Lab 13-1: **Universal Gravitation**

Purpose:
1. Find the relationship between the centripetal acceleration of a planet around the Sun and its distance to the Sun.
2. Hypothesize a theory of gravitation.

Introduction: In the beginning of the seventeenth century, Johannes Kepler discovered what are now called his Three Laws of Planetary Motion. These laws described the shapes, speeds and periods of the planets around the Sun. He discovered these laws empirically - basically by crunching numbers until he found models that matched the observational data. After this, the big question was to explain the cause of these planetary motions.

in 1687 Newton published The Principia, in which he proposed his Three Laws of Motion (which we studied earlier) and his Theory of Universal Gravitation. With this, he was able to derive Kepler's Laws and showed for the first time why the planets did what they did. Let's see if you can figure out his gravitational theory by looking at the orbital data for the six planets known in Newton's time.

Data:

Planet	*Period of Orbit (T) (years)*	*Distance to Sun (R) (AU)*
Mercury	0.24	0.39
Venus	0.62	0.72
Earth	1.00	1.00
Mars	1.88	1.52
Jupiter	11.9	5.21
Saturn	29.5	9.58

Questions:

1. What is an AU? (For this lab, leave the distances in AU - we just want you to know what this means.)

2. Derive an expression for the centripetal acceleration of a planet in terms of its orbital period T and its average distance to the sun R. Assume a circular orbit.

3. Using Logger Pro, enter the data above, keeping the units as given. Make a calculated column to find the centripetal acceleration of each planet around the Sun. What are the resulting units of centripetal acceleration?

4. Make a graph of Centripetal Acceleration vs Distance to Sun. Linearize your graph. What is the resulting equation that relates the centripetal acceleration of a planet around the Sun to its distance from the Sun?

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5. The only force acting on a planet as it goes around the sun is the gravitational attraction to the Sun. So how does the gravitational force on a planet depend on its distance to the Sun? (Think about Newton's Second Law.)

6. Notice we don't have the masses of the planets in the data above. Despite that, how does the force on the planet depend on its mass? (Again, think about Newton's Second Law.)

7. Use Newton's Third Law to propose how the gravitational force between the Sun and a planet depends on the mass of the Sun.

8. So what (and how) should the gravitational attraction between a planet and the Sun depend on?

Newton didn't call his theory "Planetary Gravitation" - he called it "Universal Gravitation." To help see why continue on...

Newton also knew that the moon orbits the earth. It takes the moon 27.3 days to go around the earth once. The radius of the moon's orbit around the earth is 60 times the radius of the earth. The radius of the earth is 6.4 Mm.

9. Calculate the centripetal acceleration of the moon around the earth, in m/s^2.

10. Compared to the acceleration of the moon around the earth, how many times larger is the acceleration due to gravity on the surface of the earth?

11. What is significant about your answer to #10? (Hint: this calculation helped convince Newton he was correct in his theory.)

12. What perhaps is Newton's Theory of Universal Gravitation? Why the term *universal*?