SCIENCE ACADEMIES FOR GRADES 5–8, PART 2

region4®

This guide was developed in collaboration with
Region 4 Education Service Center, Houston, Texas.

Science Academies for Grades 5–8, Part 2

Copyright

Science Academies for Grades 5–8, Part 2

Table of Contents

Science Academies for Grades 5–8, Part 2

Overview

Goal

The goal of this initiative is to improve the overall instruction and achievement of science classrooms in order to meet and/or exceed grade-level state standards and ensure postsecondary readiness.

This training will familiarize participants with the science Texas Essential Knowledge and Skills (TEKS) while strengthening their knowledge of the College and Career Readiness Standards (CCRS), Response to Intervention (RtI), and the English Language Proficiency Standards (ELPS). This training will also provide an opportunity for participants to garner professional support from other educators through shared resources and ongoing academic networking.

Master Schedule

Day 1

Introduction

Vertical Alignment Study

Investigating ELPS, RtI, and CCRS

Grade 5: Experimental Investigation

Day 2

Grade 6: Changes in Motion

Grade 7: Work

Day 3

Grade 8, Lesson 1: Balanced and Unbalanced Forces

Grade 8, Lesson 2: Force, Mass, and Acceleration

Defining Lesson Components

1. A **Content Builder** includes additional content knowledge for the teacher and is not intended to be taught to students. Content builders may also warn teachers of possible misconceptions.

2. A **Teacher Note** explains logistics of an activity or possible options to consider within an activity. It may also include information on where to find or purchase materials.

3. **Advance Preparation** details anything the teacher should have prepared prior to the arrival of students and the beginning of class.

4. **Teacher Instruction** provides a step-by-step list of what the teacher does during class to facilitate learning.

5. **Facilitation Questions** include a list of guiding questions and the answers students may provide to them.

6. A **Differentiation Strategy** section describes ways to accommodate students working on different cognitive levels within the same topic or activity.

7. A **Tier I Support** section aids in the facilitation of an activity such as grouping options.

TEKS VERTICAL ALIGNMENT

Physics Vertical Alignment Table

TEKS	Concept Development by Grade Level TEKS									CCRS
P(4) The student knows and applies the laws governing motion in a variety of situations. The student is expected to:	K	1	2	3	4	5	6	7	8	Physics
(A) generate and interpret graphs and charts describing different types of motion, including the use of real-time technology such as motion detectors or photogates;							(8)(D)			
(B) describe and analyze motion in one dimension using equations with the concepts of distance, displacement, speed, average velocity, instantaneous velocity, and acceleration;	(6)(C) (6)(D)	(6)(C) (6)(D)	(6)(C) (6)(D)	(6)(B)	(6)(D)	(6)(D)	(8)(B) (8)(C)	(7)(C)	(6)(A) (6)(B)	
(C) analyze and describe accelerated motion in two dimensions using equations, including projectile and circular examples;										
(D) calculate the effect of forces on objects, including the law of inertia, the relationship between force and acceleration, and the nature of force pairs between objects;				(6)(B)	(6)(D)	(6)(D)	(8)(B)	(7)(C)	(6)(A) (6)(C)	
(E) develop and interpret free-body force diagrams; and							(8)(B)		(6)(A) (6)(C)	
(F) identify and describe motion relative to different frames of reference.				(8)(C)	(8)(C)	(8)(C)	(11)(A) (11)(B)			

Texas Education Agency

Physics Vertical Alignment Table

TEKS	Concept Development by Grade Level TEKS									CCRS
P(5) The student knows the nature of forces in the physical world. The student is expected to:	K	1	2	3	4	5	6	7	8	Physics
(A) research and describe the historical development of the concepts of gravitational, electromagnetic, weak nuclear, and strong nuclear forces;							(11)(A) (11)(C)		(8)(E)	
(B) describe and calculate how the magnitude of the gravitational force between two objects depends on their masses and the distance between their centers;	(8)(B) (8)(C)	(8)(B) (8)(C)	(8)(D)	(8)(C) (8)(D)	(8)(C)	(8)(C)	(11)(A) (11)(B)		(7)(C)	
(C) describe and calculate how the magnitude of the electrical force between two objects depends on their charges and the distance between them;										
(D) identify examples of electric and magnetic forces in everyday life;	(6)(B)	(6)(B)	(6)(B)	(6)(C)	(6)(A) (6)(C) (6)(D)	(6)(A) (6)(B)				
(E) characterize materials as conductors or insulators based on their electrical properties;					(6)(B)					
(F) design, construct, and calculate in terms of current through, potential difference across, resistance of, and power used by electric circuit elements connected in both series and parallel combinations;					(6)(C)	(6)(B)				
(G) investigate and describe the relationship between electric and magnetic fields in applications such as generators, motors, and transformers; and					(6)(C)					
(H) describe evidence for and effects of the strong and weak nuclear forces in nature.										

Physics Vertical Alignment Table

TEKS	Concept Development by Grade Level TEKS									CCRS
P(6) The student knows that changes occur within a physical system and applies the laws of conservation of energy and momentum. The student is expected to:	K	1	2	3	4	5	6	7	8	Physics
(A) investigate and calculate quantities using the work-energy theorem in various situations;								(7)(A)		
(B) investigate examples of kinetic and potential energy and their transformations;							(8)(A) (9)(C)	(7)(B)		
(C) calculate the mechanical energy of, power generated within, impulse applied to, and momentum of a physical system;										
(D) demonstrate and apply the laws of conservation of energy and conservation of momentum in one dimension;							(9)(C)	(5)(C) (7)(B)	(6)(C)	
(E) describe how the macroscopic properties of a thermodynamic system such as temperature, specific heat, and pressure are related to the molecular level of matter, including kinetic or potential energy of atoms;								(8)(A)	(10)(B)	
(F) contrast and give examples of different processes of thermal energy transfer, including conduction, convection, and radiation; and							(9)(A) (9)(B)		(10)(A)	
(G) analyze and explain everyday examples that illustrate the laws of thermodynamics, including the law of conservation of energy and the law of entropy.	(6)(A)	(6)(A)	(6)(A)	(6)(A)	(6)(A)	(6)(A)	(9)(B)	(5)(C) (7)(B)	(6)(C)	

Physics Vertical Alignment Table

TEKS	Concept Development by Grade Level TEKS									CCRS
P(7) The student knows the characteristics and behavior of waves. The student is expected to:	K	1	2	3	4	5	6	7	8	Physics
(A) examine and describe oscillatory motion and wave propagation in various types of media;										
(B) investigate and analyze characteristics of waves, including velocity, frequency, amplitude, and wavelength, and calculate using the relationship between wavespeed, frequency, and wavelength;									(8)(C) (8)(D)	
(C) compare characteristics and behaviors of transverse waves, including electromagnetic waves and the electromagnetic spectrum, and characteristics and behaviors of longitudinal waves, including sound waves;	(6)(A)	(6)(A)	(6)(A)	(6)(A)	(6)(A)	(6)(A)			(8)(C)	
(D) investigate behaviors of waves, including reflection, refraction, diffraction, interference, resonance, and the Doppler effect;										
(E) describe and predict image formation as a consequence of reflection from a plane mirror and refraction through a thin convex lens; and						(6)(C)				
(F) describe the role of wave characteristics and behaviors in medical and industrial applications.									(8)(D)	
P(8) The student knows simple examples of atomic, nuclear, and quantum phenomena. The student is expected to:	K	1	2	3	4	5	6	7	8	Physics
(A) describe the photoelectric effect and the dual nature of light;										
(B) compare and explain the emission spectra produced by various atoms;									(8)(C)	
(C) describe the significance of mass-energy equivalence and apply it in explanations of phenomena such as nuclear stability, fission, and fusion; and										
(D) give examples of applications of atomic and nuclear phenomena such as radiation therapy, diagnostic imaging, and nuclear power and examples of applications of quantum phenomena such as digital cameras.										

K–8 Science Concepts TEKS

Kindergarten
(6) Force, motion, and energy. The student knows that energy, force, and motion are related and are a part of their everyday life. The student is expected to:

(A) use the five senses to explore different forms of energy such as light, heat, and sound;

(B) explore interactions between magnets and various materials;

(C) observe and describe the location of an object in relation to another such as above, below, behind, in front of, and beside; and

(D) observe and describe the ways that objects can move such as in a straight line, zigzag, up and down, back and forth, round and round, and fast and slow.

Grade 1
(6) Force, motion, and energy. The student knows that force, motion, and energy are related and are a part of everyday life. The student is expected to:

(A) identify and discuss how different forms of energy such as light, heat, and sound are important to everyday life;

(B) predict and describe how a magnet can be used to push or pull an object;

(C) describe the change in the location of an object such as closer to, nearer to, and farther from; and

(D) demonstrate and record the ways that objects can move such as in a straight line, zigzag, up and down, back and forth, round and round, and fast and slow.

Grade 2
(6) Force, motion, and energy. The student knows that forces cause change and energy exists in many forms. The student is expected to:

(A) investigate the effects on an object by increasing or decreasing amounts of light, heat, and sound energy such as how the color of an object appears different in dimmer light or how heat melts butter;

(B) observe and identify how magnets are used in everyday life;

(C) trace the changes in the position of an object over time such as a cup rolling on the floor and a car rolling down a ramp; and

(D) compare patterns of movement of objects such as sliding, rolling, and spinning.

Grade 3
(6) Force, motion, and energy. The student knows that forces cause change and that energy exists in many forms. The student is expected to:

(A) explore different forms of energy, including mechanical, light, sound, and heat/thermal in everyday life;

(B) demonstrate and observe how position and motion can be changed by pushing and pulling objects to show work being done such as swings, balls, pulleys, and wagons; and

(C) observe forces such as magnetism and gravity acting on objects.

Grade 4
(6) Force, motion, and energy. The student knows that energy exists in many forms and can be observed in cycles, patterns, and systems. The student is expected to:

(A) differentiate among forms of energy, including mechanical, sound, electrical, light, and heat/thermal;

(B) differentiate between conductors and insulators;

(C) demonstrate that electricity travels in a closed path, creating an electrical circuit, and explore an electromagnetic field; and

(D) design an experiment to test the effect of force on an object such as a push or pull, gravity, friction, or magnetism.

Grade 5

(6) Force, motion, and energy. The student knows that energy occurs in many forms and can be observed in cycles, patterns, and systems. The student is expected to:

(A) explore the uses of energy, including mechanical, light, thermal, electrical, and sound energy;

(B) demonstrate that the flow of electricity in circuits requires a complete path through which an electric current can pass and can produce light, heat, and sound;

(C) demonstrate that light travels in a straight line until it strikes an object or travels through one medium to another and demonstrate that light can be reflected such as the use of mirrors or other shiny surfaces and refracted such as the appearance of an object when observed through water; and

(D) design an experiment that tests the effect of force on an object.

Grade 6

(8) Force, motion, and energy. The student knows force and motion are related to potential and kinetic energy. The student is expected to:

(A) compare and contrast potential and kinetic energy;

(B) identify and describe the changes in position, direction, and speed of an object when acted upon by unbalanced forces;

(C) calculate average speed using distance and time measurements;

(D) measure and graph changes in motion; and

(E) investigate how inclined planes and pulleys can be used to change the amount of force to move an object.

(9) Force, motion, and energy. The student knows that the Law of Conservation of Energy states that energy can neither be created nor destroyed, it just changes form. The student is expected to:

(A) investigate methods of thermal energy transfer, including conduction, convection, and radiation;

(B) verify through investigations that thermal energy moves in a predictable pattern from warmer to cooler until all the substances attain the same temperature such as an ice cube melting; and

(C) demonstrate energy transformations such as energy in a flashlight battery changes from chemical energy to electrical energy to light energy.

Grade 7

(7) Force, motion, and energy. The student knows that there is a relationship among force, motion, and energy. The student is expected to:

(A) contrast situations where work is done with different amounts of force to situations where no work is done such as moving a box with a ramp and without a ramp, or standing still;

(B) illustrate the transformation of energy within an organism such as the transfer from chemical energy to heat and thermal energy in digestion; and

(C) demonstrate and illustrate forces that affect motion in everyday life such as emergence of seedlings, turgor pressure, and geotropism.

Grade 8

(6) Force, motion, and energy. The student knows that there is a relationship between force, motion, and energy. The student is expected to:

(A) demonstrate and calculate how unbalanced forces change the speed or direction of an object's motion;

(B) differentiate between speed, velocity, and acceleration; and

(C) investigate and describe applications of Newton's law of inertia, law of force and acceleration, and law of action-reaction such as in vehicle restraints, sports activities, amusement park rides, Earth's tectonic activities, and rocket launches.

SUPPORT FRAMEWORKS

College and Career Readiness Standards

The 79th Texas Legislature passed House Bill 1, the "Advancement of College Readiness in Curriculum," § 28.008 of the Texas Education Code, to increase the number of students who are college and career ready when they graduate high school. The Texas College and Career Readiness Standards (CCRS) that resulted from that legislation were developed and assessed by vertical teams composed of secondary and postsecondary faculty across the content areas of English/language arts, mathematics, science, and social studies, using a multilevel framework that focuses on subject matter and the way it is organized and presented in the classroom.

Incorporated into the Texas Essential Knowledge and Skills (TEKS) in 2008, the CCRS emphasize secondary-level content knowledge that stimulates students to engage in deeper levels of thinking. The framework of the CCRS recognizes that at a postsecondary level, students must (1) have core foundational knowledge of a discipline and be able to use that knowledge with facility and fluency; and (2) be able to understand the vertical structure of a discipline and how knowledge expands from the initial study of a topic.

The CCRS also address cross-disciplinary foundational knowledge and skills, which delineate the horizontal structure of learning across all disciplines and how core foundational knowledge of one subject is utilized in the mastery of other subjects. For example, when students utilize scientific inquiry, they utilize other foundational skills such as mathematics, communication, and social ethics, as well as personal skills such as time management, self-discipline, and organization.

CCRS for Science

The Science CCRS are extensive yet specific and strongly emphasize the importance of acquiring the cross-disciplinary, foundational cognitive skills needed to succeed in all entry-level college science courses. The CCRS view science vocabulary as a tool. College-ready students should be able to engage actively in the study of science and communicate with others in a clear, concise, and meaningful manner.

The Science CCRS extend the TEKS standards for each of the three traditional high school science courses—biology, chemistry, and physics—in the requirement of student mastery of the core principles and procedures for scientific inquiry, i.e., collecting, analyzing, evaluating, and synthesizing, that are necessary for the study of all science disciplines. Overall, the Science CCRS are focused to ensure student readiness to explore and appreciate the richness and complexity of the natural world, to process and develop new ideas and divergent interpretations, and to master the powerful techniques of scientific investigation.

Source: *Texas College and Career Readiness Standards*, Texas Education Agency and Texas Higher Education Coordinating Board

For a complete list of CCRS, see Texas College and Career Readiness Standards at http://www.thecb.state.tx.us/collegereadiness/CRS.pdf .

English Language Proficiency Standards

The English Language Proficiency Standards (ELPS) require that teachers provide linguistically accommodated instruction that corresponds to the students' levels of English proficiency. Districts are required to determine qualifying students' proficiency levels in the domains of listening, speaking, reading, and writing. Descriptors at each proficiency level—Beginning, Intermediate, Advanced, and Advanced High—are used to determine reasonable expectations for students in each of the four domains. It is important to remember that English language learners are a diverse group, and students may have achieved a higher level of language proficiency in one or more of the domains than others.

Beginning—Indicates the initial stages of learning English and minimal ability to communicate in English in academic settings. Comprehension is demonstrated through action, gestures, and drawings. Students often communicate using memorized words and phrases.

Intermediate—Indicates the ability to use common, basic English in routine classroom activities. Comprehension is demonstrated through the use of key words and phrases and nonverbal responses. Students communicate simply when the topic of conversation is familiar and can generally follow social conversations but not understand the details.

Advanced—Indicates the ability to use academic English in classroom activities, using more complex phrases and sentences with English language assistance provided when needed. Comprehension is demonstrated in context-reduced situations, both orally and in writing. Students still may have trouble with unfamiliar vocabulary and grammar.

Advanced High—Indicates the ability to use academic English in classroom activities with little English language support. Comprehension is demonstrated in situations with and without a context, both orally and in writing. Students communicate clearly in most situations.

From *Embedding the ELPS With E's: High School Science*, 2009, Houston, TX: Region 4 Education Service Center. Reprinted with permission.

Response to Intervention (RtI)

Response to Intervention, or RtI, a multitiered approach to instruction, is evolving as the framework of the general education program for all students including those who experience difficulties either academically or behaviorally. RtI helps to ensure that students have the opportunity to experience a full range of educational opportunities through the general education program.

Driven and documented by reliable data, the implementation of RtI in Texas schools can result in

- more effective instruction,
- increased student achievement,
- more appropriate LD identification,
- increased professional collaboration, and
- overall school improvement.

Source: *2008–2009 Response to Intervention Guidance*, Texas Education Agency

The core features of RtI include the following:

- High-quality, research-based classroom instruction
- Universal screenings of academics and behavior
- Continuous progress monitoring
- Research-based interventions
- Continuous progress monitoring during interventions
- Integrity of instruction and interventions

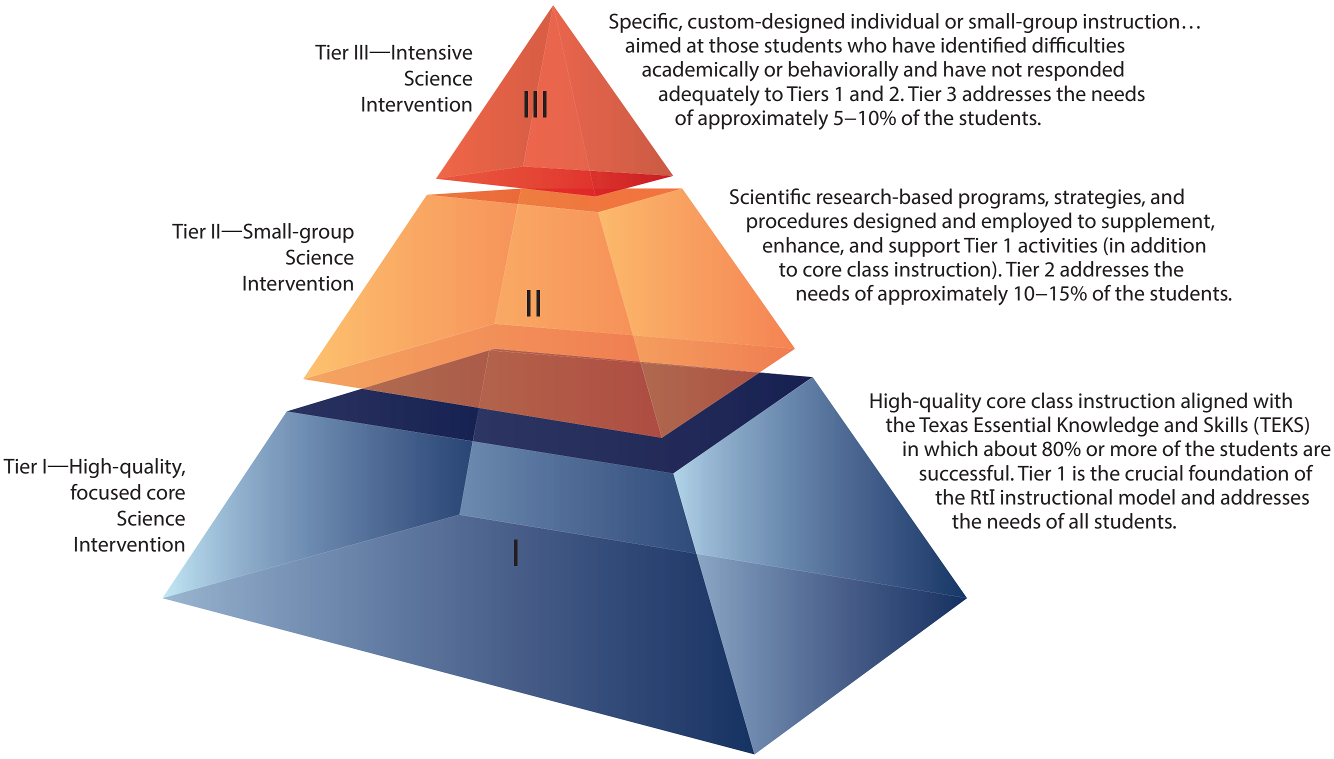
The core attributes of RtI include the following:

- Tiered interventions
- Implementation of differentiated curriculum
- Instruction delivered by staff other than classroom teachers at higher tiers
- Varied duration and frequency of interventions
- Placement decisions that serve students with varied abilities
- Standardized treatment protocol

Source: National Research Center on Learning Disabilities

Response to Intervention (RtI)

3-Tier Intervention Model



Sources:
RtI from All Sides: What Every Teacher Needs to Know, Mary Howard
2008–2009 Response to Intervention Guidance, Texas Education Agency

RtI Tier I Instruction Checklist

Imagine a classroom of days gone by—everyone sitting in rows, reading the same book, and producing the same product. One size fits all, or most.

What outcomes do you think you would see from students?

Now consider a classroom with flexible seating, leveled books, and a variety of student work products. Instruction tailored by the teacher based on students' diverse learning needs, strengths, and interests.

What outcomes do you think you would see from students?

Considering the following checklist, in which classroom would you likely see more characteristics of quality Tier I instruction?

Quality Tier 1 instruction . . .	
	Is the crucial foundation of the RtI instructional model
	Is proactive and intentional
	Is engaging differentiated instruction provided by the classroom teacher in the classroom, during class time
	Is intervention without labeling students
	Gives all students access to quality general curriculum and instruction
	Builds on student strengths and interests
	Lays the foundation for future learning
	Uses ongoing formative assessment to drive instruction
	Removes learning barriers
	Adjusts the classroom environment
	Includes • research-based strategies, supports, and interventions in each lesson • differentiated language support, when needed • flexible grouping (whole class and small groups)
	Values variety • in students • in student work learning needs and styles (varied instructional strategies and materials) • in student products (choice or tiered options for student work)
	Is supported by ongoing teacher professional development

References

Howard, M. (2009). *RtI from all sides: What every teacher needs to know*. Portsmouth, NH: Heinemann.

Mellard, D. (2007). *Understanding responsiveness to intervention in learning disabilities determination*. Retrieved from http://www.wrightslaw.com/info/rti.sld.mellard.pdf

Region 4 Education Service Center. (2009). *Embedding the ELPS with E's: High school science*. Houston, TX: Author.

Texas Education Agency. (2008). *2008–2009 Response to intervention guidance*. Retrieved from http://ecampus.esc13.net/media_libraries/ResponsetoIntervention-PuttingitAllTogetherOnlineModule_7544/doc/TEA_RtIGuidanceDocument[1][2].pdf

Texas Education Agency. (2010). *TEA science update—CAST 2010*. Retrieved from http://thetrc.org/web/assets/files/presentations/CAST2010_API_All_11-11-10_Final.pdf

Texas Education Agency, Division of Curriculum, & Texas Higher Education Coordinating Board, Division for P-16 Initiatives, College Readiness Initiatives. (2009). *Texas college and career readiness standards*. Austin, TX: The University of Texas.

NOTES

NOTES

INSTRUCTIONAL RESOURCES

The 5E Lesson Model

An effective lesson provides the most impact on student achievement by ensuring that students are actively engaged in learning. It also allows students to reflect upon their learning to make sense of their activities. Students are provided with opportunities to use, extend, and apply what is learned. The Five E (5E) instructional model developed and modified by Roger W. Bybee, past executive director of the National Research Council and Center for Science, Mathematics, and Engineering Education, provides such a model. Learning something new or understanding something familiar in greater depth involves making sense of both our prior experiences and first-hand knowledge gained from new explorations.

The Components of the 5E Instructional Model:

ENGAGE: The instructor initiates the Engage by asking well-chosen questions, defining a problem to be solved, or by showing something intriguing, such as a discrepant event. The activity is designed to interest students in the concept and to provide opportunities for making connections to past and present learning.

EXPLORE: The Explore provides the opportunity for students to become directly involved with the key concepts of the lesson through guided exploration that requires them to probe, inquire, and discover. As we learn, the puzzle pieces (processes and concepts necessary to solve the problem) begin to fit together or have to be broken down and reconstructed several times. In this stage, instructors observe and listen to students as they interact with each other and the materials used in the activity. Instructors provide probing questions to help students clarify their understanding of major concepts and redirect their questions and thinking when necessary. The exploration stage provides students with a set of common experiences and social interactions as they begin making sense of the new concept.

EXPLAIN: In the Explain, collaborative learning teams begin to sequence logically the events/facts from the investigation and communicate these findings to each other and the instructor. The instructor, acting in a facilitation role, uses this phase to offer further explanations and provide additional meaning or information, such as correct terminology. Giving labels or correct terminology is far more meaningful and helpful in retention if it is done after the learner has had a direct experience. The explanation stage is used to record the learner's development and grasp of the key processes and concepts of the lesson.

ELABORATE: The Elaborate allows students to apply, extend, and expand their understanding of the processes and concepts of the lesson. Students can then connect this knowledge with their prior learning to create understanding. During the elaboration stage, students are encouraged to use the terms and definitions provided previously. It is critical that instructors verify students' understanding during this stage.

EVALUATE: Throughout the learning experiences, the ongoing process of evaluation allows the instructor to determine whether the learner has reached the desired level of understanding of the key processes and concepts. In the Evaluate, both the teacher and the student check the student's understanding of the learning goal of the lesson.

Instructional Resources

Scientific Investigations

Students are expected to design and conduct an experiment in Grade 5.

Question: An investigation begins with a question you want answered. The question describes what you are testing or what you want answered.

Hypothesis: After doing some research, you can write a hypothesis and decide how you want to test your hypothesis. A hypothesis is a prediction (or an educated guess) that describes what a scientist thinks will be the answer to the question.

Variables: Scientists identify their controlled, manipulated, and responding variables in an experiment.

Procedure: A procedure is a set of instructions that tells a scientist how to do an experiment. Within the procedure, repeat the investigation multiple times to make sure the data is reliable. Compare data from different trials to make sure the results are similar. Repeated investigations are called trials.

Materials: A materials list should include all of the objects or items necessary to do the experiment.

Observations and Data: A scientist's observations and data can be recorded in note or paragraph form. Tables and graphs also may be used to capture measurements.

Results: Scientists examine the data and summarize the results.

Conclusion: A conclusion is drawn after all the trials are complete and results are analyzed. Scientists reflect on their predictions, or hypotheses, to see if the data supports their hypothesis.

Next Steps: Scientists list the things that were done well in the experiment as well as the things that could have been done differently or better. Based on the conclusions, a scientist may plan future experiments that build on his or her results.

Instructional Resources

Instructional Strategies

Alternate Response Products—Students produce varied products to show what they have learned. Teachers may assign tiered products or allow students to choose their output products, which encourages student engagement and ownership of learning.

Brainstorming/Discussion—Whole-class or small-group activities encourage students to discuss their thinking or ideas about a given topic. This process values student knowledge and ability while helping students share and build on their ideas.

Choice—Providing students with choice in the process and product of their learning is a way to engage students and allow them to create their own meaning.

Experience-Based Writing/Reading—Students are provided the opportunity to recognize and tap into their experiential knowledge, including cultural influences and interests.

Graphic Organizers—Graphic or visual displays can be used to show how ideas, facts, and terms are related to each other. Concept maps, Venn diagrams, T-charts, and labeled illustrations are examples of graphic organizers that are effective strategies for supporting student comprehension throughout a lesson cycle.

Grouping/Cooperative Learning—Varied grouping helps meet the needs of students and facilitates materials management. Working in cooperative learning groups allows students to discuss new content; get new ideas; and ask questions in a smaller, safer group before completing a task and/or speaking to the whole class. Students can work in pairs or in groups of three to five depending on the task and/or age of the students.

Think-Pair-Share is one instructional strategy that provides structure for cooperative learning in pairs. Pairing an English language learner (ELL) with a proficient English speaker will provide the ELL student with a language model and an opportunity to practice English skills one-on-one before sharing with the class.

Hands-on Learning/Activities—Students have their hands on materials and do science. Engaging students in hands-on learning allows them to learn by doing and helps them apply in real time what they think, know, and learn. Hands-on learning may include working with models or manipulatives. The student is actively involved in investigating and observing during the learning process.

Manipulatives/Cards—Physical objects or photo representations of objects or concepts allow students to manipulate or get their hands on the content. Teachers can differentiate manipulatives and card sorts by size, color, and number (increase/reduce the number of cards for students as needed).

Music and Rhyme—This method engages students in learning new information by using words in rhythm to songs and chants.

Instructional Strategies

Notebooking—Notebooks are used to document and organize information from class discussions, investigations, and activities. In kindergarten or first grade, teachers might use a large spiral-bound chart that has been turned on its side to function as a class notebook. In second grade and higher, students may use individual or personal notebooks to record information, observations, and reflections. Writing and/or drawing opportunities provide a means for students to express their understanding through art and nonlinguistic representations.

Pictures/Photos—Giving a visual image or context clue for students to use builds an understanding of a concept or helps identify unfamiliar vocabulary.

Role Playing—Acting taps into the interpersonal and verbal skills of students by allowing them to become involved through acting out concepts.

Rubrics—Assess and encourage student performance and reflection by explaining various ranges of skills and/or behaviors required for a task or assignment.

Sentence Frames/Starters—Visually displaying phrases and well-formed sentences provide language support needed to speak or write in complete sentences about a given topic. Sentence frames may be used throughout the lesson cycle and can be posted around the classroom.

Stations—Activity centers are set aside for students (individually or in small groups) to simultaneously complete various assigned tasks. With planning, stations can be used to differentiate instruction and can help with materials management. (Providing materials for one station is easier than providing materials for the entire class.) Teachers may allow students to choose a center using a menu or may ask all students to work through centers with leveled activities.

Technology—Differentiate activities and allow for customized, flexible/varied student materials and products by using audio and video recordings, digital copies of books, Internet searches, and apps on mobile devices.

Visual Aids—Help students visualize new and/or difficult concepts using demonstrations, models, pictures, or images that support learning. Adding pictures to reading passages or task instruction cards for hands-on activities can help students read text with less difficulty and remove barriers in understanding and/or completing tasks. Refer to the following example of using a visual aid on a task instruction card.

1. Put on your safety goggles. 

Instructional Strategies

Vocabulary Games—Games engage students in using key vocabulary in unique ways that can activate prior knowledge, reinforce key vocabulary terms, clarify meanings, and catch student misconceptions.

Word Associations—Combine a vocabulary word, a key term or phrase from the definition, and an illustration to visually display vocabulary. Students have the opportunity to make their own connections and to take ownership of their learning.

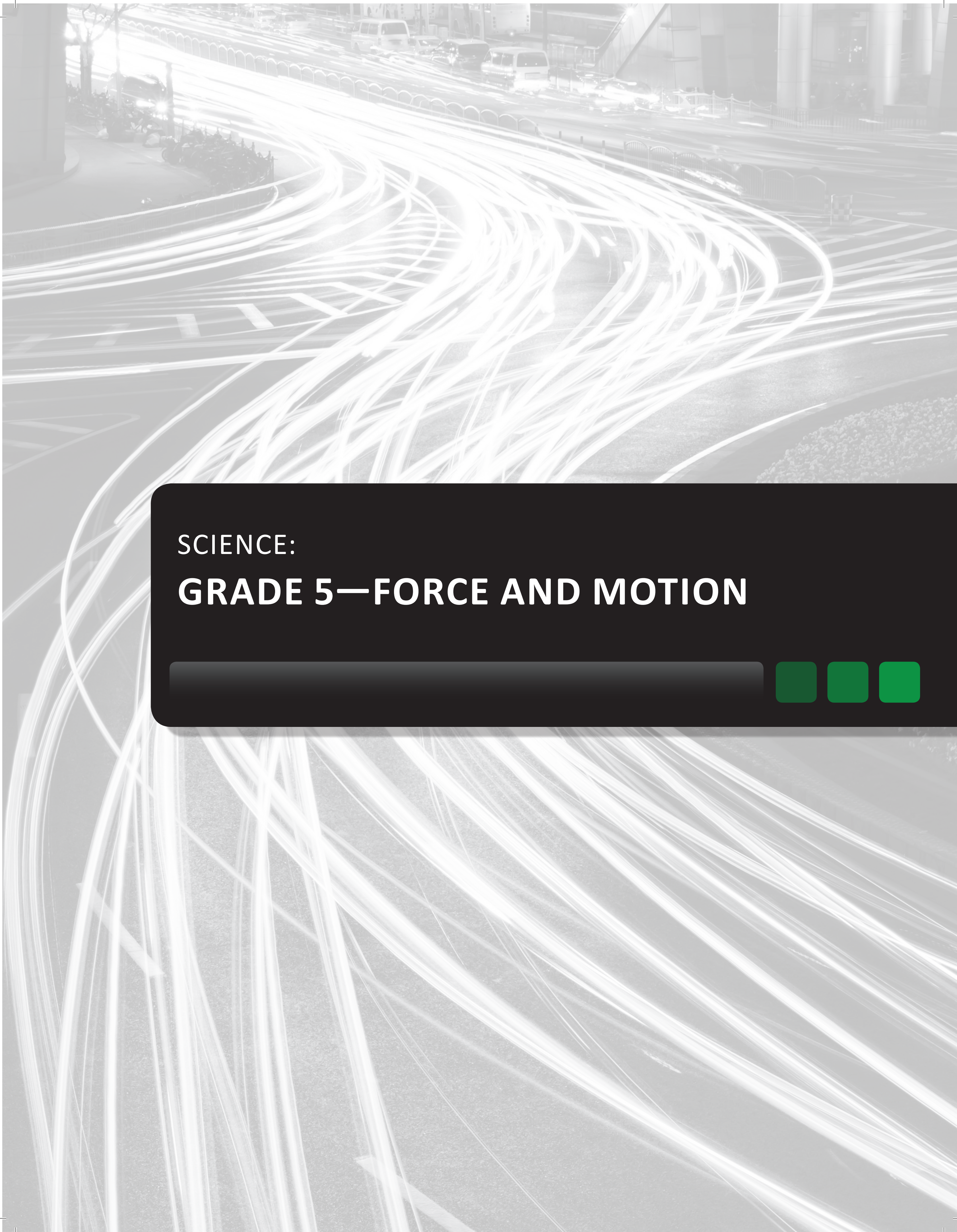
Word Bank—Listing words related to a unit of study, organized by category, supports students in accessing the vocabulary needed to complete specific tasks or assignments.

Word Wall/Personal Word Wall—Continuously displaying vocabulary needed to complete specific tasks or assignments throughout the year helps students retain information. Teachers and students can add new vocabulary words as words are covered in class.

Instructional Resources

Literacy and Math Integration

Lesson	Strategies	
	Literacy	Math
Grade 5 Experimental Investigation		
Grade 6 Changes in Motion		
Grade 7 Work		
Grade 8, Lesson 1 Balanced and Unbalanced Forces		
Grade 8, Lesson 2 Force, Mass, and Acceleration		



SCIENCE:

GRADE 5—FORCE AND MOTION

Force and Motion

Lesson Outline: Experimental Investigation

Content Objective

I can design an experiment that tests the effect of force on an object.

Language Objective

I will use the terms dependent variable*, independent variabl*e*, and* controlled variable *to accurately describe experimental investigations.*

5E Lesson Summary

Engage

Students consider a question and evaluate the experiment that is designed to answer it.

Explore

Students play a game of marbles and then apply an investigative process to it.

Differentiation Strategy

The game can be played with more or fewer marbles. Marbles can be placed in the circle in the shape of a plus sign or simply scattered. The circle can be decreased or increased in size. The larger the circle, the more difficult the game becomes. The large marbles can be rolled instead of launched.

Explain

Students define the investigative process and the difference between dependent and independent variables.

Elaborate

Students design their own experiments to test the effect of force on an object.

Differentiation Strategy

If groups cannot brainstorm an experiment to design, you may provide them with either a scenario card from *RM 6* or a scenario card with materials printed on the back side (*RMs 6–7*). *RM 6* cards detail a real-life scenario that may prompt groups to design an experiment that would model the scenario. Each *RM 7* card lists a set of materials. Groups will need to design an experiment that uses all of the materials on the card.

Force and Motion

Evaluate

Students evaluate an experiment to see if it was effectively designed and conducted.

Tier I Support

Students may work individually, in pairs, or in small groups to complete *RM 8: Evaluating an Experimental Investigation*.

Force and Motion

Notes

SCIENCE:

GRADE 5—FORCE AND MOTION

EXPERIMENTAL INVESTIGATION

Force and Motion

Experimental Investigation

Science Concept

5(6) Force, motion, and energy. The student knows that energy occurs in many forms and can be observed in cycles, patterns, and systems. The student is expected to:

(D) design an experiment that tests the effect of force on an object

Content Objective

I can design an experiment that tests the effect of force on an object.

Science Process Skills

5(2) Scientific investigation and reasoning. The student uses scientific methods during laboratory and outdoor investigations. The student is expected to:

(A) describe, plan, and implement simple experimental investigations testing one variable

(B) ask well-defined questions, formulate testable hypotheses, and select and use appropriate equipment and technology

(C) collect information by detailed observations and accurate measuring

(D) analyze and interpret information to construct reasonable explanations from direct (observable) and indirect (inferred) evidence

(E) demonstrate that repeated investigations may increase the reliability of results

(F) communicate valid conclusions in both written and verbal forms

English Language Arts and Reading

5(11) Reading/Comprehension of Informational Text/Expository Text. Students analyze, make inferences and draw conclusions about expository text and provide evidence from text to support their understanding. Students are expected to:

(C) analyze how the organizational pattern of a text (e.g., cause-and-effect, compare-and-contrast, sequential order, logical order, classification schemes) influences the relationships among the ideas

Force and Motion

English Language Proficiency Standards

(3) Cross-curricular second language acquisition/speaking. The ELL speaks in a variety of modes for a variety of purposes with an awareness of different language registers (formal/informal) using vocabulary with increasing fluency and accuracy in language arts and all content areas. ELLs may be at the beginning, intermediate, advanced, or advanced high stage of English language acquisition in speaking. In order for the ELL to meet grade-level learning expectations across the foundation and enrichment curriculum, all instruction delivered in English must be linguistically accommodated (communicated, sequenced, and scaffolded) commensurate with the student's level of English language proficiency. The student is expected to:

(D) speak using grade-level content area vocabulary in context to internalize new English words and build academic language proficiency

Language Objective

I will use the terms dependent variable, independent variable, *and* controlled variable *to accurately describe experimental investigations.*

Response to Intervention/Tier I Differentiation

All science lessons support students in receiving quality Tier I instruction. Using the 5E model, knowledge is taught in a variety of contexts, integrating math, science, and ELAR content, thus supporting the active engagement of the students with the content. Lesson-specific differentiation strategies for addressing diverse student needs can be found in sections titled "Differentiation Strategy."

Differentiation should

- focus on skills students did not understand and extend the lesson for advanced students;
- be conducted in small groups or embedded in whole-group instruction; and
- provide students with a variety of strategies to process the information, such as
    - allowing for additional opportunities for verbal brainstorming of words associated with a topic (with teacher taking dictation);
    - making clear connections of new and more complex concepts to foundational aspects and prior knowledge;
    - participating in more tangible experiences, such as experiments, investigations, and active exploration;

Force and Motion

- sorting academic vocabulary words into categories by common attributes, such as process words or science content vocabulary;
- organizing results of brainstorming into semantic maps or creating graphic organizers;
- discussing the meaning of a graphic organizer with a partner; and
- creating a visual representation to demonstrate understanding.

See the handout in the Instructional Resources section that addresses instructional strategies.

College and Career Readiness Standards—Science Standards

I.B.1 Scientific inquiry. Design and conduct scientific investigations in which hypotheses are formulated and tested.

I.E.2 Effective communication of scientific information. Use essential vocabulary of the discipline being studied.

Vocabulary Focus

experiment

force

5E Lesson Summary

Engage
Students consider a question and evaluate the experiment that is designed to answer it.

Explore
Students play a game of marbles and then apply an investigative process to it.

Explain
Students define the investigative process and the difference between dependent and independent variables.

Elaborate
Students design their own experiments to test the effect of force on an object.

Evaluate
Students evaluate an experiment to see if it was effectively designed and conducted.

Engage

Teacher Note

RM stands for reproducible master. You may choose to project *RM 1: Engage* or print it for students to observe. Student answers to the facilitation questions will indicate whether they have experience with designing an experiment [4(6)(D)].

Materials

For teacher

- RM 1

Teacher Instruction

- Instruct students to choose a partner who is sitting nearby.
- Project *RM 1* for students to observe.
- Ask student pairs to consider the question on the screen. They should decide if the experiment is correctly designed. If it is not, students should suggest ways to make it better.

Facilitation Questions

- Have you worked through an experiment before? *Answers will vary based on students' prior experiences. Students who attended fourth grade in Texas should have designed and conducted their own experiments [4(6)(D)].*
- What is the question asking? *The question is asking whether increased force moves an object a greater distance.*
- What is being tested? *Force is being tested (specifically a pushing force).*
- Is the experiment properly set up to answer the question? Why or why not? *The experiment has too many variables. To properly answer the question and to test force, students should only use one kind of sphere, or ball. They would need to launch the ball with each of the four different spring scales to see if the scale with the strongest force moved the ball the greatest distance. More than one trial should be conducted with each spring scale to collect reliable data and observations.*

Explore

Materials

For teacher

- timing device or clock

For student groups

- RM 2
- 9–13 small marbles
- 1–3 large marbles
- sorting circle, string (1.5–2 m), or sidewalk chalk
- meter stick
- tape (only necessary if using string)

Content Builder

Students are first introduced to the term *variable* in fifth grade [5(2)(A)]. Previously, the words *difference* and *change* may have been used. There are three types of variables in an experiment. An independent variable is the variable that the scientist manipulates or changes; it can also be called a manipulated variable. An experiment should have only one independent variable. For example, when looking at the question from Engage, the spring scales of different strengths are the independent variable. The second type of variable is the dependent, or responding, variable. The distance the sphere, or ball, rolled is the dependent variable in the Engage experiment. The distance the ball traveled is a result of the strength of the spring scale used to launch it. The third type of variable is the controlled variable. Controlled variables are the unchanging factors in an experiment. The kind of ball used and the surface the ball is rolled on in the Engage experiment are the controlled variables because they remain constant in every trial. These terms will be defined for students in the Explain section of the lesson.

Teacher Note

The Explore activity can be performed on different surfaces, including concrete, carpet, linoleum, or tabletops without divides or cracks. If students play on concrete, they can use the meter stick and sidewalk chalk to create a circle that is at least 50 cm in diameter. If they play on carpet, linoleum, or a table top, students can use collapsible sorting circles or a meter stick and string to create a circle at least 50 cm in diameter. Students must be careful to keep track of their marbles to make sure none are left on the floor causing someone to step on them, slip, and fall.

Marbles come in different sizes. Standard marbles are 16 mm in diameter. The next larger size marbles are 25 mm in diameter. However, marbles can be ordered in sizes as small as 12–14 mm in diameter. Depending on the sizes of the students' hands, smaller marbles may be needed.

Advance Preparation

If students are going to create circles using string, cut string that is 1.5–2 meters in length for each group.

Force and Motion

Teacher Instruction

- Divide the class into groups of three students.
- Distribute *RM 2: Marbles* and materials to play the game to each group.
- Read through *RM 2* step-by-step with the class to make sure groups know how the game is played.
- Allow groups 5–10 minutes to set up their games and practice launching their marbles.
- Allow 20–30 minutes for students to play the game.
- Debrief the activity using the facilitation questions after time has run out or game play has concluded.

Differentiation Strategy

The game can be played with more or fewer marbles. Marbles can be placed in the circle in the shape of a plus sign or simply scattered. The circle can be decreased or increased in size. The larger the circle, the more difficult the game becomes. The large marbles can be rolled instead of launched.

Facilitation Questions

- What was the goal of the game? *The goal of the game was to move the marbles out of the circle.*
- What did you do to move the marbles out of the circle? *We moved around the perimeter of the circle to get the best angle and then used the force of the large marble to knock the smaller marbles out of the circle.*
- How could the game be played differently? *We could have started with more or fewer marbles in the circle. We could have placed the marbles in a different pattern or just scattered them in the circle. We could have increased or decreased the size of the circle. We could have rolled the large marble. We could have used marbles of different sizes.*
- Were forces involved with playing this game? If so, which forces and how? *Yes, force was involved with this game. The pushing force of the large marble moved the smaller marbles.*

Force and Motion

Teacher Instruction

- Ask students to think about the marbles game as an experiment.
- Use the following facilitation questions to get students thinking about the investigative process and how it relates to the marbles game.

Facilitation Questions

- If we think about the marbles game as an experiment, what questions could we be trying to answer? What might we be trying to find out? *Answers will vary but may include what is the best way to get the marbles out of the circle, does staying in one position on the circle's perimeter make it more difficult to remove the marbles from the circle, and does rolling the large marble or launching it work better.*
- What things stayed the same in the experiment? *The things that stayed the same in the experiment were the size of the circle, the number of marbles that started in the circle, and the size of the marbles.*
- What things changed in the experiment? *The things that changed in the experiment were our positions as we moved around the perimeter of the circle, how much force we used to launch the large marble, and the distance between the marbles as the marbles moved throughout the game.*
- How would you explain how to conduct the experiment to someone else? *Groups should list the steps of how they would do the experiment; they may deviate from the way they played the game.*
- What materials would you need to conduct the experiment? *Students should list a certain amount of marbles, marbles of two sizes, something to create a circle, a meter stick, and possibly tape.*
- What observations and measurements could you make? *We could observe the direction the marbles roll and measure the distance they travel.*
- How would you record your observations and measurements? *Observations and measurements can be recorded in written paragraph form and in a table.*
- What would you use to draw a conclusion? *We could write a conclusion based on our observations and measurements.*

Explain

Content Builder

Student expectation 5(2)(A) states that students should "describe, plan, and implement simple experimental investigations testing one variable." According to the Texas Education Agency (TEA), an experimental investigation is defined as designing a fair test, which means "only one factor (variable) is changed at a time, while keeping all other conditions the same. An experimental investigation is often called a 'controlled experiment.'"

Materials

For teacher

- RM 3
- projector
- screen

For each student

- RM 3
- RM 4

Teacher Note

As students read *RM 3: Designing Experimental Investigations*, they will fill in information on *RM 4: Note-Taking Guide*. This reading strategy will help students chunk the reading to make it more meaningful and less overwhelming.

Teacher Instruction

- Project *RM 3* for the whole class.
- Point out the title, subtitles, and graphics to students. Ask students to pay attention to these text features as they read.
- Distribute *RM 3* to each student.
- Read through the first two sections on *RM 3* as a class, stopping before "Experimental Investigations."
- Distribute *RM 4* to each student.
- Instruct students to work individually or in pairs to finish reading *RM 3* while completing *RM 4*.

Facilitation Questions

- What is an experimental investigation? *An experimental investigation involves a fair test with identified controlled variables and one independent variable.*

1207343 Science Academies_Lesson 5.indd 45 4/27/2016 9:52:52 AM

Force and Motion

- What are the parts of an experimental investigation? *An experimental investigation includes asking a question; making a hypothesis; identifying variables; writing directions or a procedure detailing how to do an experiment; listing materials necessary to conduct the experiment; observing, recording, and measuring data; and interpreting data to come to a conclusion.*

- How might scientists think of questions to ask? *Scientists observe the world around them. Sometimes they are curious about how events happen. They design experiments that model a problem or an event in an effort to figure out how or why they occur.*

- What are the different kinds of variables in an experiment? *The different kinds of variables in an experiment include controlled, independent, and dependent variables.*

- What is a controlled variable? *A controlled variable identifies those factors that stay the same and do not change in an experiment.*

- What is an independent variable? *An independent variable is changed by the scientist in order to study the relationship between it and the dependent variable. For example, different types of magnets may have stronger or weaker magnetic fields. One magnet may attract a paper clip from a greater distance than another. In this case, the various magnets would be the independent variable. Independent variables are also called manipulated variables.*

- What is a dependent variable? *A dependent variable depends on the independent variable. In the above example, the distance from which a paper clip is attracted to different magnets is the dependent variable. The distance depends on the strength of the magnet. A dependent variable is also called a responding variable.*

- In what ways can scientists observe and collect data? *Scientists can make observations and collect data by writing, drawing pictures, measuring, and creating data tables and graphs.*

- How can scientists help ensure the data they collect are reliable? *Conducting multiple trials helps ensure the collection of reliable data. In the event that one trial has different data than another, it could be ruled out if enough data exist to refute it.*

- What do scientists do with their observations and data? *Scientists interpret their data in order to support or deny their hypotheses.*

Force and Motion

- Did the note-taking guide help you? If so, how? *Answers will vary but should include that the note-taking guide helps students chunk the information and extract the important parts. It should make the reading less overwhelming because students have time to process the information.*

RM 4 Answer Key

Experimental Investigation

Step: *Question*

Description:
The question describes what a scientist is testing or what a scientist wants answered.

Step: *Hypothesis*

Description:
A prediction leads to a hypothesis that describes what a scientist thinks will be the answer to the question and why.

Step: *Conclusion*

Description:
A conclusion is a scientist's interpretation of his or her results. He or she will also decide whether the experiment answered his or her question.

Step: *Variables*

Description:
Scientists identify their controlled, independent, and dependent variables in an experiment.

Step: *Results*

Description:
Scientists examine data to determine the outcome of the experimental investigation.

Step: *Directions or Procedure*

Description:
A procedure is a scientist's step-by-step description detailing how to do an experiment.

Step: *Observations and Data*

Description:
A scientist's observations and data can be recorded in note or paragraph form. Tables and graphs may also be used to capture measurements.

Step: *Materials*

Description:
A materials list should include all of the objects or items necessary to do the experiment.

1207343 Science Academies_Lesson 5.indd 47 4/27/2016 9:52:52 AM

Force and Motion

Variables		
Controlled	**Independent**	**Dependent**
C. example: small paper clip used throughout experiment	*D. example: using different kinds of magnets to test their strengths*	*A. change depends on the manipulated variable*
I. unchanging, constant variable	*E. manipulated variable*	*B. example: paper clip being attracted to a magnet from a certain distance*
	H. scientists change this variable	*F. measurable*
		G. responding variable

Elaborate

Advance Preparation

Print *RM 6: Scenario Cards* on cardstock, laminate, cut out the cards, and bag them. Print *RM 6* and *RM 7*: *Materials Cards* two-sided on cardstock with the scenarios on one side and the materials lists on the back side, laminate, cut out the cards, and bag them. Consider printing *RM 6* on one color of cardstock and two-sided *RMs 6–7* on a different color. Both RMs are built-in supports to help groups be successful in thinking of and designing experiments.

Teacher Note

RM 5: Experimental Investigation Checklist provides a checklist to guide groups as they design their experiments. The checklist includes all the parts of an experimental investigation. Some groups may rely on the checklist more than others depending on their levels of knowledge. Make sure you have plenty of materials available for students to use in their experiments. If you choose to use the materials cards from *RM 7*, read each card to verify you have those materials on hand. Allow students to write their experimental investigations on paper or by using technology.

Differentiation Strategy

If groups cannot brainstorm an experiment to design, you may provide them with either a scenario card from *RM 6* or a scenario card with materials printed on the back side (*RMs 6–7*). *RM 6* cards detail a real-life scenario that may prompt groups to design an experiment that would model the scenario. Each *RM 7* card lists a set of materials. Groups will need to design an experiment that uses all of the materials on the card.

Note: Use paper clips to model roofing nails.

Teacher Instruction

- Divide the class into groups of three students.
- Distribute *RM 5* to each student.
- Instruct groups to design an experiment using the checklist on *RM 5*. Their experiments must test the effect of force on an object.
- Distribute cards from *RM 6* or *RMs 6–7* as needed.
- Use the facilitation questions to debrief the activity.

