SUCCESS ACADEMY EDUCATION INSTITUTE

Forces and Motion: The Racetrack Challenge

Grade 3

Our Vision of Elementary School Science Excellence

Success Academy's unique commitment to science starts in kindergarten. We strive to cultivate a passion for the sciences early in life, build a comprehensive foundation of knowledge, and teach students to investigate and analyze real-world problems. Our vision of science relies on two related commitments: mastery of a substantive body of scientific knowledge and an inquiry-based approach to accumulating this knowledge. Equipping students with a firm grasp of scientific concepts is central to our model, and students must understand that these concepts aren't simply plucked from the air, but rather arrived at through scientific thinking and experimentation. To that end, our scholars do science to understand that scientific knowledge comes from posing questions, designing experiments, gathering data, and drawing conclusions. Rather than viewing scientific knowledge as etched in stone, they come to understand that ideas about the world change with new evidence. In addition, our program incorporates The Next Generation Science Standards (NGSS) and the BSCS 5E Instructional Model.

We believe excellent science classrooms are ones in which students experience curiosity and joy, and make connections between classroom science and the natural world around them. Embedded in our program is the belief that struggle and student-led inquiry are inherent to the mastery process. Through our progressive approach to learning, students realize that unexpected results do not signal failure, but instead present valuable opportunities for new questions.

Through our science program, students learn that science and engineering are creative and exciting fields. They discover that there are countless, fascinating scientific questions to be asked and engineering challenges to be solved—and will be inspired and equipped to seek out answers and solutions. No matter what path students choose to pursue in life, the SA science program will spark curiosity, sharpen problem-solving capabilities, and fuel passion for knowledge.

Essential Questions

The best questions point to and highlight the big ideas. They serve as doorways through which learners explore the key concepts, themes, theories, issues, and problems that reside within the content, perhaps as yet unseen: it is through the process of actively "interrogating" the content through provocative questions that students deepen their understanding.[1]

Use the essential question to drive the unveiling and mastery of ideas, and ground the unit in an overarching purpose, often as a storyline. Mentioning the essential question or having students answer it at the end of some lessons does not mean the teacher is using it purposefully.

[1] From Wiggins, G., & McTighe, J. (2005). *Understanding by design*. Alexandria, VA: Association for Supervision and Curriculum Development.

Purpose: The Why, What, and How of This Unit

Essential Question: What do we need to consider to build the fastest racetrack?

Why This Unit?

Living on Earth means forces are constantly acting on us—both seen and unseen. Forces can be as large as the pull of the Sun on our planet or as small as the pull of a nucleus on an electron. Forces are a part of our everyday lives, from kicking a soccer ball to picking up a pencil to write. In this unit, scholars will build their understanding of forces as they prepare for their final challenge: building the fastest racetrack. Can scholars design a successful racetrack by studying forces and energy transformations?

Throughout the unit, scholars will uncover predictable patterns of motion and discover the different factors that affect an object's motion. Using this information, scholars will construct explanations that unveil how energy, force, and friction interact.

What is the bottom line?

Science and Engineering Concepts highlighted in this unit:

- **Big Idea**: Force and motion are both vector quantities, having magnitude and direction, that act on a particular object.
- **Big Idea**: The patterns of an object's motion can be observed and measured; when past motion exhibits a regular pattern, future motion can be predicted.
- **Big Idea**: The motion of an object is affected by the surface type, mass, relative height, and slope.
- **Big Idea**: When objects collide, energy is conserved as it transfers from one object to another.

Science and Engineering Practices (SEP) highlighted in this unit:

- Analyze and Interpret Data
    - Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships.
- Construct Explanations and Design a Solution
    - Using evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem
    - Constructing explanations of observed relationships
    - Application of scientific ideas to solve design problems

***Note**: As with any unit, scholars engage in many practices in a given investigation. These practices are highlighted because they appear in the most lessons, but all high leverage SEPs can be assessed.*

How will scholars be assessed?

- Use the following materials to study and score scholar work.
    - Grade 3 Forces and Motion Exemplar Exit Tickets (within each lesson)

Safety

Plan carefully for safety in all lessons.

- Moving objects can pose a safety hazard. Plan for lessons based on the layout of your classroom.

Unit Outline

Lesson 1: Introduction to Forces

The Science teachers are hosting a competition challenging scholars across the grade to create the next great racetrack. Are your scholars up for the task? Today, scholars embark on their unit-long quest by exploring the forces that make cars move on their own.

- **Big Science Idea**: Forces have magnitude and direction and can change the motion of an object.
- **Science and Engineering Practice**: Construct Explanations and Design a Solution

Lesson 2: Moving Uphill

We've discovered how forces can make cars move on their own. But now, the competition has added a hill requirement to the track design! Can scholars overcome this obstacle by studying how different amounts of force affect a car's motion?

- **Big Science Idea**: Forces cause patterns in an object's motion that can be observed, measured, and predicted.
- **Science and Engineering Practice**: Construct Explanations and Design a Solution

Lesson 3: Does Height Affect the Speed of a Car?

The challenge allows competitors to start the car from any point on their track. Can scholars find the best starting point on the track so cars travel as far as possible?

- **Big Science Idea**: An object has potential energy based on its position. Relative height affects an object's motion.
- **Science and Engineering Practice**: Analyze and Interpret Data

Lesson 4: Finding the Perfect Slope

Scholars now know how the height of a ramp can affect the speed and distance a car can travel. Today, scholars will uncover how different slopes can also affect a car's motion!

- **Big Science Idea**: An object has potential energy based on its position. Relative slope affects an object's motion.
- **Science and Engineering Practice**: Analyze and Interpret Data

Lesson 5: Friction Can't Slow Us Down

Slowing down? That is not an option if you want to have your car travel as far as possible! Today, scholars will explore how friction affects the speed of the car by changing the surface of their track.

