Force and Motion

Purpose

Today, you will be developing some ideas about how to describe interactions between two objects that touch in terms of the pushes and pulls that the objects exert on each other. For a soccer player kicking a ball, we could say:

There is an interaction between the player's foot and the ball. The foot pushes the ball.

In this set of activities, you will be investigating the effects that pushes and pulls have on the motion of objects. We will start by examining how we can recognize when an interaction is happening, and when it is not then we will focus more specifically on how different pushes and pulls affect the motion of a ball.

ACT. ?

How does an object move when a force is acting on it?

Initial Ideas

Think about a soccer player kicking a stationary ball. As he interacts with the ball by kicking it, the ball starts to move along the ground. After the kick, the ball rolls across the grass and gradually comes to a halt. A sketch of the speed-time graph for the motion of the ball, from the moment the player's foot first contacts it until it comes to a halt again is shown.

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Using a colored pencil, highlight the portion of the graph during which you think ***the foot was in contact with the ball***. Briefly explain your reasoning.

Participate in a whole group discussion about this question. Make a note of any ideas or reasoning that are different from those of your group.

Collecting and Interpreting Evidence

Experiment #1: How are changes speed related to when the objects are in contact?

You will need:

- Racquetball
- Toy car track
- Colored pencils

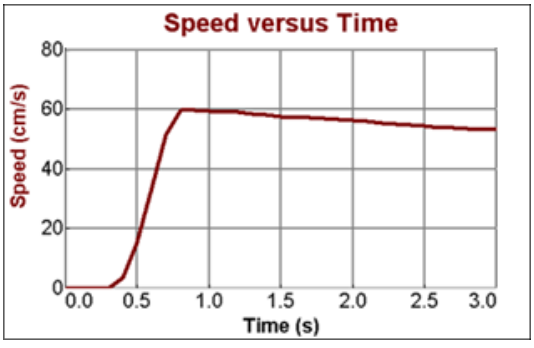
STEP 1: Place the toy car track on the table then place the ball at one end of the track. Now someone in your group should give the ball a **quick push** with their hand. Let the ball move along the track then another group member should grab the ball to stop it before it leaves the track.

What happens to the ball's speed **during** the push?

What happens to the ball's speed **after** the push?

STEP 2: How do you think the changes in speed of the ball are related to the contact between it and the hand? To help you think about this question consider the speed-time graph shown here, for a cart that was given a quick push and then moved along the track.

Using a colored pencil, highlight the portion on the graph where you think the hand was in contact with the cart. Mark an 'X' at the end of this period to show the point where you think the hand lost contact with the cart. Explain your reasoning if different from Initial Ideas.



STEP 3: You will now watch a slow-motion video of a hand giving a quick push to a low-friction cart to start it moving. The video also shows a speed vs. time graph being recorded for the motion of the cart. Look for the moment when the hand is clearly no longer touching the lip of the cart and pay close attention to what was happening on the speed-time graph at this same moment.

At the moment when the hand leaves the cart, is the cart's speed still increasing, has it reached its maximum value, or is it already starting to decrease?

Does this evidence agree with your indicated period on the graph above? If not, use a different color pencil to highlight a new period on the graph and label it appropriately.

What physically causes the ball's speed to increase **during** the interaction with your hand?

While you are pushing the ball, energy was being transferred from you to the ball. During this energy transfer, the kinetic energy of the ball increased. Why does it make sense that the ball stops increasing in speed **after** your hand loses contact with the ball?

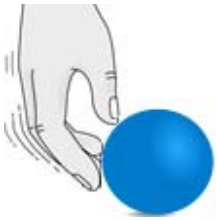
Participate in a whole group discussion about these questions. Make a note of any ideas or reasoning that are different from those of your group.

Experiment #2: How do pushes and pulls affect speed?

When scientists study the natural world they focus their attention on different types of interactions between objects. When two objects interact, they *act on* or *influence* each other in some way. In this experiment, you will study what evidence you would look for to identify the occurrence of an interaction.

You will need:

- Racquetball
- Toy car track
- Colored pencils



STEP 1: With the toy car track on the table, place the ball at one end of the track. Now someone in your group should give the ball a **quick push** with their hand. This time, when the ball has moved about halfway down the track, someone else should give it another quick push, in the **same direction** as it is already moving.