Materials

For teacher

- RM 6
- RM 7
- cardstock
- 2 sandwich-size resealable plastic bags

For student groups

- assorted materials to conduct experiments (see RM 7 for list)
- access to technology such as computers, laptops, or tablets

For each student

- RM 5

Force and Motion

Facilitation Questions

- How did your group think of an experiment to design? *Answers will vary.*
- How did force affect your experiment? *Answers will vary.*
- What were the independent, dependent, and controlled variables in your experiment? *Answers will vary.*
- What was the relationship between the variables in your experiment? *Answers will vary.*
- Did your results support your hypothesis? *Answers will vary.*
- What parts of your experiment were designed well? *Answers will vary.*
- Were there parts of your experiment that you would change or redesign? If so, what parts and why? *Answers will vary.*

Possible Answer Key

Scenario/Materials 1

1. Position one end of a ramp on a textbook with the other end of the ramp on tiled floor.
2. Set the toy car at the top of the ramp and release it.
3. Measure how far the car travels beginning from the bottom of the ramp to where the car stops moving.
4. Repeat steps 2–3 two more times, and record the distance each time.
5. Spray water on the tiled area at the bottom of the ramp.
6. Repeat steps 2–3 three times, and record the distance each time.
7. Use the towel to dry the tiled area.

Scenario/Materials 2

1. Hold an object, such as a toy soldier or paper cup, away from your body and above your head.
2. Release the object, and observe how long it takes to hit the ground.
3. Repeat steps 1–2 two more times.
4. Tape each corner of the sheet of tissue paper or opposite sides of a coffee filter to the object.
5. Hold the object above your head, and release it.

Force and Motion

6. Observe how long it takes the object to hit the ground.
7. Repeat steps 5–6 three times.

Scenario/Materials 3

1. Sprinkle 30 paper clips on the floor.
2. Use a bar magnet to pick up the paper clips.
3. Count and record the maximum number of paper clips the magnet picked up.
4. Repeat steps 1–3 two more times.
5. Repeat steps 1–3 three times using a horseshoe magnet.
6. Repeat steps 1–3 three times using a magnetic wand.

Scenario/Materials 4

1. Position one end of a ramp on a textbook with the other end of the ramp on tile or flooring covered with aluminum foil or wax paper.
2. Set the foam ball at the top of the ramp, and release it.
3. Measure how far the ball travels beginning from the bottom of the ramp to where the ball stops moving.
4. Repeat steps 2–3 two more times, and record the distance traveled each time.
5. Wrap the rubber bands around the foam ball in a starlike pattern.
6. Repeat steps 2–3 three times, and record the distance traveled each time.

Scenario/Materials 5

1. Locate an area of flooring that is 1–2 meters in length.
2. Mark a starting line with tape.
3. Measure 50 cm from the starting line with a meter stick, and mark a finish line with tape.
4. Cover that section of the floor with freezer paper (wax side up).
5. Tie one end of a string around a wooden block.
6. Make a loop in the opposite end of the string.
7. Place the front edge of the block on the starting line.
8. Spray the wax paper with water.
9. Hook the loop of the string to a spring scale, and drag the block from the starting line to finish line over the wet surface.

Force and Motion

10. Record the amount of force in Newtons used to drag the brick.
11. Repeat steps 7–10 two more times.
12. Replace the freezer paper with coarse sandpaper.
13. Repeat steps 7–10 three times.

Scenario/Materials 6

1. Locate an area with a 1–2 m length of concrete or tile.
2. Mark a starting line with chalk (concrete) or tape (tile).
3. Measure 1 m from the starting line with a meter stick, and mark a finish line with chalk (concrete) or tape (tile).
4. Tie one end of a thick string or section of twine around a brick.
5. Make a loop on the opposite end of the string or section of twine.
6. Place the front edge of the brick on the starting line.
7. Hook the loop of the string to a spring scale, and drag the brick from the starting line to finish line.
8. Record the amount of force in Newtons used to drag the brick.
9. Repeat steps 6–8 two more times.
10. Slide the string or section of twine off the brick.
11. Wrap the brick in bubble wrap that is made with small air bubbles.
12. Slide the string or section of twine back on the brick.
13. Repeat steps 6–8 three times.

Scenario/Materials 7

1. Sprinkle 75 staples on the floor.
2. Use a bar magnet to pick up as many staples as possible within 5 seconds.
3. Record the number of staples the magnet picked up.
4. Repeat steps 1–3 two more times.
5. Repeat steps 1–3 three times using a horseshoe magnet.
6. Repeat steps 1–3 three times using a ring magnet.

Evaluate

Tier I Support

Students may work individually, in pairs, or in small groups to complete *RM 8: Evaluating an Experimental Investigation*.

Materials

For each student

- RM 8

Teacher Instruction

- Determine how students will work through the Evaluate activity.
- Distribute *RM 8* to each student.
- Instruct students to use their knowledge of experimental investigations to complete *RM 8*.

RM 8 Answer Key

1. What did the students do correctly?
    - *The students included all the parts of an experimental investigation (question, hypothesis, materials, procedure, data, results, and conclusion) in their design.*
    - *The students performed multiple trials to collect more reliable data.*
    - *The controlled variables stayed the same, including the tennis ball, ramp, meter stick, and books.*
    - *The students recorded their measurements in tables using centimeters as their only unit of measurement.*
2. What could the students have done better?
    - *The students should have limited their independent variables to one. They should have chosen to test how far the ball would roll either by releasing or by launching on one type of flooring.*
    - *Students performed Part A using two books under the ramp and Part B using four books under the ramp. They should have used either two or four books for both parts.*

Force and Motion

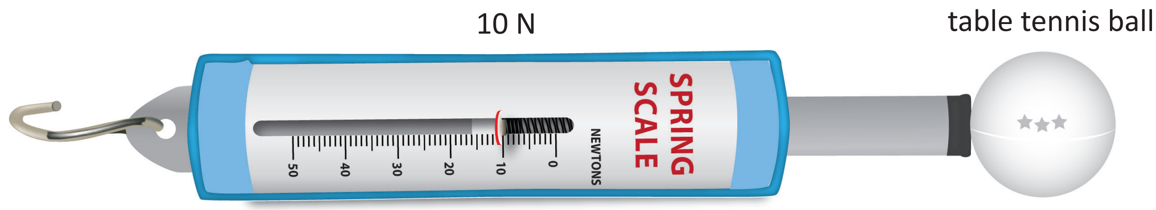
3. Based on the experiment, is the students' hypothesis supported by their data? Explain your reasoning.
   - *On a superficial level, it appears the data support the students' hypothesis. Under close inspection, the data do NOT support the hypothesis because the students conducted Part A using two books under the ramp and Part B using four books under the ramp.*

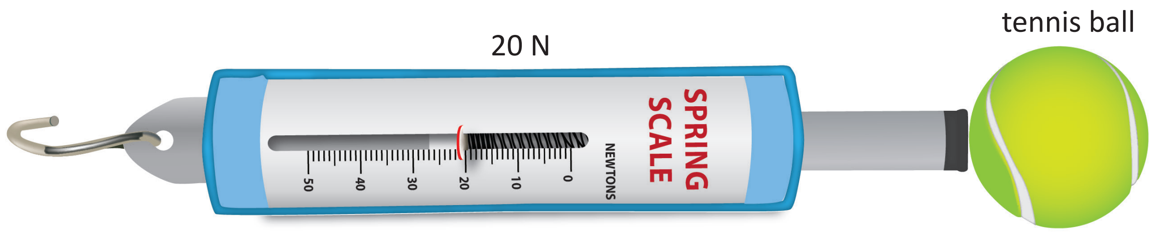
4. Did the students design the experiment to find an accurate answer to their question? Why or why not?
   - *To find an accurate answer to their question, the students would need to redo Parts A and B using the same number of books under the ramp.*
   - *Students could also simplify their experiment by having one independent, or manipulated, variable: type of flooring or releasing, instead of launching the ball.*

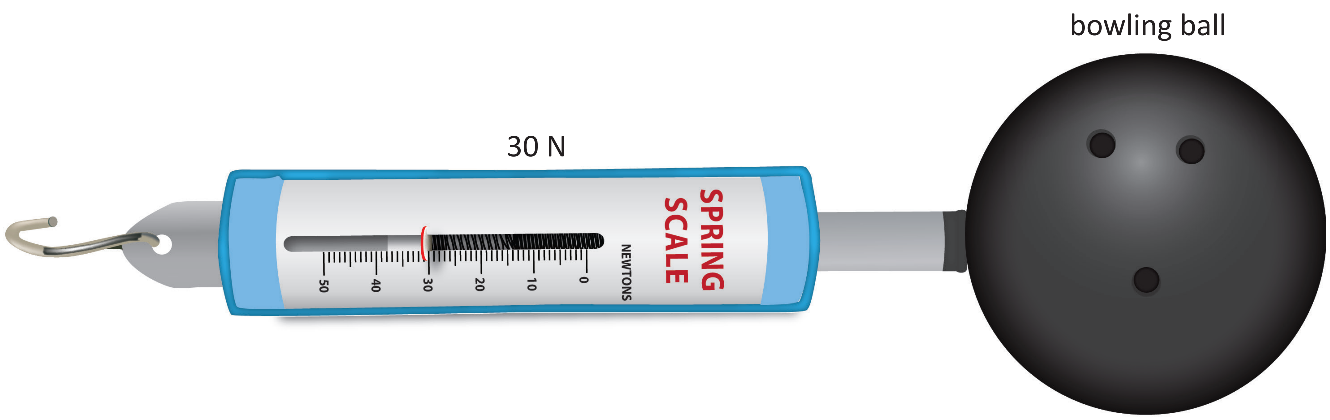
Force and Motion

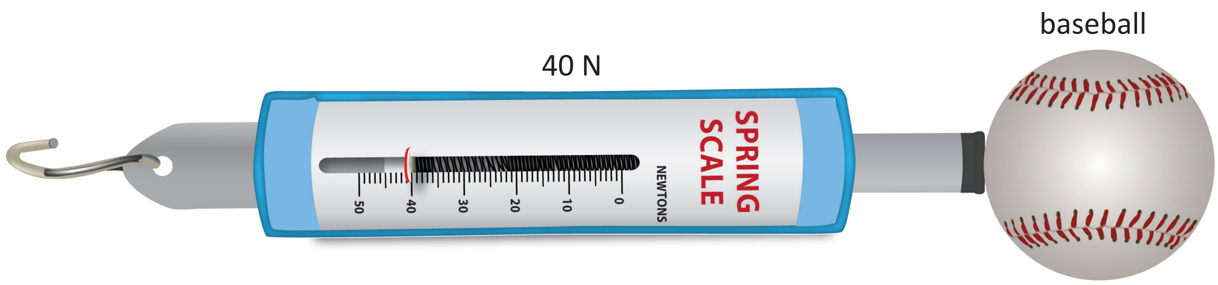
RM 1: Engage

Will more force cause a sphere, or ball, to move farther?









Force and Motion

RM 2: Marbles

Goal

Move all of the marbles out of the circle.

Materials

- 9–13 small marbles
- 1–3 large marbles
- meter stick
- sorting circle, string (1.5–2 m), or sidewalk chalk
- tape (optional)

Directions

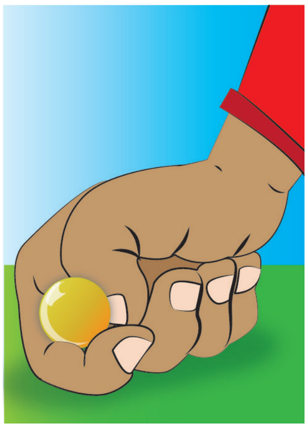
1. Decide where the game will be played. For example, if you play on concrete, you will need sidewalk chalk. If you play on carpet or tile, you will need a sorting circle or section of string to create the boundary circle.
2. Set up the game as shown in the below picture. Depending on what your teacher instructs you to do, you may choose to play with fewer marbles. Use tape to secure a circle made of string.

3. Each player will need a large marble to use as their launching marble. Depending on the amount of materials available, large marbles may need to be shared.
4. Practice forming a loose fist and placing your thumb either between your index and middle fingers or between your middle and ring fingers.

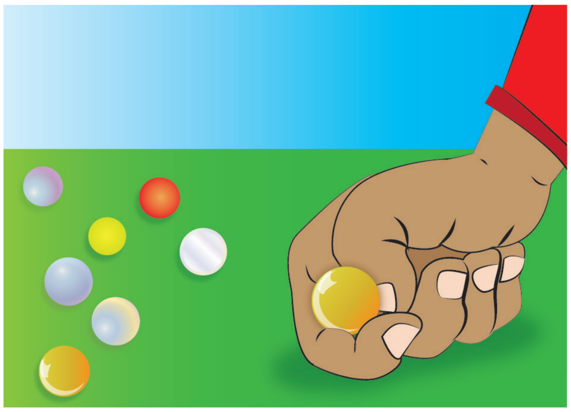
Force and Motion

RM 2 continued

5. Place a large marble on your index finger, and allow it to rest against your thumbnail.



6. Position your fist with your knuckles down on the playing surface. You may angle your fist any way you like as long as one knuckle is always touching the playing surface.



7. Take a few minutes to practice your strategy and technique for launching the large marble. The goal is for the large marble to knock the small marbles out of the circle.
8. Each player's first launch to start the game must be made from outside the circle. Remaining launches may be made from anywhere on the playing surface inside or outside the circle.
9. Decide the order of players based on who is oldest to youngest.
10. You may move around the perimeter of the circle to get the best angle for each turn.
11. If you knock a marble out of the circle, you may go again. Collect the marbles you knock out of the circle.
12. Your turn is over if you do not knock a marble out of the circle.
13. Remove your large marble from the circle after each turn.
14. The player who knocks the most marbles out of the circle wins the game.

Designing Experimental Investigations

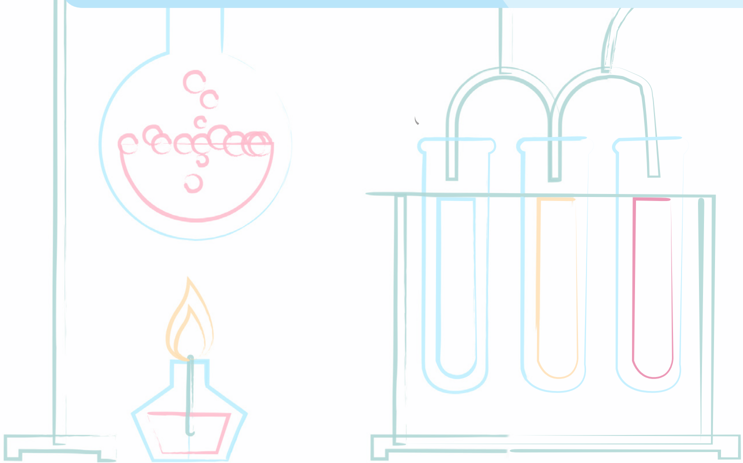
WHO IS A SCIENTIST?

WHAT MAKES SOMEONE A SCIENTIST?

WHAT DOES A SCIENTIST DO?

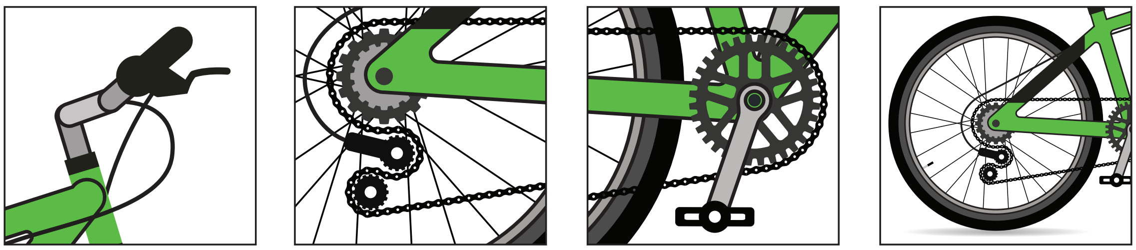
HAVE YOU EVER ASKED ANY OF THESE QUESTIONS?

A scientist is someone with knowledge of science. Scientists are curious and observant and question the world around them. They want and need to know how things work and what causes events to happen. Scientists conduct experiments and record their observations and measurements in order to come to conclusions.

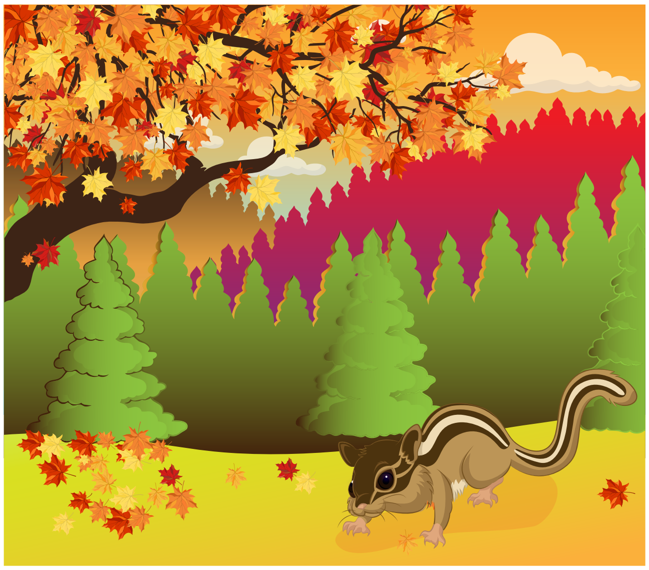


TYPES OF INVESTIGATIONS

Some investigations involve simple observations as scientists try to understand a process or behavior. For example, if a scientist wants to know how a bicycle works, she might watch someone ride a bicycle and observe how the gears, chains, wheels, handlebars, and brakes function independently or together as a system. This type of investigation is called a descriptive investigation.



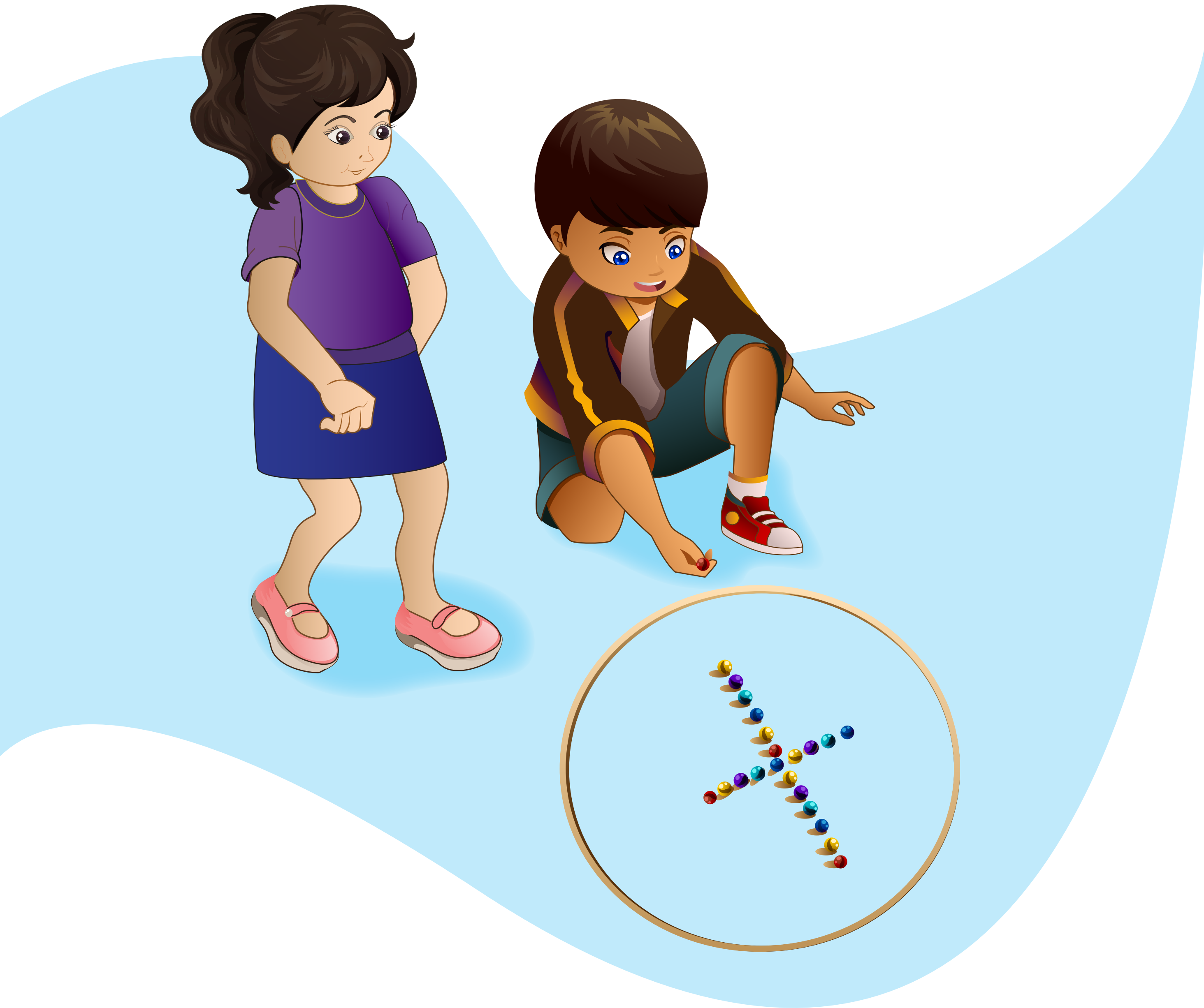
Another kind of investigation is called a *comparative investigation*. This kind of investigation involves comparing a process or behavior in two different settings. For example, a scientist may observe how a chipmunk behaves in the fall and then in the spring. The different seasons are the variable in this investigation. A scientist may predict that the chipmunk will be more active in the spring after hibernation as it searches for food and water and then be less active in the fall as it prepares to hibernate through winter.



Texas Education Agency

© 2016 TEXAS EDUCATION AGENCY. ALL RIGHTS RESERVED.

Another kind of investigation is called an *experimental investigation*. An experimental investigation involves a test with three identified variables. Some variables stay the same throughout the experiment, one variable is manipulated by the scientist, and another variable responds to the manipulated variable. Scientists observe the relationship between the variables during the experiment. This kind of experiment can also be called a *controlled experiment*.



EXPERIMENTAL INVESTIGATIONS

An experimental investigation is a process that includes several steps or parts.

The first step in an experimental investigation is to develop a question to answer. For example, will a ball roll farther on tile or carpet? The question should be observable, measurable, and testable.

The second step in an experimental investigation is to make a hypothesis regarding what will happen in the experiment. For example, a hypothesis could be “The ball will roll farther on tile.”

The third step in an experimental investigation is to identify three different variables.

- An *independent variable* is a variable that a scientist manipulates or changes. For example, an independent variable would be the type of flooring when trying to figure out if a ball will roll farther on tile or carpet. An independent variable is also called a manipulated variable.
- A *dependent variable* is the variable that changes based on the independent variable. For example, the distance the ball rolls on different types of flooring is the dependent variable. A dependent variable is also called a responding variable. This is what the scientist measures.
- A *controlled variable* is any variable that stays the same in an experiment. The ball would be a controlled variable in an experiment involving how far a ball rolls on tile versus carpet. The only fair way to test this question would be to use the same ball on both flooring surfaces. The method of releasing the ball should also be the same. Rolling the ball or pushing the ball may result in different amounts of force being used each time, so the scientist may choose to release the ball down a ramp or launch it using a push-pull spring scale.

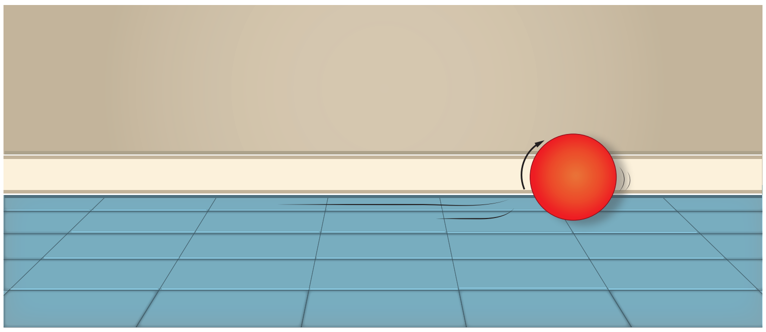
Texas Education Agency

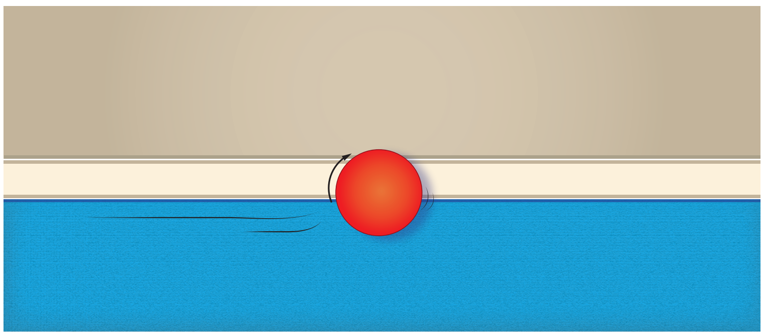
The fourth step in an experimental investigation is to write a procedure. A procedure is a step-by-step set of instructions that details how to do an experiment. The procedure needs to be written clearly enough that another scientist could re-create the exact experiment.

The fifth step in an experimental investigation is to create a materials list. The materials list should include everything a scientist needs to do the experiment.

The sixth step in an experimental investigation is to record data, such as observations and measurements, as a scientist does the experiment. Data can be recorded in a table or graph and may include sketches or written notes. Scientists should run multiple trials in an investigation to collect reliable data. The goal is to see if the majority of the trials have the same result. If so, the data is reliable. If the results from the trials are all different, the scientist will need to conduct more trials to see if the data support the hypothesis or not.

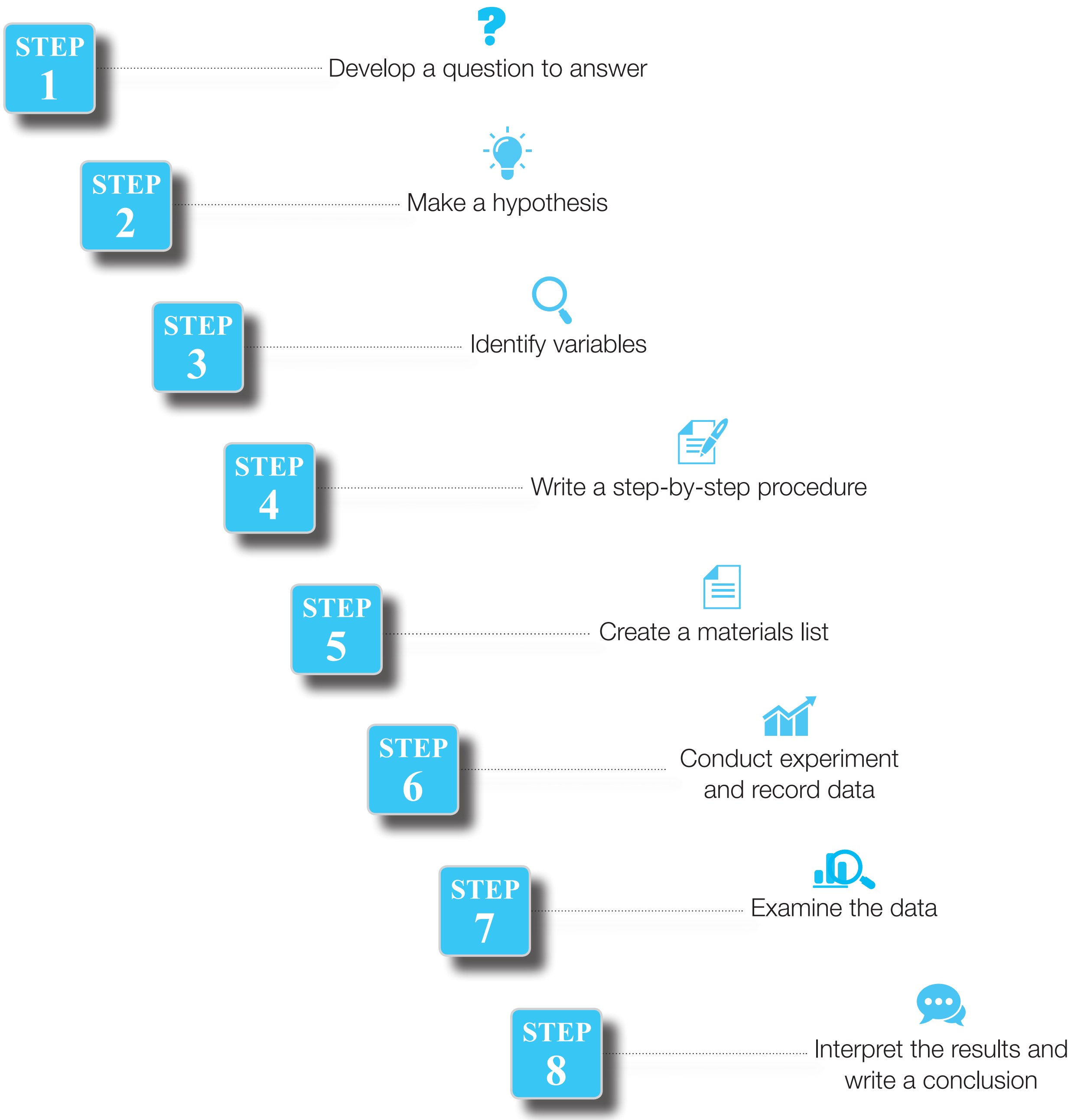
The seventh step in an experimental investigation is to examine the data. For example, in an experimental investigation that tests the force of friction, a ball should be released to roll on carpet multiple times and then released to roll on tile multiple times. If the ball consistently rolls a shorter distance on carpet than on tile, the data indicate that carpet has more friction. More friction causes the ball to roll a shorter distance.





© 2016 TEXAS EDUCATION AGENCY. ALL RIGHTS RESERVED.

The eighth, or last, step in an experimental investigation is to interpret the results and to write a conclusion that supports the hypothesis or explains why the hypothesis is incorrect.



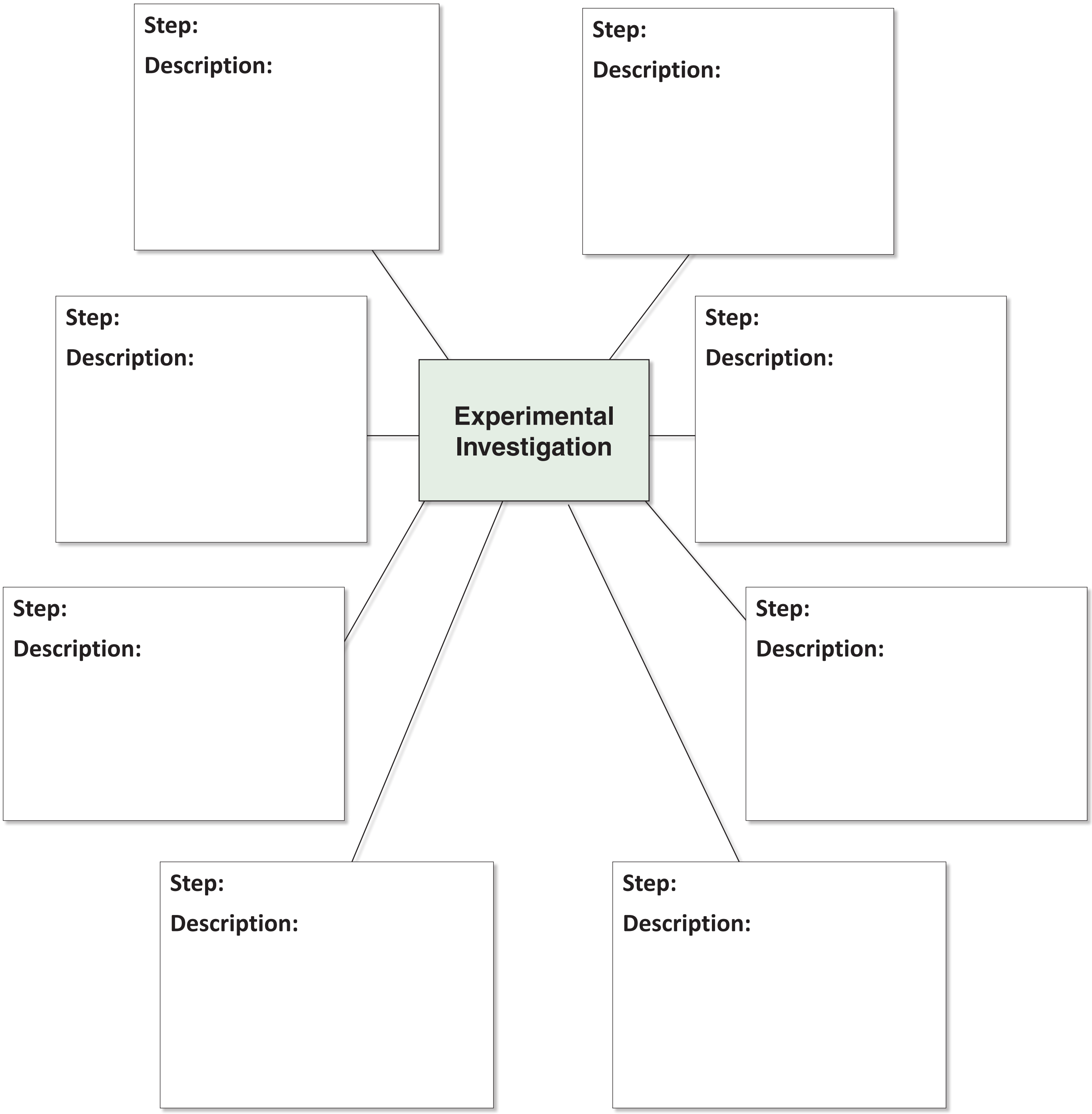
© 2016 TEXAS EDUCATION AGENCY. ALL RIGHTS RESERVED.

1207343 Science Academies_Lesson 5.indd 67 4/27/2016 9:52:58 AM

Based on the information you have just read, are you a scientist? Have you ever conducted an investigation or experiment? If so, you are a scientist! All you need to do is ask questions, be observant, and conduct safe, supervised experiments. Make sure your teacher or an adult has approved your investigation to make sure it is safe before you conduct it. After that, get going!

Force and Motion

RM 4: Note-Taking Guide



Force and Motion

RM 4 continued

Variables		
Controlled	**Independent**	**Dependent**

Write the letter of each description under the appropriate type of variable.

A *change depends on the manipulated variable*

B *example: paper clip being attracted to a magnet from a certain distance*

C *example: small paper clip used throughout experiment*

D *example: using different kinds of magnets to test their strengths*

E *manipulated variable*

F *measurable*

G *responding variable*

H *scientists change this variable*

I *unchanging, constant variable*

Force and Motion

RM 5: Experimental Investigation Checklist

Read the steps in an experimental investigation. Make sure you include all the steps in your design.

- ❑ We have asked a clear question that can be answered through an experimental investigation.
- ❑ We have identified an object on which we will test the effect of force.
- ❑ We have included at least one force in our experimental investigation.
- ❑ We have identified one independent, or manipulated, variable.
- ❑ We have identified one dependent, or responding, variable.
- ❑ We have identified controlled variables that stay the same throughout the experiment.
- ❑ We have written a procedure, or step-by-step set of instructions, that tells another scientist how to do our experimental investigation.
- ❑ We have listed all the materials necessary to do our experimental investigation.
- ❑ We have recorded our observations and measurements in a neat, organized manner (e.g., complete sentences, tables, graphs).
- ❑ We conducted multiple trials to make sure our data was reliable.
- ❑ We examined the results of our data.
- ❑ We interpreted our data to create a conclusion stating whether our hypothesis is supported by our observations and measurements.

Force and Motion

RM 6: Scenario Cards

Scenario 1 When Rachel rides her bicycle, she notices that stopping on a dry road is different than stopping on a wet road. How could she design an experimental investigation that models how force affects these two situations?	**Scenario 2** Skydivers wear parachutes to slow how fast they fall to Earth. How could you design an experimental investigation that models how force affects a skydiver?
Scenario 3 Aida's parents just had a new roof put on their home. The roofers left nails all over the ground around Aida's home. The nails need to be picked up to keep people from stepping on them and to keep cars from driving over them. How could Aida design an experimental investigation using force to pick up the nails? Note: Use paper clips to model roofing nails.	**Scenario 4** When snow becomes compacted and icy, people put chains around their tires to help the tires grip the road. This keeps the cars from slipping and sliding. How could a driver design an experimental investigation that models the effect of friction on tires with snow chains and tires without snow chains?
Scenario 5 Gabriel was in the pool when his mom called him over to the patio table for lunch. He got out of the pool, started to run, and then remembered he was supposed to walk so he would not slip and fall. Instead of having smooth concrete around the pool, Gabriel's pool has concrete with gravel in it to increase friction. How could Gabriel design an experimental investigation to test the effect of friction on wet, smooth concrete and wet concrete with gravel in it?	**Scenario 6** Some athletes wear cleats because cleats help athletes grip the ground. Cleats are shoes that have spikes or studs on their soles. A sole is on the bottom of a shoe. Baseball, football, softball, and soccer players are able to turn and stop faster when they wear cleats. How could you design an experimental investigation that models how force affects a player's ability to turn and/or stop on a playing field?
Scenario 7 A teacher is taking all the decorations off his bulletin board so he can display student work. He looks down and notices that many staples fell out of the decorations and onto the floor. The teacher asks a student to pick them up. How could a student design an experimental investigation using force to find the quickest way to pick up the staples?	

Force and Motion

RM 7: Materials Cards

Materials 2

- meter stick
- 1 sheet of tissue paper or a coffee filter
- small plastic toy soldier or other small object
- 3 oz. paper cups
- straws
- string
- tape

Materials 1

- meter stick
- ramp
- spray bottle with water
- 1 textbook
- tiled area
- toy car
- towel

Materials 4

- aluminum foil or wax paper (optional)
- foam ball (6–8 cm in diameter)
- 2 meter sticks
- ramp
- 8–10 rubber bands
- 1 textbook
- tiled area

Materials 3

- bar magnet
- goggles
- horseshoe magnet
- magnetic wand
- meter stick
- 30 paper clips
- timing device

Materials 6

- brick
- bubble wrap made with small air bubbles
- concrete or tiled area
- chalk or tape
- meter stick
- string or section of twine
- spring scale of appropriate strength

Materials 5

- coarse sandpaper
- freezer paper
- meter stick
- spray bottle with water
- spring scale of appropriate strength
- string
- tape
- wooden block

Materials 7

- bar magnet
- goggles
- horseshoe magnet
- ring magnet
- 75–100 staples
- timing device

1207343 Science Academies_Lesson 5.indd 77 4/27/2016 9:53:01 AM

Force and Motion

RM 8: Evaluating an Experimental Investigation

Name ____ Date _______________

Read the following experiment.

A group of students wants to know if a ball will roll farther when released down a ramp or when launched down a ramp. Their teacher asked them to design an experiment to answer the question. Here is what the students wrote.

Question

Will a ball roll farther when released down a ramp or when launched down a ramp on carpet or tile?

Hypothesis

The ball will roll farther when launched down a ramp on tile because launching it will involve a greater force with less friction.

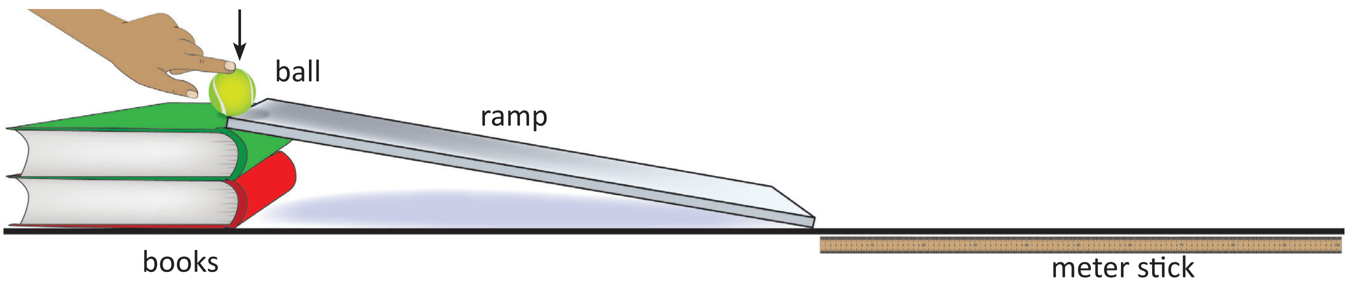
Materials

- ramp
- tennis ball
- 4 textbooks, same size
- carpeted surface
- tiled surface
- meter stick
- 5 N push/pull spring scale

Procedure

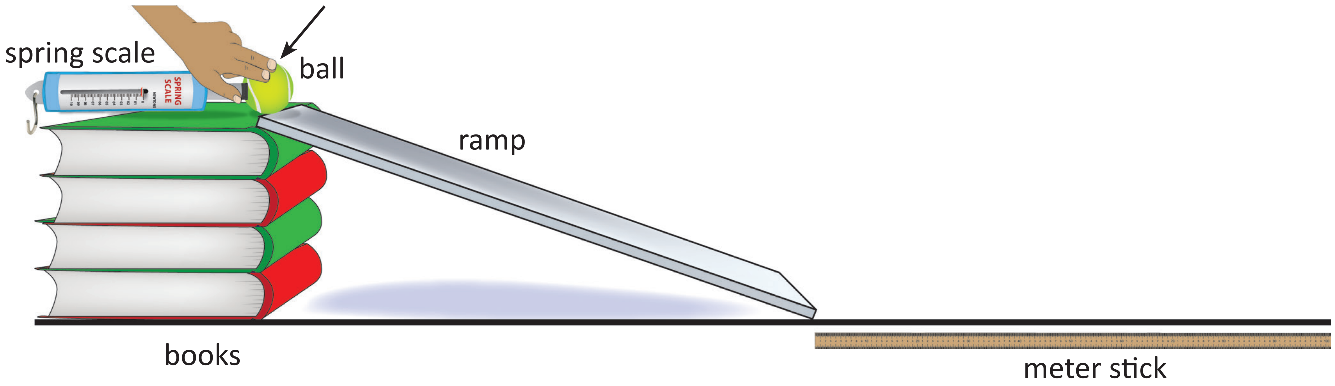
Part A

1. Stack two textbooks squarely on top of each other on a carpeted surface.
2. Rest the top edge of the ramp on the stacked textbooks with the bottom of the ramp on the floor.
3. Position the tennis ball at the top of the ramp, and hold it in place with one finger.
4. Release the tennis ball (remove your finger) allowing it to roll down the ramp.
5. Use the meter stick to measure how far the ball travels.
6. Record the distance the ball travels in the table.
7. Repeat steps 3–6 two more times.
8. Repeat steps 1–6 three times on a tiled surface.



Part B

1. Stack four textbooks squarely on top of each other on a tiled surface.
2. Rest the top edge of the ramp on the stacked textbooks with the bottom of the ramp on the floor.
3. Position the tennis ball at the top of the ramp, and hold it in place with two fingers.
4. Place the push lever of the spring scale firmly against the tennis ball measuring at 1 N.
5. Release the tennis ball by removing your hand and allowing the push lever to launch the ball.
6. Use a meter stick to measure how far the ball travels.
7. Record the distance the ball travels in the table.
8. Repeat steps 3–7 two more times.
9. Repeat steps 1–7 three times on a carpeted surface.



Data

Part A: Release	Distance Traveled (cm)		
Type of Flooring	Trial 1	Trial 2	Trial 3
carpet	52	54	40
tile	76	80	78

Part B: Launch	Distance Traveled (cm)		
Type of Flooring	Trial 1	Trial 2	Trial 3
carpet	101	105	109
tile	123	121	125

Results

The ball traveled farther on tile when launched.

Force and Motion

RM 8 continued

Conclusion

1. What did the students do correctly?

____

____

____

____

2. What could the students have done better?

____

____

____

____

3. Based on the experiment, is the students' hypothesis supported by their data? Explain your reasoning.

____

____

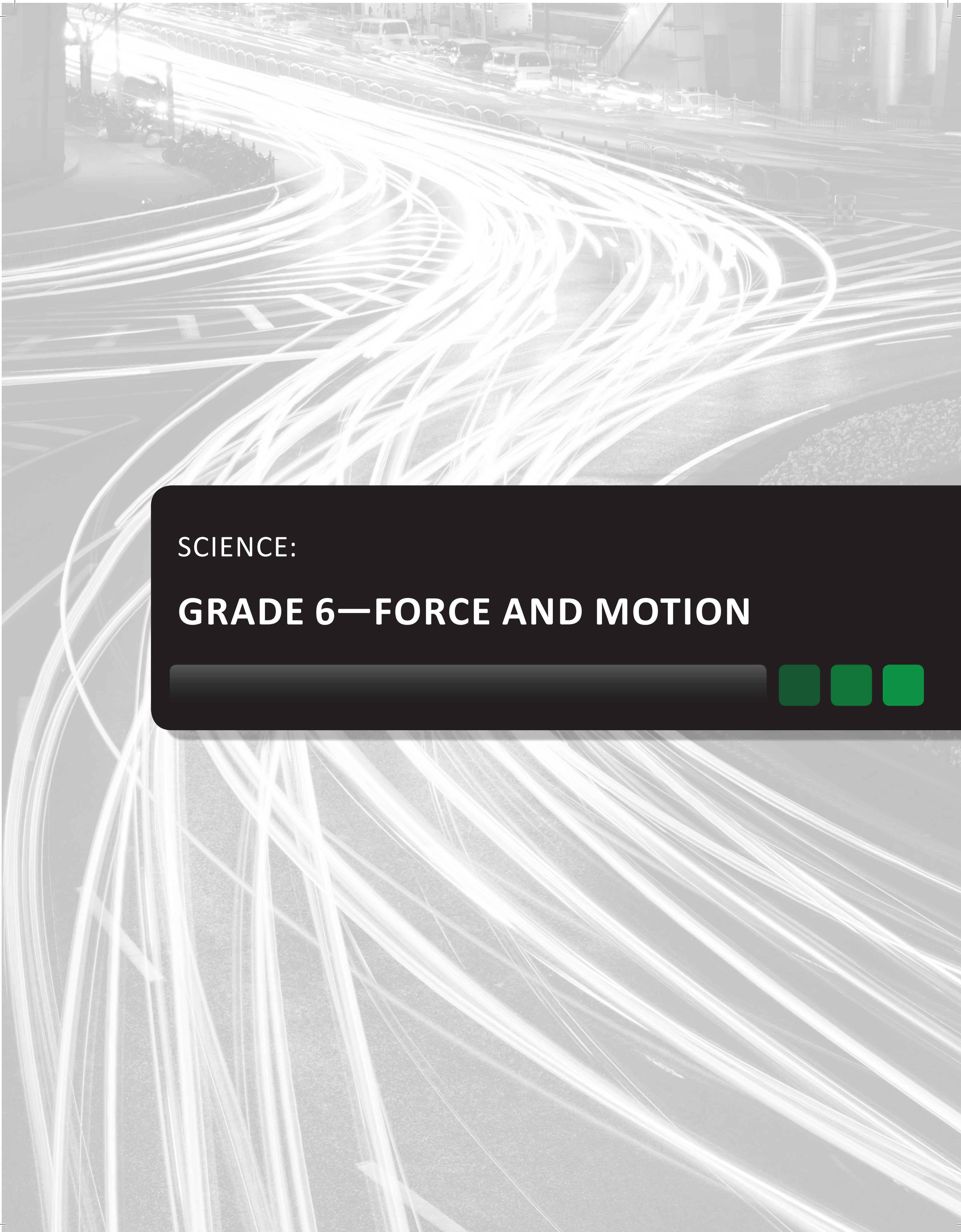
____

4. Did the students design the experiment to find an accurate answer to their question? Why or why not?

____

____

____



SCIENCE:

GRADE 6—FORCE AND MOTION

Force and Motion

Lesson Outline: Changes in Motion

Content Objectives

I can identify and describe changes in position, direction, and speed.
I can calculate average speed.
I can measure and graph changes in motion.

Language Objective

I will verbally share observations and measurements as I work with my group to collect data on the distance traveled by a moving object.

5E Lesson Summary

Engage

Students consider how force can change the position, direction, and speed of an object.

Explore

Students collect time and distance measurements in order to calculate speed and average speed. Students convert units of measurement and practice bubbling in answers on griddable items.

Tier 1 Support

To save time, students may use calculators to complete Parts 2 and 4. However, please note that students are not allowed to use calculators on the grade 8 STAAR science assessment and should be able to do the math without a calculator.

Part One

This part of Explore focuses on observing and collecting distance and time measurements.

Part Two

This part of Explore focuses on calculating speed and average speed.

Part Three

This part of Explore focuses on entering answers into griddable items.

Part Four

This part of Explore focuses on converting speed from one unit of measurement to another.

Explain

Students learn how to plot or graph time and distance data using a motion sensor. Students will also study and interpret speed graphs.

Part One

This part of Explain focuses on the relationship of actual motion to a line representing motion on a line graph.

Force and Motion

Part Two
This part of Explain focuses on teaching students how to create a distance-time graph.

Part Three
This part of Explain focuses on interpreting distance-time and speed-time graphs.

Elaborate

Students read scenarios and identify changes in position, direction, and speed as well as solve for speed and average speed. Students determine the best way to display data.

Teacher Note and Differentiation Strategy

RM 7: Practice Problems contains nine problems students can work through. The nine problems are broken into three sets, A–C. Set A problems ask students to calculate average speed and then convert it to other units of measurement. Students will record their answers on a griddable item and create a distance-time graph. Set B problems ask students to interpret the line on a speed-time graph. Set C problems ask students to calculate speed and average speed and enter their answers in the griddable items provided.

Sets A–C include three leveled problems. A1, B1, and C1 are the simplest problems. A2, B2, and C2 are a bit more difficult, and A3, B3, and C3 are the most difficult. Consider your students and determine whether level 1, 2, or 3 would be best matched to their ability levels. You may also choose to give students all three problems in a set. Try to make sure at least two groups are assigned to each problem for comparison at the end of Elaborate.

It may be helpful to print each set or level on a different color of paper. For example, you could color code according to sets A–C or Levels 1–3.

Tier 1 Support
To save time, students may use calculators to complete the problems in sets A–C. However, please note that students are not allowed to use calculators on the grade 8 STAAR science assessment and should be able to do the math without a calculator.

Evaluate

Students evaluate whether data has been best displayed based on given information.

Tier 1 Support
Students may work individually, in pairs, or in small groups.

Force and Motion

Notes

SCIENCE:

GRADE 6—FORCE AND MOTION

CHANGES IN MOTION

Force and Motion

Changes in Motion

Science Concept

6(8) Force, motion, and energy. The student knows force and motion are related to potential and kinetic energy. The student is expected to:

(B) identify and describe the changes in position, direction, and speed of an object when acted upon by unbalanced forces

(C) calculate average speed using distance and time measurements

(D) measure and graph changes in motion

Content Objectives

I can identify and describe changes in position, direction, and speed.

I can calculate average speed.

I can measure and graph changes in motion.

