A UNIT OF STUDY FOR GRADES 3-5 AND 6-8

ETRACE TO WIN







The Children's Museum of Indianapolis is a nonprofit institution dedicated to creating extraordinary learning experiences across the arts, sciences, and humanities that have the power to transform the lives of children and families. It is the largest children's museum in the world and serves more than 1 million people across Indiana as well as visitors from other states and nations. The museum provides special programs and experiences for students as well as teaching materials and professional development opportunities for teachers. To plan a visit or learn more about educational programs and resources, visit the Educator section of the museum's website at **childrensmuseum.org.**

VISIT THE MUSEUM

The museum provides special programs and experiences for students as well as teaching materials and professional development opportunities for teachers. To plan a visit or learn more about educational programs and resources, visit the Teacher section of the museum's website at **childrensmuseum.org.**

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E RACE TO WIN

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INTRODUCTION



ENDURING IDEAS

Auto racing is both a major sport and an important industry that is helping make the cars we drive safer and more efficient. To design, build, and test the fastest and safest speed machines, race teams use their skills in science, technology, engineering, and math. Speed, performance, and safety are all top priorities. Just like full-size cars, super-fast Hot Wheels® cars ignite imaginations and provide opportunities for students to learn new science, math, and visual arts concepts. A love for Hot Wheels[™] can also inspire interest in many types of automobile-related careers.



The Exhibit

Mattel's Hot Wheels brand represents the excitement of real-life racing for generations of fans young and old. As visitors enter the exhibit they walk through a Hot Wheels-themed Gasoline Alley and learn how racing teams design full-size cars and tracks for both speed and safety. Visitors learn how state-of-the-art engines work and join a pit crew to learn how a top-notch crew contributes to a winning run. Visitors also can try out Hot Wheels cars and accessories, experiment with tracks and track layouts, and experience authentic auto-racing artifacts.

The Unit of Study

This unit of study is designed to complement the *Hot Wheels*[™]: *Race* to Win[™] exhibit by inspiring students to experiment and learn how physical forces influence the distance and speed their Hot Wheels cars can travel. Students learn about the diverse sport of auto racing and the skills needed by people who pursue racing careers. Students also learn how designers and engineers deal with physical forces as they design full-size race cars and tracks for safety as well as speed. In this inquiry-based unit, students use problem-solving skills to determine which design modifications are most likely to help them reach their goals. The culminating project provides the opportunity for students to learn and apply concepts in basic physical science, engineering, and visual arts as they exercise thinking and language arts skills. As students work to solve the problem of achieving greater speed or distance, they follow the design process by brainstorming, working with the materials they have, building, testing, revising, and sharing results.

STEM

Hot Wheels: Race to Win engages students in solving real-life problems using important physical science concepts, technology, engineering practices, and math skills.

Speedometry

The Hot Wheels[®] SPEEDOMETRY[™] Math and Science Curriculum

provides Grade 4 on-line lessons that encourage inquiry and STEM learning through play and hands-on activities matched to Next Generation Science Standards: www.hotwheels.com/ en-us/speedometry.com

INTRODUCTION

What's ahead?



Lesson 1: Hot Wheels[™] on the Go!

Students experiment and carry out measurements to discover how physical forces influence the way their Hot Wheels[®] cars move and the distance they can go.



Lesson 2: Speed by Design

In this lesson, students learn that air is matter and explore the concept of aerodynamic design. They experiment with modifications they can make to their cars and determine how these changes influence the speed and distance their cars can move. They consider the ways visual artists and engineers work together to create cars designed for speed and safety.



Lesson 3: Further, Fastest, and Safest: Inquiry Project

In this inquiry project, student teams use what they have learned about the physical science concepts of friction, speed, gravity, potential energy, and kinetic energy to design and test track layouts for racing Hot Wheels cars. Students brainstorm performance concepts for their track layout and consider the science concepts involved. Then they plan, implement, and test the layout, evaluate the outcomes, and demonstrate their findings.



ILLUSTRATION BY BRYAN CHRISTIE DESIGN

What will students learn?

This unit of study enables students to develop skills in science, technology, engineering, and math (STEM) and achieve specific national and state academic standards in science, math, and visual arts. Unit experiences address the *Indiana Process Standards for The Nature of Science and the Design Process* and integrate them with Content Standard 1: Physical Science and Content Standard 4: Science, Engineering and Technology.



