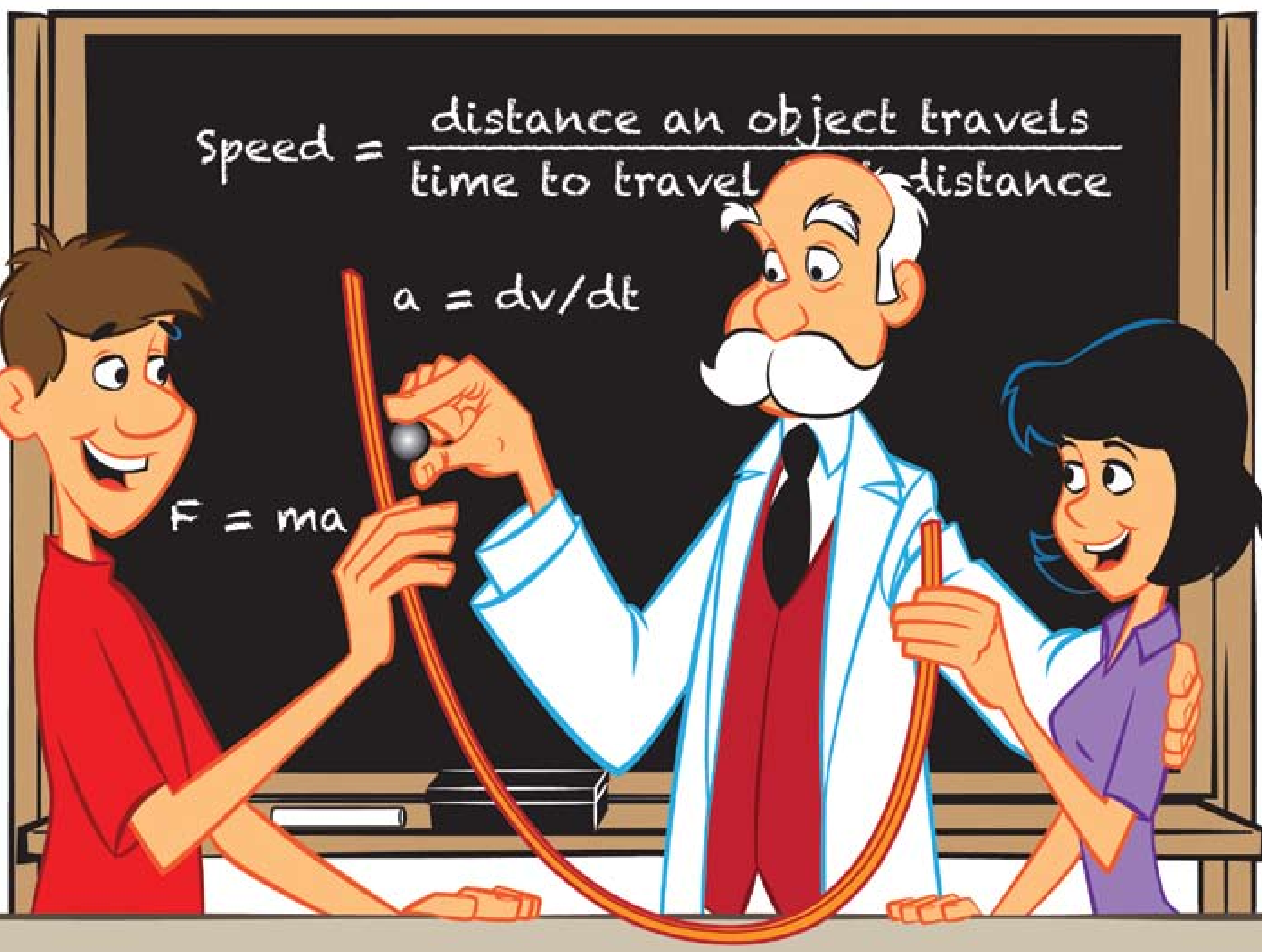
Companion Classroom Activities for

Stop Faking It!

Force & Motion



William C. Robertson, PhD
Illustrations by **Brian Diskin**

NSTA press
National Science Teachers Association

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By William C. Robertson, PhD
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NSTApress
National Science Teachers Association
Arlington, Virginia

NSTA press®
National Science Teachers Association

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14 13 12 11 4 3 2 1

Library of Congress Cataloging-in-Publication Data
Robertson, William C.
Companion classroom activities for force & motion : stop faking it! / by William C. Robertson ; illustrated by Brian Diskin.
p. cm.
Includes bibliographical references and index.
ISBN 978-1-936137-28-2 (alk. paper)
1. Motion—Study and teaching (Elementary)—Activity programs. 2. Motion—Study and teaching (Middle school)—Activity programs. 3. Force and energy—Study and teaching (Elementary)—Activity programs. 4. Force and energy—Study and teaching (Middle school)—Activity programs. I. Title.
QC128.R63 2011
531'.110712—dc22
2011012842

eISBN 978-1-936137-43-5

Contents[1]

[1] A word about the numbering system above: I explain in the Preface that the activities are organized based on the learning cycle. The numbers correlate with the phases of the learning cycle as follows: .1 = *Explore*, .2 = *Explain*, .3 = *Elaborate*. There are also .4 *Evaluation* sections interspersed throughout the book. Each chapter, with a couple of exceptions, covers one trip through the phases of the learning cycle. Thus "Teacher Guide to Activity 1.1" is the teacher guide to activity chapter 1, *Explore* phase. A few of the activities cover both *Explore* and *Explain*, so the activities are numbered .1/.2 (as in Chapter 2.1/2.2, for example). Got it? Feel free to go read the preface now!

Chapter 3 - Acceleration

Chapter 4 - Newton's First Law, Part I

Chapter 5 - Newton's First Law, Part II

Chapter 6 - Net or Unbalanced Forces

Chapter 7 - Newton's Second Law

Chapter 8 - Gravitational Forces

Chapter 9 - Mass and Weight

Chapter 10 - Newton's Third Law

Preface

From the day the first *Stop Faking It!* book was published, teachers have been asking for books of classroom activities to go with them. So, only eight years late, here is the first book of classroom activities to accompany the *Force and Motion* book. First, let's have a few words about the activities and the structure of this book.

