Unit 2 Cycle 1

Beginnings: What are forces?

LESSON TARGET IDEAS

A force is a push or a pull exerted on one object by another object during an interaction between them. In a contact push/pull interaction the force exists only while there is contact between the objects.

COMMON MISCONCEPTIONS

- *A force can be transferred from one object to another, just like energy.* (Forces are not transferred, they disappear as soon as the interaction producing them ceases.)
- *Force is a property of an object.* (It is not, it is a property of an interaction between two objects.)

NOTE: Many people have a personal definition of force that is more like what scientists call energy. They think force is something an object can have and that can be transferred to another object during an interaction. This thinking can be difficult to change and is addressed as the scientific definition of force is developed in this cycle of lessons.

WHAT TO FOCUS ON

This Cycle focuses on the effect that a single force has on the motion of an object. There are a number of deeply held misconceptions that must be dealt with in the course of this unit and it is important that the teacher attends to them. To understand how forces affect motion, students must first develop a common understanding of what is meant by the term “force.” This activity begins that process, and the idea is developed further in the next activity.

In this activity, students push and pull a foam block attached to a toy car or skateboard. The foam block serves as a “force detector” in that a deformation of the foam’s edge (being compacted or stretched) provides evidence of a force being applied. Students will likely focus on the motion of the toy car, but it is important that they also pay attention to the foam. They should observe that the foam deforms when they interact with it by pushing or pulling on it. These push and pull interactions are what scientists call forces.

MATERIALS NEEDED FOR THIS LESSON

Material	Quantity
Large toy car, mini-skateboard (or similar)	1 per student group
Foam (low density) “force detector”	1 per student group
Glue dots/double sided mounting tape pieces	Several per student group

Purpose

The concept of an interaction is a fairly simple, but important, one when dealing with forces. The teacher should take time to explain the idea and give several examples that students are familiar with.

Next, the teacher should explain that scientists often describe interactions in terms of the forces that the interacting objects apply to each other and give a simple definition of a force as a push or a pull. Finally, the purpose of the lesson should be introduced. Basically, we are trying to make sure we all understand the word "force" in the same way to avoid confusion later on.

What do we think?

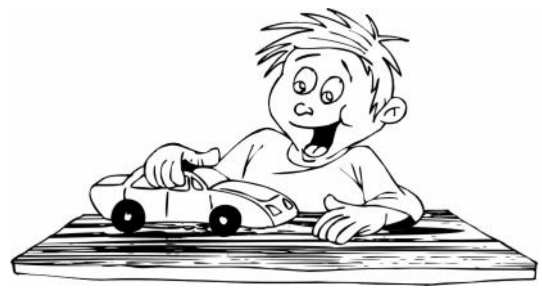
This is a fairly simple "What do we think?" task, intended simply to start students thinking about forces.

Most students will say there is a force, probably justifying this response by referring to their push.

Unit 2 Cycle 1

Beginnings: What are forces?

Purpose



When studying the world, it is useful to think about how objects affect each other. When this happens we say that there is an ***interaction*** between the objects involved. (Another way of saying this is that the objects are ***interacting*** with each other.)
For example, in Unit 1 when you investigated changes in motion, each time you pushed the ball, there was an interaction between your hand and the ball.

One way scientists describe interactions between objects is in terms of what they call ***forces***. The pushes you used are examples of forces. In this Unit we will investigate the connection between a force and the effect it has on the motion of an object. However, to start we must think about what we mean by "force". The big question we will address in this *Beginnings* activity is:

What is a force, and what are some examples of forces?

What do we think?

You will work with a partner for this activity. Each pair will need:

- Toy car

Place the toy car on the table. One of you should give it a quick push so that it starts moving. While the car is in motion the other partner should stop it suddenly.

Do you think a force was acting on the car while it was starting to move? Explain your answer.

There will likely be many different suggestions. This is just brainstorming so accept them all.

Students will likely justify their answers based on a perception as to whether another visible object is touching the car. Thus, they may agree that pulling with a rope represents a force, whereas blowing with a fan does not.

Again, we are at the very beginning of the Cycle here, so the teacher should only use the discussion to bring out students ideas about force and not impose a definition at this point. Some will identify tangible (or visible) contact as evidence for a force; others will use motion (but probably not change in motion) as evidence.

Activity: Step 1

It is very important to use foam with the right characteristics to give the desired results. You need a foam that:

- Is soft enough to show a deformation when even a weak force is applied to it.
- Is springy enough that it will "spring back" immediately when any force is removed. (Memory foam is definitely **not** recommended.) The foam from a latex foam pillow is a good option.

It is not vital that a toy car be used. (In the workshop we used a small skateboard.) The important characteristics are that it has some relatively flat surface to attach the foam to, its wheels are free to rotate and that it has enough mass that the strength of any push or pull used to start or stop it (with the foam attached) will produce an easily noted deformation in the foam.

Here we are simply establishing that the foam can serve as a "force detector." Students should notice that the foam distorts in some way when they push on it.

Describe another way you could start the car moving across the table.

Do you think a force would be acting on the car in your suggested method? Explain your answer.

Your teacher will lead a class discussion about everyone's answers to these questions, and the explanations of their thinking.

Activity: Are pulls forces too?

You will work with a partner for this activity. Each pair will need:

- Toy car
- Small mounting square (or double sided tape)
- Larger square of soft foam

STEP 1: Hold the foam square in one hand and push on its edges with your other hand.

Describe what happens to the edges of the foam square when you push on them. Do they stay the same or do they change in some way? Describe what happens.

There may be better ways to mount the foam than the mounting square(s). The teacher should experiment to find the best method. The important characteristic is that the foam should stay fixed during pushes and pulls on it, but it should still be easy to see any deformations.

Activity: Step 2

Monitor groups to make sure they are performing the "experiment" as described. It is important that there is enough time between the initial push and the stop to make them distinct enough that the foam obviously "recovers" in between.

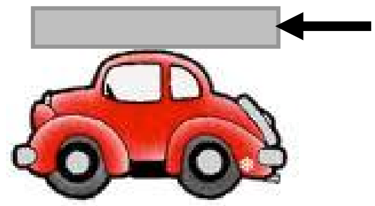
Some students may justify the presence of a force based on the fact that they interacted with it, but encourage them to also use the deformation of the foam as evidence. One way to do this might be to ask students how they could show someone else (who isn't pushing on the object) when a force is acting on the foam.

Activity: Step 3

Most students will agree that a pull is a force because it involves an interaction and can be used to produce the same effects as a push.

Because we know that your pushes are examples of forces being applied, we can use the foam square as a "force detector." ***We will take any change in shape of the foam square as an indication that a force is acting on it.***

STEP 2: Use the mounting square to attach the foam square to the top of the car. From now on you can consider the foam as being part of the car. Use your finger to start the car moving, by giving the back edge of the foam a quick push.



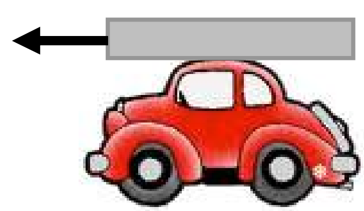
After the car has moved short distance, give the front edge of the foam a "backwards" tap to make it stop. (Do NOT make it go backward.)

Did a force act on the car while you were interacting with it to make it start moving? What about while you were stopping it? How do you know?

STEP 3: Apart from pushing on it, another way to interact with the car would be to pull on it in some way.

You know that pushes are examples of forces, but do you think pulls are also examples of forces, or not? Why do you think so?

Return the car to its starting point and start it moving again, this time using a quick firm <u>**pull**</u> on the front edge of the foam.



Again, students may justify the presence of a force based on the presence of an interaction, but encourage them to focus on the evidence provided by the foam.

It should not be hard for students to infer that a pull is a force, though they may need help tying together the evidence provided by the deformation of the foam.

While this point may seem trivial, it is important that students agree that both pushes and pulls are forces, because they will use both in later lessons and they need to recognize them both as forces.

Making Sense Questions

Question 1: We are aiming for a description that centers around the idea of “a push or a pull applied to one object by another object.” Exact wording is not important. Students will likely say that a force is a push and/or a pull but will not relate it to an interaction between objects. In this case, the teacher should probe students for a more complete answer that includes a description of force as an interaction between objects (e.g., how did pushes and pulls happen during the activity with the toy car?).

After the car has moved a short distance, give the back edge of the foam a 'backwards' pull to make it stop. (Do NOT make it go backward.)

Did a force act on the car this time while you were interacting with it to make it start moving? What about while you were stopping it? How do you know?

What do your observations of the behavior of the foam during your pushes and pulls suggest? Is a pull another example of a force, or not? Explain your thinking.

Your teacher will lead a class discussion about everyone's observations and what they tell us about whether a pull is a force or not.

Making Sense

Your teacher will lead a class discussion about forces. Write answers to the following questions after each one is discussed by the class.

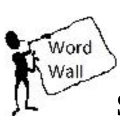
1. Describe what is meant by a force.

Question 2: Accept suggestions from the class. The main idea students should get from this discussion is that there are many different ways to apply a force to an object. Possible student answers include "kick the toy car" or "push it with a pencil" or "tie a string to the toy car and pull it" or "blow on it."

Question 3: With this question we begin making connections between forces and motion. Students should agree that the motion of the car changed (it started or it stopped) while a force was being applied to it.

Some perceptive students may be concerned that the motion of the car was also changing (slowing down) between the start and the stop. The teacher should not try to address this issue at this point, but should focus students for now on the connection between forces for which the foam provides evidence at the start and the stop. If this issue does arise, assure students that they will think about the period between the pushes in a later lesson.

Question 4: We would like students to associate every change in motion with a force. However, some students may think that there are some situations of changing motion when a force is not present. As examples, they may use motion on a slope or slowing due to friction, justifying their ideas by saying they cannot see another object doing any pushing or pulling. If this issue arises, the teacher doesn't need to resolve it at this point, but rather can say that these examples seem to be interesting, and will be investigated in a later lesson.



