# Lesson 7: Newton's Acceleration Ramp

## ☐ Getting Started

Newton's laws of motion don't just apply on Earth. If you could travel far outside of the Milky Way, you'd find evidence of them everywhere. In today's activities, you will consider how Newton's laws and the forces you observe every day may be at play to a much larger degree in the solar system. You will also learn more about Johannes Kepler and his laws of planetary motion.

### Stuff You Need

- ✓ 3 bar magnets (kit)
- ✓ five books (each about 2 cm thick)
- ✓ metal ball bearing (kit)
- ✓ extra books of any size
- ✓ marble (kit)
- ✓ ruler with a groove down the center (kit)

### Ideas to Think About

- What kinds of forces are present in our solar system? In the universe?
- How do forces influence the movement of objects in our solar system?
- What is evidence of balanced forces in our solar system?
- What is the relationship between force and motion?

### Things to Know

- Review the following concepts: Newton's laws of motion, velocity, acceleration, and force.

## Activities

### ☐ Activity 1: Newton's Acceleration Ramp

In this activity, you will be rolling a marble and a metal ball bearing down a ramp. The rolling of the metal ball will model a portion of the path of a planet as it revolves around the Sun, and magnets will represent the gravitational pull of the Sun. The marble represents an object traveling through space as if it weren't being affected by the gravity of the Sun. As you conduct the activity, consider how the movement of planets is influenced by the gravitational pull between two objects such as a planet and the Sun.

There are four pages for this activity. "Newton's Acceleration Ramp" will show you how to set up and conduct the investigation. You will use the "Acceleration Ramp Guide" to help you keep the ramp and magnets in the correct place. The "Analyzing the Data" sheets have questions and a place for you to collect and graph your data. These questions challenge you to consider the forces and motion you are observing as the balls roll down the ramp, but keep in mind that you are modeling the orbit of a planet. You will be applying what you learn about planetary orbits in the next activity!

### ☐ Activity 2: Kepler's Laws

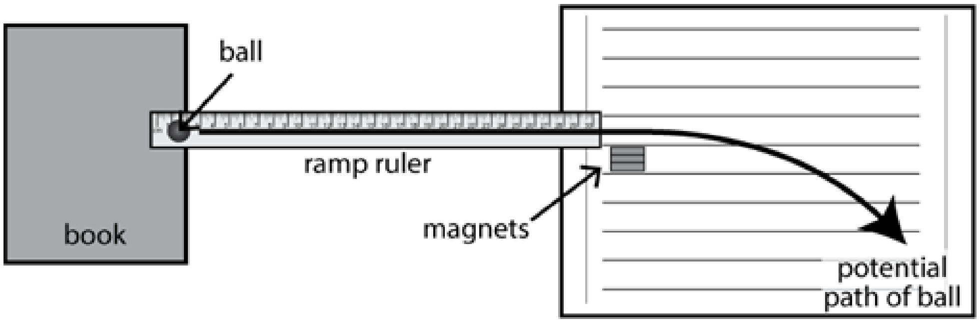
In the early 1600's, Johannes Kepler published his three laws of planetary motion. Explore the web page and video in the link below to find out more about them. Then apply his three laws, as well as what you discovered in Activity 1, to answer the questions on the "Kepler's Laws" activity sheet.

| Kepler's Laws of Orbital Motion |
|---|
| www.movingbeyondthepage.com/link/8471 |
| https://howthingsfly.si.edu/flight-dynamics/kepler%E2%80%99s-laws-orbital-motion |

## ☐ Wrapping Up

As you go about your daily life this week, consider all of the amazing things that are happening around you, and throughout the universe. Forces and motion are everywhere!

# Newton's Acceleration Ramp




**Materials**

- ruler with a groove down the center (kit)
- marble (kit)
- metal ball bearing (kit)
- three small bar magnets (kit)
- five books (each about 2 cm thick)
- a few extra books of any size

## Instructions:

1. Find a very flat surface to conduct this experiment (a dining table or coffee table could work well), and gather your materials.

