CHAPTER 2

Developing Ideas

ACTIVITY 1: Interactions and Force

Purpose

In Chapter 1 of the course you developed some ideas about how to describe contact interactions between objects in terms of a transfer of mechanical energy between the objects. For example, for a soccer player kicking the ball, previously we might have said:

"There is a contact interaction between the player's foot and the ball. Mechanical energy is transferred from the foot to the ball"

However, scientists often use a different way of describing the **same** interactions, not in terms of energy, but in terms of the pushes and pulls (which they call **forces**) that the objects exert on each other. So, for the example above, we could also say:

"There is a contact interaction between the player's foot and the ball. The foot pushes the ball" **or** *"The foot exerts a force on the ball."*

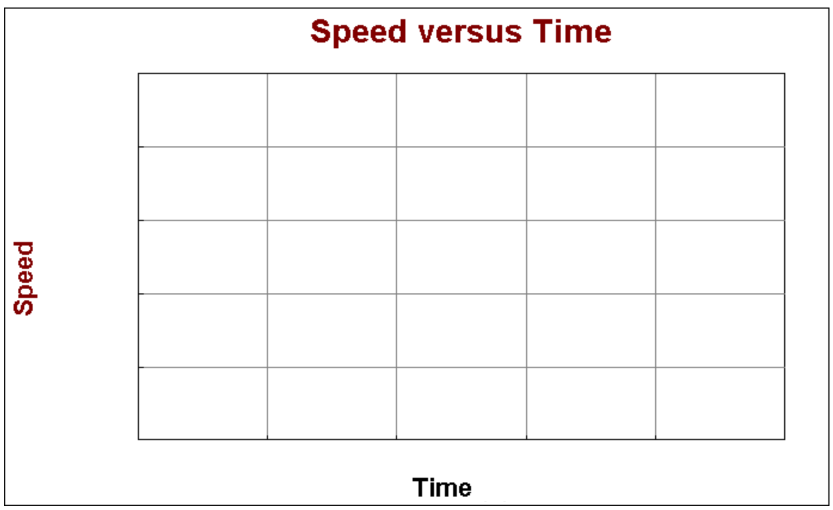
In this cycle you will be investigating the effects that forces have on the motion of objects. We will start by examining how we can recognize when a force is acting on an object, and when it is not.

When does a force stop pushing on an object?

Initial Ideas

Think about a soccer player kicking a stationary ball. As he interacts with it, by kicking it, the ball starts to move. After the kick, the ball rolls across the grass and gradually comes to a halt.

Sketch a speed-time graph for the motion of the ball. Be sure to include both the motion of the ball while the player's foot is touching it, and its motion after the foot has lost contact with it.



Using a colored pencil, indicate the period on the graph during which you think the foot was in contact with the ball and briefly explain your reasoning.

Using a different colored pencil, indicate the period on the graph during which you think there was a force pushing the ball forward. Again, explain your reasoning.

Why do you think the ball gradually slows down and eventually stops after it has been kicked?

Now draw two pictures of the ball and use arrows to show what **forces** (if any) you think are acting on the ball at two different times during its motion. Label your arrows to show where the forces come from.

i) during the time foot was in contact with the ball

ii) after the foot has lost contact and the ball is rolling across the grass.

Briefly explain the reasoning behind your pictures.

Discuss your ideas with your team and try to agree on what the speed-time graph and 'force' picture(s) should look like. Sketch your team's graph and picture(s) on a large presentation board.

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

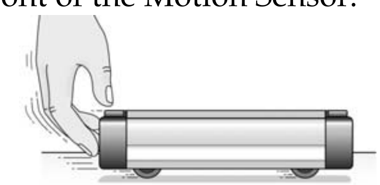
Collecting and Interpreting Evidence

Experiment: Is the motion of the cart after it has been pushed the same as during the push?