Science Vocabulary

Although the term "**force**" is introduced in this lesson, it will be developed in more depth in future lessons. Consequently, the teacher should not add this term to the word wall yet.

2. In this activity it was your hand that applied the forces to the toy car. Describe two other ways you could arrange for a force to be applied to the car. (Make sure one is a push and the other a pull.)

3. What happened to the motion of the toy car each time a force was applied to it? Did its motion change or did it stay the same?

4. If you wanted to change the motion of an object do you think you would have to apply a force to it, or could you change it without a force? Explain your thinking.

Unit 2 Cycle 1

Exploration #1: When does a force stop?

LESSON TARGET IDEA

In a contact push/pull interaction, the force ceases to exist as soon as contact between the interacting objects is lost.

COMMON MISCONCEPTIONS

- *Forces are transferred between objects during an interaction between them.*
- *After a force is transferred to an object during an interaction, the object continues to carry the force with it after the interaction ceases.*

WHAT TO FOCUS ON

In the previous activity, students saw that foam blocks could be used as force detectors—a deformation in the foam is evidence of a force being applied. In this activity, students again use the foam blocks as force detectors, looking at when a force interaction starts and stops. Using their fingers, students apply both “forward” and “backward” pushes to the foam/car assembly in separate runs. Students should observe that the edge of the foam is deformed (i.e., a force is applied) as long as their finger interacts with the foam, and that there is no deformation (i.e., no force) when the interaction ends. This evidence is especially important if students have the idea that force, like energy, is something an object carries with it as it moves, and that can be transferred to another object during an interaction (a particularly common misconception).

Students may also comment on changes in motion they observe, though these are not the main focus of this activity. If students are focusing on the motion of the car, the teacher should let them know that they will investigate motion in future activities, and ask them to focus on what is happening to the foam instead.

MATERIALS NEEDED FOR THIS LESSON

Material	Quantity
Large toy car, mini-skateboard (or similar)	1 per student group
Foam (low density) “force detector”	1 per student group
Glue dots/double sided mounting tape pieces	Several per student group

Purpose

The idea addressed in this lesson may seem trivial, but it is one of the most basic misconceptions and so must be dealt with explicitly. The teacher should give several scenarios of a "hit" in various contexts and say we are going to look at when the force of the hit stops.

What do we think?

The teacher should explain the scenario and allow students time to think, individually or in pairs, about which answer choice they agree with and why. The teacher may wish to poll the class for which of the alternatives is closest to their thinking.

The teacher should have students explain their thinking for all chosen options. Few, if any, students will choose a). Any who do will likely explain their thinking in terms of a force being transferred from the foot to the ball at the very moment of impact, with contact lasting a little longer after this transfer.

Those who choose b) (which is the most appropriate response) will likely justify their answer in terms of a force being a push applied by the foot to the ball. Once contact is lost the foot can no longer push the ball, so the force is gone. These students are thinking about force in an appropriate way, but the teacher should not disclose that at this point.

Students choosing c) may think that the force is transferred, but without continued contact, it beings to "run out" as the ball moves. They may attribute slowing of the ball to this weakening "force." Others may say the force stops at the moment the ball starts to come back down after the kick because the "force" that was pushing it upward is no longer there.

Choice d) indicates thinking that in order for an object to be moving in any manner whatsoever there must be a force pushing it. Thinking there is a transfer of the force from the foot is one way to arrive at this conclusion. These students will likely say that all the time the ball is moving forward this "force" must still be present and it only ceases when the ball stops. (They may even say the "force" is then transferred to the goalkeeper.)

Unit 2 Cycle 1

Exploration #1: When does a force stop?

Purpose

You know that when you push or pull on an object you apply a force to it. But when does that force stop acting on the object?

For example, when you hit a tennis ball, the racket exerts a force on the ball. But when does the force of the hit stop pushing on the ball?

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

When does a force stop pushing on an object?

What do we think?

Imagine a soccer player taking a shot on goal. She runs up and kicks the ball which flies toward the goal, where the goalkeeper catches it.

Which of the choices below is closest to when you think the force of the kick stopped acting on the ball?

a) Before the ball lost contact with the foot
b) At the moment the ball lost contact with the foot.
c) After the ball lost contact with the foot, but before it got to the goalkeeper.
d) When the goalkeeper stopped the ball moving.

Explain your choice.

The teacher should summarize all the different viewpoints expressed in the class and then tell students that they will test their thinking using the toy cars and foam "force detectors." Remind them that the key question is "When does a force stop pushing on an object?"

Activity: Step 1

The teacher may wish to remind the class how they used the foam to detect the presence of a force.

Students should be comfortable with the idea that there is a force during the pushes and justify it using the visible deformation of the foam.

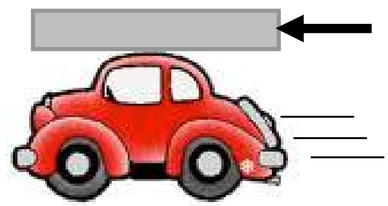
Students may be uncomfortable answering this question. The observation that the foam is not deformed between pushes is evidence that the force is gone, but they may not be willing to mentally accept what this evidence is telling them. The teacher should encourage them to go by what the evidence indicates.

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

Activity: When is the force there?

You will work with a partner for this activity. Each pair will need:

- Toy car with foam square still attached



STEP 1: Use your finger to start the car moving, by giving the back edge of the foam a quick push. This time, as the car is moving, give the back edge of the foam some more quick 'forward' pushes to increase the car's speed. Watch the edge of the foam carefully before, during, and in between your pushes.

Was a force pushing the car forward while your finger was touching the foam, **<u>during</u>** your pushes? How do you know?

Was a force pushing the car forward while your finger was not touching the foam, **<u>in between</u>** your pushes? How do you know?

STEP 2: Return the car to its starting point and start it moving again using a quick firm push. This time, as the car is moving, give the front edge of the foam some very gentle 'backwards' taps to slow and stop the car. (Do NOT make it go backward.)

Activity: Step 2

Again, students should be comfortable with the idea that there is a force during the backward taps and justify it using the visible deformation of the foam.

Students may be uncomfortable answering this question. They should have observed that the foam is not deformed between taps and take this observation as evidence that the force ceased to exist as soon as contact was lost.

Again, watch the edge of the foam carefully during, and in between, your taps.

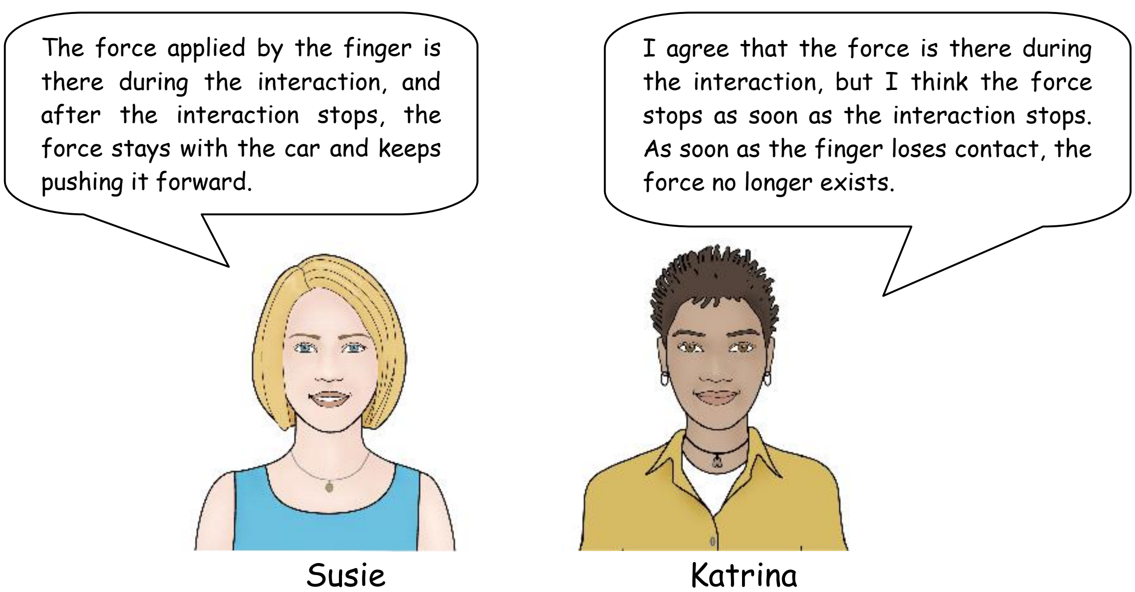
Was a force acting on the car while your finger was touching the foam, **<u>during</u>** your backward taps? How do you know?

Was a force acting on the car while your finger was not touching the foam, **<u>in between</u>** your backward taps? How do you know?

Making Sense

Your teacher will lead a class discussion about everyone's observations and what they tell us about when a force was acting on the car.

1. You know that while your finger was touching the car there was an interaction between your finger and the car. Susie and Katrina were discussing when the force of the finger was being exerted on the car and how it relates to the interaction between them.



Making Sense Questions

Question 1: The evidence students have seen by examining the foam clearly supports Katrina's, rather than Susie's, viewpoint. Many students will likely take this evidence at face value and agree with Katrina, without necessarily being totally convinced. However, the misconceptions associated with this issue are so deeply held that some students may simply not "believe their own eyes"! Others will begin to "patch" their thinking to accommodate the evidence by saying that "some other force" is responsible for keeping the car moving, or the force of the push is still there, but that the foam cannot show it for some reason.

It is not necessary to completely resolve this issue at this point, but the teacher should try to attain consensus that the evidence suggests the force of the push ceases when contact is lost.