What effect does the second push in the **same direction** as the ball is already moving have on the motion (speed) of the ball?

STEP 2: Return the ball to the starting point and start it moving with a quick push. As the ball passes the halfway point along the track tap it in the direction opposite its motion **very gently** with your finger. **Note***: This may take some practice - the tap should* **NOT** *be strong enough to reverse the direction of the ball, nor to stop the ball completely!*

What does this gentle **backwards** tap do to the motion (speed) of the ball?

STEP 3: Finally, return the ball to the starting point and again start it moving with a quick push. As the ball passes the halfway point along the track, tap it in the direction opposite its motion with your finger so that it returns to the starting point at about the same speed, as it was moving before your tap.

What effect does this harder **backwards** tap have on the motion (speed) of the ball?

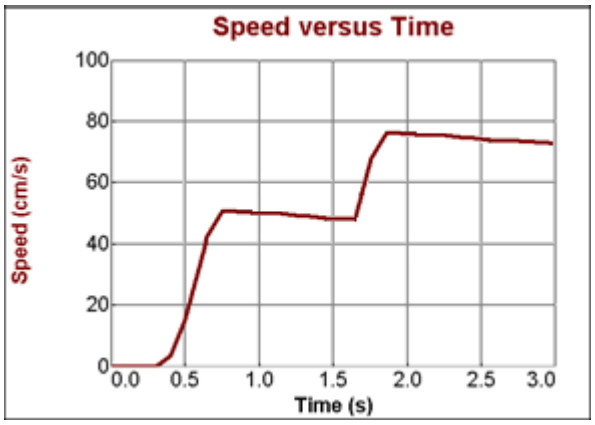
STEP 4: A device called a **motion sensor** can be used to collect data on the ball's speed to produce a plot of speed vs. time. Below are the results of using the motion sensor to collect speed-time data for each of the trials you just performs.

Sketches of the speed-time graphs produced by a motion sensor for STEPS 1 - 3.

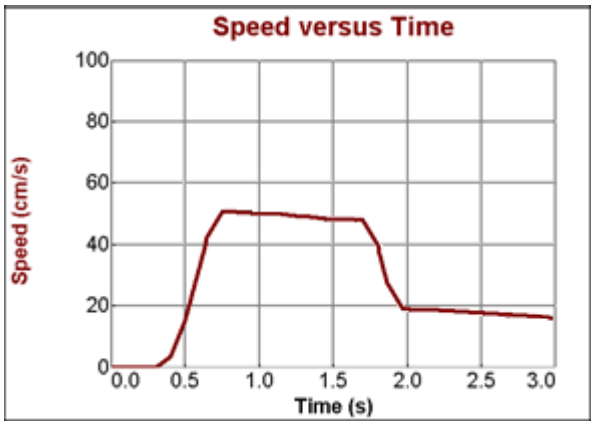
Look at all of the graphs shown. In each case, when someone's hand was interacting with the ball, did the ball's speed change in some way or did it stay about the same? What **evidence** from the speed-time graphs supports your idea?

Using a colored pencil, highlight the portion(s) of each graph during which you think the hand was in contact with the ball. Briefly explain below why you chose those particular sections.

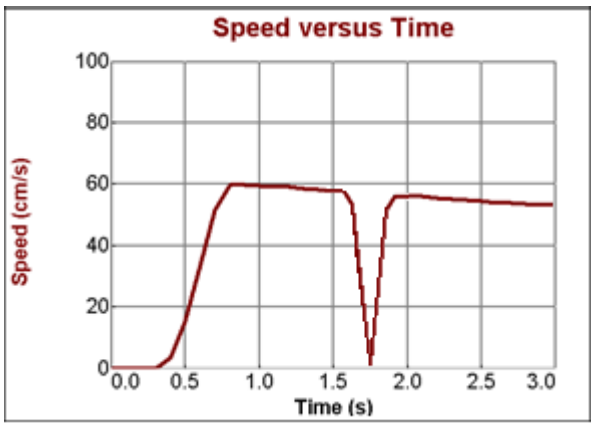
***STEP 1**: Forward push while moving*



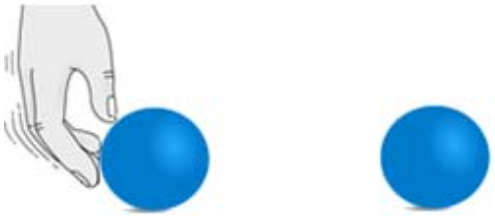
***STEP 2:** Gentle backwards tap while moving*