Science Process Skills

6(2) Scientific investigation and reasoning. The student uses scientific inquiry methods during laboratory and field investigations. The student is expected to:

(A) plan and implement comparative and descriptive investigations by making observations, asking well-defined questions, and using appropriate equipment and technology

(C) collect and record data using the International System of Units (SI) and qualitative means such as labeled drawings, writing, and graphic organizers

(D) construct tables and graphs, using repeated trials and means, to organize data and identify patterns

6(4) Scientific investigation and reasoning. The student knows how to use a variety of tools and safety equipment to conduct science inquiry. The student is expected to:

(A) use appropriate tools to collect, record, and analyze information, including journals/notebooks, beakers, Petri dishes, meter sticks, graduated cylinders, hot plates, test tubes, triple beam balances, microscopes, thermometers, calculators, computers, timing devices, and other equipment as needed to teach the curriculum

1207343 5-8 Science Academies_Grade 6.indd 90 4/27/2016 2:45:41 PM

Force and Motion

Mathematics

6(2) Number and operations. The student applies mathematical process standards to represent and use rational numbers in a variety of forms. The student is expected to:

(E) extend representations for division to include fraction notation such as a/b represents the same number as $a \div b$ where $b \neq 0$

6(4) Proportionality. The student applies mathematical process standards to develop an understanding of proportional relationships in problem situations. The student is expected to:

(B) apply qualitative and quantitative reasoning to solve prediction and comparison of real-world problems involving ratios and rates

(D) give examples of rates as the comparison by division of two quantities having different attributes, including rates as quotients

(H) convert units within a measurement system, including the use of proportions and unit rates

6(5) Proportionality. The student applies mathematical process standards to solve problems involving proportional relationships. The student is expected to:

(A) represent mathematical and real-world problems involving ratios and rates using scale factors, tables, graphs, and proportions

6(6) Expressions, equations, and relationships. The student applies mathematical process standards to use multiple representations to describe algebraic relationships. The student is expected to:

(A) identify independent quantities from tables and graphs

English Language Arts and Reading

6(12) Reading/Comprehension of Informational Text/Procedural Texts. Students understand how to glean and use information in procedural texts and documents. Students are expected to:

(A) follow multi-tasked instructions to complete a task, solve a problem, or perform procedures; and

(B) interpret factual, quantitative, or technical information presented in maps, charts, illustrations, graphs, timelines, tables, and diagrams.

Force and Motion

English Language Proficiency Standards

(3) Cross-curricular second language acquisition/speaking. The ELL speaks in a variety of modes for a variety of purposes with an awareness of different language registers (formal/informal) using vocabulary with increasing fluency and accuracy in language arts and all content areas. ELLs may be at the beginning, intermediate, advanced, or advanced high stage of English language acquisition in speaking. In order for the ELL to meet grade-level learning expectations across the foundation and enrichment curriculum, all instruction delivered in English must be linguistically accommodated (communicated, sequenced, and scaffolded) commensurate with the student's level of English language proficiency. The student is expected to:

(E) share information in cooperative learning interactions

Language Objective

I will verbally share observations and measurements as I work with my group to collect data on the distance traveled by a moving object.

Response to Intervention/Tier I Differentiation

All science lessons support students in receiving quality Tier I instruction. Using the 5E model, knowledge is taught in a variety of contexts, integrating math, science, and ELAR content, thus supporting the active engagement of the students with the content. Lesson-specific differentiation strategies for addressing diverse student needs can be found in sections titled "Differentiation Strategy."

Differentiation should

- focus on skills students did not understand and extend the lesson for advanced students;
- be conducted in small groups or embedded in whole-group instruction; and
- provide students with a variety of strategies to process the information, such as
  - allowing for additional opportunities for verbal brainstorming of words associated with a topic (with teacher taking dictation);
  - making clear connections of new and more complex concepts to foundational aspects and prior knowledge;
  - participating in more tangible experiences, such as experiments, investigations, and active exploration;
  - sorting academic vocabulary words into categories by common attributes, such as process words or science content vocabulary;

- organizing results of brainstorming into semantic maps or creating graphic organizers;
- discussing the meaning of a graphic organizer with a partner; and
- creating a visual representation to demonstrate understanding.

See the handout in the Instructional Resources section that addresses instructional strategies.

College and Career Readiness Standards—Science Standards

I.D.3 Current scientific technology. Demonstrate appropriate use of a wide variety of apparatuses, equipment, techniques, and procedures for collecting quantitative and qualitative data.

I.E.2 Effective communication of scientific information. Use essential vocabulary of the discipline being studied.

II.A.4 Basic mathematics conventions. Use proportional reasoning to solve problems.

II.D.1 Scientific problem solving. Use dimensional analysis in problem solving.

Force and Motion

Vocabulary Focus

average speed

direction

position

speed

5E Lesson Summary

Engage
Students consider how force can change the position, direction, and speed of an object.

Explore
Students collect time and distance measurements in order to calculate speed and average speed. Students convert units of measurement and practice bubbling in answers on griddable items.

Explain
Students learn how to plot or graph time and distance data using a motion sensor. Students will also study and interpret speed graphs.

Elaborate
Students read scenarios and identify changes in position, direction, and speed as well as solve for speed and average speed. Students determine the best way to display data.

Evaluate
Students evaluate whether data has been best displayed based on given information.

Engage

Materials

For teacher

- RM 1

Teacher Note

RM stands for reproducible master. Students will use the Think-Pair-Share strategy. First, they will independently think of an answer while the class is quiet. After a couple of minutes, students will share their answers with a partner. Lastly, ask a few student pairs to share their answers with the class.

When answering the question on *RM 1: Soaring Softball*, students should focus on the illustration and think about what happens to the ball in that specific event. Batters do not always hit the ball. However, when a batter does hit the ball, there are many directions and different speeds it could travel. Ultimately, a ball's position, direction, and speed will change whether or not it is hit by a batter.

Teacher Instruction

- Project *RM 1* for the class.
- Instruct the class to be silent for 2 minutes as students independently answer the question on *RM 1*.
- Ask students to share their answers with a partner.
- After 2 minutes, ask a few student pairs to share their answers with the whole class.

Facilitation Questions

- What happens to the softball after it leaves the pitcher's hand? *The softball moves forward and then gets hit by the batter.*
- What changes when the softball is hit by the batter? *The softball's direction, position, and speed change when it is hit by the batter.*
- Why do the softball's direction, position, and speed change? *The force of the bat changes the softball's direction, position, and speed.*

Force and Motion

Explore

Materials

For student groups

- 2 meter sticks
- sticky notes, flags, or dot stickers
- timing device
- wind-up toy that moves forward

For each student

- RM 2
- calculator (optional)

Tier I Support

To save time, students may use calculators to complete Parts 2 and 4. However, please note that students are not allowed to use calculators on the grade 8 STAAR science assessment and should be able to do the math without a calculator.

Part One

This part of Explore focuses on observing and collecting distance and time measurements.

Teacher Note

Wind-up toys can be ordered through bulk party goods suppliers or purchased from party stores. Wind-up toys should move forward in a crawling, walking, or scooting manner. Jumping or flipping wind-up toys will not work for the Explore investigation.

Teacher Instruction

- Distribute pages 1 and 2 of *RM 2: Distance and Time Measurements* to each student.
- Divide the class into groups of three students.
- Instruct groups to follow the directions on page 1 of *RM 2* as they conduct the investigation. They will use page 3 of *RM 2* to record their distance measurements. Students may need to adjust the time intervals depending on how the wind-up toy moves. For faster moving toys, the time interval should equal 2 seconds. For slower moving toys, the time interval should equal 4 seconds. Mathematically, even-numbered time intervals are easier to work with than odd-numbered time intervals.

Facilitation Questions

- What did you observe in the investigation? *Answers will vary and may include that students observed the toy traveling in a straight line, slowing down, and eventually stopping.*
- What units of measurement did you use? *We used centimeters for distance and seconds for time.*

Force and Motion

- Did your toy travel the same distance every 2 (or 4) seconds? How do you know? *Students most likely will say no, but it may depend on the toys used in the investigation. The data in the table will change with each time interval that passes.*
- If your toy did not travel the same distance every 2 (or 4) seconds, what did it do? *Students' toys most likely traveled the same or a shorter distance for every 2 or 4 seconds the toys moved.*
- Why did you repeat the investigation? *We repeated the investigation to collect reliable data. The more trials are conducted, the more likely the data is reliable.*
- How many times did you repeat the investigation? *We repeated the investigation in three trials.*
- What was most challenging in the investigation? *Answers will vary and may include that marking the meter stick every 2 or 4 seconds was challenging.*

Part Two

This part of Explore focuses on calculating speed and average speed.

Teacher Note

When completing page 3 of *RM 2*, students will first work across the rows in the table to calculate the speed in each trial followed by the average speed for all three trials. They will then work down the columns to calculate average speed. For the most part, the calculated average speeds should match, but on occasion, the average speeds may not match due to rounding. If students check their mathematical processes and still calculate mismatched average speeds, rounding could be the cause.

When discussing numbers with decimals, please consider how you name, or say, the number. For example, 2.2 cm should be stated as "two and two-tenths centimeters" as opposed to "two point two centimeters." This phrasing will help students transfer what they learn in math to science.

Teacher Instruction

- Distribute page 4 of *RM 2* to each student.
- Ask students to record the total distance and time measurements from each trial in the table.

Force and Motion

- Explain to students how to calculate speed by dividing distance by time. For example, explain to students that if the toy traveled 36 cm in 12 s, the toy traveled 3 cm/s because they would divide the distance, 36 cm, by the time, 12 s.
- Ask students to calculate the speed for each of their trials.
- Explain to students how to calculate average speed by adding the three speeds from Trials 1–3 and dividing them by 3.
- Instruct students to add the distance measurements from the three trials and to record the total distance traveled in the table.
- Instruct students to add the time measurements from the three trials and to record the total time in the table.
- Explain to students how to calculate average speed by dividing the total distance by the total time.
- Ask students to compare their average speeds. The average calculated by adding the three speeds and dividing them by 3 should match the average of total distance divided by total time. If the average speeds do not match, students will need to recalculate the numbers to find their mathematical error.

Facilitation Questions

- What do you need to know to calculate speed? *We need to know how far an object traveled (distance) in a given period of time.*
- How did you calculate speed? *To calculate speed, we divided the distance traveled by time.*
- How are speed and average speed different? *Speed is the rate at which an object moves. Average speed is the total distance traveled divided by the overall time.*

Part Three

This part of Explore focuses on entering answers into griddable items.

Teacher Instruction

- Distribute page 5 of *RM 2* to each student.

Force and Motion

- Instruct students to write and bubble in the speeds for Trials 1–3 in the top three griddable items followed by the average speed on the bottom griddable item.
- Remind students that they must pay attention to where the decimal is placed. It cannot be moved or ignored on the griddable item. Students should place the whole number to the left of the decimal, not against the right margin of the griddable item.

Facilitation Questions

- What is the first place value after the decimal called? *The first place value after the decimal is called the tenths place.*
- Is it always necessary to have a number in the tenths place? *No, it is not necessary to have numbers in the tenths place if the answer results in a whole number. Students have the option to fill in a zero in the tenths place.*
- If there is not a number in the tenths place, what do you do? *If there is not a number in the tenths place, leave the box blank (or empty) or write a zero in the box and fill in the appropriate bubble.*
- What is a whole number? *A whole number is a number without fractional parts and does not have numbers after the decimal*.
- How do you write a whole number in the griddable item? *A whole number belongs on the immediate left of the decimal.*

Part Four

This part of Explore focuses on converting speed from one unit of measurement to another.

Teacher Instruction

- Distribute pages 6 and 7 of *RM 2* to each student.
- Work through the conversions by multiplying by ratios equal to 1 with the class.
- Explain to students why they simplify units of measurement. Simplifying units of measurement means crossing out those units that are both on top of and below the dividing or midline. This will leave a unit ratio such as cm/s.

1207343 5-8 Science Academies_Grade 6.indd 99 4/27/2016 2:45:42 PM

Force and Motion

Facilitation Questions

- What does it mean to convert units of measurement? *Converting units of measurement means to change from one unit of measurement to another.*
- How do we convert units of measurement? *We can convert units of measurement by multiplying by a ratio equal to 1.*
- What is the relationship between centimeters, meters, and kilometers? *Centimeters, meters, and kilometers are all units of measurement for length. These units can be converted from one to another.*
- What is the relationship between seconds, minutes, and hours? *Seconds, minutes, and hours are all units of measurement for time. These units can be converted from one to another.*
- What was different about the processes for *a* and *b*? *In* a*, we converted length from cm to m. In* b*, we converted time from s to min.*
- How many times did you multiply by a ratio equal to 1 for *b, c,* and *d*? *We multiplied by a ratio equal to 1 once in* b*, twice in* c*, and three times in* d.

Explain

Part One

This part of Explain focuses on the relationship of actual motion to a line representing motion on a line graph.

Teacher Note

Students often struggle to make a connection between the line on a graph and the motion it represents. In an effort to bridge that gap, students will use a motion sensor to recreate a line on a graph. A motion sensor can be connected to a graphing calculator or to a computer using the appropriate cords. Here are the differences:

1) A motion sensor attached to a calculator allows for a greater range of motion and more individualized viewing.
2) A motion sensor can be connected to a computer, which allows for more options within the software to view and manipulate the graph.

A motion sensor records reflected soundwaves that bounce off a surface to create a line on a graph. Students can hold the motion sensor as they move or they can place the sensor in one location and move in front of it. If students choose to move in front of the sensor, it may be helpful for students to hold a sheet of foam board in front of themselves so that the sensor's soundwaves can bounce more easily. If students choose to hold the sensor, they must move in front of a blank wall that is free of obstructions such as windows, papers/posters, projector screen, or lockers; a sheet of foam board could be used to simulate a wall. If the option exists, students can use portable laptops, which can be positioned in front of a blank wall.

The cords that connect the motion sensor to a calculator or computer are more than 2 m long, which allows for forward and backward movement. Students need to be able to move about 2–3 m away from the wall or the sensor. This motion will recreate the line on the graph. Students may initially move side-to-side because the line on the graph forms from left to right. Students will find that the faster they move, the steeper the line and, inversely, the slower they move, the flatter the line.

Materials

For student groups

- motion sensor such as a Go!Motion® sensor from Vernier
- computer or graphing calculator
- cords for motion sensor to laptop and/or calculator
- blank wall without interference (e.g., no windows, bulletin boards, lockers)
- meter stick
- sheet of foam board (optional)

For each student

- RM 3

Force and Motion

Advance Preparation

If you plan to have students use a computer with the Go!Motion sensor, download the free Logger Lite® software from the Vernier website (http://www.vernier.com/products/software/logger-lite/#download) to each computer that will be used. You may also use other brands of motion sensors.

Connect your motion sensors to the graphing calculators and/or computers to make sure they are working. Use the motion sensor instructions booklet to troubleshoot any connection issues.

Based on the materials available, determine how to group students. For example, if you only have one motion sensor, you may want to connect it to the computer and project the screen for the whole class to observe. If you have 15 motion sensors and 15 laptops or graphing calculators, you may choose to pair or group students.

When students are finished using the equipment, ask them to carefully remove the batteries from the motion sensors and calculators for safe storage.

Teacher Instruction

- Divide the class into groups or present as a whole class based on available materials.
- Distribute *RM 3: The Meaning of a Line Graph* to each student.
- Work through the process of how to match the line on a graph with the class.
- Instruct students to follow the directions on *RM 3,* and allow them enough time to familiarize themselves with the technology.

Facilitation Questions

- What is the relationship modeled by the line in the graphs you attempted to match? *The graphs showed the relationship between distance and time.*
- Were you able to match the line on the graph? *Answers will vary and may include that students had to change their position by moving closer to and farther from the wall to match the line on the graph.*
- What did you do to make your line decrease, or go down? *To make the line decrease, or go down, I moved closer to the wall, which decreased the distance between the sensor and the wall.*

Force and Motion

- What did you do to make your line increase, or go up? *To make the line increase, or go up, I moved farther from the wall, which increased the distance between the sensor and the wall.*
- What does it mean if your line was lower than the line on the graph? *If my line was lower than the line on the graph, it means that I was too close to the wall.*
- What does it mean if your line was higher than the line on the graph? *If my line was higher than the line on the graph, it means that I was too far from the wall.*
- What happened when you moved faster? *When I moved faster, the line became steeper.*
- What happened when you moved slower? *When I moved slower, the line became flatter.*
- What did you do to create a horizontal line on the graph? *To create a horizontal line on the graph, I remained in one place or did not move.*
- What changed over time as you moved? *My position, direction, and speed changed over time as I moved.*
- What do line graphs mean? *Answers will vary, but should include that the lines represent changes in distance over time and not just data points from a table.*

Part Two

This part of Explain focuses on teaching students how to create a distance-time graph.

Advance Preparation

Display the graphing chart paper in a place where the whole class can see it.

Teacher Instruction

- Distribute *RM 4*: *How to Create a Line Graph* to each student.
- Explain to students that you are going to work through how to make a line graph using *RM 4*.

Materials

For teacher

- RM 4
- graphing chart paper
- colored sticky dots

continued on next page

Force and Motion

Materials *cont'd*

For teacher (cont'd)

- 1 orange dry-erase or poster marker
- 1 blue dry-erase or poster marker

For each student

- RM 4
- 2 different colored pencils or fine-tip markers
- graph paper (optional)

- Create a class graph on the graphing chart paper using the data on *RM 4*, and ask for student volunteers to help with each step.
- Ask students to use the colored sticky dots to plot the data points on the class graph.
- Allow students to plot their data points from the Explore, Part 1 activity on *RM 4* or on graph paper.

Facilitation Questions

- What is the horizontal axis called on a graph? *The horizontal axis on a graph is called the* x*-axis.*
- Which variable belongs on the *x*-axis? *The independent, or manipulated, variable belongs on the* x*-axis.*
- What is the vertical axis called on a graph? *The vertical axis on a graph is called the* y*-axis.*
- Which variable belongs on the *y*-axis? *The dependent, or responding, variable belongs on the* y*-axis.*
- What is the name of the (0,0) point on a graph? *The (0,0) point on a graph is called the origin.*
- What must you always remember to include as part of your axis labels? *We must always include our units of measurement on our axis labels.*
- How do you determine the scale on each axis? *To determine the scale on each axis, we could divide the highest number in each data column by the number of available squares on the graph paper. Then we would need to decide if it would be best to count by 1, 2, 3, or something else.*
- How do you figure out where to plot the data points? *To plot the data points, we have to count across the* x*-axis and then up the* y*-axis.*
- What does it mean when the line is steeper? *A steeper line means an object is increasing or decreasing the distance traveled at a faster rate.*
- What does it mean when the line is flatter? *A flatter line means an object is increasing or decreasing the distance traveled at a slower rate.*

- What is the overall pattern of movement shown by the line on your graph? How do you know? *Initially, the wind-up toy was moving quickly, then slowed down, and eventually stopped. The line on the graph started steeper, began to flatten, and then became parallel to the X-axis.*
- What changed over time as the wind-up toy moved? *The wind-up toy's position and speed changed over time as it moved. The wind-up toy's direction may have changed if it did not move in a straight line.*

Part Three

This part of Explain focuses on interpreting distance-time and speed-time graphs.

Materials

For each student

- RM 5
- RM 6

Teacher Instruction

- Project *RM 5: Speed Reading* for the whole class to see.
- Ask students to identify text features such as the title and graphics, including pictures, tables, and/or graphs.
- Distribute *RM 5* and *RM 6: What Do You Know?* to each student.
- Instruct students to read *RM 5* individually or in pairs.
- Instruct students to complete the statements on *RM 6*.

Facilitation Questions

- What did you use in the reading passage to help you understand the content? *We used the text features and visuals to understand the content.*
- What kind of visuals were in the reading passage? *The reading passage had visuals including pictures, graphs, and ratios that multiply by one.*
- Do you feel like you understand how to interpret graphs more effectively? *Answers will vary but should include that they understand that the line on a graph represents changes in distance or speed over time as opposed to plotted data points.*
- What kind of information can you extract from a graph? *From reading a graph, we can see how far and how fast an object is traveling. We can make assumptions about why an object's motion is changing based on our prior knowledge. We can use the information on a graph to calculate speed in intervals as well as average speed.*

Force and Motion

RM 6 Answer Key

1. Movement changes because *forces act on objects.*
2. The line on a graph shows *the relationship between two quantities.*
3. A distance-time graph shows *change in distance over time.*
4. A speed-time graph shows *change in speed over time.*
5. A major difference between a distance-time graph and a speed-time graph is *what a horizontal line means. A horizontal line on a distance-time graph means an object is not moving. A horizontal line on a speed-time graph means an object is maintaining a constant speed.*

TEA Texas Education Agency

Elaborate

Teacher Note and Differentiation Strategy

RM 7: Practice Problems contains nine problems students can work through. The nine problems are broken into three sets, A–C. Set A problems ask students to calculate average speed and then convert it to other units of measurement. Students will record their answers on a griddable item and create a distance-time graph. Set B problems ask students to interpret the line on a speed-time graph. Set C problems ask students to calculate speed and average speed and enter their answers in the griddable items provided.

Sets A–C include three leveled problems. A1, B1, and C1 are the simplest problems. A2, B2, and C2 are a bit more difficult, with A3, B3, and C3 being the most difficult. Consider your students and determine whether level 1, 2, or 3 would be best matched to their ability levels. You may also choose to give students all three problems in a set. Try to make sure at least two groups are assigned to each problem for comparison at the end of Elaborate.

It may be helpful to print each set or level on a different color of paper. For example, you could color code according to sets A–C or Levels 1–3.

Students may choose to graph data in minutes or hours for set A.

Materials

For teacher

- RM 7

For each student

- graph paper
- calculator (optional)

Advance Preparation

Locate and label nine different areas in your room where students can post solutions to the problems in sets A–C.

Tier 1 Support

To save time, students may use calculators to complete the problems in sets A–C. However, please note that students are not allowed to use calculators on the grade 8 STAAR science assessment and should be able to do the math without a calculator.

Teacher Instruction

- Divide the class into groups of 2–3 students.
- Distribute selected problems from *RM 7* to each pair or group of students.
- Make sure students have graph paper.
- Ask students to post their solutions to the assigned problems in the designated areas after everyone has finished working.

Force and Motion

- Assign each group to one of the nine solved problems. To ensure familiarity, groups should begin with the problem they worked on first and then move through the other problems.
- Instruct students to compare the solutions and strategies each group used to solve the problems.
- Instruct students to move to other posted problems as time allows to compare strategies and solutions used by different groups.

Facilitation Questions

- How did you convert units of measurement? *We multiplied by ratios equal to 1 to convert units of measurement.*
- What are the two ways to calculate average speed? *Average speed can be calculated by determining the average of the speeds from individual trials or by dividing the total distance from more than one trial by the total time from more than one trial.*
- What is the difference between a horizontal line on a distance-time graph and a horizontal line on a speed-time graph? *A horizontal line on a distance-time graph indicates no movement. A horizontal line on a speed-time graph indicates a constant speed that is neither increasing nor decreasing.*
- On a speed-time graph, what do decreasing and increasing lines mean? *On a speed-time graph, a decreasing line indicates decreasing speed while an increasing line indicates increasing speed*.
- Did your group solve your problem the same way as other groups? *Answers will vary and may include that some groups solved the problems the same way while others did not.*

1207343 5-8 Science Academies_Grade 6.indd 108 4/27/2016 2:45:42 PM

Force and Motion

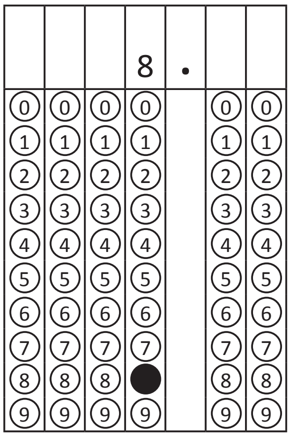
RM 7 Answer Key

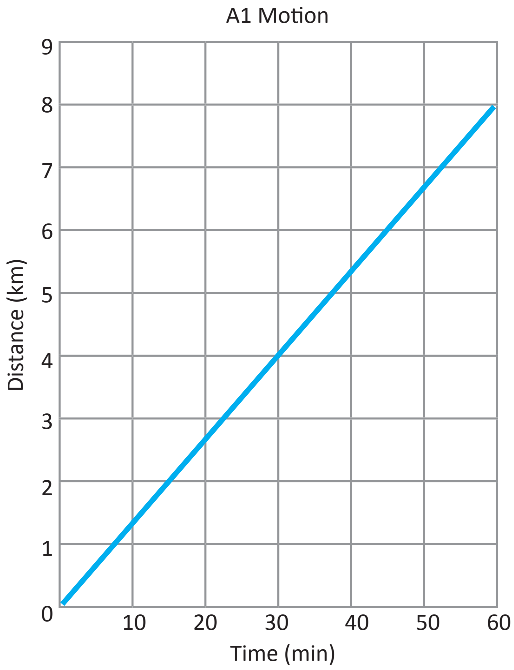
A1

A student runs 4 km in 30 minutes at a steady pace.

- What is the student's average speed in km/hr? Bubble in your answer on the griddable item.
- Create a distance-time graph to show the relationship between the student's total distance and time.

$$\frac{4\text{ km}}{30\text{ min}} \bullet \frac{60\text{ min}}{1\text{ hr}} = \frac{240\text{ km}}{30\text{ hr}} \div \frac{30}{30} = \frac{8\text{ km}}{1\text{ hr}} = 8\text{ km/hr}$$





1207343 5-8 Science Academies_Grade 6.indd 109 4/27/2016 2:45:42 PM

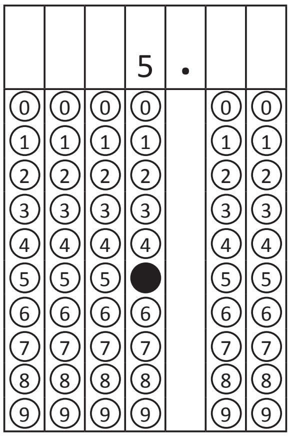
Force and Motion

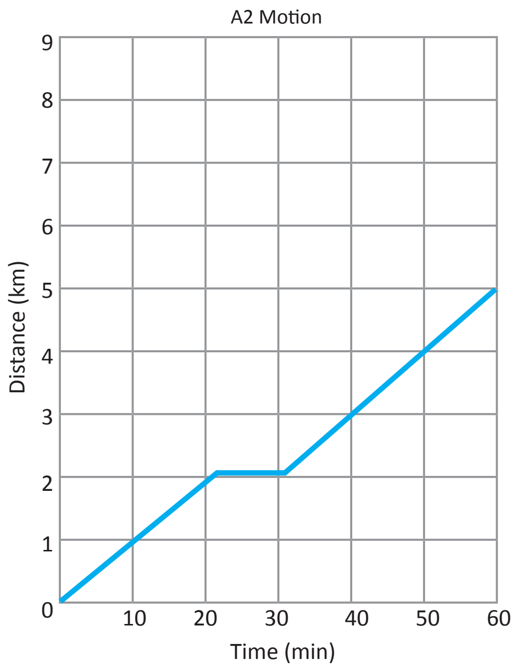
A2

A student runs 2 km in 20 minutes to the store. The student then rests for 10 minutes before running 3 km to a friend's house in 30 minutes.

- What is the student's average speed in km/hr? Bubble in your answer on the griddable item.
- Create a distance-time graph to show the relationship between the student's total distance and time.

$$\frac{5\ km}{60\ min} \bullet \frac{60\ min}{1\ hr} = \frac{300\ km}{60\ hr} \div \frac{60}{60} = \frac{5\ km}{1\ hr} = 5\ km/hr$$





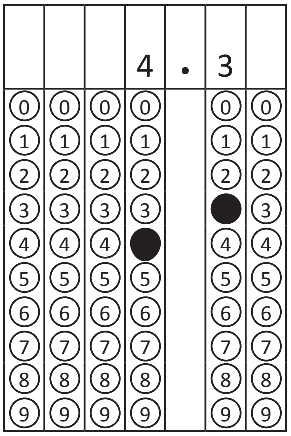
Force and Motion

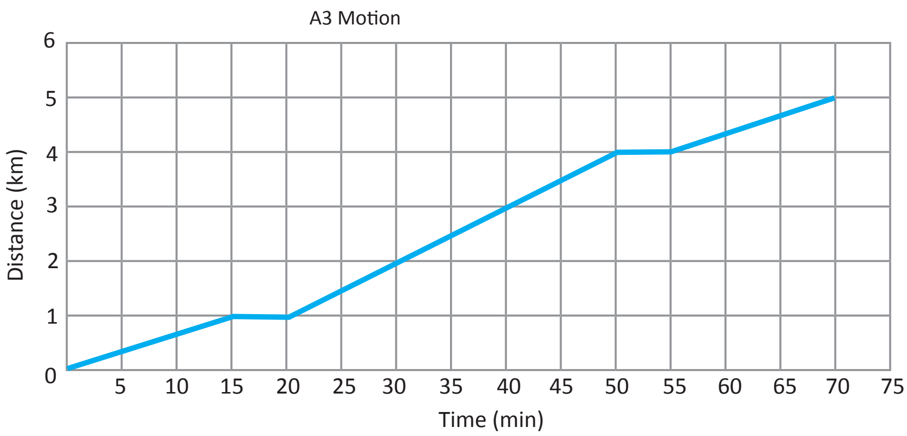
A3

A student walks 1 km from home to the school track in 15 minutes. The student then stops to rest for 5 minutes before running 3 km in 30 minutes. The student rests for 5 minutes and then walks 1 km to a friend's house in 15 minutes.

- What is the student's average speed in km/hr from the time he leaves home until he arrives at his friend's house? Round to the nearest tenth and bubble in your answer on the griddable item.
- Create a distance-time graph to show the relationship between the student's total distance and time.

$$\frac{5\text{ km}}{70\text{ min}} \bullet \frac{60\text{ min}}{1\text{ hr}} = \frac{300\text{ km}}{70\text{ hr}} \div \frac{70}{70} = \frac{4.3\text{ km}}{1\text{ hr}} = 4.3\text{ km/hr}$$



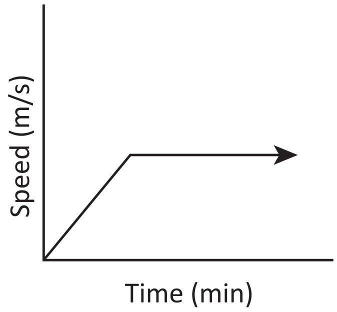


1207343 5-8 Science Academies_Grade 6.indd 111 4/27/2016 2:45:43 PM

Force and Motion

B1

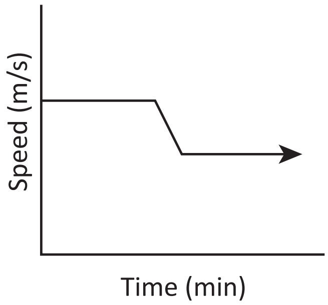
Explain the motion of the object based on the graph.



The increasing line from the origin means an object's speed increases. Once the line becomes horizontal, or flat, the object's speed holds constant.

B2

Explain the motion of the object based on the graph.

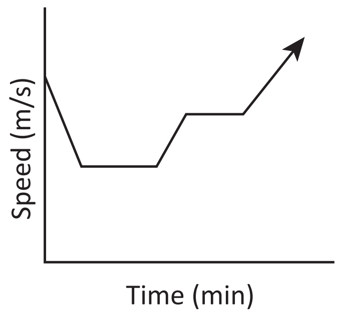


The horizontal, or flat, line means an object's speed is constant. When the line begins to decrease, it means the object's speed is decreasing. When the line becomes horizontal again, the object's speed holds constant.

Force and Motion

B3

Explain the motion of the object based on the graph.



The object's speed decreases (decreasing line), then holds constant (horizontal line), increases (increasing line), holds constant (horizontal line), and then increases again (increasing line).

C1

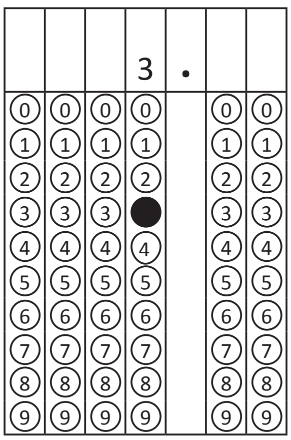
Observe the data in the table.

- Calculate the speed of each trial. $(s = \frac{d}{t})$
- Calculate the average speed of both trials two ways.
- What is the average speed in cm/s? Bubble in your answer on the griddable item.

Trial	Distance (cm)	Time (s)	Speed (cm/s)
1	15	5	*3*
2	18	6	*3*
Total	*33*	*11*	

Average Speed (cm/s)
3

Average Speed (cm/s)	*3*	→	*3*



1207343 5-8 Science Academies_Grade 6.indd 113 4/27/2016 2:45:44 PM

Force and Motion

C2

Observe the data in the table.

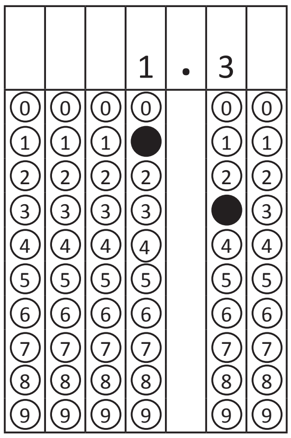
- Calculate the speed of each trial. $(s = \frac{d}{t})$
- Calculate the average speed of both trials two ways.
- What is the average speed in km/min? Round the average speed to the nearest tenth of a km/min. Bubble in your answer on the griddable item.

Trial	Distance (km)	Time (min)	Speed (km/min)
1	83	62	*1.3*
2	47	39	*1.2*
Total	*130*	*101*	

Average Speed (km/min)
1.3

Average Speed (km/min)	*1.3*

→ *1.3*



TEA Texas Education Agency

1207343 5-8 Science Academies_Grade 6.indd 114 4/27/2016 2:45:44 PM

C3

Observe the data in the table.

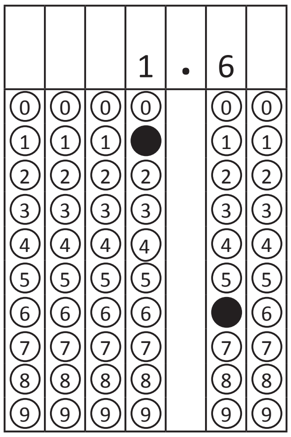
- Calculate the speed of each trial. $(s = \frac{d}{t})$
- Calculate the average speed of both trials two ways.
- What is the average speed in m/s? Round the average speed to the nearest tenth of a m/s. Bubble in your answer on the griddable item.

Trial	Distance (m)	Time (s)	Speed (m/s)
1	320	201	*1.6*
2	303	183	*1.7*
3	296	197	*1.5*
Total	*919*	*581*	

Average Speed (m/s)
1.6

↓

Average Speed (m/s)	*1.6*	→	*1.6*



Force and Motion

Evaluate

Materials

For each student

- RM 8

Tier I Support

Students may work individually, in pairs, or in small groups.

Teacher Instruction

- Distribute *RM 8: Evaluate* to each student.
- Instruct students to use their knowledge of distance, time, speed, average speed, and changes in position and direction to complete *RM 8*.

RM 8 Answer Key

1. Observe the data in the table. Calculate the average speed and round to the nearest tenth of a m/s to see if the swimmer is meeting her goal.

	Trial 1		Trial 2		Trial 3	
	Distance (m)	Time (s)	Distance (m)	Time (s)	Distance (m)	Time (s)
	100	62	100	48	100	55
Speed (m/s)	*1.6*		*2.1*		*1.8*	

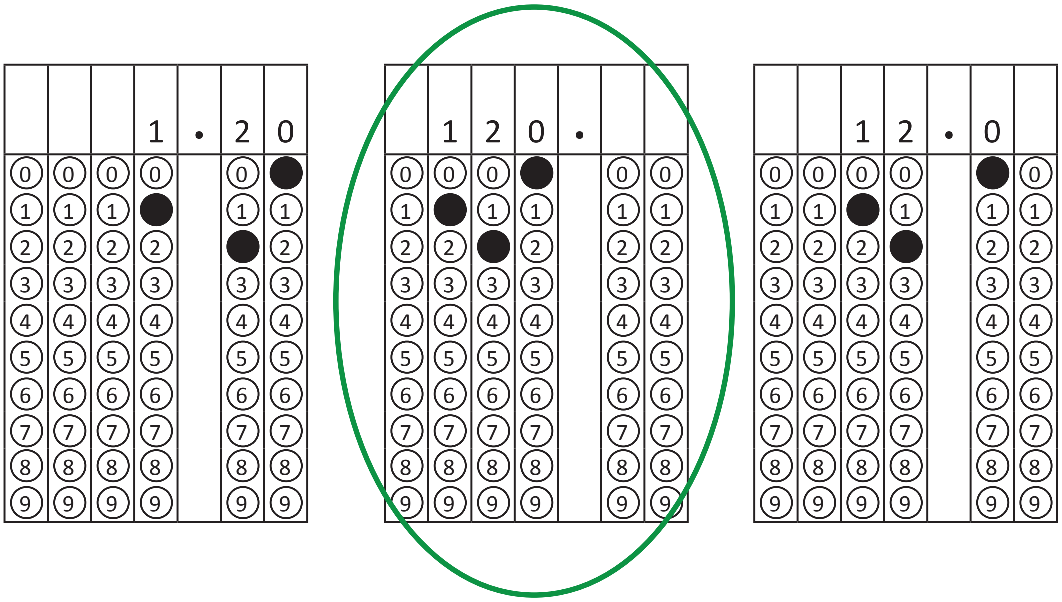
$$\frac{1.8\ m}{s} \bullet \frac{60\ s}{1\ min} = \frac{108\ m}{1\ min} = 108\ m/min$$

Is the swimmer's average speed 120 m/min or faster? Explain your reasoning.
The swimmer is swimming 108 meters in 1 minute. Her goal is to swim 120 meters in 1 minute. This means the swimmer is slower than she wants to be. The swimmer met her goal in the second trial; however, she is not consistently meeting her goal.

TEA Texas Education Agency

Force and Motion

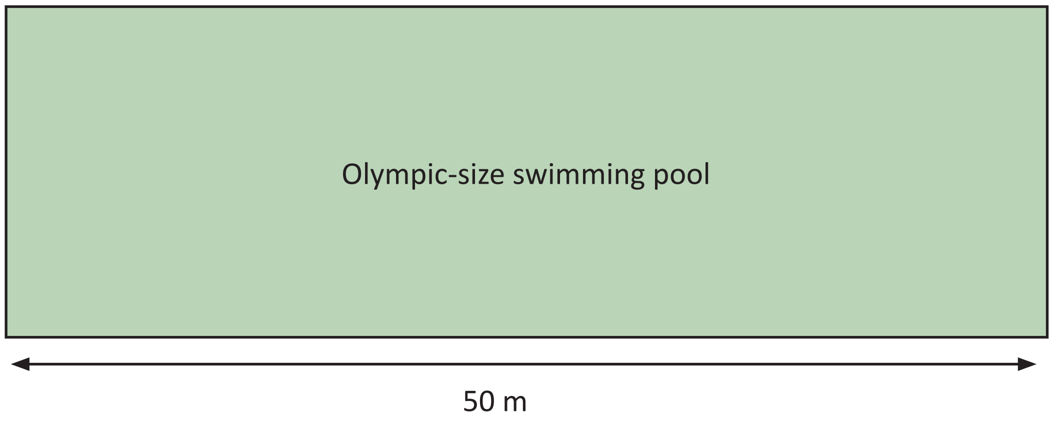
2. Circle the griddable item that shows the correct way to bubble in 120 m/min.



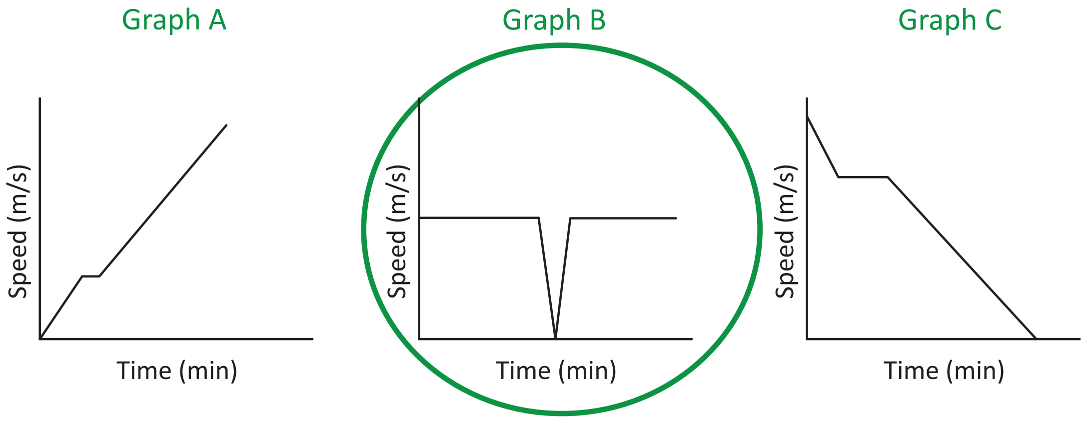
The griddable item in the middle is correct because 120 is a whole number, which means it belongs to the left of the decimal.

Force and Motion

3. An Olympic-size swimming pool is 50 m in length.



The swimmer is swimming a length of 100 m at a constant speed except for when the swimmer turns around to complete the 100 m length. Circle the graph that most likely shows the swimmer's motion when swimming.



Explain why you chose one graph and why the other two graphs are most likely incorrect.

Graph B is most likely correct because the two horizontal sections of the line are of equal length. That represents a constant speed for the swimmer during the first 50 m length and then the second 50 m length. The momentary decrease and increase in speed occurs at the midway point on the line, representing when the swimmer turns around and changes direction to complete the 100 m length.

Graph A is most likely incorrect because the two longer sections of the line represent an increasing speed instead of a constant speed. Also, these two sections of the line are not of equal length. The same is true of Graph C, only the line represents a decreasing speed.

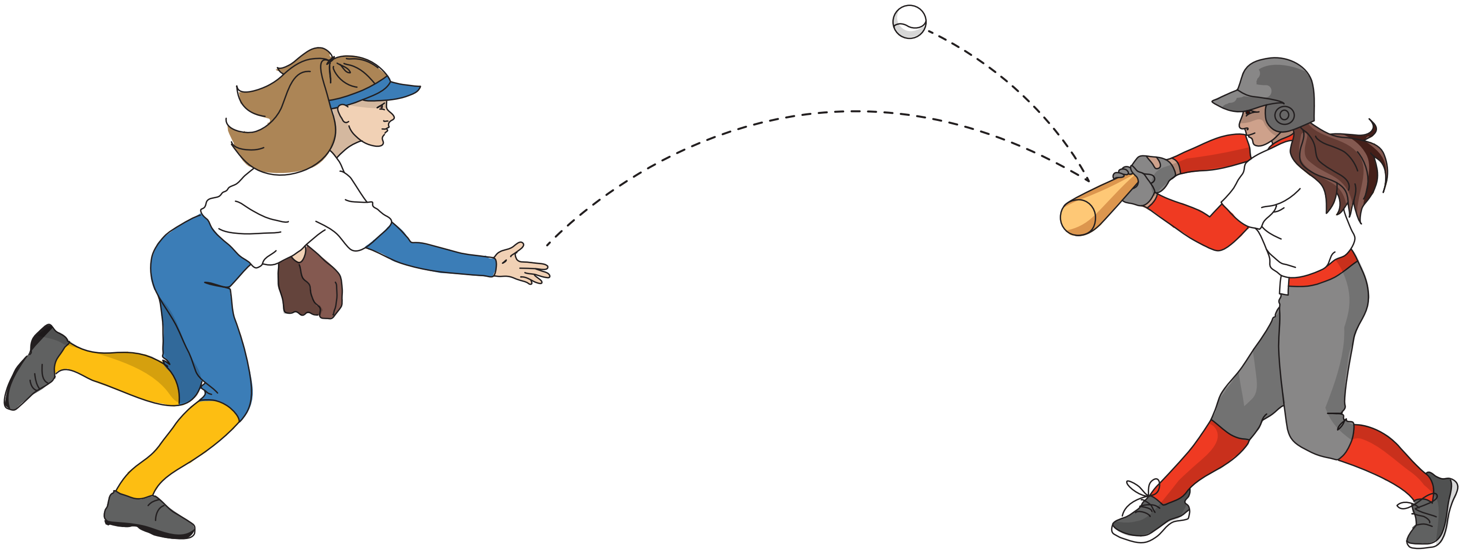
TEA Texas Education Agency

1207343 5-8 Science Academies_Grade 6.indd 118 4/27/2016 2:45:46 PM

Force and Motion

RM 1: Soaring Softball

What happens to the softball after it leaves the pitcher's hand?



1207343 5-8 Science Academies_Grade 6.indd 119 4/27/2016 2:45:47 PM

Force and Motion

RM 2: Distance and Time Measurements

Instructions

1. Assign each member of your group one of the following roles.

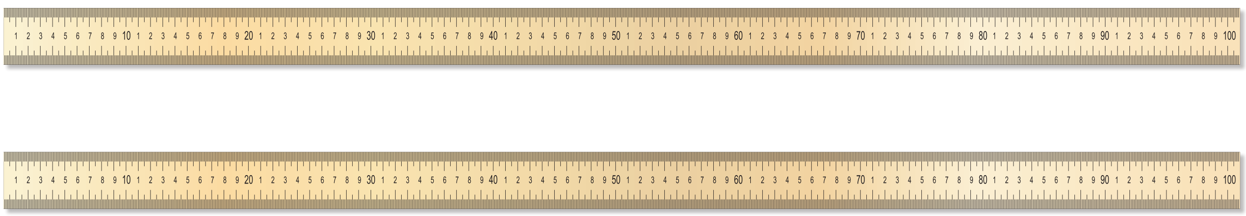
   - **Timer:** This person will say “go” when he or she starts the timing device. The Timer will also say “now” every 2 or 4 seconds after the time starts until the toy stops moving.

   - **Position Marker:** This person will place a sticky note, flag, or sticker dot on the meter stick when the Timer says “now.” The sticky note, flag, or sticker dot will align to where the front edge of the toy is when the Timer says “now.” The Position Marker should have a few sticky notes, flags, or sticker dots in hand at the beginning of each trial as some toys will move quickly.

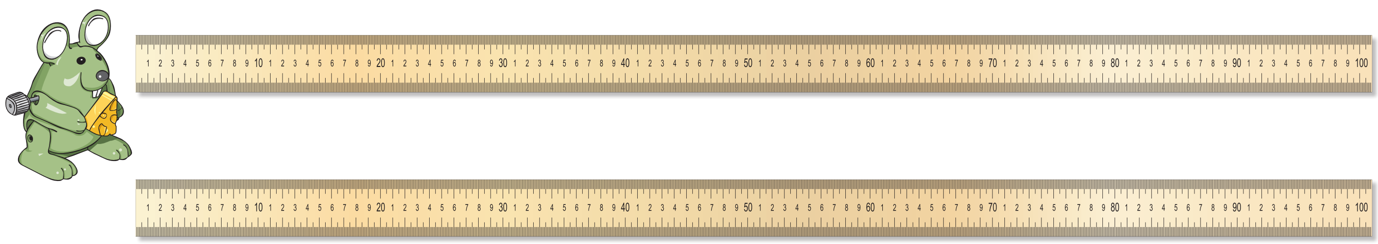
   - **Recorder:** This person will turn the crank on the wind-up toy and hold it in place at 0 cm until the Timer says “go.” The Recorder will also write the distances at which the sticky notes, flags, or sticker dots are placed on the meter stick after each trial.

2. Locate a flat, smooth surface at least 100 cm in length.

3. Position two meter sticks side-by-side with enough space between them for the wind-up toy to freely move.



4. Place the front edge of the wind-up toy at 0 cm on the meter sticks.



5. Turn the crank on the wind-up toy the same number of times for each trial.

6. Set the wind-up toy at 0 cm and hold it in place until the Timer says “go.”

7. After the Timer says “go,” release the toy.

1207343 5-8 Science Academies_Grade 6.indd 121 4/27/2016 2:45:49 PM

Force and Motion

RM 2 continued

8. Place a sticky note, flag, or sticker dot on one of the meter sticks when the Timer says “now.” The sticky note, flag, or sticker dot should align to the front edge of the toy.

9. Record the distance to the nearest tenth of a centimeter at each sticky note, flag, or sticker dot on the meter stick for the trial.

10. Conduct three trials.

1207343 5-8 Science Academies_Grade 6.indd 123 4/27/2016 2:45:49 PM

Force and Motion

RM 2 continued

Data Sheet

2-second intervals

	Trial 1	Trial 2	Trial 3
Time (s)	**Distance (cm)**		
0			
2			
4			
6			
8			
10			
12			
14			
16			
18			
20			

Data Sheet

4-second intervals

	Trial 1	Trial 2	Trial 3
Time (s)	**Distance (cm)**		
0			
4			
8			
12			
16			
20			

1207343 5-8 Science Academies_Grade 6.indd 125 4/27/2016 2:45:49 PM

Force and Motion

RM 2 continued

Calculating Speed and Average Speed

1. Record the total distance and total time from each trial in the table.

2. Calculate the speed for each trial. Round the speed to the nearest tenth, and record it in the table.

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

3. Average the speeds for each trial. Round the average speed to the nearest tenth and record it in the table.

$$\text{Average Speed} = \frac{\text{Speed from Trial 1} + \text{Speed from Trial 2} + \text{Speed from Trial 3}}{3}$$

4. Add the distances for each trial to get the total distance traveled for all three trials, and record it in the *Total Distance* column.

5. Add the times for each trial to get the total time the toy traveled for all three trials, and record it in the *Total Time* column.

6. Calculate the average speed for all three trials. Round the average speed to the nearest tenth, and record it in the table.

$$\text{Average Speed} = \frac{\text{Total Distance Traveled in All Three Trials}}{\text{Total Time Traveled in All Three Trials}}$$

The average speed calculated in Step 3 should equal the average speed calculated in Step 6. If these numbers do not match, check your mathematical processes on both steps.

Trial	Total Distance (cm)	Total Time (s)	Speed (cm/s)
1			
2			
3			
Total			

Average Speed (cm/s)

Average Speed (cm/s)	

Force and Motion

RM 2 continued

7. Record the speed for each trial and the average speed. Make sure you pay attention to the placement of the decimals.

Speed for Trial 1

				•		
0	0	0	0		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	3	3	3		3	3
4	4	4	4		4	4
5	5	5	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	9	9	9		9	9

Speed for Trial 2

				•		
0	0	0	0		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	3	3	3		3	3
4	4	4	4		4	4
5	5	5	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	9	9	9		9	9

Speed for Trial 3

				•		
0	0	0	0		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	3	3	3		3	3
4	4	4	4		4	4
5	5	5	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	9	9	9		9	9

Average Speed of all 3 Trials

				•		
0	0	0	0		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	3	3	3		3	3
4	4	4	4		4	4
5	5	5	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	9	9	9		9	9

1207343 5-8 Science Academies_Grade 6.indd 129 4/27/2016 2:45:50 PM

Force and Motion

RM 2 continued

8. Practice converting, or changing, units of measurement.

- What was the average speed of your toy? Remember to include the units of measurement.

  ____

- When converting units of measurement, we often multiply by a ratio equal to 1. For example,

  $\frac{1\text{ m}}{100\text{ cm}} = 1$ because 100 cm are in 1 m.

  When working with speed measurements, we will convert units of length, including centimeters (cm), meters (m), and kilometers (km), and units of time, including seconds (s), minutes (min), and hours (hr).

- For example, let's say the average speed of the wind-up toy is 2 cm/s. What is the average speed in m/s? To figure this out, we need to multiply by a ratio equal to 1.

  $$\frac{2\text{ cm}}{\text{s}} \bullet \frac{1\text{ m}}{100\text{ cm}} = \frac{2\text{ m}}{100\text{ s}}$$

  We could say that the wind-up toy traveled 2 m in 100 s. Now we need to divide the numerator by the denominator.

  $2 \div 100 = 0.02$ m/s The wind-up toy traveled 0.02 m/s.

  The entire equation looks like this:

  $$\frac{2\text{ }\cancel{\text{cm}}}{\text{s}} \bullet \frac{1\text{ m}}{100\text{ }\cancel{\text{cm}}} = \frac{2\text{ m}}{100\text{ s}} = 0.02\text{ m/s}$$

---

a. What is the average speed in m/s?

