What effect do combinations of forces have on motion?

Purpose

You now know what happens when a combination of forces (either balanced or unbalanced) acts on an object that is not moving. We will now examine what happens to an object that is already moving when a combination of forces acts on it.

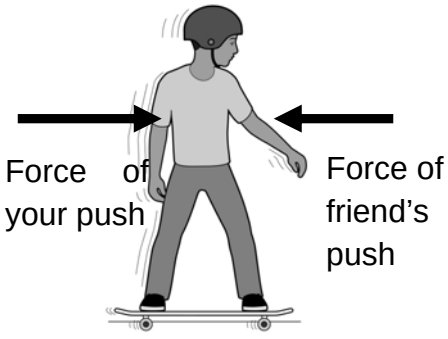
For example, suppose a boy pulls on his toy wagon to start it moving across the floor in the direction of his pull. Since her teddy bear is in the wagon, his sister starts to pull on the wagon in the opposite direction to her brother. How would the speed of the wagon behave now, with this combination of forces acting on it? Would it matter whether the combination of forces was balanced or unbalanced?

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

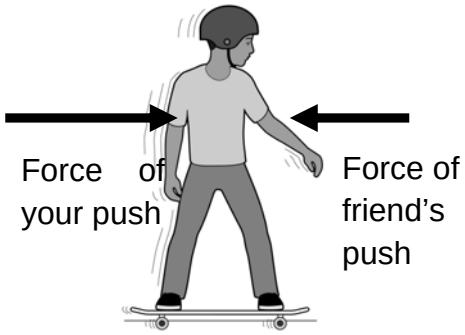
What effect does a combination of forces have on a moving object?

What do we think?

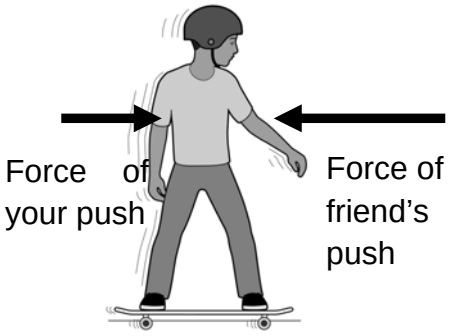
Imagine your friend is already moving along on his skateboard. As he is moving, you push on him in the **same** direction as he is moving, while another friend pushes on him in the **opposite** direction. What will his motion be like while you are both pushing? Would your answer be different depending on which force was strongest?



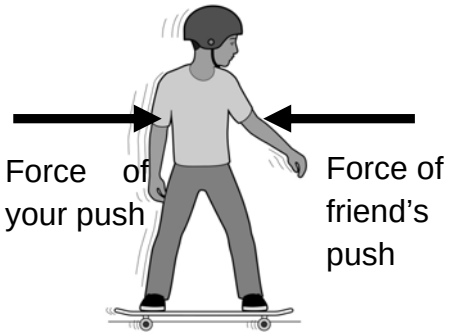
If your forward push was **stronger** than your friend's backward push, do you think the skateboarder's speed would increase, decrease, or stay constant? Why do you think so?



If your forward push was **weaker** than your friend's backward push, do you think the skateboarder's speed would increase, decrease, or stay constant? Why do you think so?



If your forward push was **equal in strength** to your friend's backward push, do you think the skateboarder's speed would increase, decrease, or stay constant? Why do you think so?