- **Big Science Idea**: An object sliding on a surface or sitting on a slope experiences resistance due to friction. Friction opposes an object's motion.
- **Science and Engineering Practice**: Construct Explanations and Design a Solution

Lesson 6: Finding the Perfect Car

The competition is nearing, and scholars are almost ready to build a perfect track. Are there other factors that affect how fast and far their car can travel? Today, scholars will experiment to see if a car's mass affects its motion on a racetrack.

- **Big Science Idea**: The mass of an object affects the amount of force necessary to make it move or reach a certain speed.
- **Science and Engineering Practice**: Analyze and Interpret Data

Lesson 7: Giving a Little Boost

Scholars know they need to consider their car's mass carefully. Their cars also need enough energy to travel far enough to meet the constraints of the competition. Today, scholars will experiment to learn how energy can be transferred to the car.

- **Big Science Idea**: Kinetic energy is present whenever there are moving objects, and this energy can be transferred to another object.
- **Science and Engineering Practice**: Construct Explanations and Design a Solution

Lesson 8: Collision Safety Test

We are almost ready for the competition, but we have to ensure the car will not break if it crashes! Today, scholars will conduct testing to see if their car is safe.

- **Big Science Idea**: During a collision or when objects are in contact, energy can transfer from one object to another; this can result in a change in an object's motion.
- **Science and Engineering Practice**: Construct Explanations and Design a Solution

Lesson 9: Engineering Challenge

The competition is almost here! Are scholars up for the challenge? Scholars will use all of their knowledge about forces to plan and design a successful racetrack! The class will provide feedback before scholars build their tracks tomorrow.

- **Big Science Idea**: When predicting an object's motion, many factors must be considered (i.e., the slope of the ground, the mass of the object, the friction, etc.).
- **Science and Engineering Practice**: Construct Explanations and Design a Solution

Lesson 10: Track Day!

This is it! Today is the day to build our tracks! Scholars build the racetracks and determine if they meet the requirements of the challenge.

- **Big Science Idea**: When predicting an object's motion, many factors must be considered (i.e., the slope of the ground, the mass of the object, the friction, etc.).
- **Science and Engineering Practice**: Construct Explanations and Design a Solution

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Lesson 1: Introduction to Forces

The Science teachers are hosting a competition challenging scholars across the grade to create the next great racetrack. Are your scholars up for the task? Today, scholars embark on their unit-long quest by exploring the forces that make cars move on their own.

Lesson Objectives

- **Big Science Idea**: Forces have magnitude and direction and can change the motion of an object.
    - **Key Takeaways**:
        - A force is a push or a pull.
        - A force is a vector quantity having magnitude (strong, weak) and direction (upward, downward, forward, backward).
        - Forces can be contact or noncontact. Gravity is a noncontact force that pulls objects towards Earth.
- **Science and Engineering Practice**: **Construct Explanations and Design a Solution** Scholars engage in this Science and Engineering Practice as they construct explanations about the forces acting on objects.

Materials Needed

- For each table:
    - Activity 1: 1 balloon, tape, and car
    - Activity 2: 10 dominos
    - Activity 3: plastic cup, paper clip, bar magnet on a string
    - Activity 4: golf ball, ping pong ball

Prep

- Tie the bar magnets to a piece of string for each group prior to the experiment. Place the paper clip in the cup.

Launch

- Show a video of cars racing on a racetrack. How do you know which car won the race?
- Introduce the Unit Storyline: The science teachers are having a grade-wide competition. Scholars must design and build the fastest racetrack, with a budget for materials! Are scholars up for the challenge?
- Present the lesson challenge: To enter the competition, scholars must prove they have an understanding of forces and how they influence an object's motion.

Activity

- **Procedure**:
    - Activity 1: Scholars use a balloon and tape to try to make a car move.
    - Activity 2: Scholars lineup dominos close together without touching and then try to knock all the dominos down by touching one domino.
    - Activity 3: Scholars try to "fish" a paper clip out of a cup using a magnet on a string.
    - Activity 4: Scholars drop a ping-pong ball and a golf ball at the same time.

    - After each activity scholars record their observations.
- Circulate and listen for scholars who can describe forces in different ways (i.e., as pushes and pulls, by their strengths and direction).

Discourse

- **Debrief activity**: What are forces? Define **force**.
    - Compare and contrast the forces applied in each activity.
    - Can an object, such as a car, begin to move without any forces acting on it?
- **Introduce the Essential Question**: What do we need to consider to build the fastest racetrack?
    - Record initial scholar thoughts to come back to and revise throughout the unit.

Accountability (Informal Exit Ticket)

Use this Exit Ticket as a baseline to check scholar understanding coming into the unit as they will continue to build on these ideas throughout the unit.

Assignment:

Kamari and Ian were discussing their ideas about forces.

1. Determine what is true about forces by putting an **X** next to all of the statements that are **true**.

    __X___ A force is a push or a pull.

    ______ Objects can begin moving on their own without any forces acting on them.

    __X___ Forces can be described by their direction and strength.

    ______ A force can't make an object move.

2. Choose an object in the classroom. Explain a force acting on the object.
    When I let go of a pencil, the force of gravity pulls it to the ground.

Scoring:

This Exit Ticket is not scored. Use it to informally identify prior knowledge and misconceptions scholars are coming into the unit with.

Lesson 2: Moving Uphill

We've discovered how forces can make cars move on their own. But now, the competition has added a hill requirement to the track design! Can scholars overcome this obstacle by studying how different amounts of force affect a car's motion?

Lesson Objectives

- **Big Science Idea**: Forces cause patterns in an object's motion that can be observed, measured, and predicted.
    - **Key Takeaways**:
        - When an object is at rest, it has balanced forces acting on it. An object at rest can be moved by an unbalanced force.
        - The magnitude and direction of an applied force affect an object's motion.
- **Science and Engineering Practice**: **Construct Explanations and Design a Solution** Scholars engage in this Science and Engineering Practice as they construct an explanation about the relationship between an applied force and the resulting changes in patterns of motion.

