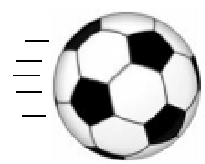
Next Gen PET LC

**Unit FM**

# LESSON 1: Interactions, Force and Motion

## Purpose and Key Questions

When one object pushes or pulls on another object, scientists say it is exerting a ***force***. All forces can be considered to be pushes or pulls. For example, when a soccer player kicks a ball, we say that the foot exerts a force on the ball. In this unit, we will be investigating the effects that forces have on the motion of objects.



We will start by examining how we can recognize when a force is acting on an object, and when it is not. In the example above, after the soccer player gets the ball moving with his kick (which is a quick push), is there still a force pushing the ball forward after the kick is over?

***(1) When does the force of a quick push stop acting on an object?***

***(2) When an object is moving, does this mean there must be a force pushing it in the direction of its motion?***

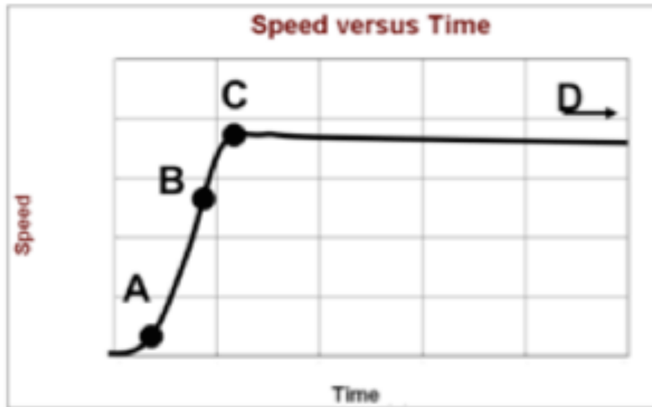
## Predictions, Observations and Making Sense

### Part 1. When does a force stop acting on an object?

To begin, watch a movie **(UFM L1 Mov1)** of a person giving a cart a quick push to get it moving along a track. The cart and track are designed to minimize the effects of friction, so after the cart leaves the person's hand it moves along the rest of the track with very little slowing down.

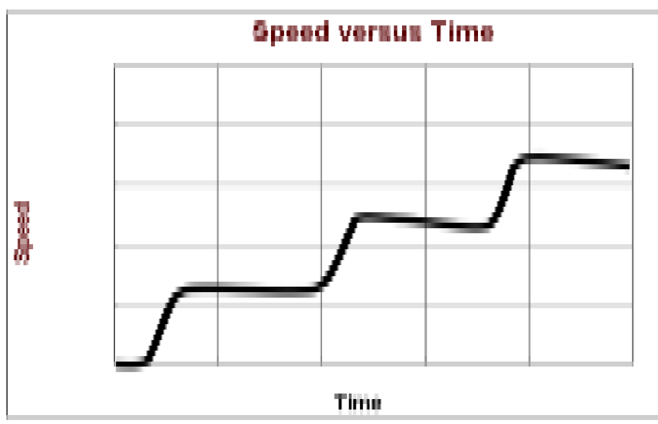
A speed-time graph for the cart is shown below. Discuss with your neighbors over what period on the graph you think the force caused by the hand is acting on the cart. Which labeled point on the graph is closest to your idea about when the force from the hand stops acting on the cart? Explain why you chose that particular point.

**CQ 1-1: Which point on the graph is closest to where you think the force of the hand on the cart stopped acting on the cart?**




A. Point A
B. Point B
C. Point C
D. Not until he grabs it at the end of the track

Next, watch another movie **(UFM L1 Mov2)**. In this case the cart will be given a gentle push to start it moving and then, while it is moving along the track, it will be given some more quick taps in the same direction as its motion.