What will students be able to do? Unit goals: Students will

- examine the different kinds of skills and training needed by people in racing careers, such as race drivers, designers, engineers, mechanics, pit crews, and safety experts;
- test different surfaces to determine how friction varies and affects motion;
- explore the concepts of gravity, potential energy, and kinetic energy, and their influence on objects;
- explain how Newton's laws of motion can be observed in different situations;
- demonstrate that air is matter and explore examples of aerodynamic design;
- examine the ways designers and engineers use their knowledge of physical forces to design safer cars and race tracks;
- work in teams to design and test different track layouts for Hot Wheels cars to achieve maximum speed or maximum distance while maintaining a good safety record; and
- evaluate test results and demonstrate the outcomes of an inquiry project.

INTRODUCTION



Museum Links

Hot Wheels™: Race to Win™, created by The Children's Museum of Indianapolis. will travel to several museums and science centers throughout the United States and Canada over the next five years, returning to The Children's Museum each May. The exhibit provides an excellent opportunity for students to explore behind the scenes and learn about the science principles and technology that produce the world's most exciting racing events. Students begin to appreciate racing teamwork as they take on the role of designers, engineers, drivers, and pit crew members and engage in hands-on experiences and programs. They learn how the parts of an auto engine work and how the combustion process turns fuel into power. Using Hot Wheels® cars and track, they can test the different variables that affect performance and safety, such as car design, track and tire design, and pavement features. As a seasonal exhibit returning to the museum each spring, Hot Wheels: Race to Win will be a yearly experience that enhances your curriculum.

GETTING STARTED



Classroom Environment

Let other teachers and the school media specialist know that you are planning a unit on auto racing using Hot Wheels cars and layouts in which students will practice math skills and examine physical science concepts. The visual arts teacher may want to do joint planning to weave art concepts into Lesson 2, in which students explore automotive design. Establish a student reading center with car-related nonfiction books on cars, automobile inventors, auto racers, and automotive history, design, and careers. See the **Resources** section of this unit for suggestions. Make sure students have access to a computer for web-based searching. All students should be able to use both print and electronic media to conduct research. Create several spaces in the classroom where teams can work on track layouts and experiments. Collect sections of Hot Wheels track and gather two or three large plastic tubs to store track and other materials. See a variety of Hot Wheels cars and accessories at the official Hot Wheels website: hotwheels.com/collections.

Family Connections

Many parents have warm memories of playing with Hot Wheels cars and tracks as children. Some may have saved their cars and layouts or have become collectors. A few might be willing to donate track or accessories to the class. Most parents enjoy introducing their children to Hot Wheels cars and will be delighted that children can learn important concepts in science, math, and visual arts as they play. Keep parents informed about the educational goals of this unit. Some parents may want to visit the class and demonstrate their "vintage" Hot Wheels cars and accessories. You may also want to invite parents to visit on the days when students are reporting on their inquiry projects with Hot Wheels track layouts in Lesson 3.



LESSON 1: HOT WHEELS™ ON THE GO!

Students experiment and carry out measurements to discover how forces such as friction and gravity influence the way their Hot Wheels move and the distances they can go.

Focus Questions

- How far and how fast can Hot Wheels[®] cars travel on different surfaces?
- Why does the type of surface make a difference?
- How does a track layout affect the speed and distance of a Hot Wheels car?
- What can cause a Hot Wheels car to change directions?

Objectives

Students will

- predict how Hot Wheels cars will perform on different surfaces
- calculate and compare the speed of cars on different surfaces
- develop and use definitions of terms such as **speed** and **friction**
- work in teams to gather and record data on how cars perform on inclined surfaces
- explain how **potential energy**, **kinetic energy**, and the force of **gravity** influence how far and how fast a car will move
- observe and identify examples of Newton's laws of motion

What Is Speed?

Speed is the distance an object travels per unit of time. For example, in the United States, the speed of cars is usually given in miles per hour. For students working with Hot Wheels cars, speed can be measured on a smaller scale, such as centimeters or feet per second. Younger students should be able to make simple measurements to determine the distance and time traveled by their Hot Wheels cars. To calculate the average speed, students in Grades 4 and above can divide the distance travelled by the time needed to travel that distance.

You will need

For each group, you will need ...