- Write your average speed on the first blank.
- Simplify the units by crossing through *cm* because it is above and below the dividing line. The units simplify because they have a value of 1. This leaves a ratio of m/s.
- Multiply the numerators first. Then multiply the denominators.
- Divide the numerator by the denominator.

$$\frac{\_\_\_\text{ cm}}{\_\_\_\text{ s}} \bullet \frac{1\text{ m}}{100\text{ cm}} = \frac{\_\_\_\text{ m}}{\_\_\_\text{ s}} = \_\_\_\_\_\_$$

Force and Motion
RM 2 continued

b. What is the average speed in cm/min?

- Write your average speed on the first blank.
- Simplify the units by crossing through *s* because it is above and below the dividing line. The units simplify because they each have a value of 1. This leaves a ratio of cm/min.
- Multiply the numerators first. Then multiply the denominators.
- Divide the numerator by the denominator.

$$\frac{\underline{\qquad}\ \text{cm}}{\text{s}} \bullet \frac{60\ \text{s}}{1\ \text{min}} = \frac{\underline{\qquad}\ \text{cm}}{\text{min}} = \underline{\qquad\qquad}$$

c. What is the average speed in m/min?

- Write your average speed on the first blank.
- Simplify the units by crossing through *cm* and *s* above and below the dividing line. Those units simplify because they each have a value of 1. This leaves a ratio of m/min.
- Multiply the numerators first. Then multiply the denominators.
- Divide the numerator by the denominator.

$$\frac{\underline{\qquad}\ \text{cm}}{\text{s}} \bullet \frac{1\ \text{m}}{100\ \text{cm}} \bullet \frac{60\ \text{s}}{1\ \text{min}} = \frac{\underline{\qquad}\ \text{m}}{\text{min}} = \underline{\qquad\qquad}$$

d. What is the average speed in km/min?

- Write your average speed on the first blank. Simplify the units by crossing through *cm*, *m*, and *s* above and below the dividing line. Those units simplify because they each have values of 1. This leaves a ratio of km/hr.
- Fill in the remaining ratios that are equal to 1.
- Multiply the numerators first. Then multiply the denominators.
- Divide the numerator by the denominator.

$$\frac{\underline{\qquad}\ \text{cm}}{\text{s}} \bullet \frac{\underline{\qquad}\ \text{m}}{\underline{\qquad}\ \text{cm}} \bullet \frac{\underline{\qquad}\ \text{km}}{\underline{\qquad}\ \text{m}} \bullet \frac{\underline{\qquad}\ \text{s}}{\underline{\qquad}\ \text{min}} = \frac{\underline{\qquad}\ \text{km}}{\text{min}} = \underline{\qquad\qquad}$$

1207343 5-8 Science Academies_Grade 6.indd 133 4/27/2016 2:45:50 PM

Force and Motion

RM 3: The Meaning of a Line Graph

Goal: Match the line on the graph through your movement.

Option A: Motion Sensor with Computer or Laptop*

1. Locate a blank, flat section of wall near the computer you will be using. Make sure the section of the wall you will use does not have windows, projection screens, or lockers on it because they can cause interference as the soundwaves from the motion sensor bounce off the wall. If interference happens, the line on the graph will not be accurate.
2. Connect the motion sensor to the computer or laptop using the appropriate cord.
3. Flip open the motion sensor head and move the sensitivity switch toward the person and basketball icons. Close the motion sensor head, making sure you hear it click into place.
4. Open the motion sensor software on the computer. You should see the light on the motion sensor change from red to green.
5. The program will default to a 5-second timeframe for you to match the graph. To extend the time limit, go to "Experiment," then "Data Collection," and enter the time you want next to "Duration." Click "Done."
6. To adjust the data collected in the table on the left side of the screen, go to "Data, Column Options." "Time" and "Position" are the only two columns that will be used for this lesson. (Velocity and acceleration will be addressed in eighth grade.)
7. Click on "Match" within the software program (second icon from right on top menu bar). A line will be generated on the graph.
8. Note how far from the bottom of the graph the line begins. Use a meter stick to measure and position yourself the same distance from the wall.
9. Hold the motion sensor directly in front of you about chest high. The sensor should face the wall.
10. When you are ready to begin, press the green button with the white triangle within the software program (right next to the "Match" icon). You will hear the motion sensor begin to make a clicking sound.
11. Move closer or farther from the wall as you attempt to match or recreate the line shown on the graph. It may take some practice to figure out which movements cause the line to go up, down, or stay constant.
12. To attempt matching the same graph again, click on the green button with the white triangle.
13. To try matching a different graph, repeat steps 7–11.
14. When you are finished with the equipment, disconnect the wire from the motion sensor. This will turn the sensor off and conserve battery power. Remove and store the batteries if the class is finished using the equipment.

*These instructions are for the Go!Motion motion sensor and Logger Lite® software. If you are using a different motion sensor and software, the directions may be slightly different.

Force and Motion

RM 3 continued

Goal: Match the line on the graph through your movement.
Option B: Motion Sensor and TI-83 Plus Graphing Calculator*

1. Locate a blank, flat section of wall. Make sure the section of the wall you will use does not have windows, projection screens, or lockers on it because they can cause interference as the soundwaves from the motion sensor bounce off the wall. If interference happens, the line on the graph will not be accurate.

2. Connect the motion sensor to the graphing calculator using the appropriate cord.

3. Turn the calculator on by pressing the “ON” button on the bottom left corner.

4. Press the “CLEAR” and then the “APPS” buttons.

5. Press 2, or use the arrow keys to scroll down; select 2: “CBL/CBR;” and press “ENTER.”

6. Press “ENTER” after the “CBL/CBR” screen appears.

7. Press 3, or use the arrow keys to scroll down; select 3: “RANGER;” and press “ENTER.”

8. After you see the “prgmRANGER” and “Texas Instruments” screens, press “ENTER.”

9. Press 3, or use the arrow keys to scroll down; select 3: “APPLICATIONS;” and press “ENTER.”

10. Press 1 or “ENTER” to select 1: “METERS.”

11. Press 1 or “ENTER” to select 1: “DIST MATCH.”

12. You will see a screen that instructs you to match the graph on the next screen. Press “ENTER” when you are ready.

13. Before trying to match the line on the graph, count the tick marks on the left side of the calculator screen. Each tick mark equals 1 meter. Use a meter stick to measure and position yourself that distance from the wall.

14. Hold the motion sensor directly in front of you about chest high. The sensor should face the wall. You will hold the calculator in your other hand.

15. Move closer or farther from the wall as you attempt to match the line shown on the graph. It may take some practice to figure out which movements cause the line to go up, down, or stay constant.

16. When you are ready to begin, press “ENTER” on the calculator. You will hear the motion sensor begin to make a clicking sound.

17. To attempt matching the same graph again, press “ENTER.” On the following screen, press 1, or “ENTER” to select 1: “SAME MATCH.”

Force and Motion

RM 3 continued

18. To try matching a diferent graph, press 2, or use the arrow keys; scroll down; select 2: “NEW MATCH;” press “ENTER;” and repeat steps 15–17.

19. When you are finished using the equipmet, disconnect the motion senso. This will turn the sensor off and onserve batery power. To turn off the alculator, press the “2nd” buton (top left orner) and then the “ON” buton. Remove and store the bateries if the class is finished using the equipment.

* These instructions ae for the Go!Motion motion sensor and TI-83 Plus aphing calculator. If you are using a diferent motion sensor and gaphing calculator, the directions my be slightly diferent.

Force, Motion, and Energy

RM 3 continued

Goal: Match the line on the graph through your movement.

Option C: Motion Sensor and TI-84 Plus Silver Edition Graphing Calculator*

1. Locate a blank, flat section of wall. Make sure the section of the wall you will use does not have windows, projection screens, or lockers on it because they can cause interference as the soundwaves from the motion sensor bounce off the wall. If interference happens, the line on the graph will not be accurate.

2. Connect the motion sensor to the graphing calculator using the appropriate cord.

3. Turn the calculator on by pressing the "ON" button on the bottom left corner.

4. Press the "CLEAR" and then the "APPS" buttons.

5. Use the arrow keys to scroll down to "EasyData" and press "ENTER."

6. Press the "WINDOW" button (second from the left directly below the screen) to select "Setup."

7. Press 3, or use the arrow keys to scroll down; select 3: "Distance Match;" and press "ENTER."

8. Press the "ZOOM" button (third from the left directly below the screen) to select "Start."

9. You will see a screen that instructs you to match the graph on the next screen. Press the "ZOOM" button to select "Next."

10. Before trying to match the line on the graph, count the tick marks on the left side of the calculator screen. Each tick mark equals 1 meter. Use a meter stick to measure and position yourself that distance from the wall.

11. Hold the motion sensor directly in front of you about chest high. The sensor should face the wall. You will hold the calculator in your other hand.

12. Move closer or farther from the wall as you attempt to match the line shown on the graph. It may take some practice to figure out which movements cause the line to go up, down, or stay constant.

13. When you are ready to begin, press the "ZOOM" button to select "Start." You will hear the motion sensor begin to make a clicking sound.

14. To attempt matching the same graph again, press the "ZOOM" button to select "Retry." On the following screen, press the "ZOOM" button to select "Start."

15. To try matching a different graph, press "WINDOW" to select "New;" press "ZOOM" to select "Start;" and repeat steps 12–14.

Force and Motion

RM 3 continued

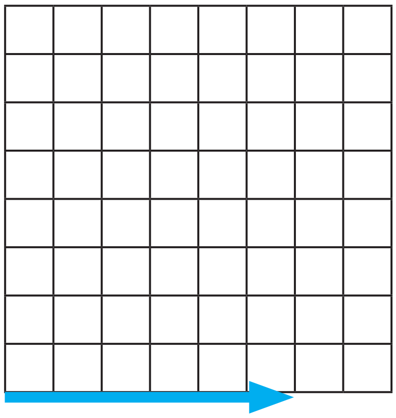
16. When you are finished using the equipment, disconnect the motion sensor. This will turn the sensor off and conserve battery power. To turn off the calculator, press the “2nd” button (top left corner) and then the “ON” button. Remove and store the batteries if the class is finished using the equipment.

* These instructions are for the Go!Motion motion sensor and TI-84 Plus Silver Edition graphing calculator. If you are using a different motion sensor and graphing calculator, the directions may be slightly different.

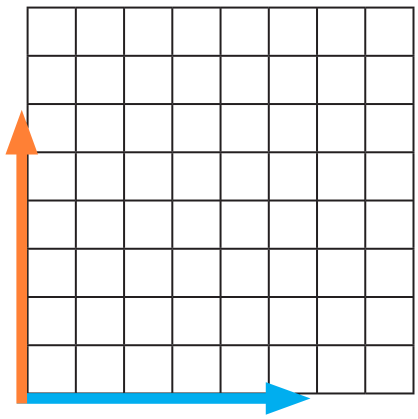
Force and Motion

RM 4: How to Create a Line Graph

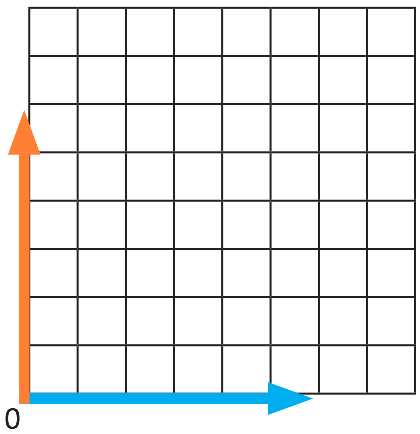
1. On a sheet of graph paper, use a blue marker to draw a horizontal line near the bottom of the page from left to right. This will be the *x*-axis. The independent, or manipulated, variable belongs on the *x*-axis. This is the variable that a scientist tests. Time often belongs on the *x*-axis.



2. Use an orange marker to draw a vertical line extending up from the left end of the *x*-axis. This will be the *y*-axis. The dependent, or responding, variable belongs on the y-axis. This is the variable that is measured. For example, distance can be measured over time.



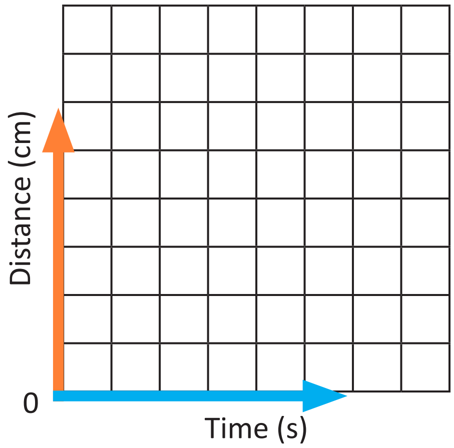
3. Write a *0* at the intersection of the *x*- and *y*-axes. This is the origin.



Force and Motion

RM 4 continued

4. Use a blue marker to label the *x*-axis with *Time* in seconds (s) and use an orange marker to label the *y*-axis with *Distance* in centimeters (cm). Always remember to include the units of measurement.



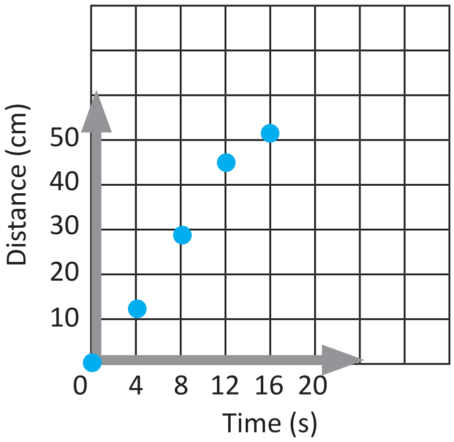
5. Determine the scale for each axis. It may be helpful to divide the highest number in each column in the data table by how many squares are available on the graph. Determine whether it would be best to count by 1, 2, 3, or something else for each axis. Once determined, write numbers accordingly along each axis in the corresponding colors used above. Be sure to place the numbers on the gridlines, not between them.

6. Before plotting data points, use the blue marker to outline the column with time measurements and the orange marker to outline the column with distance measurements.

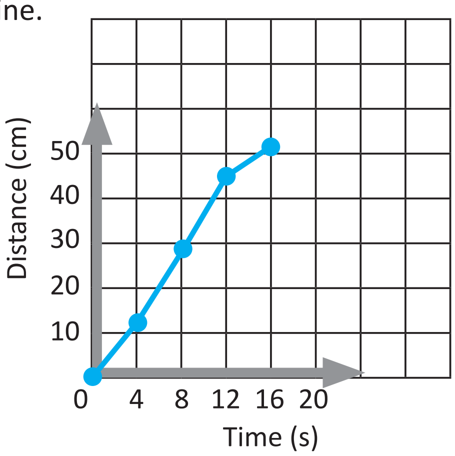
Distance Traveled by a Wind-up Toy	
Time (s)	**Distance (cm)**
0	**0**
4	**13**
8	**29**
12	**45**
16	**52**

7. Begin plotting data points on the graph. The first point will be at (0, 0). Place a sticky dot or make a dot on (0, 0).
    - The second point will be at (4, 13). Count across to 4 on the *x*-axis and then up to 13 on the *y*-axis.
    - Continue the same process for the remaining data points. Always count across on the *x*-axis and then up on the *y*-axis.

Distance Traveled by a Wind-up Toy	
Time (s)	**Distance (cm)**
0	**0**
4	**13**
8	**29**
12	**45**
16	**52**

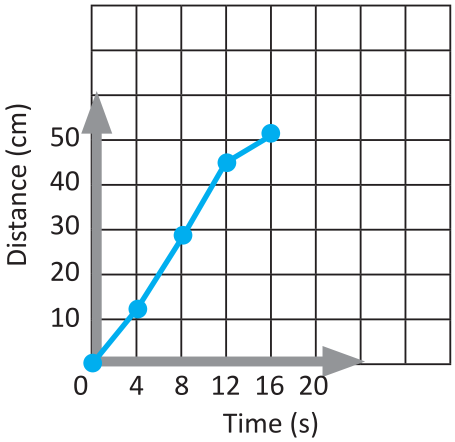


8. Connect the data points with a line.



9. Title the graph. Make sure the title correctly represents the plotted data.

Distance Traveled by a Wind-up Toy



Force and Motion

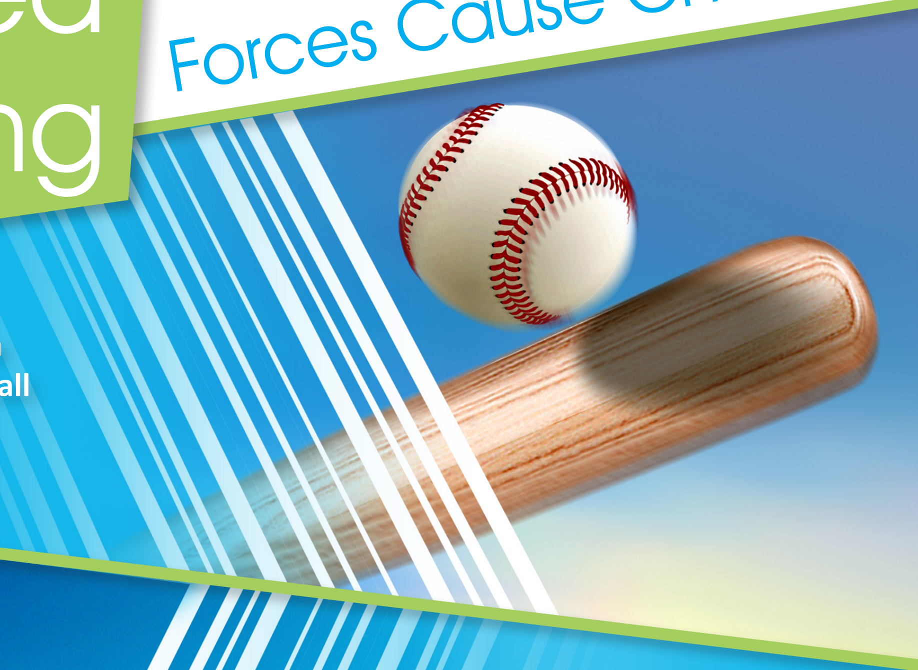
RM 4 continued

10. Create a distance-time line graph by plotting the data points from your investigation in Explore, Part 1.

1207343 5-8 Science Academies_Grade 6.indd 151 4/27/2016 2:45:52 PM

Speed Reading

Forces Cause Change



The force of a bat hitting a baseball causes the baseball to change direction.

The force of the wind blowing can cause a sailboat to change position as the sail is pushed.

The force of friction between tires and the road can cause a car's speed to change.

Texas Education Agency

Texas Education Agency

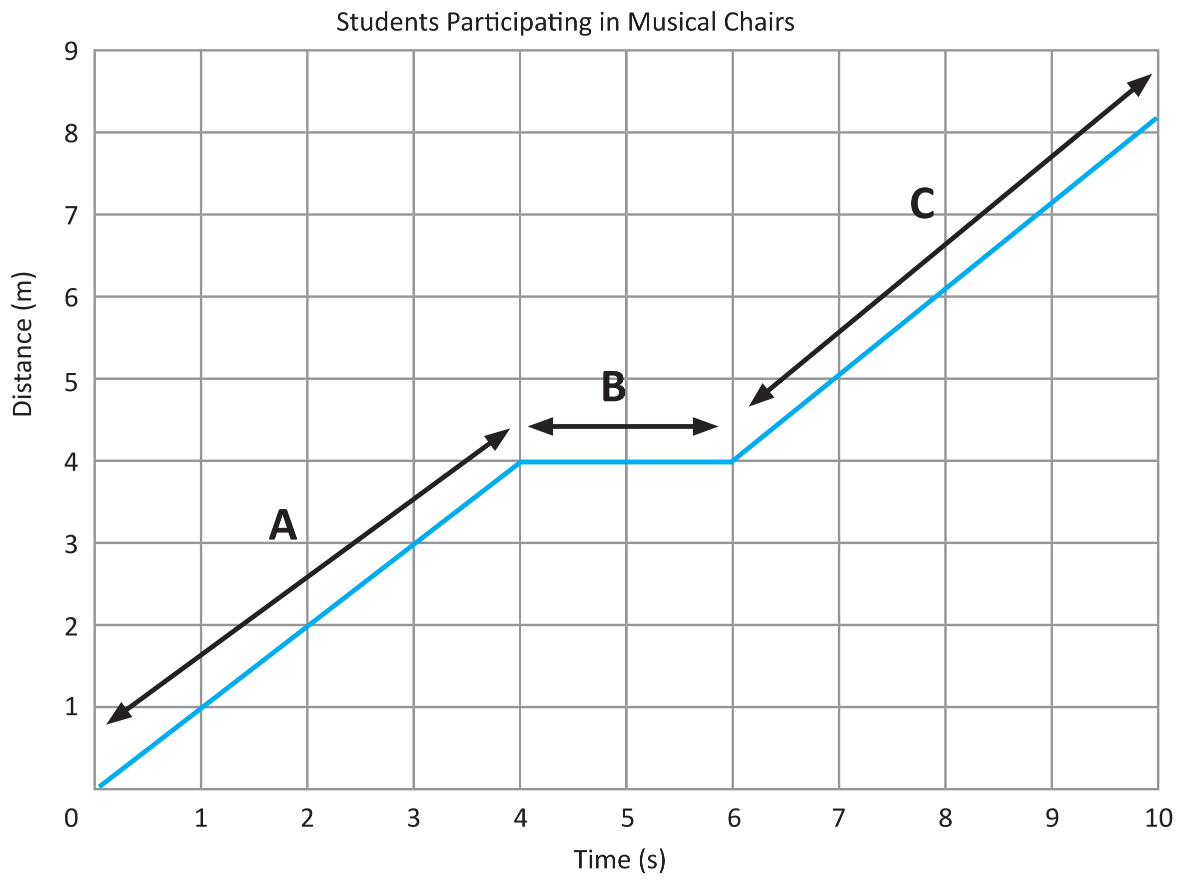
© 2016 TEXAS EDUCATION AGENCY. ALL RIGHTS RESERVED.

1207343 5-8 Science Academies_Grade 6.indd 153 4/27/2016 2:45:52 PM

Distance-Time Graphs

Forces are all around us and cause change. Sometimes, graphs are created to show how and where the change in motion of an object occurs.

Observe the graph.



What happens when kids play musical chairs? They move around a circle of chairs while the music plays but must quickly find a chair to sit in when the music stops. When the music begins playing, the students stand up and move around the circle again. Is that what the student in this graph did? How do you know?

Let's say that 0 seconds is the starting point. The music begins playing and the student begins moving around the circle. How far did the student move and for how long?

Look at Section A on the graph. The student moved 4 meters away from the starting point in 4 seconds. So what happened in Section B? The student stayed at a distance of 4 meters for 2 seconds. That means the music must have stopped, so the student found a chair in which to sit!

What did the student do in Section C? The student moved 4 more meters in 4 seconds after the music began playing again. From this graph, we can see the student's movement and how it changed. What else can we tell from the graph?

© 2016 TEXAS EDUCATION AGENCY. ALL RIGHTS RESERVED.

1. We can calculate the student's speed in Sections A, B, and C.

$$\text{Speed in Section A} = \frac{\text{distance}}{\text{time}} = \frac{4\text{ m}}{4\text{ s}} = \frac{1\text{ m}}{1\text{ s}} = 1\text{ m/s}$$

The student's speed in Section A is 1 m/s. The student's speed is the same in Section C because the student traveled the same distance in the same amount of time as in Section A. The student was not moving in Section B because the line is flat. That means that the student remained at the same distance from the starting point during the fourth and fifth seconds.

2. We can calculate the student's average speed.

$$\text{Average Speed} = \frac{\text{total distance}}{\text{total time}} = \frac{8\text{ m}}{10\text{ s}} = \frac{0.8\text{ m}}{1\text{ s}} = 0.8\text{ m/s}$$

For total distance, remember to add the distance the student moved in Sections A, B, and C.

Distance in Section A	+	Distance in Section B	+	Distance in Section C	=	Total Distance
4 m	+	0 m	+	4 m	=	8 m

For total time, look at when motion started and when it was completed. The line started at 0 s and stopped at 10 s. The total time is 10 s. The student's average speed is 0.8 m/s.

3. We can convert the student's average speed to km/hr.

$$\frac{0.8\text{ m}}{\text{s}} \bullet \frac{1\text{ km}}{1000\text{ m}} \bullet \frac{60\text{ s}}{1\text{ min}} \bullet \frac{60\text{ min}}{1\text{ hr}} = \frac{2{,}880\text{ km}}{1{,}000\text{ hr}} = \frac{2.9\text{ km}}{1\text{ hr}} = 2.9\text{ km/hr}$$

To convert 0.8 m/s to km/hr, we have to multiply by a ratio equal to 1 more than once. For example, look at the following equivalencies.

1,000 m = 1 km   60 s = 1 min   60 min = 1 hr

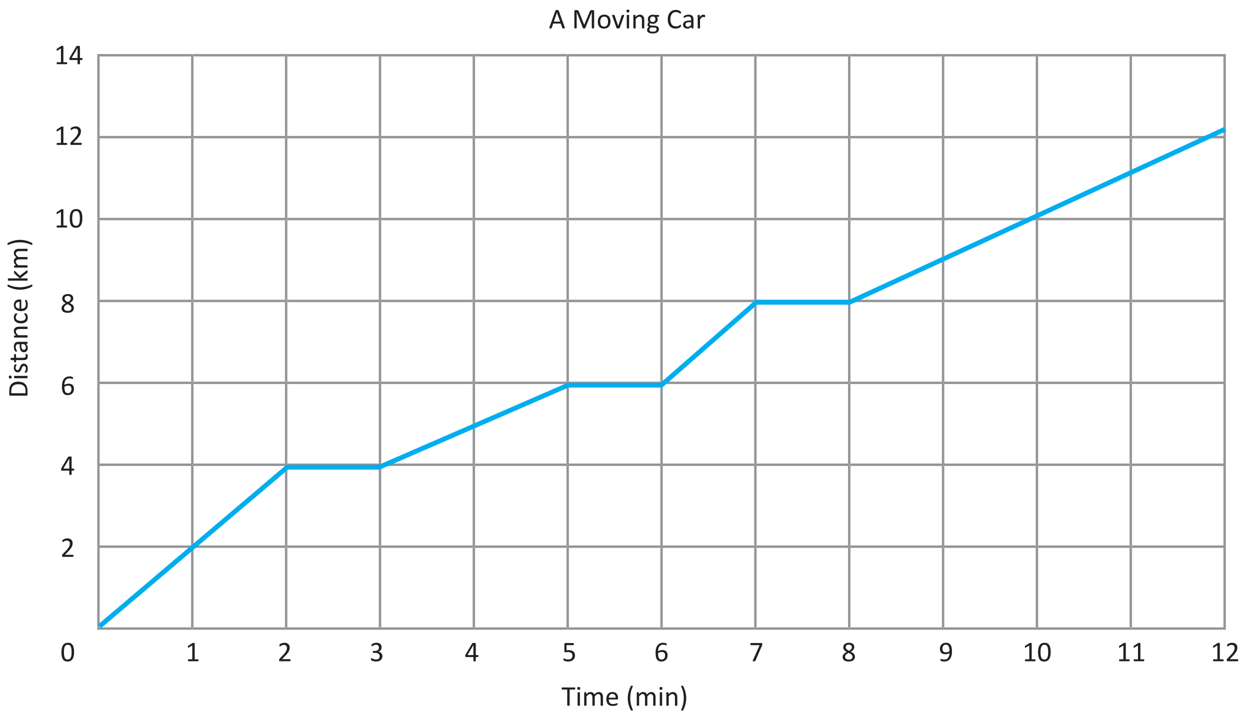
$$\frac{0.8\text{ m}}{\text{s}} \bullet \boxed{\frac{1\text{ km}}{1000\text{ m}}} \bullet \boxed{\frac{60\text{ s}}{1\text{ min}}} \bullet \boxed{\frac{60\text{ min}}{1\text{ hr}}} = \frac{2.9\text{ km}}{1\text{ hr}} = 2.9\text{ km/hr}$$

When multiplying by a ratio equal to 1, make sure you set up the units of measurement so that they are on opposite sides of the midline. This means they will simplify to 1.

$$\frac{0.8\,\cancel{\text{m}}}{\cancel{\text{s}}} \bullet \frac{1\text{ km}}{1000\,\cancel{\text{m}}} \bullet \frac{60\,\cancel{\text{s}}}{\cancel{\text{min}}} \bullet \frac{60\,\cancel{\text{min}}}{1\text{ hr}} = \frac{2.9\text{ km}}{1\text{ hr}} = 2.9\text{ km/hr}$$

Multiply the numerators, and then multiply the denominators. Divide the numerator by the denominator. Simplify the units to leave a ratio of km/hr.

Let’s look at a different example.



The graph shows a car’s change in distance over time. Again, the starting point is at (0, 0). Judging by the line, is the car traveling on a city street or a freeway? If you think the car is traveling on a city street, you may be correct. If you think the car is traveling on a freeway, you may also be correct. So, why might both answers be right?

By looking at the line on the graph, we can determine what was happening. Between 2 and 3 minutes, the car remains at 4 km, indicating that it is stationary, or not moving. Why might the car be stopped for 1 minute? Did you say because of a stoplight or maybe traffic? If so, either explanation is reasonable. Drivers encounter stoplights on city streets and traffic on freeways that may cause them to stop. The constant stops and starts shown by the line help us infer that if the car is on a city street, more than one stoplight exists. If the car is on the freeway, the driver is experiencing stop-and-go traffic.

1207343 5-8 Science Academies_Grade 6.indd 156 6/16/2016 8:46:56 AM

When is the car traveling fastest? The car is traveling fastest between 6 and 7 minutes. We know this because the line on the graph is steeper than anywhere else on the graph. The car travels 2 km in 1 minute.

What is the total distance and time the car travels? The car travels 12 km away from the starting point in 12 minutes.

What is the car's average speed?

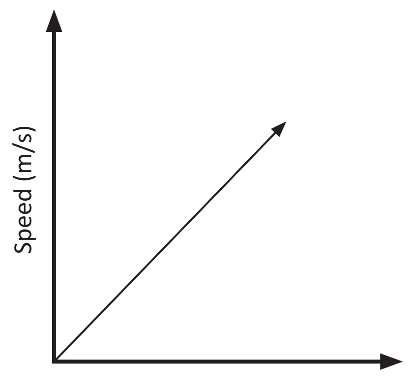
$$\text{Average Speed} = \frac{\text{total distance}}{\text{total time}} = \frac{12\text{ km}}{12\text{ min}} = \frac{1\text{ km}}{1\text{ min}} = 1\text{ km/min}$$

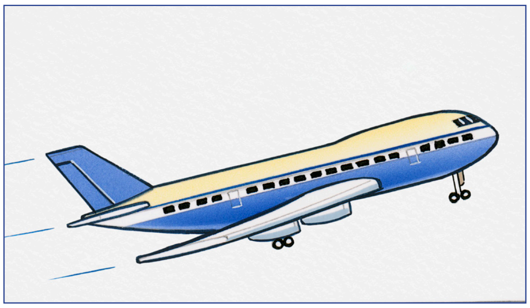
What is the car's average speed in km/hr?

$$\frac{1\text{ km}}{\text{min}} \bullet \frac{60\text{ min}}{1\text{ hr}} = \frac{60\text{ km}}{1\text{ hr}} = 60\text{ km/hr}$$

Speed-Time Graphs

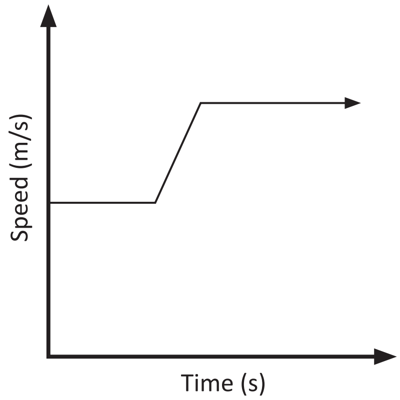
Now, let's think about and observe graphs that show speed.



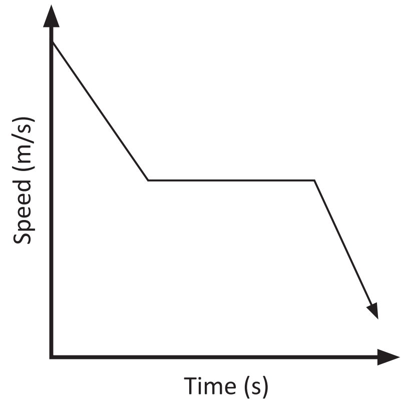


What does the line on the graph mean? If the line is going up, speed is increasing over time. This could represent a plane taking off or a train leaving a station.

1207343 5-8 Science Academies_Grade 6.indd 157 4/27/2016 2:45:53 PM



If an increasing line means increasing speed, what does it mean when the line is horizontal, or flat? A horizontal, or flat, line means the speed is not changing; the object is maintaining a constant speed. What could this line represent? A car traveling down the freeway may travel at a constant speed and then increase in speed to change lanes. After changing lanes, the car may resume a constant speed.

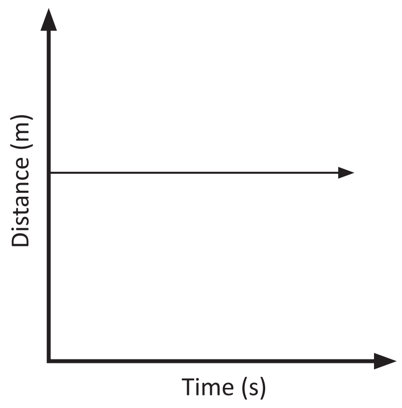


If an increasing line means increasing speed and a horizontal line means no change in speed, what does a decreasing line mean? A decreasing line means a decrease in speed. If a person is running and becomes tired, he or she will slow down to conserve energy. At that point, the runner might maintain the same speed until he or she becomes fatigued again. When that happens, he or she might decrease his or her speed again.

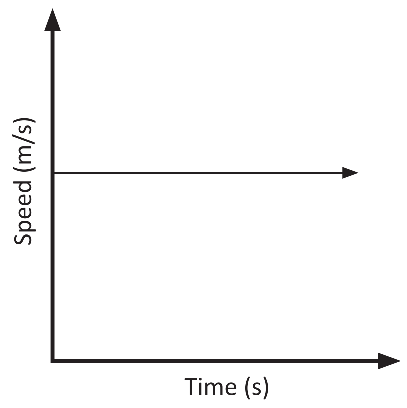
© 2016 TEXAS EDUCATION AGENCY. ALL RIGHTS RESERVED.

Distance-Time Versus Speed-Time Graphs

Let's take a second to think about distance-time graphs versus speed-time graphs. What is the main difference between a horizontal line on a distance-time graph versus a speed-time graph?



A horizontal line on a distance-time graph means an object is not moving because distance is not changing. For example, a car that is stopped or parked would be represented by a horizontal line.



A horizontal line on a speed-time graph means an object's speed is constant, neither increasing nor decreasing. For example, a car traveling down a freeway maintains a constant speed if there is no road construction or traffic.

What causes distance and speed to change over time? Remember, forces are all around us and cause change, such as in distance and speed. Friction, gravity, magnetism—any force that pushes or pulls—can cause change in the motion of an object, including position, direction, and speed.

© 2016 TEXAS EDUCATION AGENCY. ALL RIGHTS RESERVED.

Force and Motion

RM 6: What Do You Know?

Name:____ **Date:** __________________

Directions: Complete each statement. You may add pictures or visuals if they help illustrate your answers.

1. Movement changes because . . .

2. The line on a graph shows . . .

3. A distance-time graph shows . . .

4. A speed-time graph shows . . .

5. A major difference between a distance-time graph and a speed-time graph is . . .

Force and Motion

RM 7: Practice Problems

Set A

A1

A student runs 4 km in 30 minutes at a steady pace.

- What is the student's average speed in km/hr? Bubble in your answer on the griddable item.
- Create a distance-time graph to show the relationship between the student's total distance and time.

				.		
0	0	0	0		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	3	3	3		3	3
4	4	4	4		4	4
5	5	5	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	9	9	9		9	9

A2

A student runs 2 km in 20 minutes to the store. The student then rests for 10 minutes before running 3 km to a friend's house in 30 minutes

- What is the student's average speed in km/hr? Bubble in your answer on the griddable item.
- Create a distance-time graph to show the relationship between the student's total distance and time.

				.		
0	0	0	0		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	3	3	3		3	3
4	4	4	4		4	4
5	5	5	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	9	9	9		9	9

1207343 5-8 Science Academies_Grade 6.indd 163 4/27/2016 2:45:54 PM

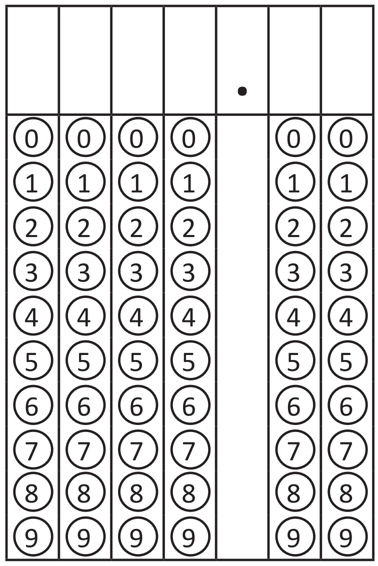
Force and Motion

RM 7 continued

A3

A student walks 1 km from home to the school track in 15 minutes. The student then stops to rest for 5 minutes before running 3 km in 30 minutes. The student rests for 5 minutes and then walks 1 km to a friend's house in 15 minutes.

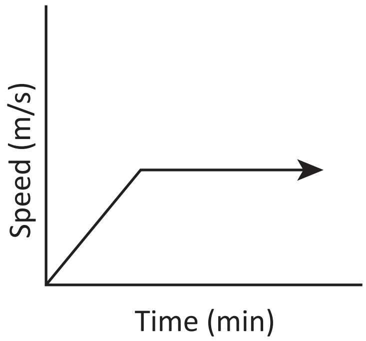
- What is the student's average speed in km/hr from the time he leaves home until he arrives at his friend's house? Round the average speed to the nearest tenth and bubble in your answer on the griddable item.
- Create a distance-time graph to show the relationship between the student's total distance and time.



Set B

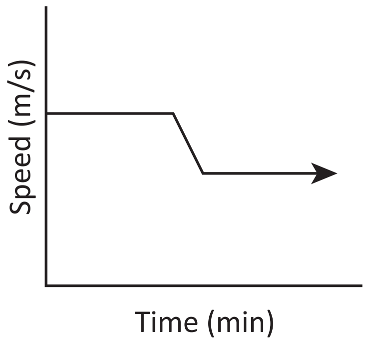
B1

Explain the motion of the object based on the graph.



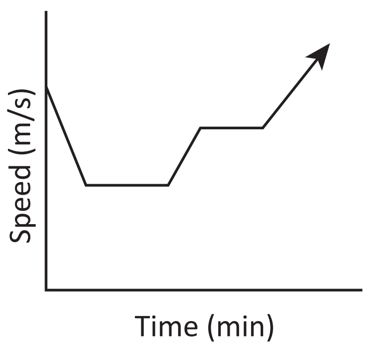
B2

Explain the motion of the object based on the graph.



B3

Explain the motion of the object based on the graph.



Set C

C1

Observe the data in the table.

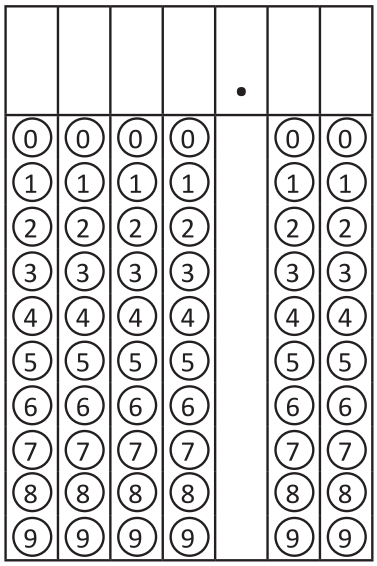
Trial	Distance (cm)	Time (s)	Speed (cm/s)
1	15	5	
2	18	6	
Total			

Average Speed (cm/s)

Average Speed (cm/s)	

- Calculate the speed of each trial.
- Calculate the average speed of both trials two ways.
- What is the average speed in cm/s? Bubble in your answer on the griddable item.

$$(s = \frac{d}{t})$$



Texas Education Agency

Force and Motion

RM 7 continued

C2

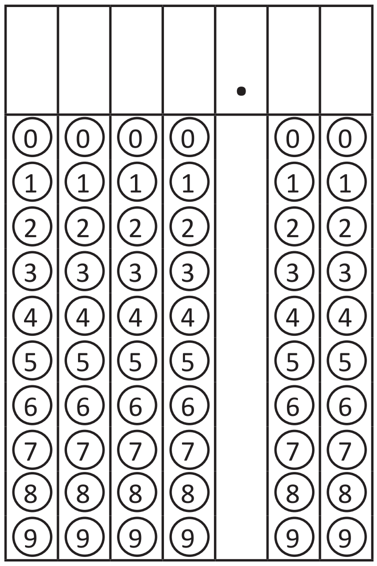
Observe the data in the table.

Trial	Distance (km)	Time (min)	Speed (km/min)
1	83	62	
2	47	39	
Total			

Average Speed (km/min)

Average Speed (km/min)	

- Calculate the speed of each trial. ($s = \frac{d}{t}$)
- Calculate the average speed of both trials two ways.
- What is the average speed in km/min? Round the average speed to the nearest tenth of a km/min. Bubble in your answer on the griddable item.



Force and Motion

RM 7 continued

C3

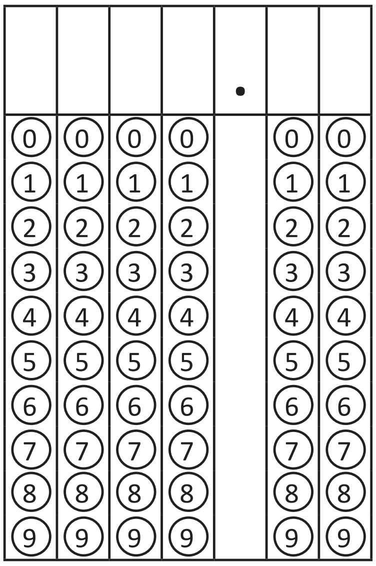
Observe the data in the table.

Trial	Distance (m)	Time (s)	Speed (m/s)
1	320	201	
2	303	183	
3	296	197	
Total			

Average Speed (m/s)

Average Speed (m/s)	

- Calculate the speed of each trial. $(s = \frac{d}{t})$
- Calculate the average speed of both trials two ways.
- What is the average speed in m/s? Round the average speed to the nearest tenth of a m/s. Bubble in your answer on the griddable item.



1207343 5-8 Science Academies_Grade 6.indd 173 4/27/2016 2:45:55 PM

Force and Motion

RM 8: Evaluate

Competitive Swimming Goal

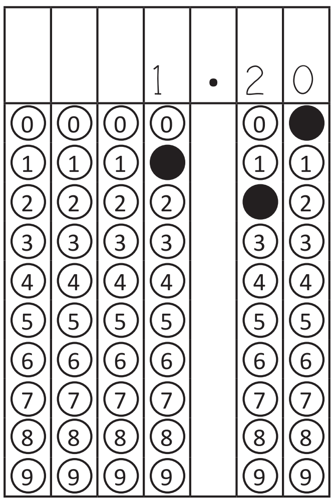
A competitive swimmer has a goal of swimming 100 m at a speed of 120 m/min or faster.

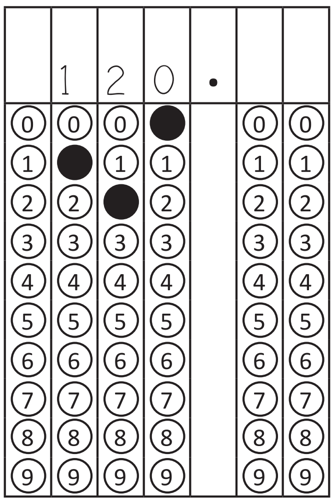
1. Observe the data in the table. Calculate the average speed and round to the nearest tenth of a m/s to see if the swimmer is meeting her goal.

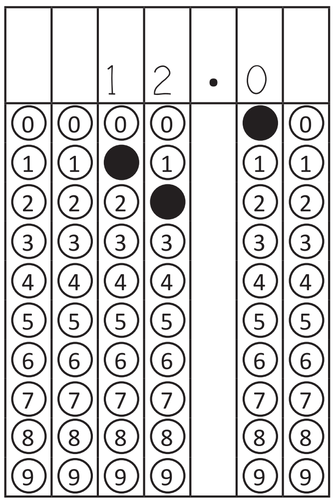
	Trial 1		Trial 2		Trial 3	
	Distance (m)	**Time (s)**	**Distance (m)**	**Time (s)**	**Distance (m)**	**Time (s)**
	100	62	100	48	100	55
Speed (m/s)						

Is the swimmer's average speed 120 m/min or faster? Explain your reasoning.

2. Circle the griddable item that shows the correct way to bubble in 120 m/min.



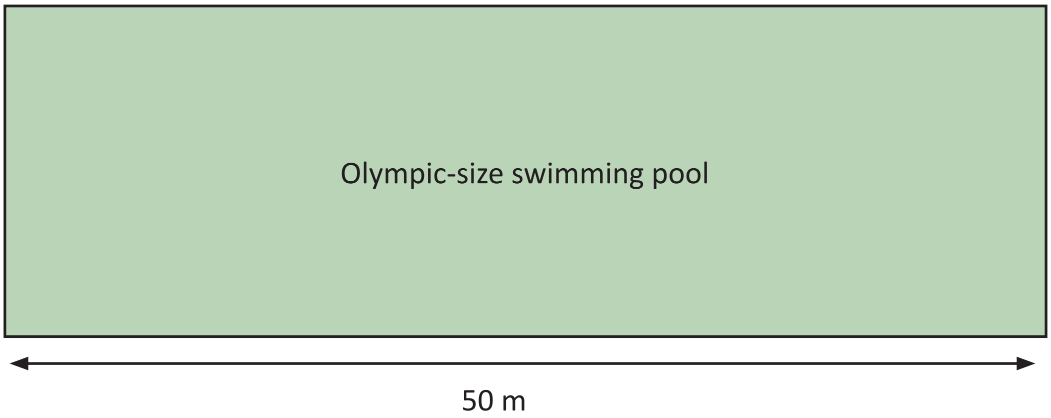




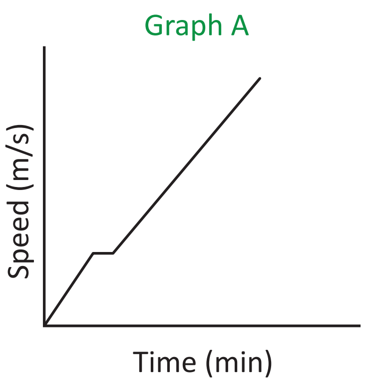
Force and Motion

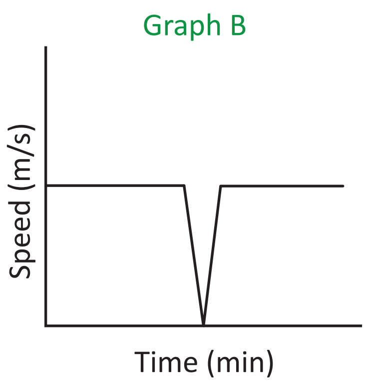
RM 8 continued

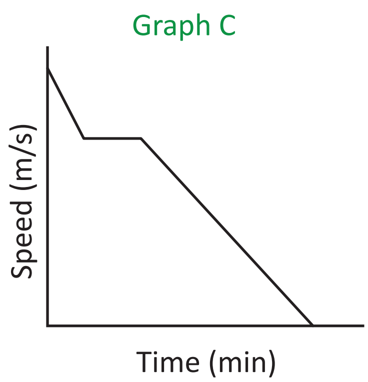
3. An Olympic-size swimming pool is 50 m in length.



The swimmer is swimming a length of 100 m at a constant speed except for when the swimmer turns around to complete the 100 m length. Circle the graph that most likely shows the swimmer's motion when swimming.

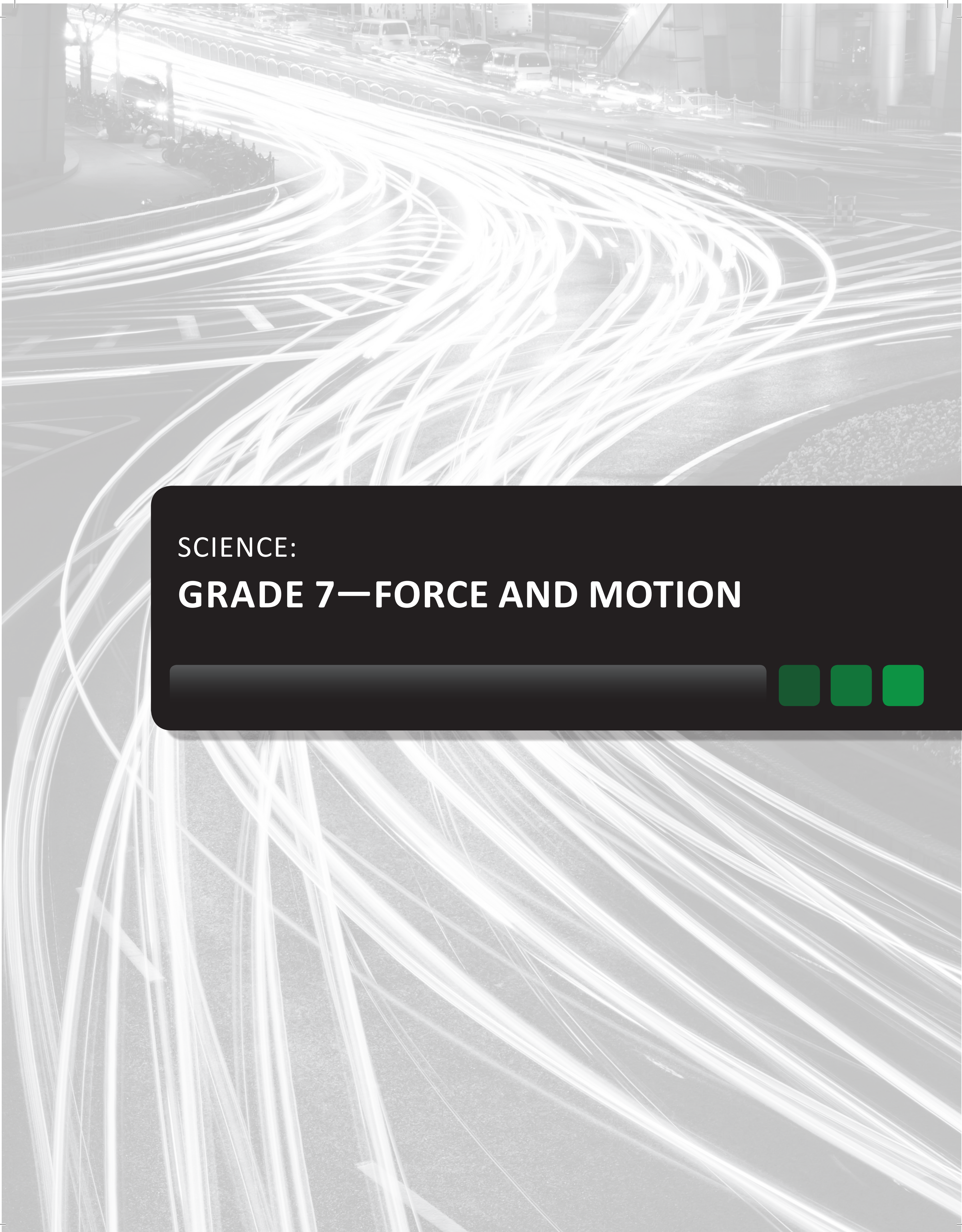






Explain why you chose one graph and why the other two graphs are most likely incorrect.