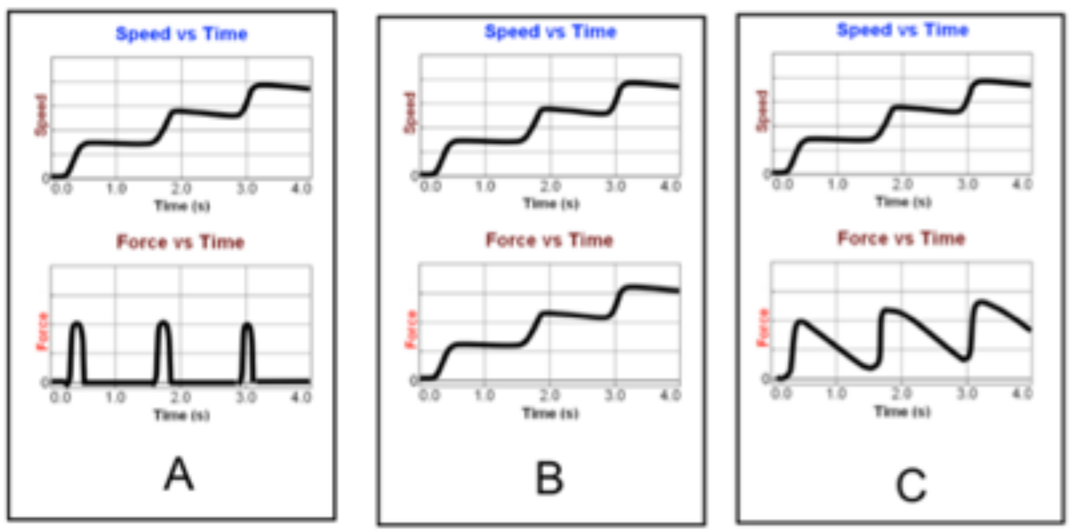



Its speed-time graph measured with a motion sensor should look similar to that shown above.

Highlight the sections of the speed-time graph in which you think the hand was in contact with the cart. Why did you choose these sections?

When do you think the force caused by the hand is acting on the cart in this demonstration? Is it acting the whole time the cart is moving, or only during certain periods? Supposing you could measure the strength of this force while the cart is moving, which of the force-time graphs shown below best represents your thinking? Discuss this question with you neighbors and record your reasoning below.

**CQ 1-2: Which force-time graph best represents your thinking about the force of the hand acting on the cart?**

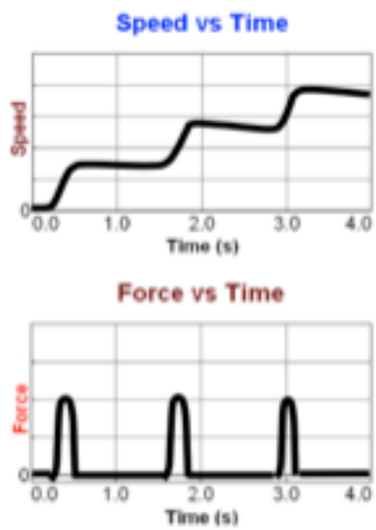


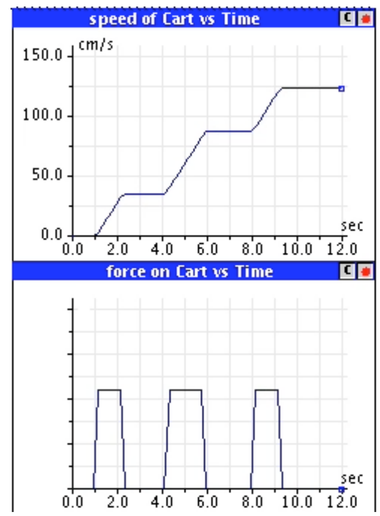

To check your thinking, watch a movie **(UFM L1 Mov3)** of an experiment in which the strength of the force applied to the cart by the hand is measured, along with the speed.

Which of the options in the question above most closely corresponds to the data recorded in the experiment?

Next, watch another movie **(UFM L1 Mov4)**, this time from a computer simulation. Whenever the black arrow appears near the cart, that corresponds to when the cart is being pushed. The red arrow above the cart shows its relative speed. The duration of each push or force on the cart is longer than in the previous movie, so it is easier to see how the speed-time and force-time graphs are connected. Play the movie at least twice to see how the speed-time and force-time graphs are related.

