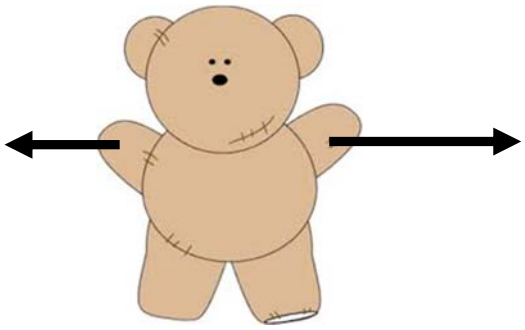
# Exploration #1: What combinations of forces have the same effect?

## Purpose

In the *Beginnings* activity, you saw that when an unbalanced combination of forces acts on an object, it will start to move. But, after it has started, would the motion of the cart be **exactly the same** for ***all*** **unbalanced** combinations of forces or would it depend how strong each force was?



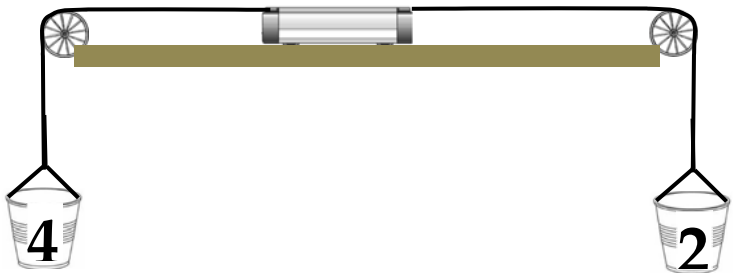
The big question we will address in this *Exploration* activity is:

**What unbalanced combinations of forces have exactly the same effect on an object?**

## What do we think?

In the previous activity, you saw a low-friction cart being acted on by various combinations of forces. In that case, we were only interested in which combinations started the cart moving and which did not. In this lesson, we will be interested in which combinations make the cart move in exactly the same manner?

Suppose you had a setup like that shown below, with 4 sugar cubes in one cup and 2 in the other. You know that if this cart was released it would start to move to the left. We will judge the manner in which it moves from the amount of distance it travels in a certain amount of time.



Suggest two or three other arrangements of sugar cubes you could put in the two cups that would make the cart move **in exactly the same manner** as the 4-2 combination. (That is, make the cart travel the same distance as the 4-2 combination in the same amount of time.)

Explain why you think your arrangements would work.

Your PD leader will lead a class discussion about everyone's answers to this question, and the explanations.

## Activity #1: Which combinations behave the same?

Your group will work together for this activity. The group will need:

- A laptop or iPad on which to view movies.

One suggestion that has been made is that it is only the strongest force that determines how an object behaves and that the weaker force will not make any difference. If this is the case, then any combination that has 4 sugar cubes in one cup and 1, 2, or 3 sugar cubes in the other cup, should behave in exactly the same manner.

Do you think a 4-1 or a 4-3 combination will behave in exactly the same manner as a 4-2 combination, or not? Explain your thinking.

**STEP 1:** Open Exploration 1 Movie 1: Comparing Unbalanced Combinations. You will now watch the first 30 seconds of the movie in which 4-1, 4-2, and 4-3 combinations are tested at the same time. **Pause the movie at time 0:30** then answer the following questions.

What does the movie show? Do ***all*** three combinations behave in **exactly the same manner** or not?

The idea we were trying to test in this STEP was that any combinations of forces for which the strongest force is the same would make the cart move in exactly the same manner.

 Does the result of the test you saw in the movie support or disprove this idea?

Another suggestion that has been made is that it is the ratio of the stronger to the weaker force that determines how an object behaves. For the 4-2 combination, the stronger force is twice as big as the weaker force. So, if this idea is correct, then any combination for which the stronger force is double the weaker force, such as 6-3 or 2-1, should have exactly the same effect as the 4-2 combination.

 Do you think either a 6-3 or a 2-1 combination would behave in exactly the same manner as a 4-2 combination, or not? Explain your thinking.

**STEP 2:** Resume the movie. You will now see a movie segment in which 6-3, 4-2, and 2-1 combinations are tested at the same time. **Pause the movie at time 0:55** then answer the following questions.