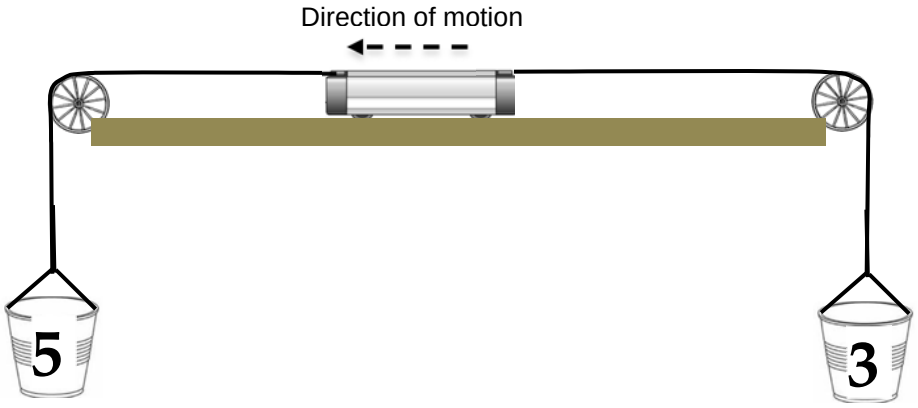
Your PD leader will lead a group discussion about everyone's answers to these questions.

Activity #1: How does the speed behave when unbalanced forces act on a moving object?

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

- Laptops on which to view movies, or a way for the whole group to view a projected movie.

We will again test our ideas using the setup of a cart on a track and loading sugar cubes into the cups attached to each end. Suppose you had a setup like that shown below, with a 5 - 3 combination of sugar cubes. You know that when this cart is released it will start to move to the left but now we are interested in what happens to its speed **after it starts moving**, while this unbalanced combination of forces is still being applied to it.

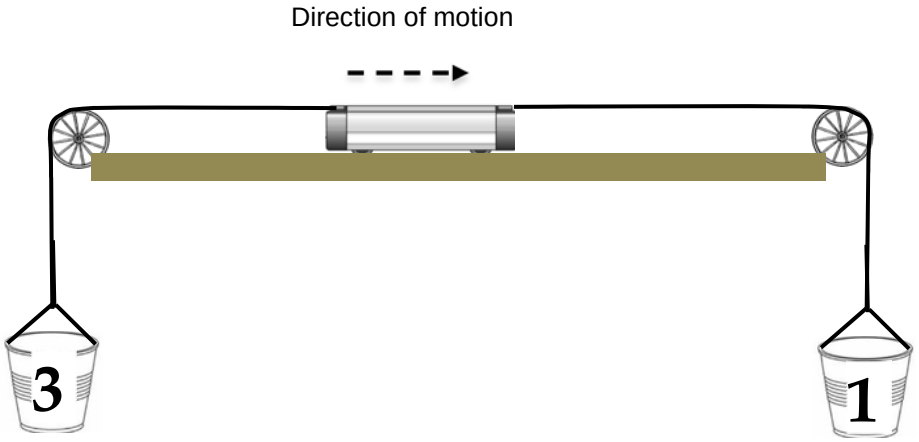


After it starts moving, do you think the cart's speed will increase, decrease, or stay constant? Why do you think so?

STEP 1: Open Exploration 2 Movie: Force Combinations when in Motion. In order to judge what is happening to the cart's speed, its position will be marked with a white dot at one-second time intervals. Watch the movie then **pause it at time 0:50** to then answer the following questions.

After it starts moving, does the cart's speed increase, decrease, or stay constant? How does the pattern of dots tell you this?

Now we want to check what happens if the strongest force is pulling in the opposite direction to the cart's motion. To see this we will take the 3-1 combination setup shown below, but start it moving to the right with a quick push. After the push is over the strongest force will be pulling on the cart in the opposite direction to its motion.



After the push, while the cart is moving to the right, do you think its speed will increase, decrease, or stay constant? Why do you think so?

STEP 2: In order to judge what is happening to the cart's speed, its position will be marked with a dot at one-second time intervals. Continue watching the movie then **pause it at time 1:45** to then answer the following questions.

After the quick push is over, what happens to the cart's speed at first? Does it increase, decrease, or stay constant? How does the pattern of WHITE dots tell you this?

Why do you think the cart starts moving back in the opposite direction after it has come to a stop?