Discuss the following questions with your group. Carefully compare the speed-time and force-time graphs from the two movies that you have just seen (displayed below). Remember that the *definition of force is that it is a push or a pull by one object on another*.



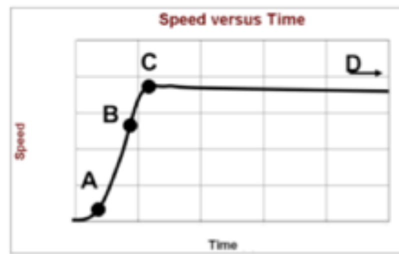

Did the hand exert a force on the cart the entire time it was moving, or only at certain times?

What happened to the speed of the cart while the hand was exerting a force on it? Did it increase quickly, decrease quickly, or remain reasonably constant?

What happened to the speed of the cart while the hand was **not** exerting a force on it? Did it increase quickly, decrease quickly, or remain reasonably constant?

According to the evidence from the graphs, did the force caused by the hand continue acting on the cart after it had lost contact with the cart? How do you know?

Returning to CQ 1-1, which point on the speed-time graph is closest to where you think the force of the hand stopped acting on the cart?



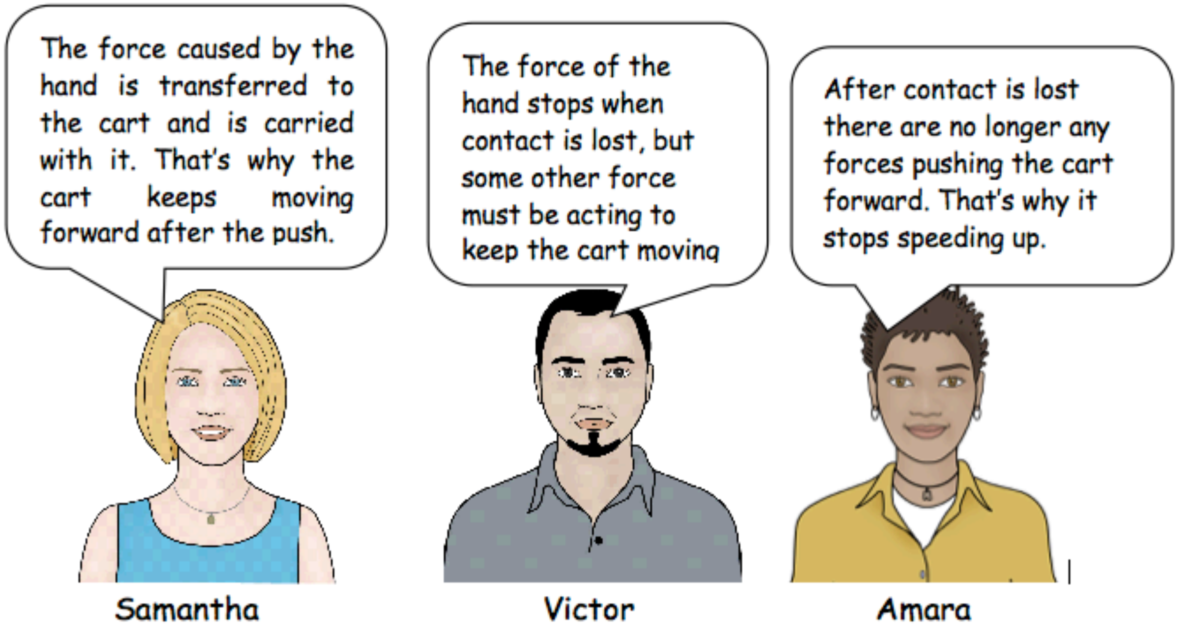

## Part 2. If an object is moving, does that imply there must be a force acting on it in the direction of its motion?

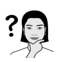
Let us summarize what the class most likely agreed on in the previous part of the lesson.