Adjusting to Your Needs

The suggested grade range for these activities is 5 through 9. The activities are appropriate for upper elementary and middle school physical science, as well as high school conceptual physics. With such a wide range of ages and abilities of students exposed to these activities, you will most likely have to adjust to your particular group of students. I have done most of these activities with students as young as third grade, so with patience there is little in here your students won't be able to do physically. On the other hand, some concepts might be beyond younger students. Although I strongly believe that you can teach students of any age almost anything given enough time, you might not think it worth the time in all cases. So, you might choose to avoid certain more abstract ideas, especially ones that involve mathematical reasoning. It is ultimately up to you, the teacher, to determine what to include and what to leave out. I should mention that the approximate times specified in the activities are about what one would expect from average seventh graders (if there is such a thing as *average* seventh graders!). You might have to adjust these times up or down to fit the needs of your students.

Reading Level

This is related to the Adjusting Your Needs section. It's difficult to write explanations that fifth graders can read and ninth graders won't find insulting, so I have simply written the student explanations in as clear and entertaining a way as I can. I have found over the years that when you write in the manner you speak, and imagine the audience to whom you're speaking, most students "get it." When you write so as to meet a particular reading level, your writing becomes stilted and boring. So, I've done my best for the given audience. Still, you are free to decide how to handle the readings with your class. You might wish to read and explain the concepts to them or you might wish to have the students read aloud or work in pairs. Whatever works. The main idea is for the students to understand the concepts.

The Learning Cycle

These activities and readings are written using the learning cycle. There are three basic phases of the learning cycle—*Explore*, *Explain*, and *Elaborate*. I outline the purpose of each in the following section, but before I do that you might notice that the labels for these sections are the same ones used in the 5E Learning Cycle. The middle three sections of the 5 Es are, in fact, the learning cycle. I was on the curriculum development team at Biological Sciences Curriculum Study (BSCS) that "fleshed out" the 5 Es. Credit for adding two phases (*Engage* and *Evaluate*) to the Learning Cycle goes to Rodger Bybee, then associate director of BSCS, and the rest of us, along with Rodger, did nothing more than hash out how all five phases would work for us in curriculum development.

So why not use the 5E Learning Cycle? Personally, I find that using all five steps all the time, which is what teachers have come to expect, can be restrictive. It's easier, I think, to focus on the learning cycle and then use the extra steps of the 5 Es whenever necessary. I don't think it's always necessary, for example, to use the *Engage* phase (attention grabber) of the 5 Es, nor is it necessary to *Evaluate* (last stage of 5 Es) every time you have completed a cycle. So, what you have in this book is the learning cycle, using the names of phases incorporated in the 5 Es. Now let's examine the phases of the learning cycle.

Explore

The purpose of this phase is to "set up" the learner for understanding certain science concepts. It usually consists of hands-on activities, but not always. It consists of providing a common set of experiences for all the students in the classroom so everyone is on the same page when it comes time to explain concepts. An important part of *Explore* is the "debriefing" of students or student teams, discussing what results they all obtained in a particular activity. The *Explore* phase is *not* the time to explain concepts or provide background material. That might be what one does in more traditional teaching, but not in the learning cycle. Another useful thing to do in the *Explore* phase is to find out what the students know about concepts prior to formal education. To that end, I highly recommend using the formative assessment probes in the book by Page Keeley and Rand Harrington, *Uncovering Student Ideas in Physical Science, Vol. 1*, published by NSTA Press. You can use these probes prior to or during the Exploration activities in this book. You might also use them after the completion of Elaboration activities to evaluate how much your students have learned. Not all of the probes in that book fit nicely with the activities in this book, but many do. It would be worth your while to browse through the probes to discover which ones fit best.

Explain

The purpose of the *Explain* phase is to explain certain concepts in terms of the Explore activities the learner has just done. People understand concepts better when they are anchored in concrete experiences. In this book, most of the explanations are provided in readings, but you can also explain concepts by "drawing out" student explanations for what has happened and gradually leading them to an understanding of the appropriate science concepts. The *Explain* phase is where *traditional* instruction begins, as an abstract presentation without benefit of previous concrete experiences. Research has shown that such traditional instruction is inferior in terms of student learning to the learning cycle as used in this book.

Elaborate

Once the students have been exposed (in the *Explain* phase) to given science concepts, you can't expect them to have a complete grasp of the ideas. The students need to apply these concepts in novel situations, which is what happens in the *Elaboration* phase. The students attempt to perform new activities and apply the concepts they've learned. It's appropriate in this phase for you to let the students struggle a bit as they attempt to apply concepts, but it's also appropriate for you to step in and help them figure things out.

Evaluations

There are sets of multiple-choice items interspersed between activities in this book. You can use these as you see fit. While you might incorporate them in determining grades, these items are just as useful as *formative* evaluations—helping you know where the students are in their understanding as you go through the lessons.

Working in Teams

Each activity has suggested group sizes, but these are only suggestions. I have written curriculum in which not only team size is dictated, but particular cooperative learning roles are dictated. I found that strict dictation of team size and team duties can be rather restrictive for teachers (and for me as a writer!) and that the focus on cooperative learning too often distracts from the learning of concepts. That said, you are more than welcome to incorporate cooperative learning strategies into these activities. There are many good books on the subject, and using cooperative groups can, at minimum, help with potential classroom management headaches that can accompany hands-on science teaching.

Finally, I should mention that although many of the activities here are the same or similar to activities in the *Stop Faking It!* book, some are different. In those cases, I have hopefully provided enough background information to help you figure out what's going on. And in case you're new to science teaching, it's a good idea to figure out what's going on before you do activities in the classroom! I hope you enjoy these activities and that they help improve your students' understanding of force and motion concepts.

Regarding the new activities not contained in the *Stop Faking It!* book, I have the original developers of the curriculum used in the Mickelson/ExxonMobil Teacher's Academy to thank for many of them. Those people are Carla Billups, Sharon Bowers, Justin DeWall, Rich Hogan, Sharon Pearson, and Joe Sciulli.

Chapter 3
Acceleration

Changing Motion

Objectives: The students will describe and demonstrate at least two methods for changing the speed only, the direction only, and both direction and speed of a moving object. The students will use the terms *speed* and *velocity* properly.

Process Skills Addressed: Observing, classifying, communicating, designing investigations, acquiring data

National Science Education Standards Addressed: Content standard B: Position and motion of objects; Properties and changes of properties in matter; Motions and forces

Position in the Learning Cycle: *Explore.* You are having the students do activities that will set them up for understanding the definition of acceleration. The students have a fair amount of freedom in meeting three challenges. This is not the time to introduce the concept of acceleration. You can, however, use this activity as an elaboration of the concepts of speed and velocity.

Relevant Pages in *Force and Motion Stop Faking It!* Book: Pages 17–21

Suggested Group Size: 2 or 3

Materials: 1 golf ball (or similar) per group. Various other materials from around the room. You might leave Hot Wheels tracks and rolls of masking tape lying around.