Materials Needed

- For each table:
    - Activity 1: marshmallow shooters made with plastic cup and balloon, mini-marshmallows, ruler, and measuring tape
    - Activity 2: pendulum made with paper, tape, string, battery or gram masses, straw, sheet of paper, and measuring tape

Prep

- Instructions to make the marshmallow shooters can be found here. Place the measuring tape flat on tables or rugs for scholars to measure how far the objects travel.
- Instructions to make the pendulum can be found in this video. Place a battery or gram masses in the pendulum, so it has a larger, more observable path.

[**Materials Tip**: Test out materials ahead of time to determine how to arrange groups and which weight works better for the pendulums.]

Launch

- Show scholars a picture of Kingda Ka, the tallest rollercoaster in the world! Explain that for Kingda, the car needs to be launched up it instead of starting near the top of the hill.
    - How could we get our car to travel up a slope? Define **slope**.
- Present the lesson challenge: Using what we've learned about forces, how can we get our car to travel up a steep slope in a track?
- Before beginning the experiment, record a class prediction to return to during Discourse. Ask the scholars: Do you think a car needs a lot, some, or a little energy to travel at the fastest speed and for the longest distance? Define **energy**.

Activity

- **Procedure**:

- Activity 1: Scholars try three trials using the marshmallow shooter, using slightly more energy by pulling back the balloon further each trial. Scholars record the amount of force used, the distance the object traveled, and the speed for each trial.
- Activity 2: Scholars take turns using the pendulum. The first scholar uses the straw to blow, the second taps with a paper, the third scholar taps with their hand. Scholars record the amount of energy used, the distance the object traveled, and the speed for each trial.
- Scholars draw conclusions about how the force applied affects the object's motion.

- Circulate and listen for scholars supporting or refuting the class prediction. Press scholars to discuss the relationship between force, speed, and distance.

Discourse

- **Debrief activity**: Was our prediction correct? What is your evidence?
  - What patterns of motion did you observe in each activity? Define **motion**.
  - Can an object's motion be predicted? Define *balanced* and *unbalanced* forces.
    - Describe the relationship between energy and the object's motion (speed and direction).
- **Make connections to the essential question**: What do we need to do to make sure our car will go up a slope on a racetrack?
  - Scholars should be discussing that more force is necessary for our car to travel over a hill on a track and making connections between forces and energy at the end of this lesson.
- **Make broader connections**: Show scholars this video about Newton's First Law of Motion.
  - How does Newton's law help us predict the pattern of an object's motion?

Accountability (Exit Ticket)

In this Exit Ticket, scholars use their understanding of the Big Science Idea to predict an object's motion.

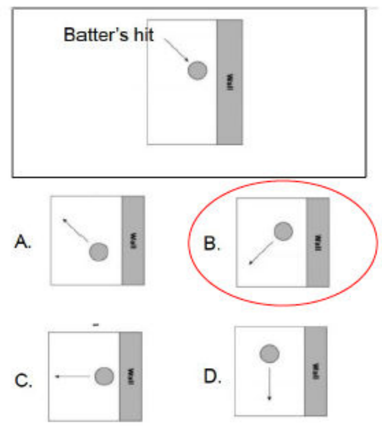
Assignment:

Last week, Jim had a baseball game. In the third inning, he was the pitcher and threw the ball to the batter.

[Optional] Draw (or find) an image for students of a baseball batter with a ball heading toward him.

1. How will the batter's force on the baseball change its motion? [1]
   A. The force will change the ball's direction.
   B. The force will change the ball's mass.
   C. The force will change the ball's shape.
   D. The force will change the ball's color.

2. The batter hit a homerun! The ball bounced off the back wall of the stadium. Where did the ball most likely go after it hit the wall? [1]



Scoring:

1. Award 1 point for correctly identifying choice A.
2. Award 1 point for correctly identifying choice B.

Lesson 3: Does Height Affect the Speed of a Car?

The challenge allows competitors to start the car from any point on their track. Can scholars find the best starting point on the track so cars travel as far as possible?

Lesson Objectives

- **Big Science Idea**: An object has potential energy based on its position. Relative height affects an object's motion.
  - **Key Takeaways**:
    - The potential energy of an object increases as its position increases in height. When you increase potential energy, you increase the potential an object has for sustained motion.
    - This type of potential energy is a direct result of gravity. **Note**: Gravitational potential energy is only one of many types of potential energy, but it is the only one covered in this unit.
    - Kinetic energy is the energy an object has due to motion.
- **Science and Engineering Practice**: **Analyze and Interpret Data** Scholars engage in this [Science and Engineering Practice](#) as they reveal patterns in data to determine how height influences the motion of an object.

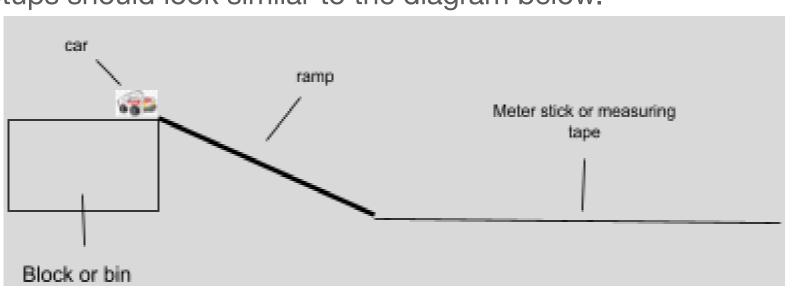
Materials Needed

- For the teacher: bouncy ball
- For each table: 2 meter sticks or rulers, bin or wooden block, measuring tape or additional meter stick, and Hot Wheels car

[**Materials Management Tip**: For this unit, scholars can explore ramps using rulers or meter sticks. Meter sticks will generate more visible results. If necessary, two meter sticks can be held together using painters tape to create a wide enough surface for a Hot Wheels car.]

Prep

- To create the slope, tape the ramp to a bin or wooden block. Then, place tape at three equidistant spots on the ramp. Label the spots 1, 2, and 3. At the bottom of the ramp, place measuring tape or a meter stick. Setups should look similar to the diagram below.



