eMATH

Kepler's Constant

Purpose:

1. To verify Kepler's constant for our solar system.
2. To determine Kepler's constant for Jupiter's moons.

Background:

Kepler's third law states:
The ratio of a planet's orbital period squared to its orbital radius cubed is a constant. All objects orbiting the same focus have the same constant.

Kepler's constant expressed in SI units is $3.01 \times 10^{-19}\ s^2/m^3$. Using astronomical units and the period of Earth's orbit, we can make Kepler's constant to be $1\ y^2/AU^3$. The first purpose of this eMATH is to verify Kepler's constant using the data on the planets from Table 5.5 in your Physics textbook. Recall that Kepler's constant can be written mathematically as:

$$K = \frac{T^2}{r^3},$$

where T is the orbital period of a planet, and
r is the mean orbital radius of the same planet.

The second objective is to determine Kepler's constant for the moons of Jupiter using the same formula but the orbital radius and periods of Jupiter's moons from Table 5.6 in your Physics textbook.

Instructions:

1. Download and open the accompanying Excel spreadsheet. You will find Tables 5.5 and 5.6 from the textbook. They are slightly modified so that Kepler's constant can be determined more easily. In Table 5.5 there are two extra columns with no data: "Orbital Period (years)," and "Kepler's Constant (y^2/AU^3)." It is your job to fill these columns with the correct data so that Kepler's constant can be determined. Since Kepler's constant uses units of Earth years, the orbital periods must be converted to years. To do this, divide the orbital period of the planet (in days) by the number of days in an Earth year (365.25). Enter the value in the next column titled "Orbital Period (years)." If you are familiar with the spreadsheet's capability of entering formulas, you might wish to have the spreadsheet do the calculations for you.

2. To determine Kepler's constant for each planet, you must use the formula $K = \frac{T^2}{r^3}$. The spreadsheet can do this if you follow these steps:

   a. Click on cell G5.
   b. Enter the formula "=POWER(D5,2) / POWER(F5,3)", then press enter. *(Note: Do not include the quotation marks.)*

This formula takes the period (cell D5), squares it, then divides it by the orbital radius (cell F5) cubed.

c. Click on cell G5 again and drag the cursor to cell G17. Select the "Fill → Down" feature from the "Edit" menu.
This will copy the formula you just created to all the cells in this column and perform the calculation of Kepler's constant for each celestial object.

3. Kepler's constant will be determined for the moons of Jupiter using the SI units of metres and seconds. First determine the period of each moon's orbit in seconds. To do this, divide its period in days by the number of seconds in a day (86400 s/day). Place these values in the next column on the spreadsheet titled "Orbital Period (s)." If you are familiar with the spreadsheet's capability of entering formulas, you might wish to have the spreadsheet do the calculations for you.

4. Determine Kepler's constant for each moon in the same fashion as you did for the planets. Follow these steps:

a. Click on cell M5.
b. Enter the formula "=POWER(K5,2) / POWER(L5,3)", then press enter.
(Note: Do not include the quotation marks.)
This formula determines Kepler's constant for the moons of Jupiter using their period and orbital radii.
c. Click on cell M5 again and drag the cursor to cell M8. Select the "Fill → Down" feature from the "Edit" menu.
This will copy the formula you just created to all the cells in this column and perform the calculation of Kepler's constant for each moon.

Analysis:

1. What is the value of Kepler's constant for all the planets? Does this value agree with the book's value?

2. Why do all the planets give the same value of Kepler's constant?

3. What is the value of Kepler's constant for the moons of Jupiter? Why were SI units used to determine this value?

4. Why is the value of Kepler's constant for the moons of Jupiter different than the SI value of Kepler's constant for the planets ($K = 3.01 \times 10^{-19}\ s^2/m^3$)?