1.4 Balanced and Unbalanced Forces

An object at rest has multiple forces acting on it. However, all the forces compensate for each other, adding up to a zero net force (a force with zero strength). This situation of equilibrium among forces is referred to as a **balanced** system of forces. Forces that do *not* add up to zero can cause changes in an object's speed or direction of motion (the object will move in the same direction as the net force). This kind of system is referred to as an **unbalanced** system of forces.

PURPOSE

In previous lessons, students have learned that a force is a push or pull that causes an object to move, changes its direction, or slows or accelerates its movement. In this lesson, students learn that forces are also responsible for keeping an object in mechanical equilibrium, or a state of rest. To illustrate the concept of forces in balance, students will play a game that involves pulling with equal force on ropes attached to a ring, to keep the ring steady above a cone. Understanding that balanced forces keep objects at rest will reinforce the idea that unbalanced forces cause motion.

OBJECTIVES

By the end of the lesson, students will be able to:

- Explain that if an object is at rest, two equal forces in opposite directions will cause the object to stay at rest
- Explain that when two forces are applied to an object, motion results if the forces are not equal, or if they are not applied in opposite directions

VOCABULARY

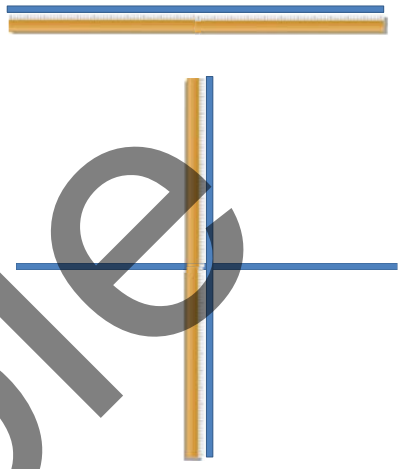
Introduce the following words during the course of the lesson. Make sure students have many opportunities to see the words in the classroom environment and to use the words as part of the lesson. There are definitions of the words at the end of the teacher's manual and in the optional *Student Activity Book*.

- Balanced
- Direction
- Force
- Unbalanced

PREPARING FOR THE LESSON

1. Before *Session 1*, find a clear floor space for students to play a tug-of-war game. A school corridor, for example, should allow enough space for all the students to participate in the activity. Attach the ribbon to the middle of the rope and use masking tape on the floor to indicate the initial position of the ribbon. Students may become very competitive during the tug-of-war and the push-of-war games. If the competition becomes too intense, be prepared to intervene and stop the activity.

   You will also need to set up the Balanced/Unbalanced Machine following the instructions in the ***Balanced/Unbalanced Machine Kit***.



2. Before *Session 2*, find a clear floor space to prepare a set of perpendicular lines. Take two yard sticks and align them on the floor end-to-end. Place a 6-ft. strip of masking tape alongside the yard sticks. Then, rotate the yard sticks 90 degrees so that they intersect the middle of the tape line perpendicularly, and place another strip of tape. Place the cone at the intersection of the two lines.

   Before starting with the Tug-of-War cone activity, make sure there are only two ropes attached to the ring. During the session you will add the other two ropes to the ring one by one.

Session 1: *What is the difference between balanced and unbalanced forces?*

Time: 40-45 minutes

Materials:

- KS ***Balanced/Unbalanced Forces Kit***
- KS ***Balanced/Unbalanced Machine Kit***
- KS Masking tape
- KS 2 Arrows

Session 2: *How can we create balanced forces that keep an object at rest?*

Time: 40-45 minutes

Materials:

- KS ***Balanced/Unbalanced Forces Kit***
- KS 2 Yard/meter sticks
- KS Masking tape
- KS *Activity Sheet 1: Balancing Forces*

TEACHING THE LESSON

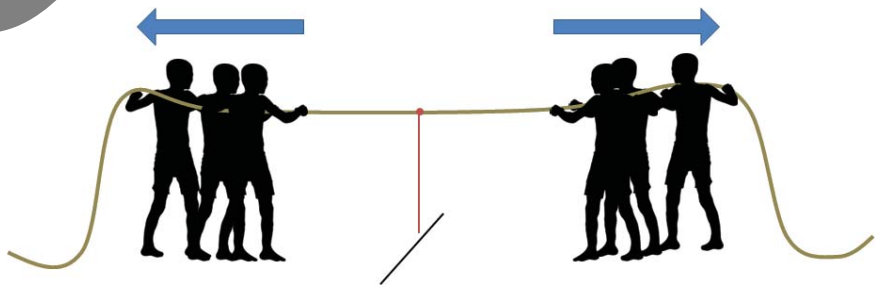
Session 1: *What is the difference between balanced and unbalanced forces?*

NOTE: During the next activity, students will play a tug-of-war game as well as a modified version using a pole. In both cases ask students to be mindful of safety, and make sure that they do not pull the rope or push the pole with too much strength.