[**Materials Management Tip**: You will need the ramps for Lessons 2 to 6. Consider how you will have scholars store and set up ramps for these activities.]

Launch

- Show students a picture of a racetrack with a loop. Tell students a car was dropped from the downward track right before the loop. Tell scholars the competition allows competitors to start the car from any point on the track.
  - Where should we start the car on the track so it travels the longest distance?
- Present the lesson challenge: Scholars have proven that they know about forces, so it is time to start planning for their track! Today, scholars will determine whether starting height affects the motion and distance a car can travel. Define **distance**.

Activity

- **Procedure**:
  - Scholars record predictions and then start the car down the slope from the spot marked "1" recording the speed (slow, medium, or fast) and distance traveled.
  - Scholars repeat from height "2" and height "3."
  - Scholars revisit their predictions and draw conclusions.
- Press scholars to evaluate if their predictions are correct or incorrect as they record their data. Identify scholar data to share during Discourse.

Discourse

- **Debrief activity**: What is the relationship between starting height, speed, and distance? Define **speed**.
  - Reevaluate the class prediction from the Launch.
  - How does our data inform the relation between energy and force in yesterday's experiment? Define **potential energy**.
    - Explain that gravity gives objects that are raised off the surface of the Earth potential energy. They can remember this by thinking about how far an object has the *potential* to fall before it hits Earth's surface. Objects that are higher, and therefore farther from the ground, have more potential energy. When an object starts to move, potential energy changes to kinetic energy. Define **kinetic energy**.
- **Make connections to the essential question**: If you had to build your track today, what new information do we have about how we would design the track? Why?
  - Scholars should be discussing that starting at a higher point, the car will have more potential energy and once in motion have kinetic energy allowing the car to travel a longer distance and faster.
- **Make broader connections**: Show scholars a bouncy ball. Where should I release the ball from to get it to reach the highest speed and bounce the highest?
  - Let a scholar drop the bouncy ball from different heights to test predictions.

Accountability (Exit Ticket)

This Exit Ticket assesses scholars' understanding of how potential energy influences motion. This Big Science Idea will be revisited in the Lesson 4 Exit Ticket. Scholars also analyze and interpret data. Scholars will also be assessed on this Science and Engineering Practice in Exit Tickets 4, 5, 6, and 8.

Assignment:

John, Riley, Lea, and Amy went skiing together. They all had the exact same skis and took turns skiing down the slope.

Skiing Data

Name	Mass of Person (kilograms)	Starting Height (meters)	Speed at the bottom of the hill (meters per second)
John	62	50	5.3
Riley	62	100	6.2
Lea	62	25	3.7
Amy	62	150	7.1

1. Which skier had the most potential energy before skiing down the hill? [1]
    A. John and Amy started at a higher point on the ski slope than Riley, so they started with more potential energy.
    B. Amy reached the fastest speed, so she had the most potential energy.
    C. Riley had the least potential energy, so she reached the slowest speed.
    D. Lea had the most potential energy because she started at the lowest point.

Scoring:

1. Award 1 point for correctly identifying choice B.

Lesson 4: Finding the Perfect Slope

Scholars now know how the height of a ramp can affect the speed and distance a car can travel. Today, scholars will uncover how different slopes can also affect a car's motion!

Lesson Objectives

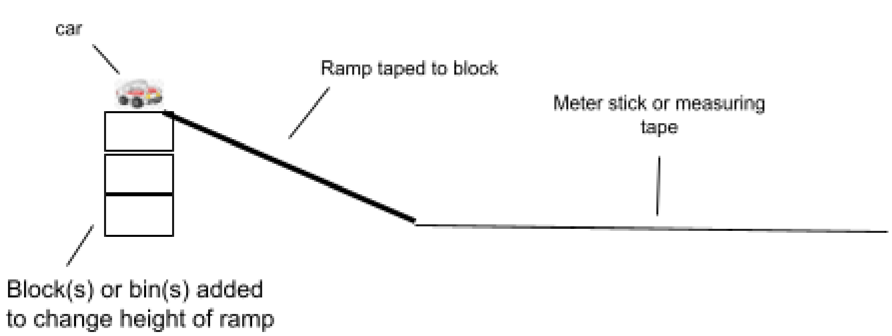
- **Big Science Idea**: An object has potential energy based on its position. Relative slope affects an object's motion.
  - **Key Takeaways**:
    - The steepness of a slope affects the motion of an object traveling on it.
    - When you increase the slope of a ramp, you increase the object's ability to pick up speed quickly. ***Note****: Scholars do not need to learn the word "acceleration" in this unit.*
- **Science and Engineering Practice**: **Analyze and Interpret Data** Scholars engage in this Science and Engineering Practice as they represent data in tables to reveal patterns that show how slope affects the motion of an object.

Materials Needed

- For each table: timer, ramp, Hot Wheels car, 3 wooden blocks or bins, and measuring tape or meter stick

Prep

- Place measuring tape or meter stick on table or rug. To create the gradual slope, tape the meter stick to one block or bin. Scholars will add blocks or bins under the ramp throughout the experiment.
- The three setups should resemble the diagram below.



Launch

- Show a snowy hill. If we wanted to move down the hill at the fastest speed, where is the best spot to start sledding?
  - What would happen if we changed the slope of the hill?
- Present the lesson challenge: Scholars have discovered how to make a car go up and down slopes, but there is another element they must consider! Today, scholars will use their data to determine how slope affects speed and distance traveled.

Activity

- **Procedure**:
  - Scholars record predictions and record the results for two trials using the gradual slope. Scholars continue to add one block for the medium and steep slopes, repeating the procedure.
  - Scholars analyze the data and construct a conclusion about how slope affects motion.
- Press scholars to refute or support their prediction. Ensure scholars are drawing conclusions based on their data.