Question 2: Following on from the discussion of the previous question and recalling the return of the foam edge to its original shape after a push, most students will likely be willing to say that the force stops as soon as contact is lost. Students may also say that the motion of the car changed while they were applying a force and didn't change once they stopped touching the car, however the teacher should not raise this issue if students do not. Still, many students will not be totally convinced yet that the force stops acting at the instant contact is lost.

After the class discusses Question 2 would be a good opportunity for the class to revisit the question in the "What do we think?" section of this lesson. Ask students to consider whether their thinking has changed, and how the evidence from the foam and toy car activity affected their thinking.

Question 3: This question tries to tie together what students have seen in this and the previous lesson. We are hoping they will say that the effect of a force is to change the motion of an object. If this idea does not emerge, ask students what happened to the motion of the toy car each time they gave it a push or pull.

Question 4: This question again tries to tie together what students have seen in this and the previous lesson. Previously, they saw that an interaction is needed to change the motion of an object, and now they have evidence (from their observations of the foam) that a force exists only during an interaction.

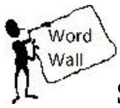
Some students may agree, but only for contact push/pull interactions. They may still not associate gravity or friction with an interaction. This is OK at this point as we will get to those interactions soon.

Do you agree with Susie or Katrina? What evidence have you seen in this activity that supports your thinking?

2. When you hit a tennis ball the racket applies a force to the ball. At what moment do you think the force of the hit stops acting on the ball? Why do you think so?

3. What effect does a force have on the motion of an object? While the force is acting does the object's motion change, or does it stay constant?

4. Do you think a force could be applied to one object, even if it does not interact with something else, or is an interaction with another object needed to create a force?



Science Vocabulary

There is no new science vocabulary introduced in this lesson. However, if students understand and can explain what a "**force**" is, then it would be appropriate to add this term to the word wall.

Unit 2 Cycle 1

Exploration #2: Forces without contact?

LESSON TARGET IDEAS

There are certain special types of interactions for which the objects do not need to touch to exert forces on each other. Examples are magnetic, electric charge, and gravitational interactions.

COMMON MISCONCEPTIONS

- *Gravity is not an interaction between two objects.* (It is - between any two objects with mass – though only gravitational interactions between objects and Earth are noticeable in everyday life!)
- *When an object falls it is interacting with something called "gravity."* (It is not. It is interacting with Earth.)
- *Gravity is a magnetic force.*
- *Gravity is caused by the atmosphere of Earth pushing down on objects.*
- *Gravity is caused by the rotation of Earth or its orbit around the Sun.*

WHAT TO FOCUS ON

In this lesson we look at certain specific interactions for which contact is not required.

In prior lessons, the deformation of a piece of foam (the force detector) provided one type of evidence that a force was being applied. In most of this lesson, the change in an object's motion serves as evidence that a force is being applied. Students should be able to feel the attraction and repulsion between two magnets as evidence of a force in Activity 1 Step 1 (what they "feel" is their applying a force to each magnet to balance the forces between the two magnets so that they don't move together or apart). In Activity 1 Step 2, the evidence of a force is the change in motion of the paperclip before the magnet comes into contact with it. Similarly, the evidence for a force in Activity 2 is the students' hair and pieces of paper beginning to move toward the "charged" (rubbed) balloon. In Activity 3, the evidence of a force is the change in motion of the ball as it starts to fall (and continues to increase speed while falling).

Students may struggle to associate all of the non-contact forces in this lesson, particularly gravity, with two objects. It is important for students to recognize that the non-contact forces they are investigating occur because of the presence of two or more objects. We want to end up with students thinking that gravity is a "pull" force that always acts between Earth and every object on Earth.

Misconceptions about the cause/source of gravity are likely to arise in Activity 3: Step 1. The teacher notes in that section include specific suggestions for addressing these misconceptions.

MATERIALS NEEDED FOR THIS LESSON

Material	Quantity
Magnets	2 per student group
Metal paper clips	Several per student group
Balloons	1 per student group
Shredded paper	1 handful per student group
Sheet of thick paper	1 per student group
Tennis ball	1 per student group

Purpose

The teacher should introduce the lesson and may choose to poll the class as to their thinking on the key question. Many students will think that contact is required for a force to exist, especially in light of the efforts made in the previous lessons to establish evidence for a force.

What do we think?


Some students may suggest blowing on the paperclips. If so, the teacher should elicit the idea that something (the air) is still touching them in this case. It is likely that some students will suggest using a magnet. When prompted to explain their thinking they will likely cite previous experience with magnets.

The teacher can then tell students they will investigate their ideas, starting with magnets, but looking at other types of interactions also.

Unit 2 Cycle 1

Exploration #2: Forces without contact?

Purpose

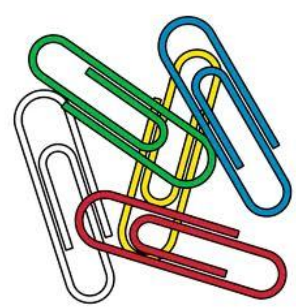
You have observed that in order for you to apply a force to another object, you have to touch it in some way. For example, if you wanted to move a sled across a snowy field, you could do it by pushing it or pulling it with your hands. Even if you used a rope to pull it, then the rope would have to be tied to the sled, and so the rope would be touching it.

But can objects apply forces to each other without touching, or must there always be contact between two objects for a force to exist?

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

> ***Can any objects apply forces without touching each other?***

What do we think?



Imagine there were some metal paper clips lying on the table in front of you.

Do you think there is any way you could make them start to move without touching them? If so, how do you think you could do it?

Your teacher will lead a class discussion about everyone's answers to this question.

Activity 1

Make sure the magnets are strong enough for the activity to work as intended. Some cheap, commercially available magnets are very weak and may not work well for this activity.

Activity 1: Step 1

Monitor the groups to make sure they are not letting the magnets touch each other. They need to bring the magnets close to one another slowly to allow time to notice the forces involved. Some students may never have tried this, so make sure everyone gets to feel it. Students may not be able to feel attraction, but the repulsion of like poles should be more evident. They may say that it feels like there is a "bubble" between the two magnets.

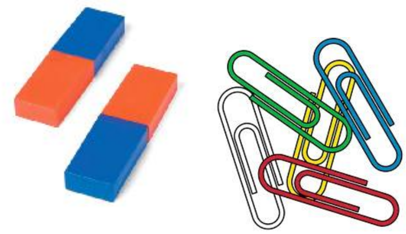
They will likely agree that they can "feel" a force pushing the magnets apart (and maybe pulling them together if the magnets are strong enough). Do not allow students to get distracted investigating more magnetic phenomena, we are simply trying to establish that forces can exist without touching.

Activity 1: Step 2

Again, monitor the groups to make sure they are moving the magnet slowly enough that they have a chance to see the paperclip "react" before contact occurs.

Students should use the fact that the paperclip *started to move* as evidence of a force. They may need reminding that a change in motion is evidence for a force.

Activity 1: Playing with magnets



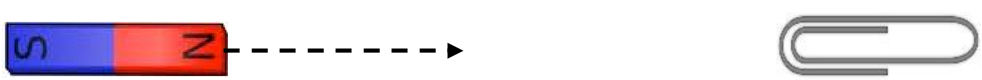
You will work in groups for this activity. Each group will need:

- Two magnets
- Some metal paper clips

STEP 1: ***Each group member should try this.*** Hold one magnet in each hand and slowly bring their ends together until they are almost, but not quite, touching.

Do the two magnets apply forces to each other, even though they are not touching? How can you tell?

STEP 2: Place a paperclip on one side of the table/desk and lay one of the magnets on the other side of the table. Slowly slide the magnet, end first, toward the paperclip.



Describe what happens as the magnet gets close to the paperclip.

Did the magnet apply a force to the paperclip before they touched each other? How can you tell?

Activity 2

The pieces of paper should be small enough that the rubbed balloon can easily pick them up. Dots from a paper punch are ideal for this experiment.

Students may need help inflating and tying the balloon.

The atmospheric humidity will play a role in how well these experiments work. They will work much better on a cold, dry day than a warm humid one. Nevertheless, the experiments should work to some visible degree if the procedure is followed quickly.

Activity 2: Step 1

Monitor the groups and make sure everyone gets to try this. It is important that the rubbed side of the balloon is the one brought close to the hair. (The unrubbed side is not charged and so will not attract the hair!)

Again, students should use the observation that the hair moves toward the balloon, even before they touch, as evidence that a force is being exerted on the hair by the balloon. Not all hair will be attracted to the balloon as the texture of the hair and the presence of conditioner, styling products, oil, etc. can affect this activity. Dry, fine hair without conditioner or styling products tends to work best. The teacher should be prepared to acknowledge that some hair is attracted to the balloon and other hair is not, and briefly discuss possible reasons why.

Activity 2: Step 2

Again, students should use the observation that the paper moves toward the balloon, even before they touch, as evidence that a force is being exerted on the paper by the balloon without touching.

Activity 2: Rubbing a balloon

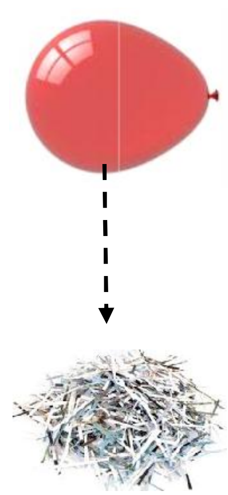
You will work in groups for this activity. Each group will need:

- Rubber balloon
- Some small pieces of paper

STEP 1: Inflate the balloon and tie a knot in the end. (Ask your teacher for help if you can't do this.)

Each group member should try this. Hold the balloon on one side and rub the other side up and down several times on your shirt or sweater. Now quickly bring the rubbed side of the balloon close to, **but not touching**, someone else's hair.

Does the balloon apply a force to the hair? How can you tell?



STEP 2: Place some small pieces of paper on the table. Again, rub one side of the balloon on your shirt or sweater. Now quickly bring the rubbed side of the balloon above the paper on the table. Bring the balloon toward, **but not touching**, the paper until you see something happen.