1207343 5-8 Science Academies_Grade 6.indd 177 4/27/2016 2:45:56 PM



SCIENCE:

GRADE 7—FORCE AND MOTION

Force and Motion

Lesson Outline: Work

Content Objectives

I can describe and calculate work being done on an object.

I can recognize when no work has been done.

Language Objective

I can use the terms distance*,* force*, and* work *to compare the amount of work done on different objects.*

5E Lesson Summary

Engage

Students compare images showing people moving boxes and discuss ideas about who is doing the most work.

Explore

Students measure the amount of force applied to an object and the distance the object moves.

Tier I Support

The four tasks can be set up in advance as stations with the distance already measured and marked at each station. Each student group can carry their load object from one station to the next so that they use the same object for each task.

Explain

Students learn about work as a science concept and analyze the Explore activity to determine work.

Differentiation Strategy

Students who are working on language acquisition may have difficulty understanding that the word *work* has different meanings and uses. Instruct those students to complete an IDEA vocabulary card for the word *work* prior to reading *RM 3* to learn more about students' ideas about the meaning of work. Students can complete a second IDEA vocabulary card during or after the reading to better understand how we use the term *work* in science.

Tier I Support

Students may read independently or with a partner. The reading passage can be recorded in advance so students can hear the words spoken aloud as they read along.

Sentence starters can be used to support productive conversations.

Part One
This part of the Explain focuses on developing the idea of work as a science concept.

Part Two
This part of the Explain focuses on calculating work using the formula, $W = Fd$

Elaborate

Students compare the amount of work done when lifting an object with the amount of work done when moving the object up a ramp.

Part One
This part of the Elaborate focuses on calculating work done with and without a ramp.

Part Two
This part of the Elaborate focuses on applying new ideas about work to the scenarios discussed during the Engage activity.

Evaluate

Students analyze the amount of work done in different scenarios and then rank the items based on the amount of work done.

Tier I Support
Students may work individually, in pairs, or in small groups to work through the Evaluate activity on *RM 6*.

Force and Motion

Notes

SCIENCE:

GRADE 7—FORCE AND MOTION

DOING WORK

GRADE 7

Force and Motion

Doing Work

Science Concept

7(7) Force, motion, and energy. The student knows that there is a relationship among force, motion, and energy. The student is expected to:

(A) contrast situations where work is done with different amounts of force to situations where no work is done such as moving a box with a ramp and without a ramp, or standing still

Content Objectives

I can describe and calculate work being done on an object.

I can recognize when no work has been done.

Science Process Skills

7(2) Scientific investigation and reasoning. The student uses scientific inquiry methods during laboratory and field investigations. The student is expected to:

(A) plan and implement comparative and descriptive investigations by making observations, asking well-defined questions, and using appropriate equipment and technology

(C) collect and record data using the International System of Units (SI) and qualitative means such as labeled drawings, writing, and graphic organizers

(D) construct tables and graphs, using repeated trials and means, to organize data and identify patterns

(E) analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends

Mathematics

6(4) Proportionality. The student applies mathematical process standards to develop an understanding of proportional relationships in problem situations. The student is expected to:

(H) convert units within a measurement system, including the use of proportions and unit rates

7(3) Number and operations. The student applies mathematical process standards to add, subtract, multiply, and divide while solving problems and justifying solutions. The student is expected to:

(A) add, subtract, multiply, and divide rational numbers fluently; and

(B) apply and extend previous understandings of operations to solve problems using addition, subtraction, multiplication, and division of rational numbers.

English Language Arts and Reading

7(2) Reading/Vocabulary Development. Students understand new vocabulary and use it when reading and writing. Students are expected to:

(B) use context (within a sentence and in larger sections of text) to determine or clarify the meaning of unfamiliar or ambiguous words

7(12) Reading/Comprehension of Informational Text/Procedural Texts. Students understand how to glean and use information in procedural texts and documents. Students are expected to:

(A) follow multi-dimensional instructions from text to complete a task, solve a problem, or perform procedures

7(18) Writing/Persuasive Texts. Students write persuasive texts to influence the attitudes or actions of a specific audience on specific issues. Students are expected to write a persuasive essay to the appropriate audience that:

(A) establishes a clear thesis or position

Figure 19

Reading/Comprehension Skills. Students use a flexible range of metacognitive reading skills in both assigned and independent reading to understand an author's message. Students will continue to apply earlier standards with greater depth in increasingly more complex texts as they become self-directed, critical readers. The student is expected to:

(A) establish purposes for reading selected texts based upon own or others' desired outcome to enhance comprehension

(D) make complex inferences about text and use textual evidence to support understanding

GRADE 7

Force and Motion

English Language Proficiency Standards

(3) Cross-curricular second language acquisition/speaking. The ELL speaks in a variety of modes for a variety of purposes with an awareness of different language registers (formal/informal) using vocabulary with increasing fluency and accuracy in language arts and all content areas. ELLs may be at the beginning, intermediate, advanced, or advanced high stage of English language acquisition in speaking. In order for the ELL to meet grade-level learning expectations across the foundation and enrichment curriculum, all instruction delivered in English must be linguistically accommodated (communicated, sequenced, and scaffolded) commensurate with the student's level of English language proficiency. The student is expected to:

(D) speak using grade-level content area vocabulary in context to internalize new English words and build academic language proficiency

(5) Cross-curricular second language acquisition/writing. The ELL writes in a variety of forms with increasing accuracy to effectively address a specific purpose and audience in all content areas. ELLs may be at the beginning, intermediate, advanced, or advanced high stage of English language acquisition in writing. In order for the ELL to meet grade-level learning expectations across foundation and enrichment curriculum, all instruction delivered in English must be linguistically accommodated (communicated, sequenced, and scaffolded) commensurate with the student's level of English language proficiency. For Kindergarten and Grade 1, certain of these student expectations do not apply until the student has reached the stage of generating original written text using a standard writing system. The student is expected to:

(B) write using newly acquired basic vocabulary and content-based grade-level vocabulary

Language Objective

I can use the terms distance, force, *and* work *to compare the amount of work done on different objects.*

Response to Intervention/Tier I Differentiation

All science lessons support students in receiving quality Tier I instruction. Using the 5E model, knowledge is taught in a variety of contexts, integrating math, science, and ELAR content, thus supporting the active engagement of the students with the content. Lesson-specific differentiation strategies for addressing diverse student needs can be found in sections titled "Differentiation Strategy."

Force and Motion

Differentiation should

- focus on skills students did not understand and extend the lesson for advanced students;
- be conducted in small groups or embedded in whole-group instruction; and
- provide students with a variety of strategies to process the information, such as
  - allowing for additional opportunities for verbal brainstorming of words associated with a topic (with teacher taking dictation);
  - making clear connections of new and more complex concepts to foundational aspects and prior knowledge;
  - participating in more tangible experiences, such as experiments, investigations, and active exploration;
  - sorting academic vocabulary words into categories by common attributes, such as process words or science content vocabulary;
  - organizing results of brainstorming into semantic maps or creating graphic organizers;
  - discussing the meaning of a graphic organizer with a partner; and
  - creating a visual representation to demonstrate understanding.

See the handout in the Instructional Resources section that addresses instructional strategies.

College and Career Readiness Standards—Science Standards

I.E.1 Effective communication of scientific information. Use several modes of expression to describe or characterize natural patterns and phenomena. These modes of expression include narrative, numerical, graphical, pictorial, symbolic, and kinesthetic.

II.B.1 Mathematics as a symbolic language. Carry out formal operations using standard algebraic symbols and formulae.

II.B.2 Mathematics as a symbolic language. Represent natural events, processes, and relationships with algebraic expressions and algorithms.

III.B.3 Scientific reading. Recognize scientific and technical vocabulary in the field of study and use this vocabulary to enhance clarity of communication.

III.B.4 Scientific reading. List, use, and give examples of specific strategies before, during, and after reading to improve comprehension.

VIII.D.3 Mechanical energy. Understand the relationship of work and mechanical energy.

Force and Motion

Vocabulary Focus

Joule

load

work

5E Lesson Summary

Engage
Students will compare images showing people moving boxes and discuss ideas about who is doing the most work.

Explore
Students will measure the amount of force applied to an object and the distance the object moves.

Explain
Students will learn about work as a science concept and analyze the Explore activity to determine work.

Elaborate
Students will compare the amount of work done when lifting an object with the amount of work done when moving the object up a ramp.

Evaluate
Students will analyze the amount of work done in different scenarios and then rank the items based on the amount of work done.

Engage

Content Builder

Students are introduced to the concept of work in third grade [3(6)(B)]. In third grade, students should demonstrate and observe work being done on an object when it is pushed or pulled and its position and motion change. In seventh grade, students should be able to calculate the amount of work done on an object and recognize when work is or is not done on an object.

The purpose of the Engage activity is to elicit student ideas about doing work rather than determining the correct answer at this time. Students may respond that Mover 1 does the most work because he or she is using the most force. Students will revisit the Engage scenario after the Elaborate activity to check for understanding. By the end of the lesson, students should understand that no work is done on the box when carrying it because the direction of the force acting on the box is up, but the box is moving forward. Mover 3 does 400 J of work to the 20 kg box when lifting it 2 meters. Mover 2 does 500 J of work to the 25 kg box when he or she pushes it up the 4 m ramp, so Mover 2 does the most work on the box

Materials

For each student

- RM 1
- half-sheet of blank paper

For teacher

- RM 1 to project (optional)

Teacher Note

RM stands for reproducible master.

Teacher Instruction

- Distribute *RM 1: Working Hard or Hardly Working?* to each student or project it to the whole group.
- Ask students to study the three situations and think about who is doing the most work. Students will not record any responses on their copy of *RM 1* at this time.
- Instruct students to describe which mover they think did the most work and explain why on a half-sheet of blank paper. They should not record their names.
- After students have recorded their ideas, instruct students to crumple their half-sheet into a ball and pass or toss the paper balls around the room for 20–30 seconds. Students should pick up paper balls that land near them and continue to pass or toss papers until time is up.

Force and Motion

- When time is up, each student should pick up a paper ball near him or her and read the response.
- Ask all students with responses that describe Mover 1 to move to one area of the room, students with responses that describe Mover 2 to move to a second area of the room, and students with responses that describe Mover 3 to move to a third area of the room.
- Allow 2–3 minutes for each group to discuss the responses on the half-sheets they received.
- Ask each group to share some of the reasons students chose Mover 1, Mover 2, or Mover 3.
- Explain to students that they will be learning more about work as a science concept and that they will revisit the three movers once they have learned more about doing work in science. Do not address the correct answer at this time.

Facilitation Questions

- What do you think it means to do work? *Accept all answers with justification. Students will learn about the concept of work during the Explore and Explain activities.*
- What are some reasons students think Mover 1 does the most work? *Answers will vary.*
- What are some reasons students think Mover 2 does the most work? *Answers will vary.*
- What are some reasons students think Mover 3 does the most work? *Answers will vary*

Explore

Content Builder

During the Explore investigation, students measure the amount of force used to move an object a certain distance. During the Explain activity, students read about work as a science concept. After students have learned how to calculate work, they will revisit the Explore activity to determine how much work was done during each task.

Teacher Note

Each group will need an object that they can push, pull, and lift using a push-pull spring scale. The objects do not have to be large, but they should have enough mass to require at least 3–4 N of force to be moved. An object with a mass of 300–400 grams is ideal if using a 5 N spring scale.

Some objects that can be used:

- Plastic bottle with screw hook in lid and filled with sand or gravel
- Wood block with a hook screwed in one end
- Wood block with string tied tightly around the block
- Hooked masses or slotted mass set
- Small plastic bottle with string tied tightly around the neck of the bottle

Spring scales can become uncalibrated very easily and may need to be adjusted often. To check a spring scale, hold it or suspend it using the hanger. The 0 N line should be at the top of the scale. If the indicator bar lines up with the top of the 0 N line, the scale does not need to be adjusted. If the indicator bar does not line up with the 0 N mark, slowly turn the adjustment knob at the top of the spring scale until the indicator bar lines up with the top of the 0 N line.

Materials

For student groups

- push-pull spring scale
- load object (bottle, block, or other object)
- meter stick or metric measuring tape

For each student

- RM 2

Force and Motion

Advance Preparation

Prepare a small plastic soda bottle or water bottle for each group to use as the load object they will move. Insert a screw hook into the center of the plastic lid of the bottle. Screw hooks (also called screw eyes or eye bolts) can be purchased at a hardware store or at major discount retail stores. Fill each bottle with sand or gravel to get the desired mass. Load objects with a mass of 300–400 grams are ideal if using a 5 N spring scale, but more mass can be used if students will use 10 N spring scales. Attach the lid securely to the bottle. To prevent injuries, a small piece of modeling clay or some hot glue can be applied to the pointed end of the screw hook inside of the bottle cap. Super glue or hot glue may be used to ensure lids are secure.

Teacher Instruction

- Assign students to groups of 2–4.
- Distribute *RM 2: Measuring Forces* to each student and materials to each student group.
- Discuss the term *load* with students. Explain to students that they will need to find the mass of the load object in grams and then convert the mass to kilograms.
- Review the instructions for the Explore activity.
- Demonstrate the proper method for using the hook of the spring scale to lift or pull an object, and then check for understanding by asking students to demonstrate. Repeat the modeling and student demonstration for the proper method for using the push bar of the spring scale to push an object.
- Allow students time to complete the investigation. Monitor students as they work.
- Use the facilitation questions to debrief the activity.

Tier I Support

The four tasks can be set up in advance as stations with the distance already measured and marked at each station. Each student group can carry their load object from one station to the next so that they use the same object for each task.

Force and Motion

Facilitation Questions

- What tool is used to measure force? *A spring scale is used to measure force.*
- What is the SI unit for force? *Force is measured in Newtons (N).*
- What tool is used to measure distance? *A meter stick is used to measure distance.*
- How many centimeters are in a meter? *There are 100 centimeters in 1 meter.*
- How do we convert centimeters to meters? *To convert centimeters to meters, divide the number of centimeters by 100.*
- What is the load in this investigation? *Answers will vary depending on the materials provided. The load is the object being moved.*
- During Task 1, how much force was used to lift the load 0.5 m? *Answers will vary depending on the load object.*
- During Task 1, in what direction was the force acting on the load? *The direction of the force was up.*
- During Task 1, in what direction was the load moving? *The load was moving up.*
- During Task 2, how much force was used to pull the load across the floor or table? *Answers will vary depending on the load object.*
- During Task 2, in what direction was the force acting on the load? *Answers will vary. The direction of the force will usually be represented with an arrow to the right or an arrow to the left.*
- During Task 2, in what direction was the load moving? *Answers will vary. The direction the load moves should be in the same direction as the pulling force.*
- During Task 3, how much force was used to push the load across the floor or table? *Answers will vary depending on the load object.*
- During Task 3, in what direction was the force acting on the load? *Answers will vary. The direction of the force will usually be represented with an arrow to the right or an arrow to the left.*
- During Task 3, in what direction was the load moving? *Answers will vary. The direction the load moves should be the same direction as the pushing force.*

1207343 Science Academies_Lesson 7 .indd 193 4/27/2016 2:54:44 PM

Force and Motion

- During Task 4, how much force was used to carry or suspend the load from the spring scale? *Answers will vary depending on the object.*
- During Task 4, in what direction was the force acting on the load? *The direction of the force is up.*
- During Task 4, in what direction was the load moving? *The load was moving forward or the direction the student walked; the direction the load moves is not in the direction of the force used to hold the load up.*
- Compare the amount of force used for each task. Was the same amount of force applied in each task? Why or why not? *More force is used to lift the load. The amount of force used to pull or push the load should be approximately the same. Less force is needed to pull or push the load because the table is also applying a force to the object.*

RM 2 Answer Key

Answers will vary based on students' measurements.

In science, the term *load* can be used to describe an object that is being moved.

What object are you using as the load for this investigation? *plastic bottle with sand*

Use the spring scale to find the mass of the load in grams and kilograms.
(1 kg = 1,000 g)

mass of load in grams *298 g*
mass of load in kilograms (round to nearest tenth) *0.3 kg*

1207343 Science Academies_Lesson 7 .indd 194 4/27/2016 2:54:45 PM

Force and Motion

Task	Description	Force (N)	Direction of Force	Distance (m)	Direction of Motion
example	*Use the spring scale to pull the load 0.5 m across the floor or table.*	*2 N*	→	*0.5 m*	→
1	Use the spring scale to slowly lift the load 0.5 m from the floor or table.	*3.0 N*	↑	*0.5 m*	↑
2	Use the spring scale to slowly pull the load 1 m across the floor or table.	*0.5 N*	→	*1 m*	→
3	Use the push bar of the spring scale to slowly push the load 1.5 m across the floor or table.	*0.5 N*	←	*1.5 m*	←
4	Use the spring scale to slowly carry the load 2.5 m across the room.	*3.0 N*	↑	*2.5 m*	→

Force and Motion

Materials

For teacher, student groups, or each student

- completed RM 2 from Explore
- RM 3
- RM 4
- access to a glossary or dictionary (optional)

Explain

Teacher Note

Students will use *RM 4: IDEA Vocabulary Card* to create an IDEA vocabulary card for the term *work* as it is used in science. In this context, IDEA stands for illustrate, describe, elaborate, and associate. Creating a nonlinguistic representation of the word helps students process the meaning of the word. The elaboration and association activities help students make connections to the vocabulary term. This strategy can be beneficial before, during, and after reading. If students have access to a glossary or dictionary, have them write out the pronunciation of the word. Writing and practicing the pronunciation helps students with language acquisition.

Students may use the blank IDEA vocabulary card on the first page of *RM 4*, make their own card on a half-sheet of paper or note card, or record in their science notebook. Students may benefit from viewing the IDEA vocabulary cards created by their classmates.

After students have completed the reading and IDEA vocabulary cards, they will revisit the Explore activity and calculate the amount of work done during each task.

Part One

This part of the Explain focuses on developing the idea of work as a science concept.

Teacher Instruction

- Distribute *RM 3: What Is Work?* and *RM 4* to each student.
- Explain to students that they will create an IDEA vocabulary card for the term *work* as they read *RM 3*. Use *RM 4* to demonstrate how to create an IDEA vocabulary card. The IDEA vocabulary card for force can be used as an example.
- Instruct students to read *RM 3* and use *RM 4* to create a vocabulary card for the term *work* as it is used in science.

1207343 Science Academies_Lesson 7 .indd 196 4/27/2016 2:54:45 PM

- After students complete the reading and create their cards, instruct students to move around the room and find a partner. Allow one minute for the students to exchange IDEA vocabulary cards with their partner and then discuss how their cards are similar or different. Sentence starters can be used to support productive conversations. Refer to the Tier I Support section for possible sentence starters.
- After one minute has passed, ask students to thank their partners and find a new partner. Repeat the activity one or two times.
- Use facilitation questions to lead a whole group discussion of the reading passage. Encourage students to share their IDEA vocabulary cards.

Tier I Support

Students who are working on language acquisition may have difficulty understanding that the word *work* has different meanings and uses. Instruct students to complete an IDEA vocabulary card for the word *work* prior to reading *RM 3* to learn more about students' ideas about the meaning of work. Students can complete a second IDEA vocabulary card during or after the reading to better understand how we use the term *work* in science.

Students may read independently or with a partner. If students struggle with reading, the reading passage can be recorded in advance so students can hear the words spoken aloud as they read along.

Sentence starters can be used to support productive conversations. Sentence starters can be posted in the room or saved in students' science notebooks. Some sentence starters to consider include the following:

- I like your idea about . . . because . . .
- I think it is interesting that you chose . . . because . . .
- One thing we did similarly was . . .
- One thing we did differently was . . .
- I agree with . . . because . . .
- I disagree with . . . because . . .

Force and Motion

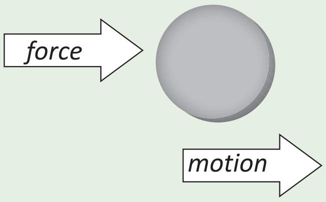
Facilitation Questions

- What are some different ways we use the word *work* outside of science class? *Answers will vary but may include a job or career, making an effort, doing labor, a creation or work of art, or to succeed or function properly.*
- What does it mean to do work in science? *Work is done on an object when a force is applied to the object and the object moves in the direction of the applied force.*
- What did you draw to represent work on your IDEA vocabulary card? *Answers will vary.*
- What did you write to describe work on your IDEA vocabulary card? *Answers will vary.*
- How did you elaborate on work on your IDEA vocabulary card? *Answers will vary.*
- How did you associate work with something you know, have read, or have seen? *Answers will vary.*
- Is work done every time a force is applied to an object? *No; work is done only if the object moves in the direction of an applied force. If the object doesn't move, no work is done.*
- What is an example of work being done on an object? *Answers will vary. Examples from the reading passage include a girl pulling a wagon, a man lifting a box, and a woman pushing a stroller.*
- The delivery man did work on the box when he lifted it, but he did not do work on the box while he was carrying it. Why not? *Work is only done on an object when a force is applied to the object and the object moves in the direction of the applied force. He applies an upward force on the box, but the box isn't moving up while he carries it. It is moving forward.*
- How can we calculate work? *Work equals force times distance (W = Fd).*
- What is the SI unit for work? *Joules (J)*
- How are work and energy related? *Energy is the ability to do work. When work is done on an object, energy is transferred from one object to another.*

Force and Motion

RM 4 Answer Key

Answers will vary.

Vocabulary Term:	*work*		
I **Illustrate**	**D** **Describe**	**E** **Elaborate**	**A** **Associate**
	*wərk* *Work is done when a force applied to an object makes the object move in the direction of the force.*	Examples • *lifting* • *pushing* • *pulling* Nonexamples • *carrying* • *force without motion*	*When I push my brother in his stroller, I am doing work on the stroller.*

Part Two

This part of the Explain focuses on calculating work using the formula $W = Fd$.

Teacher Instruction

- Instruct students to draw another column on the right side of the table in *RM 2* completed during the Explore activity. They will use this space to calculate the work done on the load during each task.
- Instruct student groups to discuss each task done during the Explore activity and to calculate work done during each task. The example task can be used as a model. In the example, 2 N of force to the right is used to pull a load 0.5 m. The load is moving in the same direction as the force, so work is being done. The work done on the load equals 2 N times 0.5 m, or 1 J of work.

Task	Description	Force (N)	Direction of Force	Distance (m)	Direction of Motion	Work (J)
example	*Use the spring scale to pull the load 0.5 m across the floor or table.*	*2 N*	→	*0.5 m*	→	*W = Fd* *W = 2 N • 0.5 m* ***W = 1 J***

Force and Motion

- Allow students time to work.
- Use facilitation questions to discuss the work done during each task in the Explore activity. While debriefing the activity, ask student volunteers to show how they calculated work for each task.

Facilitation Questions

- How much work was done in Task 1? Task 2? Task 3? *Answers will vary based on measurements. A sample key is provided below.*
- How much work was done in Task 4? *No work was done in Task 4. The load does not move in the direction of the applied force.*

RM 2 Answer Key with Work (J)

Answers will vary based on students' measurements. If students record distance in centimeters, they must convert the distance to meters before calculating work in Joules.

Task	Description	Force (N)	Direction of Force	Distance (m)	Direction of Motion	Work (J)
example	*Use the spring scale to pull the load 0.5 m across the floor or table.*	*2 N*	→	*0.5 m*	→	*W = Fd* *W = 2 N • 0.5 m* *W = **1 J***
1	Use the spring scale to slowly lift the load 0.5 m from the floor or table.	*3.0 N*	↑	*0.5 m*	↑	*W = Fd* *W = 3 N • 0.5 m* *W = **1.5 J***
2	Use the spring scale to slowly pull the load 1 m across the floor or table.	*0.5 N*	→	*1 m*	→	*W = Fd* *W = 0.5 N • 1 m* *W = **0.5 J***
3	Use the push bar of the spring scale to slowly push the load 1.5 m across the floor or table.	*0.5 N*	←	*1.5 m*	←	*W = Fd* *W = 0.5 N • 1.5 m* *W = **0.75 J***
4	Use the spring scale to slowly carry the load 2.5 m across the room.	*3.0 N*	↑	*2.5 m*	→	*No work is done because motion is not in the direction of the force.*

Elaborate

Content Builder

In sixth grade, students “investigate how inclined planes and pulleys can be used to change the amount of force to move an object” [6(8)(E)]. The goal of the Elaborate activity is for students to compare the amount of work done using different inclined planes. Students should find that although a shorter, steeper inclined plane requires more force to move the load than a longer inclined plane with a gradual slope, approximately the same amount of work is done on the load.

Forces are always working on objects on Earth. The force of gravity is always pulling objects toward Earth. Friction acts on all moving objects in the direction opposite of motion. The force applied to an object must overcome the forces of gravity and friction to cause the object to move. In this investigation there is negligible friction when lifting the load. However, there is friction between the moving load and the surface of the inclined plane. For this reason, students are likely to do more work when using an inclined plane than when lifting the load straight up.

Work is measured in Joules, and one Joule is equal to one Newton • one meter. To calculate work in Joules, force must be measured in Newtons and distance must be measured in meters. If students measure distance in centimeters, they should convert centimeters to meters before calculating work. To convert centimeters to meters, divide the number of centimeters by 100. (1 m = 100 cm)

After students complete the Elaborate activity, they will revisit *RM 1* from the Engage activity and apply what they have learned about work.

Teacher Note

For this activity, the load object is moved to the top of a box by lifting the load object and by pulling the object up two different inclined planes. Students measure the force applied to the load object and the distance the load moves. Measurements are used to calculate the amount of work done on the object.

Materials

For student groups

- push-pull spring scale
- metric ruler, meter stick, or metric measuring tape
- load object that can be attached to spring scale
- two different lengths of cardboard or foam board to make inclined planes
- empty cardboard box or plastic crate

For each student

- RM 1
- RM 5

Force and Motion

Empty paper boxes or plastic storage crates are an ideal size for this activity. Sturdy cardboard or foam board strips can be used as inclined planes. Foam board can be purchased at craft stores. Another option is to provide one rectangular piece of cardboard or foam board to student groups. Students can use the shorter side of the rectangle for Task 2 and the longer side of the rectangle for Task 3.

Advance Preparation

Each group will need two different inclined planes for the Elaborate activity. Sturdy cardboard or foam board can be used to make the inclined planes. The inclined planes do not need to be the width of the box but should be wide enough for students to push or pull the load up the surface of the ramp. One inclined plane should be at least 10 cm longer than the other inclined plane.

Part One

This part of the Elaborate focuses on calculating work done with and without a ramp.

Teacher Instruction

- Assign students to groups of 2–4.
- Distribute *RM 5: Ramping Up the Work* to each student.
- Explain to students that they will calculate and compare the amount of work done to the load as it is moved to the top of a box using three different methods. They will lift the load straight up to the top of the box and move it to the top of the box using two different inclined planes or ramps. Model the three tasks for the class.
- Instruct students to predict which task will require the most work: lifting the load straight up, moving it up a steep inclined plane, or moving it up a gradual inclined plane. Students should record predictions on their student sheets.
- Distribute materials to each group. Remind students to measure force in Newtons and distance in meters. If students measure distance in centimeters, they will need to convert the measurement to meters before they calculate work.
- Allow 15–25 minutes for students to complete the activity.
- Debrief the activity using the facilitation questions.

Force and Motion

Facilitation Questions

- How did your results compare with your prediction? *Answers will vary.*
- Compare the amount of work done in the three tasks. *The least work is done on the load when lifting it straight up during Task 1, but more force was used. More work is done on the object when using the inclined planes in Tasks 2 and 3. Approximately the same amount of work is done with both inclined planes.*
- How does Task 2 compare with Task 3? *Approximately the same amount of work is done in Task 2 and Task 3. More force is applied to the load in Task 2, but it is applied over a shorter distance. Less force is applied to the load in Task 3, but it is applied over a greater distance.*
- How does the use of an inclined plane affect the amount of force and distance? *The inclined plane allows you to use less force over a longer distance.*
- During each task, the load is moved from the table to the top of the box. One might expect the same amount of work to be done in each task, but we found less work was done in Task 1, lifting the load straight up. What are some possible reasons less work is done in Task 1 and more work is done in Tasks 2 and 3? *Possible reasons more work is done when using inclined planes include friction between the load and the surface of the inclined planes and variation in rounding measurements and calculations.*

RM 5 Answer Key

Answers will vary based on students' measurements.

Predict

Is more work done when you lift an object straight up; pull the object up a short, steep inclined plane (ramp); or pull the object up a long, gradual inclined plane (ramp)? Explain your reasoning. *Answers will vary.*

What object are you using as the load for this investigation? *plastic bottle with sand*

Use the spring scale to find the mass of the load in grams and kilograms. (1 kg = 1,000 g)

mass of load in grams *298 g*
mass of load in kilograms (round to nearest tenth) *0.3 kg*

GRADE 7

Force and Motion

Task 1

Applied Force (N)	Direction of Force	Distance (m)	Direction of Motion	Work (J) *W = F • d*
3.0 N	↑	*.26 m*	↑	*W = 3.0 N • 0.26 m* *W =* ***0.8 J***

Task 2

Applied Force (N)	Direction of Force	Distance (m)	Direction of Motion	Work (J) *W = F • d*
2.8 N	↖	*.38 m*	↖	*W = 2.8 N • 0.38 m* *W =* ***1.1 J***

Task 3

Applied Force (N)	Direction of Force	Distance (m)	Direction of Motion	Work (J) *W = F • d*
2.2 N	↖	*.50 m*	↖	*W = 2.2 N • 0.50 m* *W =* ***1.1 J***

Analysis

1. Compare the amount of work done in the three tasks. *The least work is done on the load when lifting it straight up, but more force was used. More work is done on the object when using the inclined planes. Approximately the same amount of work is done with both inclined planes.*
2. Was your prediction accurate? Why or why not? *Answers will vary.*
3. Compare Task 2 and Task 3. How does the use of an inclined plane affect work, force, and distance?
   Approximately the same amount of work is done in Tasks 2 and 3. More force is applied in Task 2 over a shorter distance. Less force is applied in Task 3 over a longer distance.
4. Approximately the same amount of work should be done on the load in Task 2 and Task 3. Did you calculate the same amount of work in Tasks 2 and 3? What factors may contribute to any differences in the results?
   Friction between the load object and the different inclined planes may result in slight variations in the results.

1207343 Science Academies_Lesson 7 .indd 204 4/27/2016 2:54:46 PM

Force and Motion

Part Two

This part of the Elaborate focuses on applying new ideas about work to the scenarios discussed during the Engage activity.

Teacher Instruction

- Distribute a copy of *RM 1* from the Engage activity to each student, or instruct students to refer to the copies received during the Engage activity.
- Instruct students to calculate the amount of work done by each mover and determine who did the most work.
- After students have completed *RM 1*, ask students who think Mover 1 did the most work on the box to move to one area of the room, Mover 2 to a second area, and Mover 3 to the third area.
- If all students select Mover 2, debrief the activity using the facilitation questions.
- If some students still select Mover 1 or Mover 3, instruct each group to explain why they think the mover they chose does the most work on the box. After each group explains their thinking, allow students to move to a different group if their ideas have changed.

Facilitation Questions

- Who did the most work on the box? How do you know? *Mover 2 did the most work on the box. Mover 1 did not do work on the box. Mover 2 applied less force than Mover 3 but over a greater distance.*
- How much work did Mover 1 do on the box? *Mover 1 didn't do any work on the box while the box is carried. The force applied to the box was upward, but the box did not move up. The box moved toward the truck. If Mover 1 lifted the box before carrying it to the truck, work was done on the box when it was lifted. Once the box was carried and moved horizontally, work was no longer done on the box.*
- How much work did Mover 2 do on the box? *500 N*
- How much work did Mover 3 do on the box? *400 N*

RM 1 Answer Key

Which mover did the most work? Explain your reasoning.

Mover 2 did the most work. Mover 1 did not do work on the box. Mover 2 applied less force than Mover 3 but over a greater distance.

Force and Motion

Mover 1

Force = 250 N up   distance = 10 m toward the truck

No work was done on the box because the box didn't move in the direction of the force.

Mover 2

Force = 125 N up the ramp   distance = 4 m up the ramp

W = Fd

W = 125 • 4

*W = **500 J***

Mover 3

Force = 200 N straight up   distance = 2 m straight up

W = Fd

W = 200 • 2

*W = **400 J***

GRADE 7

Evaluate

Teacher Instruction

- Distribute *RM 6: Evaluate* to each student.
- Determine how students will work through the Evaluate activity.
- Instruct students to use their knowledge of work, force, and distance to complete *RM 6*.

Materials

For each student

- RM 6

Tier I Support

Students may work individually, in pairs, or in small groups to work through the Evaluate activity on *RM 6*.

RM 6 Answer Key

1.

Student	Description	Work (J) *W = Fd*
Aiden	My brother used 150 N of force to pull a wagon of soil 12 m from our truck to the garden.	*F = 150 N d = 12 m* *W = 150 • 12* *W =* ***1,800 J***
Jessica	My dad used 65 N of force to carry my baby sister 5 m from the front door to the car.	*F = 65 N d = 5 m* *No work is done because the baby is not moving in the direction of the force.*
Robert	I used 130 N to lift the end of the sofa 0.5 meters so my dad could vacuum under it.	*F = 130 N d = 0.5 m* *W = 130 • 0.5* *W =* ***65 J***
Katelyn	My mom used 210 N of force to push a lawn mower 9 meters across our backyard.	*F = 210 N d = 9 m* *W = 210 • 9* *W =* ***1,890 J***

Force and Motion

2. Who did the most work? Rank the student's examples from least work done to most work done. *Jessica, Robert, Aiden, Katelyn*

3. A school district is planning to build a new middle school. Which design would you recommend to the principal? Explain your reasoning.
   Design 3 would allow people to use the least force to get to the front entrance of the school. Inclined planes can be used to do the same amount of work, such as getting to a higher elevation. However, an inclined plane will allow you to use less force to do the work over a longer distance. As the distance increases, the amount of force needed decreases. Design 3 has the longest ramp (11 m), so it would require the least force to move the same load to the height of the school entrance.

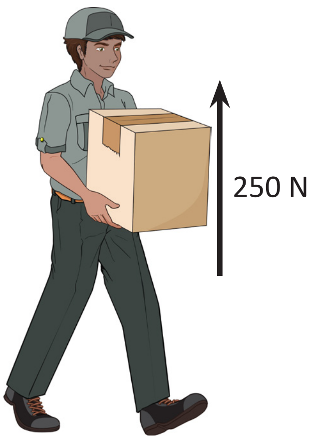
Force and Motion

RM 1: Working Hard or Hardly Working?

A group of college students started their own moving company. They help other college students move in and out of residence halls and apartments around the college campus.

Study the three situations below. Each person is moving a box.

Mover 1



A mover uses 250 N of force to carry a 25 kg box 10 m to the truck.

Mover 2

A mover uses 125 N of force to push a 25 kg box up a 4 m ramp to the bed of the truck.

Mover 3

A mover uses 200 N of force to lift a 20 kg box 2 m to the bed of the truck.

Which mover is doing the most work? Explain your reasoning.

Force and Motiony

RM 2: Measuring Forces

Materials

- push-pull spring scale
- load object (bottle, block, or other object)
- meter stick or metric measuring tape

Procedure

In science, the term *load* can be used to describe an object that is being moved.

What object are you using as the load for this investigation? ______________________________

Use the spring scale to find the mass of the load in grams and kilograms. (1 kg = 1,000 g)

mass of load in grams ______ mass of load in kilograms (round to nearest tenth) _______

For each of the tasks described in the table below, you will use a push-pull spring scale to slowly move the load object. For each task, you will

- measure and record the force in Newtons (N) that is applied to the load while it is moving,
- draw an arrow to represent the direction of the force,
- measure and record the distance the load is moved in meters (m), and
- draw an arrow to represent the direction the load is moved.

An example is provided in the table.

Task	Description	Force (N)	Direction of Force	Distance (m)	Direction of Motion
example	*Use the spring scale to pull the load 0.5 m across the floor or table.*	*2.0 N*	→	*0.5 m*	→
1	Use the spring scale to slowly lift the load 0.5 m from the floor or table.				
2	Use the spring scale to slowly pull the load 1 m across the floor or table.				
3	Use the push bar of the spring scale to slowly push the load 1.5 m across the floor or table.				
4	Use the spring scale to slowly carry the load 2.5 m across the room.				

1207343 Science Academies_Lesson 7 .indd 211 4/27/2016 2:54:47 PM

What Is Work?

WHAT DO YOU THINK ABOUT WHEN YOU SEE OR HEAR THE WORD *WORK*?

We use the word *work* in many different ways.

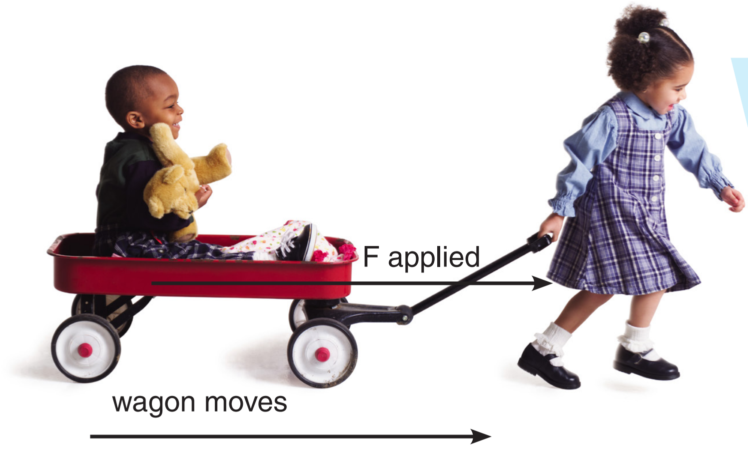
- Sometimes we say we are doing work when we are doing an activity that requires physical or mental effort. “Chopping wood is hard work.”
- Work might be used to describe your job or place of employment. “I am on my way to work.”
- Work can be used to describe how something functions. “This computer does not work.”
- Something done or made can be called a work. “I really like that work of art.”

In science, work has a specific meaning that is different from the other ways we use this term.

TEA Texas Education Agency

DOING WORK

When a force is applied to an object, and the object moves in the direction of that force, **work** has been done on the object. Let's look at some examples:

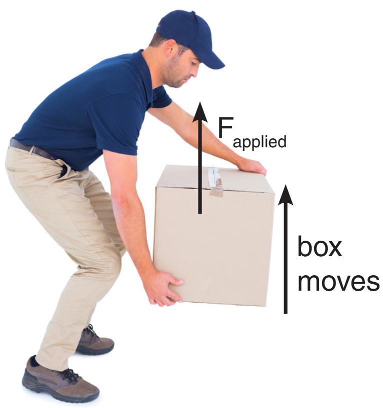


A girl pulls her brother in a wagon. Is work done on the wagon?

The girl is doing work on the wagon because she applies a force to the wagon, and the wagon moves in the direction of the force.

A woman pushes on a van, but the van does not move. Is work done on the van?

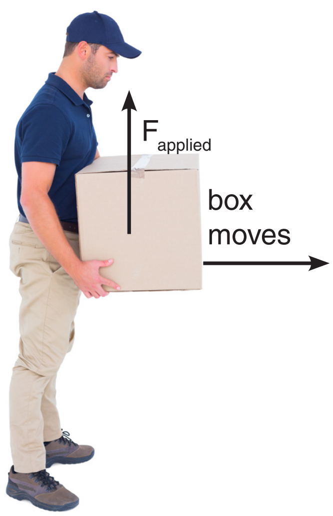
Work is not done on the van because the woman applies a force to the van, but the van does not move. Work is only done on an object when it moves in the direction of an applied force.



A delivery man picks up a package and carries it to the front door of a house. Is work done on the box?

This one is tricky! Work is only done when an object moves in the direction of an applied force.

Work is done on the box when the delivery man lifts it because he applies an upward force on the box, and the box moves upward. No work is done on the box while the man is carrying it. He applies an upward force to the box to hold the box in place, but the box is not moving upward. The man and the box are both moving forward. Since the motion of the box is not in the same direction as the force applied to the box, no work is done on the box.



CALCULATING WORK

The amount of work done on an object can be calculated by multiplying the force applied to the object times the distance the object moves *in the direction of the force*. The formula for work is Work = Force x distance.

$$W = Fd$$

Work is measured in a unit called a Joule (J). One Joule of work is done when one Netwon (N) of force is applied to an object and the object moves a distance of one meter (m).

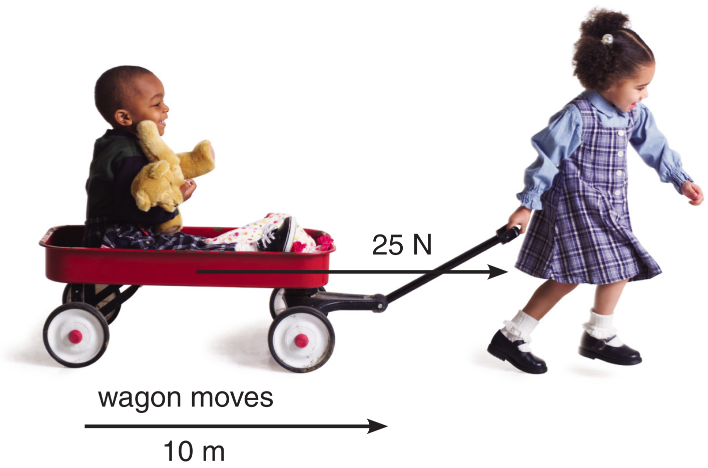
$$1\ J = 1\ N \bullet 1\ m$$

Because one Joule equals one Newton • one meter, remember to measure the distance in meters when calculating work.

Let's practice:

EXAMPLE 1

A girl takes her brother for a ride in a wagon. She applies 25 N of force to the wagon, and pulls the wagon a distance of 10 meters. How much work is done on the wagon?



$W = Fd$

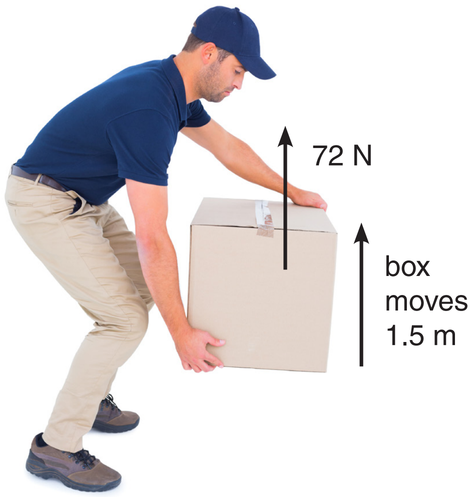
Force = 25 N   distance = 10 m

$W = 25 \bullet 10$

$W = \underline{\textbf{250 J}}$

EXAMPLE 2

A delivery man uses 72 N of force to lift a box 1.5 m. How much work is done on the box?



$W = Fd$

Force = 72 N   distance = 1.5 m

W = 72 • 1.5

W = **108 J**

WORK AND ENERGY

It takes energy to do work. In fact, in science, energy is defined as the ability to do work. Like work, energy can be measured in Joules. An object with 20 J of energy has the ability to do 20 J of work on another object. When work is done, energy is transferred from one object to another.

SUMMARY

- When a force is applied to an object and causes the object to move in the direction of the force, work is done on the object.
- When work is done on an object, energy is transferred to that object.
- Work can be calculated in Joules using the formula $W = Fd$.

Force and Motion

RM 4: IDEA Vocabulary Card

IDEA Vocabulary Card Instructions

Vocabulary Term:			
I Illustrate	D Describe	E Elaborate	A Associate
Draw a picture or symbol to represent the word.	Write a brief description or definition of the word. If a glossary or dictionary is available, write the pronunciation of the word.	List or create one of the following elaborations: • Examples • Nonexamples • Synonyms • Antonyms • Characteristics • Simile • Metaphor • Analogy	How does this word relate to something you know, have read, or have seen? Write a sentence describing how this word is relevant to you.

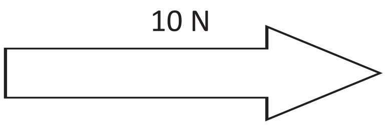
IDEA Vocabulary Card

Vocabulary Term:			
I Illustrate	D Describe	E Elaborate	A Associate

Force and Motion

RM 4 continued

IDEA Vocabulary Card Example

Vocabulary Term:	**Force**		
I **Illustrate**	**D** **Describe**	**E** **Elaborate**	**A** **Associate**
	fôrs an interaction, such as a push or a pull, that causes a change in motion	Examples • push • pull • gravity • friction	When I stand on the sand at the beach, the force of my weight makes a footprint in the sand.

Force and Motion

RM 5: Ramping Up the Work

The goal of this investigation is to determine the amount of work done on the load when it is moved straight up from the table to the top of the box and the amount of work done on the load when it is pushed or pulled up different inclined planes.

Materials

- push-pull spring scale
- metric ruler, meter stick, or metric measuring tape
- load object that can be attached to spring scale
- two different lengths of cardboard or foam board to make inclined planes
- empty cardboard box or plastic crate

Predict

Is more work done when you lift an object straight up; pull the object up a short, steep inclined plane (ramp); or pull the object up a long, gradual inclined plane (ramp)? Explain your reasoning.

Procedure

What object are you using as the load for this investigation? ________________________________

Use the spring scale to find the mass of the load in grams and kilograms.(1 kg = 1,000 g)

mass of load in grams _______ mass of load in kilograms (round to nearest tenth) ________

Task 1

- Measure the force applied to the load as it is lifted from the table to the top of the box. (Read the spring scale while the object is moving.)
- Measure the distance from the bottom of the table to the top of the box to the nearest hundredth of a meter.
- Calculate the amount of work done on the load. Round your answer to the nearest tenth of a Joule.

Applied Force (N)	Direction of Force	Distance (m)	Direction of Motion	Work (J) $W = F \cdot d$

1207343 Science Academies_Lesson 7 .indd 221 4/27/2016 2:54:49 PM

Force and Motion

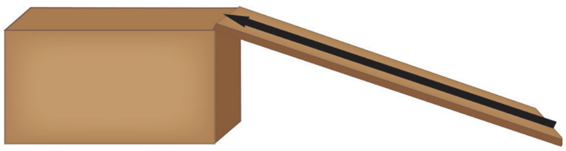
RM 5 continued

Task 2

- Use the shorter piece of cardboard or foam board to create a steep inclined plane from the table to the top of the box.
- Measure the force applied to the load as it is pulled slowly up the short, steep inclined plane from the table to the top of the box. Be sure to keep the spring scale in line with the load while pulling it up the inclined plane. (Read the spring scale while the object is moving.)
- Measure the distance from the bottom of the inclined plane to the top of the inclined plane to the nearest hundredth of a meter.
- Calculate the amount of work done on the load. Round your answer to the nearest tenth of a Joule.

Applied Force (N)	Direction of Force	Distance (m)	Direction of Motion	Work (J) $W = F \cdot d$

Task 3



- Use the longer piece of the cardboard or foam board to create a gradual inclined plane from the table to the top of the box.
- Measure the force applied to the load as it is pulled slowly up the long, gradual inclined plane from the table to the top of the box. Be sure to keep the spring scale in line with the load while pulling it up the inclined plane. (Read the spring scale while the object is moving.)
- Measure the distance from the bottom of the inclined plane to the top of the inclined plane to the nearest hundredth of a meter.
- Calculate the amount of work done on the load. Round your answer to the nearest tenth of a Joule.

Applied Force (N)	Direction of Force	Distance (m)	Direction of Motion	Work (J) $W = F \cdot d$

TEA Texas Education Agency

1207343 Science Academies_Lesson 7 .indd 223 4/27/2016 2:54:50 PM

Force and Motion

RM 5 continued

Analysis

1. Compare the amount of work done in the three tasks.

2. Was your prediction accurate? Why or why not?

3. Compare Task 2 and Task 3. How does the use of an inclined plane affect work, force, and distance?

4. Approximately the same amount of work should be done on the load in Task 2 and Task 3. Did you calculate the same amount of work in Tasks 2 and 3? What factors may contribute to any differences in the results?

Force and Motion

RM 6: Evaluate

1. Students in a science class were given a homework assignment to describe an example of work being done on objects in everyday life. The responses of four students are described in the table below. Determine the amount of work done in each student's example

Student	Description	Work (J) *W = Fd*
Aiden	My brother used 150 N of force to pull a wagon of soil 12 m from our truck to the garden.	
Jessica	My dad used 65 N of force to carry my baby sister 5 m from the front door to the car.	
Robert	I used 130 N to lift the end of the sofa 0.5 meters so my dad could vacuum under it.	
Katelyn	My mom used 210 N of force to push a lawn mower 9 meters across our backyard.	

2. Who did the most work? Rank the student's examples from least work done to most work done.

Force and Motion

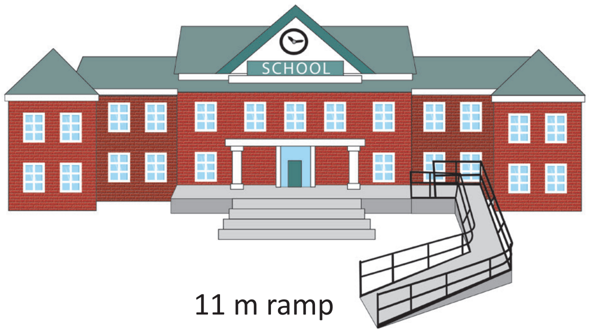
RM 6 continued

3. A school district is planning to build a new middle school. The entrance of the school is elevated, so there is a large set of stairs at the front entrance. Because there are stairs at the front entrance, the building will also need to have a ramp. The architect working with the district has submitted three design plans that are shown below.

Design A

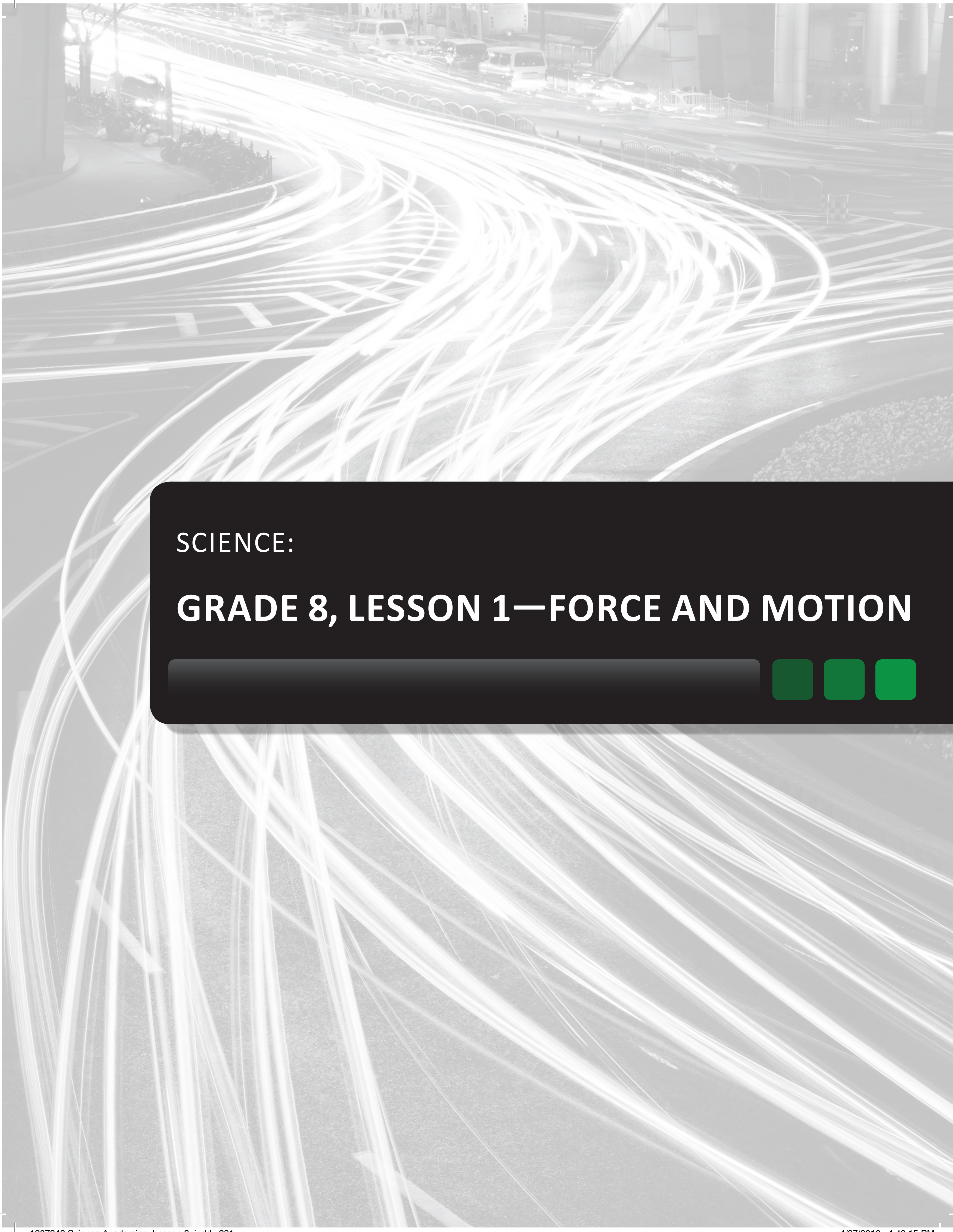
Design B

Design C



People who will use the ramps include people who use canes, walkers, and wheelchairs as well as people moving carts of supplies and materials in and out of the building. The principal wants to choose the ramp that will require the least amount of force.

