Build Your Own Solar System

Overview: What would happen if our solar system had three Suns? Or the Earth had two moons? You can find out all these and more with this lesson on orbital mechanics. Instead of waiting until you hit college, we thought we'd throw some university-level physics at you… without the hard math.

What to Learn Key concepts about gravity:

a. Gravity is a force that attracts things to one another.
b. All bodies (objects) have a gravitational field.
c. The larger a body is, the greater the strength of the gravitational field.
d. Bodies must be very, very large before they exert any noticeable gravitational field.
e. Gravity accelerates all things equally. Which means all things speed up the same amount as they fall.
f. Gravity does not care what size things are or whether things are moving. All things are accelerated toward the Earth at the same rate of speed.
g. Gravity does pull on things differently. Gravity is pulling greater on objects that weigh more.
h. Weight is a measure of how much gravity is pulling on an object.
i. Mass is a measure of how much matter (how many atoms) make up an object.

Materials

- Access to a computer with Internet
- Ruler

Experiment

<u>About the Concept of Gravity</u>

1. Even though we deal with gravity on a constant basis, there are several misconceptions about it. Let's get to an experiment right away and I'll show you what I mean.
2. When you drop a golf ball and a ping pong ball from the same height, what happens?
3. What you should see is that both objects hit the ground at the same time! Gravity accelerates both items equally and they hit the ground at the same time. Any two objects will do this, a brick and a Buick, a flower and a fish, a kumquat and a cow!
4. But what if you drop a feather and a ball at the same time? There is one thing that will change the results and that is *air resistance*. The bigger, lighter and fluffier something is, the more air resistance can affect it and so it will fall more slowly. Air resistance is a type of friction which we will be talking about later. In fact, if you removed air resistance, a feather and a flounder would hit the ground at the same time!!!
5. Where can you remove air resistance? The moon!!! One of the Apollo missions actually did this (well, they didn't use a flounder, they used a hammer). An astronaut dropped a feather and a hammer at the same time and indeed, both fell at the same rate of speed and hit the surface of the moon at the same time.
6. Which will hit the ground first, if dropped from the same height, a bowling ball or a tennis ball? Most people will say the bowling ball. In fact, if you asked yourself that question 5 minutes ago, would you have gotten it right? It's conventional wisdom to think that the heavier object falls faster.
7. Unfortunately, conventional wisdom isn't always right. Gravity accelerates all things equally. In other words, gravity makes all things speed up or slow down at the same rate.
8. This is a great example of why the scientific method (more on this later) is such a cool thing. Many, many years ago, there was a man of great knowledge and wisdom named Aristotle. Whatever he said, most

people believed to be true. The trouble was, he didn't test everything that he said. One of his statements was that objects with greater weight fall faster than objects with less weight. Everyone believed that this was true. Hundreds of years later, Galileo came along and said "Ya know...that doesn't seem to work that way. I'm going to test it" The story goes that Galileo grabbed a melon and an orange and went to the top of the Leaning Tower of Pisa. He said, "Look out below!" and dropped them! By doing that, he showed that objects fall at the same rate of speed no matter what their size. It is true that it was Galileo who "proved" that gravity accelerates all things equally no matter what their weight, but there is no real evidence that he actually used the Leaning Tower of Pisa to do it.

9. Key concepts about Gravity:
    a. Gravity is a force that attracts things to one another.
    b. All bodies (objects) have a gravitational field.
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    e. Gravity accelerates all things equally. Which means all things speed up the same amount as they fall.
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<u>About the Computer Simulation</u>

1. To get you experienced with the force of gravity without getting lost in the math, there's an excellent computer program that allows you to see how multi-object systems interact. Most textbooks are limited to the interaction between a very large object, like the Earth, and much smaller objects that are very close to it, like the Moon. This seriously cuts out most of the interesting solar systems that are out there in the real universe.
2. The University of Colorado at Boulder designed a great system to do the hard math for you. Don't be fooled by the simplistic appearance – the physics behind the simulation are rock-solid… meaning that the results you get are exactly what scientists would predict to happen.
3. Go to the My Solar System simulation on the PhET website and carefully follow the instructions for each activity. Answer the questions and record your results before going on to the next activity. Visit: *http://phet.colorado.edu/sims/my-solar-system/my-solar-system.swf*
4. Once the program opens, hit start. You'll see the purple Earth orbit around the yellow Sun. Do you notice how the Earth also causes the Sun to follow a tiny orbit? That's because the Earth pulls on the Sun just as the Sun pulls on the Earth.
5. Press stop. Notice the "V?" That stands for direction and speed, as in 55 mph north. It gives how fast you are going as well as the direction you're going. Or in this case, the planet. Notice near the bottom that you can change the mass of the object. Increase the mass so that it's larger than the Sun. Press start.
6. Reset, and change the purple object (Earth) to be the size of the Moon (make it 1). Did you notice a change in the orbit path?
7. Change the purple mass back to 10, and increase the speed to a larger number. What happened?
8. The Earth is at a very special mass and speed, isn't it?
9. Reset and make your speed 200. Did it stay in orbit?
10. Add a third and fourth object by pulling down the menu on the upper right. Select "Sun, planet, and moon" and hit "Start".
11. What happens if you uncheck "show trace"? (You'll only see the objects themselves orbiting, not the path they take.)