Describe what happens as the balloon gets close to the paper.

Did the balloon apply a force to the paper before they touched each other? How do you know?

The teacher should lead a discussion of the evidence students have seen to support the idea that it is possible for forces to exist without contact between the interacting objects.

Within this discussion it is important to establish:
1) Evidence for this force is a *change* in motion occurring without evident contact (keep in mind that when an object goes from not moving to moving, its motion changes).
2) Even though there is no contact, two objects were involved in each case. They just do not need to touch.
3) It is only certain special types of interaction for which this happens. For ordinary manual pushes and pulls, contact is required.

Non-touching Interactions

The next section of this narrative tries to establish the idea that sometimes it may seem like the motion of an object is changing "on its own," but in reality it just seems this way because we cannot see (or are not aware of) the partner object in the interaction. This point is important because students who do not think of gravity as an interaction often do not realize it is Earth that is the interaction partner.

The teacher should lead students in moving a paper clip with an unseen magnet to get a sense of how this activity is possible. (If you have a strong enough magnet it may even be possible to do it on a table with the magnet underneath, rather than on a sheet of paper.)

Make the point to students that there are two objects interacting, even though they cannot see one of the objects, and have them experience it from the point of view of an observer who does not know the magnet is there.

Your teacher will lead a class discussion about everyone's observations and what they tell us about whether objects always need to touch for a force to exist.

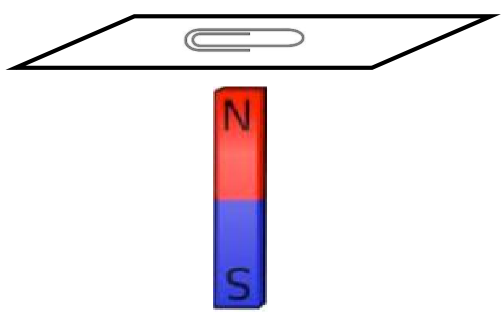
Non-touching Interactions

In order for most objects to interact with each other, and so apply forces to each other, they must be touching. For example, for you to apply a force to a ball, you must touch it, either with part of your body, or with some other object that you are holding. However, in a **few special cases** some objects can interact, and so apply forces, without touching each other.

One common example you are probably familiar with is ***magnetic interactions***. You saw in Activity 1 that magnets can apply forces to other magnets, and some other objects (like steel paperclips), without touching them. In Activity 2 you saw another example, that of ***electric charge interactions***. In this example you gave a balloon an electric charge by rubbing it and then saw that it could apply forces to someone's hair and to some pieces of paper, without touching them.

One interesting thing about non-touching interactions is that sometimes they can make it appear as if an object starts to move on its own. For example, even if a magnet was hidden from view, it could still apply a force to a paperclip and make it move. To anyone who could not see the magnet, it would look like the paperclip is moving on its own.

To see this, have one of your group hold a sheet of paper with a paperclip on it. Then another person should hold the magnet below the paper and use it to move the paperclip around on top of the paper.



To someone looking down from above the paper, it appears as if the paperclip is moving on its own, but really a force is being applied to it by the magnet.

Activity 3: Step 1

It is obvious that the ball falls, but it may not be obvious that for this to happen the ball must start moving downward, and so a downward force must be responsible for starting the ball moving in that direction.

Most students will "know" that the force is "gravity" without understanding what gravity really is. Remind them that for any force (a push or a pull) to exist there must be an interaction between *two* objects, even if they are not touching.

With prompting some students will say that Earth is the other object in a gravitational interaction. Others will say it is "gravity" and at this point the teacher should challenge them to describe what this object called "gravity" looks like. If they cannot draw a picture of an actual object then they likely need to look elsewhere for the interaction partner.

Yet others may say it is the air pushing the ball downward. If so they can be shown the Apollo video from the Moon in which objects were dropped and fell to the lunar surface. There is no air on the Moon, yet there still seems to be gravity! (The hammer versus feather aspect of this video is not important for this lesson!)

The video can be found at:
http://video.google.com/videoplay?docid=6926891572259784994

Others may express the idea that gravity is a magnetic effect and that Earth's magnetic field attracts objects toward it. If so, have them check whether all objects are attracted to magnet in the same way as all objects seem to be attracted to Earth.

Finally, some may express the idea that it is Earth's rotation that causes objects to be attracted to it. To counter this idea, try having a student spin on the spot while holding a ball on a string at arm's length. If rotation causes attraction then the ball should move inward as the student spins. It will not, it will move outward. This activity provides evidence that rotation cannot be the cause of a force that attracts objects toward Earth.

Unfortunately, we cannot easily do any experiments to further establish the true nature of the gravitational attraction of Earth, so the best we can do at this point is address some of the misconceptions (see above) and then end up with the idea that Earth simply seems to attract everything toward it.

Activity 3: Dropping a ball

You will work in groups for this activity. Each group will need:

- Tennis ball (or similar)

STEP 1: Hold the ball above the ground and release it.

Describe what happens to the ball after you release it.

You know that for the ball to start moving downward a force must be acting on it. What force do you think this is?

You know that for a force to act on one object it must be interacting with another object. A force acted on the paperclips because they were interacting with the magnet, and a force acted on the strips of paper because they were interacting with the charged balloon.

What other object do you think the ball was interacting with, to create the force that pulls it downward?

Making Sense Questions

Question 1: All students should now agree that objects can apply forces to other objects without touching for certain specific types of interactions and should be able to give examples from the lesson (i.e., magnetic attraction between a magnet and paperclips, interactions involving charged objects like a rubbed balloon and paper pieces, and gravitational interactions such as a tennis ball falling from a student's hand).

Questions 2: Most will likely identify Earth at this point, though they may be unsure of the nature of this attraction. For now it is enough to establish that the attraction is there and that Earth applies a force to all objects that makes them fall, if not supported.

Science Vocabulary

"**Contact forces**" and "**non-contact forces**" are introduced in this lesson. If students can identify forces between two objects that are touching one another as "**contact forces**," then it would be appropriate to add this term to the word wall. If students can identify magnetic, electric charge, and gravitational interactions as examples where there is a push/pull involved between objects that do not need to be touching, then it would be appropriate to add "**non-contact forces**" to the word wall.

Making Sense

Write answers to the following questions after each one is discussed.

1. Can some objects apply forces to other objects without touching them? If so, give some examples.

2. When an object falls to the ground, a force must be acting on it. What other object is applying a force to it?

Unit 2 Cycle 1

Exploration #3: What happens if a force keeps acting?

LESSON TARGET IDEAS

- When a force acts on an object in the same direction as its motion (and no other forces oppose it), the object's speed will continue to increase as long as the force keeps acting.
- When a force acts on an object in the opposite direction to its motion (and no other forces push it forward), the object's speed decreases. (If the force acts for long enough for the speed to decrease to zero, the object will then begin to move in the opposite direction with increasing speed, because the same force is now acting in the new direction of motion.)

COMMON MISCONCEPTIONS

- *Speed is proportional to force, so a constant force will give rise to a constant speed.* (It is acceleration that is proportional to force, not speed!)
- *With a single constant force being applied, an object's speed will increase at first, but then "level off."* (It will not, if there is only one force acting, the speed would continue to increase. For the speed to "level off," some additional force becoming equal in magnitude to the first one, but in the opposite direction, would have to be acting.)
- *It is a natural tendency of moving objects to slow, even in the absence of an opposing force.* (It is not. All slowing must be due to an opposing force of some type. In the absence of any forces, an object's speed will not change.)

WHAT TO FOCUS ON

So far we have concentrated mostly on the effect of forces that act only for a short time. In this lesson we look at what happens when a "forward" or "backward" force acts on an object and keeps acting. It is difficult to apply a constant force manually, so we will use the continuous gravitational force (addressed in the previous lesson) to do it. To provide evidence for the idea that a continuous "forward" force causes the speed of the object to increase, students need to connect the continuous presence of the gravitational force with the observation that the speed of a car going down a ramp continually increases. Therefore, a key aspect for implementing the activity is to set up the ramp to produce a continued increase in speed that can be detected. The students should observe that the time required for the car to travel through equal length segments of the ramp progressively decreases.

To provide evidence for the idea that a continuous "backward" force causes the speed of the object to decrease, the students need to connect the continuous presence of the gravitational force with the observation that the speed of a car going up a ramp continually decreases. The students should observe that the time required for the car to travel through equal length segments of the ramp progressively increases.

For this activity, students should focus on the gravitational pull as the continuous force. Some students may bring up frictional forces opposing the motion of the car. If so, the teacher should let them know that they will investigate friction in future lessons and that, for now, they should focus on gravity being used as the continuous force in this lesson.

MATERIALS NEEDED FOR THIS LESSON:

Material	Quantity
Meter stick	1 per class
Large toy car	1 per class
Stop watch	at least 2 per class
Masking tape roll	1 per class
Large flat board (or similar) for ramp	1 per class
Large ball (e.g. basketball, soccer)	1 per class

Purpose

The teacher should clearly explain the objective of the lesson. A few students may still be holding the idea that a force "stays" with an object after the interaction has ceased, and so they might be confused about what is being discussed. This activity is about a continuous interaction (and thus the force is continuously applied).

What do we think?

In this section we try to get students to think about a continuous force as a series of short pushes, all "joined together."

Students should be comfortable with the idea that a quick push made the ball's speed increase.

Again, having done this activity themselves, students should be comfortable saying that each push would make the ball's speed increase. If the class has covered speed-time line graphs, the teacher should ask groups to construct a line graph for this situation. Either way, the teacher should get students to express the idea that if each push makes the ball's speed increase, then by the time the ball gets the final push its speed will be much greater than at the beginning of its motion.

Exploration #3: What happens if a force keeps acting?