 What does the movie show? Do ***all*** three combinations behave **in exactly the same manner** or not?

The idea we were trying to test was that any combinations of forces for which the stronger force is twice as large as the weaker force would make the cart move in exactly the same manner.

 Does the result of the test you saw in the movie support or disprove this idea?

A third suggestion that has been made is that it is how much bigger the stronger force is than the weaker force that determines how an object behaves. For the 4-2 combination the stronger side has two more sugar cubes than the weaker side. This idea suggests that any combination for which one cup has two more sugar cubes than the other should have exactly the same effect as the 4-2 combination. Examples of such combinations would be 5-3 and 3-1.

 Do you think either a 5-3 or a 3-1 combination would behave in exactly the same manner as a 4-2 combination, or not? Explain your thinking.

**STEP 3:** Resume the movie. You will now see a movie segment in which 5-3, 4-2, and 3-1 combinations are tested at the same time. **Pause the movie at time 1:20** then answer the following questions.

 What does the movie show? Do ***all*** three combinations behave **in exactly the same manner** or not?

The idea we were trying to test was that combinations of forces that produce the same effect are those for which the stronger force is bigger than the weaker force by the same amount.

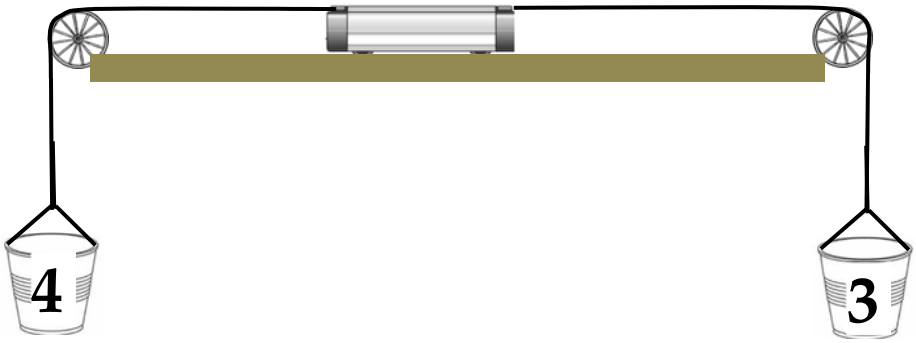
Does the result of the test you saw in the movie support or disprove this idea?

**STEP 4:** You have now seen tests of three possible ideas about what unbalanced combinations of forces have the same effect on the cart.

Your PD leader will lead a class discussion about these tests

Which of the three ideas you have seen tested seems to be correct?

**STEP 5:** In STEP 1, you saw that a 4-2 combination did not have exactly the same effect on the cart as a 4-3 combination.




Use the idea you identified as correct in STEP 4 to suggest two or three different combinations that you think would have exactly the same effect on the cart as a 4-3 combination. Explain your thinking.

Your PD leader will lead a class discussion about everyone's ideas and then you will see two movie segments in which you will see various combinations tested at the same time as a 4-3 combination.

Make a note of the combinations tested in the movie that behave **in exactly the same manner** as the 4-3 combination?

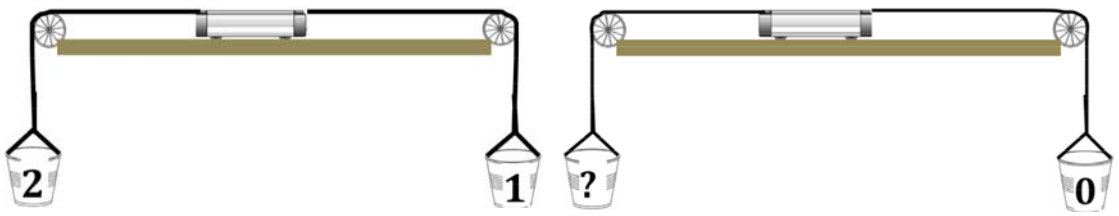
Why do you think all these combinations behaved in the same manner? What did these arrangements have in common?

## Activity #2: Combinations for which one force is zero?

Your group will work together for this activity. The group will need:

- A laptop or IPad on which to view movies.