Approximate Time: 45 minutes

Procedure:

1. **Ask the students to give examples of objects that are changing their motion.** Examples are cars speeding up and slowing down, people walking and then stopping, and someone falling off a skateboard. Although some of the students might give examples of objects changing direction, don't expect everyone to see that as a change in motion. The purpose of this initial discussion is to get the students to think about changing motion, not to refine their thinking. Remember that this is an Explore activity, meaning the students gain experiences from which to understand concepts to be introduced later.

Changing Motion

2. **Introduce the three tasks,** which are: (A) change the speed of a golf ball without changing the direction it moves, (B) change the direction a golf ball moves without changing its speed, and (C) change both the direction the golf ball moves and the speed at which it's moving. They're to provide two ways of meeting each challenge and record them on the sheet provided. They can use anything available in the room to meet these challenges as long as they don't break things—throwing a golf ball through a window is not a viable option.

3. Once the students are working on their challenges, **circulate around the room and help focus the students on the task.** Things that might help you:

   - One common mistake in challenge C is for the students to first change the direction and then to change the speed. These are to be accomplished in one instance.
   - Students don't always pay attention to detail. They might bounce the ball off a wall and claim that this is simply a change in direction, but in the process of bouncing off the wall, the ball slows to a stop and then speeds up again. Thus, while this meets challenge C, it doesn't meet challenge A or B.
   - Students might roll the ball down a curved track (Hot Wheels track) or curved surface in order to speed it up, but because the track is curved, the ball also changes direction. If the track or surface is straight (supported by a book, maybe), though, then the ball doesn't change direction.
   - Changing the speed of the ball without changing its direction is often simpler than it seems. If you drop a ball straight down, it is speeding up but not changing direction. Simply rolling a ball across a carpet causes the ball to slow down while not changing direction.
   - For most students, changing the direction of the ball while not changing its speed is the most difficult challenge. They can accomplish this by striking the ball from the side while it's rolling along the floor, by spinning it so it curves as it moves along the floor, or by causing the ball to move in a circular path. For a circular path, rolling the ball along a curved section of track while the track is on its side works, as does putting the ball in the middle of a roll of masking tape and swirling the roll of tape so the ball moves in a circle. Perfectionists in your class might argue that it's virtually impossible to keep the ball from slowing down during any of these actions, and that's true. As long as they can "pretty much" keep the ball at constant speed, that's good enough.
   - Keep in mind the purpose of the activity, which is for your class to experience various changes in velocity. As such, it's okay for one group to see what another group is doing and copy it.

4. **Have the students record their methods on the sheet provided.**

5. **Discuss with the class how they met the challenges.** Use the opportunity to deal with any methods that did or didn't meet the challenge exactly. For example, why does bouncing the ball against the wall not just change the direction of

motion, but also the speed (the ball slows to a stop and then speeds back up as it hits the wall)? Remember that all you're doing at this point is debriefing the activity. Don't explain acceleration and how it applies to what the class did. Of course, it's perfectly fine to clear up any misconceptions on what speed and velocity are. Even though you've dealt with those concepts, it's quite probable that many students don't have a solid grasp of them at this point.

Student Activity 3.1

Changing Motion

You are to meet the following challenges in any safe way you can. Safe means no one and nothing gets hurt in the process. Here are your challenges:

A. Start a ball rolling on the floor or on a table. Once it's rolling, cause the ball to change speed but not direction.

B. Start a ball rolling on the floor or on a table. Once it's rolling, cause the ball to change direction but not speed.

C. Start a ball rolling on the floor or on a table. Once it's rolling, cause the ball to change both speed and direction. Do this with one action. That means you haven't met the challenge if you change the ball's speed and then start the ball rolling again and this time change its direction.

1. List two ways you changed the speed of the ball without changing its direction.

   a. ______________________________

   ____

   ____

   b. ______________________________

   ____

   ____

Changing Motion

2. List two ways you changed the direction the ball was moving without changing its speed.

   a. ____

   ____

   ____

   b. ____

   ____

   ____

3. List two ways you changed both the speed and the direction of the ball.

   a. ____

   ____

   ____

   b. ____

   ____

   ____

Accelerating

Objectives: The students will be able to explain that acceleration refers to a change in direction, speed, or both of an object. They will be able to determine whether things are accelerating or not based on this definition of acceleration.

Process Skills Addressed: Analyzing, comparing

National Science Education Standards Addressed: Content standard B: Position and motion of objects; Properties and changes of properties in matter; Motions and forces

Position in the Learning Cycle: *Explain.* After the students read an explanation, you help them tie the concept of acceleration to the activity Changing Motion (p. 37) and to their everyday experiences.

Relevant Pages in *Force and Motion Stop Faking It!* Book: Pages 17–21

Suggested Group Size: Individual or Whole class

Materials: Copy masters of the student reading Accelerating

Approximate Time: 30 minutes

Procedure:

1. If you have not fully "debriefed" the activity Changing Motion, do that before the students tackle the reading. **Make sure everyone has a solid grasp of what it means to change the direction and/or speed of an object.**
2. **After the reading, discuss the concept of acceleration with the students.** Acceleration can be a change in speed, a change in direction, or both. Likely the students are already familiar with acceleration being an increase in speed, so it's your job to help them expand this definition. Many textbooks insist on calling a decrease in speed a deceleration, but this is not scientifically correct. This is one place where everyday language conflicts with a scientific definition.

Accelerating

3. **Emphasize the labeling of various parts of a car as accelerators.**[1] It seems silly to call a steering wheel and a brake accelerators, but this mental picture stays with students and reminds them of the true meaning of acceleration.
4. I would not recommend discussing positive and negative accelerations with the students. Many texts describe positive accelerations as increases in speed and negative accelerations as decreases in speed, but this isn't an accurate scientific description. Positives and negatives assigned to physical quantities are actually quite arbitrary, and can change with the situation. It's best to avoid this concept rather than give the students misconceptions that will confuse them later.
5. **Answers to the questions at the end of the reading:** 1) A dog chasing its tail is accelerating, because it's changing direction as it spins in a circle. 2) An airplane moving at a constant speed of 500 miles per hour in a straight line is not accelerating. Despite the fact that the plane is moving very fast, it is not changing speed nor direction. 3) A race car rounding a curve is accelerating because it's changing direction.

[1]If you want to get picky, there are actually five accelerators on a car. The emergency brake acts as an accelerator, and the gear shifting mechanism acts as an accelerator (you can "shift down," put the car in neutral, or foolishly put the car in reverse).