Discourse

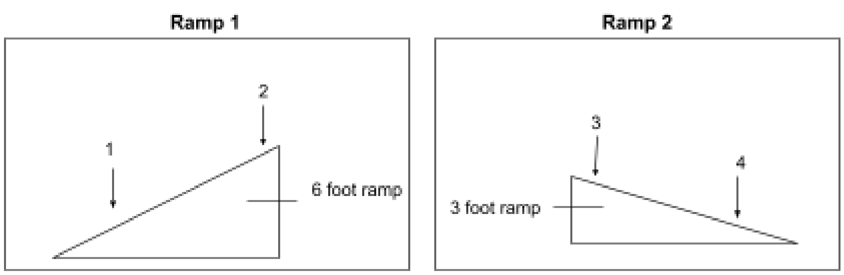
- **Debrief activity:**
  - How does slope affect the motion of a car? Ensure scholars discuss the speed and distance it will travel.
- **Make connections to the essential question**: What kind of slopes will we want to use in our racetrack? Why?
  - Scholars should conclude a track with a steeper slope will allow the car to travel a longer distance and faster.

Accountability (Exit Ticket)

In this Exit Ticket, scholars will continue to use their understanding of potential energy and how slope affects motion. Scholars also analyze and interpret data. Scholars will also be assessed on this Science and Engineering Practice in Exit Tickets 5, 6, and 8.

Assignment:

Sam and Saniyah are at the park. There are two different ramps and four different starting points that Sam and Saniyah biked down.



1. Complete the chart with a prediction for the distance and speed traveled from each position. [1]

Position (1–4)	Distance Traveled (meters)	Speed (mph)
Position 1	20	10
Position 2	30 (any # more than 25)	20 (any # more than 15)

Position 3	25	15
Position 4	15 (any # less than 20)	5 (any # less than 10)

2. The bikes gained ______ kinetic energy when they started at position 4. [1]
   A. the most
   B. the least
   C. no

3. To make both Sam and Saniya travel faster, they should _________. [1]
   A. decrease their starting height
   B. use a ramp with a steeper slope
   C. start at an earlier time

Scoring:

1. Award 1 point for a plausible data table.
   - **Note**: See data table for acceptable ranges.
2. Award 1 point for correctly identifying choice B.
3. Award 1 point for correctly identifying choice B.

Lesson 5: Friction Can't Slow Us Down

Slowing down? That is not an option if you want to have your car travel as far as possible! Today, scholars will explore how friction affects the speed of the car by changing the surface of their track.

Lesson Objectives

- **Big Science Idea**: An object sliding on a surface or sitting on a slope experiences resistance due to friction. Friction opposes an object's motion.
  - **Key Takeaways**:
    - Friction is the resistance that one surface or object encounters when moving over another.
    - Rough surfaces create more friction, while smoother surfaces create less friction.
    - Friction between two surfaces can warm both of them (as energy is being released as heat energy) (e.g., rubbing hands together).
- **Science and Engineering Practice**: **Construct Explanations and Design a Solution** Scholars engage in this Science and Engineering Practice as they use evidence to construct or support an explanation about how friction changes an object's motion.

Materials Needed

- For each table: ramp covered with aluminum foil, ramp covered with sandpaper, Hot Wheels car, timer, 2 wooden blocks or bins, measuring tape or meter stick

Prep

- Prep the ramps by taping or wrapping the sandpaper and aluminum foil on the different ramps.
- Place measuring tape or meter stick at bottom of the ramp to measure how far the car travels.

Launch

- Have scholars rub their hands together quickly for 10 seconds. Have scholars rub their hands on the rug quickly for 10 seconds.
  - What happens as you rub your hands together? On the rug? Is there a force acting on your hands?
- Show a video of people sledding (0:00–0:12). Is there a force acting on them that slows them down? Define **friction**.
- Present the lesson challenge: Slowing down is not an option for our racetrack! Scholars need to find the right material to prevent the car from slowing down. Today, scholars will use evidence to determine how different materials affect the motion of a car.

Activity

- **Procedure**:
  - Scholars record a prediction and slide the car down each ramp (aluminum foil and sandpaper) for two trials, recording the distance and time traveled.
  - Scholars write an explanation for how different materials affect motion.

[**Instructional Tip**: The first four lessons had scholars describe the speed of an object as fast, medium, or slow. Ensure scholars understand how measuring time can be used to make inferences about speed.]

- While scholars are writing conclusions, press them to provide evidence.

Discourse

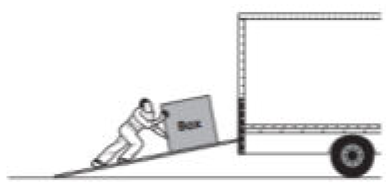
- **Debrief activity**: Were your predictions correct? Explain.
  - Compare both materials and their effects on the car's motion.
- **Make connections to the Essential Question**: What type of material would we want to use for the surface of our track? Why?
  - A track with a smooth surface will have less friction and will allow the car to travel a longer distance and reach a faster speed. Friction is a force that opposes motion and will slow down the car.
- **Make broader connections**: Show scholars this video on friction.
  - What types of surfaces create more friction? Less friction?
  - When have you experienced friction outside of today's lesson?

Accountability (Exit Ticket)

Scholars use their knowledge of friction to identify the correct surface. Scholars will not revisit this Big Science Idea in an Exit Ticket. Scholars analyze and interpret the data, which will be revisited in Exit Tickets 6 and 8.

Assignment:

Chico is moving a box that weighs 25 lb. He plans to push the box up a ramp onto the moving truck.



He has a choice of four ramps to use.

Ramp Materials	Amount of force needed to push the box (Newtons)	Mass of box (lb)
Metal	5	25
Wood	10	25
Cardboard	7	25
Plastic	3	25

1. On which ramp will the box travel the slowest? [1]
   A. metal
   B. wood
   C. cardboard
   D. plastic

2. The box is easier to move when the surface of the ramp is smoother because there is less __________. [1]
    A. mass in the box
    B. gravity pulling on the box
    C. distance to push the box
    D. friction opposing the box

Scoring:

1. Award 1 point for correctly identifying choice B.
2. Award 1 point for correctly identifying choice D.

Lesson 6: Finding the Perfect Car

The competition is nearing, and scholars are almost ready to build a perfect track. Are there other factors that affect how fast and far their car can travel? Today, scholars will experiment to see if a car's mass affects its motion on a racetrack.