- 3 or 4 Hot Wheels cars
- several sections of Hot Wheels track to make a straight section 4 feet long
- several pieces of sandpaper to cut and arranged in a long strip
- 1 narrow section of fabric, such as felt
- glue that will adhere to plastic
- 1 stopwatch
- 1 yardstick or meter stick
- 1 Hot Wheels 3-speed launcher
- books or other items to create a ramp 3 to 4 inches high
- masking tape or painter's tape
- two 1-foot long sections of track joined together with a connector
- 1 curved section of track
- handouts: Student Data Sheets #1 and #2 - pages 16 and 17

Fast Words

friction • gravity kinetic energy • potential energy predict • speed • surface

Academic Standards

Indiana's Academic Standards for Science, 2010

Process Standards for the Nature of Science include:

- Making observations, questions, and predictions
- Designing a test and planning and carrying out investigations using appropriate tools and technologies
- Testing predictions with multiple tests
- Keeping accurate records and communicating findings to others
- Comparing the results of an investigation with the prediction

Content Standard 4:

3.4.1, 3.4.2; 4.4.1, 4.4.2, 4.4.3, 4.4.4

<u>National Science Standards</u> Next Generation Science Standards, 2014

3-PS2-1; 4-PS3-1; 5-PS2-1; MS-PS2-2; MS-PS3-1, MS-PS3-2, MS-PS3-5





EXPERIENCE 1 WHEN THE RUBBER HITS THE ROAD

Students work in teams to record the distance their Hot Wheels® cars can go on surfaces that have different textures. They create graphs showing car performance on each surface and speculate about the reasons for differences they observe. Students will learn that **friction** is one of the major factors car designers must consider.

Procedures

- A day or two before teaching Experience 1, prepare the tracks for student use. For each group, prepare a sandpaper track and a fabric track. Make these tracks by gluing strips of sandpaper to one 4-foot section of track so that the track is completely covered with sandpaper, and then gluing strips of fabric to a second 4-foot section of track.
- As an alternative, assemble several different kinds of materials with different types of surfaces and allow teams of student to choose the surfaces they want to test and prepare their sections of track for testing.

- On the day of instruction, introduce a Hot Wheels car and encourage the class to tell its story. Ask: Can you identify this type of car? Was it a car that you or someone in your family played with?
- Ask students if they have Hot Wheels cars at home and let two or three volunteers tell about their favorites.
- Ask: What is so special about your Hot Wheels cars? Why do you like them so much? What can they do?
- Insist that students give specific answers. If students say, "They're cool!" have them explain. Are the cars cool because they are fast, because of the way they look, or both?

- Roll the car across a flat surface, such as the floor or a tabletop, and ask students to describe how it moves. What would make the car move faster? Students may suggest that it needs a track. Ask students to explain why this might make a difference.
- Introduce a section of Hot Wheels track and place it on a flat surface. Ask students to observe as the car is rolled across the track and determine if it appears to move faster.
- Ask students why the track helps the car move faster. Some students may suggest that the track helps the car move in a straighter line. Others may say that the track is smooth. Both of these factors allow the car to move fast.
- Help students explore the idea that the surface can make a difference in a car's speed. Give each group of students a bare track, a sandpaper track, and a fabric track or, as an alternative, allow groups to choose three different kinds of material to test.
- Ask students to predict which materials will cause the cars to move faster or slower.
- Have students calculate the speed of their car on the three tracks. Students will need to use a stopwatch to time the cars and use a meter stick or a yardstick to measure the distance the cars move on the track.
- To insure that students always push the cars with the same force, have them use a Hot Wheels 3-speed launcher set to the first notch. If a launcher isn't available, mark the starting line and make sure that students release the car at that point using approximately the same arm motions with a similar amount of force.



Teacher Tip Student Data Sheet 1

To adapt this material for different learning needs, consider limiting the variables students will test. For example, in Data Sheet 1, students who haven't yet studied division or learned to average numbers should establish a specific distance for the cars to travel and then only test for time. They can compare the times in each of the three trials, and choose an approximate number for the Average Speed column. If a car completes the trip over a 4-foot section of bare track in 2.5 seconds, 4 seconds, and 3 seconds, 3 would be the closest to an average number. Be sure to discuss the reasons why the time might be slightly different in each trial. The possibility that human error could affect results is one reason scientists repeat tests several times!

- Tell students that they need to perform at least three trials on each surface, calculate the speed for each trial, and average the results for each surface. Students who haven't learned to average numbers should be able to compare the results of each trial to determine an approximate average.
- Students should record their data on Student Data Sheet #1 on page 16. After students examine the data, ask them to discuss the reasons for conducting three trials of each surface.
- Have students make a bar graph to compare the speeds for the different surfaces. Ask students to explain their results.