1. Gather students in the area you have prepared for the tug-of-war game, and divide them into two teams. Make sure there are the same number of students on each team, and that the two teams are of approximately equivalent strength. Ask each team to hold the rope from the ***Balanced/Unbalanced Forces Kit*** without exerting any force. Center the ribbon above the mark you placed on the floor earlier.
2. Now, ask the students to start the competition. While students are pulling the rope, ask **"Is this a push or a pull?"** [Pull.] If you notice that one team is stronger than the other, try to address the situation by exchanging some students for others on the teams. Then restart the game. When the two teams are even, the ribbon will not move much. While the ribbon is not moving ask, **"Why is the ribbon not moving?"** [We are even; each team is pulling with the same amount of force.]

NOTE: Students may become extremely competitive during the tug-of-war game. To make sure they focus on the concept of balanced forces rather than on the intensity of competition, ask the students to keep the rope steady for a moment. You may want to help one of the teams or place your hands on the rope, one on each side of the ribbon, and hold tightly to make sure the ribbon is not moving.

3. Show students the 2 arrows from the Balanced/Unbalanced Forces Kit, and explain that they can be used to represent the "pull" that each team is applying. Ask the students which way each of the arrows should face in order to show the current balance in the tug-of-war game. **"Are the two arrows the same length? Which way are they pointing?"** [The arrows are the same length because the forces being applied are the same, but the arrows are pointing in opposite directions, because both teams are pulling.] If necessary, guide students to understand that the arrows should be placed in the following way:



4. Now ask the two teams to push. Students may react with surprise but should realize quickly how to push until the two teams collide. Students will realize that it is not possible to push on a rope because the rope is not rigid. Ask the

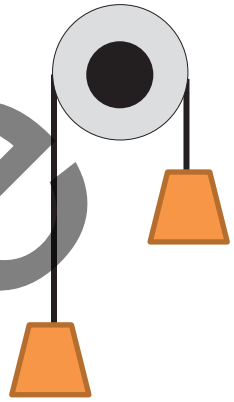
two teams to hold the pole in the ***Balanced/Unbalanced Forces Kit*** and, once in place, start pushing against each other. Guide them to see that, as in the case of the rope, there is no movement if the opposing forces are of the same magnitude. This activity is essentially the same as the tug-of-war activity, except that pulls are replaced by pushes.

EXPLAIN

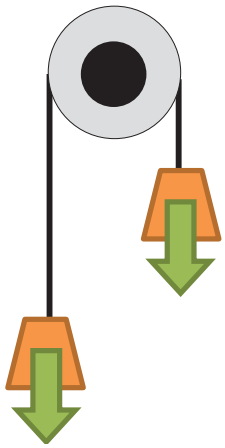
5. Explain that when two forces are pulling away or pushing toward each other with the same force, the two forces are balanced. When forces are balanced, there is no motion.

Constructing Explanations

6. Show students the *Balanced/Unbalanced Machine*, and the two equal masses in the kit. Explain that these two masses are equal in weight. Adjust the rope hanging from the pulley so that each side is at a different height. While holding the rope steady, attach a mass to each side as shown in the figure to the right. Before releasing the rope, ask students to predict what will happen to the masses when you let go. "**Will the mass on the left move up or down? What about the mass on the right?"** Give students an opportunity to share their predictions, and then release the rope. There should be no change to the height of either mass**.**



7. Ask a volunteer to rearrange the two masses. When the student releases the masses, they will not change their position. Ask another volunteer to choose a different arrangement. Again, the masses will not move from their new position. Explain that, as in the tug-of-war game, the two masses are being pulled by gravity with the same amount of force, so the masses are balanced and there is no movement. The 2 forces are opposing each other along the rope. Use the 2 arrows from the ***Balanced/Unbalanced Forces Kit*** to help students visualize the forces acting on the 2 masses, as in the figure to the right.



ENGAGE

8. Repeat the tug-of-war activity. Use the same "balanced teams" from before. This time the objective is to introduce unbalanced forces, so choose a team, and ask one student at a time to leave it. This operation will create unbalanced forces because the team with fewer students will not be able to apply the same force as the other team. Ask, **"Is the ribbon moving? Why?"** [The ribbon is moving because one team is stronger than the other.] Explain that "pulls" in this case are different, the forces are not balanced.

