ACTIVITY 3

Moving Masses

OBJECTIVES

Students learn that more massive objects require a greater force than do less massive objects for the same acceleration. They then use this information to predict how mass affects the rate at which two balls fall.

The students

- describe the relationship between mass and weight
- observe the relationship between force and acceleration
- observe the relationship between force and mass
- predict the falling rate of balls of different masses

SCHEDULE

About 20 minutes as a review; longer if concepts are being introduced for the first time

VOCABULARY

acceleration
mass
Newton's second law of motion

MATERIALS

For each student

1	Activity Sheet 3

For each team of four

1	bag, for spring scale
1	ball, steel
1	ball, wooden
1	book, hardcover*
1	scale, spring

*provided by the teacher

PREPARATION

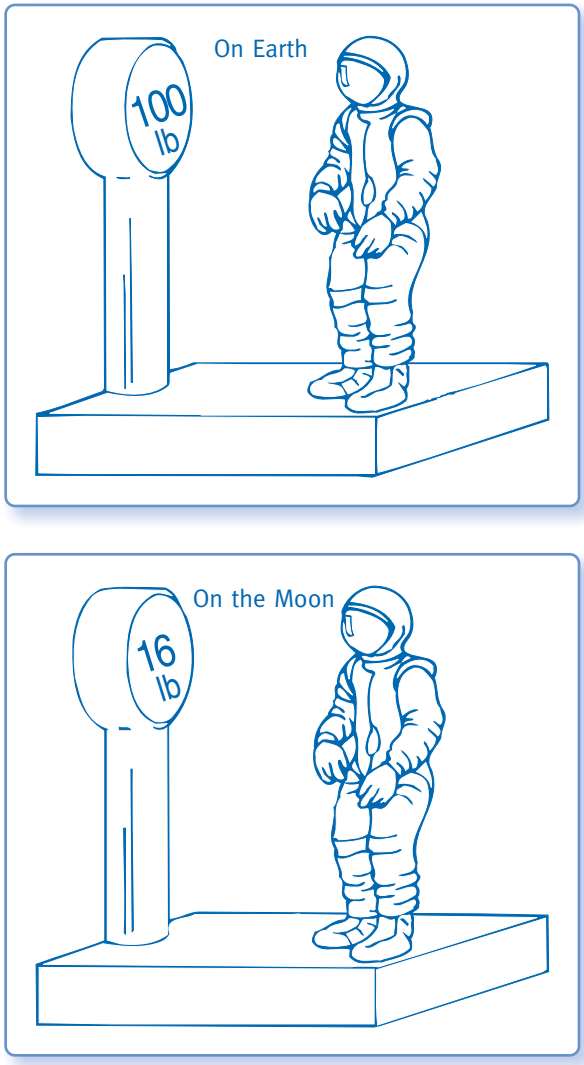
1. Make one copy of Activity Sheet 3 for each student.
2. Each team of four students will need one steel ball, one wooden ball, one spring scale, one bag, and one hardcover book. Be certain that the spring scales are zeroed before students use them.
3. Each group will need a flat surface on which to roll the balls, as well as a table off of which they can push the balls. Practice step 2 of the activity sheet beforehand to be certain the flat surfaces are smooth enough for students to be able to observe the greater acceleration of the less massive ball.
4. If your classroom is not carpeted, you may want each group to use a folded bath towel or a flat notebook or other cushion onto which the balls can land as they roll off the table.

BACKGROUND INFORMATION

Gravity force pulls more strongly on objects that have more mass than on objects that have less mass. Although there is a direct relationship between mass and weight, the two are not the same. Mass is an intrinsic

property of an object; it is a measure of how much matter is in the object. Weight is the measure of gravity's pull and is affected by the mass of the object and the surface gravity of the planet the object is on. A person can lose five-sixths of his or her weight just by going to the Moon, where the surface gravity is weaker than on Earth (see Figure 3-1). But even though the person would weigh less, he or she would have exactly the same mass.

A spring scale measures weight. Students are given the masses of the two balls in grams. By weighing the balls, students can see the direct relationship between mass and weight.



▲ ***Figure 3-1.*** *Weight is affected by gravity.*

In this activity, students observe behaviors that confirm ***Newton's second law of motion***. That law states that *a greater unbalanced external force causes a greater acceleration of an object in the direction of the force. A greater unbalanced external force is required to accelerate an object with more mass.* If your students are comfortable with algebraic expressions, $F = ma$ is a more complete description of this law, where F = force, m = mass, and a = acceleration.

Students use this law in interpreting the behavior of balls of different masses and then apply this law in predicting which ball will fall faster when both balls are dropped from the same height at the same time.

Acceleration is the rate of change in the speed and direction of an object. Therefore, acceleration can mean speeding up, slowing down, or changing direction. In this activity, however, it is used in the context of change in speed only. This is because if an object is moving in a straight line, acceleration refers only to the rate at which its speed changes.

▼ **Activity Sheet 3**

Moving Masses

1. Hold the wooden ball in one hand and the steel ball in the other. The wooden ball has a mass of 23 g. The steel ball has a mass of 235 g. The steel ball contains about ten times as much matter as the wooden ball. Use the spring scale and the bag to measure in newtons the force required to keep each ball from falling. This measure is also equal to the weight of each ball.