Auto racing is a dangerous sport. Drivers wear safety gear especially designed to protect them in high-impact collisions and fires, including a helmet, fire suit, gloves, boots, and a seatbelt/harness. Racetrack walls are designed to absorb the force of an impact and help prevent injuries.

Careers in Racing – A Driving Force

When a race begins and rubber hits the road, race car drivers have to use their knowledge and skills with split-second accuracy. The driver has to determine how the tires are performing under specific track conditions. Changes in the weather can cause the track to be wet and slick so there isn't enough traction or hot and sticky in ways that produce too much friction. An accident can produce debris that can injure drivers or damage cars and tires. Drivers must have excellent timing to avoid hazards. They must decide quickly when to brake and slow the car down for dangerous situations, curves, and maneuvers while pushing for maximum speed. In addition to being able to "read" the road, a driver has to be alert, strong, and healthy and must understand how his or her car reacts to intense physical forces.

- Explain that the car experienced more friction on the sandpaper, fabric, or other rough-surface tracks than it did on the bare track. Friction is a force that resists the movement of two surfaces that are touching. The strength of the force of friction depends on the touching surfaces. In general, friction is greater when one or both surfaces are rough.
- Hot Wheels cars and tracks are designed to minimize friction because friction slows the turning of the wheels.
- In contrast, the tires of full-size cars are designed to maximize friction. The engine of a full-size car turns the car wheels and tires, and friction between the tires and the road keeps the tires from slipping. If no friction existed between the tires and the road, the car would not move. However, friction between moving parts in a full-size car reduces the efficiency of the car engine.
- Ask students: Why is friction both a good thing and a bad thing? When do you need for a car's tires to grip the road? How are tires designed to create friction when needed? How do the brakes use friction to bring a car to a stop? How does friction between moving parts of a full-size car affect the car's engine?



All pit crew members wear protective gear and focus on safety as well as speed. The stakes are high! Pit crew performance can make the difference in winning or losing a race.

Careers in Racing Precision in Motion: The Pit Crew

A highly synchronized pit crew is fascinating to watch! Each member of the crew performs a specialized job and must do it precisely in only a few seconds. When a race car comes into the pit, tires often have to be changed due to wear, damage, or because track conditions require tires that produce more or less friction. Four crew members, one for each tire, rapidly make the change while other crew members refuel the car if necessary, check for problems, make adjustments and repairs, and get the driver safely back on the track.



EXPERIENCE 2 - RAMP IT UP!

Students explore potential energy, kinetic energy, and the force of gravity as they test their Hot Wheels® cars on different ramps and record their data. They study how ramp height changes how far and how fast the cars move and connect these differences with the energy of the cars.

Procedures

- Ask students how they could make their cars move without pushing them or using a launcher.
- Students will probably think of raising one end of the track to build a ramp that the cars will run down.
- Encourage students to start by experimenting with gentle inclines of 2 or 3 inches and gradually work up to greater heights.
- Help small groups of students step up an investigation using ramps made of a 2-foot length of track raised to three different heights. The groups should record data on how far and how fast their cars moved using **Student Data Sheet #2** on page 17.
- For each trial, instruct students to start their cars at the top of the ramp and release them without pushing. Make sure tracks are set up in areas with plenty of room to allow the cars to go as far as possible before stopping on their own.

Teacher Tip Student Data Sheet 2

To adapt this experience for different learning needs, limit the variables by testing only how far or how fast a car goes. For example, students might only measure the distance a car goes at three different heights. To test only for speed, establish a stopping point with a piece of track, wooden blocks or another type of barrier and have students record the time it takes for the car to travel this distance from different ramp heights.

After teams have recorded their data, discuss the results. Students will probably discover that steeper ramps produce greater speeds and longer distances traveled.