Lesson Objectives

- **Big Science Idea**: The mass of an object affects the amount of force necessary to make it move or reach a certain speed.
    - **Key Takeaways**:
        - Moving an object that is more massive requires more force.
        - While moving at a given speed, objects that are more massive are harder to stop.
- **Science and Engineering Practice**: **Analyze and Interpret Data** Scholars engage in this Science and Engineering Practice as they represent data in tables to reveal patterns that indicate how mass affects motion.

Materials Needed

- For each table: Hot Wheels car, two 5-gram masses, ramp, 2 blocks or bins, and timer, tape, measuring tape or meter stick

Prep

- Tape the meter stick to the two blocks or bins ahead of time, so the slope doesn't move.
- Place the measuring tape or meter stick at the bottom of the ramp to measure how far the Hot Wheels roll.

Launch

- Show scholars this picture. Tell scholars the car on the left has a mass two times larger than the car on the right. Do you think mass affects motion? Define **mass**.
    - What evidence will we be looking for in our data to prove our prediction right or wrong?
- Present the lesson challenge: It is almost time to build the tracks for the competition, but scholars still don't know if there are other factors that affect motion! Today, scholars will determine if mass affects the speed and distance an object can travel.

Activity

- **Procedure**:
    - Scholars record their predictions and roll the Hot Wheels car (without any added masses) down the slope for two trials, recording results.
    - Scholars tape the 5-gram mass onto the car and roll the Hot Wheels car down the slope for two trials, recording results.
    - Scholars tape another 5-gram mass onto the car and repeat the procedure.
    - Scholars write conclusions based on the data with a claim and strong evidence.
- Circulate and listen for scholars drawing conclusions about how mass affects the motion. Press scholars to use evidence to support their response.

Discourse

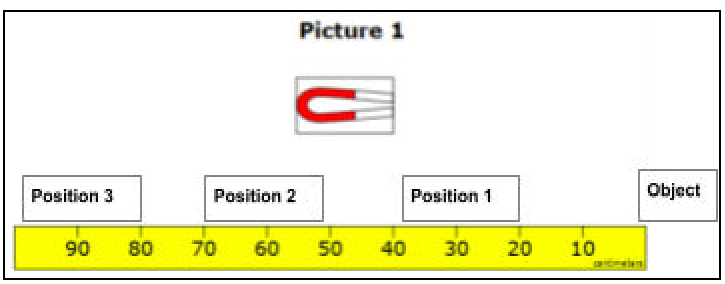
- **Debrief activity**: Discuss predictions.
    - How did mass affect the motion of the car?
- **Make connections to the essential question**: What type of a car should we use in our competition? What is your evidence?
    - Scholars should consider the benefits and drawbacks of using a car with more mass. The ideal choice may actually differ from track to track! (One benefit includes the ability of a heavier car to resist stopping more than a lighter car. One drawback is that heavier cars pick up speed more slowly and experience increased friction.)
- **Make broader connections**: Show scholars this video, pausing at 0:26.
    - Which object do you think will travel farther? Faster? Why?
    - What forces are acting on the objects?

Accountability (Exit Ticket)

This is the final Exit Ticket where scholars must use the Big Science Idea that an object's location and mass affect its motion. Scholars apply their understanding of this content to a new context, force of attraction.

Assignment:

Students are learning about the magnetic force of attraction, a noncontact force that pulls an object to a magnet. Picture 1 shows each position the magnet is placed.



Force of Attraction Results

Object Name	Mass (grams)	Position of Magnet	Did the magnet attract (or pull) the object?
Paper clip	1	Position 1	Yes
		Position 2	Yes
		Position 3	No
3 paper clips	3	Position 1	Yes
		Position 2	No

		Position 3	No

1. Which of the following statements is true about the magnetic force of attraction? [1]
    A. The shorter the distance between an object and a magnet, the weaker the force of attraction.
    B. The greater the distance between an object and a magnet, the stronger the force of attraction.
    C. The greater mass an object has, the stronger the force of attraction must be to pull it.
    D. The smaller mass an object has, the stronger the force of attraction must be to pull it.

Scoring:

1. Award 1 point for correctly identifying choice C.

Lesson 7: Giving a Little Boost

Scholars know they need to consider their car's mass carefully. Their cars also need enough energy to travel far enough to meet the constraints of the competition. Today, scholars will experiment to learn how energy can be transferred to the car.

Lesson Objectives

- **Big Science Idea**: Kinetic energy is present whenever there are moving objects, and this energy can be transferred to another object.
  - **Key Takeaways**:
    - During contact, energy can transfer from one object to another.
    - When energy is transferred between objects, the motion of one or more of the objects can change.
- **Science and Engineering Practice**: **Construct Explanations and Design a Solution** Scholars engage in this Science and Engineering Practice as they construct an explanation about energy transfers during collisions

Materials Needed

- For the teacher: figure 8 Hot Wheels track with the booster
- For each table: 3 marbles, ruler with a ridge in the middle, 2 blocks of the same height

Prep

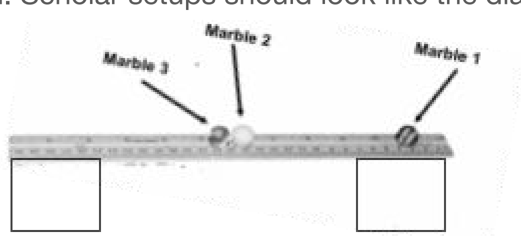
- For the Launch, build the figure 8 Hot Wheels track with the booster.