2. Place one of the books, the "Acceleration Ramp Guide" sheet, the ruler, and the magnets on the table so they are set up like the diagram above. Your book should be about 2 cm thick. The 1 cm end of the ruler should be on top of the book, resting on the book at the 2 cm mark so it won't fall off. Line up the 30 cm end with the line marked "Ruler" on the paper. Create a barrier with the extra books about a foot away from your paper so the balls won't roll off the table.

3. Test your setup by rolling the marble down the ruler. Make sure the ruler is lined up straight with the lines on the paper. The marble should roll straight down between the two lines. When you have everything working, tape the paper to the table, and then put a piece of tape on the left or right side of the ruler to keep it from sliding off the paper. Also tape the right side of the magnets to the paper. (You don't want tape anywhere near the path of the ball.)

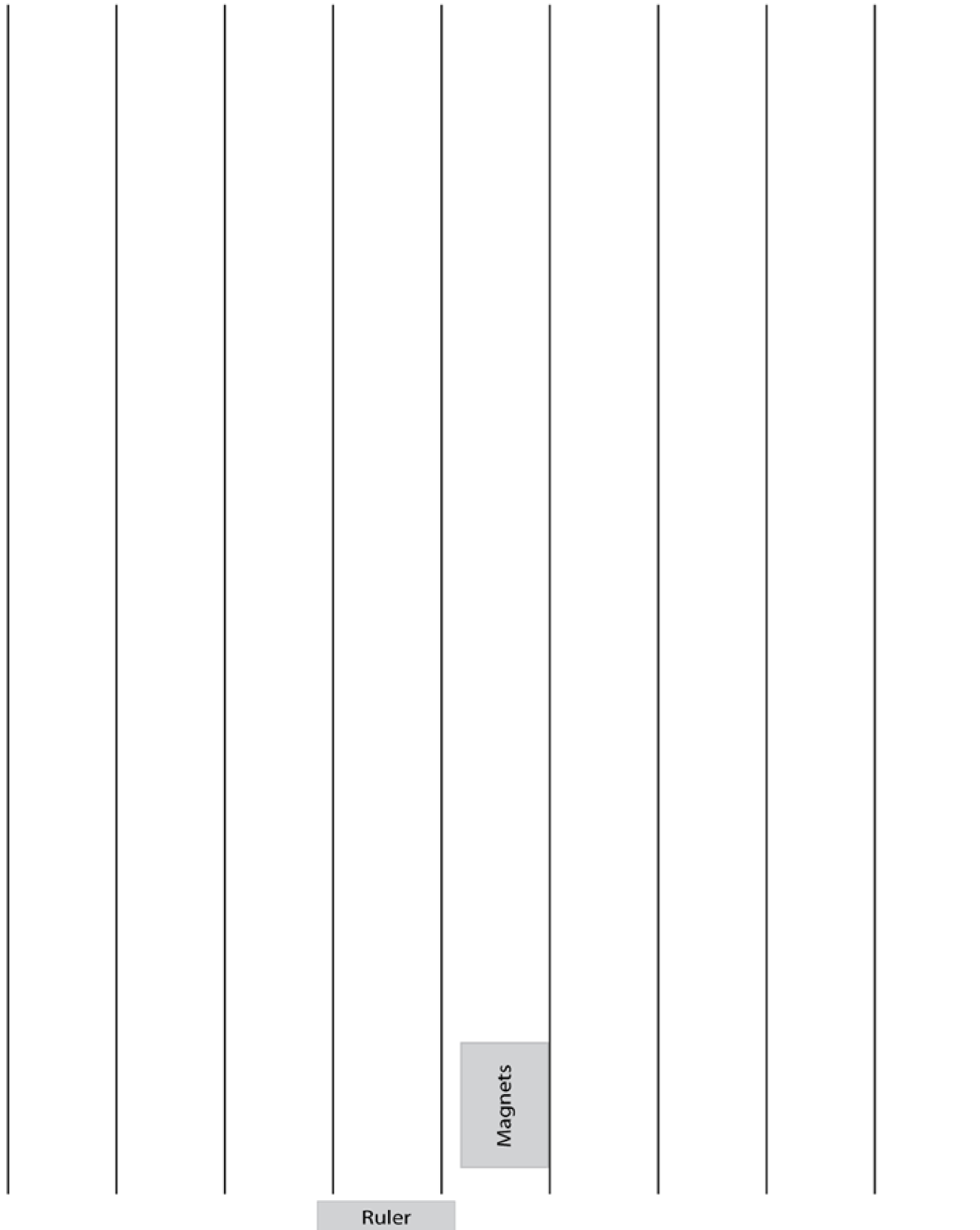
4. Roll the marble again and note where it rolls off the paper. Do this several times until you get a fairly consistent result, and then mark the spot with a dot. Label the dot "M1" ("M" for marble and "1" for the first trial).