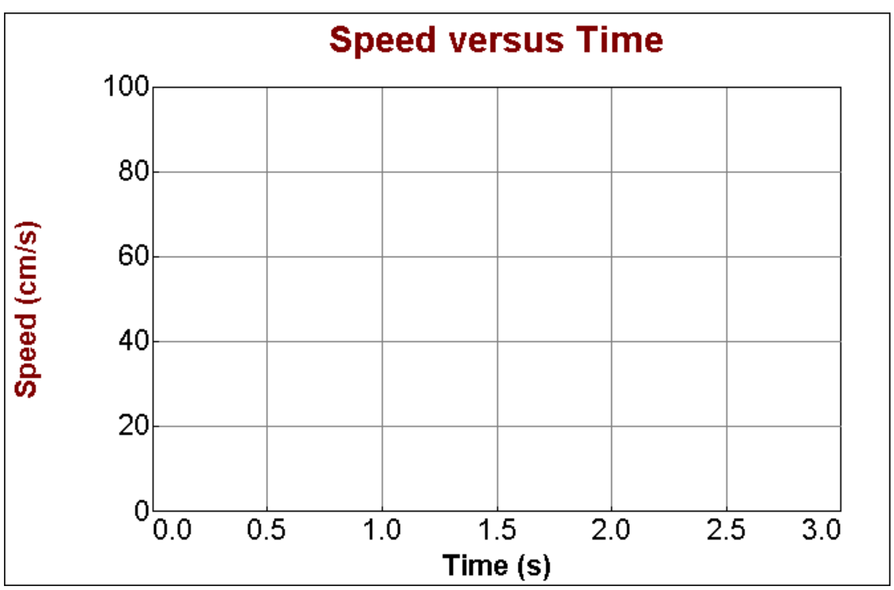
You will need:

- Low-friction cart
- Track
- Access to a Motion Sensor connected to a computer
- Access to the I&M computer simulator

STEP 1: Open the Motion Sensor data collection file for this experiment. Place your cart at rest on the track about 20 - 30 cm in front of the Motion Sensor. Start collecting Motion Sensor data and then have one of your team give the cart a quick push away from the sensor. (Stop the cart when it reaches the other end of the track.)



Sketch the speed-time graph for the motion of the cart.

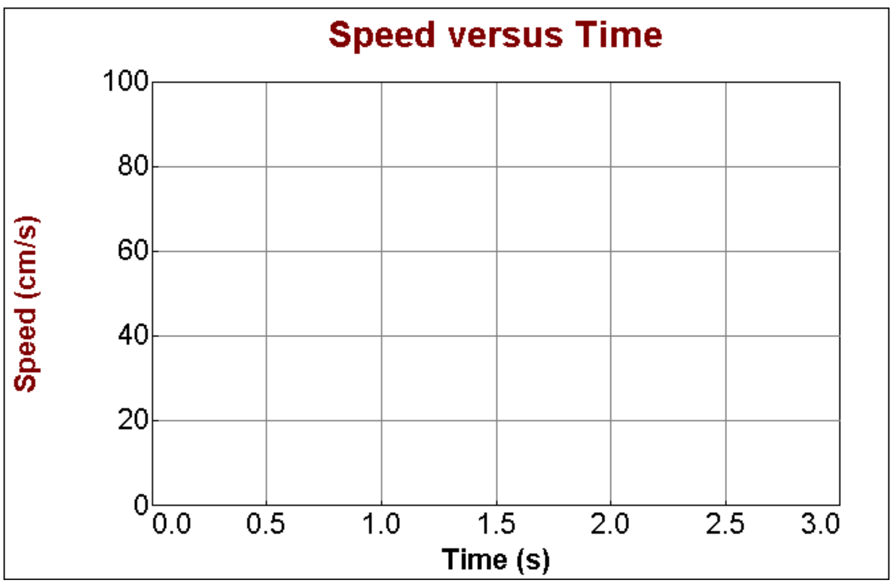


What happens to the speed of the cart while the hand is actually in contact with it? Does it speed up quickly, slow down quickly, or move at a reasonably constant speed?

After the hand has lost contact with the cart does the behavior of the cart's speed change, or does it continue moving in the same manner as when your hand was in contact with it?