Purpose

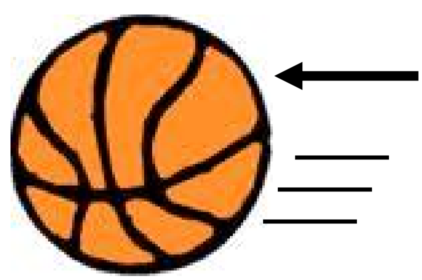
You know that when you gave a toy car a quick push or pull, your hand lost contact with the car very quickly. This means that the force acting on the car lasted only for a very short time. But what would happen if you kept applying the force so that it continued to act on the car for a much longer time? For example, suppose you were to pull a toy with a string, and keep pulling with the same strength force. What would the motion of the toy be like all the time you were pulling it?

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

How does an object move if a force continues to act on it?

What do we think?

In an earlier activity you gave a ball a quick "forward" push as it rolled across the floor.



What effect did the force of your push have on the ball's speed?

Now suppose you arranged for lots of people to each give the ball a quick "forward" push, **<u>one after another</u>**. What effect would the force of each of these pushes have on the speed of the ball?

In the class discussion, make sure students understand what is being described: that the pushes are applied in rapid succession and in the direction of the ball's motion (i.e., the ball does not have time to slow down during the gaps between pushes).

The teacher should lead a group of at least six students in performing this experiment, while the rest of the class watches. Make sure students push from "behind" the ball. If they push from on top they may inadvertently slow the ball as it "rubs" on their hands. It may take a few "runs" to get this to work as it should. Start the ball rolling quite slowly and rely on students' visual perception to see that its speed increases each time it is pushed, and that all these increases add together to produce a very fast final speed.

The teacher should make sure any uncertain students record the observation that each push made the ball's speed increase, even though this may not have occurred in initial trial runs. If a speed-time graph has been drawn, the class can discuss whether it represents (at least approximately) what actually happened.

Overlapping pushes: Make sure students understand the scenario. Basically we want the same procedure as before, but with no "gaps" between pushes.

We are looking for students to say that this will produce bursts of increasing speed, just as before, but with no "gaps" in between. So, all we should see would be continuously increasing speed.

Students may point out that the ball's motion slows down when each new pair of hands touches the ball. If this happens, have students imagine that the same person is pushing the ball continuously, and ask what would happen to the speed of the ball.

At the end of the class discussion, the teacher should summarize the students' thinking in a general way that is not specific to this particular situation. For example, "So, you seem to think that if a force keeps acting on an object it will continue to increase in speed?" This general statement will be easier to relate to what is coming next.

Activity 1: Step 1

Students may wish to try applying a constant force to a rolling object. The activity does not call for it because it is very difficult to "pull off" in a reasonable way. Nevertheless, the teacher may wish to let the class try it to see that. Then the idea of finding another way to apply a continuous force in the next section of the lesson will seem well justified.

Avoid using a narrow ramp or a toy car that fails to go straight because either can lead to the car falling off the side of the ramp before it has moved the required distance.

Remind students that gravity is a force that is always acting on objects, so we can use it to check their ideas. However, falling straight down happens too quickly to measure accurately, so we will use a ramp to allow us to more closely observe and measure the effect of gravity over a greater period of time.

Your teacher will lead a class discussion about everyone's answers to these questions, and then lead the class in an experiment to check what happens.

Did the ball behave as you expected it to? If not, describe what happened.

Now suppose you could arrange for each person's push to overlap with each other, with no gaps in between. This would mean that there was a force pushing the ball forward the whole time.

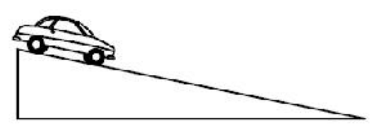
If you were able to do this, how do you think the speed of the ball would behave all the time it was being pushed? Why do you think so?

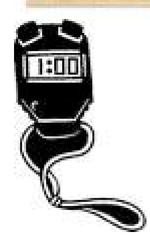
Your teacher will lead a class discussion about everyone's answers to this question.

Activity 1: Moving down a slope

The whole class will work together on this activity. The class will need:

- Ramp
- Toy car
- Meter ruler
- Stopwatches
- Masking tape





STEP 1: We want to examine what happens to an object when a force acts on it for a long time. In reality, it is very hard for people to apply a constant force on an object for longer than a second or two, so we will have to find another way to do this. We know that Earth pulls with a constant gravitational force on objects, but we also know that it is hard to measure the speed of falling

Activity 1: Step 2

The teacher may need to help students see the connection between this situation and the people pushing the basketball; in both cases there is a force acting on the object of interest the whole time it is moving.

Tell students we need to measure the speed of the toy on different parts of the ramp, then let them suggest how to do it. They will likely suggest variations of measuring times and/or distances at different places on the ramp.

In this discussion, the teacher should assist students in thinking about whether their ideas are able to be tested using the available classroom materials.

Let students suggest the distance/time intervals to be measured. If the class suggests distances/times that seem impractical, and time permits, let them go ahead and try them to see why. Then guide them to choose a more practical arrangement such as dividing the total distance into three equal segments and recording the time required for the toy to complete each segment.

objects because they move so quickly. One way to overcome this problem is to have an object move down a ramp instead. When this happens, the gravitational force is still pulling the object down the ramp, but because the ramp is also supporting the object, it will move down the ramp more slowly than if it fell straight downward. (In effect the ramp is cancelling out some, but not all, of the gravitational force.)

STEP 2: Your teacher will show you a ramp and a toy car. As the car rolls down the ramp the gravitational force of Earth will be pulling on it the whole time.

What do you think will happen to the speed of the car as it rolls down the ramp? Why do you think so?

Suggest a way you could check how the speed of the car behaves as it rolls down the ramp.

Your teacher will lead a class discussion about everyone's ideas and how they could be checked.

Describe how the class has decided to check what happens to the speed of the car as it rolls down the ramp?

Activity 1: Step 3

Let students time the toy on different sections of the ramp and help them calculate the speed of each section. It is best to get several measurements for each section. If enough stopwatches are available this can be done by several students at the same time. Otherwise the class will need to run the experiment several times (making sure to start the toy from the same point on the ramp each time.) Be sure consensus is reached about what part (front, back) of the toy is being considered when timing its completion of ramp sections. We recommend using the front of the toy car in this and the subsequent activity (moving up a slope) because it will make carrying out the next activity somewhat easier. Results can be entered on a table on a display board for later discussion.

If no clear pattern emerges from the data, or if timing becomes difficult at the bottom of the ramp, an alternative strategy is to measure the total time for the toy to move from the very start to the end of each segment of the ramp. The time for each individual segment can then be found by subtracting successive times. If necessary, the teacher will likely have to suggest this strategy and perform these calculations for the class.

To calculate average speed for each stage, divide the distance traveled by the time it took the toy car to travel that distance in that stage (i.e., Speed = Distance ÷ Time).

Once the calculations have been performed it should be evident the speed of the toy was increasing as it moved down the ramp. In an experiment like this, there is sometimes a “rogue” measurement that does not fall into the general pattern. If so, the teacher can take the opportunity to talk about causes of uncertainty in measurements and how scientists know that this can happen and so look at the overall trend, rather than focusing too much on one particular value.

STEP 3: The class will now work together to carry out an experiment to measure the speed of the car as it rolls down the ramp.

Record the data the class collects in the table below. Your teacher will help you calculate the speed on each stage of the car's trip down the ramp.

Stage	Distance	Time	Speed

What happened to the speed of the car while the gravitational force was pulling it down the slope? Did it increase the whole time, stay constant the whole time, or increase at first and then stay constant the rest of the time?

Activity 2: Step 1

Now we will do the same thing to see what happens when a force keeps acting on an object in the opposite direction to its motion. To do this, we will arrange for the toy to move up the slope, while the gravitational force is opposing this motion.

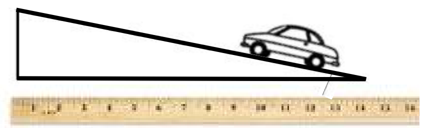
Make sure that students understand that we will have to give the toy a push to start it moving up the ramp, but that after we push it, there will not be an upward force acting on the toy and the gravitation force will be acting downward continuously. Because this force is pulling down the ramp, it will be acting on the toy in the opposite direction to its motion.

Most students will already be aware that the toy will move slower and slower as it goes up the ramp, but may not be able to explain the behavior in terms of the idea that a force is acting in the opposite direction to motion.

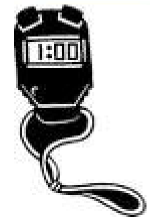
Students will likely suggest doing this in the same way as when the toy rolled down the ramp. The teacher may wish to demonstrate what is going to happen, to start a discussion about what to do if the toy does not make it all the way to the top, and when timing should start. To prevent any damage, consideration should also be given to the possibility that the toy falls after reaching the top of the ramp.

Activity 2: Moving up a slope

The whole class will work together on this activity. The class will need:



- Ramp
- Toy car
- Meter ruler
- Stopwatches
- Masking tape



STEP 1: In the first activity you saw what happened to the speed of an object when a force keeps acting on it in the same direction as its motion. Now suppose you could arrange for a force to keep acting on an object in the opposite direction to its motion. What would happen to it then?

To check our thinking on this question we need to arrange for a force to keep acting on an object in the opposite direction to its motion. One way to do this is to give the toy car a quick push up the ramp. After the quick push is over the car will still be moving up the ramp, but the gravitational force will keep pulling "backwards" on it in the opposite direction to its motion, down the ramp.

What do you think will happen to the speed of the car as it rolls up the ramp (after being given a quick push at the bottom)? Why do you think so?

Your teacher will lead a class discussion about everyone's ideas and how they could be checked.

Activity 2: Step 2

Getting the toy car to travel the full distance of the ramp without going off the top edge is difficult. Instead, indicate a defined end point near the top of the ramp by drawing a line or marking the end point with masking tape. Make sure to measure distances and times using this defined end point.