5. Now roll the metal ball down the ramp and note where it rolls off the paper. Again, do this several times until you get a fairly consistent result, and then mark the spot with a dot. Label the dot "B1" ("B" for ball bearing and "1" for the first trial). If the ball sticks to the magnets, move the magnets just a tiny bit to the right and roll again. Notice the path the metal ball took compared to the marble. To increase the curve of the ball, try moving the magnets a tiny bit to the left.

6. Raise the height of the ramp to 4 cm and repeat steps 3-5. Make sure the ruler is in the same location each time so that the distance the balls travel down the ramp remains consistent. Remember to change your labels to reflect the correct trial (for example, M2 and B2).

7. Raise the height of the ramp to 6 cm, 8 cm, and then 10 com, repeating steps 3-5 each time, and changing the labels to reflect the trial number.

8. Now you are ready to record your data and analyze your results! Follow the steps on the "Analyzing the Data" sheet.


Magnets
Ruler

# Analyzing the Data

| Trial | Height | Marble Exit Location | | Ball Bearing Exit Location | |
|---|---|---|---|---|---|
| 1 | 2 cm | M1 | | B1 | |
| 2 | 4 cm | M2 | | B2 | |
| 3 | 6 cm | M3 | | B3 | |
| 4 | 8 cm | M4 | | B4 | |
| 5 | 10 cm | M5 | | B5 | |

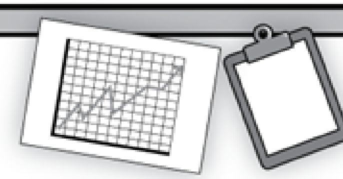
1. We will consider the dot most in line with the ruler to be 0 cm because the marble should have traveled down the ramp and off the paper in a straight line. Don't worry if your straightest marble roll isn't M1. Just record a 0 on the chart for whichever marble roll was the straightest.

2. Measure the distance between that dot and each of the other three marble dots and record the distances in the chart (in cm). (If your marble rolls to the left instead of straight, you can note that by making it a negative number.)

3. Next, measure the distance between the marble dot you have marked as 0 cm and each of the ball bearing dots, just like you did with the marbles. You are comparing the exit location of the marble that rolled in the straightest line with the exit location of each of the ball bearings. Record your results in the chart.

4. Graph the results of both balls. You may want to use a different color for each ball. Use "Height of Ramp (in cm)" for the x-axis and "Displacement of Balls (in cm)" for the y-axis.

# Analysis



1. What forces were acting on the marble as it rolled down the ramp and past the magnets? Name as many as you can think of.

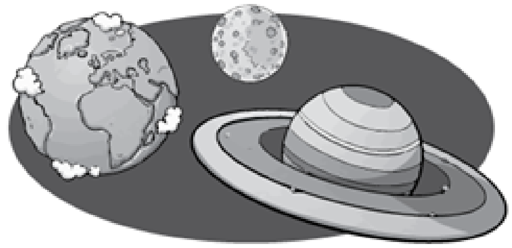
2. Were the exit locations of the marble fairly consistent? If they weren't, what factors may have contributed to your results?