STEP 2: Return the cart to its starting position. Start collecting Motion Sensor data and then have one of your team members give the cart a **gentle** push away from the sensor with their hand. While the cart is moving, and before the data collection stops, give the cart two or three more pushes, in the **same direction** as the first push. (Stop the cart when it reaches the other end of the track.)

Sketch the speed-time graph for the motion of the cart.

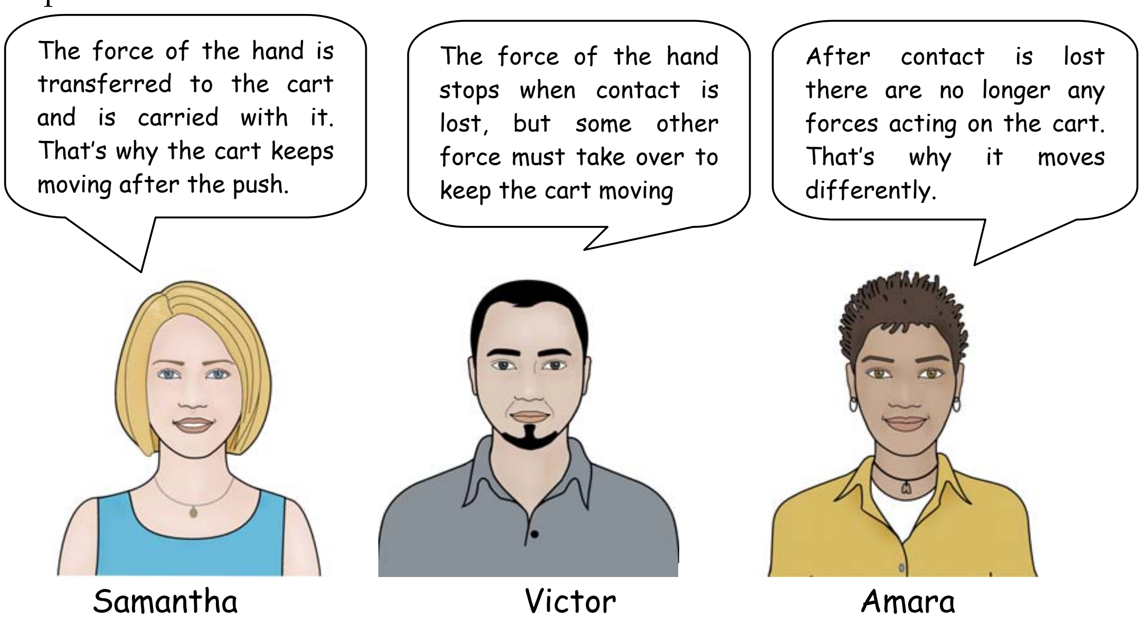


Each time the hand interacts with the cart, what happens to the cart's speed? Does it speed up quickly, slow down quickly, or move at a reasonably constant speed?

During the periods when the hand is not interacting with the cart what happens to the cart's speed? (Is it increasing, decreasing, or fairly constant?) Does the cart move in the same manner as when the hand is interacting with it, or is the speed behaving differently?

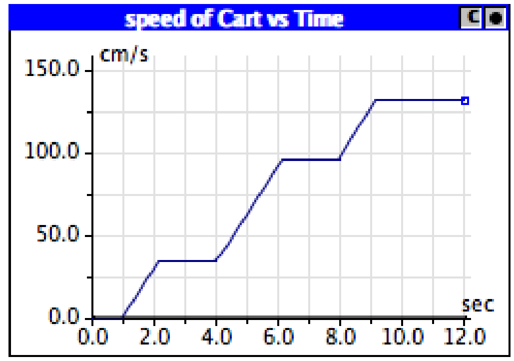
What evidence would you look for to tell you that a force is acting on the cart? To illustrate your thinking, use a colored pencil to indicate on the two speed-time graphs above the sections of the graph during which you think there is a force pushing the cart. Explain your reasoning below.