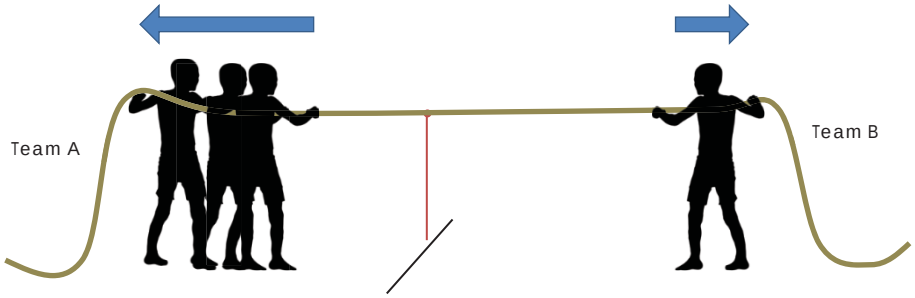
EXPLORE

9. Show students the 2 arrows from the ***Balanced/Unbalanced Forces Kit***, and explain that they can be used to represent the "pull" that each team is applying. Ask the students which way each of the arrows should face in order to show the current balance in the tug-of-war game. **"Are the two arrows the same length? Which way are they pointing?"** [The arrows have different lengths

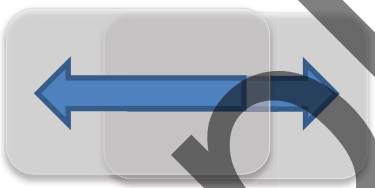
EXPLAIN

Constructing Explanations

because the forces being applied are different. The arrows are still pointing in opposite directions, because both teams are pulling.]



If necessary, guide students to understand that the arrows should be placed in the following way, with one overlapping the other, so that it appears longer (you may also use copy paper to cover the back end of the arrow to make it appear shorter).



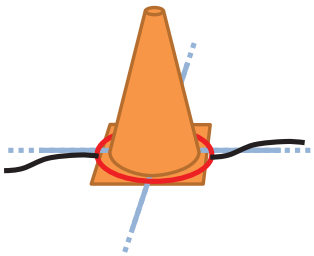
NOTE: In the following activity, you may need to hold the *Balanced/Unbalanced Machine*'s rope to stop the lighter mass from going too close to the pulley. Not holding the rope may cause the lighter mass to be released from the rope.

10. Return to the Balanced/Unbalanced machine. Replace one of the two masses with the bigger mass in the kit. Hang and hold the two masses and ask **"What will happen if I release the two masses?"** [The heaviest will go down, and the lightest will go up.] Release and show that the heaviest moves downward while the lightest moves upward. Ask a volunteer to rearrange the placement of the two masses. Once again the two masses will move. Explain that this, as in the previous tug-of-war game, is an example of unbalanced forces. Unbalanced forces cause movement.
11. Conclude the lesson by reminding students that the previous lesson focused on force as a push or pull that gets an object at rest going. Then say, **"Very often a push or pull does not move an object."**
    a. When two or more forces act on an object so it does not move, we say that the forces are balanced.
    b. When an object moves as a result of a push or a pull, we say that the forces on the object are unbalanced.
12. With the students working in pairs, ask them to come up with a list of five examples of balanced forces acting on an object and five examples of unbalanced forces acting on an object. When the pairs have completed their work, share the lists with the whole class and verify that that the examples have been correctly classified.

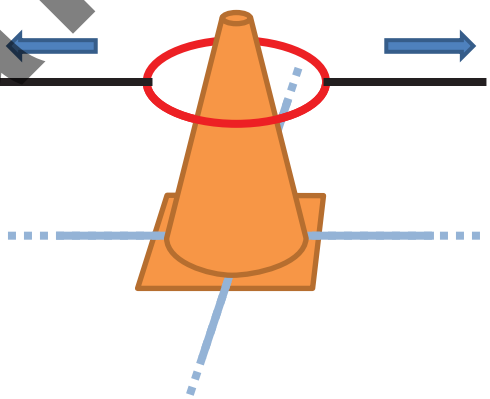
Session 2: *How can we create balanced forces that keep an object at rest?*

Planning & Carrying Out Investigations

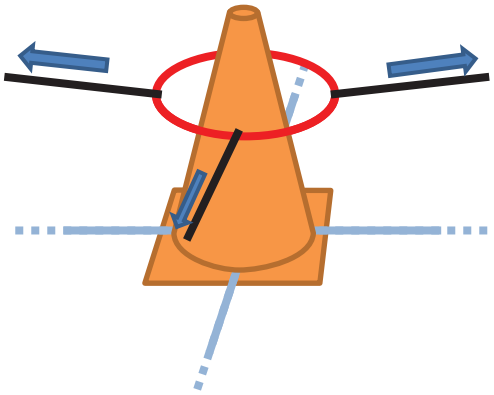
NOTE: During the next activity, ask students to be mindful of safety, and make sure that they do not pull the ropes with too much strength.