3. What forces were acting on the ball bearing?

4. What happened to the ball bearing when you rolled it at the 2 cm height?

5. What happened to the path of the ball bearing as you changed the height of the ramp? Use Newton's second law to explain.

# Kepler's Laws



**Directions: After reviewing the "Kepler's Laws of Orbital Motion" web page and video, answer the following questions.**

1. **Draw an illustration of the orbit of a planet around the Sun. Underneath it, briefly list Kepler's three laws of planetary motion.**

2. **How is the movement of the planets around the Sun similar to the movement you observed with the bucket activity in Lesson 2?**

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3. **According to Kepler's three laws, how is the bucket activity different from actual planetary movements?**

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4. **Why do planets closer to the Sun, like Mercury, orbit the Sun faster than planets far away, like Saturn?**

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5. **Why is the velocity of a planet's motion around the Sun so important? (Consider what happened when you raised the height of the ramp in Activity 1.)**

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6. **What would happen if the size of the Sun was increased? Decreased?**

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# Lesson 7: Newton's Acceleration Ramp

## Getting Started

**Big Ideas**

- What kinds of forces are present in our solar system? In the universe?
- How do forces influence the movement of objects in our solar system?
- What is evidence of balanced forces in our solar system?
- What is the relationship between force and motion?

**Facts and Definitions**

- Review the following concepts: Newton's laws of motion, velocity, acceleration, and force.

**Skills**

- Analyze evidence to explain observations, make inferences and predictions, and develop the relationship between evidence and explanation. (S)
- Model the effects of velocity and gravity on the orbit of an object. (S)

**Introducing the Lesson**

In this lesson your child will be challenged to consider how forces (especially the force of gravity) and Newton's laws of motion are at play to a much larger degree in the solar system and throughout the known universe. He will also be introduced to Kepler's laws of planetary motion.