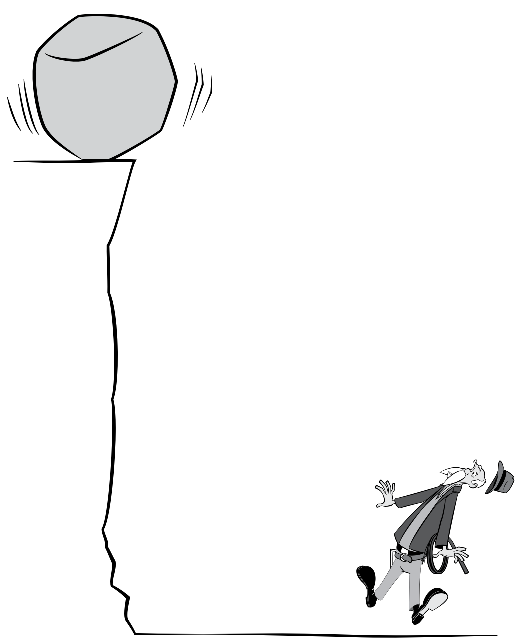
Accelerating

Student Activity 3.2

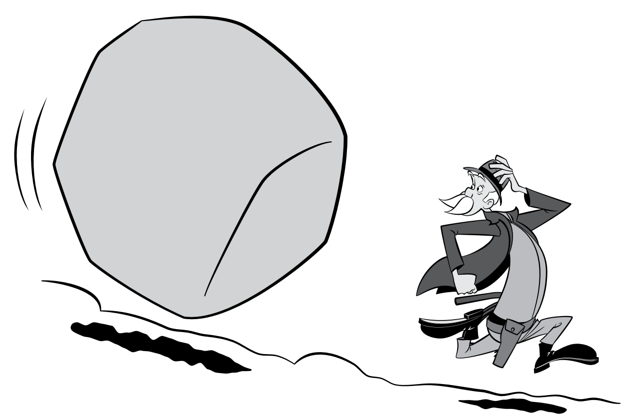
In the activity you did, you were challenged with changing the motion of an object—changing its speed without changing its direction, changing its direction without changing its speed, and changing both its speed and direction. Now you might (hopefully!) remember that when you specify both the speed of an object and the direction it's moving, you are talking about the **velocity** of the object. So, if you change the speed, the direction, or both, you are changing the velocity of the object. There's a special name for a change in speed and/or direction. It's called **acceleration**. When an object goes faster, it is accelerating. When an object goes slower, it is accelerating. When an object changes direction, as with a car rounding a corner, it is accelerating.

All of the following are accelerating:

Object starting from rest and moving — an acceleration



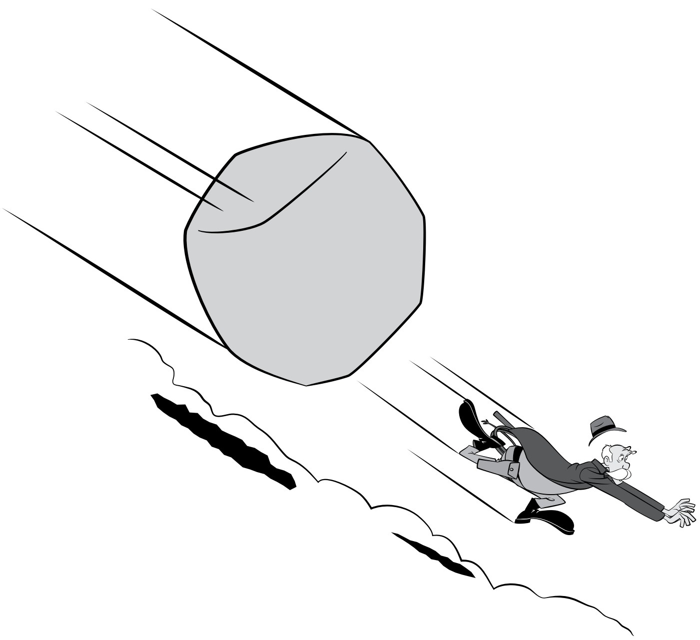
Object speeding up — an acceleration



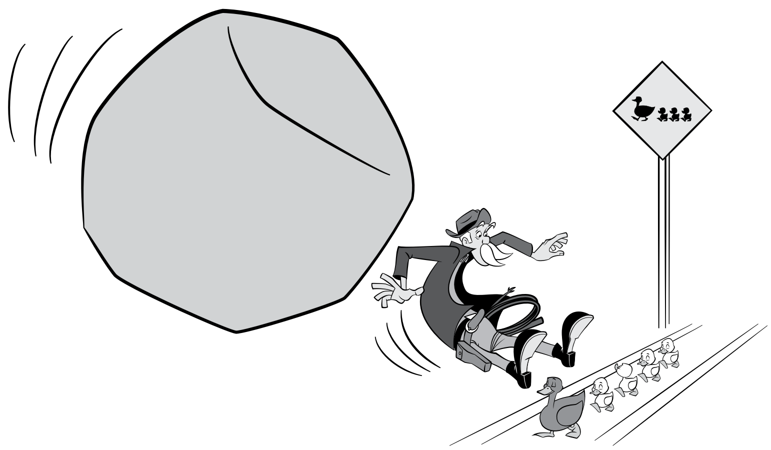
Student Activity 3.2

Accelerating

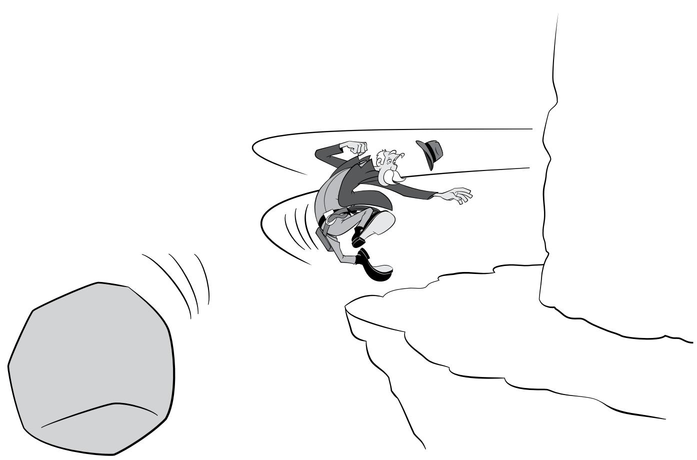
Object speeding up even more — an acceleration