12. What happens if you uncheck "system centered"? (The system will eventually wander off the screen as the entire system has acceleration.)
13. Play with the program for a bit, changing the location distance the objects are apart, the speed and direction they initially start out at, and their masses.

    b. What does the yellow object represent?_____

    c. What is the mass of the yellow object? _____
    (Note: No units are given, so no units are necessary.)

    d. What does the purple object represent? _____

    e. What is the mass of the purple object? _____

    f. What does the red arrow represent? _____

14. Complete the data table. Notice at the end that you will predict the necessary mass, velocity, and distance from the Sun of a planet in order for this planet to make a circular orbit around a Sun.

Reading

In 1666, Isaac Newton did his early work on his Three Laws of Motion. To this day, those laws still hold true. There has been some allowances for really big things (like the cosmos) and for really small things (like the atom). Other than that, Newton's Laws are pretty much dead on.

Newton's Laws are all scientists and engineers used to get the first man to the moon. They are an amazingly powerful and wonderful area of physics. I like them because evidence of them is everywhere. If something moves or can be moved, it follows Newton's Laws. You can't sit in a car, walk down the road, drink a glass of milk, or kick a ball without using Newton's Laws. I also like them because they are relatively easy to understand and yet open up worlds of answers and questions. They are truly a foundation for understanding the world around you.

Whenever I teach a class about gravity, I'll drop something (usually something large). After the heads whip around, I ask the hard question: *"Why did it fall?"* You already know the answer – **gravity**.

But *why?* Why does gravity pull things down, not up? And when did people first start noticing that we stick to the surface of the planet and not float up into the sky?

No one can tell you *why* gravity is… that's just the way the universe is wired. Gravitation is a natural thing that happens when you have mass. Galileo was actually one of the first people to do science experiments on gravity.

Build Your Own Solar System Data Table 1

Use the original preset for all values for a Sun and Planet,
except change the mass of body 2 (purple object) as shown below:

Mass of Body 2	**Diameter of Orbit** *(measure with ruler)*
1000	
100	
10	
1	
0.1	
0.01	
0.001	
0.0001	

Exercises: *(Note that the exercise questions are below each data table)*

1. What effect does changing the mass of orbiting planet have on the diameter of the orbit?

Build Your Own Solar System Data Table 2

Use the original preset for all values for a Sun and Planet,
except change the mass of body 2 (purple object) and velocity as shown below:

Mass of Body 2	Velocity of Body 2	Describe what happened…?
0.1	y velocity = 130	
0.1	y velocity = 140	
0.1	y velocity = 150	
0.1	y velocity = 600	
0.1	y velocity = 80	
0.1	y velocity = 40	
0.1	y velocity = 20	
0.1	y velocity = 0	

2. What effect does changing the speed have on a planet's orbit?

Build Your Own Solar System Data Table 3

Use the original preset for all values for a Sun and Planet,
except change the mass of body 2 to 50 and the x-distance of body 2 as shown below:

x distance for Body 2	**Diameter of Orbit** *(measure with ruler)*
30	
60	
90	
120	
150	
180	
210	
240	

3. What happens to the planet's orbit when you increase the initial distance between the planet and the Sun?

Build Your Own Solar System Data Table 4

Use the original preset for a Binary Star and Planet. Change only the masses and record your observations below.

Mass of Body 1	Mass of Body 2	Mass of Body 3	Is the orbit stable?

4. Find the mass values needed for a stable orbit. Circle the values on the table that make a stable orbit.

Build Your Own Solar System Data Table 5

Use the original preset for Ellipses. Change only the masses and record your observations below.

Mass of Body 1	Mass of Body 2	Mass of Body 3	Mass of Body 4	What happened?
250	10	1	0.1	

5. Why don't a feather and a brick hit the ground at the same time?

Answers to Exercises: Build Your Own Solar System

1. What effect does changing the mass of orbiting planet have on the diameter of the orbit?

2. What effect does changing the speed have on a planet's orbit?

3. What happens to the planet's orbit when you increase the initial distance between the planet and the Sun?

4. Find the mass values needed for a stable orbit. Circle the values on the table that make a stable orbit.

5. Why don't a feather and a brick hit the ground at the same time? (They do…if you're on the moon! On Earth, the friction between the air and the feather causes the feather to slow down and the brick to win the race.)