- When the hand was pushing on the cart (in contact with it), the hand exerted a force on the cart.
- When the hand did not push on the cart, the hand did not exert a force on the cart.
- When the hand was exerting a force on the cart, the cart speeded up.
- When the hand was not exerting a force on the cart, the cart did not speed up, but instead moved at a (nearly) constant speed.

So, in deciding whether a force is or is not being exerted on a cart, evidence we can look for is whether the cart is speeding up or moving at constant speed.

Three students were considering the last movie you had just seen in the previous part of this lesson. They all agreed that while the hand is pushing the cart, there is a force acting on it, but had different ideas about whether a force is still pushing the cart forward after the hand has lost contact with it.

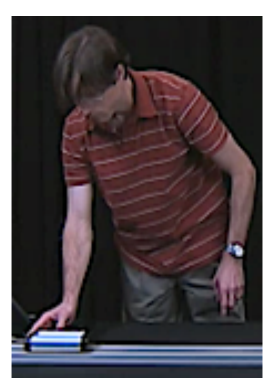




Discuss the students' ideas with your group, and then decide whom you agree with (if any).

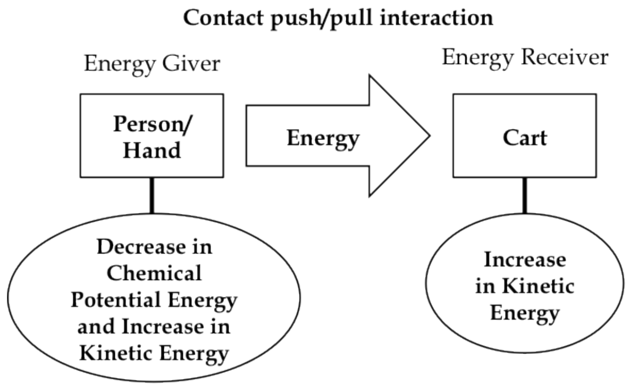
**CQ 1-3: In the discussion between three students about the force acting on the cart after the quick push, whom do you agree with?**

**a. Samantha**
**b. Victor**
**c. Amara**
**d. None of them**

## Part 3. Force, energy and transfer



In Unit EM you learned that during an interaction, energy is transferred from the giver to the receiver. Consider again the person giving the cart a quick shove with his hand. The person/hand and cart are interacting only during the short period of time when the hand is in contact with the cart. Below is a G/R energy diagram for just the interaction between the person/hand and the cart.




***The interaction occurs only during the period when the hand and cart are in contact***, and it is only during that period that the speed of the cart changes from zero to some final value. It is also during that period that energy is transferred from the person/hand to the cart. As a consequence, the person/hand decreases in energy and the cart increases in energy (by the same amount). After the interaction is over, the person/hand continues with a smaller amount of energy, and the cart continues with a greater amount of energy, the difference being what was transferred. So the person/hand and the cart each have energy before the interaction, as well as after the interaction, but just different amounts.[1]

On the other hand, *a 'force' only exists during the interaction*. It does not exist before the interaction begins, and it does not exist after the interaction is over. Furthermore, a force always involves two objects—one object exerts a force on (interacts with) the other. A single object cannot interact with itself, and therefore an object cannot exert a force on itself.

[1] As analogy, think of transferring money from your checking account to your savings account. Before the transfer, each account has money. During the transfer, the checking account decreases in the amount of money it has and the savings account increases in the money it has. After the transfer, both the checking and savings accounts each have money, just a different amount (assuming you don't empty out your checking account).

## Summarizing Questions

**S1:** Consider what quantity (or quantities) is (are) transferred during an interaction between two objects.

**CQ 1-4: During a contact push/pull interaction between two objects, what do you think is <u>transferred</u> from one object to the other?**

A. Energy
B. Force
C. Both energy and force
D. Neither energy nor force

Explain your reasoning.

**S2**. In addition to being able to look at a speed-time graph and infer something about the force acting on the object, you should also be able to look at a force-time graph and infer something about how the speed of the object is changing.

**CQ 1-5: Suppose the force-time graph for a force acting on a certain object looked like this. Which of the speed-time graphs below <u>could</u> be produced by applying a single force in this way?**