Name ________________________

Star Wobble

Introduction: How do astronomers find planets around distant stars? If you look at a star through binoculars or a telescope, you'll quickly notice how bright the star is, and how difficult it is to see anything other than the star, especially a small planet that doesn't generate any light of its own! Astronomers look for a shift, or wobble, of the star as it gets gravitationally "yanked" around by the orbiting planets. By measuring this wobble, astronomers can estimate the size and distance of larger orbiting objects.

Doppler spectroscopy is one way astronomers find planets around distant stars. If you recall the lesson where we created our own solar system in a computer simulation, you remember how the star could be influenced by a smaller planet enough to have a tiny orbit of its own. This tiny orbit is what astronomers are trying to detect with this method.

In this lab exercise, you're going to observe how different sizes of planets and stars wobble when they are connected by gravity, or in our case, a toothpick!

Materials:

- 5 bouncy balls of different sizes and weights (soft enough to stab with a toothpick)
- Scale
- Toothpicks

Procedure:

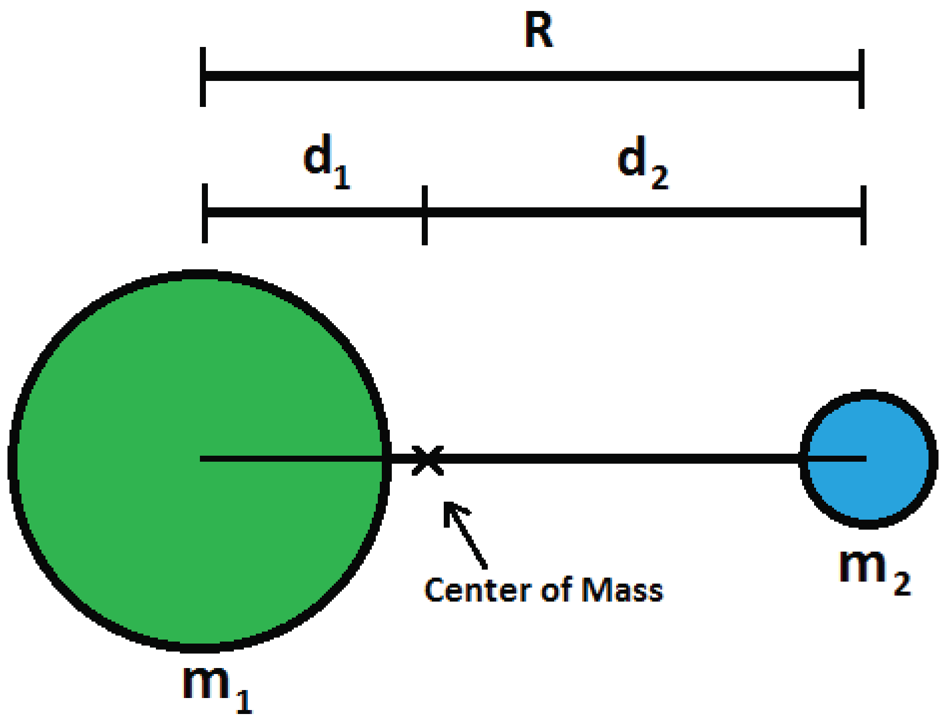
1. Does your ball have a number written on it? If so, that's the weight, and you can skip measuring the mass with a scale.
2. If not, measure the mass of each one and make a note in the data table on the next page.
3. Take the heaviest ball and spin it on the table (by itself). Can you get it to spin in place? That's like a rotating Sun without any planets around it.
4. Next, you're going to be creating combinations of stars and planets using your toothpicks. Following the combinations listed in the table on the next page, insert a toothpick into the heavier ball, then insert the other end into the lighter ball (this will mimic gravity connecting the two).
5. Now spin the heavier of the two balls and observe/record how much it wobbles compared to the other combinations in the space provided.

Ball #	Mass (grams)
1	
2	
3	
4	

Combination	Wobble Observations
Ball 1 and Ball 2	
Ball 1 and Ball 3	
Ball 1 and Ball 4	
Ball 2 and Ball 3	
Ball 2 and Ball 4	
Ball 3 and Ball 4	

Which combination had the most wobble? Which combination had the least wobble? You should have seen that the combination with the least wobble was the pairing of the heaviest ball and the lightest ball, and the combination with the most wobble was the pairing of the two balls with the most similar masses. But why is this?

Well when you spun the unconnected ball in the beginning, it was allowed to spin in place because its center of mass was directly in the center of the ball. However, when you connect two balls together by a toothpick, the center of mass is shifted away from the axis of the heavier ball. When the two are spun, they rotate on an axis around their center of mass. So the further away the center of mass is from the heavier ball, the more wobble you will see! Check out the diagrams and equations on the next page.



In the diagram above, you can see how the center of mass of the two balls is not centered on the axis of the larger ball, so when spun, it will wobble. The equations that relate this system are as follows:

$$m_1 d_1 = m_2 d_2$$

$$d_1 + d_2 = R$$

So imagine you have two balls of equal mass (**m**). This would mean $\mathbf{d_1 = d_2}$, and the center of mass would be in the center of the toothpick, causing the most wobble possible!

Problems:

1. If you have two balls; one with mass 10 kg, one with mass 2 kg that are separated by a 2 meter rod, how far from the center of the 10 kg ball with the center of mass be?

2. How far will the center of mass be from the 2 kg ball?

3. Given that Mercury (the closest planet to the sun) has a mass of 328.5x1021 kg, the sun has a mass of 1.989x1030 kg, and that the distance between the two bodies is 57,910,000 km, what is the distance from the center of the sun to the center of mass of the two bodies?

Unit 7: Lesson 2

Answers:

1. 0.33m
2. 1.67m
3. 9.7km