Which design would you recommend to the principal? Explain your reasoning.



SCIENCE:

GRADE 8, LESSON 1—FORCE AND MOTION

GRADE 8, LESSON 1

Force and Motion

Lesson Outline: Balanced and Unbalanced Forces

Content Objectives

I can calculate the net force acting on an object.

I can describe how the motion of the object changes as a result of a force.

I can identify and describe examples of speed, velocity, and acceleration.

I can explain the differences between speed, velocity, and acceleration.

Language Objective

I will read about force and motion using Interactive Notation System for Effective Reading and Thinking (INSERT) symbols.

5E Lesson Summary

Engage

Students sort cards to differentiate speed and velocity.

Tier I Support

Students can work independently, with a partner, or in a small group.

Teacher Note and Differentiation Strategy

If students struggle to differentiate between speed and velocity during the Engage activity, it may indicate that students do not understand the difference between distance and displacement. Part Two is provided as an optional activity to strengthen students' knowledge of distance and displacement.

Part One

This part of Engage focuses on comparing and contrasting speed and velocity.

Part Two

This part of Engage focuses on using movement to compare distance and displacement.

Explore

Students explore different ways to change the speed and direction of a moving object.

Differentiation Strategy

If students are overwhelmed when selecting materials, provide a limited selection or specific set of materials for each investigation.

Force and Motion

Explain

Students establish that a force is needed to change the speed or direction of an object and calculate net force.

Tier I Support

Students can work independently or with a partner. The reading passage may be chunked into smaller sections. Assign the sections about speed, velocity, and acceleration, and then stop to debrief before students move on to the sections about the different types of forces.

Allow students to use materials such as blocks or balls to model the forces in each scenario described in *RM 5*.

Part One

This part of Explain focuses on establishing the idea that a net force results in a change in velocity (speed or direction).

Part Two

This part of Explain focuses on calculating net force.

Elaborate

Students use fan carts to explore how balanced and unbalanced forces affect the motion of an object.

Evaluate

Students analyze scenarios and describe how balanced and unbalanced forces affect the motion of various objects.

Tier I Support

Students can work independently, with a partner, or with a small group.

GRADE 8, LESSON 1

Force and Motion

Notes

SCIENCE:

GRADE 8, LESSON 1—FORCE AND MOTION

Balanced and Unbalanced Forces

Force and Motion

Balanced and Unbalanced Forces

Science Concept

8(6) Force, motion, and energy. The student knows that there is a relationship between force, motion, and energy. The student is expected to:

(A) demonstrate and calculate how unbalanced forces change the speed or direction of an object's motion

(B) differentiate between speed, velocity, and acceleration

Content Objectives

I can calculate the net force acting on an object.

I can describe how the motion of the object changes as a result of a force.

I can identify and describe examples of speed, velocity, and acceleration.

I can explain the differences between speed, velocity, and acceleration.

Science Process Skills

8(2) Scientific investigation and reasoning. The student uses scientific inquiry methods during laboratory and field investigations. The student is expected to:

(A) plan and implement comparative and descriptive investigations by making observations, asking well-defined questions, and using appropriate equipment and technology;

(B) design and implement comparative and experimental investigations by making observations, asking well-defined questions, formulating testable hypotheses, and using appropriate equipment and technology;

(C) collect and record data using the International System of Units (SI) and qualitative means such as labeled drawings, writing, and graphic organizers;

(D) construct tables and graphs, using repeated trials and means, to organize data and identify patterns; and

(E) analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends.

Force and Motion

English Language Arts and Reading

7(12) Reading/Comprehension of Informational Text/Procedural Texts. Students understand how to glean and use information in procedural texts and documents. Students are expected to:

(A) follow multi-dimensional instructions from text to complete a task, solve a problem, or perform procedures

Figure 19

Reading/Comprehension Skills. Students use a flexible range of metacognitive reading skills in both assigned and independent reading to understand an author's message. Students will continue to apply earlier standards with greater depth in increasingly more complex texts as they become self-directed, critical readers. The student is expected to:

(A) establish purposes for reading selected texts based upon own or others' desired outcome to enhance comprehension

(C) reflect on understanding to monitor comprehension (e.g., summarizing and synthesizing; making textual, personal, and world connections; creating sensory images)

(D) make complex inferences about text and use textual evidence to support understanding

Force and Motion

English Language Proficiency Standards

(4) Cross-curricular second language acquisition/reading. The ELL reads a variety of texts for a variety of purposes with an increasing level of comprehension in all content areas. ELLs may be at the beginning, intermediate, advanced, or advanced high stage of English language acquisition in reading. In order for the ELL to meet grade-level learning expectations across the foundation and enrichment curriculum, all instruction delivered in English must be linguistically accommodated (communicated, sequenced, and scaffolded) commensurate with the student's level of English language proficiency. For Kindergarten and Grade 1, certain of these student expectations apply to text read aloud for students not yet at the stage of decoding written text. The student is expected to:

(F) use visual and contextual support and support from peers and teachers to read grade-appropriate content area text, enhance and confirm understanding, and develop vocabulary, grasp of language structures, and background knowledge needed to comprehend increasingly challenging language

Language Objective

I will read about force and motion using Interactive Notation System for Effective Reading and Thinking (INSERT) symbols.

Response to Intervention/Tier I Differentiation

All science lessons support students in receiving quality Tier I instruction. Using the 5E model, knowledge is taught in a variety of contexts, integrating math, science, and ELAR content, thus supporting the active engagement of the students with the content. Lesson-specific differentiation strategies for addressing diverse student needs can be found in sections titled "Differentiation Strategy."

TEA
Texas Education Agency

Force and Motion

Differentiation should

- focus on skills students did not understand and extend the lesson for advanced students;
- be conducted in small groups or embedded in whole-group instruction; and
- provide students with a variety of strategies to process the information, such as
  - allowing for additional opportunities for verbal brainstorming of words associated with a topic (with teacher taking dictation);
  - making clear connections of new and more complex concepts to foundational aspects and prior knowledge;
  - participating in more tangible experiences, such as experiments, investigations, and active exploration;
  - sorting academic vocabulary words into categories by common attributes, such as process words or science content vocabulary;
  - organizing results of brainstorming into semantic maps or creating graphic organizers;
  - discussing the meaning of a graphic organizer with a partner; and
  - creating a visual representation to demonstrate understanding.

See the handout in the Instructional Resources section that addresses instructional strategies.

College and Career Readiness Standards—Science Standards

I.E.1 Effective communication of scientific information. Use several modes of expression to describe or characterize natural patterns and phenomena. These modes of expression include narrative, numerical, graphical, pictorial, symbolic, and kinesthetic.

II.B.1 Mathematics as a symbolic language. Carry out formal operations using standard algebraic symbols and formulae.

II.B.2 Mathematics as a symbolic language. Represent natural events, processes, and relationships with algebraic expressions and algorithms.

III.B.3 Scientific reading. Recognize scientific and technical vocabulary in the field of study and use this vocabulary to enhance clarity of communication.

III.B.4 Scientific reading. List, use, and give examples of specific strategies before, during, and after reading to improve comprehension.

VIII.B.1 Vectors. Understand how vectors are used to represent physical quantities.

VIII.C.2 Forces and motion. Understand forces and Newton's Laws.

1207343 Science Academies_Lesson 8 .indd 239 4/27/2016 4:48:16 PM

Force and Motion

Vocabulary Focus

acceleration

balanced forces

net force

speed

velocity

unbalanced forces

5E Lesson Summary

Engage
Students sort cards to differentiate speed and velocity.

Explore
Students explore different ways to change the speed of a stationary object, change the speed of a moving object, and change the direction of a moving object.

Explain
Students establish that a force is needed to change the speed or direction of an object and calculate net force.

Elaborate
Students use fan carts to explore how balanced and unbalanced forces affect the motion of an object.

Evaluate
Students analyze scenarios and describe how balanced and unbalanced forces affect the motion of various objects.

1207343 Science Academies_Lesson 8 .indd 240 4/27/2016 4:48:16 PM

Force and Motion

Engage

Content Builder

The goal of Engage is to help students understand the difference between speed and velocity. It is important that students understand how velocity is different from speed. If students have incorrect ideas about velocity, they may also develop incorrect ideas about acceleration.

Speed is a scalar quantity, meaning it is described by a number (magnitude). Speed can be calculated by dividing the total distance traveled by total time. Velocity is a vector quantity, meaning it is described by a number (magnitude) and a direction. We can define velocity as the change in position (displacement) over time. Part Two of Engage is designed to help students understand the difference between distance and displacement and support correct ideas about speed and velocity.

Outside of science, the term *acceleration* is usually used to describe something that is speeding up. In science, the term *acceleration* is used to describe any change in velocity. Because velocity has a speed (magnitude) and a direction, any change in speed or change in direction is considered an acceleration.

Materials

For student groups

- RM 1
- 2 pieces of yarn or string, one 3’ in length and one 5’ in length

Teacher Note

RM stands for reproducible master.

During Part One, yarn or string is used to create a graphic organizer on the student work surface. Consider the following alternative methods:

- Use chalk to draw the graphic organizer on lab tables or on a concrete surface
- Draw the graphic organizer on chart paper or bulletin paper

If students struggle to differentiate between speed and velocity during the Engage activity, it may indicate that students do not understand the difference between distance and displacement. Part Two is provided as an optional activity to strengthen students’ knowledge of distance and displacement.

Force and Motion

During the Engage activity, students move forward and backward at a rate of one step per second to help solidify understanding of speed and velocity. If space is limited or there is another reason students are not able to move around the room, have a volunteer move forward and backward at the front of the room, and ask the class to describe the speed and velocity of the student

Part One

This part of Engage focuses on comparing and contrasting speed and velocity.

Advance Preparation

For each group, print a copy of *RM 1: Speed and Velocity Cards* on cardstock. Laminate and cut each set of cards, and place in an envelope or plastic bag for storage.

Teacher Instruction

- Distribute one set of *RM 1* cards and yarn or string to each group.
- Instruct students to use the yarn or string to create the circle within a circle graphic organizer.
- Instruct students to use cards to label the outer circle "velocity" and the inner circle "speed."
- Instruct students to read and discuss each card to determine whether the card describes speed, velocity, or both. If the card only describes velocity, it should be placed in the outer circle.
- After groups have completed the graphic organizer, debrief the activity using the facilitation questions.
- If students have placed cards in a different location, provide an opportunity to discuss.

Tier I Support

Students can work independently, with a partner, or in a small group.

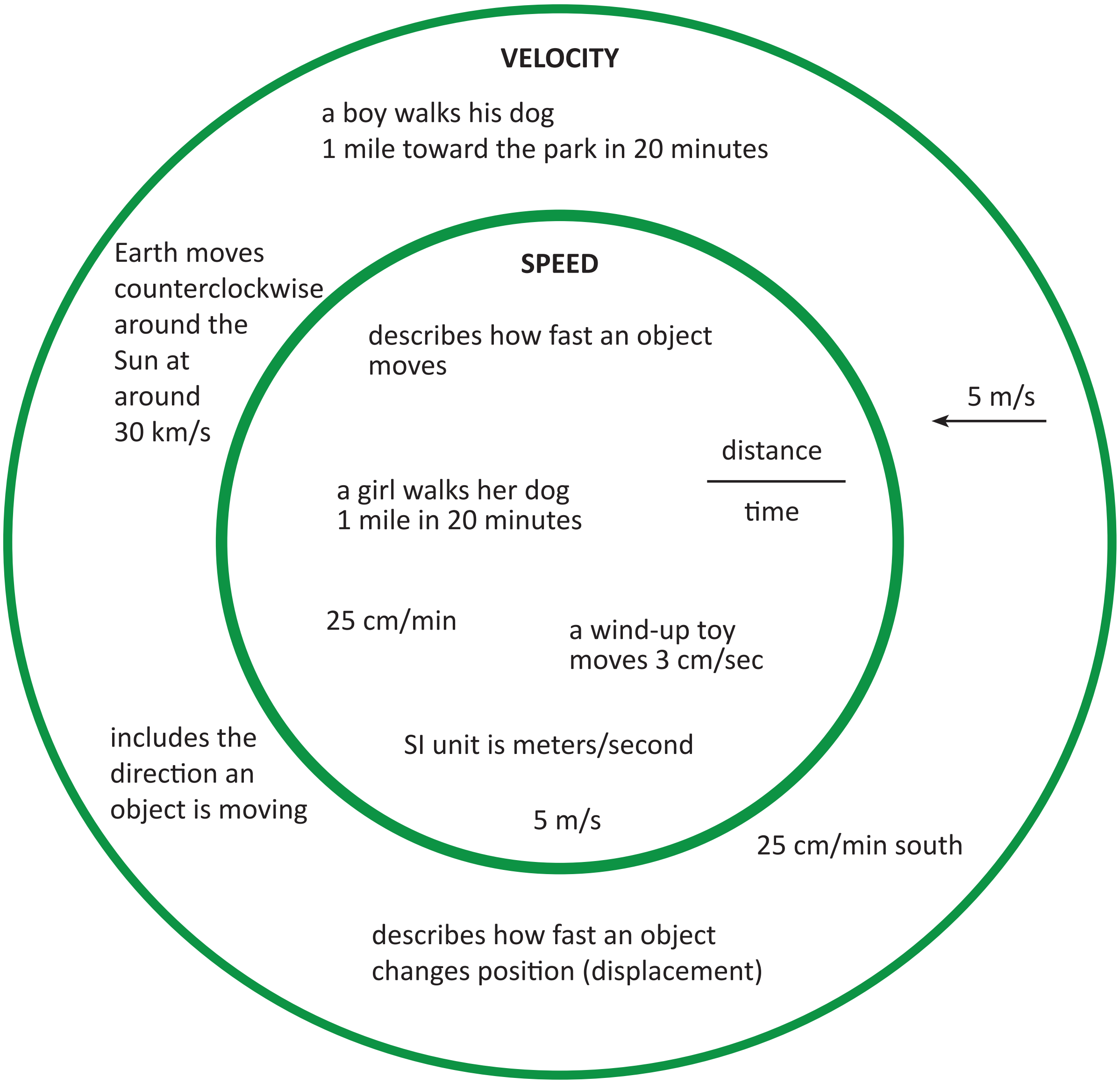
Facilitation Questions

- Why is the speed circle inside the velocity circle? *Speed is a component of velocity.*

Force and Motion

- What are the two components of velocity? *Velocity has a speed (magnitude) and a direction.*
- How are speed and velocity similar? *Both can be used to describe how fast an object is moving. The same units of measurement are used for speed and velocity.*
- How are speed and velocity different? *Speed is used to describe the distance traveled in a period of time. Velocity is used to describe how the position of an object changes in a period of time. The direction of motion is important for velocity but is not a factor for speed.*

RM 1 Answer Key



Force and Motion

Part Two

This part of Engage focuses on using movement to compare distance and displacement.

Teacher Instruction

- Instruct students to stand where they have enough room to take 5–6 small steps forward.
- Explain to students that they will participate in an activity to help them understand the difference between distance and displacement.
- Explain to students that they will be moving at a steady rate of one step per second. Using a clock or timer, clap or snap each second to provide a beat students can follow. Instruct students to practice walking one step per second for 5–6 seconds. Continue providing a beat while students are moving. After students are comfortable moving at this rate, ask them to return to their starting position.
- Instruct students to take five small steps forward while moving one step per second. Provide the beat for three or four seconds, and then have all students start moving at the same time. Continue providing a beat while students are moving.
- Ask volunteers to describe the total distance they traveled and their displacement from their starting point. *Students move a distance of five steps. Their displacement is five steps forward.*
- Ask students to return to their starting position.
- Instruct students to take three small steps forward and two small steps backward while moving one step per second. Students may need an opportunity to practice the movement on their own before moving as a group. Provide the beat for three or four seconds, and then have all students start moving at the same time. Continue providing a beat while students are moving.
- Ask volunteers to describe the total distance they traveled and the displacement from their starting point. *Students move a total distance of five steps. Their displacement is one step forward compared to their starting position.*
- Debrief the activity using the facilitation questions.

TEA
Texas Education Agency

Force and Motion

Facilitation Questions

- Based on the activity, how would you define distance? *Distance describes how far something moves.*
- Based on the activity, how would you define displacement? *Displacement describes how the position of an object changes compared to where it started.*
- How are distance and displacement different? *The direction of movement is important for displacement.*
- How are distance and displacement related to speed and velocity? *Speed is used to describe the distance traveled in a period of time. Velocity is used to describe how the position of an object, or displacement, changes in a period of time.*

Force and Motion

Materials

For each student

- RM 2
- safety glasses

For student groups

- small sphere (e.g., golf ball, table tennis ball, marble, tennis ball)
- variety of materials students may use to change the speed and direction of the object (e.g., blocks, rulers, meter sticks, cardboard, books, boxes)

Explore

Content Builder

The goal of Explore is to help students develop the idea that a force is needed to change the velocity (speed or direction) of an object. Each group may find a different way to complete the three investigations. For example, one group may build a ramp to change the speed of the ball while another group may use a ruler to tap the ball and make it move faster. All groups should come to the conclusion that a force (e.g., tap, hit, push, pull, gravity, etc.) is needed to change the speed or direction of an object.

Teacher Note

A variety of materials can be used to complete the investigations. Common materials such as rulers or meter sticks should be provided. Additional materials might include balls, wood blocks, books, and plastic or cardboard boxes. The same materials should be available to each group of students. If materials are limited, provide one ball for each group and set up a central materials center with additional materials that all groups can use.

Teacher Instruction

- Assign students to groups of 2–4.
- Remind students to put on their safety glasses.
- Distribute *RM 2: Changing the Velocity of an Object* to each student and investigation materials to each group.
- Review Investigations A, B, and C as described on *RM 2.* Explain which materials students may use and which areas of the room may or may not be used. Remind students to roll the ball slowly and to use materials safely.
- Allow 20–30 minutes for students to complete the Explore activity.
- Debrief each of the Explore investigations using the facilitation questions. Ask groups to share how they completed each investigation.

Differentiation Strategy

If students are overwhelmed when selecting materials, provide a limited selection or specific set of materials for each investigation.

Force and Motion

Facilitation Questions

- How did you increase the speed of the ball? *Answers will vary. Possible answers include hitting the ball with another object or rolling the ball down a ramp to make it speed up.*
- How did you decrease the speed of the ball? *Answers will vary. Possible answers include rolling the ball into a stationary object, hitting the ball with a force in the direction opposite of motion, or rolling the ball up a ramp.*
- How did you change the direction of the moving ball? *Answers will vary. Possible answers include hitting the ball, rolling the ball into another object at an angle, or rolling the ball along a curved surface.*
- How is velocity different than speed? *Speed describes how far an object moves in a certain amount of time. Velocity describes how an object's position changes in a certain amount of time. Velocity includes the speed and direction of a moving object.*
- Based on the investigations, what must happen to change the velocity of an object? *A force must be applied to an object to change its speed or direction.*

Force and Motion

Explain

Materials

For each student

- RM 3
- RM 4 page 1 INSERT Symbols Bookmarks
- RM 4 page 2 INSERT Symbols Chart (optional)
- RM 5
- sticky notes

Content Builder

The INSERT symbols reading strategy can help students interact with text and learn to monitor comprehension during reading. Students can use INSERT's coding system while reading to identify concepts and facts that are already known, ideas that are confusing, and concepts that are new or surprising. After reading, students can share their markings with a partner and discuss their questions with a partner or small group before discussing the text with the teacher as a whole class. As questions and confusing ideas are cleared up, students can mark a star next to the question mark.

Students can mark the symbols in the margin or at the beginning of a statement. It is important to explain to students that they should not mark every sentence in the text. Students who need a strategy with more structure can use the INSERT Symbols Chart on the second page of *RM 4: INSERT Symbols* to organize symbols and statements from the text.

Advance Preparation

Print the first page of *RM 4* on cardstock, and cut into individual bookmarks. Prepare enough bookmarks to provide one for each student.

Part One

This part of Explain focuses on establishing the idea that a net force results in a change in velocity (speed or direction).

Teacher Instruction

- Distribute *RM 3: Changing Velocity* and an INSERT symbol bookmark from the first page of *RM 4* to each student.
- Explain to students that they will use the INSERT symbol strategy while reading. Conduct a think-aloud to model the strategy for students using the first paragraph of the reading passage or a sample text.
- Allow 15–25 minutes for students to read and code the text independently.

Force and Motion

- After students complete the reading, allow 5 minutes for students to share their INSERT marks with a partner. Students should take time to discuss concepts or statements that they found confusing. If they clear up the idea during the discussion with their partner, they can mark a star next to the question mark. If they still have a question after discussion with a partner, students should write the page number, statement, and question on a sticky note and post it in a designated area of the room.
- Debrief the reading passage one section at a time using the facilitation questions. Be sure to address questions posted on sticky notes

Tier I Support

Students can work independently or with a partner. The reading passage may be chunked into smaller sections. Assign the sections about speed, velocity, and acceleration, and then stop to debrief before students move on to the sections about the different types of forces.

Facilitation Questions

- What is the difference between speed and velocity? *Speed describes how far an object moves in a certain amount of time. Velocity describes how an object's position changes in a certain amount of time. Velocity includes the speed and direction of a moving object.*
- In science, what do we call changes in velocity? *Changes in velocity are called accelerations.*
- What are the three types of acceleration? *The three types of acceleration are speeding up, slowing down, and changing direction.*
- What causes acceleration? *Forces cause accelerations.*
- What is net force? *The net force is the total of all the forces acting on an object.*
- How do we calculate net force? *We calculate net force by adding forces acting in the same direction and subtracting forces acting in opposite directions.*
- What are balanced forces? *All the forces acting on an object cancel out. The net force is zero.*

Force and Motion

- How do balanced forces affect the motion of an object? *Balanced forces result in no change in motion. The object may be motionless or may be moving with constant speed and direction.*
- What are unbalanced forces? *The forces do not cancel out. There is a net force in a particular direction.*
- How do unbalanced forces affect the motion of an object? *Unbalanced forces cause a change in motion—speeding up, slowing down, or changing direction.*
- Do you still have questions about the reading that we have not answered? *Answers will vary. Refer to sticky note feedback, and address ideas and statements that students find confusing.*
- Look at Example 3 in the reading. What is the net force acting on the block? *The net force is 0 N.*
- Do the forces change the motion of the block in Example 3? *The motion does not change because the forces are balanced. The object will remain at rest.*
- Look at Example 4 in the reading. What is the net force acting on the block? *The net force is 5 N to the right.*
- How do the forces change the motion of the block in Example 4? *The block moves to the right. The speed of the object will increase as long as the net force is acting on the block.*
- Look at Example 5 in the reading. What is the net force acting on the block? *The net force is 2 N to the right.*
- How do the forces change the motion of the block in Example 5? *The block moves to the right. The speed of the object will increase as long as the net force is acting on the block.*
- How does the net force in Example 4 compare with the net force in Example 5? *In both examples, the net force is to the right, but the net force in Example 4 is greater than the net force in Example 5.*
- How does the motion of the block in Example 4 compare with the motion of the block in Example 5? Why? *The block in Example 4 will speed up faster than the block in Example 5 because there is a larger net force in Example 4.*

Force and Motion

Part Two

This part of Explain focuses on calculating net force.

Teacher Instruction

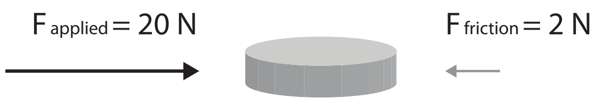
- Distribute *RM 5: Calculating Net Force* to each student.
- Remind students that net forces cause changes in motion. If there is a net force, the motion of the object is changing in some way—speeding up, slowing down, or changing direction.
- Allow 15–20 minutes for students to complete *RM 5.*
- After students are finished working, assign students to groups of 2–4. Assign each group one of the problems from *RM 5* to present to the class.
- Allow 3–5 minutes for each group to present their problem to the class. Allow students to use materials to present their explanations to the class if necessary.

Differentiation Strategy

Students can work independently or with a partner. Allow students to use materials such blocks or balls to model the forces in each scenario described in *RM 5.*

RM 5 Answer Key

1. A hockey player hits a stationary hockey puck with 20 N of force at the beginning of a hockey match. The ice applies 2 N of force to the hockey puck due to friction

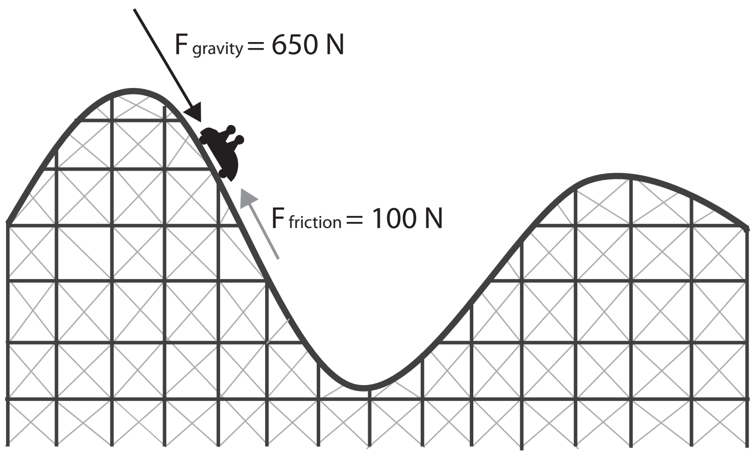


What is the net force acting on the hockey puck? Include the direction of the force.
Net force = 20 N (right) – 2 N (left) = 18 N to the right

How does the net force affect the velocity (speed and direction) of the hockey puck?
The hockey puck will move to the right with increasing speed.

Force and Motion

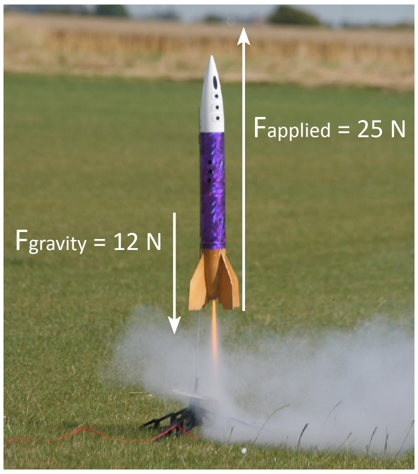
2. A roller coaster car moves down a large hill along the track. The force of gravity pulls the roller coaster car down the track with 650 N of force. The friction between the cart and the track applies 100 N of force in the opposite direction.



What is the net force acting on the roller coaster car? Include the direction of the force.
Net force = 650 N (down) – 100 N (up) = 550 N down

How does the net force affect the velocity of the roller coaster car?
The roller coaster car will speed up as it moves down the hill.

3. The science club launches a model rocket. The engine of the rocket applies 25 N of force to launch the rocket upward. The force of gravity applies 12 N of force on the rocket.



What is the net force acting on the model rocket? Include the direction of the force.
Net force = 25 N (up) – 12 N (down) = 13 N up

Force and Motion

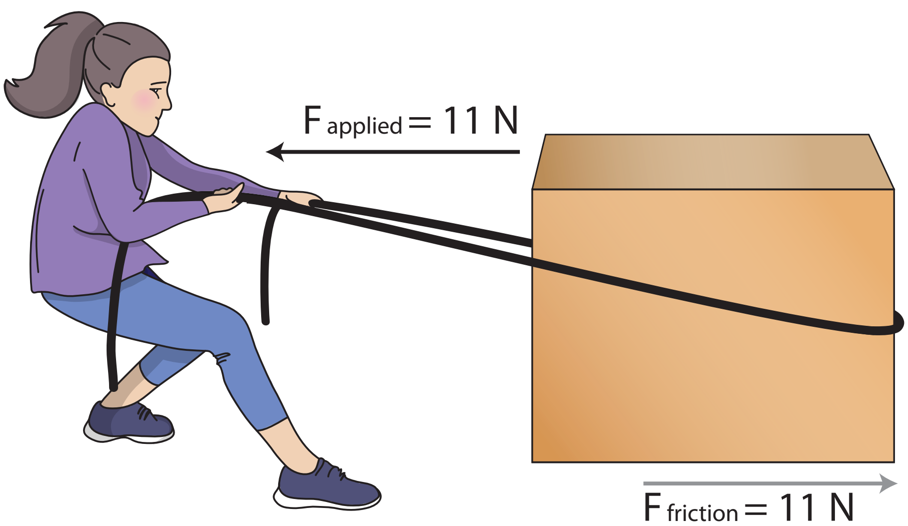
How does the net force affect the velocity of the model rocket?
The rocket will move up with increasing speed.

4. The engine of the model rocket burns out a few seconds after the model rocket is launched. Once the engine burns out, it no longer applies an upward force on the model rocket. The rocket continues moving upward, but gravity still applies a downward force of 12 N on the rocket.

   What is the net force acting on the model rocket after the engine burns out? Include the direction of the force.
   The net force is 12 N down. There is no upward force.

   How does the net force affect the velocity of the model rocket?
   The rocket is already moving upward. The net force acts in the opposite direction, so the rocket will slow down as it moves upward. Eventually the rocket will stop for a moment, change directions, and fall toward the ground.

5. A student is asked to move a large box. She pulls on a rope looped around the box. The floor applies a force to the box due to friction.

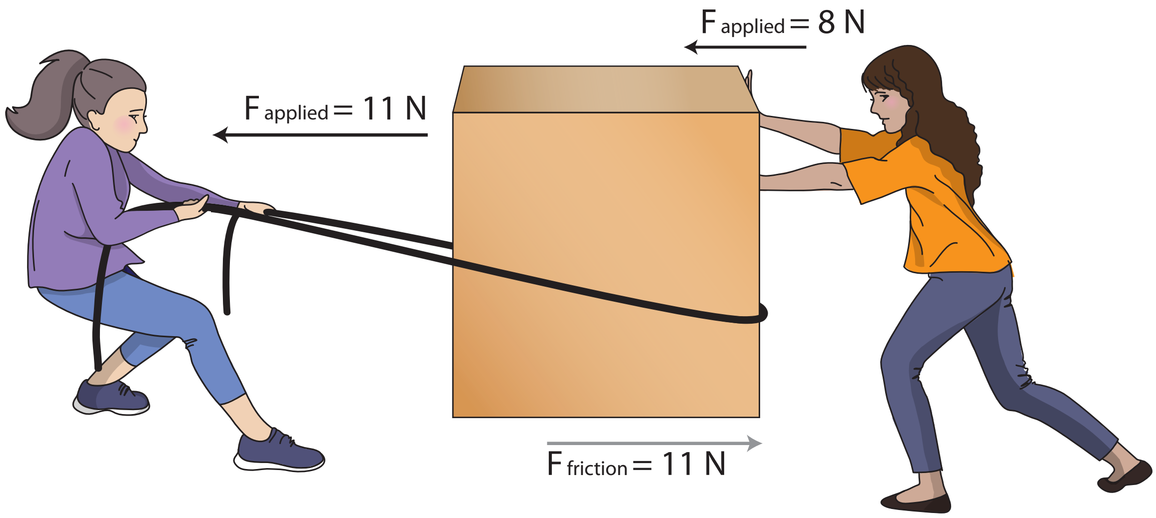


What is the net force acting on the box? Include the direction of the force.
Net force = 11 N (left) – 11 N (right) = 0 N

How does the net force affect the velocity of the box?
The box will not move because there is no net force.

Force and Motion

6. Two students are moving a large box. One student pushes on the box while the other student pulls on a rope looped around the box. The floor applies a force to the box due to friction.



What is the net force acting on the box? Include the direction of the force.
Net force = 11 N (left) + 8 N (left) – 11 N (right) = 8 N to the left

How does the net force affect the velocity of the box?
The box will speed up as it moves to the left.

1207343 Science Academies_Lesson 8 .indd 254 4/27/2016 4:48:18 PM

Elaborate

Content Builder

Students often have misconceptions about balanced and unbalanced forces. When the forces acting on an object are balanced, there is no change in motion. The object is either motionless or it is moving with constant speed and direction. When the forces acting on an object are unbalanced, there is a change in motion. The object is speeding up, slowing down, or turning.

Students often neglect to consider the forces of gravity and friction when thinking about all the forces acting on an object. This can lead to misconceptions about force and motion. During Parts 5 and 6 of Elaborate, the forces applied by the fans are balanced, and the set of carts is supposed to move with constant speed and direction. Students will likely observe that the cart moves a short distance and then stops. It is important to have a conversation about other forces acting on the cart in addition to the fans. The forces of gravity and friction are also acting on the cart and are the reason the cart does not move with constant velocity.

Teacher Note

Fan carts can be purchased from many different science education vendors. Each cart has a small battery-operated fan that applies a force to the cart. (Technically the fan applies a force to the air, which in turn applies an equal and opposite force to the fan and causes the cart to move. This lesson refers to the force of the fan as F_{fan} for initial understanding.) Most carts come with a plastic "sail." Do not use the sail for this investigation. If the sail is attached to the cart, the cart will not move. If commercially manufactured carts are not available, handheld fans can be attached to Hall's carriage carts or dynamics carts. Use rubber bands to secure the handheld fan to the bottom of a small plastic cup. Use additional rubber bands to secure the cup and fan to the cart.

If hands-on materials are not available, students can explore the fan cart simulation on the Texas Gateway website at www.texasgateway.org. The online simulation also can be used after a hands-on activity to provide additional experiences for students.

During Elaborate, two fan carts are connected together in different arrangements to model balanced and unbalanced forces. The carts should be connected so that they remain aligned while moving. Depending on the type of fan cart available, different materials can be used to connect the carts. Two examples of the set-up are pictured on the next page.

Materials

For student

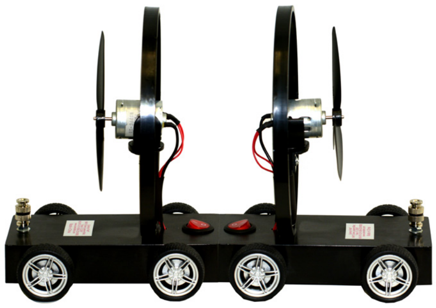
- RM 6

For student groups

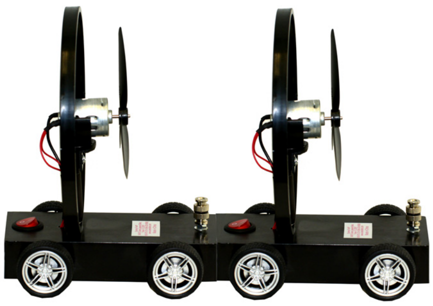
- two fan carts with batteries
- materials to connect carts together

Force and Motion

It is not recommended to conduct this investigation on lab tables because the carts may roll off of the table and break. Have students place the cart system on a floor with a smooth surface during this investigation, and make sure the area around the cart system is clear of any obstacles.



Two carts connected to form a cart system with forces applied in opposite directions.



Two carts connected to form a cart system with forces applied in the same direction.

During Parts 3 and 6, students will turn on one fan to get the cart system moving and then switch on the second fan and observe motion changes. One way to do this is to have one student turn on the first fan and have a second student waiting about 0.5–1 m away. When the cart system passes the second student, he or she should try to flip the switch on the second fan while applying as little force as possible to the cart system. Students may need to repeat this activity multiple times. If students are not able to switch on the second fan while the fan cart system is moving, they may observe the motion of the system with one fan on and then with two fans on and compare the resulting motions.

Most commercially available fan carts use AA batteries. Heavy-duty or long-lasting batteries are recommended for the fan carts because the batteries can run down quickly when the fans are running for extended periods of time. Remind students to turn off the fans when not conducting the investigation. As the batteries run down, the fan and cart move more slowly.

Force and Motion

Advance Preparation

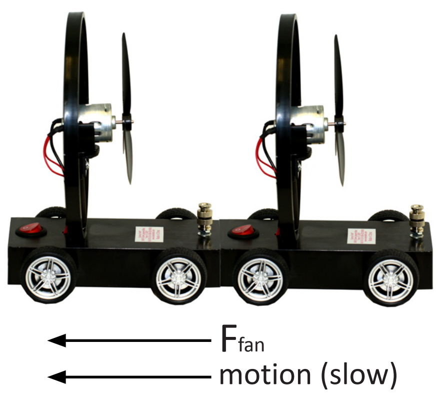
Determine what materials will be used for the activity. If students will be using fan carts, try using different materials to connect the fan carts. Be sure to perform all parts of the Elaborate activity to test the selected materials. Be prepared to address possible issues with equipment that may occur during the investigation.

Teacher Instruction

- Assign students to groups of 2–4.
- Distribute *RM 6: Balanced and Unbalanced Forces* to each student and investigation materials to each group.
- Explain to students that they will be using a “system” of carts. Two carts are connected together and will move as one large object.
- Model the proper use of the fan carts. Demonstrate an appropriate method students can use to connect the fan carts together.
- Review the different parts of the activity. Remind students that the fans will be facing the same way for Parts 1, 2, and 3. The fans will face away from each other for Parts 4 and 5 of the activity.
- Allow 30 minutes for students to complete the activity.
- Debrief the activity using the facilitation questions.

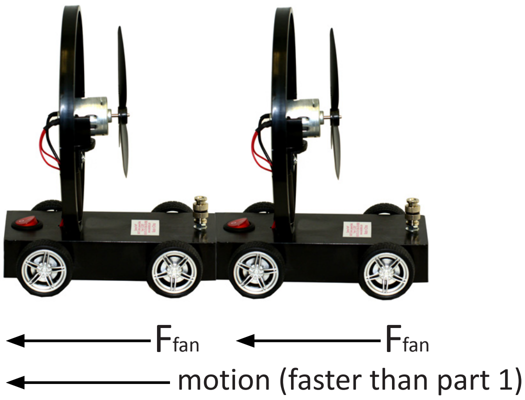
Facilitation Questions

- During Part 1, only one fan was turned on. Were the forces acting on the cart system balanced or unbalanced? Explain. *Unbalanced: Only one fan was turned turned on, so there was only one force applied to the cart system.*

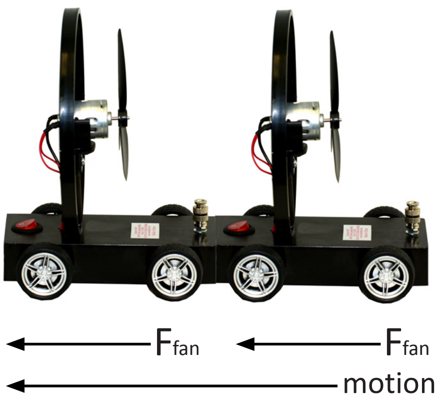


Force and Motion

- How did the motion of the cart system change during Part 1? *The cart system started at rest. When the fan was turned on, the cart system started moving and sped up.*
- During Part 2, both fans were on and facing the same direction. Were the forces acting on the cart system balanced or unbalanced? Explain. *Unbalanced: Both fans were turned on and applied force in the same direction.*



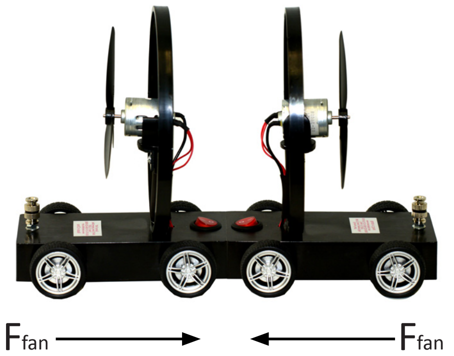
- How did the motion of the cart system change during Part 2? *The cart system started at rest. When the fans were turned on, the cart system started moving and sped up.*
- How did the motion of the cart system in Part 1 compare with the motion of the cart system in Part 2? *The cart sped up faster during Part 2 when both fans were turned on compared with Part 1 when only one fan was turned on.*
- During Part 3, one fan was turned on, causing the cart system to start moving, and then a second fan was turned on. Were the forces acting on the cart system balanced or unbalanced? Explain. *Unbalanced: Both fans were turned on and applied force in the same direction.*



TEA Texas Education Agency

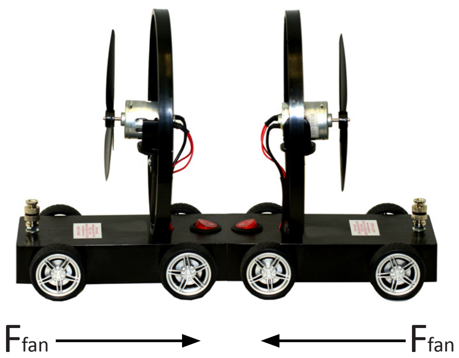
Force and Motion

- How did the motion of the cart change when the second fan was turned on? *The cart system sped up faster when the second fan was turned on.*
- During Part 4, both fans were turned on but faced away from each other. Were the forces acting on the cart system balanced or unbalanced? Explain. *Balanced: Both fans were turned on, but the fan forces acted in opposite directions and canceled each other out.*



no motion

- How did the motion of the cart system change during Part 4? *The motion did not change. The cart system started at rest. When the fans were turned on, the cart system remained at rest.*
- During Part 5, both fans were turned on but faced away from each other. Were the fan forces acting on the cart system balanced or unbalanced? Explain. *Balanced: Both fans were turned on, but the fan forces acted in opposite directions and canceled each other out.*

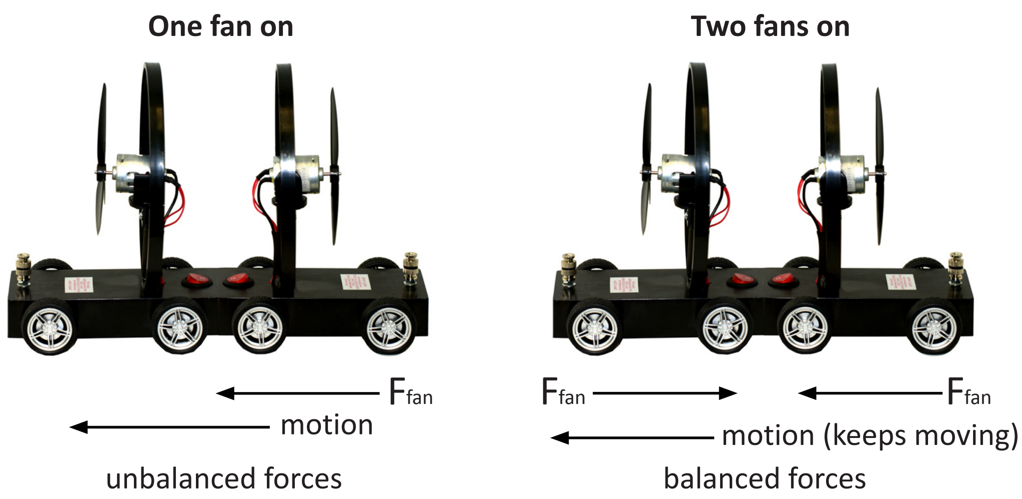


balanced forces, system keeps moving

Force and Motion

- If the forces are balanced in Part 5, the cart system should continue moving. Why didn't the cart system keep moving forward? Were there other forces acting on the cart system? *The force of friction and the weight of the cart system due to the force of gravity caused the cart system to slow down and stop.*

- During Part 6, were the fan forces acting on the cart system balanced or unbalanced? Explain. *The forces were unbalanced when only one fan was turned on. The forces from the fans were balanced when both fans were turned on. The fan forces acted in opposite directions and canceled each other out.*



- Were there other forces acting on the cart system? *Yes. The force of gravity affects all objects on Earth. The force of friction affects all moving objects on Earth.*

Evaluate

Teacher Instruction

- Distribute *RM 7: Evaluate* to each student.
- Determine how students will work through the activity.
- Instruct students to use their knowledge of speed, velocity, acceleration, and forces to complete *RM 7.*

Materials

For each student

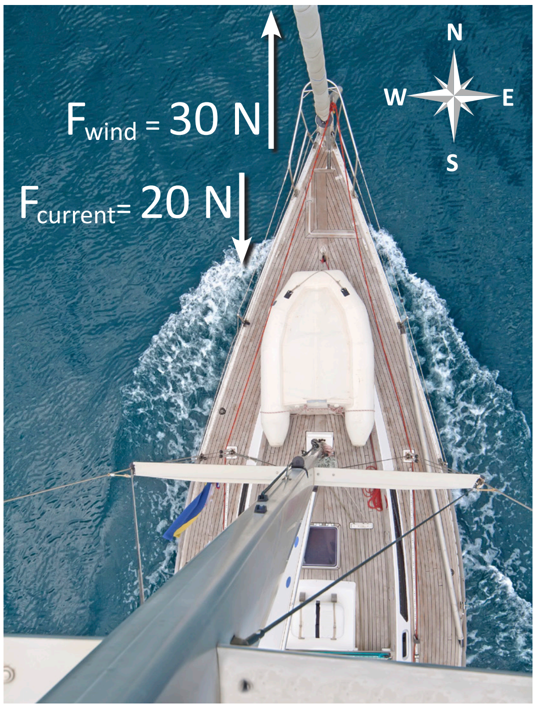
- RM 7

Tier I Support

Students can work independently, with a partner, or with a small group.

RM 7 Answer Key

1. The diagram shows wind pushing a sailboat with 30 N of force to the north against a 20 N current to the south.



How will the motion of the sailboat be affected if it moves to an area of the water where the current is 25 N? Use evidence to justify your answer.
If the force of the current increases, the boat will continue to move to the north but at a slower speed.

Force and Motion

2. Three brothers and their dog are playing with a wagon. One brother pulls on the wagon with 22 N of force. A second brother pushes on the back of the wagon with 15 N of force. The grass applies 17 N of force on the wagon due to friction between the grass and the wagon wheels.

   a. Draw and label arrows to represent the three forces acting on the wagon

   b. Calculate the net force acting on the wagon.
   Net force = 22 N (right) + 15 N (right) – 17 N (left) = 20 N to the right

   c. How do the forces affect the motion of the wagon?
   The wagon will move to the right with increasing speed.

   d. Are the forces acting on the wagon balanced or unbalanced? Use evidence to support your answer.
   The forces are unbalanced because the forces do not cancel out. There is a net force to the right. The motion of the wagon is changing.

1207343 Science Academies_Lesson 8 .indd 262 4/27/2016 4:48:30 PM

Force and Motion

3. The London Eye is one of the largest Ferris wheels in the world. It rotates at a constant speed around 0.6 miles per hour. This is slow enough for passengers to board and exit the passenger cars while it is moving. It takes about 30 minutes to make one full rotation.

   Do the passenger cars on the wheel travel at a constant velocity or do the passenger cars accelerate? Use evidence to support your answer.
   The speed of the passenger cars does not change. The passenger cars are traveling in a circle, so the direction of the cars changes constantly. Because the velocity (direction) changes, the passenger cars accelerate.

4. A toy train travels on a straight part of its track. The train is moving to the right with a constant speed of 1.2 m/s.

   The motor in the toy train applies 6 N of force on the toy train. The track applies 6 N of force on the toy train due to friction.

   a. What is the net force acting on the toy train?
   Net force = 6 N (right) – 6 N (left) = 0 N

   b. How do the forces affect the motion of the toy train?
   There is no net force, so there is no change in motion. The toy train will continue moving to the right at 1.2 m/s.

   c. Are the forces balanced or unbalanced? Use evidence to support your answer.
   The forces are balanced because the forces cancel out. The net force is zero. There is no change in motion.

   d. What will happen to the motion of the train if the force applied to the train is increased to 10 N?
   The train will continue to move to the right with increasing speed.

Force and Motion

5. Use the table below to differentiate between speed, velocity, and acceleration.
Accept all appropriate responses.

	Write a definition in your own words.	**Describe an example.**
speed	*Speed is the distance an object travels over a period of time.*	*Correct answers will include a distance and time. Direction is not included with speed. Some examples include the following:* • *50 mph* • *3 m/s* • *Object moves 8 meters in 1 minute*
velocity	*Velocity is a change in position or displacement over a period of time.*	*Correct answers will include speed and direction. Some examples include the following:* • *50 mph east* • *3 m/s to the left* • *Object moves 8 meters in 1 minute toward the wall*
acceleration	*Acceleration is any change in velocity (speed or direction)*	*Correct answers will describe objects that include one or more of the following:* • *speeding up* • *slowing down* • *changing direction*

Force and Motion

RM 0: Ideas about Force and Motion Sort

Agree	Disagree
There cannot be a force without motion.	
The stronger the force, the faster an object moves.	
Objects can continue to move in a straight line without a force being applied.	
Constant speed results from constant force.	
Forces act on objects at rest.	
If there is no motion, then there is no force acting.	
Moving objects stop when their force is used up.	
A force is necessary to change the direction of motion.	
When an object is moving, there is always a force in the direction of its motion.	

Force and Motion

RM 0: Ideas about Force and Motion Sort Key

The pre-lesson sort can be used to assess participants' ideas about force and motion. In the Science Academies for Grades 5 to 8, Part 2: Force and Motion, we will use this sort before and after each grade 8 lesson.

The statements in this activity include the most common misconceptions about force and motion. When using the sort activity before instruction, it is important to observe how groups sort the statements, but correct answers should not be provided or discussed before instruction. Use the sort to identify misconceptions and then provide learning experiences to challenge incorrect ideas. Participants can sort the statements again after instruction to see how their ideas about force and motion have changed.