Object slowing down — an acceleration

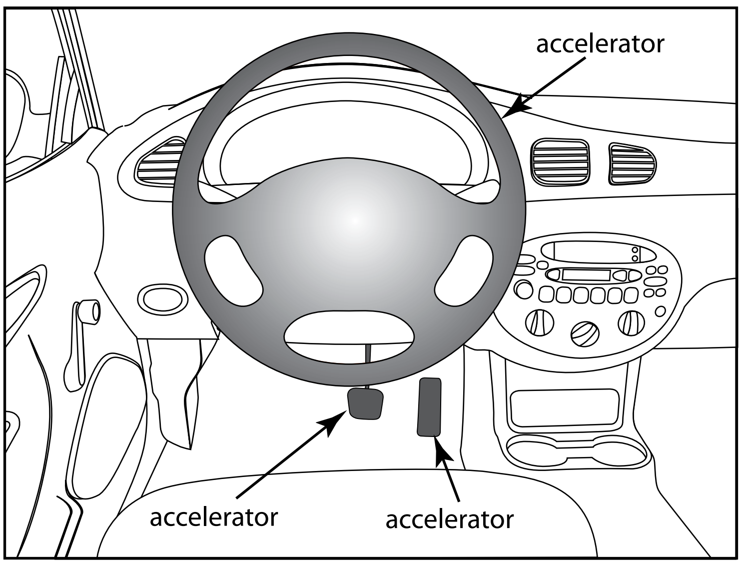


Object changing direction — an acceleration



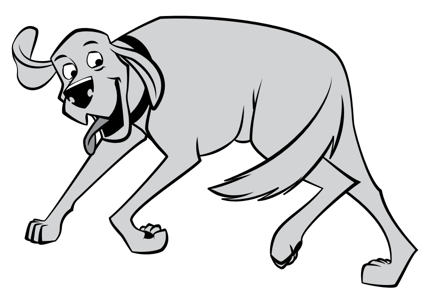
Accelerating

Now this definition of acceleration is a scientific one, and it's different from the everyday use of the word. Most often we think of acceleration as speeding up. After all, isn't that pedal on a car called an accelerator? When a car slows down, we sometimes call that a deceleration, but that's a word that scientists don't use. When a car slows down, it's changing its velocity, so it's accelerating. So if you want to label car parts as a scientist would, you would call the gas pedal an accelerator because it tends to change the velocity of the car, you would call the brake pedal an accelerator because it tends to change the velocity of the car, and you would call the steering wheel an accelerator (!) because it tends to change the velocity of the car (a change in direction).



State whether or not each of the following is accelerating. Explain your answers.

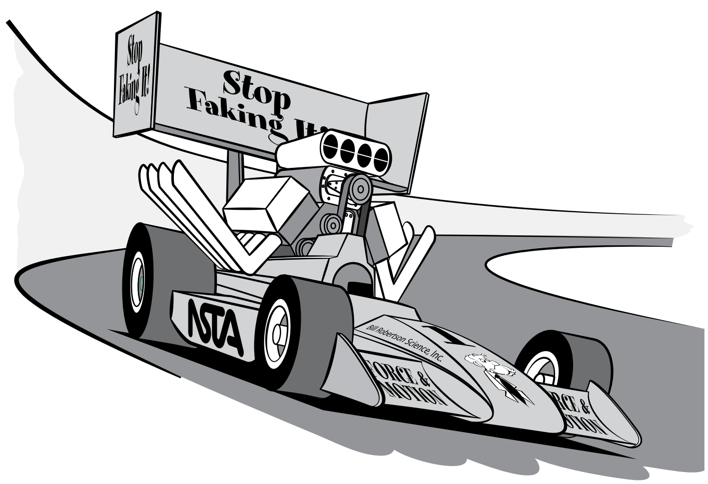
1. A dog chasing its tail.



Accelerating

2. An airplane moving at a constant speed of 500 miles per hour in a straight line.

3. A race car rounding a corner at a constant speed of 200 miles per hour.



Accelerating or Not

Objectives: The students will be able to determine when a roller coaster in a simulation is accelerating and when it is not. The students will justify their answers based on whether or not the velocity of the coaster is changing.

Process Skills Addressed: Observing, classifying, communicating, analyzing

National Science Education Standards Addressed: Content standard B: Position and motion of objects; Properties and changes of properties in matter; Motions and forces

Position in the Learning Cycle: *Elaborate.* The students have been introduced to the concept of acceleration, so this is a chance for them to apply that concept to a new situation. Expect them to struggle with the concept at this point. It is fine to correct their misunderstandings and re-explain any of the concepts of speed, velocity, and acceleration.

Relevant Pages in *Force and Motion Stop Faking It!* Book: Pages 11–21

Suggested Group Size: Entire class

Materials: The roller coaster simulation in the NSTA Science Object, Force and Motion. You can download the Science Object for free at *www.nsta.org*. Locate "Science Objects" on the site and you can add them to your shopping cart. Checkout is free for the Science Objects. The simulation is in the first Force and Motion Science Object, Position and Motion. Navigate to the section "More on Motion" and open the roller coaster simulation.

Approximate Time: 45 minutes

Procedure:

1. For this lesson to work effectively, you have to be able to show the simulation to the entire class. If you have an LCD projector, then great. Otherwise, you'll have to improvise and have the students view the simulation on separate computers and draw them back for a general discussion from time to time.

Accelerating or Not

2. **Show the simulation without comment.** You'll be showing it several times, and this is just a chance for the students to get a general idea of what's going on.
3. **After the first showing, ask the students to concentrate on the white arrow that appears above the coaster.** Ask them what the white arrow represents, and then show the simulation again. You'll likely get many different answers, and don't be frustrated that many students don't understand that the arrow represents the **velocity** of the coaster. Sometimes these concepts take time. Show the simulation as many times as necessary to ensure that most of the students understand why this arrow represents velocity. Its length represents the magnitude of the velocity (speed) and its direction represents, ummmmmm… direction. NOTE: You might think that because you have already discussed velocity, the students should immediately know what the arrow represents. Not so. Have patience.
4. Once you've established that the arrow above the coaster represents velocity, it's time to move on to the concept of acceleration. **Ask the students to identify places where the coaster is accelerating, and where it isn't accelerating.** Then show the simulation again, and possibly again and again. Expect disagreement. You might first focus on where the coaster is not accelerating.
5. **As you show the simulation as many times as necessary, focus the students' attention on particular portions.** There are a couple of places where the coaster is moving at constant speed in a straight line, and these are places where the coaster is not accelerating. Constant speed and constant direction means the velocity is not changing. The two places where the coaster is not accelerating are on the initial upslope and on the flat part near the middle. Note that the speed of the coaster has nothing to do with whether or not it's accelerating. Acceleration is all about changes in velocity, not the magnitude of the velocity.
6. Where is the coaster accelerating? Wherever the velocity is changing. That means wherever the coaster is changing speed and/or direction. Although the coaster is moving slowly at the first crest, it is changing direction and is therefore accelerating. On the first downhill, the coaster is speeding up and pretty much everyone will agree that there's an acceleration. On the flat part, many students will think the coaster is accelerating because it's moving fast, but because acceleration is a change in velocity, the actual speed doesn't matter. No change in speed or direction means zero acceleration. On the vertical loop, the coaster is accelerating because it's changing both speed and direction.
7. **Focus the students' attention on the last part of the coaster's motion,** where it climbs a hill, stops, and reverses direction. Ask whether or not the coaster is accelerating as it climbs the last incline. Expect a lot of "no" answers. Here's a chance to clarify the scientific meaning of acceleration. As the coaster climbs the incline, it slows down. This is an acceleration (not a deceleration!) because the coaster is changing its velocity. NOTE: Many elementary textbooks