Now suppose you wanted to find a combination that behaved in exactly the same way as a 2-1 combination, ***but were not allowed to put any sugar cubes in one of the cups***.



Suppose you tested both a 1-0 and a 2-0 combination alongside a 2-1 combination.

Which of the 1-0 and 2-0 combinations do you think would behave **in the same manner** as the 2-1 combination, both of them, only one, or neither? Explain your thinking.

**STEP 1:** Close the previous movie and open Exploration 1 Movie 2: What's the Equivalent Single Force? You will now see a movie segment in which 2-1, 1-0, and 2-0 combinations are tested at the same time. **Pause the movie at time 1:00** then answer the following questions.

What does the movie show? Which combination behaves in exactly the same manner as the 2-1 combination, the 1-0 or the 2-0?

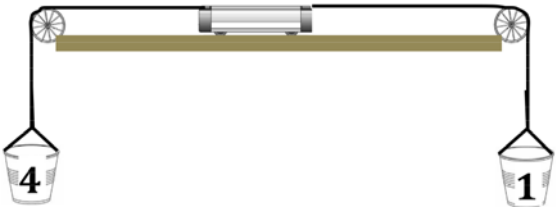
Why do you think it is that this particular combination behaves in the same manner as the 2-1 combination?

## Net Force

As you have seen, there were many combinations of sugar cubes that would have the same effect on the cart as the 2-1 combination. (For example, 3-2, 4-3, etc.) You have also seen that there was only one combination in which a single sugar cube placed in only one of the two cups had the same effect. Because there was a sugar cube in only one cup, and none in the other, there was only a **single force** acting on the cart in this case. When a combination of forces acts on an object, you can always find a single force that will have exactly the same effect. We call the strength of the single force that will have same effect as a combination of forces the **net force** acting on the object.

For example, if we had 2 sugar cubes in one cup and 1 sugar cube in the other, we could also make the cart behave **in exactly the same way** by putting only 1 sugar cube in one cup and leaving the other empty. So we can say that the net force acting on the cart was that of only 1 sugar cube.

**STEP 2:** Now suppose you had a 3-1 combination and a 4-1 combination.



What is the net force for each of these combinations?


How could you make the cart move in the same manner as each of these, by placing sugar cubes in only one cup?

Your PD leader will lead a class discussion about everyone's ideas and then you will see two movie segments in which you will see various combinations tested.

**STEP 3:** Watch the remainder of the movie then answer the following questions.

Which combination behaves in exactly the same manner as the 3-1 combination, the 2-0 or the 3-0?

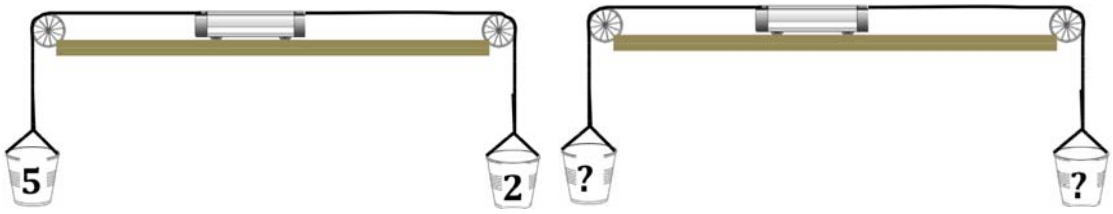
Which combination behaves in exactly the same manner as the 4-1 combination, the 2-0 or the 3-0?

Why do you think it is that these particular combinations behave in the same manner as the 3-1 and 4-1 combinations?

## Making Sense

Discuss with your group the answers to the following questions and be prepared to contribute to the whole group discussion lead by your PD leader.

1. Suppose the combination was changed to have 5 sugar cubes in one cup and 3 in the other.




a) Suggest two different arrangements of sugar cubes that would make the cart behave in the same manner as the 5-2 combination.

b) What is the net force for the 5-2 arrangement? How do you know?

2. Suppose you had three cups and placed sugar cubes in them as shown below.


What is the net force of this arrangement of sugar cubes? How do you know?

3. Describe how you can find the net force acting for any combination of forces acting on an object.

4. If a balanced combination of forces acts on an object, what is the net force acting on it?