Launch

- Have the Hot Wheels figure 8 track in the front of the classroom (without the booster added). Explain to scholars that you cannot get the car to make it all the way around the track! Show scholars the unattached booster.
  - Why is the car unable to get all the way around the track without the booster? What can we do to get the car to complete a run?
- Present the lesson challenge: Scholars need to determine how to transfer energy from the booster to the track. Define **transfer**.

Activity

- **Procedure**:
  - Scholars place the ruler on top of both blocks and put two marbles in the middle of the ruler and one marble at the end. Scholar setups should look like the diagram below.



  - Scholars attempt to get Marbles 2 and 3 to the end of the ruler without touching Marble 3, Marble 2, or the ruler.

  - Scholars record the before, during, and after applying a force that resulted in the marbles' movement. Scholars discuss and record how the energy moved or transferred.

Discourse

- **Debrief activity:**
  - How did you get Marble 3 to change positions? What happened to the kinetic energy?
  - Return to the Hot Wheels track from the Launch.
    - What do you predict will happen when the car travels through the booster? Why?
    - Demonstrate adding the booster to show the car can now successfully travel around the track. The booster transferred energy from its motion to the car.
- **Make connections to the essential question**: How can we use an energy transfer to get the car to travel around our track?
- **Make broader connections**: Play this video. Additional videos may include Dominos or Trick Shot.
  - What caused all the other popsicle sticks to go into motion?

Accountability (Lab Notebook)

Use scholars' Lab Notebooks to assess the Big Science Idea and Science and Engineering Practice.

Scoring:

1. Award points as follows:
   - Award 1 point for a claim indicating yes.
   - Award 1 point for including relevant evidence such as the energy was transferred or sent between marbles due to a collision (saying the marbles hit one another is sufficient).
   - Award 1 point for reasoning that explains that during a collision, energy is conserved and/or can be transferred from one object to another.

Lesson 8: Collision Safety Test

We are almost ready for the competition, but we have to ensure the car will not break if it crashes! Today, scholars will conduct testing to see if their car is safe.

Lesson Objectives

- **Big Science Idea**: During a collision or when objects are in contact, energy can transfer from one object to another; this can result in a change in an object's motion.
    - **Key Takeaways:**
        - Interactions between two objects can cause changes in one or both of the objects.
        - When energy is transferred to an object by an unbalanced force, it can result in a change in the speed and/or direction of an object.
        - An object's mass and motion affect its behavior during and after a collision.
- **Science and Engineering Practice**: **Construct Explanations and Design a Solution** Scholars engage in this Science and Engineering Practice as they construct an explanation of how energy transfers during a collision affect an object's motion.

Materials Needed

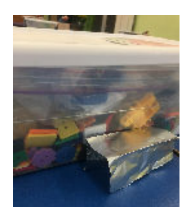
- For each table: 2 wooden blocks or bin, ramps, 2 Hot Wheels car, tape, and pieces of aluminum foil (6 small pieces for front of car and 6 larger pieces for the walls)

Launch

- Scholars are almost ready to create the tracks for the challenge. The competition requires that all cars pass a safety collision test. Define **collision**.
    - How will you know if your car is safe to travel in?
    - What do you predict would happen if your car collided with another car?
- Present the lesson challenge: Explore the interactions between two objects during a safety collision test. Scholars ensure cars are safe to run down the track during the competition by crash testing into a barrier wall and predicting how changes in slope will affect the collisions.
    - Explain to scholars we will model how real cars react to a collision using aluminum foil. Additionally, we will use aluminum foil to create "barriers" for the cars to collide with.

Activity

- **Procedure**:
    - Scholars record their predictions and set up their ramps. Scholars add aluminum foil to the front of both of their Hot Wheels cars with tape and create six aluminum foil walls.
    - Scholars place the first wall at the end of the ramp and put a block or bin behind the wall for support. Scholar cars and walls should look like the pictures to the right.



    - Collisions 1 and 2: gradual slope
        - Scholars send the first Hot Wheels down the ramp and observe if there are changes, repeating this procedure with a new car.
    - Collisions 3 and 4: steep slope

        - Scholars replace the aluminum foil on the front of the Hot Wheels, set up a new aluminum wall, and add another block or bin to increase the height of the slope of the ramp. Scholars repeat the procedure for two trials.
    - Collision 5 and 6: steep slope, more mass
        - Scholars repeat the setup procedure with the higher ramp and add a 5-gram mass to Hot Wheels cars using tape. Scholars repeat the procedure for two trials and discuss how the change in slope, mass, and energy impacted the collision.
- Press scholars to discuss the change in the objects when the collision occurs. Push scholars to predict how the collisions will change for each trial.

Discourse

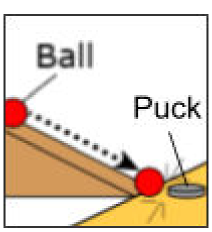
- **Debrief activity**: Discuss predictions.
    - How did the slope change affect the motion of the car? How did it change the collision?
    - What would you expect to happen if two cars of the same mass collide? What about one lighter car and one very heavy truck? Why?
        - Discuss how when two objects interact or collide, it can cause changes in one or both of the objects.
        - Ensure scholars understand that heavier objects are more likely to "hold their ground" in a collision and not move as far, as they require more force to be moved and their additional mass creates stronger frictional forces. Lighter objects, on the other hand, will likely be moved (or "bounce back," if they are the instigator) farther!
- **Make broader connections**: Show a video of Newton's cradle.
    - What causes the ball's motion to change? Explain.

Accountability (Exit Ticket)

This Exit Ticket assesses scholar knowledge of energy transfers. Scholars must complete the diagram using their knowledge of the Big Science Idea. Scholars must also use the Science and Engineering Practice to construct an explanation to select the correct evidence.

Assignment:

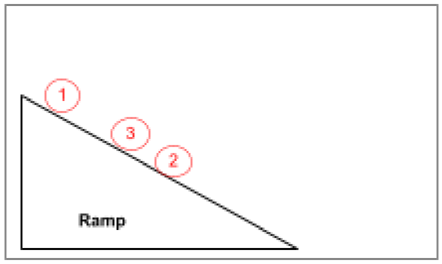
Alex and Mateo compete in a science competition where students roll a ball down a ramp so it collides with a puck at the bottom, causing the puck to slide across the floor. The team whose puck has the most kinetic energy after the collision wins.