STEP 3: Three students are discussing the motion of the cart and the force acting on it. They all agree that while the hand is pushing it there is a force acting on the cart, but have different ideas about what happens during the periods when the hand is not in contact.

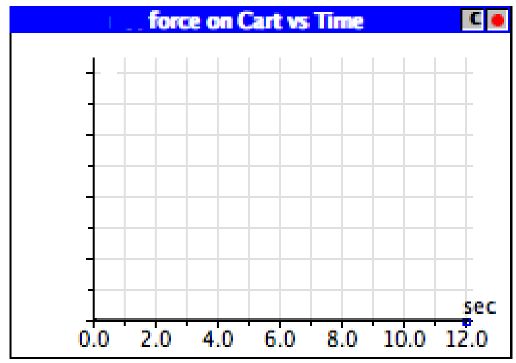


Do you agree with Samantha, Victor, or Amara, or with none of them? Explain your thinking.

Simulator Exploration. On the right is a speed-time graph taken from an *I&M Simulator* set-up that models the experiment from STEP 2 where you pushed the cart two or three times.



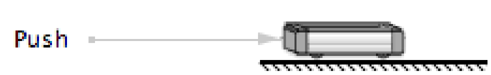
Indicate the periods on the speed-time graph when you think the cart in the simulator was being pushed. How do you know?



The *I&M Simulator* can also 'measure' the force acting on the cart in the simulator model. On the blank force-time graph above, sketch how you think the force acting on the simulator cart varies (if at all) during the same 12-second time period shown on the speed-time graph. (Note: It is only the shape of the graph that is important for now, so no values for the force are shown.)

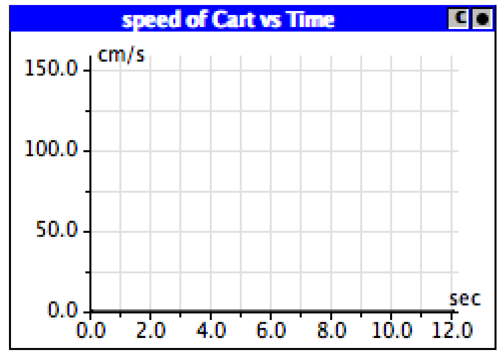
Explain the reasoning that led you to draw your force-time graph the way you did.

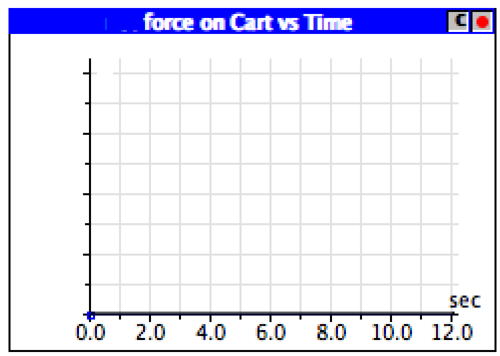
STEP 4: You can use the *I&M Simulator* to compare your ideas with those scientists' ideas upon which the simulator model is based. Open the simulator set-up file for this activity. (See your instruction sheet if you've forgotten how to do this.) The set-up shows a cart on a track, together with speed-time and force-time graphs.



While the simulator is running you can give the cart a 'push' by pressing on the spacebar of your computer keyboard. The push will continue (at a constant strength) as long as you hold the spacebar down. The simulator will stop on its own after 12 seconds.

Run the simulator a few times (remember to click 'rewind' to get back to the start) and check that you understand how the spacebar 'push' works. When you are ready, try to reproduce the speed-time graph from STEP 3.





Sketch the speed-time and force-time graphs from the simulator.

During the periods when the simulator cart was being 'pushed' was there a force acting on it? What evidence from the simulator graphs supports your idea?

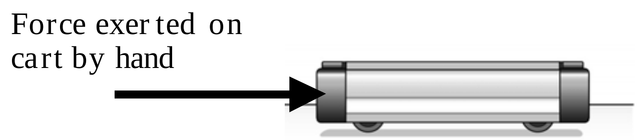
During the periods in between the pushes, was there a force acting on the simulator cart? Again, what evidence from the graphs supports your idea?