insist on using the term *deceleration* for an object that's slowing down. Know that those textbooks are wrong.

8. **Have the students answer the questions on the student pages.** The answers are as follows: (1) Yes, the students are accelerating. They are on a spinning Earth, and anything that's changing direction (the Earth's surface) is accelerating. (2) No matter how fast you're moving, if you are not changing speed or direction then you aren't accelerating. It's common for students to equate high speeds with accelerations, but the value of a speed says nothing about whether or not something is accelerating. (3) Lara is incorrect. Any object that is changing its motion is accelerating, and the object doesn't have to be moving in order to do this. For example, a ball that hits the floor is momentarily at rest, but it is definitely still changing speed and direction. If an object is not accelerating, all that means is that the object is not changing its speed or direction. So, something can be moving at a high rate of speed, and as long as the speed is constant and the object is not changing direction, the object is not accelerating.

Extra Challenge: The following steps in the procedure cover a more advanced idea than the rest of the lesson, so they might not be for all classes.

9. **Focus the students' attention at the turnaround point at the end of the coaster motion.** As before, show the simulation as many times as necessary. Ask the students whether or not the coaster is accelerating at the very top of its turnaround point. Most of the students will likely say that the coaster is not accelerating at that point.
10. **Ask the students for a definition of acceleration,** and gradually get them to agree that an acceleration is a change in velocity. At the end point of the coaster's motion, it has zero velocity, yes? (yes) Does that mean the velocity isn't changing? (Expect a variety of answers or silence) Now this is a tough sell for adults let alone kids, so expect disagreement, but in fact the coaster is accelerating at the top of the far right incline. It might be motionless (zero velocity), but the velocity is definitely changing. The coaster is changing direction (an acceleration) and it is changing speed (from a slow speed to zero speed to another slow speed in the opposite direction). The coaster is accelerating at this farthest right point. This is a difficult idea even for college students, so be patient and don't be surprised if not all the students are convinced.

Student Activity 3.3

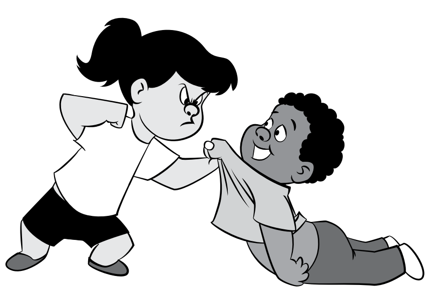
Accelerating or Not

Answer the following questions as completely as possible.

1. Are you accelerating right now? How do you know?

2. You're on a skateboard, moving very fast but at a constant speed. Are you accelerating? Explain.

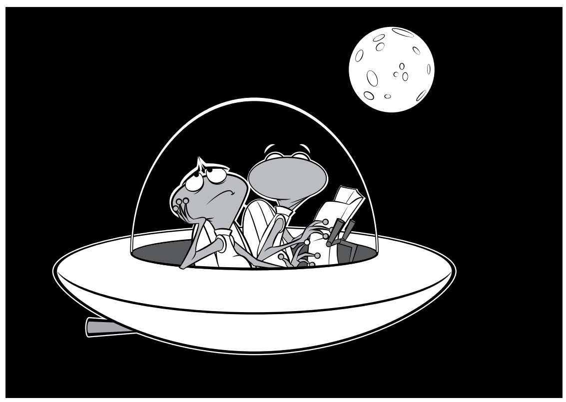
3. Lara claims that if an object is accelerating, it must be moving. She also claims that if an object is not accelerating, it must be at rest. Do you agree with Lara? If not, what would you say to her to convince her she's wrong?



Evaluation

Answers to Student Activity 3.4
The following is a list of objects. Figure out which ones are accelerating and which ones aren't. Some are easy and some are not so easy.

The Moon



"Has that moon always been there?"

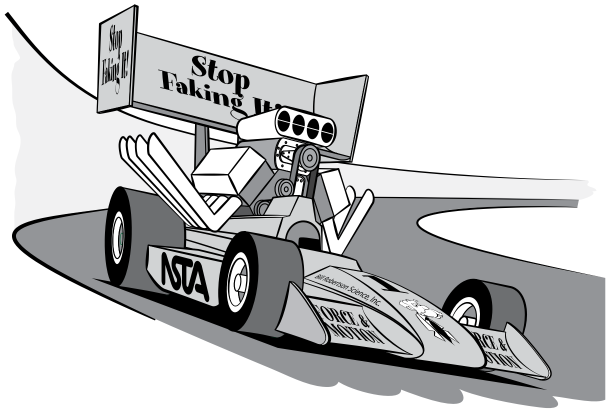
Answer: *The moon is moving in a circular path around the Earth, and thus changing direction. Because the moon is changing its direction of motion, it's accelerating.*

A broom falling

Answer: *As any object falls, it speeds up. That's a change in speed, and therefore a change in direction. The broom is accelerating. The students might not realize that falling things speed up. It might be worthwhile to have the students watch broomlike things, such as metersticks, fall over.*

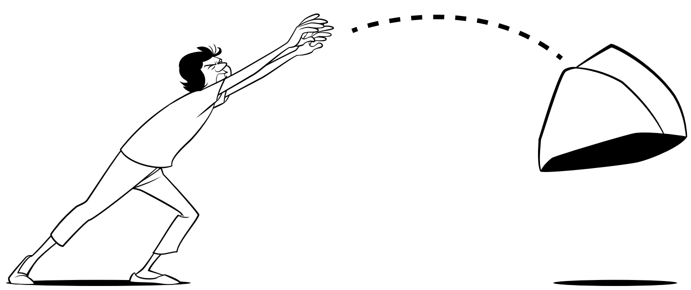
Evaluation

A race car as it moves around an oval track



Answer: *This thing accelerates a lot. Not only does a race car change speed often, it changes direction whenever it negotiates a curve.*