   Weight of the wooden ball: about 0.3 N Weight of the steel ball: about 3 N

   What is the relationship you have observed between mass and weight?

   An object with more mass weighs more.

2. Place both balls at the edge of a smooth, flat table. With a hardcover book, give the balls a quick push of the same strength, toward the opposite edge of the table. Compare the behaviors of the two balls.

   The wooden ball rolls faster.

   It would take a force ten times stronger to accelerate the steel ball as much as you accelerate the wooden ball. Try pushing harder on the steel ball to cause both balls to accelerate at the same rate.

3. Now make a prediction.
   Imagine dropping both balls from the same height at the same time.

   Predict which ball will reach the ground first. Predictions will vary.

   Give a reason for your prediction.

   Reasons will vary.

   Use a book to push both balls off the table at exactly the same time. Watch as they hit the floor. Repeat this experiment three times to be certain that both balls are leaving the table at the same time. Describe the results of your experiment:

   Both balls hit the ground at the same time.

4. In his second law of motion, Sir Isaac Newton described what you have just observed.

   An object acted on by a force will accelerate in the direction of the force. A greater unbalanced external force is required to accelerate an object with more mass.

   Use this law to describe what you have observed in these experiments.

   The steel ball has a greater mass than the wooden ball. Each ball accelerated at the same rate. The steel ball must have experienced a greater unbalanced external force.

Guiding the Activity

Additional Information

1 Write the terms *weight* and *mass* on the board. Ask, **What is weight? What is mass?**

*Weight is a measure of the amount of gravity pulling on an object. **Mass** is a measure of the amount of matter in an object. Therefore, an object's weight is affected not only by the mass of the object but also by gravity.*

Discuss the relationship between mass and weight with students. Be certain they are comfortable with both concepts. After the discussion, say to the class, **Give me an example of when an object loses weight but not mass.**

When an object is in a "weightless" environment, such as in a spacecraft; when an object is taken from Earth and placed on the Moon.

2 Distribute a spring scale, a bag, a steel ball, a wooden ball, and a hardcover book to each team of four. Give each student a copy of **Activity Sheet 3**. Allow the class time to read the activity sheet. Answer any questions the students may have about the steps. Tell the groups to complete step 1.

You may need to remind the class to read the newtons side, not the grams side, of the spring scale to find the weight of each ball in step 1. Remind students to record their data.

Students should find that an object with more mass also has more weight.

Help students conclude that the gravity force acting on a more massive object is stronger.

3 Before the teams try step 2, write the term *acceleration* on the board. Ask, **What is acceleration?** Be certain that students are familiar with the term.

***Acceleration** means the rate of change in speed and direction. When an object is falling, its speed increases. Acceleration is a measure of the rate of increase (or decrease) in speed. If the speeds of two objects increase at the same rate, then the objects have the same acceleration. At this point, be certain that the word does not become a stumbling block for your students.*

Tell teams to complete step 2 of the activity sheet.

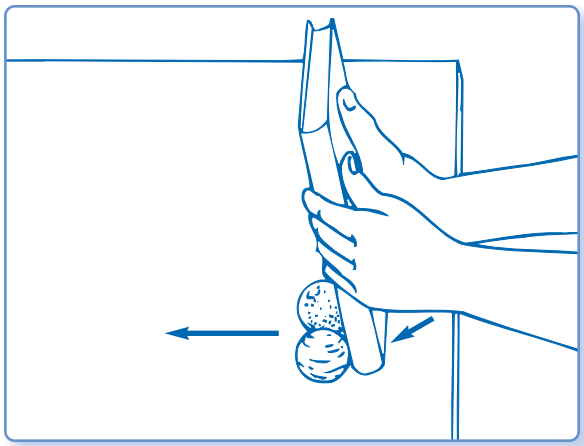
4 Watch as students push both balls with a book (see Figure 3-2). This activity works well on a smooth surface. If the surface produces too much friction, it will slow the balls and destroy the effect that students are supposed to observe.

Guiding the Activity

If students do not observe the greater acceleration of the less massive ball, point it out.

It is also important for students to push the balls and pull the book away quickly. If they move the book forward with the balls, they will not achieve the results intended.

Additional Information



▲ ***Figure 3-2.*** *Accelerating the balls.*

5 After teams have completed step 2, ask, **What is the relationship between force and acceleration in this step? between acceleration and mass?**

The stronger the force, the greater the acceleration (the harder the push, the faster the ball rolls—direct relationship).

Newton's second law of motion explains the phenomenon students have observed. It states: **An object acted on by a force will accelerate in the direction of the force.** Further, the acceleration of an object is directly proportional to the external force acting on it and inversely proportional to the object's mass.

Newton's second law states that the force on an object is the product of its mass and its acceleration—force (F) *= mass* (m) *× acceleration* (a), *or* F = ma. *Thus, acceleration* (a) *= force* (F) *÷ mass* (m), *or* a = F/m.