***STEP 3**: Backwards tap to return to start*



STEP 5: Work with another group on this STEP. Place one group's ball at rest halfway down the track. Give the other group's ball (we will call this the *launched ball*) a **gentle** push with someone's hand so that it collides with the other ball (we will call this the *target ball*). Watch carefully what happens to the motion of ball balls during the collision between them.



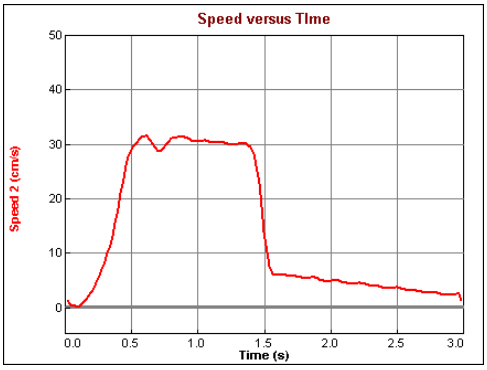
Describe what happens to the motion (speed and direction) of each ball during the collision.

Shown to the right are speed vs. time graphs for each ball. On the graphs use two different colored pencils to indicate:

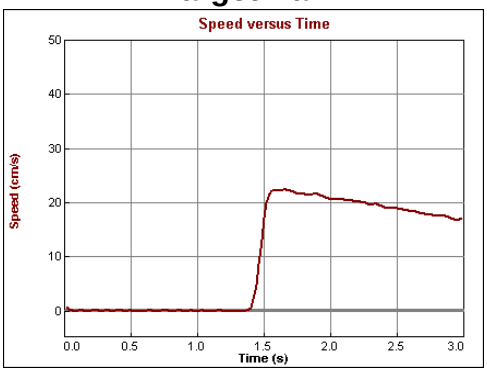
a) when the graphs provide evidence that a **stationary object** is interacting with another object. Explain why you chose these particular periods.

b) when the graphs provide evidence that a **moving object** is interacting with another object. Explain why you chose these particular periods.

Launched Ball



Target Ball



We will call an interaction in which two objects ***in contact*** push or pull on each other a **contact push/pull interaction**. If this is the only interaction influencing the two objects then there will be a change in speed (or direction) for at least one of them during the interaction[1].

Participate in a whole group discussion about these questions. Make a note of any ideas or reasoning that are different from those of your group.

Experiment #3: How does an object move when a force is acting on it?

The pushes the hand has been giving the ball are examples of forces. Whenever your hand (***object 1***) pushes or pulls on the cart (***object 2***), we say that object 1 is exerting a force on object 2. A force is simply a push or a pull that one object exerts on another.

In this experiment, you will again give the ball different types of pushes. This time we want to think more about the direction each push is given and how this affects the ball's motion.

You will need:

- Racquetball
- Toy car track
- Colored pencils

STEP 1: With the toy car track on the table, place the ball halfway along the track. Now someone in your group should give the ball a quick push to the **left** with their hand.

What effect does this quick push to the **left** have on the motion (speed and direction) of the stationary ball?

[1] If an object is involved in more than one contact push/pull interaction at the same time, then it is possible that the tendency of one interaction to change the speed of the object may cancel another interaction out, and the speed of the object not change at all. For example, if two people were to try to push the cart along the track in opposite directions (with the same strength push), then the cart would not move at all, even though it is involved in two interactions simultaneously.

STEP 2: Return the ball to its starting point halfway along the track. Now someone in your group should give the ball a **stronger**, quick push to the **left** with their hand.

What effect does this **stronger** quick push to the **left** have on the motion (speed and direction) of the stationary ball?

STEP 3: Return the ball to the starting point halfway along the track. Now someone in your group should give the ball a quick push to the **right** with their hand.

What effect does this quick push to the **right** have on the motion (speed and direction) of the stationary ball?