A thrown rock after it leaves the thrower's hand and before it hits the ground

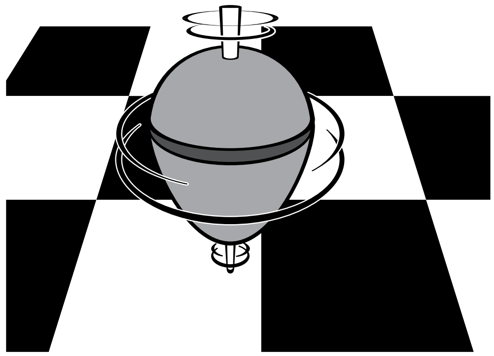


Answer: *The answer should be relatively obvious if you actually throw a rock and observe it carefully. It continually changes direction, and it also changes speed. A thrown rock definitely accelerates.*

Evaluation

Teacher Guide to 3.4

A toy top that is spinning, but staying in one place on the floor

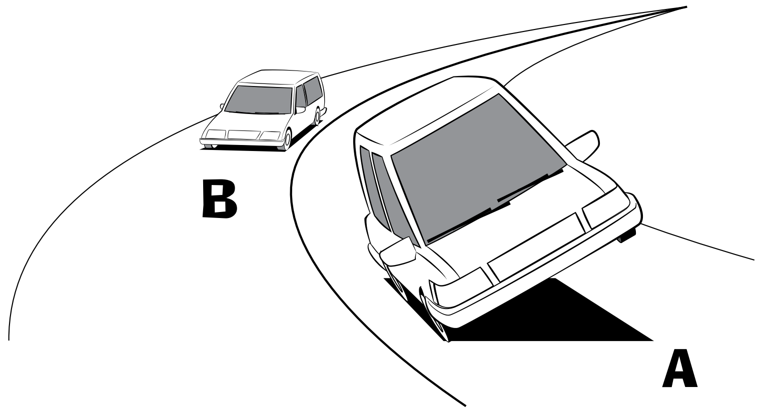


Answer: *This one's a bit tricky. If the top stays in one place on the floor, you might think it's not accelerating. However, each part of the top changes its direction as the top spins. Therefore, the top is accelerating.*

A book sitting on a table

Answer: *The book is not accelerating. It is sitting at rest. Plus, no part of the book is changing direction. So, the book is not accelerating. Okay, that's a tiny lie. The table and the book are on the surface of the Earth, and the Earth is spinning (changing direction), so the book really is accelerating.*

Teacher Guide to 3.4 Evaluation



Two cars are rounding curves. Both cars are traveling at a constant speed of 40 kilometers per hour. Car A is rounding a very sharp curve and car B is rounding a gradual curve. Which of the following are true regarding the motion of the cars?

Car A and car B have the same acceleration because they have the same speed.

Answer: *Not true. Acceleration is a change in velocity, and the two cars are changing velocity at different rates. Also, the value of an object's speed at any one moment doesn't tell you anything about its acceleration.*

Car A and car B have the same acceleration because they have the same velocity.

Answer: *Also not true. The value of an object's velocity at any one moment doesn't tell you anything about how the velocity is changing, which is what acceleration is.*

Cars A and B both have zero acceleration because their speeds are not changing.

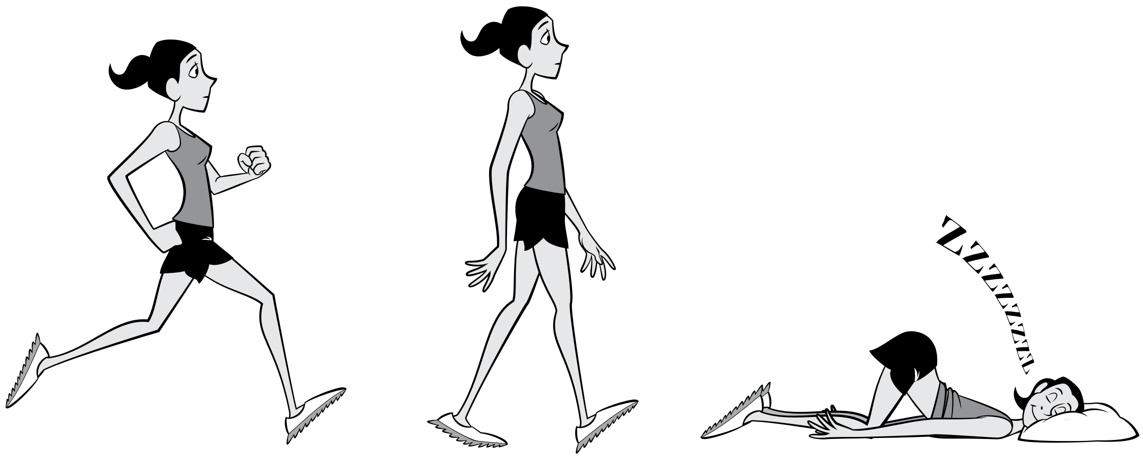
Answer: *Not true. Acceleration takes into account both speed and direction. Constant speed does not mean constant velocity. In this case the cars are changing direction, so they are changing their velocities and are therefore accelerating.*

Car A is accelerating more than car B because it is changing direction at a faster rate.

Answer: *True. Because it is rounding a sharper curve, car A is accelerating more than car B.*

Evaluation

Teacher Guide to 3.4



A long-distance runner out for a workout runs 4 kilometers in 20 minutes, walks for a distance of 1 kilometer, which takes 10 minutes, and then rests in one spot for 10 minutes. After that, she runs another 6 kilometers in 35 minutes. Which of the following are true with respect to her motion? (There may be more than one correct answer.)

When she was at rest, you could not assign a number to her speed or to her acceleration.

Answer: *Not true. When at rest, her speed was zero kilometers per minute. If you ignore the very beginning and end of her resting period, her acceleration is also zero because she's not changing her velocity.*

Her average speed for the entire trip is about 0.15 kilometers per minute.

Answer: *True. Her average speed is her total distance traveled divided by the time to travel that distance. The total distance is 11 kilometers and the total time is 75 minutes. 11 divided by 75 is 0.15 kilometers per minute.*

She never accelerates because whenever she runs, walks, or rests, she does so at a constant speed and direction.