Once the calculations have been performed it should be evident that the speed of the toy was decreasing as it moved up the ramp.

The teacher may also wish to demonstrate what happens to the toy if it slows to a stop before it gets to the top of the ramp. It will then roll back down, increasing in speed as it goes. Ask the class why this happens.

STEP 2: The class will now work together to carry out an experiment to measure the speed of the car as it rolls up the ramp.

Record the data the class collects in the table below. Your teacher will help you calculate the speed on each stage of the car's trip up the ramp.

Stage	Distance	Time	Speed

What happened to the speed of the car while the gravitational force was pulling it in the opposite direction to its motion? Did it decrease the whole time, stay constant the whole time, or decrease at first and then stay constant the rest of the time?

Making Sense Questions

Question 1: By now students should be comfortable with the idea that the object's speed will continue to increase when a force keeps acting in the direction of its motion. Make sure students cite evidence from the activities in this lesson to support their answers.

Question 2: Students may have trouble expressing their thinking on this question, so the teacher should be prepared to help.

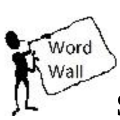
As the person applies a force to the ball, its speed will increase. In order to keep applying the force, the person's speed will also have to increase to keep up with the ball. This would be difficult to do because people cannot easily run faster and faster. If students attempted this earlier in this lesson (just before Activity 1 step 1), they should cite these experiences as evidence for their answer to this question.

Question 3: By now students should be comfortable with the idea that the object's speed will decrease when a force keeps acting in a direction opposite to its motion. Make sure students provide evidence for their answer to this question. For example, a student might say "When a force keeps acting on an object in the opposite direction to its motion, the object's speed will decrease. We saw this when the toy car rolled up the slope and its speed decreased because Earth's gravitational pull kept acting in the direction opposite to its motion."

Question 4: Students may need help thinking this scenario through in steps. In the end it would be the same as if the toy had gone up and then back down the ramp. Breaking it into stages we get:

- On the way up, the gravitational force is acting on the ball in the opposite direction to its motion so its speed is decreasing. Eventually it will slow to such a point that its speed reaches zero, meaning it stops (though only momentarily).
- When the rising ball stops (as its speed reaches zero), the downward gravitational force is still acting on it. When a force acts on an object that is at rest, it will begin to move in the direction of that force, so the ball begins to move downward.
- As the ball moves downward, the gravitational force is now acting on it in the same direction as its motion, so the ball's speed increases as it falls.

Help students relate the motion of the ball in the air to what they observed when the toy car moved on the ramp.



Science Vocabulary

The term "**continuous force**" is introduced in this lesson. If students can demonstrate that they understand what a "**continuous force**" is, and how it is different from a force that is applied only briefly, then it would be appropriate to add the term "**continuous force**" to the word wall.

Making Sense

Your teacher will lead a class discussion on what happens to objects when a force keeps acting on them. Write answers to the following questions after each one is discussed.

1. When a force keeps acting on an object in the same direction as its motion, what happens to its speed?

2. Suppose one person wanted to check their ideas about forces and tried to keep applying a "forward" force to a ball as it was rolling across the floor. How would that person have to move in order to keep up with the ball and keep pushing on it? Why might this be hard to do?

3. When a force keeps acting on an object in the opposite direction to its motion, what happens to its speed?

4. When you toss a ball straight up into the air it comes back down. What do you think is happening to its speed on the way up and then on the way back down? How would you explain this behavior in terms of the gravitational force acting on it?

Unit 2 Cycle 1

Exploration #4: Slowing and stopping

LESSON TARGET IDEAS

Most moving objects slow and stop because a frictional force acts on them. Friction is a force that acts on a moving object in the opposite direction to its motion when it moves across a surface.

COMMON MISCONCEPTIONS

- *Objects slow and stop because it is their "natural tendency" to do so.* (It is not. A force, usually frictional in nature, must be responsible.)
- *When an object moves across a horizontal surface, the frictional force acts on it in an upward or downward direction.* (It does not. The frictional force acts in the opposite direction to motion.)
- *Objects move slower because the force pushing them forward gradually runs out.* (This misconception is usually accompanied by the idea that this force was transferred from some other object. These ideas are specifically addressed in Unit 2 Cycle 1 Exploration #1: When does a force stop?)
- *Objects slow and stop because of the gravitational force acting on them.* (Because the gravitational force always acts downward at Earth's surface, it can only be responsible for slowing an object that is moving upward. However, if an object is moving across a horizontal surface then it is the gravitational force that "holds" it on that surface as it moves, which then in turn produces a frictional force.)

WHAT TO FOCUS ON

In this lesson we attempt to tackle another of the deeply held misconceptions—that it is a natural, innate tendency of a moving object to slow and stop. When people hold this idea it is usually because they either do not appreciate the role that frictional forces play in the motion of an object, or that they do not consider "friction" to be a force. In this lesson we attempt to show that friction is indeed a force, and that it acts to oppose the motion of objects.

In the activity, students move a wooden block across a flat surface, first pushing on foam (the force detector) attached to the top of the block. The deformation of the foam provides evidence that a force is being applied (in the direction of motion). Next, students push the block with foam attached to the bottom of the block. They should observe that the foam deforms, providing evidence of a force acting opposite the motion of the block; this force is the force of friction. In this part of the activity, it is important that students pay close attention to the bottom "leading" edge of the foam in order to see the deformation, as it is not as obvious as the deformation caused by the push of a finger.

Throughout the lesson, students may also suggest gravity is a force that acts on the objects they are observing, causing them to move slower and slower. Although gravity affects the force of friction, the relationship between the two is not an appropriate concept for students at this grade level. The teacher should acknowledge that gravity is a force that is acting on the object, but redirect the students' focus to forces that act in the direction of or in the direction opposite to the object's motion.

MATERIALS NEEDED FOR THIS LESSON

Material	Quantity
Foam (low density) "force detector"	1 per student group
Large toy car	1 per class
Wooden block (approximately 2" X 4" X 2")	1 per student group
Glue dots/double sided mounting tape pieces	Several per student group

Purpose

The teacher should set the scene for the lesson by asking the class what seems to happen to moving objects if they are left alone. Many students will agree that most things seem to slow and stop if nothing else is done to keep them moving. The teacher can then tell the class that it is this tendency that will be examined in this lesson.

What do we think?

Make sure students understand that the ball is rolling across the grass. It was not kicked into the air.

Some students may say that the grass is slowing the ball down, without necessarily associating this with a force. Others may explicitly say “friction” without saying what is causing it.

Some may still hold the idea that because the ball is moving forward there must be a force pushing it forward and so may take the question in a way that was not intended!

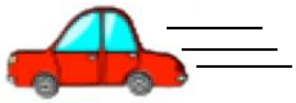
The teacher should accept all ideas at this point and summarize the thinking about whether there are any forces acting on the ball while it is slowing as it moves across the grass. Then, the teacher should introduce the next part of the lesson, telling the class that they will use the “force detectors” they used earlier, this time to investigate the forces acting on an object as it slows down.

Unit 2 Cycle 1

Exploration #4: Slowing and stopping

Purpose

You have already done several experiments in which you started an object moving with a quick push, but so far we have not studied what happens after such a push.



For example, after you give a toy car a quick push, you know it will get slower and slower, and eventually stop. In this activity we will examine why this happens to most moving objects if the force that started them stops acting.

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

Why do most moving objects slow and stop?

What do we think?

Imagine you were to give a soccer ball a quick kick, so that it rolls across the ground, getting slower and slower, until it comes to a stop.

While the ball is rolling, after your kick, do you think a force is acting on it, or not? Explain your thinking.

Your teacher will lead a class discussion about everyone's answers to this question.

Activity

The teacher should check that the foam has the right properties to visibly deform when slid across a table attached to a block. Note that this activity uses a different type of foam than the earlier activity (Unit 2, Cycle 1, Exploration #1: "When is the force there?"); regular density or low density polyurethane foam will likely be best for this activity. Using a black marker, create a black line on the bottom "leading" edge of the foam; this will make it easier for students to see the foam deforming when the block is pushed, foam side down, against the table in this activity. A short section of a 2" x 4" piece of wood is a good size for the block.

Activity: Step 1

Make sure that students push the block firmly enough that it moves at least a short distance before coming to a stop. They should not get the impression it stops immediately, but instead slows down quickly before stopping.

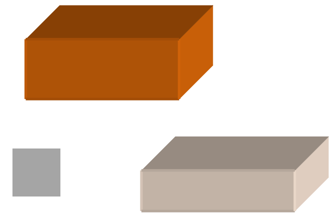
Some students may agree that a force is acting and use the block's slowing as their justification. Others may refer to friction and/or rubbing without necessarily associating it with a force. The teacher should not try to direct thinking at this point as they will see some evidence to direct them in the next step.

Instead, the teacher should remind the class that they know that a force acting on an object in the opposite direction to its motion can slow its motion. The teacher could then get a further sense of student thinking at this point by asking if objects would slow and stop on their own anyway, even if such a force were not present.

Activity: Step 2

Remind the class of the foam "force detector" they used earlier. They will use a piece of foam again to see what forces act on a block while it is being moved across the table.

Activity: Why do most objects slow and eventually stop moving?



You will work in groups for this activity. Each group will need:

- Wood block
- Mounting square
- Foam square

STEP 1: Place the wood block on the table in front of you and give it a quick firm push to start it moving. Watch what happens to the block <u>**after your push**</u>.

Describe what happens to the block after your push.

During your push you know that you were applying a force to the block. Do you think a force was acting on the block after your push? Explain your reasoning.

STEP 2: After your push, the block slowed and stopped very quickly. You know that a force acting "backwards" on a moving object can have this effect, but is a force always needed to make this happen, or do some moving objects just naturally slow and stop on their own? In order to investigate this question we will need to find out if a "backward" force acts on the block as it slides across the table.