While the cart is moving back to its starting point, does its speed increase, decrease, or stay constant? How does the pattern of RED dots tell you this?

Why do you think the cart the cart's speed behaves like this on the way back to the starting point? What is it about the forces acting on it that makes this happen?

STEP 3: In the previous lesson, you saw that when an unbalanced combination of forces acts on an object, you can always combine those forces into a single force, called the net force that would have the same effect.

In the setup you saw in STEP 1, was the net force acting on the cart in the same direction as its motion or in the opposite direction to its motion?

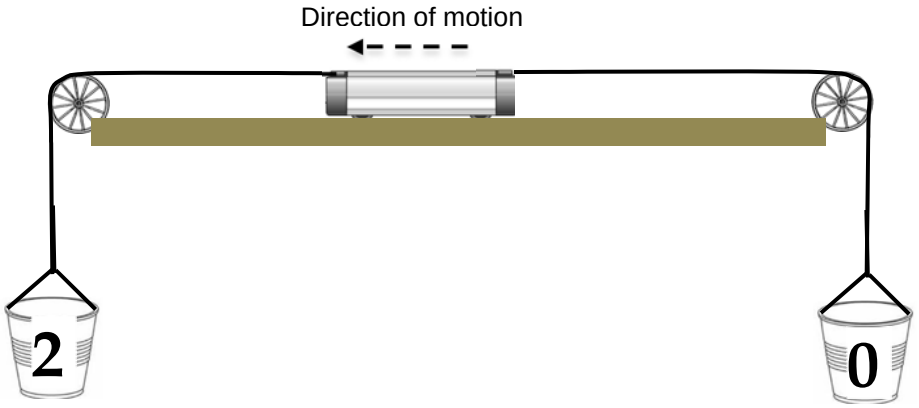
Why might it make sense that when the strongest force is acting in the **same** direction as the cart's motion, its speed increases?

In the setup you saw in STEP 2, was the net force acting on the cart in the same direction as its motion, or in the opposite direction to its motion?

Why might it make sense that when the strongest force is acting in the **opposite** direction to the cart's motion, its speed decreases (and it then reverses direction)?

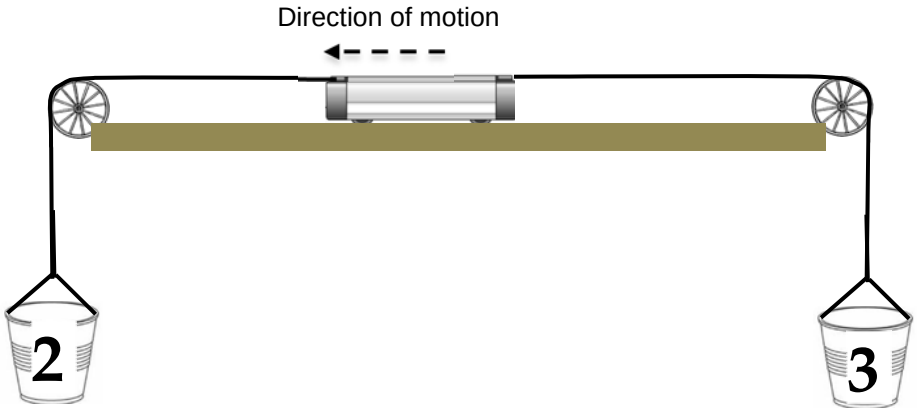
Your PD leader will lead a group discussion about these questions.

Now let's check our thinking with a slightly more complicated situation. Suppose we release the cart while a 2-0 combination is applied to it.



After it starts moving (with the 2-0 combination still being applied), do you think the cart's speed will increase, decrease, or stay constant? Explain your thinking.

After the cart has been moving for a short time, 3 sugar cubes will be dropped into the right cup, making the force in the opposite direction stronger than the force in the direction of motion.



 After the 3 sugar cubes are dropped into the right cup, do you think the speed of the cart will increase, decrease, or stay constant? Why do you think so?