Results

Team	Distance puck travels (meters)
Team 1	3
Team 2	1.5
Team 3	2

1. In the box below, **draw** and **label** where each team's **ball** started on the ramp. [1]



Alex asks Mateo, “What observation proves the puck gained the most kinetic energy for the winning team?”

2. Select the explanation that correctly completes Mateo’s answer. He says, “The puck that gained the most kinetic energy from the ball …” [1]

    A. makes the loudest sound during the collision, because it transfers the most kinetic energy into sound.
    B. travels the greatest distance before stopping, because it had the greatest speed after the collision.
    C. makes the quietest sound during the collision, because it transfers the most kinetic energy into the puck.
    D. travels the least distance before stopping, because it transfers its kinetic energy the quickest into its surroundings.

Scoring:

1. Award 1 point for indicating the balls in the correct order (from highest on the ramp to lowest) of Team 1, Team 3, Team 2.
    - **Note**: Models should be graded holistically, but it must be clear to the grader which ball belongs to each team.
2. Award 1 point for correctly identifying choice B.

Lesson 9: Engineering Challenge

The competition is almost here! Are scholars up for the challenge? Scholars will use all of their knowledge about forces to plan and design a successful racetrack! The class will provide feedback before scholars build their tracks tomorrow.

Lesson Objectives

- **Big Science Idea**: When predicting an object's motion, many factors must be considered (i.e., the slope of the ground, the mass of the object, the friction, etc.).
- **Science and Engineering Practice**: **Construct Explanations and Design a Solution** Scholars engage in this Science and Engineering Practice as they apply scientific ideas to design a racetrack.

Materials Needed

- For each table: Hot Wheels car, scissors, rolls of painter's tape, gram weights, cardboard tubes, larger cardboard tubes, paper, index cards, blocks, yarn, straws, Play-Doh, construction paper, Materials List

Prep

- Print a Materials List for each group.

Launch

- Show scholars this video.
  - What did the engineers have to consider when building this racetrack?
  - What do you think may be difficult about designing and building a racetrack?
- Present the lesson challenge: Today is the day to design the track for the challenge! Scholars will create a plan for their track and share an explanation as to why their track will allow the car to keep going and won't allow it to slow down and stop. Scholars will need to design their track based on a budget of $30.

Activity

- **Procedure**:
  - Scholars discuss what features and materials should be part of the track, recording materials they plan to use and calculate their budget.
  - Scholars record and label their plan and will present ideas to the class with an explanation for why their track will meet the requirements.
  - Scholars should have a chance to revise their designs after Discourse.
- Press scholars to consider what they know about forces and why their racetrack will be successful.

Discourse

- **Debrief activity**: Scholars present the tracks and field questions from the class.
  - What forces did you consider when designing your track? How will these affect your car's motion?
- Scholars revise designs based on Discourse.
- **Make broader connections**: Show this video that showcases insane Hot Wheels tracks!

- What would you have added to your design if you had a bigger budget?
- What did the engineers have to consider when building these tracks?

Accountability (Informal)

There is no Exit Ticket for today's lesson. Allow scholars ample time to plan for their racetracks.

Lesson 10: Track Day!

This is it! Today is the day to build our tracks! Scholars build the racetracks and determine if they meet the requirements of the challenge.

Lesson Objectives

- **Big Science Idea**: When predicting an object's motion, many factors must be considered (i.e., the slope of the ground, the mass of the object, the friction, etc.).
- **Science and Engineering Practice**: **Construct Explanations and Design a Solution** Scholars engage in this Science and Engineering Practice as they apply scientific ideas to design a racetrack.

Materials Needed

- For each table: Hot Wheels car, scissors, rolls of painter's tape, gram weights, cardboard tubes, larger cardboard tubes, paper, index cards, blocks, yarn, straws, Play-Doh, construction paper, Materials List

Prep

- Print a Materials List for each group. Determine how scholars will get the materials for building.

Launch

- Have scholars discuss how they plan to work as a team to complete the challenge ahead.
- Present the lesson challenge: It is competition day! Scholars will build and test their racetracks.

Activity

- **Procedure**:
  - Scholars use their designs to build and test their racetrack as a team, making any last minute improvement before testing in front of the class.
- Press scholars to consider why they are building each part of the track and how it will help the car travel.

Discourse

- **Debrief activity**: Each group tests their track in front of the class.
  - Does this track meet the competition requirements?
  - Scholars give feedback on the success of the racetrack and how it can be improved for the future.
- Scholars record improvement notes and independently record and label an improved racetrack.

Accountability (Lab Notebook)

Use scholars' Lab Notebooks to assess the Big Science Idea and Science and Engineering Practice.

Scoring:

1. For the observational drawing:
    a. Award 1 point for creating and labeling the improvement plan for the racetrack.
2. For the explanation:

a. Award 1 point for a claim that indicates if the track meets the competition requirements.
b. Award 1 point for including evidence from their track design to support the claim.

Unit Vocabulary

Flashcards

- Send home Vocabulary Flashcards for scholars to study.

Vocabulary List

- **energy** - the ability to do work
- **slope** - a rising or falling surface
- **distance** - measures how far an object can travel
- **speed** - measures how fast an object is changing positions
- **force** - a vector quantity having magnitude and direction
- **friction** - a contact force that opposes the motion of an object
- **mass** - how much matter is in an object
- **potential energy** - energy in an object based on its position relative to other objects
- **kinetic energy** - energy of an object has due to its motion
- **motion** - a change in an object's position
- **transfer** - to move from one place to another
- **collision** - when one moving objects hits another

Extra Resources

In addition to the resources linked throughout the guide, use the following materials to help you prepare to launch this unit with scholars:

- Lab Notebook
- Unit-Specific Content - Resources to help you understand content at an adult level