- Ask students why they think steeper ramps caused the cars to move faster and farther. What caused their cars to move down the ramp? Why did the height of the ramp make a difference?
- Explain to students that gravity is a force that pulls objects together. The gravity between Earth and objects on or near Earth's surface is strong and pulls the objects toward the center of Earth.
- Then explain that because gravity pulls objects downward, objects have potential energy. **Potential energy** is the energy an object has because of its position. An object's potential energy is greater when it is higher off the ground. So a Hot Wheels[®] car has more potential energy when it is at the top of a tall ramp than it does when it is at the top of a short ramp.
- Next, tell students that as the Hot Wheels car rolls down the ramp, its potential energy is converted into kinetic energy. Kinetic energy is the energy of motion. An object's kinetic energy depends on its mass and its speed. Thus, the more kinetic energy an object has, the faster it moves.
- Ask why the cars continued to move after they were off the ramp. Help students understand that the cars still had kinetic energy even after they finished going down the ramp, so they kept moving.
- Discuss with students why the cars eventually came to a stop. Ask them to use what they now know about friction to develop an explanation. Make sure students understand that friction between the car and the floor converted the car's kinetic energy into thermal energy and sound energy. Once the car's kinetic energy was converted into other forms of energy, the car stopped.



Some Kinds of Potential Energy

- Gravitational Potential Energy: Gravitational potential energy is the energy an object has because of its distance off the ground. Objects that are high off the ground or have a longer distance to fall have more gravitational potential energy than objects closer to the ground.
- Elastic Potential Energy: Elastic potential energy is energy stored by the deformation of an elastic object. A stretched rubber band has elastic potential energy. When a stretched rubber band is let go, its elastic potential energy is converted into kinetic energy as it springs back into its relaxed shape. A Hot Wheels 3-speed launcher contains a rubber band that stores elastic potential energy when it is stretched. This potential energy is converted into kinetic enverted into kinetic energy is added to the kinetic energy of the launched car.
- Chemical Potential Energy: Chemical potential energy is energy stored in the bonds of molecules. Chemical potential energy can be released and converted into other forms of energy when the bonds are broken. For example, chemical potential energy in gasoline is released when it is burned. Gasoline burned in car engines is converted into thermal energy (which causes the engine to heat up) and kinetic energy (which powers the car).



Newton's Laws of Motion

- The First Law of Motion: The first law of motion describes the motion of an object when no force acts on the object. The law can be broken down into two parts: objects at rest and objects in motion. The first part of the law states that an object at rest (i.e., an object that is not moving) will stay at rest if no unbalanced force acts on it. This part of the law is easy to understand: an object will not move unless a force pushes or pulls it. The second part of the law states that an object in motion will stay in motion at a constant speed and in a constant direction unless an unbalanced force acts on it. This part of the law is not as obvious because most objects have the unbalanced force of friction acting on it. Friction on an object causes the object to slow down and eventually stop.
- The Second Law of Motion: The second law of motion describes how an unbalanced force on an object affects the object's motion. The second law states that the acceleration of an object is equal to the force on the object divided by the mass of the object. Thus, for an object with a constant mass, the acceleration of the object increases as the force on the object increases. However, if the force on an object with constant mass is also constant, the acceleration of the object decreases. Thus, a greater force is needed to give an object with greater mass the same acceleration as an object with lower mass.
- The Third Law of Motion: The third law of motion describes the interaction between objects that exert forces on each other. The third law states that when an object exerts a force on a second object, the second object exerts a force on the first object that is equal in size but opposite in direction. When a steel ball bearing is dropped on a hard surface, the ball exerts a downward force on the floor. At the same time, the floor exerts an upward force on the ball. This upward force causes the ball to bounce up.



Newton's Laws and Safety Gear

Much of the safety equipment a race car driver uses is designed with Newton's laws of motion in mind. According to the second part of Newton's first law, an object in motion will remain in motion until it encounters an opposing force. A driver is an object in motion, just like the car. If the car hits the track wall or another car, the driver would continue to move forward at high speed and strike the windshield or another object. To prevent a deadly impact, seatbelts and a harness hold the driver's body in the seat. A specially designed racing helmet keeps the driver's head from snapping forward to avoid head and neck injuries.





EXPERIENCE 3 - ROUNDING THE CURVE

Students study Newton's laws of motion using Hot Wheels® cars. They investigate the first and third laws of motion by observing how a force can change the direction a Hot Wheels car moves. Students learn that the cars move around a curve because of a sideways unbalanced force on the car.



- This Experience may be done as an activity with older students but is best done as a demonstration with younger students.
- Point out to students that so far, their cars have been traveling only in straight lines. Ask students how they could make their cars turn a corner. Students will likely answer that the car needs a curved piece of track.
- Construct a curved wall using two 1-foot sections of track connected together. Tilt the track on its edge on the floor or a table. Use masking tape or painter's tape to securely hold one end of the track on its edge. Gently bend the track to form a curved wall and use tape to hold the track in the curved shape. You may need to tape the track in three or four places. (Note: The track will

form a curved wall that the car will roll next to. The car will not roll on the track.) Make sure that the tape is flat against the surface of the track and the floor or table so that it does not interfere with the movement of the car.