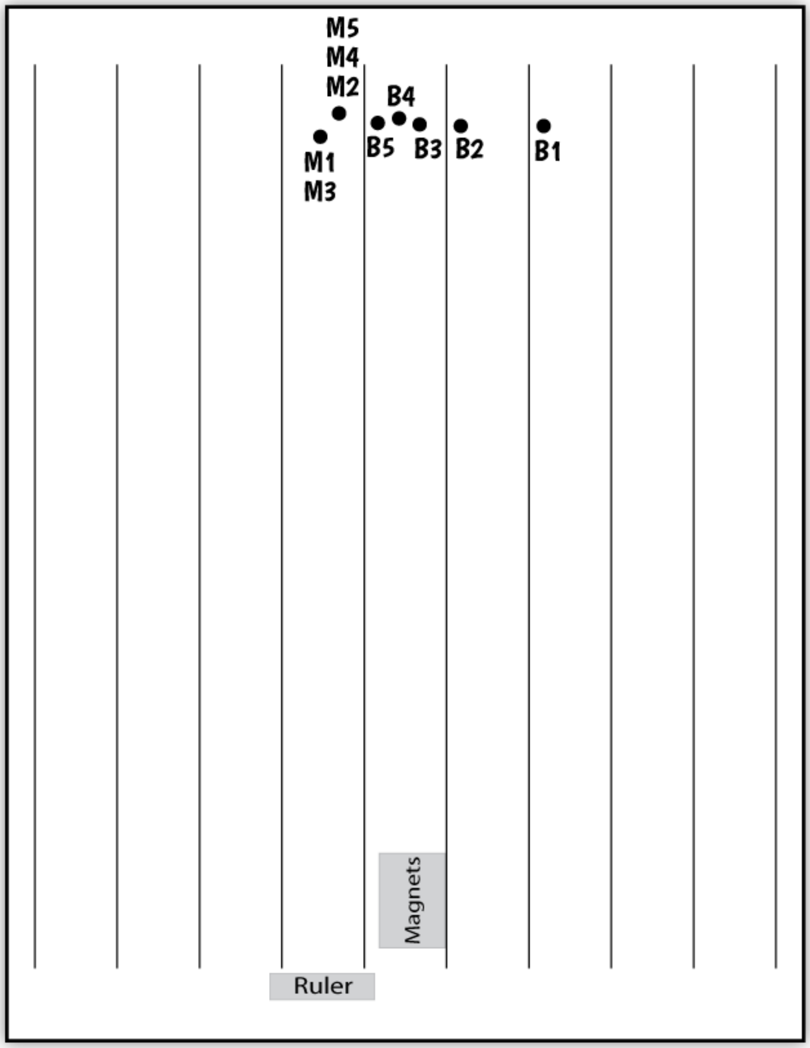
## Activities

**Activity 1: Newton's Acceleration Ramp**

In this activity your child has partially modeled the path of a planet around the sun, and experimented with increasing the velocity of the "planet" (the ball bearing). If you would like, talk to your child about the use of controls and variables in this experiment. He has used a control (the marble), which was not affected by the magnets (gravity), to compare the path an object will take through space when it is *not* affected by a gravitational force versus the path an object could take when it *is* affected by a gravitational force. His variable was the height of the ramp, which changed the velocity of the balls.

On the "Acceleration Ramp Guide" your child should have marked where each ball exited the paper. His results will be slightly different but should look something like this:

*Sample Acceleration Ramp Guide*

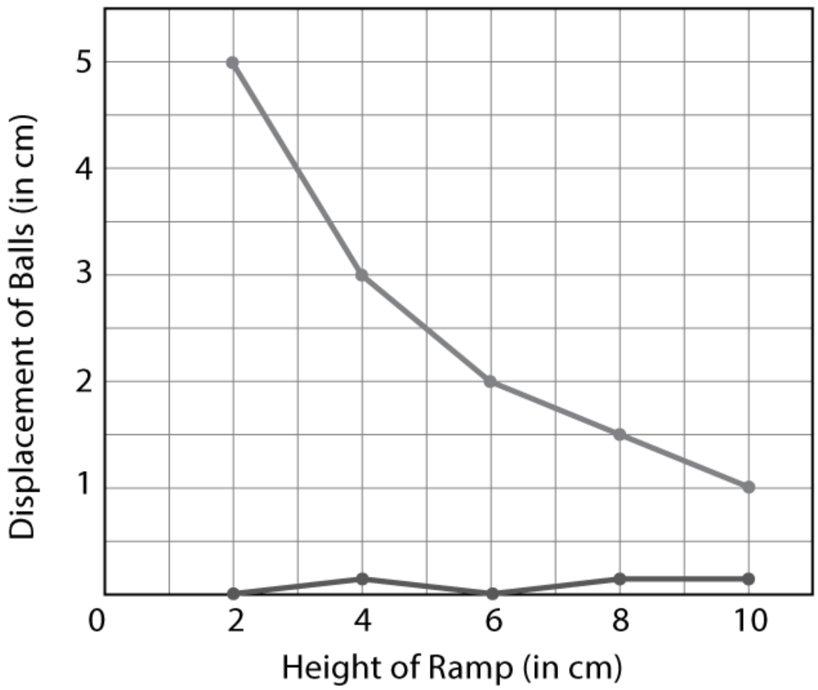



The following is an example of a completed chart and graph for the "Analyzing the Data" activity sheet. Your child's data and graph will be slightly different, but in general should show that as the ramp height increases, the distance the ball bearing curves will decrease.