Use the mounting square to attach the foam square to one face of the wooden block. Place the block on the table with the foam square on the top. Push on

Monitor the groups to make sure 1) the foam is mounted firmly on the block, and 2) they know to keep pushing and not just give a quick shove.

It should be evident to students from the visible deformation of the foam that a "forward" force is acting.

Again, it should be evident that it is the hand that was interacting with the block to produce this "forward" force.

Make sure students understand that they will be pushing on the block, but watching the foam that is now in contact with the table. Monitor the groups to make sure they are looking at the "front" edge of the foam and noticing the deformation of the foam.

NOTE: If the deformation of the foam is hard to see, it may be made more visible by darkening the "front" edge of the foam that touches the surface with a black marker.

Students should agree that a force was acting "backward" on the block, based on the visible deformation of the foam.

Because it now was the table in contact with the foam, it must have been the interaction with the table that created the "backward" force.

The teacher should lead a class discussion on what the students have seen and what this seems to imply in terms of a backward force acting on the block as it slides across the table.

The teacher should then give a brief introduction to frictional forces.

the foam to start the block moving, and **keep pushing** so that the block keeps moving across the table.

Was a force pushing "forward" on the block while it was moving across the table? How do you know?

If a force was acting, what other object was the block interacting with to create that force?

Return the block to its starting point and turn it over so that the foam square is now on the bottom (resting on the table). Now push on the block to start it moving, and **keep pushing** so that the block keeps moving across the table. Look carefully at the foam square while the block is moving across the table.

Was a force pushing "backwards" on the block while it was moving across the table? How do you know?

If a force was acting, what other object was the block interacting with to create that force?

Your teacher will lead a class discussion about everyone's observations and what they mean.

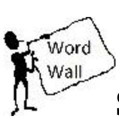
Making Sense Questions

Question 1: Given the discussion that has just taken place, students will likely attribute the slowing to "friction." The teacher should prompt students to explain in more detail, asking whether they think the "backward" force they saw evidence for would still be present *after* a quick push, and if so, what effect this force would have. A typical student answer to this making sense question might be: "Friction made the block slow down." The teacher will likely need to probe for a more complete answer: that the friction between the block and the surface it was sliding on was a force in the direction opposite of the block's motion (or "backward force") that caused the speed of the block to decrease. Asking students where the force of friction occurred and in what direction may help elicit a more complete answer.

Question 2: Again, students will likely attribute this behavior to friction now. (Note: Actually, the main source of friction for a wheeled vehicle is usually between the wheels, axles, and mountings, rather than between the wheels and the surface. However, this level of detail is not important, and may be confusing, at this point.) A typical student response to this question might also be "The toy car stopped because of friction." The teacher should probe for a more complete answer that includes a reference to friction as a force acting in the direction opposite of the toy car's motion (or "backward force") that causes the speed of the toy car to decrease.

Question 3: Students may simply say that the car was on wheels, whereas the block was not. The teacher should prompt the class to say something about how strong the frictional force was in each case. For example, the teacher may ask the follow-up question: How does the frictional force between the moving block and the table compare with the frictional force between the rolling car and the table? (We are looking for a comparison of strengths, not actual values!) The desired response to this question is: "there was less friction for the rolling car than the sliding block, so the force in the direction opposite of the object's motion (or "backward force") was weaker for the car and its speed decreased more slowly."

Note: This is the first time students have been asked explicitly about force strengths. It is really in preparation for the next Cycle and should not be delved into too deeply here.



Science Vocabulary

The term "**friction**" is introduced in this lesson. If students understand the concept of "**friction**" at this point, it would appropriate to add this term to the word wall.

Friction

Whenever an object moves across a surface it is touching (or two surfaces rub together), they interact with each other to create a "backwards" force acting on the moving object. We call this type of force a ***frictional force***, or ***friction*** for short. So, as the block moved across the table, the table applied a "backwards" frictional force to the block.

Making Sense

Your teacher will lead a class discussion on friction. Write answers to the following questions after each one is discussed.

1. When you gave the wood block a quick push, it slowed and stopped very quickly. Why did this happen?

2. Place a toy car on the table (or on the floor) and give it a quick push. It should also slow and stop (but move a lot farther while doing so). Why do you think the toy car slowed and stopped?

3. Why do you think the toy car moved a lot farther than the wood block while it was slowing and stopping?

Unit 2 Cycle 1

Application: What if there were no force?

LESSON TARGET IDEAS

If no forces act on an object its speed and direction will remain constant. This principle applies to an object at rest (it will remain at rest) and an object in motion (it will continue moving at a constant speed in a straight line.)

COMMON MISCONCEPTIONS

- *If no forces act on a moving object it will slow and stop.* (It will not. There needs to be a "backward" force to make this happen!)
- *The "natural state" of an object, in the absence of any forces acting on it, is to be at rest.* (It is not. In the absence of any forces, an object's "natural state" is for its motion to remain constant.)

WHAT TO FOCUS ON

Having established that the effect of "forward" and "backward" forces is to change the speed and/or direction of an object, we now finally come to examine what happens when no forces act. It is another widely held misconception that in the absence of any forces a moving object will slow and stop. To make it easier to confront, we have slowly been building a logical framework associating forces with changes in motion. Hopefully, in this way, it will be easier for students to associate "no forces" with "no change in motion."

In the activity, students first push a CD balloon puck across a flat surface, and should observe it slow and then stop quite quickly. Students should recognize that the force of friction between the puck and the flat surface causes the puck to slow and stop. Then, they inflate the balloon and push the puck while the balloon slowly deflates and provides a cushion of air between the CD and flat surface greatly reducing friction. They should observe the puck move at a fairly constant speed and in the same direction of the push for a much longer time. This observation provides evidence that if no forces act on an object in motion, its speed and direction will remain constant.

In the last part of the activity, students predict and then experiment with different ways to change the motion of the puck (with the balloon deflating) after it is pushed. Students should observe that the motion of the puck changes only when they apply a force to it.

During discussions about the forces that act on the puck while it is riding on a cushion of air, students may bring up the force of gravity. The teacher should acknowledge that gravity is acting on the puck, and indicate that the air coming out of the balloon cancels out the force of gravity (which is why the puck floats or hovers above the surface), and should encourage students to focus on other forces that act affect the puck's motion (forward, backward, and sideways forces).

MATERIALS NEEDED FOR THIS LESSON

Material	Quantity
CD-based balloon puck Instructions for assembly of the balloon puck are available at the following website: http://www.exo.net/~pauld/activities/frictionless_cd_puck.html	1 per student group

Purpose

In the introduction to the lesson, the teacher should remind the class of what they have discovered so far about the connection between forces and motion. Namely, that forces seem to change the motion of an object in some way. (Perhaps giving some examples.) The teacher might then pose the following questions (but not have students answer at this point): "But what would happen to an object if no forces act on it?" and "What if we used a force to start it moving and then took all the forces away?"

What do we think?

Make sure students understand that this is a question about the ball's motion between the pushes. Most will likely say the speed is decreasing, either because of a frictional force, or because there is no force. Some may say that the speed is constant, based on some reasoning about the connection between forces and change in motion. Accept all answers at this point.

Unit 2 Cycle 1

Application: What if there were no force?

Purpose

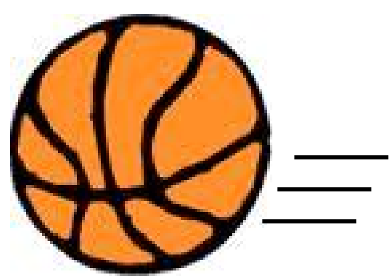
You have now seen that when a force acts on an object, its motion changes in some way; either it gets faster, or it gets slower, or its changes direction. Now we will use these ideas to think about what would happen to an object if **no force** acted on it. In other words, we will investigate what happens to an object's speed and direction during any period of time in which no force acts on it.

For example, suppose you stood on a skateboard and someone gave you a quick push to start you moving. What would your motion be like after their push?

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

What happens to an object's speed and direction if no force acts on it?

What do we think?



When you were experimenting with the ball rolling across the floor, there were periods during which you were not pushing it. What do you think was happening to the ball's speed while you were not exerting a force on it?

In between your pushes, do you think the speed of the ball was increasing, decreasing, or staying constant? Why do you think so?

The teacher should establish the different ideas in the class. Try to have the class consider explicitly what would happen if friction were present versus if it were not.

Activity

The teacher should show the class a puck, but not how it works at this point. For management purposes, it would be okay to distribute the pucks without balloons for this part of the lesson. Alternatively, the teacher may choose to do the puck activities as a teacher-led demonstration. In either case, the activity works best on a level, smooth surface.

Activity: Step 1

Be sure to first demonstrate what happens when the puck is pushed and the balloon is either not attached, not inflated, or is inflated but the valve is closed (i.e., the balloon is not deflating). Students should note that the puck slows and stops very quickly and will likely attribute this behavior to a frictional force caused by sliding across the table.

Let students brainstorm on this question. It may be worth having a brief class discussion to establish the ideas present in the class. There are likely to be up to three different ideas:

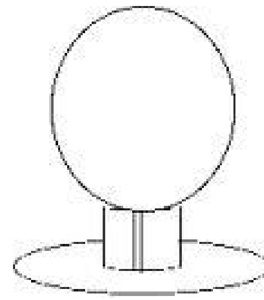
1) Some may say it will slow and stop in just the same way as before. Those who think this way are likely attributing the subsequent motion of the puck to the force that got it started moving to begin with. They may even still hold the idea that the force of the initial push is transferred to the puck and then “runs out” quickly. Hopefully this will be few, if any, students.
2) Some may say the puck will still slow and stop, but it will take a lot longer to do so. There may be two lines of reasoning for this thinking. First, that friction cannot be completely eliminated so there will still be a very weak force that eventually stops the puck. However, the more likely line of thinking will be based on a “natural tendency” of moving objects to eventually slow and stop, even in the absence of any “backward” forces.
3) A few students may reason that, given the connection between forces and changes in motion, in the absence of any friction to slow it down, the puck will just keep moving.