Forces and Force Diagrams

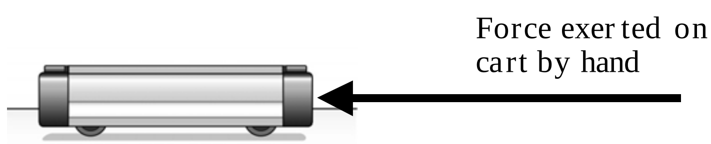
The pushes you used in this activity are examples of forces. Whenever one object is pushing or pulling on another object we say it is exerting a force on the other object. Notice that this means the pushes and pulls you used in

Chapter 1 to investigate contact interactions could also be described in terms of forces exerted on the cart by a person, another cart, or a rubber band.

Just as with the energy description of contact interactions you developed in Chapter 1, we can also draw a diagram to help us analyze and explain the force description of the same interactions. In such a force diagram, we identify the object of interest and all the forces (pushes and pulls) being exerted on it by **other** objects at a **particular moment in time**. We represent these forces with 'force arrows' on the diagram, which are labeled to show what they represent. For example, the force of your hand pushing the cart could be represented like this:



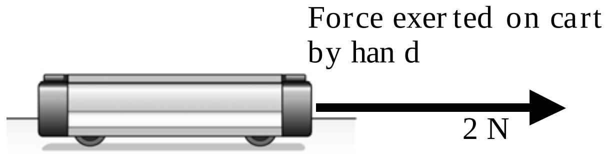
As you might expect, the direction of these force arrows indicates the direction of the forces they represent. In addition, the length of the arrows is drawn to indicate the relative strengths of the forces. So, for example, if you pushed the cart in the other direction, with a stronger push, the force diagram would look like this (note the longer arrow):



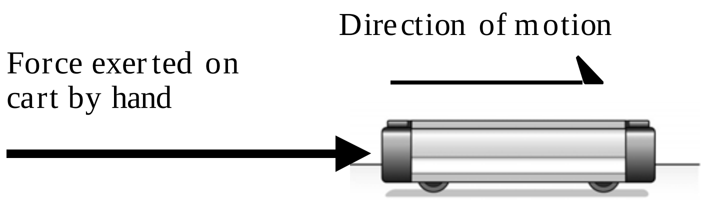
Notice that the force diagram shows only one of the objects involved in the interaction (the cart), and that the other object involved (the hand) is only mentioned in the labeling of the arrow representing the force it is exerting. In this sense these force diagrams are very like the Input/Output (I/O) energy diagrams you drew at the end of Chapter 1.

The strength of a force is measured in units of newtons (N), named in honor of Sir Isaac Newton, a famous English scientist you will learn more about later on. Your instructor will give you a spring-scale that can be used to measure the strength of forces in units of newtons. Pull on the scale to get a feeling for forces of different strengths (in newtons).

Sometimes it may be necessary to add information on the strength of a force to a force diagram. For example, if a hand pulls on a cart with a force of 2 N, that would be represented by the following diagram[1]:



Finally, if the object is moving at the moment in time for which we are drawing the force diagram, then it is important to know in which direction. When this is relevant we can show this by drawing a speed arrow above the object (just like the speed arrow in the *I&M Simulator*). (We use a half-arrow so as not to confuse it with the force-arrows, since it represents the speed of the cart, **not** a force acting on the cart.) The length of the speed arrow represents the relative speed of the object. For example, when you gave the moving cart a push in the same direction as its motion, the force diagram would look like this:



Note that the speed arrow only tells about the speed of the object at the particular moment in time for which the force diagram is being drawn. It does not tell anything about whether the object's speed is in the process of changing, or whether it is remaining constant.