- Put a Hot Wheels car in a 3-speed launcher set to the first or second notch. Place the launcher and car at one end of the curved wall. Ask students to predict how the car will move when you hit the release button on the launcher. Students will probably predict that the car will follow the curved wall.
- Ask students what will happen when the car reaches the end of the curved wall: Will the car keep moving in a curved path or will it move in a different way? Ask students to explain their answers.

- Have students observe the car as you hit the release button. You may want to repeat the demonstration a few times. Ask students to describe how the car moved. Students should note that the car followed the curved wall and then moved in a straight line when the wall ended.
- Explain to students that as the car rolled next to the curved wall, it pushed against the wall. At the same time, the wall pushed back on the car due to Newton's third law of motion. The push of the wall on the car caused the car to change directions and follow a curved path.
- Then explain that once the car went past the end of the curved wall, nothing was pushing the car sideways. Because there was no sideways push, the car no longer turned. Instead, it moved in a straight line, which demonstrates Newton's first law of motion.
- You may also point out that the car sitting in the 3-speed launcher also demonstrates the first law of motion. The car stayed in the launcher because no unbalanced force acted on it. But when the launcher was released, an unbalanced force pushed on the car and made it move.
- Conclude by showing students a curved piece of Hot Wheels track. Point out that the curved track is banked, which means that the track is tilted inward. Explain that the tilt in the track acts in a similar way as the curved wall in the demonstration. As a car rolls on the curved track, it pushes against the track and the track pushes on the car. Because the track is tilted, part of the push on the car is directed sideways, which makes the car change directions.

Hot Wheels 3-Speed Launcher and Newton's Second Law



The Hot Wheels 3-speed launcher is more accurately a 3-acceleration launcher. The launcher works when a plunger strikes a car with force that causes the car to move, thereby accelerating the car.



The size of the force depends on how far the plunger is pulled: the farther it is pulled, the stronger the force it exerts when it is released. According to Newton's second law of motion, the greater the force on an object, the faster the acceleration of the object.



As a result, a car launched using the first notch on the launcher (the smallest force) has a smaller acceleration than the same car launched using the third notch on the launcher (the largest force). Students can easily observe the differences in acceleration using the launcher.

When The Rubber Hits The Road Grades 3–5

Group:

	track length (cm)		Time (s)		Estimated Average Speed
		Trial 1	Trial 2	Trial 3	
Bare Track					
Sandpaper Track					
Fabric Track					

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Group:			Bare Track	Sandpaper Track	Fabric Track
	track length (cm)				
		Trial 1			
	Time (s)	Trial 2			
		Trial 3			
	sp (track l	Trial 1			
	eed (cm/s ength divi time)	Trial 2			
	s) ded by	Trial 3			
	Average Speed (cm/s)				

B STUDENT DATA SHEET #1

Grades 3–5

Group:

Estimated Average Speed			
	Trial 3		
Time (s)	Trial 2		
	Trial 1		
l (cm)	Trial 3		
nce Traveled	Trial 2		
Dista	Trial 1		
Ramp Height (cm)			

Group:

Average Speed (cm/s)			
s) I Divided	Trial 3		
eed (cm/s Traveled by Time)	Trial 2		
Sr (Distance	Trial 1		
	Trial 3		
Time (s)	Trial 2		
	Trial 1		
d (cm)	Trial 3		
se Travele	Trial 2		
Distanc	Trial 1		
Ramp Height (cm)			

Grades 6–8





LESSON 2: SPEED BY DESIGN

In this lesson, students explore basic concepts of aerodynamics and the way visual artists and engineers work together to design cars. They experiment with modifications they can make to their cars and determine how these changes influence the speed and distance cars can move.

Focus Questions

- Are some cars faster than others because of their design?
- Why can changes in design make a difference in how fast and how far they can go?
- What changes will have the best results?
- How do artists work hand-in-hand with engineers to create cars that are as fast as they look?

You will need

For each group, you will need ...