Your teacher will lead a class discussion about everyone's answers to this question.

Activity: What if there were no friction?

You will work in groups on this activity. Each group will need:

- CD balloon puck



STEP 1: Place the CD balloon puck on the table (or on the floor) and give it a quick push to start it moving.

Describe what happens to the puck after your push. Why do you think it behaves like this?

Imagine you could arrange for the puck to move without being affected by a friction force.

If there were no friction, what do you think would happen to the puck after you gave it a quick push? Do you think it would still slow and stop, or would something else happen? Why do you think so?

STEP 2: One way to greatly reduce the effect of friction is to have an object float on a thin cushion of air, like a hovercraft. In this way we can prevent an object from touching the surface as it moves along.

Activity: Step 2

The teacher should demonstrate how the puck works. For hygiene reasons it is best for each student to have their own balloon. Be sure the valve is closed (pop-up top pushed in) before attaching the balloon. Twisting the neck of the balloon after it is inflated allows it to be placed on the puck without losing a lot of air.

If you did not distribute balloons earlier, you will need to do so now.

Ask students to be careful in attaching the balloon and in opening the valve as the bottle top might come unglued. They should hold the bottom of the bottle top (**not** the CD surface) while they pull up on the valve. Including the toilet paper tube collar is important because it keeps the balloon directly above the air nozzle, preventing it from "leaning" or dragging on the table or floor.

Activity: Step 3

It should be obvious to students that the puck does not slow and stop as it did before, but keep moving (unless it hits something). Some students may focus on the fact that the puck does eventually stop, when the air in the balloon runs out. Encourage them to focus on how the puck behaves before this happens.

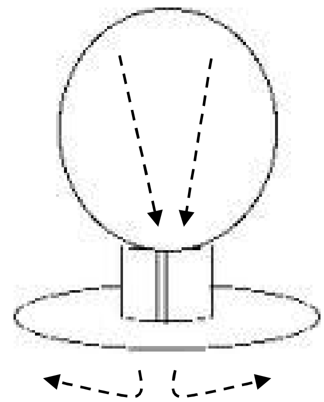
Important: If the table or floor is not level and/or smooth, some students may actually see the puck slow, increase speed, and/or change direction. The teacher should have a level, smooth surface ready to demonstrate the expected behavior, just in case!

Students should infer that the puck's speed stays constant (at least approximately). They may need some help in reasoning this from the observation that it does not slow and stop quickly.

Again, students should infer that the puck's direction does not change.

Check that students were focusing on what happens before the air runs out. At the least everyone should agree that the puck seems to have a tendency to "keep going" rather than slow and stop quickly. Some may wish to add that the speed and direction seem to remain constant after the initial push.

Your CD-balloon puck can be made to behave like a hovercraft. When the balloon is inflated and placed on the puck, air flows down through the hole in the middle and out under the sides of the CD, lifting it off the surface a little. As the puck moves, it rides on this thin cushion of air, rather than actually touching the surface it is on.



Your teacher will instruct you how to use the puck in this way.

STEP 3: Place the puck, with balloon inflated and attached, on the table (or floor). Carefully release the pop-up top so that air can flow to the bottom of the puck. It should now be floating on a very thin cushion of air, allowing it to move across the surface with **<u>little or no friction</u>**.

Give the puck a quick push to start it moving.

What happens to the puck **<u>after your push</u>**? Does it slow and stop like it did in STEP 1, or does it just keep moving?

What does this behavior tell you about its speed **<u>after your push</u>**? Did its speed decrease quickly, or did it stay constant?

After your push, did the puck keep moving in a straight line, or did its direction change?

Your teacher will lead a class discussion about everyone's observations.

Activity: Step 4

Make sure students understand that we are now talking about **after** their initial push, with the puck already moving. Also make sure they justify any method proposed in terms of a force in the appropriate direction relative to motion.

It should be obvious to students that a force applied in the direction of motion will make the speed increase. This force could be applied in any number of ways, such as with the hand, another object, or even by blowing. Some may suggest tilting the table. This is OK providing they can justify this action in terms of having the gravitational force pull on the puck down the slope.

Some students may say that we simply need to wait for the balloon to run out of air. If so, the teacher should redirect their thinking to before this happens. Most students will propose that a force be applied in the opposite direction to motion. This force could again be applied in any number of ways, such as with the hand, letting the puck hit another object, or tilting the table.

Again, students will likely propose that a force be applied in a "sideways" direction to motion, in any number of ways.

Monitor the groups to make sure they apply the forces soon enough to see the desired effect. If they are tapping the puck backward to decrease its speed, make sure they are gentle enough to make speed decrease, but not make the puck reverse direction. (Or better still, have them do both!)

Students should say that they had to interact with the puck in order to apply a force to it. If they used other objects, or tilted the table to use the gravitational force, the teacher may need to re-phrase this question in terms of having another object interact with the puck, rather than just the students themselves.

Most students will say that it will stop when the balloon runs out of air. The teacher can then ask why it would stop only when this happens: "What does running out of air change about the puck's interactions with the surroundings?"

STEP 4: Now think about what the puck's behavior **<u>after your push</u>** and what you could do to change its motion in some way.

What could you do to make the puck's speed increase?

What could you do to make the puck's speed decrease?

What could you do to change the puck's direction?

Now use the puck to check your thinking.

Did your ideas about how to change the motion of the puck work?

Why do you think you had to interact with the puck in some way to change its motion?

If you did not interact with the puck in any way do you think it would ever stop moving? If so, why?

Making Sense Questions

Question 1: We are looking for the idea that if no forces act on an object, then its speed and direction will remain constant. Some students will say that such an object would never start moving, and they are correct in the sense that a force is needed to start it moving. However, for this question have them imagine applying a force to start an object moving, and then removing that force once the object is moving. Encourage students to use observations from the CD-puck activity to support their explanations.

Question 2: There are likely to be several schools of thought on this question, all of which are worth pursuing. In any case, ask students what evidence from the activity would support their hypothesis:

1) Some students will say that the puck would reach the other end of the hallway because no forces would act on it to change its motion once it has been started. This answer is acceptable.
2) Some students will say that the puck would slow and stop very gradually because there is still a little friction present (perhaps from the air rather than the floor). Although this is also an acceptable answer, encourage students to imagine what would happen if there were no friction at all.
3) Some students may say that there will be small imperfections in the floor that will slow and stop the puck. Students who answer similar to 1, 2, or 3 are really thinking in the same way about force and motion, but disagree as to whether the actual conditions are "ideal." In the discussion, the teacher should aim toward having students agree that IF there were truly no forces (e.g., friction), then speed and direction would remain constant, but in the real world it is very hard to have no forces at all.
4) A few students may still say that it is the natural tendency of objects to slow and stop eventually. So, depending on the length of the hallway, the puck may not make it to the other end. These students have still not made the connection between forces and changes in motion. Hopefully there will be few (if any) students still thinking this way. If there are still a substantial number it may be worth reviewing the evidence connecting force and motion and trying to come up with a simple set of "rules":
   A. If a force acts on a moving object in the same direction as its motion, its speed will increase.
   B. If a force acts on a moving object in the opposite direction to its motion, its speed will decrease.
   C. If a force acts on a moving object in a "sideways" direction, its direction of motion will change.

   Given these rules, ask students to think logically what would happen to a moving object if no forces act on it.

Question 3: It is worth pointing out to students that an object at rest has a constant speed. (It just happens to be constant at zero!) Students may say the pencil's speed does not change because nothing is pushing it to make it move. If so, have them rephrase this in terms of the idea that no forces are acting on it, so its speed does not change. Some students may argue (correctly) that a gravitational force, and perhaps a supporting force (again, correctly), is acting on the pencil. If this comes up, the question can be modified to address the idea that the pencil is not moving horizontally, so no horizontal forces are acting on it.

Making Sense

Your teacher will lead a class discussion on how objects behave when no forces act on them. Write answers to these questions after each one is discussed.

1. When you start an object moving, and then arrange for no forces to act on it, how will its speed and direction behave? Why is this?

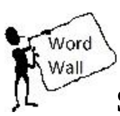
2. Suppose you could attach a very large balloon to the puck and then start it moving down a very long hallway. Do you think it would reach the other end or not? Explain your thinking.

3. Lay your pencil on the table in front of you. As it sits there, its speed stays constant (it stays at zero). Why do you think its speed is not changing?

Question 4: Students should be comfortable saying that in order to start an object moving, a force is needed, and that to apply a force, an interaction is needed. Again, some may suggest tilting the table. If so, the teacher should ask whether they are still using some type of interaction to start the pencil moving. (They are; the force that starts the pencil moving is Earth's gravitational pull.)

Question 5: Hopefully, by this time, most students will agree with Yuri. In the absence of any opposing forces (we will get to combinations of forces in the next Cycle), no forward force is needed to maintain motion at constant speed in a straight line. However, a force is needed to start motion, because "starting to move" is a change in motion and we need a force to cause such a change. Have students use their observations from the CD-puck activity as a source of support for their explanations.

A few students may agree with Spike. If so, they might not realize that there is no air in space (and thus no air resistance) and think that air resistance is a force acting on the spacecraft. It is more likely, though, that they still hold the idea that it is a natural tendency of moving object to slow and stop, even in the absence of opposing forces. If this is the case, the intellectual argument outlined above for question 2 number 4 should be used at this point.



Science Vocabulary

There is no new science vocabulary introduced in this lesson.

4. To start your pencil moving you would have to interact with it in some way? Why is this?

5. Suppose a spacecraft is at rest in deep space, far from any stars or planets, so that no frictional or gravitational forces can act on it. Two astronauts want to move the spacecraft to a different place that is far away and discuss how they could do this.

Do you agree with Yuri or Spike? Explain why.