 Your PD leader will lead a group discussion about this question.

STEP 5: As usual, in order to judge what is happening to the cart's speed, its position will be marked with a dot at one-second time intervals. Continue watching the movie then **pause it at time 2:45** to then answer the following questions.

 After it starts moving, while the 2-0 combination is applied to it, does its speed increase, decrease, or stay constant? How does the pattern of WHITE dots tell you this?

 Why does its speed behave in this manner at first?

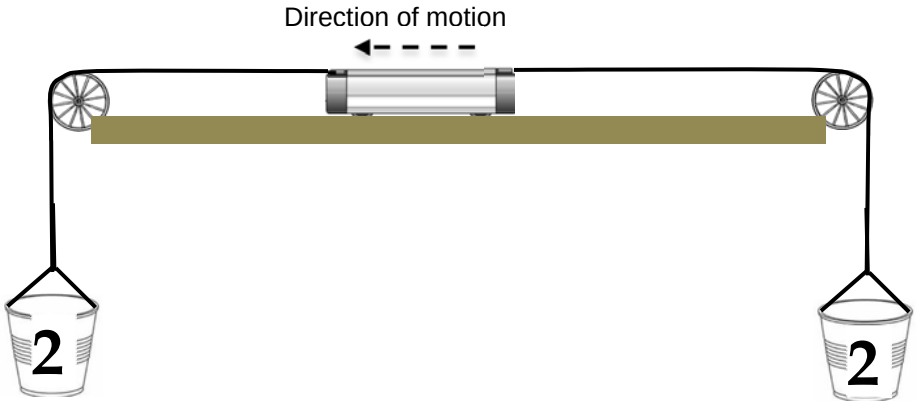
 After the 3 sugar cubes are dropped in the right cup, does the cart's speed then increase, decrease, or stay constant? How does the pattern of GREEN dots tell you this?

Why do you think the cart's speed behaves differently after the 2-0 combination is changed to a 2-3 combination?

Activity #2: How does the speed behave when balanced forces act on a moving object?

In the first part of this lesson, we investigated how an unbalanced combination of forces affects an object that is already moving. Now we will think about what would happen if balanced forces are applied to an object that is already moving.

We will again test our thinking by releasing the cart while a 2-0 combination is applied to it. However, after the cart has been moving for a short time, 2 sugar cubes will be dropped into the right cup, making the forces **exactly balanced**.



After the 2 sugar cubes are dropped into the right cup, do you think its speed will increase, decrease, or stay constant, or will something else happen? Why do you think so?

Your PD leader will lead a group discussion about this question.

STEP 1: The white dots will show that the cart's speed was increasing while the 2-0 combination was applied. Watch the remainder of the movie then answer the following questions.

After the 2 sugar cubes are dropped in the right cup, does the cart's speed then increase, decrease, or stay constant? How does the pattern of GREEN dots tell you this?

Why do you think the cart's speed behaves in this way after the 2-0 combination is changed to a 2-2 combination?

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. a) When an **unbalanced** combination of forces acts on a moving object, what happens to its speed? Does it change or does it remain constant?

b) Why does this make sense in terms of the **net force** acting on the object?

2. a) When a **balanced** combination of forces acts on a moving object, what happens to its speed? Does it change or does it remain constant?

b) Why does this make sense in terms of the **net force** acting on the object?

3. A car is waiting at a stop light. When the light turns green, it starts moving, getting faster and faster. After a few seconds, it reaches 30 mph and then continues at a constant speed down a long straight road for a while. It then slows and stops at the next stop light. For each part of its motion, decide whether the forces acting on the car are balanced or unbalanced and explain how you know.

a) While the car is waiting at the red light, not moving.

b) While the car is getting faster and faster as it moves away from the light.

c) While the car is moving at a constant speed of 30 mph down a long straight road.

d) While the car is getting slower and slower as it approaches the next stop light.