You may have noticed that all the situations discussed above show only one force acting on the cart. It is certainly possible for more than one force to act on an object at the same time, but it is important to understand the effect of a single force before considering situations involving multiple forces. Thus, in

[1] As you saw in Chapter 1, a push and a pull of the same strength have exactly the same effect on the motion of an object. Thus we could equally well represent this pull to the right using exactly the same force arrow as we would use for a push to the right. Since the effect is the same, whether we choose to distinguish between pushes and pulls is a matter of choice. In this course, we will always draw force arrows on the side of the object from which the force is applied. Hence, a push will always be represented by a force arrow pointing toward the object, and a pull will always be represented by an arrow pointing away from the object.

the activities that follow you will study the effect that a single force has on an object. Later in this chapter you will examine situations where more than one force acts on an object at the same time.

Summarizing Questions

First discuss these questions with your team and note your ideas. Leave space to add any different ideas that may emerge when the whole class discusses their thinking.

S1: While the hand is exerting a force on the cart, what is the motion of the cart like? What evidence from this activity supports your idea?

S2: Do you think the force of the hand was transferred from the hand to the cart during the interaction between them, and then continued to act on it after contact was lost? What evidence supports your idea?

S3: At what moment do you think the force of the hand stopped acting on the cart?

S4: During a contact interaction, what do you think is transferred from the source to the receiver: energy, force, both, or neither? Explain your reasoning.

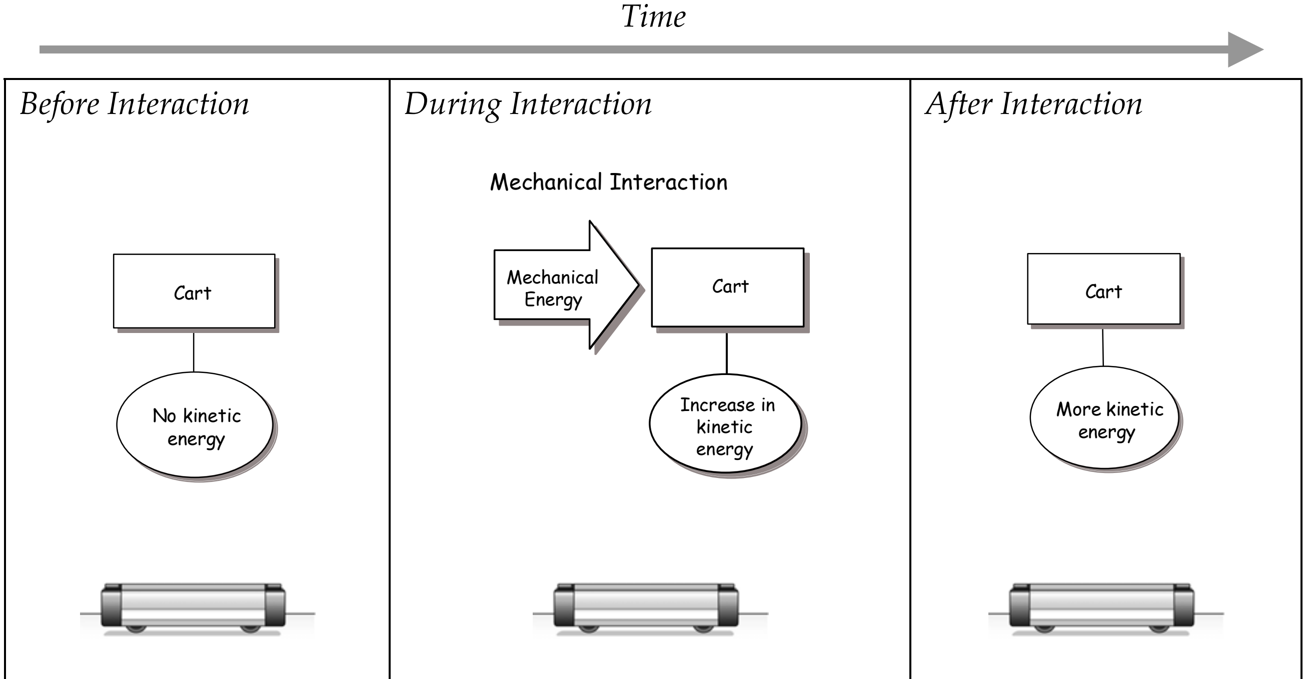
Comparing Force and Energy Diagrams

In Chapter 1 you explained the behavior of objects during contact interactions in terms of a transfer of mechanical energy from one interacting object to the other. In this chapter you are developing ideas that will help explain the same interactions in terms of the force that one of the interacting objects exerts on the other.