Answer Key

Agree

Statement	Explanation
Forces act on objects at rest.	*Forces can act on objects at rest.*
Objects can continue to move in a straight line without a force being applied.	*A force is needed to make an object start moving, but once the object is in motion, its inertia keeps it moving. The object will continue moving at the same speed and in the same direction until an unbalanced (net) force is applied to the object. Because outside forces, including friction and gravity, affect the motion of objects on Earth, objects usually slow down and stop if no additional force is applied to keep the object in motion.*
A force is necessary to change the direction of motion.	*An unbalanced (net) force is needed to change the direction or speed of an object.*

Disagree

Statement	Explanation
There cannot be a force without motion.	*Forces can act on objects at rest.*
The stronger the force, the faster the object moves.	*Stronger force results in greater acceleration. Greater acceleration may result in an object speeding up faster, but it can also mean an object is slowing down faster or changing direction faster.*
Constant speed results from constant force.	*If speed is constant (in a straight line), the forces acting on the object are balanced. A constant force will result in a change in motion, such as speeding up, slowing down, or changing direction.*

Force and Motion

RM 0: Ideas about Force and Motion Sort Key

If there is no motion, then there is no force acting.	*Forces can act on objects at rest.*
Moving objects stop when their force is used up.	*A force is an interaction between two objects. Force cannot be stored and "used up." Moving objects stop because an unbalanced force (usually friction) caused the object to slow down and stop.*
When an object is moving, there is always a force in the direction of its motion.	*An unbalanced force is required to make an object start moving. Once the object is in motion, it may continue moving without a force applied the in the direction of its motion. The inertia of the object keeps it in motion.*

Force and Motion

RM 1: Speed and Velocity Cards

SPEED	VELOCITY	
25 cm/min	$\frac{\text{distance}}{\text{time}}$	a girl walks her dog 1 mile in 20 minutes
25 cm/min south	Earth moves counterclockwise around the Sun at around 30 km/s	a wind-up toy moves 3 cm/s
includes the direction an object is moving	describes how fast an object moves	5 m/s ←
5 m/s	a boy walks his dog 1 mile toward the park in 20 minutes	SI unit is meters/second
describes how fast an object changes position (displacement)		

Texas Education Agency

1207343 Science Academies_Lesson 8 .indd 271 6/16/2016 8:52:13 AM

Force and Motion

RM 2: Changing the Velocity of an Object

How can you change the velocity of an object?

Materials

- a small ball (e.g., golf ball, marble, tennis ball, etc.)
- additional materials such as rulers, meter sticks, blocks, additional ball, etc.

Investigation A—Increasing Speed

Slowly start the ball rolling across the floor or table. Using the materials provided, find a way to noticeably increase the speed of the ball.

Describe the method you used to change the speed of the ball. Include a labeled drawing of your investigation setup.	Record your observations.

Investigation B—Decreasing Speed

Slowly start the ball rolling across the floor or table. Using the materials provided, find a way to noticeably decrease the speed of the ball.

Describe the method you used to change the speed of the ball. Include a labeled drawing of your investigation setup.	Record your observations.

Force and Motion

RM 2 continued

Investigation C—Changing Direction

Slowly start the ball rolling across the floor or table. Using the materials provided, find a way to change the direction of the moving ball.

Describe the method you used to change the direction of the ball. Include a labeled drawing of your investigation setup.	Record your observations.

Investigation Questions

Use complete sentences to answer the following questions.

1. How is velocity different from speed?

2. Based on the investigations, what must happen to change the velocity (speed or direction) of an object?

Changing VELOCITY

SPEED

In science there are many terms that can be used to describe motion. The **speed** of an object describes the distance an object travels in a certain period of time. Average speed is calculated by dividing the total distance traveled by the total time. The formula for average speed is speed = distance ÷ time.

$$s = \frac{d}{t}$$

Texas Education Agency

1207343 Science Academies_Lesson 8 .indd 277 4/27/2016 4:48:34 PM

EXAMPLE 1

A toy car moves 50 cm in 5 seconds. What is the average speed of the car?

$$s = \frac{d}{t}$$

$$s = \frac{50\text{ cm}}{5\text{ sec}} = 10\text{cm/sec}$$

VELOCITY

The speed of an object describes how fast an object is moving, but it does not give any information about the direction the object is moving. The **velocity** of an object describes how its position, or displacement, changes over time. Velocity describes the *speed* of an object as well as the *direction* the object travels. An arrow can be used to represent the velocity of an object. A larger arrow represents greater velocity.

EXAMPLE 2

A cyclist travels west at 10 km/hr on her bicycle. Describe the speed and the velocity of the cyclist.

Speed = 10 km/hr
Velocity = 10 km/hr west

ACCELERATION

During the Explore activity, you determined that a force is needed to change the speed or direction of an object. In science, any change in velocity (speed or direction) is called an **acceleration**. There are three types of acceleration:

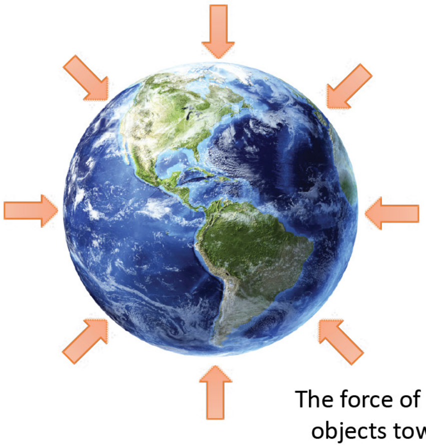
- increasing speed
- decreasing speed
- changing direction

Based on the Explore investigations, we learned that forces are needed to change the velocity (speed or direction) of an object. This means that all accelerations are caused by forces.

According to Newton's first law of motion, an object will remain at rest until a force causes it to start moving. A moving object will continue to move at the same speed and in the same direction until a force changes its motion. Another way to state Newton's first law of motion is that forces cause *changes* in motion, or accelerations.

TYPES OF FORCES

What kinds of forces act on objects? There are many forces that can affect the motion of an object. For example, the force of gravity is always pulling downward on an object toward the center of Earth. Friction is another force that affects the motion of objects. The force of friction is always acting in the direction opposite of the direction of motion. Friction causes moving objects to slow down and eventually stop.

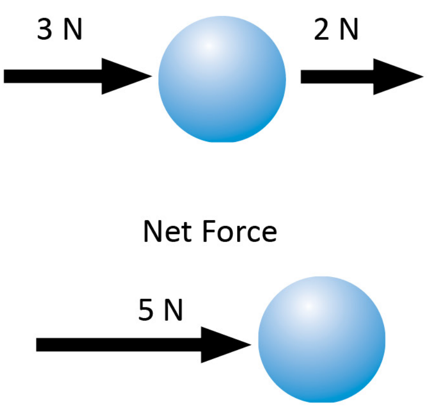
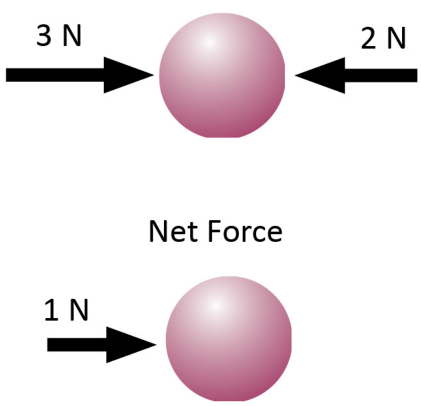


The force of gravity pulls objects toward Earth.

The force of friction is always in the opposite direction of the motion of the object.

NET FORCE

When we talk about a force acting on an object, we are usually describing **net force**. The net force is the total of all the forces acting on an object. The forces acting on an object can be used to calculate the net force.

If forces are acting in the same direction, the forces can be added together.	If forces are acting in opposite directions, the forces are subtracted.
	

© 2016 TEXAS EDUCATION AGENCY. ALL RIGHTS RESERVED.

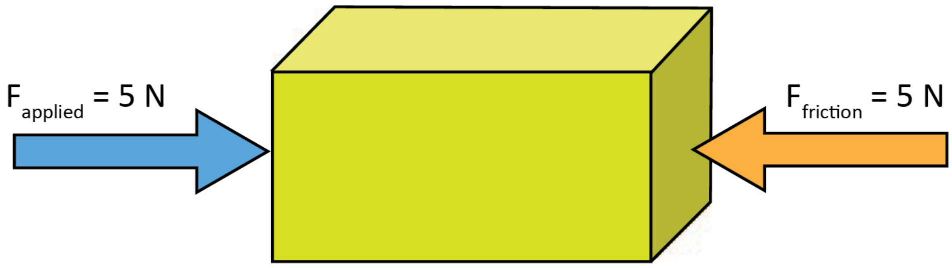
1207343 Science Academies_Lesson 8 .indd 280 4/27/2016 4:48:36 PM

BALANCED FORCES

If the forces acting on an object cancel out, the net force is zero. These forces are called **balanced forces**. When the forces acting on an object are balanced, there is no change in motion because there is no net force. The object is not speeding up, slowing down, or changing direction.

EXAMPLE 3

A 5 N force is applied to a wood block resting on a table. The force of friction applies 5 N of force to the block in the opposite direction.



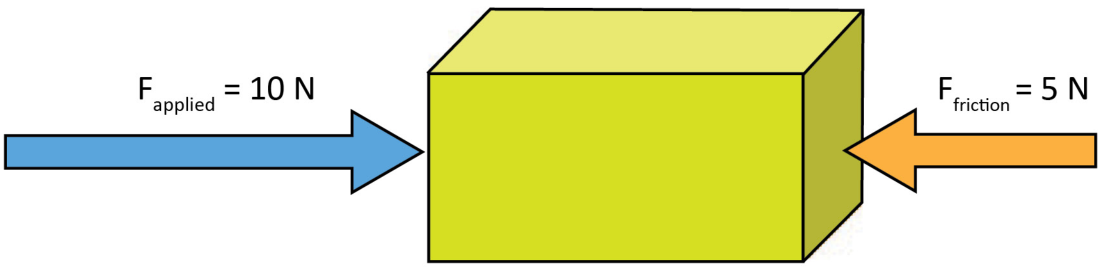
What is the net force acting on this block? Do the forces change the motion of this block?

UNBALANCED FORCES

If the forces acting on an object do not cancel out, a net force is applied to the object. These forces are called **unbalanced forces**. When the forces acting on an object are unbalanced, there is a net force that always results in a change in motion, or an acceleration. While a net force is applied, the object is speeding up, slowing down, or changing direction.

EXAMPLE 4

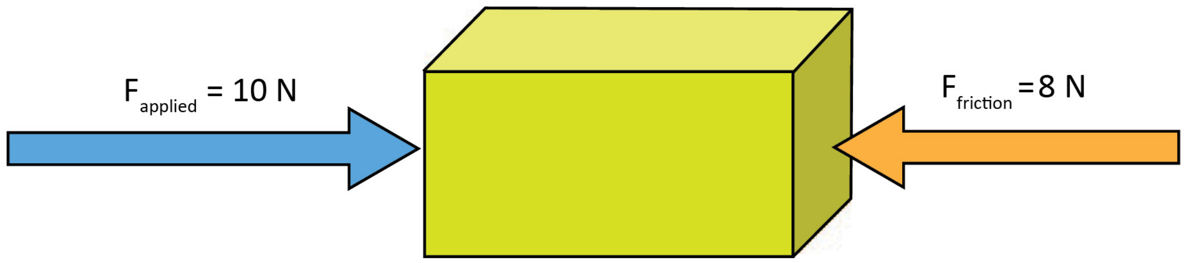
A 10 N force is applied to a wood block resting on a table. The force of friction applies 5 N of force to the block in the opposite direction.



What is the net force acting on this block? How do the forces change the motion of this block?

EXAMPLE 5

A 10 N force is applied to a wood block resting on a floor with carpet. The force of friction applies 8 N of force to the block in the opposite direction.



What is the net force acting on this block? How do the forces change the motion of this block?

How does the net force in Example 4 compare with the net force in Example 5?

How does the motion of the block in Example 4 compare with the motion of the block in Example 5?

1207343 Science Academies_Lesson 8 .indd 283 4/27/2016 4:48:38 PM

Force and Motion

RM 4: INSERT Symbols

INSERT Symbols Bookmarks

INSERT Symbols
Reading Strategy

✓ Draw a check mark next to concepts or facts you already know.

? Draw a question mark next to concepts or statements that are confusing.

! Draw an exclamation point next to information that is new, unusual, or surprising.

★ Draw a star next to any question marks that are cleared up during discussion.

INSERT Symbols
Reading Strategy

✓ Draw a check mark next to concepts or facts you already know.

? Draw a question mark next to concepts or statements that are confusing.

! Draw an exclamation point next to information that is new, unusual, or surprising.

★ Draw a star next to any question marks that are cleared up during discussion.

INSERT Symbols
Reading Strategy

✓ Draw a check mark next to concepts or facts you already know.

? Draw a question mark next to concepts or statements that are confusing.

! Draw an exclamation point next to information that is new, unusual, or surprising.

★ Draw a star next to any question marks that are cleared up during discussion.

INSERT Symbols
Reading Strategy

✓ Draw a check mark next to concepts or facts you already know.

? Draw a question mark next to concepts or statements that are confusing.

! Draw an exclamation point next to information that is new, unusual, or surprising.

★ Draw a star next to any question marks that are cleared up during discussion.

INSERT Symbols
Reading Strategy

✓ Draw a check mark next to concepts or facts you already know.

? Draw a question mark next to concepts or statements that are confusing.

! Draw an exclamation point next to information that is new, unusual, or surprising.

★ Draw a star next to any question marks that are cleared up during discussion.

INSERT Symbols
Reading Strategy

✓ Draw a check mark next to concepts or facts you already know.

? Draw a question mark next to concepts or statements that are confusing.

! Draw an exclamation point next to information that is new, unusual, or surprising.

★ Draw a star next to any question marks that are cleared up during discussion.

Force and Motion

RM 4 continued

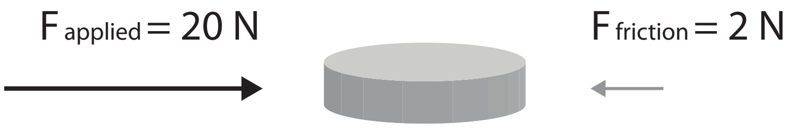
INSERT Symbols Chart

Page	Statement	Symbol	Question or Reflection

Force and Motion

RM 5: Calculating Net Force

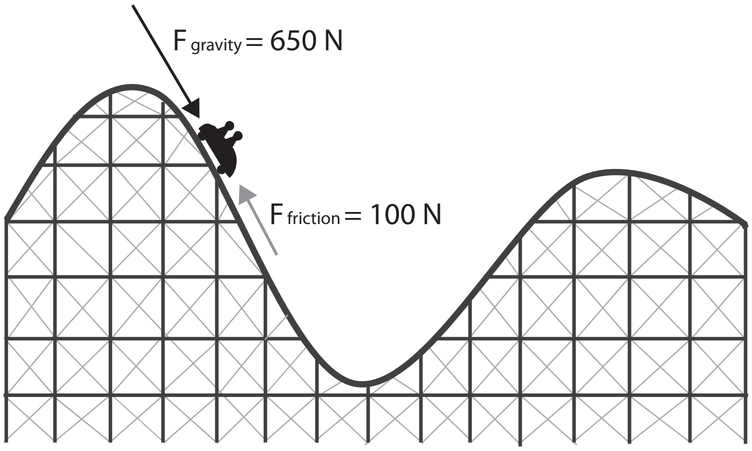
1. A hockey player hits a stationary hockey puck with 20 N of force at the beginning of a hockey match. The ice applies 2 N of force to the hockey puck due to friction.



What is the net force acting on the hockey puck? Include the direction of the force.

How does the net force affect the velocity (speed and direction) of the hockey puck?

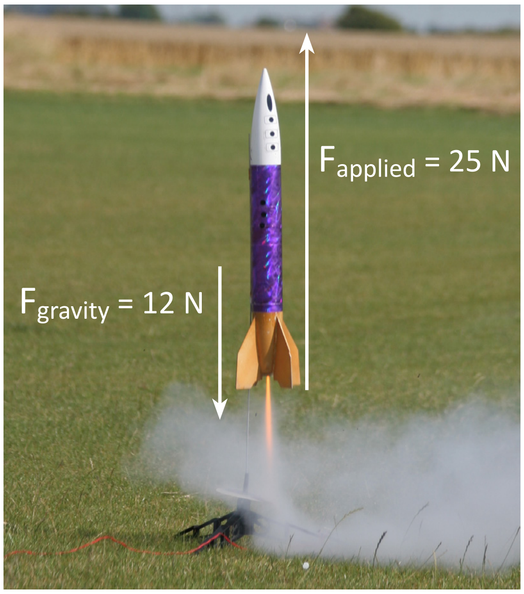
2. A roller coaster car moves down a large hill along the track. The force of gravity pulls the roller coaster car down the track with 650 N of force. The friction between the cart and the track applies 100 N of force in the opposite direction.



What is the net force acting on the roller coaster car? Include the direction of the force.

How does the net force affect the velocity of the roller coaster car?

3. The science club launches a model rocket. The engine of the rocket applies 25 N of force to launch the rocket upward. The force of gravity applies 12 N of force on the rocket.



What is the net force acting on the model rocket? Include the direction of the force.

How does the net force affect the velocity of the model rocket?

4. The engine of the model rocket burns out a few seconds after the model rocket is launched. Once the engine burns out, it no longer applies an upward force on the model rocket. The rocket continues moving upward, but gravity still applies a downward force of 12 N on the rocket.

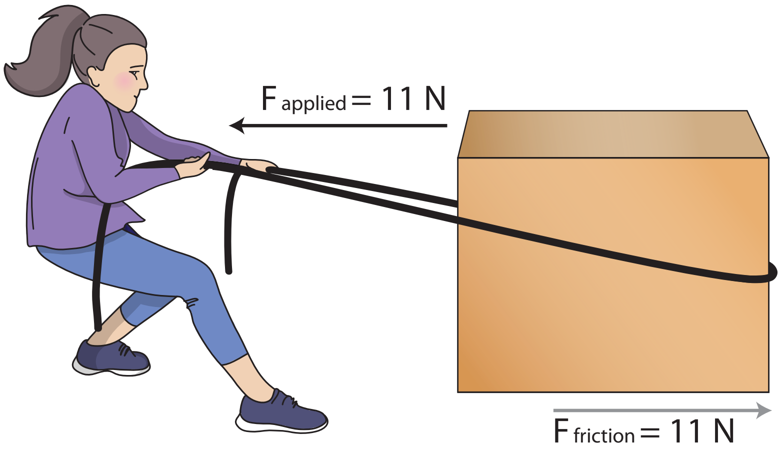
What is the net force acting on the model rocket after the engine burns out? Include the direction of the force.

How does the net force affect the velocity of the model rocket?

Force and Motion

RM 5 continued

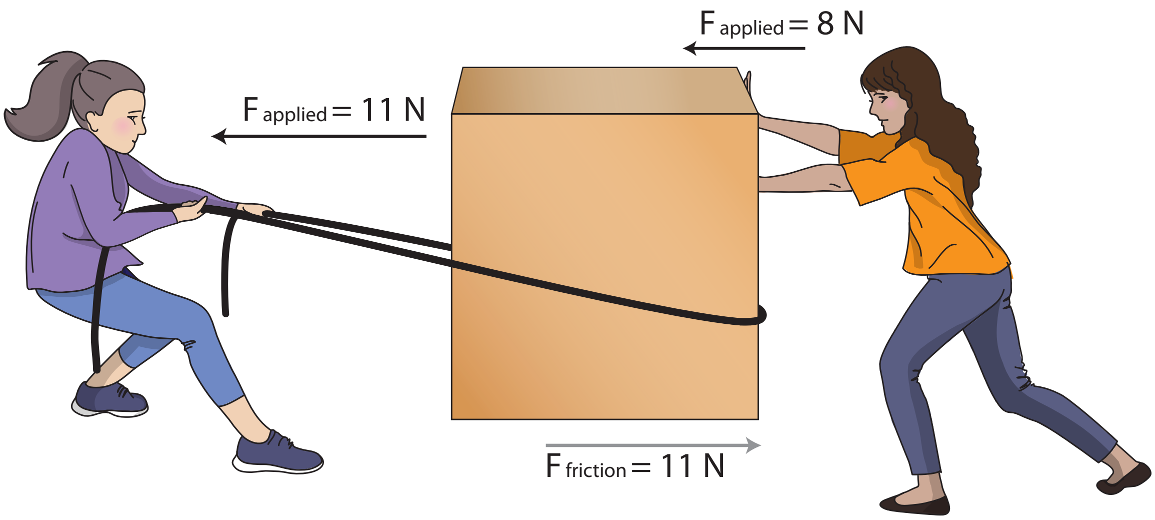
5. A student is asked to move a large box. She pulls on a rope looped around the box. The floor applies a force to the box due to friction.



What is the net force acting on the box? Include the direction of the force.

How does the net force affect the velocity of the box?

6. Two students are moving a large box. One student pushes on the box while the other student pulls on a rope looped around the box. The floor applies a force to the box due to friction.



What is the net force acting on the box? Include the direction of the force.

How does the net force affect the velocity of the box?

1207343 Science Academies_Lesson 8 .indd 293 4/27/2016 4:48:40 PM

Force and Motion

RM 6: Balanced and Unbalanced Forces

For this investigation, you will connect two fan carts together. Because the carts are connected and will move as one large object, we can call this a *cart system*. Use the materials provided and follow your teacher's instructions for connecting the carts to form a cart system.

When the fans are on, they apply a force to the cart system. We can call these *fan forces*, or F_{fan}.

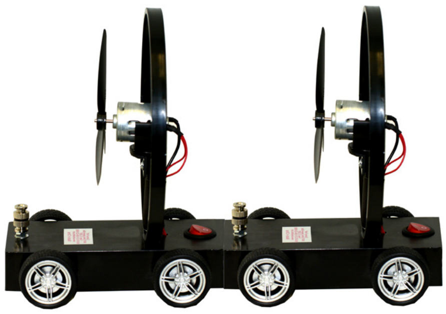
Note: It is not recommended to conduct this investigation on lab tables because the carts may roll off of the table and break. Place the cart system on a floor with a smooth surface during this investigation. Make sure the area around the cart system is clear of any obstacles.

Part 1

Connect the two fan carts so that the fans are pointing the same direction.

While the cart system is at rest, turn on one fan.

Observe the motion of the cart system. After making your observations, stop the cart system and turn off the fan.



Draw a diagram of the cart system. Include labeled arrows to indicate the direction of the fan force (F_{fan}) and the direction of the motion.	Describe the motion of the cart system.

Are the fan forces (F_{fan}) acting on the cart system balanced or unbalanced? Explain.

Does the motion of the cart change? Explain.

Texas Education Agency

Force and Motion

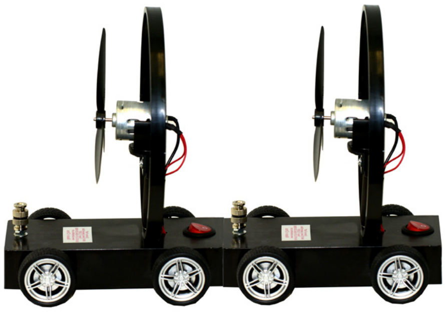
RM 6 continued

Part 2

Leave the two fan carts connected so that the fans are pointing the same direction.

While the cart system is at rest, turn on both fans.

Observe the motion of the cart system. After making your observations, stop the cart system and turn off both fans.



Draw a diagram of the cart system. Include labeled arrows to indicate the direction of the fan force (F_{fan}) and the direction of the motion.	Describe the motion of the cart system.

Are the fan forces (F_{fan}) acting on the cart system balanced or unbalanced? Explain.

Does the motion of the cart change? Explain.

How does the motion of the cart system in Part 1 compare with the motion of the cart system in Part 2?

Force and Motion

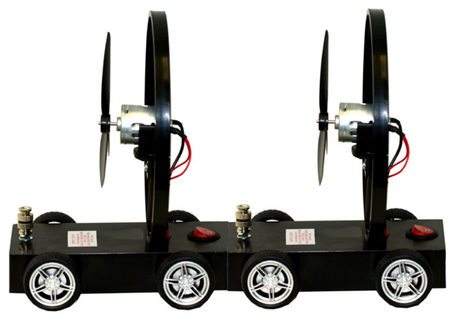
RM 6 continued

Part 3

Leave the two fan carts connected so that the fans are pointing the same direction.

Turn on one of the fans to get the cart system moving. While the cart system is moving, turn on the second fan.

Observe the motion of the cart system. After making your observations, stop the cart system and turn off both fans.



Note: If you are not able to turn on the second fan while the cart system is in motion, observe the motion of the cart when one fan is turned on and then the motion of the cart when both fans are turned on.

Draw a diagram of the cart system. Include labeled arrows to indicate the direction of the fan force (F_{fan}) and the direction of the motion.	Describe the motion of the cart system.

Are the fan forces (F_{fan}) acting on the cart system balanced or unbalanced? Explain.

Does the motion of the cart change? Explain.

Force and Motion

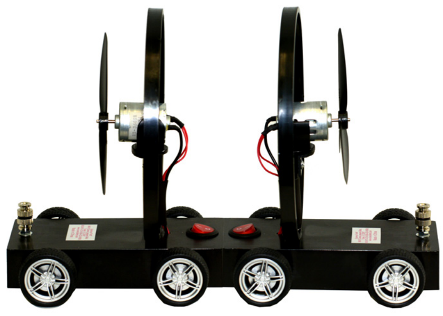
RM 6 continued

Part 4

Connect the fan carts so that the fans are pointing away from each other.

While the cart system is at rest, turn on both fans.

Observe the motion of the cart. After making your observations, stop the cart system and turn off both fans.



Draw a diagram of the cart system. Include labeled arrows to indicate the direction of the fan force (F_{fan}) and the direction of the motion.	Describe the motion of the cart system.

Are the fan forces (F_{fan}) acting on the cart system balanced or unbalanced? Explain.

Does the motion of the cart change? Explain.

Force and Motion

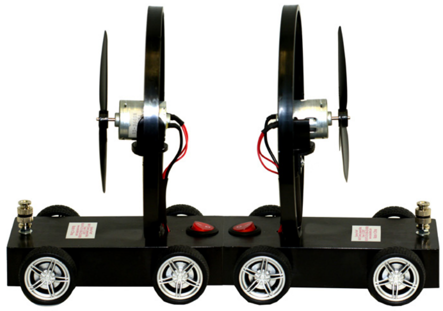
RM 6 continued

Part 5

Leave the fan carts connected so that the fans are pointing away from each other.

While the cart system is at rest, turn on both fans. Push the cart system so that it moves at least 1 meter.

Observe the motion of the cart system. After making your observations, stop the cart system and turn off both fans.



Draw a diagram of the cart system. Include labeled arrows to indicate the direction of the force and the direction of the motion.	Describe the motion of the cart system.

Are the fan forces acting on the cart system balanced or unbalanced? Explain.

Does the motion of the cart change? Explain.

What other forces might affect the motion of the cart system?

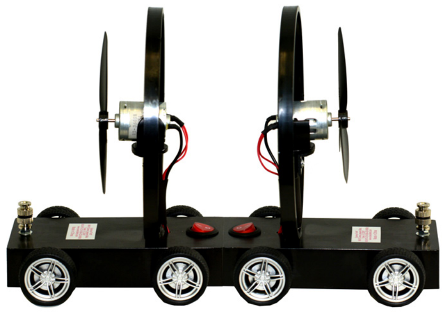
1207343 Science Academies_Lesson 8 .indd 303 4/27/2016 4:48:45 PM

Part 6

Leave the fan carts connected so that the fans are pointing away from each other.

Turn on one of the fans to get the cart system moving. While the cart system is moving, turn on the second fan.

Observe the motion of the cart system. After making your observations, stop the cart system and turn off both fans.



Note: If you are not able to turn on the second fan while the cart system is in motion, observe the motion of the cart when one fan is turned on and then motion of the cart when both fans are turned on.

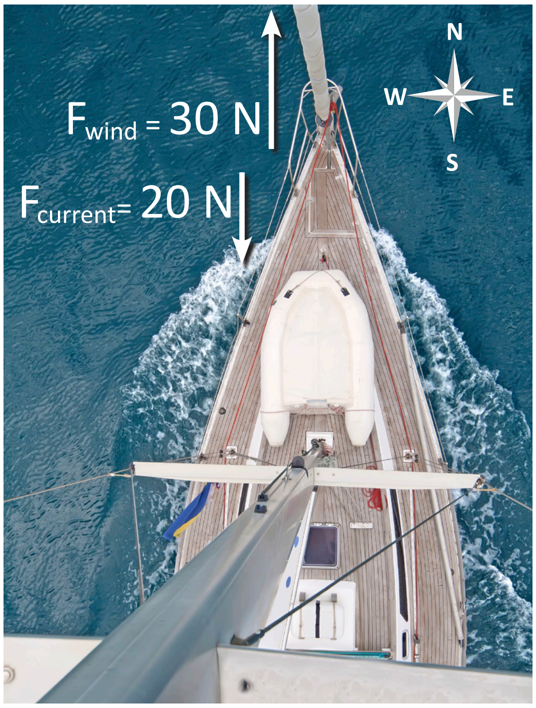
Draw a diagram of the cart system. Include labeled arrows to indicate the direction of the force and the direction of the motion.	Describe the motion of the cart system.

Are the fan forces acting on the cart system balanced or unbalanced? Explain.

Does the motion of the cart change? Explain.

RM 7: Evaluate

1. The diagram shows wind pushing a sailboat with 30 N of force to the north against a 20 N current to the south.



How will the motion of the sailboat be affected if it moves to an area of the water where the current is 25 N? Use evidence to justify your answer.

Force and Motion

RM 7: Evaluate

2. Three brothers and their dog are playing with a wagon. One brother pulls on the wagon with 22 N of force. A second brother pushes on the back of the wagon with 15 N of force. The grass applies 17 N of force on the wagon due to friction between the grass and the wagon wheels.

   a) Draw and label arrows to represent the three forces acting on the wagon.

   b) Calculate the net force acting on the wagon.

   c) How do the forces affect the motion of the wagon?

   d) Are the forces acting on the wagon balanced or unbalanced? Use evidence to support your answer.

Force and Motion

RM 7 continued

3. The London Eye is one of the largest Ferris wheels in the world. It rotates at a constant speed around 0.6 miles per hour. This is slow enough for passengers to board and exit the passenger cars while it is moving. It takes about 30 minutes to make one full rotation.

   Do the passenger cars on the wheel travel at a constant velocity or do the passenger cars accelerate? Use evidence to support your answer.

4. A toy train travels on a straight part of its track. The train is moving to the right with a constant speed of 1.2 m/s.

   The motor in the toy train applies 6 N of force on the toy train. The track applies 6 N of force on the toy train due to friction.

   a) What is the net force acting on the toy train?

   b) How do the forces affect the motion of the toy train?

   c) Are the forces balanced or unbalanced? Use evidence to support your answer.

   d) What will happen to the motion of the train if the force applied to the train is increased to 10 N?

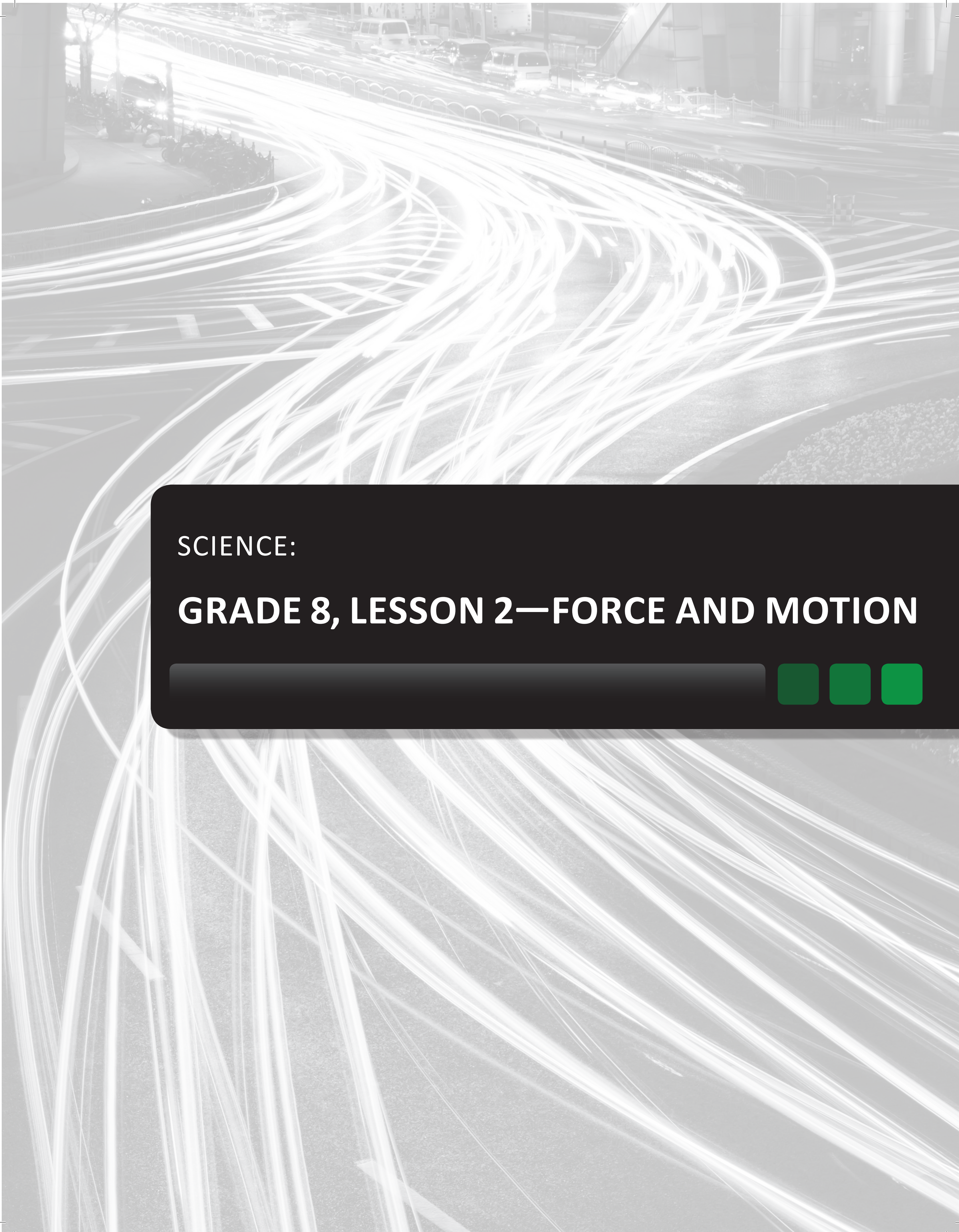
Force and Motion

RM 7 continued

5. Use the table below to differentiate between speed, velocity, and acceleration.

	Write a definition in your own words.	**Describe an example.**
speed		
velocity		
acceleration		

1207343 Science Academies_Lesson 8 .indd 313 4/27/2016 4:48:50 PM



SCIENCE:

GRADE 8, LESSON 2—FORCE AND MOTION

Force and Motion

Lesson Outline: Force, Mass, and Acceleration

Content Objectives

I can describe how force, mass, and acceleration are related.
I can solve problems using the formula F = ma*.*

Language Objective

I will write rules, or claims, about the relationships among force, mass, and acceleration based on observations during an investigation and evidence from text.

5E Lesson Summary

Engage

Students discuss examples and non-examples of acceleration.

Part One

This part of the Engage focuses on sorting and discussing examples and non-examples of acceleration.

Part Two

This part of the Engage focuses on classifying and discussing examples of acceleration as "large" accelerations and "small" accelerations.

Explore

Students complete three stations to investigate how force, mass, and acceleration are related.

Tier I Support

Provide sentence stems for students as an option for writing the generalization for each investigation.

Explain

Students discuss how force, mass, and acceleration are related.

Tier I Support

Students may read independently, with a partner, or with a small group. An audio recording of the text can be created for student use while reading. Calculators may be provided to allow students to check their calculations.

Part One

This part of the Explain focuses on debriefing the Explore activity and the relationships between force, mass, and acceleration.

Part Two
This part of the Explain focuses on using evidence from the reading passage and the Explore activity to support students' claims about force, mass, and acceleration.

Part Three
This part of the Explain focuses on using a problem solving chart and the formula $F = ma$ to calculate force, mass, and acceleration.

Elaborate
Students solve problems using the formula $F = ma$.

Tier I Support
Students may work independently or with a partner. Students may refer to the example problems on *RM 5* while completing the Elaborate activity. Calculators may be provided to allow students to check for multiplication and division errors.

Evaluate
Students analyze and answer questions about force, mass, and acceleration.

Tier I Support
Students can work independently, with a partner, or with a small group. Blank problem-solving charts from *RM 10: Problem-Solving Chart* can be provided as an optional support for students. Calculators may be provided to allow students to check for multiplication and division errors.

Force and Motion

Notes

SCIENCE:

GRADE 8, LESSON 2—FORCE AND MOTION

Force, Mass, and Acceleration

Force and Motion

Force, Mass, and Acceleration

Science Concept

8(6) Force, motion, and energy. The student knows that there is a relationship between force, motion, and energy. The student is expected to:

(A) demonstrate and calculate how unbalanced forces change the speed or direction of an object's motion

Content Objectives

I can describe how force, mass, and acceleration are related.

I can solve problems using the formula F = ma.

Science Process Skills

8(2) Scientific investigation and reasoning. The student uses scientific inquiry methods during laboratory and field investigations. The student is expected to:

(A) plan and implement comparative and descriptive investigations by making observations, asking well-defined questions, and using appropriate equipment and technology

(C) collect and record data using the International System of Units (SI) and qualitative means such as labeled drawings, writing, and graphic organizers

(E) analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends

Mathematics

6(4) Proportionality. The student applies mathematical process standards to develop an understanding of proportional relationships in problem situations. The student is expected to:

(H) convert units within a measurement system, including the use of proportions and unit rates

6(10) Expressions, equations, and relationships. The student applies mathematical process standards to use equations and inequalities to solve problems. The student is expected to:

(A) model and solve one-variable, one-step equations and inequalities that represent problems, including geometric concepts

Texas Education Agency

Force and Motion

8(1) Mathematical process standards. The student uses mathematical processes to acquire and demonstrate mathematical understanding. The student is expected to:

(B) use a problem-solving model that incorporates analyzing given information, formulating a plan or strategy, determining a solution, justifying the solution, and evaluating the problem-solving process and the reasonableness of the solution

English Language Arts and Reading

7(12) Reading/Comprehension of Informational Text/Procedural Texts. Students understand how to glean and use information in procedural texts and documents. Students are expected to:

(A) follow multi-dimensional instructions from text to complete a task, solve a problem, or perform procedures

Figure 19

Reading/Comprehension Skills. Students use a flexible range of metacognitive reading skills in both assigned and independent reading to understand an author's message. Students will continue to apply earlier standards with greater depth in increasingly more complex texts as they become self-directed, critical readers. The student is expected to:

(D) make complex inferences about text and use textual evidence to support understanding

Force and Motion

English Language Proficiency Standards

(5) Cross-curricular second language acquisition/writing. The ELL writes in a variety of forms with increasing accuracy to effectively address a specific purpose and audience in all content areas. ELLs may be at the beginning, intermediate, advanced, or advanced high stage of English language acquisition in writing. In order for the ELL to meet grade-level learning expectations across foundation and enrichment curriculum, all instruction delivered in English must be linguistically accommodated (communicated, sequenced, and scaffolded) commensurate with the student's level of English language proficiency. For Kindergarten and Grade 1, certain of these student expectations do not apply until the student has reached the stage of generating original written text using a standard writing system. The student is expected to:

(B) write using newly acquired basic vocabulary and content-based grade-level vocabulary

Language Objective

I will write rules, or claims, about the relationships among force, mass, and acceleration based on observations during an investigation and evidence from text.

Response to Intervention/Tier I Differentiation

All science lessons support students in receiving quality Tier I instruction. Using the 5E model, knowledge is taught in a variety of contexts, integrating math, science, and ELAR content, thus supporting the active engagement of the students with the content. Lesson-specific differentiation strategies for addressing diverse student needs can be found in sections titled "Differentiation Strategy."

Differentiation should

- focus on skills students did not understand and extend the lesson for advanced students;
- be conducted in small groups or embedded in whole-group instruction; and
- provide students with a variety of strategies to process the information, such as
  - allowing for additional opportunities for verbal brainstorming of words associated with a topic (with teacher taking dictation);
  - making clear connections of new and more complex concepts to foundational aspects and prior knowledge;
  - participating in more tangible experiences, such as experiments, investigations, and active exploration;

- sorting academic vocabulary words into categories by common attributes, such as process words or science content vocabulary;
- organizing results of brainstorming into semantic maps or creating graphic organizers;
- discussing the meaning of a graphic organizer with a partner; and
- creating a visual representation to demonstrate understanding.

See the handout in the Instructional Resources section that addresses instructional strategies.

College and Career Readiness Standards—Science Standards

I.E.1 Effective communication of scientific information. Use several modes of expression to describe or characterize natural patterns and phenomena. These modes of expression include narrative, numerical, graphical, pictorial, symbolic, and kinesthetic.

II.B.1 Mathematics as a symbolic language. Carry out formal operations using standard algebraic symbols and formulae.

II.B.2 Mathematics as a symbolic language. Represent natural events, processes, and relationships with algebraic expressions and algorithms.

III.B.3 Scientific reading. Recognize scientific and technical vocabulary in the field of study and use this vocabulary to enhance clarity of communication.

III.B.4 Scientific reading. List, use, and give examples of specific strategies before, during, and after reading to improve comprehension.

VIII.C.2 Forces and motion. Understand forces and Newton's Laws.

Force and Motion

Vocabulary Focus

acceleration

force

mass

5E Lesson Summary

Engage
Students discuss examples and non-examples of acceleration.

Explore
Students complete three stations to investigate how force, mass, and acceleration are related.

Explain
Students discuss how force, mass, and acceleration are related.

Elaborate
Students solve problems using the formula $F = ma$.

Evaluate
Students analyze and answer questions about force, mass, and acceleration.

Engage

Content Builder

The goal of the Engage is to elicit student ideas about acceleration. Students should be able to describe acceleration as any change in velocity, including speeding up, slowing down, and/or change in direction. In the previous lesson, it was established that a force is required to cause an acceleration. A common misconception about force and acceleration is that a large force always makes an object move faster. However, a larger force results in a faster change in velocity, causing an object to speed up, slow down, or change direction faster. After students have identified examples of accelerations, they can further classify the examples as large accelerations or small accelerations. When debriefing the Engage, use the facilitation questions to provide an opportunity for students to discuss and compare large accelerations to small accelerations.

Materials

For student groups

- RM 1 in an envelope or plastic bag
- chart paper or bulletin paper (optional)
- tape or chalk (optional)

Teacher Note

RM stands for reproducible master.

Students will complete an Example/Non-Example T-chart as a group. If chart paper or bulletin paper is not available, consider the following alternative methods:

- Use chalk to draw the T-chart on lab tables or on a concrete surface outside.
- Use masking tape or painter's tape to create a T-chart on lab tables or desks.

Advance Preparation

For each group, print a set of *RM 1: Acceleration Cards* on cardstock. Laminate and cut each set of cards, and place in an envelope or plastic bag for storage. Create an Example/Non-Example T-chart on chart paper or bulletin paper for each group (optional).

Part One

This part of the Engage focuses on sorting and discussing examples and non-examples of acceleration.

Force and Motion

Teacher Instruction

- Instruct each group to use chalk or tape to create an Example/Non-Example T-chart on their work surface.
- Distribute one set of acceleration cards to each group.
- Instruct students to read and discuss each card to determine whether the card is an example or a non-example of an acceleration.
- After groups have completed the T-chart, discuss the placement of each card as a whole group. A copy of *RM 1* can be used as an answer key. The left column includes examples of accelerations. The right column includes non-examples of accelerations.
- Debrief the activity using the facilitation questions.

Facilitation Questions

- In science, what do we call changes in velocity? *Changes in velocity are called accelerations.*
- What are the three types of acceleration? *The three types of acceleration are speeding up, slowing down, and changing direction.*
- What causes an acceleration? *Forces cause accelerations.*

Part Two

This part of the Engage focuses on classifying and discussing examples of acceleration as “large” accelerations and “small” accelerations.

Teacher Instruction

- Explain to students that a “large” acceleration does not always result in an object going very fast. A large acceleration means that the velocity of an object is changing very quickly. The object is quickly speeding up, slowing down, or changing direction.
- Ask student volunteers to describe examples of large accelerations.
- Explain to students that a “small” acceleration means that the velocity of the object is changing slowly. The object gradually speeds up, slows down, or changes direction.
- Ask student volunteers to describe examples of small accelerations.

- Ask students to think about the difference between large accelerations and small accelerations and how these feel when we experience different types of acceleration.
- Use the facilitation questions to debrief and discuss the difference between large accelerations and small accelerations.
- Instruct students to sort the examples of accelerations into large accelerations and small accelerations.
- Assign an example card to each student group, and ask the group to explain how they classified the example. Students may interpret examples differently based on their own experiences. Accept reasonable responses with appropriate justification. Examples of large accelerations should include objects that are quickly speeding up, slowing down, or changing direction, such as "an airplane slows down *quickly* after landing." Examples of small accelerations should include objects that are gradually speeding up, slowing down, or changing direction, such as "a soccer ball rolls to a stop in the grass."

Facilitation Questions

- Can you feel the difference between a large acceleration and a small acceleration? *Yes*
- How does speeding up very quickly in a car feel compared with speeding up gradually? *It feels like you are being pressed back into the seat when a car takes off quickly. The feeling is not as noticeable when you speed up slowly.*
- How does slowing down very quickly in a car feel compared with slowing down gradually? *It feels like you are being pushed or thrown forward when a car slows down quickly. The feeling is not as noticeable when you slow down slowly.*
- How does turning very quickly in a car feel compared with turning gradually? *It feels like you are being pushed or thrown to the side of the car when a car turns quickly. The feeling is not as noticeable when you turn slowly.*
- Which cards describe examples of large accelerations? *Answers will vary. Accept responses that include cards that describe an object speeding up, slowing down, or turning quickly. An airplane slowing down quickly and a rollercoaster car going down a hill may be interpreted as large accelerations.*

Force and Motion

- Which cards describe examples of small accelerations? *Answers will vary. Accept responses that include cards that describe an object speeding up, slowing down, or turning slowly. A soccer ball rolling to a stop in the grass may be interpreted as a small acceleration.*

Explore

Content Builder

The purpose of the Explore is for students to explore the relationships between force, mass, and acceleration. Students will make qualitative observations rather than quantitative measurements. By middle school, students are accustomed to taking measurements during science investigations. For this reason, many students will feel the need to measure the distance the cart travels as a measure of acceleration during Investigations 1 and 2. Acceleration describes how quickly the speed or direction of an object changes—how quickly the cart "takes off." Because there are other factors that may affect the distance the cart travels (e.g., mass, friction, hitting the meter stick), measuring the distance does not really indicate the acceleration of the cart.

Take time to conduct a whole-group discussion about making qualitative observations during the investigations. During Investigations 1 and 2, students will change the force or the mass, compare the relative accelerations of the cart, and write a rule to describe each relationship. Remind students that they should observe and compare how the cart takes off when force or mass are changed. Ask students to think about the following questions as they work:

- If you increase the force applied to the cart, what happens to the acceleration (take off) of the cart?
- If you increase the mass of the cart, what happens to the acceleration (take off) of the cart?

During Investigation 3, acceleration will be constant, and students will change mass to see how it is related to force. The cart will roll down a ramp to achieve a constant acceleration, and the cart will apply a force to an object at the bottom of the ramp. Students compare how hard the cart hits the object as the mass of the cart changes. The ramp should not be very steep so that the cart moves fairly slowly, and the angle of the ramp should not be changed during the investigation. Ask students to think about the following question as they work:

- If you increase the mass of the cart, what happens to the amount of force the cart applies to the object at the bottom of the ramp?

Materials

For teacher

- hot glue or other adhesive to glue plastic (optional)
- small, plastic containers or film canisters (optional)

For each student

- RM 3
- safety glasses

For student groups

- RM 2
- Hall's carriage cart or toy car
- 5 N or 10 N push-pull spring scale
- 2 meter sticks
- masking tape or painters tape (optional)
- washers, pennies, marbles, or other objects that can be used to add mass
- foam board or other sturdy material that can be used to make a ramp

continued on next page

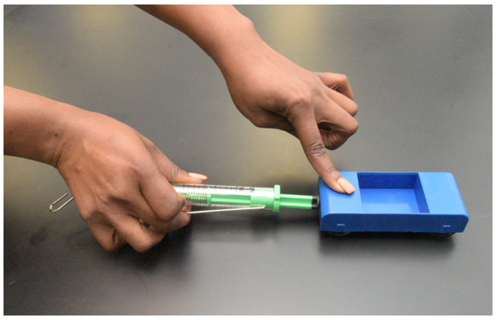
Force and Motion

- 1–2 1″ blocks or a book that is no more than 2″ thick (used to make a ramp)
- small plastic container of sand with lid

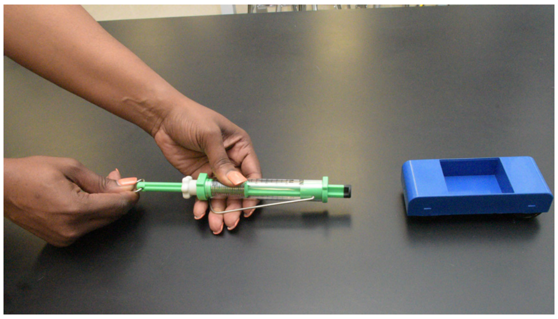
Teacher Note

The three investigations use many of the same materials. If enough materials are available, provide each group with materials and instructions for all three investigations. If materials are limited, the activity can be set up as station rotations. Because there are only three stations, you may need to prepare two or three set ups for each station.

Students need an opportunity to practice using the push-pull spring scale to “launch” the cart or toy car. The most consistent method is to place the spring scale on the table with the push bar facing the cart. While holding the spring scale in place with one hand, use your other hand to push the toy car against the push bar until the spring scale reaches the desired number of Newtons of force.



Do



Don’t

A common misconception is that heavier objects fall faster than lighter objects. If students struggle with this misconception, they may not recognize that acceleration is constant in Investigation 3 as long as the angle of the ramp does not change. An optional teacher demonstration or student activity is to use a timer to measure the amount of time it takes the cart to roll down the ramp with different amounts of mass. The amount of time should be about the same regardless of the mass of the cart.

Advance Preparation

If Hall’s carriage carts or similar carts are not available, small toy cars can be used at each station. Use hot glue to attach a small container, such as a plastic film canister or small plastic container with a lid, to the top of each toy car so that mass may be added to the car. If small containers are not available, students may tape washers or coins to the top of the car to add mass. Make sure the tape does not interfere with the motion of the toy car.

For Investigations 1 and 2, the meter sticks are used as a “track” to guide the motion of the cart. Masking tape can be placed over the numbers on the meter sticks to discourage students from measuring distance to describe acceleration.

Texas Education Agency

1207343 Science Academies_Lesson 8 .indd 330 4/27/2016 3:37:48 PM

Force and Motion

For Investigation 3, the cart will hit an object at the bottom of a ramp. The object should not move more than a few centimeters when it is hit by the cart. A sealed plastic container with sand or rice works well for this station. Prepare a plastic container with an appropriate amount of sand for each group. Another option is to place some sand or rice in a plastic bag, and place the sealed bag in a plastic beaker.

Teacher Instruction

- Assign students to groups of 2–4 students.
- Distribute *RM 3: Investigating Force, Mass, Acceleration Student Page* to each student.
- Distribute *RM 2: Investigating Force, Mass, and Acceleration* instruction cards and materials to each group. If using station rotations, explain how student groups will move from one station to the next.
- Use the facilitation questions to review the terms *independent variable*, *dependent variable*, and *controlled variable*.
- Describe each of the three investigation activities.
- Model the appropriate method to use a push-pull spring scale to launch the cart or toy car.
- Conduct a class discussion about different ways to observe and compare the acceleration of the cart or toy car. Guide students to the understanding that they don't have an accurate way to measure acceleration with the materials they are using for this investigation. Measuring distance and time will help them determine an average speed, but it will not help them determine acceleration. Students should observe and compare how quickly the cart takes off when different amounts of force or mass are used. They may need to repeat many trials before they write their generalizations.
- Allow 25–30 minutes for students to complete the activity.

Tier I Support

Provide sentence stems for students as an option for writing the generalization for each investigation. Possible sentence stems include the following:

- If the force increases/decreases, the acceleration . . .
- If the mass increases/decreases, the acceleration . . .
- If the mass increases/decreases, the force . . .

