I. Objectives

1. Investigate the relationship between a, a planet's average distance from the Sun in AU and P, its orbital period in years.
2. Apply Kepler's Third Law to the orbits of the planets**.**
3. Explore a numerical relationship between the actual distances of the planets from the Sun and those predicted by Bode's Law.

II. Introduction

Kepler's Third Law of Planetary Motion is a useful and simple equation to describe the relationships between the average distances, or semimajor axes, of the planets from the Sun and their orbital periods. The required calculations are very easy on our modern calculators, but we need to keep in mind that Johannes Kepler had no such tools when he arrived at this law in 1606 and that all of his calculations had to be done meticulously by hand!

In 1772, Johann Bode published a mathematical formula that could be utilized to calculate the distance of each planet from the Sun. The formula was originally noted in a work by Swiss naturalist Charles Bonnet and developed by Johann Titius. No scientific relationship has been discovered to explain why Bode's Law can be used to predict the approximate distances of the planets from the Sun. The mathematical relationship, however, is interesting and easy to use.

III. Theory and Calculations

Kepler's Third Law states that the ratio of the squares of the revolutionary periods for two planets is equal to the ratio of the cubes of their semimajor axes. Mathematically, this simply means that if we divide the square of the time it takes for a planet to go around the Sun in years, P^2, by the cube of its distance from the Sun in AU, a^3, the result should be the same for each planet, $P^2 = a^3$ or $P^2/a^3 = 1$. In order to simplify the calculations, we will use AUs as the distances of the planets from the Sun and use units of years for the orbital periods.
The Titius-Bode Law relies on a simple mathematical method. Starting with 0, then adding 3 and doubling each successive number yields the sequence 0, 3, 6, 12, 24, 48, 96, 192, and 384. Then, adding 4 to each of these numbers and dividing by 10 results in some distances that are close to the actual distances in AU for most of the planets, but much different for one of them.

IV. Prelab Definitions

1. semimajor axis

2. astronomical unit

3. orbital period

4. revolution

5. rotation

V. Lab Procedure

1. Calculate a^3 for each planet and write the results in the *Planet Actual and Predicted Distances and Orbital Periods* table below. $C = B^3$.

2. Calculate P^2 for each planet. $E = D^2$.

3. Calculate the ratio P^2/a^3 for each planet. F = E/C.

4. Calculate the values in column H. H = G + 4.

5. Calculate the values in column I. I = H/10.

6. Compute the difference between column B, Actual distance from the Sun in AU and column I, Bode's predicted distance in AU and write the results in column J. J = | B - I |

Planet Actual and Predicted Distances and Orbital Periods

A	B	C	D	E	F	G	H	I	J
Planet	Actual distance a from Sun in AU	a^3 in AU^3	Orbital period P in years	P^2 in $years^2$	P^2/a^3	Bode's sequence	G + 4	Bode's predicted distance in AU	Difference between predicted and actual
Mercury	0.3871		0.2408			0			
Venus	0.7233		0.6151			3			
Earth	1		1			6			
Mars	1.5237		1.8808			12			
Jupiter	5.2028		11.867			48			
Saturn	9.5388		29.461			96			
Uranus	19.18		84.013			192			
Neptune	30.0611		164.793			384			

VI. Lab Discussion

1. What is the value of P^2/a^3? What does this tell you about the relationship between P^2 and a^3?

2. According to Kepler's Third Law, if a planet had an orbital period P of 300 years, what would a, its average distance from the Sun be in AU? Show your work.

3. According to Kepler's Third Law, if a planet was an average distance a of 60 AU from the Sun, what would be its orbital period P in years? Show your work.

4. Why might Kepler's Third Law be useful to those who are looking for distant planets? Explain your answer.

5. Kepler said "By the study of the orbit of Mars, we must either arrive at the secrets of astronomy or forever remain in ignorance of them." What did he mean? Explain your answer.

6. For which planets does Bode's Law seem to come close to predicting the actual distance from the Sun in AU?

7. For which planet does it not come close?

8. Is it possible that this relationship is a numerical coincidence and that there may be other numerical relationships that would better predict the actual distances of the planets from the Sun? Why? Explain your answer.