Name ___________________________________

Satellite Motion Lab

Purpose
To experiment with satellite motion using an interactive simulation in order to gain an understanding of Kepler's Laws of Planetary Motion and Newton's Law of Universal Gravitation.

Expectations
You are to create your own individual solar system. Do not use the work of others. You need the experiences gained in the experiments in order to understand the physics.

Materials
You need a computer with internet access. The simulation can be found at:

http://phet.colorado.edu/sims/my-solar-system/my-solar-system_en.html

Procedure

Part 1 Circular Orbits

1. Launch your browser and load the simulation.
2. Select the show grid option.
3. Set the number of bodies to four.
4. Leave the mass of the central body (Body 1) at 200 units. Set the velocity of the central body to 0 (both x and y values). This object will be your sun.
5. Set the masses of the other bodies (Body 2, 3, and 4) to 0.001 units. These objects are your planets.
6. Set the x position value (the radius) of the outermost planet (Body 3) to 200, so that it is at the intersection of a grid line.
7. Adjust the y value of the velocity of the outermost planet until its orbit is as perfectly circular as possible. (The grid will help you determine if your orbit is a circle. Once the orbit is circular, the planet should be the same distance from the sun at all times.) Record the velocity on the line below.

   Body 3 Velocity ____________________

8. Leave the other planets alone for now.

9. In the space below, discuss how the orbital velocity changes in an elliptical orbit. Compare this with the velocity in a circular orbit. Connect these observations with Kepler's Second Law.

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Part 2 Determining the Gravitational Constant (G)

1. In the real world, $G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$. The simulation, however, uses a different value. In this part of the lab, you will determine the value of G for the simulation.
2. Start by setting the centripetal force equal to the force of gravity: $F_c = F_g$.
3. Substitute the appropriate formulas and rearrange the resulting equation to solve for G.
4. Substitute the appropriate values from your circular orbit (from Part 1) into the equation and solve for G. Round your answer to the nearest whole number. Show your work in the space below.

$G =$ ____________________

Part 3 Testing G

1. If your value for G is correct, it should work for any planet in your solar system. In this part of the lab, you will use your value of G to create circular orbits for the other 2 planets in your solar system.

2. Start by solving your equation from Part 2 for velocity instead of G.

3. Use this equation to calculate the velocity the second planet (Body 2) needs to have in order to have a circular orbit. Remember to use your value of G, not the real one. Show your work in the space below.

Body 2 Velocity ____________________

4. Enter your calculated velocity for the second planet into the simulation (enter it in the y value). If your value of G is correct, then the resulting orbit should be a perfect circle on your first try. If not, find the error.

Part 4 Create a Solar System

1. Calculate the velocity the last planet (Body 4) needs to have in order to have a circular orbit. Use the same method as in Part 3. Show your work in the space below.

Body 4 Velocity ____________________

2. Try out your solar system. It should produce three circular orbits with the same center, like a bullseye. If not, then there is something wrong with your value of G, or with your calculations. Find the error and fix it.

Part 5 Kepler's Third Law

1. Use the timer in the simulation to measure the period of each planet in your solar system. Do your best to get as close to one orbit as possible. (Hint: Set the slider to accurate.) Record the period of each orbit below.

Body 2 Period _______________

Body 3 Period _______________

Body 4 Period _______________

2. Kepler's Third Law states that the period squared is proportional to the radius cubed for a satellite. This means that if you graph T^2 vs r^3, the resulting graph should be a straight line.

3. Create a graph of T^2 vs r^3 using the data for your 3 planets. Calculate the slope of the graph.

	$\boldsymbol{T^2}$	$\boldsymbol{r^3}$
Body 2		
Body 3		
Body 4		

4. The slope of your graph is Kepler's constant for the solar system you have created. Record the value of your constant below.

Kepler's Constant ______________________

Part 6 Perturbation

1. The planets in your model were all given masses of 0.001 units. This made the mass of the central star how many times larger than the mass of each planet?

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2. Why do you think the instructions called for such tiny planets?

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3. What happens if one of the planets is given a mass larger than 1 unit? Try increasing the mass of one of your planets until something happens. Describe your observation(s) in the space below.

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