*Sample Chart*

| Trial | Height | Marble Exit Location | | Ball Bearing Exit Location | |
|---|---|---|---|---|---|
| 1 | 2 cm | M1 | 0 cm | B1 | 5 cm |
| 2 | 4 cm | M2 | .2 cm | B2 | 3 cm |
| 3 | 6 cm | M3 | 0 cm | B3 | 2 cm |
| 4 | 8 cm | M4 | .2 cm | B4 | 1.5 cm |
| 5 | 10 cm | M5 | .2 cm | B5 | 1 cm |

***Sample Graph***




1. What forces were acting on the marble as it rolled down the ramp and past the magnets? Name as many as you can think of. *Answers will vary. Your child may mention gravity, friction, or air resistance.*
2. Were the exit locations of the marble fairly consistent? If they weren't, what factors may have contributed to your results. *The ruler may have moved, the paper may have moved, or he may have let the marble go in a slightly different manner.*
3. What forces were acting on the ball bearing? *Your child should mention magnetism, and may also mention gravity, friction, or air resistance.*
4. What happened to the ball bearing when you rolled it at the 2 cm height? *It should have veered to the right once it passed the magnets because the metal bearing was attracted to the magnet.*
5. What happened to the path of the ball bearing as you changed the height of the ramp? Use Newton's second law to explain. *The ball bearing rolled past the magnets faster, which lessened the effect the magnets had on it. According to Newton's second law, f = ma. The ball's mass did not change, but its acceleration did. Therefore a greater amount of magnetic force would be required to alter its path the same amount.*

**Activity 2: Kepler's Laws**

This activity introduced your child to Kepler's laws of planetary motion. The questions on the activity sheet challenge him to apply what he learned, as well as what he observed in Activity 1, to the motion of planets in our solar system.

Answer Key:

1. Draw an illustration of the orbit of a planet around the Sun. Underneath it, briefly list Kepler's three laws of planetary motion.
*The illustration should show an elliptical orbit. Kepler's three laws are: 1. Planets orbit the Sun in an ellipse. 2. As a planet comes closer to the Sun during its orbit, the planet speeds up. As it moves away from the Sun, it slows down. 3. Planets farther from the Sun have a larger and slower orbit than planets closer to the Sun.*

2. How is the movement of the planets around the Sun similar to the movement you observed with the bucket activity in Lesson 2?
*The Sun's enormous gravitational force exerts a pull towards itself, similar to the centripetal force you created by pulling on the bucket with the rope. Without the pull of this force, the moving planets would continue in motion in a straight line (Newton's first law). This constant unbalanced force (the Sun's gravitational force) acting on the planets causes a constant acceleration toward the Sun, which causes the planets to move in a circular motion.*

3. According to Kepler's three laws, how is the bucket activity different from actual planetary movements?
*In the bucket activity, you swung the bucket around you in a circle. The actual orbit of a planet is an ellipse, not a circle. Also, the bucket swung at a consistent speed. A planet will speed up as it gets closer to the Sun and slow down as it moves farther away.*

4. Why do planets closer to the Sun, like Mercury, orbit the Sun faster than planets far away, like Saturn?
*The closer a planet is to the Sun, the stronger is the force on it due to the Sun's gravity. This stronger (unbalanced) force causes a greater inward acceleration, which causes the planet to travel faster around the Sun. This is Kepler's third law.*

5. Why is the velocity of a planet's motion around the Sun so important? (Consider what happened when you raised the height of the ramp in Activity 1.)
*The velocity of each of the planets, along with its size and distance from the Sun, is one of the things that keeps it in its orbit. If a planet was traveling faster, it might be possible for it to "escape" the Sun's gravitational pull and leave its orbit.*

6. What would happen if the size of the Sun was increased? Decreased?
*If the Sun were larger, its gravitational pull would be greater. If the Sun suddenly became larger and no other changes occurred, the planets would eventually be pulled into the Sun. If the Sun were smaller, its gravitational pull would be less. If the Sun suddenly became smaller and no other changes occurred, the planets would eventually move away from the Sun.*

## Wrapping Up

**Questions to Discuss**

- Have you observed any interesting examples of Newton's laws of motion this week?
- What is the most useful thing you've learned about force and motion in this unit?

**Things to Review**

- Planets move in an elliptical orbit.
- Planets close to the Sun orbit faster than planets farther away.