Answer: *No. Every time she changes velocity, she's accelerating, and she changes velocity a number of times.*

She accelerated whenever she changed her speed.

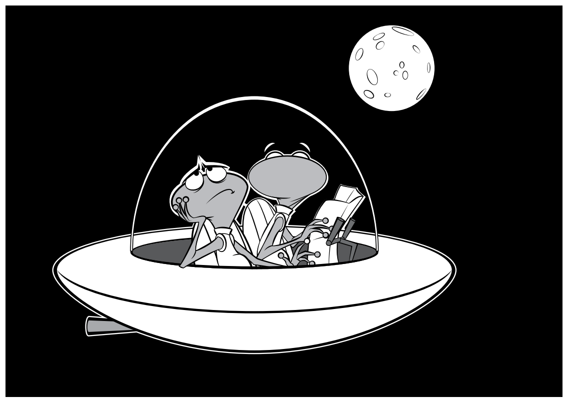
Answer: *True. Any change in speed is a change in velocity, and a change in velocity is an acceleration.*

Student Activity 3.4

Evaluation

The following is a list of objects. Figure out which ones are accelerating and which ones aren't. Some are easy and some are not so easy.

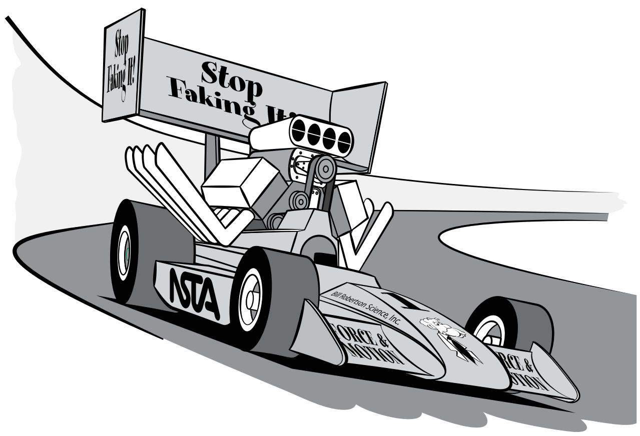
The Moon



"Has that moon always been there?"

A broom falling

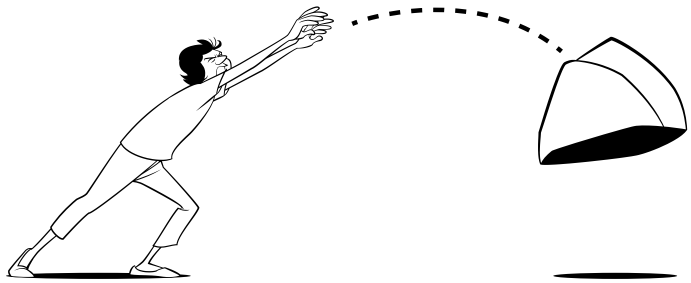
A race car as it moves around an oval track



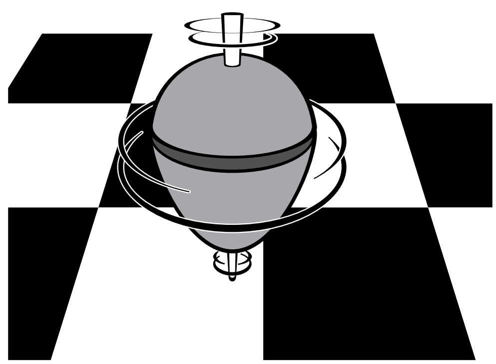
Evaluation

Student Activity 3.4

A thrown rock after it leaves the thrower's hand and before it hits the ground



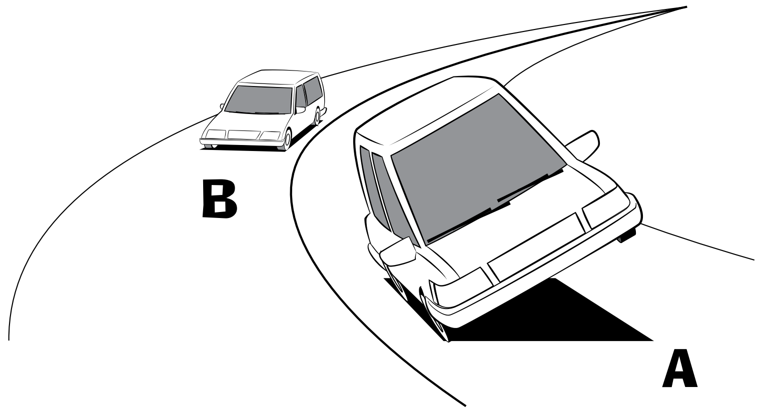
A toy top that is spinning, but staying in one place on the floor



A book sitting on a table

Student Activity 3.4

Evaluation



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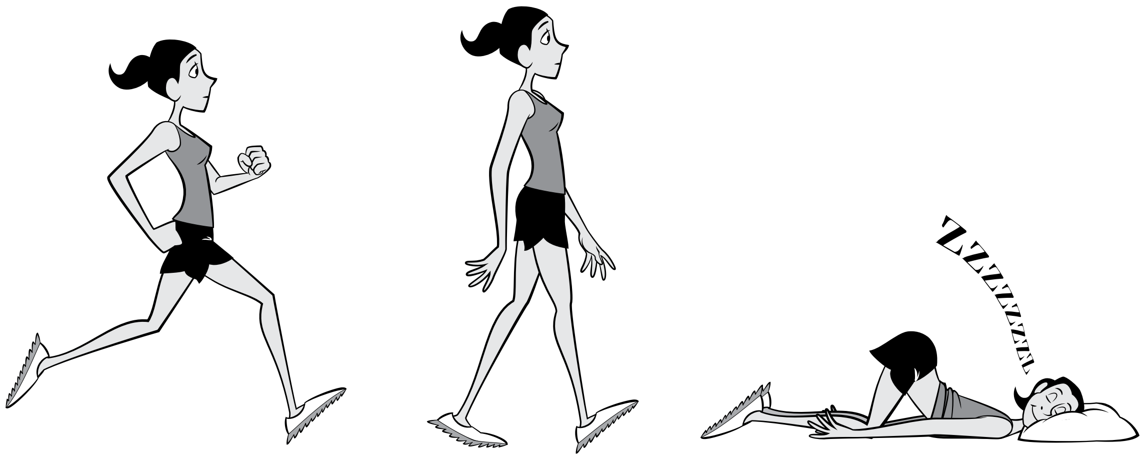
Evaluation



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She accelerated whenever she changed her speed.

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