STEP 4: Next place the ball at the left end of the track. Have someone in your group give the ball a quick push to the **left** with their hand to start it moving along the track. When the ball is about halfway down the track, give the ball another quick push to the **left**.

What effect does this second quick push to the **left** have on the motion (speed and direction) of the moving ball?

STEP 5: Return the ball at the left end of the track. Have someone in your group give the ball a quick push to the **left** with their hand to start it moving along the track. When the ball is about halfway down the track, give the ball a **gentle** push to the **right**.

What effect does this **gentle** quick push to the **right** have on the motion (speed and direction) of the moving ball?

STEP 6: Return the ball at the left end of the track. Have someone in your group give the ball a quick push to the **left** with their hand to start it moving along the track. When the ball is about halfway down the track, give the ball a **stronger** push to the **right**.

What effect does this **stronger** push to the **right** have on the motion (speed and direction) of the moving ball?

Speed vs. time graphs for STEPs 4 – 6 are shown and are identical to those considered in Experiment 2.

On the graphs, use two different colored pencils to indicate when:

a) a force acts **in the direction** of motion.

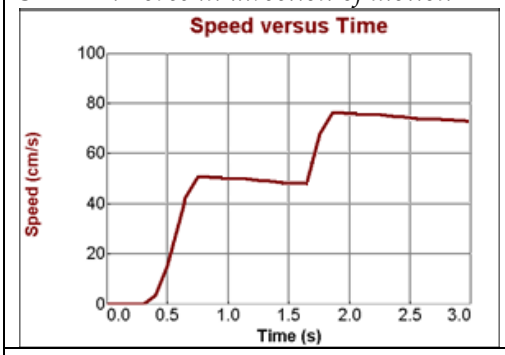
b) a force acts **in the opposite direction** of motion.

In between the hand pushes, what was happening to the speed of the ball?

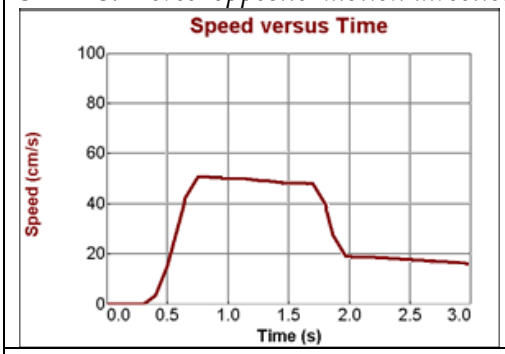
What might be causing this change in the ball's speed?

Does this suggest that the ball was involved in a contact push/pull interaction with some other object? Support your answer with evidence from the graphs.

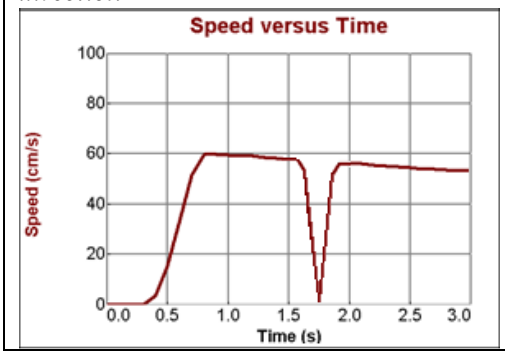
***STEP 4**: Force in direction of motion*



***STEP 5:** Force opposite motion direction*



***STEP 6**: Stronger force opposite motion direction*



Does this suggest that a force was acting on the ball? If so, was the force in the direction of motion or opposite the direction of motion? How do you know?

Does this suggest that friction is a force that acts in the opposite direction of motion causing the object's speed to decrease? Explain your thinking.

Suppose you could start an object moving and then arrange for absolutely **no forces** to act on it. How would it move from then on? To help you think about this question consider the following:

Suppose a spacecraft is at rest in deep space, far from any stars or planets, so that no form of friction or gravity is acting on it. The main engine, at the rear of the spacecraft, is fired for a period of 2 seconds (to start the spacecraft moving) and is then shut off.

What do you think the motion of the spacecraft would be like after the engine is shut off? Explain your reasoning.

Participate in a whole group discussion about these questions. Make a note of any ideas or reasoning that are different from those of your group.