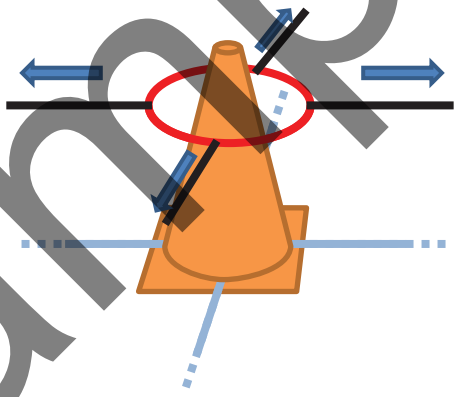
1. Gather the students in the area in which you have prepared the Tug-of-War Cone activity. Place the cone at the intersection of the straight lines you have prepared before class. Attach two ropes to opposite sides of the ring, and place the ring over the cone.
2. Explain to the class that they are going to play a game that requires them to keep opposing forces in balance. Point out the intersecting straight lines on the floor that you created with tape. Ask for 4 volunteers to help you demo this activity.
3. Procedure:
    a. Tell students that the object of the activity is to raise the ring gently toward the top of the cone without the ring touching the cone.
    b. Ask two students to stand at either end of one of the straight lines. Invite each student to pick up a rope attached to the ring, and ask them to pull gently and steadily on their ropes until they lift the ring without the ring touching the cone. They must continue to stand on the straight line. When they successfully balance one another's force, the ring will not touch the cone. Say to the class, **"Both the students are applying force to the ring. Why is the ring not moving?"** [They are applying equal force in opposite directions, so the ring stays still and does not touch the cone.]



    c. Attach a third rope to the ring at a 90° angle to the first two ropes (along the second straight line). Ask another student start gently pulling on the third rope. Ask the class to observe what happens. The first two students will likely automatically adjust the direction of their forces to keep the ring centered on the cone. If so, ask the students, **"Why did you move?"** [To keep the ring centered on the cone.] If the students did *not* adjust their positions, ask them to find a way to re-center the ring.



d. Have the students return to their original positions along the straight lines on the floor. Attach a fourth rope to the ring at a 90° angle to the other ropes and invite the fourth volunteer to stand on the line opposite the third student. Direct the four students to pull gently and steadily and raise the ring until it does not touch the cone. Ask the class to observe what happens. [Opposing forces are once again in balance and the ring is centered on the cone. The fourth student has balanced the pull of the third student.]



Analyzing and Interpreting Data; Obtaining, Evaluating, and Communicating Information

EVALUATE

4. Explain to students that these demonstrations have shown them how an object can be balanced even if more than 2 forces are being applied to it, as long as each force cancels all of the others out.
5. Ask students to complete *Activity Sheet 1: Balancing Forces*.

NOTE: During the next activity, ask students to be mindful of safety, and make sure that they do not pull the spring scales with too much strength. Otherwise, they may deform the spring or cause the scale to break, which may become unsafe.

6. To conclude the lesson, introduce students to the unit used to measure forces: the Newton, which was named after Sir Isaac Newton. Say: **"Until now, you have applied forces and felt the strength of a force in comparison with another. How can we measure forces?"** Let the students share their thoughts, and listen to what they have to say. Remind students that to measure the length of an object we can use a ruler, which is an object with very specific length (the ruler is divided into centimeters or inches). Therefore to measure

length we need to define a very specific length to use as standard. To measure forces the procedure is not different. We define a very specific amount of force to be our standard. Show students the 10N spring scale (make sure to show students the scale in Newtons (N), not the one in grams). Circulate around the classroom and show students where 1 Newton (1N) is on the scale. Ask students to hold the spring scale and pull until the scale measures 1 Newton. What they are feeling as they pull the spring is our standard force, a force of 1 Newton.

ABOVE AND BEYOND

Give the students an opportunity to explore the concept of balanced forces further by attaching five or six ropes to the ring. Then have students try to balance the ring around the cone without touching the cone. What do they discover? What conclusions can they draw?

