated by students should be very close to them, but may not be exactly the same.

The basic process is to obtain the planet's average distance from the sun and its sidereal period (using either Kepler's 3rd Law or the included table), in order to calculate the circumference of the planet's orbit. Then divide the circumference by the sidereal period to obtain an orbital speed, and finally convert that speed to miles (or kilometers) per hour. Unless this is being used as an arithmetic drill, calculators will make it all *much* easier!

Other science and math topics that could be discussed include converting the final answers from English to metric (or vice versa), the pattern of planetary speeds with distance from the sun as revealed by Kepler's 3rd Law, the factor-label method of conversion, significant figures in calculations, and error in measurement (for instance, students may get different "correct" answers due to the accuracy/significant figures of their source if they look up the planet's radius, or due to roundoff/truncation errors in different calculators, etc.)

Finding the Planet's Sidereal Period Using Kepler's 3rd Law (optional)

1. After picking a planet, obtain the planet's average distance from the sun in AU (1 AU is 1 *A*stronomical *U*nit, the average distance of Earth from the sun). This information can be found in the table included with this activity.

2. The mathematical form of Kepler's Third Law for our solar system is $P^2 = D^3$,

   where P = the planet's sidereal period in Earth years
   and D = the planet's average distance from the sun in AU.

   The sidereal period can then be found by

$$P = \sqrt[2]{D^3}.$$

   Remember that this works *only* if D is in AU and P is in Earth years! For inferior planets (those between Earth and the sun), multiply P by 365.25 to obtain their periods in days.

Finding the Circumference of the Planet's Orbit

3. Calculate the planet's average distance from the sun in miles or kilometers (called r, because it is the radius of the planet's orbit), remembering that 1 AU is approximately 92,956,000 miles (149,598,000 kilometers). The circumference of the planet's assumed circular orbit is given by the equation.

$$c = 2 \pi r, \qquad \text{where } \pi = 3.14.$$

Finding the Planet's Speed

4. For inferior planets or Earth, divide the orbit's circumference in miles (or kilometers) by the planet's sidereal period in days to get the speed in miles (or kilometers) per day. Divide that by 24 for miles (or kilometers) per hour; divide that by 60 for miles (or kilometers) per minute; divide that by 60 for miles (or kilometers) per second.

5. For superior planets (those beyond Earth), divide the orbit's circumference in miles (or kilometers) by the planet's sidereal period in years to get the speed in miles (or kilometers) per year. Divide that by 365.25 for miles (or kilometers) per day; divide that by 24 for miles (or kilometers) per hour; divide that by 60 for miles (or kilometers) per minute; divide that by 60 for miles (or kilometers) per second.

Planetary Orbit Characteristics

Planet	Mean Distance from Sun (AU)	Mean Distance from Sun (km)	Mean Distance from Sun (miles)	Sidereal Period
Mercury	0.39	57,910,000	35,900,000	88.97 days
Venus	0.72	108,210,000	67,090,000	224.70 days
Earth	1.00	149,598,000	92,956,000	365.25 days
Mars	1.52	227,940,000	141,320,000	1.8 years
Jupiter	5.20	778,300,000	482,550,000	11.86 years
Saturn	9.55	1,429,390,000	886,220,000	29.42 years
Uranus	19.22	2,875,040,000	1,782,520,000	83.75 years
Neptune	30.11	4,504,500,000	2,792,790,000	163.72 years

Actual Values for Planetary Orbital Speeds in Miles per Second (Kilometers per second in parentheses)

Mercury: 29.8 (47.9)	Venus: 21.8 (35.0)	Earth: 18.5 (29.8)
Mars: 15.0 (24.1)	Jupiter: 8.1 (13.1)	Saturn: 6.0 (9.6)
Uranus: 4.2 (6.8)	Neptune: 3.4 (5.4)	

Point out the pattern: *the farther a planet is from the sun, the more slowly it moves.*