To help you start thinking about how these two ways of describing contact interactions relate to each other, consider the situation of a stationary cart that is given a quick shove with a hand to start it moving. Shown below is a timeline of I/O energy diagrams showing how the energy transfer to the cart and changes in its kinetic energy are related to the interaction.

Below the energy diagrams are three pictures of the cart. Use these pictures to draw force diagrams, representing the force (due to the contact interaction between the cart and the hand) acting on the cart at the same three points in time as the energy diagrams. (Be sure to include force and speed arrows as you think appropriate. However, if you think there is no force acting at a particular time, then do not draw a force arrow.)

Time



Participate in a whole class discussion to go over your answers to the Summarizing Questions and force diagrams.

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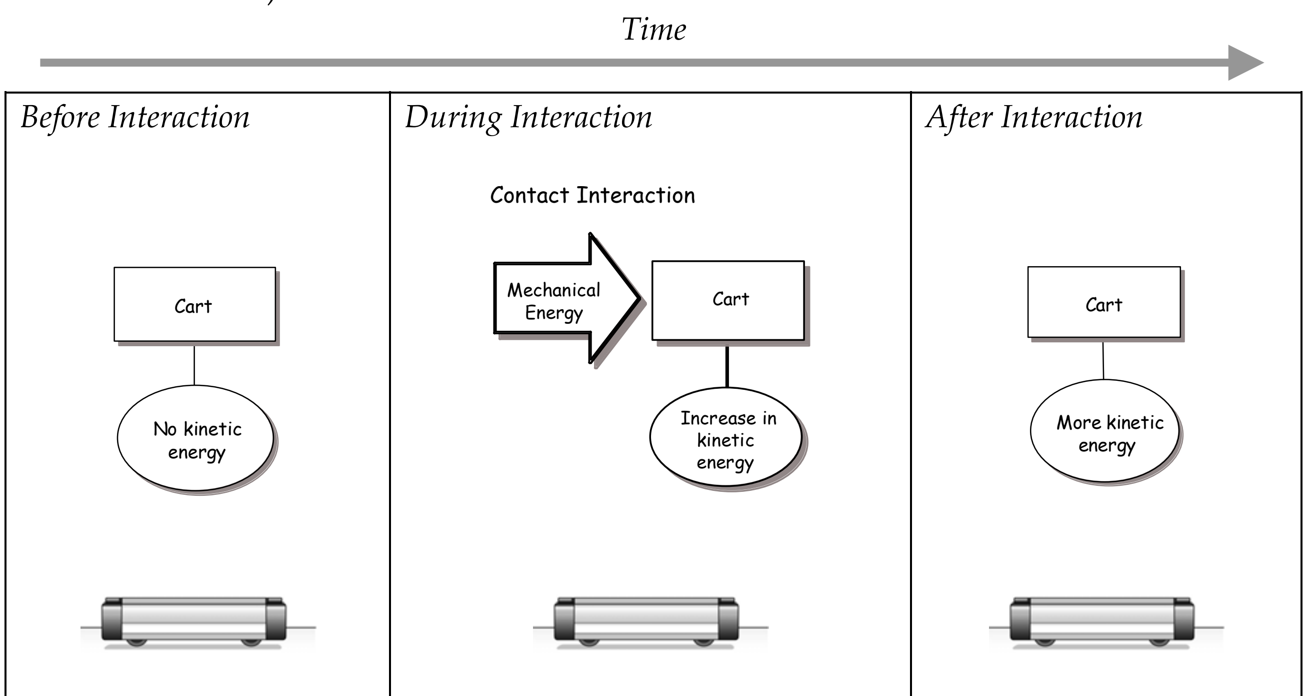

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