ASSESSING STUDENT LEARNING

Communication

Divide the class into groups of 3-4 students. Ask them to explain to each other what adjustments they had to make to their pulling force during the cone/ring activity, in order to balance the ring around the cone without touching the cone.

Other Possible Assessments

1. You can use a rubric such as the one that follows to assess students' learning. With some modifications, you can use the rubric for student self-assessment.

	NOVICE	PRACTITIONER	ADVANCED
Explains that if an object is at rest, two equal forces in opposite directions will cause an object to stay at rest	Can explain with substantial help from the teacher.	Can explain with some help from the teacher.	Can explain independently and references the cone and ring activity as an illustration.
Explains that when two forces are applied to an object, motion results when the forces are not equal or not applied in the opposite direction.	Can explain with substantial teacher assistance.	Can explain with some help from the teacher.	Can explain independently using the vocabulary of the lesson and citing the example of the cone and ring activity.

2. Ask students to work in pairs or small groups, and create an activity which demonstrates that an object will remain at rest if two equal forces from opposite directions are exerted upon it.
3. *Activity Sheet 1: Balancing Forces* can be used as assessment.

CROSSCUTTING CONCEPTS

Cause and Effect: Mechanism and Explanation; Stability and Change

In this lesson, students physically explore the concept of balanced and unbalanced forces. When they engage in the cone and ring activity, they actively feel the opposing forces that keep an object at rest or precipitate its motion. In the process, they recognize that stability is a function of dynamic forces, and that a small change in the direction or magnitude of those forces can destroy the equilibrium.

SCIENTIFIC AND ENGINEERING PRACTICES

Planning and Carrying Out Investigations; Analyzing and Interpreting Data; Constructing Explanations; Obtaining, Evaluating, and Communicating Information

STANDARDS CORRELATIONS

Next Generation Science Standards

3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

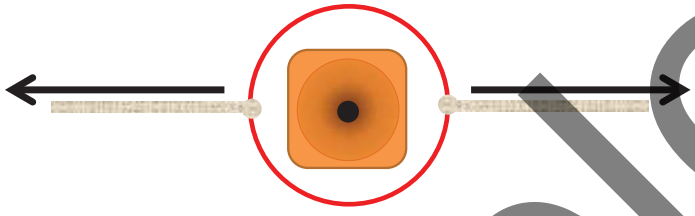
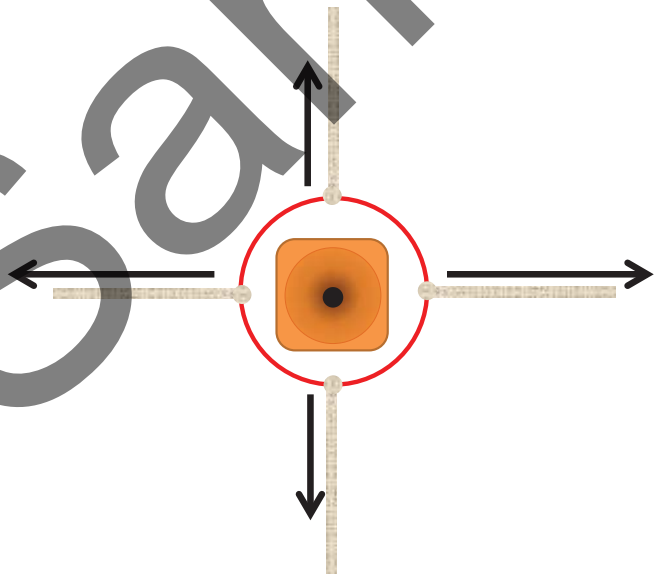
Common Core State Standards for English Language Arts

CCSS.ELA-LITERACY.SL.3.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 3 topics and texts, building on others' ideas and expressing their own clearly.

Activity Sheet 1: Balancing Forces

Name _____

Directions: Draw the forces applied in each case to keep the ring centered above the cone using arrows to represent the force. Then answer the following questions.

2 students pulling
 The two arrows are expected to be approximately equal and pointing away from each other.
4 students pulling
 The horizontal and vertical pair of arrows are, respectively expected to be approximately equal and pointing away from each other.

1. When only two students are participating, are the forces balanced? How the arrow you drew represent the situation?

The forces are balanced. This is represented by two arrows of equal length pointing away from each other

2. When four students are participating, do all four student need to apply the same force to keep the center of the ring above the cone?

No. Only opposite forces should be the same.

3. Do the forces in each pair balance?

Yes.

4. Do balanced forces cause motion?

No.