In this example—the book striking two balls of different masses—the force (F) *applied by the book is the same for each ball. Since* a = F/m, *and the force* (F) *is the same for each ball, for a greater mass* (m) *the value for acceleration* (a) *will be less. So, for the ball with the greater mass, acceleration is less and it rolls slower. For the ball with the lesser mass, acceleration is greater and it rolls faster.*

6 Allow the teams to complete step 3. Do not let the students drop the balls in step 3 before making their predictions about which ball will reach the ground first. Tell students to give a reason for their prediction.

Some students will predict that the more massive ball will reach the ground first, because the gravity force acting on the more massive ball is stronger. Other students will predict that the less massive ball will reach the ground first, because the less massive ball accelerates more quickly.

Guiding the Activity

Additional Information

Note: *If your classroom is not carpeted, you may want to have groups use a towel, a flat notebook, or other cushion as a landing pad for the balls to muffle the sound of dropping balls.*

7 After students have recorded their predictions, have students practice pushing both balls off the table to be certain that both balls are leaving the table at the same time. Then have a student at ground level in each team confirm that both balls hit the ground at the same time.

After students confirm this observation, ask, **How can you explain this observation, using Newton's second law of motion?** You might let the students discuss the logic in small groups to see whether each group can put all of the pieces together for a correct explanation.

The two balls hit the ground at the same time and were dropped from the same height. Thus, they accelerated at the same rate.

A greater force is required to accelerate the ball with more mass at the same rate as the ball with less mass. Here is how this is explained in terms of Newton's second law: Since a = F/m, *the acceleration* (a) *is the same for each ball and the mass* (m) *of each ball is different, the force* (F) *acting on each ball must be different. For the ball with greater mass* (m), *the force* (F) *must be greater for acceleration to be equal to that of the less massive ball.*

Remind students that, based on previous experiments, they know that the ball with more mass will experience a greater gravity force because the magnitude of the gravity force is directly proportional to the mass of the ball.

Tell students to complete step 4 individually.

Reinforcement

Collect the spring scales and the bags. Then give each team one table tennis ball. Ask the teams to predict which of the three balls will accelerate most quickly when the balls are hit with the book. Ask them to predict which of the three balls will reach the ground first. Then let the teams do the experiments and report their results.

Science Notebooks

Have students place their completed activity sheets in their science notebooks.

Cleanup

Return the spring scales, the bags, and the wooden and steel balls to the kit.

Science at Home

Tell students to look for examples of objects falling at the same rate, such as people in roller coasters. If the roller car and passengers did not fall downward at the same rate, the passengers would not be able to stay in the seats of the roller car.

Then ask students to think of times when one object fell more slowly than another object. Students might think of objects attached to parachutes.

Connections

Science Challenge

- Ask students what they think happens when two forces act on an object in different directions. Discuss students' ideas. Then have pairs or teams of students do the following activity to test their ideas. On a large sheet of paper, draw a wide, straight river with two docks on opposite banks. Position a pencil point representing a boat at one dock, and "row the boat" (move the point) across the river to the opposite dock. What path does the boat follow? (a straight line) Now tape two sheets of paper together to form a long strip, trim it to the width of the river, and put it over the river. Repeat the boat's travel across the river, but this time gently pull the paper strip to represent water flowing in the river. Where does the boat land this time? (downriver from the opposite dock) Ask students to explain this result. (The forward motion of the boat caused by rowing straight across the river and the sideways motion of the current combine to move the boat diagonally across the river.)

- Ask students to think of other examples in which two or more forces combine to affect an object's motion. For each example, have students identify whether acceleration occurs (i.e., whether there is a change in the object's speed and/or direction of motion). Ask students to describe the effect on the object. What happens to an object if two equal forces push or pull on it in opposite directions? (No acceleration occurs, and the object remains stationary or maintains its original motion.)

Science Extension

- Students observed that the wooden ball and the steel ball hit the ground at the same time even though the weight of the steel ball is about ten times the weight of the wooden ball. From this observation, what can they infer about the gravitational forces attracting the balls? (The gravitational force acting on the steel ball is about ten times greater than the force acting on the wooden ball.) Provide balls of different weights, and have students weigh each ball. Then have them drop the balls in pairs to determine whether they hit the ground at the same time. Ask students to describe the gravitational force acting on each ball compared with the force acting on the wooden ball.

- Show a short film or video, and stop at various points and ask students to identify examples of acceleration that they see. Make sure students understand that a change either in speed or in direction—not necessarily both at the same time—is acceleration.

Science and Language Arts

- Explain that scientists use the term *acceleration* to refer to either an increase or a decrease in an object's speed. Ask students what word is commonly used by nonscientists to describe a decrease in speed. (deceleration) Have students suggest other terms that have different meanings in science and in common usage.

- Ask students to think about what the world would be like if Earth's gravitational force attracted all objects with equal force, regardless of their mass—if, for example, a car were attracted to Earth with the same amount of force as a person is normally attracted, or vice versa. Suggest that students write short stories to describe such a world. Give volunteers an opportunity to read their stories to the rest of the class. Students also may enjoy working in groups to create and act out skits based on their stories.