Gravity and Orbits

Group discussion: Solar system orbit demonstration

Discussion questions:
What did you notice about the shape of the orbits?
What did you notice about the speeds of the different orbits?
What do you think causes these differences?
What other objects besides planets have orbits?

MATERIALS
• 3/8'' beveled Washers
• Lots of string/ribbon; cut into ~3ft length pieces
• Piece of paper
• Plastic Straws (1-2 per student)
• Tape
• Glue
• Scissors

<u>ACTIVITY: REVIEW ORBITS (~5-10 minutes)</u>

Q: Why do planets orbit the sun?
A: Gravitational attraction. The sun has the most mass in our solar system and thus the strongest gravitational pull. Draw the gravitational force on the board.
Q: What would happen if the gravitational force was no longer applied?
A: Accept all answers. Explain that we are going to model the orbit using the ball and string.

1. Tape an arm's length piece of string/thread to a piece of paper
2. Crumple the paper into the ball
3. Model an orbit by swinging the paper ball in a circle
4. Why does the paper ball moves in a circle?

Explain that orbit occurs because the paper ball has some initial speed (it is moving in some direction) and then it gets pulled toward the center by the string. This is a model f*or a space shuttle orbiting the earth where the ball is the space shuttle and the string is gravity*.

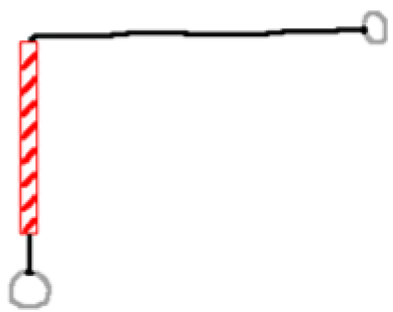
5. There are two ways you can show this "initial speed/direction"

a. When the ball is "orbiting" let go of the string and see where the ball goes. The thread should leave a trail behind the ball so you can see the direction that it was traveling.
b. Make a loop on the other end of the string and put that loop around a pencil. Flick the paper ball in an "initial direction" and (hopefully) the ball will be pulled by the string to make a circular path.

DISCUSSION:
Q: Where did the ball go?
A: Go inside and draw an arrow from the circle to represent the path of the ball when you

released it.
Q: So none of the planets flew into you (i.e. the sun). Why don't planets spin into the sun, i.e. what keeps them far away?
A: Inertia of their orbit drives planets outward into deep space. The two forces from the gravitational pull and the planets inertia are balanced, keeping planets in a set orbit. Draw the sideways force on the planet.

ACTIVITY: ORBITING (~10 – 15 minutes)
1. Using the same string and ball, thread the end of the string through the straw and attach it to the washer.
2. Begin with lots of room. Holding the straw and washer assembly upright, pull the string until the bottom washer rests against the bottom of the straw.



(Image from: strachild.gsfc.nasa.gov)
3. Hold the straw with one hand with your arm fully extended in front of your body. By rapidly rotating the wrist of the extended arm, start spinning the string/washer assembly until the string is fully extended. **Note**: If the paper ball is difficult to rotate, you can flip it upside down and use the washer as a planet (but make sure the kids don't swing the washer toward each other!).
4. Continue spinning the system at a constant rate as you use your other hand to pull slowly down on the bottom washer. **Note:** The spinning ball should be going at a steady rate before students start to pull the string. If students' are having difficulty they can spin their 'planet' in a vertical circle. Make a special effort to help students pull the string slowly enough that the washer can make complete orbits at each radius before you pull the string more.
5. Q: What is a year? Discuss how a year on Earth is not the same as a year on Mars. Calculate age on different planets using the worksheet. (Ex: 10 years old, $10 \div 1.88 \; = 5.31 \; Mars\ years$)

DISCUSSION:
Q: What do you notice about the speed at which the spinning washer is traveling as the orbit it makes gets shorter and shorter?
A: The ball orbits faster as its orbit radius gets smaller.
Q: What are **two ways** that you can make the ball orbit faster or slower?
A: You can swing/pull it harder or you can make the orbit smaller. (We can say that pulling it harder is like a stronger gravitational force and making the string shorter is like making the orbit smaller)
Q: What does this have to do with planets orbiting the Sun?

A: The planets more distant from the Sun have a longer orbital path AND move slower around that path than the planets closer to the Sun. This results from distance and from differences in the effect of gravitational pull from the Sun. The amount of pull depends on the distance between the objects, just like you can feel with your string.

For tutors: $F = \frac{G\, m_1 m_2}{r^2}$

Therefore, the pull exerted on one body by another equals Newton's Constant times the mass of the first body times the mass of the second body divided by the square of the distance between the centers of the two bodies. Notice that in this equation, there is no distinction between which body is doing the pulling.

Q: In these examples we are looking at circular orbits, but do orbits have to be circles like in our model?

A: No – Earth's orbit is nearly a perfect circle, but most orbits are elliptical/eccentric. The orbits still result from gravitational forces, but these forces are not fixed in space/time.

MATERIALS:

Rocks (different sizes)
Flour
Cocoa
Container

ACTIVITY METEOROIDS AND THE CRATERS THEY MAKE: (~5-10 minutes)

1. Discuss what is a meteoroid and what happens when they crash.
2. Try to predict the appearance of a crater formed by a rock of the same size dropped at different levels (one higher than the other)
3. Have the students drop the rocks at successively higher levels.
4. Make sure that all trajectories are vertical for consistency in the test.
5. If there is extra time try different angles and rock sizes.

DISCUSSION QUESTIONS:

Do the craters correspond to the prediction?
What makes the bigger crater and why?

Fnal discussion: Future directions to understand gravity and orbits
https://www.youtube.com/watch?v=4GbWfNHtHRg

What is new about this idea of gravity compared with the one we just learned about?