Force and Motion

Facilitation Questions

- What is a variable in an experimental investigation? *A variable is any factor in an investigation that can change.*
- In an experimental investigation, what is the independent variable? *The independent variable is the variable that is changed, or manipulated, by the investigator. There is only one independent variable in an experimental investigation.*
- In an experimental investigation, what is the dependent variable? *The dependent variable is the responding variable. The dependent variable changes as a result of the independent variable. There is only one dependent variable in an experimental investigation.*
- In an experimental investigation, what are controlled variables? *Controlled variables are any variables that remain constant during an investigation. There can be more than one controlled variable in an investigation.*

Explain

Content Builder

Students will create a folded model with manipulatives during Part One of Explain. The manipulative is designed to help students visualize the relationships they investigated during Explore. Read through all of the teacher instructions before debriefing the Explore activity and creating the folded model with manipulatives.

In science, a claim is an answer to an investigation question that is supported by evidence. When students created their generalization, or rule, during Explore, they were writing a claim. Their observations were evidence to support their claim. During Part Two of Explain, students will read about force, mass, and acceleration. After reading, groups will use their completed *RM 3* from the Explore activity to complete *RM 6: Using Evidence to Support a Claim*, evaluate evidence from the Explore activity and the reading passage, and make real-world connections to one of their claims. This strategy supports student discussion about the content and helps students make connections with what they experienced during Explore, what they read during Explain, and what they have observed in the world around them. Conducting a gallery walk to view the work of other groups provides additional opportunities for discussion, analysis, and reflection.

Materials

For teacher
- RM 6
- RM 7

For each student
- RM 4 (3 strips per student)
- cardstock
- three small brass fasteners
- RM 5
- highlighters (optional)
- scissors

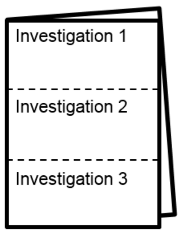
For student groups
- chart paper
- markers
- sticky notes
- RM 6 (optional)
- hole punch (optional)

Part One

This part of the Explain focuses on debriefing the Explore activity and the relationships between force, mass, and acceleration.

Teacher Instruction

- Distribute one piece of paper or cardstock, three aFm strips from *RM 4: aFm Strips*, and three brass fasteners to each student.
- Instruct students to fold the paper or cardstock in half to form a booklet, and cut the front page of the booklet to form three flaps.

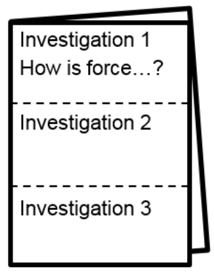


- Instruct students to label Investigation 1, Investigation 2, and Investigation 3 at the top of the three flaps as shown in the diagram. Students will record information from each investigation on the three flaps.

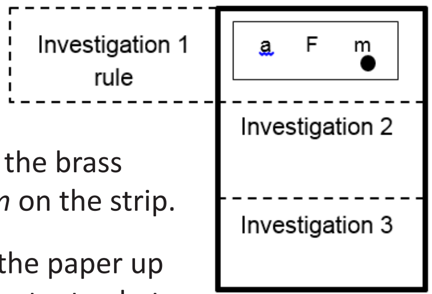
Force and Motion

Investigation 1

- Instruct students to record the question from Investigation 1, “How is force related to acceleration?” on the front of the flap labeled Investigation 1.
- Use the following questions to debrief Investigation 1.



  - What did you observe in Investigation 1? What was your generalization, or rule? *Answers will vary.*
  - What were the independent and dependent variables in Investigation 1? *The independent variable was force, and the dependent variable was acceleration.*
  - What was held constant in Investigation 1? *Mass was held constant.*
- Instruct students to look at one of the aFm strips. Ask, “What do you think the *a*, the *F*, and the *m* stand for?” *acceleration, force, and mass*



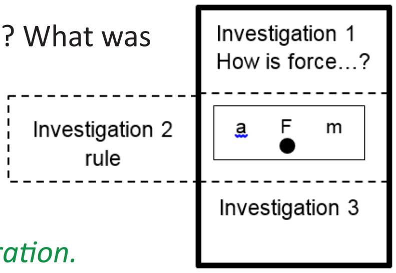
- Instruct students to use a brass fastener to attach an aFm strip inside the flap of the Investigation 1 section of the folded model. Explain to students that because mass was held constant in Investigation 1, the brass fastener should be positioned below the *m* on the strip.
- Instruct students to move the free end of the paper up and down. Ask students, “If the mass is constant, what happens to acceleration as force increases?” As you ask the question, raise the free end of the strip, and the *a* and the *F* will both move up. Ask, “Does this model support your rule about force and acceleration?”
- Ask students, “If the mass is constant, what happens to acceleration as force decreases?” As you ask the question, lower the free end of the strip, and the *a* and the *F* will both move down. Ask, “As force moves down, or decreases, on this model, what happens to acceleration? Does this model support your rule about force and acceleration?”
- Instruct students to record their generalization, or rule, for force and acceleration on the inside of the Investigation 1 flap.

TEA Texas Education Agency

1207343 Science Academies_Lesson 8 .indd 334 4/27/2016 3:37:49 PM

Investigation 2

- Instruct students to record the question from Investigation 2, "How is mass related to acceleration?" on the front of the flap labeled Investigation 2.
- Use the following questions to debrief Investigation 2.
    - What did you observe in Investigation 2? What was your rule? *Answers will vary.*
    - What were the independent and dependent variables in Investigation 2? *The independent variable was mass, and the dependent variable was acceleration.*
    - What was held constant in Investigation 2? *Force was constant.*



- Instruct students to use a brass fastener to attach an aFm strip inside the flap of the Investigation 2 section of the folded model. Explain to students that because force was held constant in Investigation 2, the brass fastener should be positioned below the *F* on the strip.
- Instruct students to move one end of the paper up and down. Ask students, "If the force is constant, what happens to acceleration as mass increases?" As you ask the question, raise the end of the strip labeled *m*, and the *a* will move down. Ask, "Does this model support your rule about mass and acceleration?"
- Ask students, "If the force is constant, what happens to acceleration as mass decreases?" As you ask the question, lower the end of the strip labeled *m*, and the *a* will move up. Ask, "Does this model support your rule about mass and acceleration?"
- Instruct students to record their rule for mass and acceleration on the inside of the Investigation 2 flap.

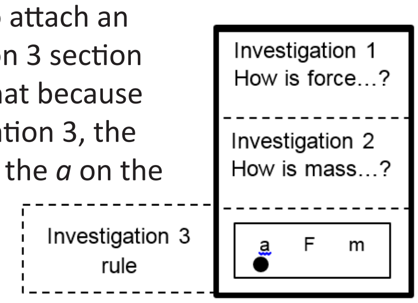
Investigation 3

- Instruct students to record the question from Investigation 3, "How is mass related to force?"
- Use the following questions to debrief Investigation 3.
    - What did you observe in Investigation 3? What was your rule? *Answers will vary.*

Force and Motion

  - What were the independent and dependent variables in Investigation 3? *The independent variable was mass, and the dependent variable was force.*
  - What was held constant in Investigation 3? *Acceleration was constant.*

- Instruct students to use a brass fastener to attach an aFm strip inside the flap of the Investigation 3 section of the folded model. Explain to students that because acceleration was held constant at Investigation 3, the brass fastener should be positioned below the *a* on the strip.



- Instruct students to move the free end of the paper up and down. Ask students, "If the acceleration is constant, what happens to force as mass increases?" As you ask the question, raise the end of the strip labeled *m*, and the *m* and the *F* will both move up. Ask, "Does this model support your rule about force and mass?"
- Ask students, "If the acceleration is constant, what happens to force as mass decreases?" As you ask the question, lower the end of the strip labeled *m*, and the *m* and the *F* will both move down. Ask, "As mass moves down, or decreases, on this model, what happens to force? Does this model support your rule about force and mass?"
- Instruct students to record their rule for mass and force on the inside of the Investigation 3 flap.

Part Two

This part of the Explain focuses on using evidence from the reading passage and Explore activity to support students' claims about force, mass, and acceleration.

Teacher Instruction

- Assign students to groups of 3–4.
- Distribute the *RM 5: Force, Mass, and Acceleration* reading passage to each student.
- Determine whether students will read independently or with a partner.
- Instruct students to read pages 1 and 2 and the box at the top of page 3 of *RM 5*. Students may choose to use a reading strategy, such as highlighting important information, as they read.

- After students have completed the reading, assign a different investigation question from Explore to each student group.
- Display *RM 6* for the whole class to view. A copy of *RM 6* can be provided to each group or to each student.
- Distribute chart paper, markers, and sticky notes to each group.
- Explain that in science, a claim is a possible answer to a question that is being investigated. In science, we must use evidence to support a claim.
- Instruct student groups to complete *RM 6* for their assigned investigation question on the chart paper.
- Allow 15–20 minutes for groups to complete the activity. Instruct groups to post their chart paper when they are finished.
- Conduct a gallery walk. Instruct students to use sticky notes to leave feedback on their peers' completed charts. Display the sentence stems on *RM 7: Gallery Walk Sentence Starters* to provide ideas for feedback.
- Provide time for student groups to review and discuss feedback from their peers.
- Debrief the claim and evidence charts.
- Use the facilitation questions to reflect on the activity as a whole group.

Tier I Support

Students may read independently, with a partner, or with a small group. An audio recording of the text can be created for student use while reading.

Facilitation Questions

- Did any of the feedback from your peers clarify or extend your understanding? Why? *Answers will vary based on the type of feedback they receive from their peers.*
- What do you think is the strongest evidence to support your claim? Why? *Answers will vary. Students may describe evidence from the investigation as the strongest evidence to support their claim because the investigation provides physical evidence and a personal experience.*
- Can you describe a real-world example that supports your claim? *Answers*

Force and Motion

will vary based on their ideas and background experiences. For example, more force is needed to push a grocery cart full of groceries than an empty grocery cart.

Part Three

This part of the Explain focuses on using a problem-solving chart and the formula *F = ma* to calculate force, mass, and acceleration.

Teacher Instruction

- Assign students to groups of 3–4.
- Determine whether students will read independently or with a partner.
- Instruct students to read *Calculating Force, Mass, and Acceleration* on pages 3 and 4 of *RM 5*. Students may choose to use a reading strategy, such as highlighting important information, as they read.
- Instruct students to complete Example 3 at the end of the reading passage.
- Use the facilitation questions, problem solving chart, and example problems to debrief the reading passage.

Tier I Support

Students may read independently, with a partner, or with a small group. An audio recording of the text can be created for student use while reading. Calculators may be provided to allow students to check their calculations.

Facilitation Questions

- Which of Newton's laws of motion describes the relationships between force, mass, and acceleration? *Newton's second law of motion relates force, mass, and acceleration.*
- What formula is used to describe the relationships between force, mass, and acceleration? *Force equals mass times acceleration, or* F = ma.
- What is the SI unit for force? *Force is measured in Newtons (N).*
- What is the SI unit for mass? *Mass is measured in kilograms (kg).*

Force and Motion

- What is the SI unit for acceleration? *Acceleration is measured in meters per second squared (m/s^2).*
- When using the problem-solving chart, what should you do if your solution is not reasonable (close to your estimate)? *If the solution to the problem is not reasonable, there may have been a calculation error or a procedural error. Check calculations for errors. If there are no multiplication or division errors, try a different process to solve the problem.*

Answer Key

Example 3: A bowler uses 10.5 N of force to roll a bowling ball, and the ball accelerates down the bowling lane at a rate of 2.5 m/s^2. What is the mass of the bowling ball to the nearest tenth of a kilogram?

Known variables	*force = 10.5 N acceleration = 2.5 m/s^2*
Write the **Formula**	F = m • a
Substitute known variables	*10.5 = m • 2.5*
Make a reasonable **Estimate**	*What times 2.5 equals 10.5?* *4 x 2.5 = 10, so the answer should be around 4.* *10 ÷ 2.5 = 4, so I should divide.*
Solve the equation	*10.5 = m • 2.5* $\frac{10.5}{2.5} = \frac{m \bullet 2.5}{2.5}$ *4.2 = m* *mass = 4.2 kg*

1207343 Science Academies_Lesson 8 .indd 339 4/27/2016 3:37:50 PM

Force and Motion

Elaborate

Materials

For each student

- RM 5
- RM 8
- calculator (optional)

Content Builder

Students begin substituting numbers into formulae and solving for variables in grade 6 mathematics. Students in grade 8 science should be able to use the formula $F = ma$ to solve for force, mass, or acceleration. The problem-solving chart was developed to help students use a problem-solving method that is similar to what students experience in their mathematics classes. In mathematics, middle school students focus on identifying what is known and substituting known variables into the formula. Before solving the equation, students should make a reasonable estimate based on the information provided. When students solve the problem, they should compare their answer with their estimate to check the reasonableness of the answer. If a calculated answer is significantly different than an estimate, it is possible that the student made one of the following errors:

- A substitution error, such as replacing a variable with the wrong number
- A procedural error, such as multiplying instead of dividing
- A calculation error, such as a mistake when multiplying or dividing numbers

If students find their answer is not reasonable based on their estimate, they should check for an error and try a different process.

Teacher Instruction

- Distribute *RM 8: Calculating Force, Mass, and Acceleration* to each student.
- Review the proper method for recording an answer and filling in bubbles on the answer grid.
- Instruct students to complete *RM 8*. Students may want to refer to the sample problems from the *RM 5* reading passage as they complete *RM 8*.
- Allow 20–30 minutes for students to complete *RM 8*.
- After students finish, instruct students to find a partner or form a group of three students. Allow 5–10 minutes for students to discuss and compare their calculations.
- Use the answer key and facilitation questions to debrief the activity.

Force and Motion

Tier I Support

Students may work independently or with a partner. Students may refer to the example problems on *RM 5* while completing the Elaborate activity. Calculators may be provided to allow students to check for multiplication and division errors.

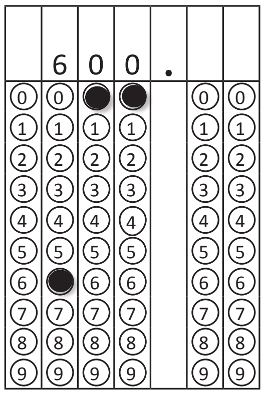
Facilitation Questions

- How did you make a reasonable estimate? *Answers will vary.*
- Does your solution to the problem make sense? Is it close to your estimate? *Answers will vary.*

RM 8 Answer Key

1. A passenger with a mass of 50 kg is riding an amusement park ride. When the ride starts, the passenger accelerates at a rate of 12 m/s^2. How much force in Newtons does the passenger experience?

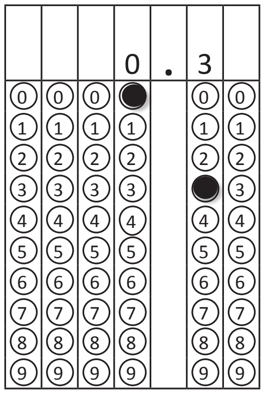
Known variables	mass = *50 kg* acceleration = *12 m/s^2*
Write the **Formula**	*F = m • a*
Substitute known variables	*F = 50 • 12*
Make a reasonable **Estimate**	*50 times 10 is 500, so the answer should be more than 500.*
Solve the equation	*F = 50 • 12* *F = <u>**600 N**</u>*



Force and Motion

2. A gardener uses a wheelbarrow to move soil to a flower bed. The wheelbarrow of soil has a mass of 32 kg. If the gardener applies a force of 9.6 N, what is the acceleration of the wheelbarrow to the nearest tenth m/s^2?

Known variables	*mass = 32 kg* *force = 9.6 N*
Write the **Formula**	$F = m \bullet a$
Substitute known variables	$9.6 = 32 \bullet a$
Make a reasonable **Estimate**	*9.6 can be rounded to 10; 32 can be rounded to 30.* $10 = 30 \bullet a$ *What times 30 = 10?* *10 is 1/3 of 30, so 1/3 times 30 = 10.* *The answer should be close to 1/3 or 0.33.*
Solve the equation	$96 = 32 \bullet a$ $\frac{9.6}{32} = \frac{32 \bullet a}{32}$ $0.3 = a$ ***acceleration = <u>0.3 m/s²</u>***



Force and Motion

3. A car runs out of gas, and the driver decides to push the car to the gas station at the end of block. When the driver applies 190 N of force, the car has an acceleration of 0.2 m/s². What is the mass of the car in kilograms?

Known variables	*force = 190 N acceleration = 0.2 m/s²*
Write the **Formula**	*F = m • a*
Substitute known variables	*190 = m • 0.2*
Make a reasonable **Estimate**	*190 can be rounded to 200.* *0.2 is the same as 1/5.* *200 is 1/5 of 1000.* *The answer should be close to 1000.*
Solve the equation	*190 = m • 0.2* $\frac{190}{0.2} = \frac{m \cdot 0.2}{0.2}$ *950 = m* *mass =* ***950 kg***

	9	5	0	.		
0	0	0	●		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	3	3	3		3	3
4	4	4	4		4	4
5	5	●	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	●	9	9		9	9

4. A 40-kg person is riding a 100-kg motorcycle. How much force is needed to accelerate the motorcycle and its rider at a rate of 2.5 m/s²?

Known variables	*Mass of motorcycle and rider = 140 kg* *acceleration = 2.5 m/s²*
Write the **Formula**	*F = m • a*
Substitute known variables	*F = (40 + 100) • 2.5* *F = 140 • 2.5*
Make a reasonable **Estimate**	*140 can be rounded to 150.* *150 • 2 = 300* *150 • 3 = 450* *The answer should be between 300 and 450.*
Solve the equation	*F = 140 • 2.5* *F =* ***350 N***

	3	5	0	.		
0	0	0	●		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	●	3	3		3	3
4	4	4	4		4	4
5	5	●	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	9	9	9		9	9

1207343 Science Academies_Lesson 8 .indd 343 4/27/2016 3:37:51 PM

Force and Motion

5. During a science investigation, students used a spring to apply 10 N of force to a cart with different amounts of mass. The mass of the cart during each trial is recorded in the table below.

Trial	Mass of the Cart (kg)
1	0.25
2	0.50
3	0.75
4	1.0

During which trial does the cart have the greatest acceleration? Explain your answer.

The car has the greatest acceleration during Trial 1 because objects with less mass will accelerate more than objects with greater mass. The acceleration of the car can be calculated for each trial as additional evidence to support the answer.

Trial 1: $F = ma \quad 10\ N = 0.25 \bullet a \quad \frac{10}{0.25} = \frac{0.25 \bullet a}{0.25} \quad \text{acceleration} = 40\ m/s^2$

Trial 2: $F = ma \quad 10\ N = 0.50 \bullet a \quad \frac{10}{0.50} = \frac{0.50 \bullet a}{0.50} \quad \text{acceleration} = 20\ m/s^2$

Trial 3: $F = ma \quad 10\ N = 0.75 \bullet a \quad \frac{10}{0.75} = \frac{0.75 \bullet a}{0.75} \quad \text{acceleration} = 13.3\ m/s^2$

Trial 4: $F = ma \quad 10\ N = 1.0 \bullet a \quad \frac{10}{1.0} = \frac{1.0 \bullet a}{1.0} \quad \text{acceleration} = 10\ m/s^2$

1207343 Science Academies_Lesson 8 .indd 344 4/27/2016 3:37:51 PM

Evaluate

Teacher Instruction

- Distribute *RM 9: Evaluate* to each student.
- Determine how students will work through the Evaluate activity.
- Instruct students to use their knowledge of force, mass, and acceleration to complete *RM 9*.

Materials

For each student

- RM 9
- RM 10 (optional)
- calculator (optional)

Tier I Support

Students can work independently, with a partner, or with a small group. Blank problem-solving charts from *RM 10: Problem-Solving Chart* can be provided as an optional support for students. Calculators may be provided to allow students to check for multiplication and division errors.

RM 9 Answer Key

1. For an investigation, a student drops four different density cubes from a height of 1 meter into a container of sand. Each cube has the same volume but a different mass. The mass of each cube is recorded in the table below.

Cube	Mass (g)
Aluminum cube	22.4
Brass cube	66.3
Plastic cube	11.2
Wood cube	6.4

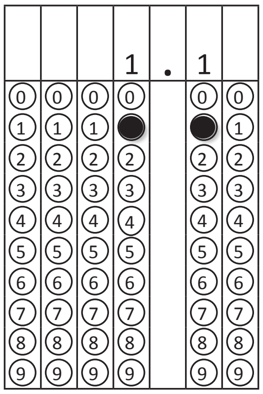
Because of the force of gravity, each cube will accelerate at the same rate as it falls. When a cube is dropped into the sand, it creates a crater in the sand.

Which cube will make the biggest crater? Explain why.

The brass cube will make the biggest crater because it will hit the sand with the most force. If objects accelerate at the same rate, the object with the most mass will apply the most force.

Force and Motion

2. A person playing mini golf hits a 0.2 kg golf ball, and the ball accelerates 5.5 m/s^2. How much force was applied to the golf ball to the nearest tenth of a Newton?



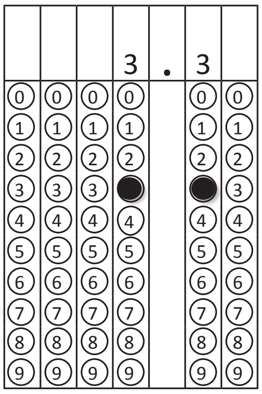
mass = 0.2 kg   *acceleration = 5.5 m/s^2*

F = ma

F = 0.2 • 5.5

*F = **1.1 N***

3. A team of sled dogs applies 500 N of force to a 150 kg sled. What is the acceleration of the sled to the nearest tenth of a m/s^2?



force = 500 N   *mass = 150 kg*

F = ma

500 = 150 • a

$$\frac{500}{150} = \frac{150 \cdot a}{150}$$

3.3 = a

*acceleration = **3.3 m/s^2***

4. During a science investigation, students used a spring scale to apply different amounts of force to a cart. The force of the spring scale and acceleration of the cart are recorded in the table below.

Trial	Force (N)	Acceleration (m/s^2)
1	2	0.5
2	4	1.0
3	6	1.5
4	*10*	2.5

How much force was applied to the cart during trial 4? Use evidence to support your answer.

The force is 10 N during Trial 4. As force increases, acceleration also increases. Looking at the pattern, as the force increases 2 N, the acceleration increases 0.5 m/s^2. F = ma *can be used to determine the mass based off of data in one of the other trials. If the mass is known, force can be calculated for Trial 4.*

Force and Motion

5. Three different sports balls are kicked during gym class.

soccer ball	football	playground ball
		
mass = 0.45 kg	mass = 0.40 kg	mass = 0.48 kg
force = 13.5 N	force = 15 N	force = 16.5 N

Calculate the acceleration for each type of ball. Rank the three balls in order from least acceleration to greatest acceleration. Show your work.

soccer ball, playground ball, football

soccer ball	*football*	*playground ball*
$F = m \cdot a$	$F = m \cdot a$	$F = m \cdot a$
$13.5 = 0.45 \cdot a$	$15 = 0.40 \cdot a$	$16.5 = 0.48 \cdot a$
$\frac{13.5}{0.45} = \frac{0.45 \cdot a}{0.45}$	$\frac{15}{0.40} = \frac{0.40 \cdot a}{0.40}$	$\frac{16.5}{0.48} = \frac{0.48 \cdot a}{0.48}$
30 = a	37.5 = a	34.4 = a
acceleration = ***30 m/s²***	*acceleration* = ***37.5 m/s²***	*acceleration* = ***34.4 m/s²***

Force and Motion

RM 1: Acceleration Cards

Examples of Acceleration	Non-Examples of Acceleration
a roller coaster car goes down a hill	a roller coaster car is stationary as passengers are unloading
an airplane slows down quickly after landing	an airplane travels at 150 miles/hour along a straight flight path
a car travels along a curved road at a constant speed 	a car travels across a straight bridge at a constant speed 

1207343 Science Academies_Lesson 8 .indd 349 4/27/2016 3:37:56 PM

Force and Motion

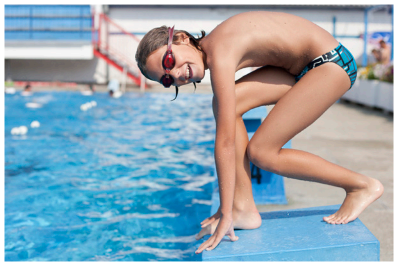
RM 1 continued

a group of children ride a merry-go-round

a football rests on a stand

a runner takes off at the beginning of a race

a swimmer waits on the platform to start a race



a soccer ball rolls to a stop in the grass

an escalator moves at a constant speed

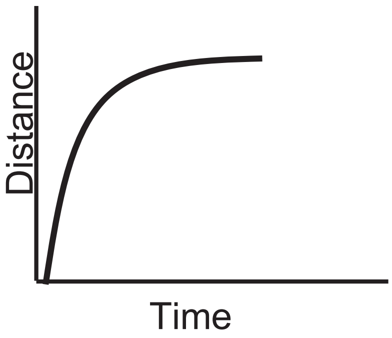
m/s^2

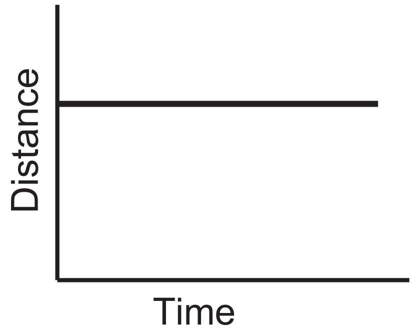
m/s

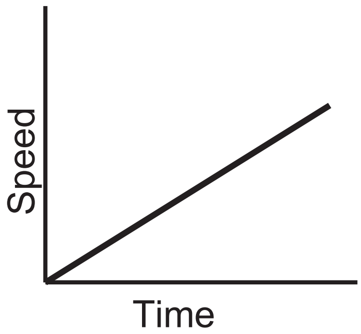
1207343 Science Academies_Lesson 8 .indd 351 4/27/2016 3:38:02 PM

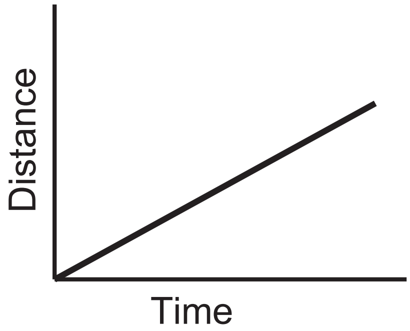
Force and Motion

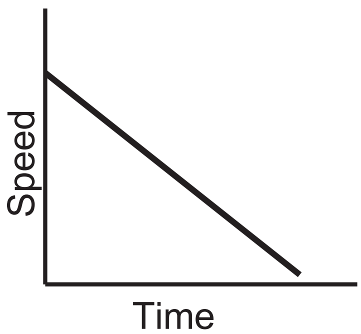
RM 1 continued

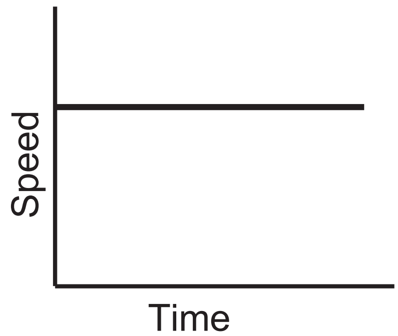


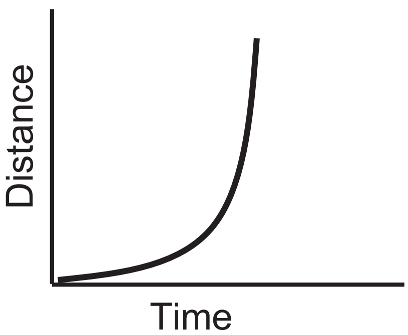












1207343 Science Academies_Lesson 8 .indd 353 4/27/2016 3:38:02 PM

Force and Motion

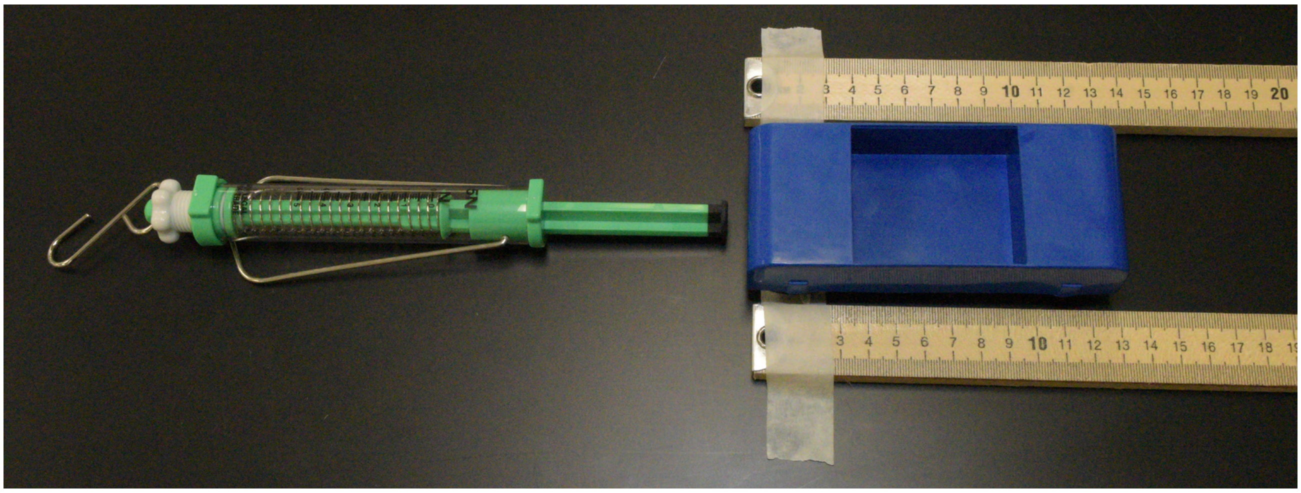
RM 2: Investigating Force, Mass, and Acceleration

Investigation 1
How is *force* related to *acceleration*?

Materials

- Push–pull spring scale
- Hall's carriage cart or toy car
- 2 meter sticks
- masking tape or painters tape (optional)
- washers, pennies, marbles, or other objects that can be used to add mass
- safety glasses

Note: There is not an accurate method to measure acceleration for this investigation using the materials provided. Focus on observing how changes in force affect how the car "takes off," or accelerates.



Procedure

Use the materials provided to conduct an investigation to determine how the amount of force affects the acceleration of an object.

1. Describe and sketch your investigation.
2. Record the independent, dependent, and controlled variables in this investigation.
3. Record your observations.
4. Write a generalization (rule) that describes the relationship between force and acceleration based on your observations.

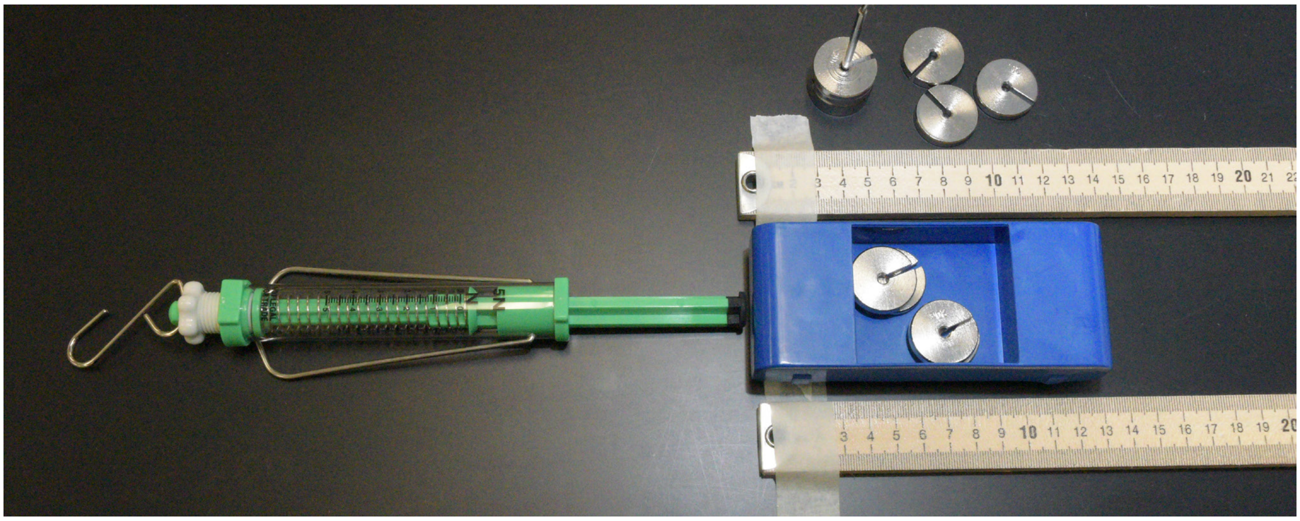
1207343 Science Academies_Lesson 8 .indd 355 4/27/2016 3:38:04 PM

Investigation 2
How is *mass* related to *acceleration*?

Materials

- Push–pull spring scale
- Hall's carriage cart or toy car
- 2 meter sticks
- masking tape or painters tape (optional)
- washers, pennies, marbles, or other objects that can be used to add mass
- safety glasses

Note: There is not an accurate method to measure acceleration for this investigation using the materials provided. Focus on observing how changes in mass affect how the car "takes off," or accelerates.



Procedure

Use the materials provided to conduct an investigation to determine how the mass of an object affects its acceleration.

1. Describe and sketch your investigation.
2. Record the independent, dependent, and controlled variables in this investigation.
3. Record your observations.
4. Write a generalization (rule) that describes the relationship between mass and acceleration based on your observations.

Force and Motion

RM 2 continued

Investigation 3
How is *mass* related to *force*?

Materials

- Hall's carriage cart or toy car
- foam board or other sturdy material that can be used to make a ramp
- 1–2 blocks or a book (to make a ramp)
- meter stick
- pennies, washers, or other objects that can be used to add mass
- small, sealed plastic container with sand
- safety glasses

Note: The cart will accelerate as it moves down the ramp. Do not change the angle of the ramp during the investigation so that acceleration remains the same. Focus on observing how changes in mass affect force.

Procedure

Use the materials provided to conduct an investigation to determine how the mass of an object affects the force it applies to another object.

1. Describe and sketch your investigation.
2. Record the independent, dependent, and controlled variables in this investigation.
3. Record your observations.
4. Write a generalization (rule) that describes the relationship between mass and force based on your observations.

Investigating Force, Mass, and Acceleration
Investigation 1: How is *force* related to *acceleration*?

If you increase the force applied to the cart, what happens to the acceleration (take off) of the cart?

1. Describe and sketch the investigation.

2. Circle **F**, **m**, or **a** to identify each of the variables in this investigation.

Independent Variable (manipulated)	Dependent Variable (responding)	Controlled Variable (constant)
F m a	**F m a**	**F m a**

3. Record your observations.

4. Write a generalization (rule) that describes the relationship between force and acceleration based on your observations.

Force and Motion

RM 3 continued

Investigation 2: How is *mass* related to *acceleration*?

If you increase the mass of the cart, what happens to the acceleration (take off) of the cart?

1. Describe and sketch the investigation.

2. Circle **F**, **m**, or **a** to identify each of the variables in this investigation.

Independent Variable (manipulated)	Dependent Variable (responding)	Controlled Variable (constant)
F m a	**F m a**	**F m a**

3. Record your observations.

4. Write a generalization (rule) that describes the relationship between mass and acceleration based on your observations.

Force and Motion

RM 3 continued

Investigation 3: How is *mass* related to *force*?

If you increase the mass of the cart, what happens to the amount of force the cart applies to the object at the bottom of the ramp?

1. Describe and sketch the investigation.
2. Circle **F**, **m**, or **a** to identify each of the variables in this investigation. Independent Variable (manipulated): **F m a** Dependent Variable (responding): **F m a** Controlled Variable (constant): **F m a**
3. Record your observations.
4. Write a generalization (rule) that describes the relationship between mass and force based on your observations.

Force and Motion

RM 4: aFm Strips

a	F	m
a	F	m
a	F	m

a	F	m
a	F	m
a	F	m

Force, Mass, and Acceleration

Newton's Laws of Motion

Sir Isaac Newton published *Philosophiae Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy)* in 1687. In his work, he described three ideas about motion that are now known as Newton's Laws of Motion.

First Law: Law of Inertia

An object at rest will remain at rest until an unbalanced force causes it to move. An object in motion will continue moving at the same speed and in the same direction until an unbalanced force changes its motion.

Second Law: Law of Force and Acceleration

The second law describes the relationship between force, mass, and acceleration. When mass is constant, acceleration is directly related to force. The relationship can be described mathematically using the formula Force = mass • acceleration.

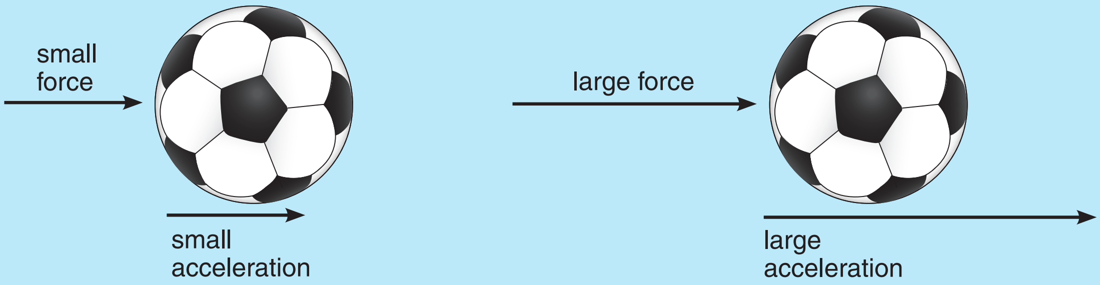
Third Law: Law of Action–Reaction

Forces occur in pairs, and every action (force) has an equal and opposite reaction (force). This means when a force is applied to an object, that object applies an equal force in the opposite direction.

Let's look more closely at the relationships between force, mass, and acceleration described in Newton's second law of motion.

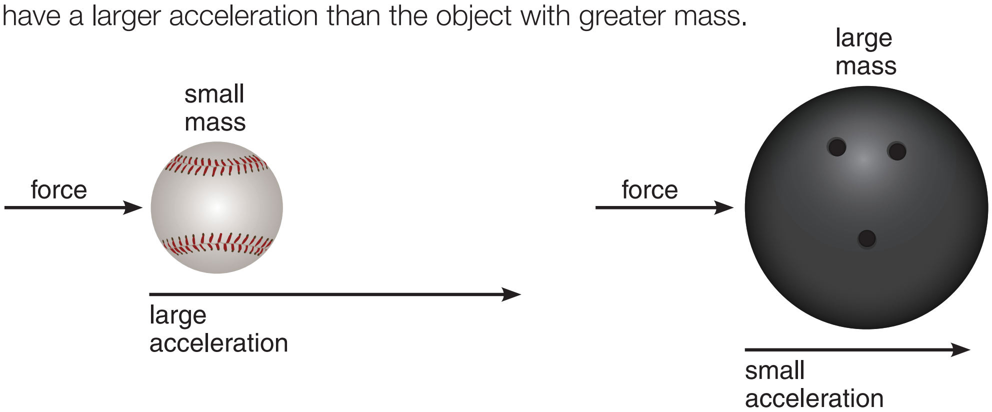
HOW ARE FORCE AND ACCELERATION RELATED?

An unbalanced force will result in a change in motion—speeding up, slowing down, or changing direction. In science, these changes in motion are called accelerations. According to the second law of motion, the acceleration of the object is directly related to the force that caused the change in motion. This means a small force will result in a small acceleration, and a large force will result in a large acceleration.



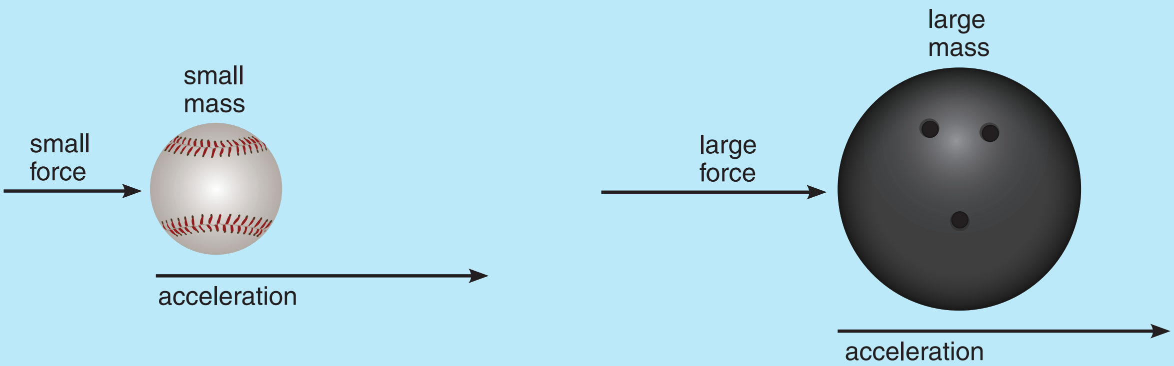
HOW ARE MASS AND ACCELERATION RELATED?

The acceleration of an object is inversely related to its mass. **Inverse** means opposite. If variables are inversely related, one variable increases as the other variable decreases. What does this tell us about mass and acceleration? If the same amount of force is applied to objects with different mass, the object with less mass will have a larger acceleration than the object with greater mass.



HOW ARE FORCE AND MASS RELATED?

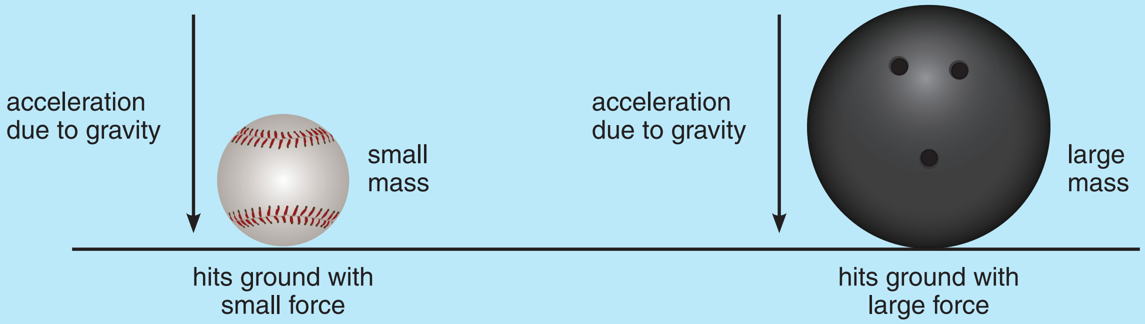
Force and mass are directly related. If variables are directly related, one variable increases as the other variable increases. What does this tell us about force and mass? More force is needed to accelerate an object with a large mass. Less force is needed to accelerate an object with a small mass.



© 2016 TEXAS EDUCATION AGENCY. ALL RIGHTS RESERVED.

1207343 Science Academies_Lesson 8 .indd 370 4/27/2016 3:38:09 PM

Let's think about force and mass another way. If two balls are falling at the same rate of acceleration and hit the ground, the ball with more mass applies a greater force to the ground than the ball with less mass.



CALCULATING FORCE, MASS, AND ACCELERATION

The second law of motion describes the relationships between force, mass, and acceleration using the formula Force = mass • acceleration.

$$F = ma$$

This formula can be used to calculate
- force in Newtons (N),
- mass in kilograms (kg), and
- acceleration in meters per second squared (m/s^2).

The following steps can be used when solving problems about force, mass, and acceleration.
1. Read the problem, and record the **Known** variables.
2. Write the **Formula**.
3. **Substitute** know variables into the formula.
4. Make a reasonable **Estimate** for the solution to the problem.
5. **Solve** the equation, and check the reasonableness of the solution.

Let's practice using a problem-solving chart to calculate force, mass, and acceleration.

Example 1: A soccer player kicks a 0.45 kg soccer ball, and the ball accelerates at a rate of 200 m/s^2. How much force did the soccer player use to kick the ball?

Known variables	mass = 0.45 kg acceleration = 200 m/s^2
Write the **Formula**	$F = m \cdot a$
Substitute known variables	F = 0.45 • 200
Make a reasonable **Estimate**	0.45 is close to 0.5, or 1/2. Half of 200 is 100. The answer should be close to 100.
Solve the equation	F = 0.45 • 200 0.45 x 200 = 90 F = 90 **Force = <u>90 N</u>**

Example 2: A spring scale is used to apply 4 N of force to a toy car with a mass of 0.3 kg. What is the acceleration of the toy car to the nearest tenth m/s^2?

Known variables	Force = 4 N mass = 0.3 kg
Write the **Formula**	$F = m \cdot a$
Substitute known variables	4 = 0.3 • a
Make a reasonable **Estimate**	0.3 is about 1/3. 4 is 1/3 of what? 4 is 1/3 of 12, so the answer should be close to 12.
Solve the equation	4 = 0.3 • a $\frac{4}{0.3} = \frac{0.3 \cdot a}{0.3}$ 13.3 = a **acceleration = <u>13.3 m/s^2</u>**

Try the next problem on your own.

A bowler uses 10.5 N of force to roll a bowling ball, and the ball accelerates down the bowling lane at a rate of 2.5 m/s^2. What is the mass of the bowling ball to the nearest tenth of a kilogram?

Known variables	
Write the **Formula**	
Substitute known variables	
Make a reasonable **Estimate**	
Solve the equation	

Force and Motion

RM 6: Using Evidence to Support a Claim

Question: *Record your investigation question.*	
Claim: *Record the rule you wrote based on your observations.*	
Evidence from Investigation: *What evidence from the investigation supports your claim?*	**Evidence from Text:** *What evidence from the reading passage supports your claim?*
Evaluating the Evidence: *What do you think is the strongest evidence? Why?*	
Real-World Connection: *Describe a real-world example that supports your claim.*	

TEA Texas Education Agency

Force and Motion

RM 7: Gallery Walk Sentence Starters

- I wonder . . .
- It's interesting . . .
- I'm surprised . . .
- What about . . .
- How did you decide . . .
- What do you mean by . . .
- Have you considered . . .
- I agree/disagree with . . . because . . .
- Ours is different/similar in that . . .

RM 8: Calculating Force, Mass, and Acceleration

Calculating Force, Mass, and Acceleration

Use the formula *F = ma* to solve each problem. If a griddable item is provided, record your answer, and fill in the bubbles.

1. A passenger with a mass of 50 kg is riding an amusement park ride. When the ride starts, the passenger accelerates at a rate of 12 m/s^2. How much force in Newtons does the passenger experience?

   Record and bubble your answer. Be sure to use the correct place value.

Known variables	mass = acceleration =
Write the **Formula**	*F = m • a*
Substitute known variables	
Make a reasonable **Estimate**	
Solve the equation	

				.		
0	0	0	0		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	3	3	3		3	3
4	4	4	4		4	4
5	5	5	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	9	9	9		9	9

1207343 Science Academies_Lesson 8 .indd 377 4/27/2016 3:38:10 PM

Force and Motion

RM 8 continued

2. A gardener uses a wheelbarrow to move soil to a flower bed. The wheelbarrow of soil has a mass of 32 kg. If the gardener applies a force of 9.6 N, what is the acceleration of the wheelbarrow to the nearest tenth m/s^2?

   Record and bubble your answer. Be sure to use the correct place value.

Known variables	
Write the **Formula**	
Substitute known variables	
Make a reasonable **Estimate**	
Solve the equation	

				.		
0	0	0	0		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	3	3	3		3	3
4	4	4	4		4	4
5	5	5	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	9	9	9		9	9

3. A car ran out of gas, and the driver decides to push the car to the gas station at the end of block. When the driver applies 190 N of force, the car has an acceleration of 0.2 m/s^2. What is the mass of the car in kilograms?

   Record and bubble your answer. Be sure to use the correct place value.

Known variables	
Write the **Formula**	
Substitute known variables	
Make a reasonable **Estimate**	
Solve the equation	

				.		
0	0	0	0		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	3	3	3		3	3
4	4	4	4		4	4
5	5	5	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	9	9	9		9	9

Force and Motion

RM 8 continued

4. A 40 kg person is riding a 100 kg motorcycle. How much force is needed to accelerate the motorcycle and its rider at a rate of 2.5 m/s^2?

   Record and bubble your answer. Be sure to use the correct place value.

Known variables	
Write the **Formula**	
Substitute known variables	
Make a reasonable **Estimate**	
Solve the equation	

				.		
0	0	0	0		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	3	3	3		3	3
4	4	4	4		4	4
5	5	5	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	9	9	9		9	9

5. During a science investigation, students used a spring scale to apply 10 N of force to a cart with different amounts of mass. The mass of the cart during each trial is recorded in the table below

Trial	Mass of the Cart (kg)
1	0.25
2	0.50
3	0.75
4	1.0

During which trial does the cart have the greatest acceleration? Explain your answer.

1207343 Science Academies_Lesson 8 .indd 381 4/27/2016 3:38:11 PM

Force and Motion

RM 9: Evaluate

1. For an investigation, a student drops four different density cubes from a height of 1 meter into a container of sand. Each cube has the same volume but a different mass. The mass of each cube is recorded in the table below.

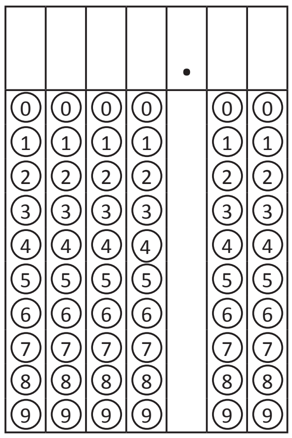
Cube	Mass (g)
Aluminum cube	22.4
Brass cube	66.3
Plastic cube	11.2
Wood cube	6.4

   Because of the force of gravity, each cube will accelerate at the same rate as it falls. When a cube is dropped into the sand, it creates a crater in the sand.

   Which cube will make the biggest crater? Explain why.

2. A person playing mini golf hits a 0.2 kg golf ball, and the ball accelerates 5.5 m/s^2. How much force was applied to the golf ball to the nearest tenth of a Newton?

   Record your answer, and fill in the bubbles on the grid. Be sure to use the correct place value.



1207343 Science Academies_Lesson 8 .indd 383 4/27/2016 3:38:11 PM

Force and Motion

RM 9 continued

3. Dog sledding is an important means of transportation in arctic regions.

A team of sled dogs applies 500 N of force to a 150 kg sled. What is the acceleration of the sled to the nearest tenth of a m/s^2?

Record your answer, and fill in the bubbles on the grid. Be sure to use the correct place value.

				•		
0	0	0	0		0	0
1	1	1	1		1	1
2	2	2	2		2	2
3	3	3	3		3	3
4	4	4	4		4	4
5	5	5	5		5	5
6	6	6	6		6	6
7	7	7	7		7	7
8	8	8	8		8	8
9	9	9	9		9	9

4. During a science investigation, students used a spring scale to apply different amounts of force to a cart. The force of the spring scale and acceleration of the cart are recorded in the table below.

Trial	Force (N)	Acceleration (m/s^2)
1	2	0.5
2	4	1.0
3	6	1.5
4		2.5

How much force was applied to the cart during trial 4? Use evidence to support your answer.

Force and Motion
RM 9 continued

5. Three different sports balls are kicked during gym class.

soccer ball

mass = 0.45 kg

force = 13.5 N

football

mass = 0.40 kg

force = 15 N

playground ball

mass = 0.48 kg

force = 16.5 N

Calculate the acceleration for each type of ball. Rank the three balls in order from least acceleration to greatest acceleration. Show your work.

Force and Motion

RM 10: Problem-Solving Chart

Known variables	
Write the **Formula**	
Substitute known variables	
Make a reasonable **Estimate**	
Solve the equation	

Known variables	
Write the **Formula**	
Substitute known variables	
Make a reasonable **Estimate**	
Solve the equation	