- 3 or 4 Hot Wheels® cars
- pieces of track and connectors
- books or blocks to build a ramp
- 1 stopwatch
- 1 yardstick or meter stick
- various materials for modifications, such as card stock paper or index cards, clay, and pennies or other small objects to act as weights
- car images from magazines or the web
- sketching paper, pencils, and markers for 2-D designs
- clay for 3-D designs
- Student Data Sheets #3 and #4 pages 28–29

Objectives

Students will

- work in teams to design and make modifications to Hot Wheels[®] cars
- conduct controlled trials to determine the effect of modifications made to Hot Wheels cars
- use tools to collect distance and time data to calculate the speed of the cars
- explain how thrust, drag, weight, and lift affect the aerodynamic performance of full-size cars
- draw a diagram illustrating possible design modifications that could be made to a full-size car to improve its aerodynamic performance
- reevaluate previously made modifications in light of new information and make improvements based on the new knowledge
- draw conclusions from the results of controlled trials

Fast Words

aerodynamics • design drag • lift • thrust variable • weight

Academic Standards

Indiana's Academic Standards in

Science, 2010

Process Standards for the Nature of Science:

- Making observations, questions, and predictions
- Designing a test and planning and carrying out investigations using appropriate tools and technologies
- Testing predictions with multiple tests
- Keeping accurate records and communicating findings to others
- Comparing the results of an investigation with the prediction

Process Standards for the Design Process:

- Identifying a need or problem to be solved
- Brainstorming potential solutions
- Selecting a solution and the materials needed
- Creating, evaluating, and testing the solution
- Communicating the solution and evidence of results
- Communicating how to improve the solution

Content Standards:

• 3.4.1; 4.4.1, 4.4.2, 4.4.3, 4.4.4; 5.4.2

Indiana's Academic Standards for Visual Arts, 2008

Content Standard 7

• 3.7.1, 3.7.2; 4.7.1, 4.7.2; 5.7.1, 5.7.2

National Standards

Next Generation Science Standards, 2015

 3-PS2-1; 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3; MS-PS2-2; MS-ETS1-1, MS-ETS1-2

National Standards for Arts

Education - Visual Arts, 2014

Creating/ Process Component: Investigate, Plan, Make – VA:Cr1.1.3a, 1.1.4a; 1.2.2a, 1.2.3a, 1.2.4a





RACE CAR ALBUM

There are many different types of auto races and each requires cars with different capacities and designs.



Formula One racing has the largest international audience and features the fastest road-racing cars in the world. Each season, Formula One teams build a new chassis for their single-seat, open-wheel cars and install 600-horsepower V-6 engines. They compete on temporary street courses or road courses built with many twists and turns. Formula One race cars can corner at high speeds because their aerodynamic design produces a strong downforce and helps keep cars on the road. Maximum speeds can reach 240 mph but actual racing speeds are lower, due to the demands of the complex racecourses.

Indy Car racing is the fastest kind of auto racing in the United States and Canada. Indy teams don't design and build a new car every year. Instead, teams buy more or less the same chassis (the basic framework of the car, including the driver's compartment) from *Dallara Automobili*, an Italian auto company, and use twin-turbo V-6 engines producing 575 to





Stock Car racing is the most popular spectator sport in North America. This racing style uses stock cars, which are conventional autos modified to meet racing specifications, with closed-wheel bodies and the engine in front. Like most sports car models, they have rear-wheel drive. Along with other modifications, the cab has a built-in roll cage along with other safety features to protect the driver. With V-8 engines producing 900 horsepower, stock car racers usually compete on an oval track where they can reach speeds of over 200 mph.



Funny cars are specialty dragsters that often compete against each other. They originated from the souped-up Mustang and Camaro coupes of the mid-1960s but have evolved into sleeker, more aerodynamic forms.

Drag Racing involves competing to see which car can accelerate from a standing stop most rapidly. Cars are usually raced against each other two at a time on a straight track measuring either 1/8 or 1/4 mile. The winner of a match

goes on to race against other winners. Cars start from a dead stop and can accelerate to over 300 mph in three seconds. Braking parachutes, used to bring the cars to a stop, are a safety feature for both drivers and fans. Car designs range from modified street models to dragsters designed specifically for racing. The powerful engines may be mounted in the rear or in front of the driver and car bodies often take a wedge-shaped form that produces the downforce needed to keep these "rockets" on the track.

675 horsepower. On oval tracks, Indy cars race at speeds of over 230 miles mph. They also compete on road courses and temporary street courses. The Indianapolis 500, with its oval track, is the most famous racing event for this type of car.



EXPERIENCE 1 - HOW FAST CAN YOU GO?

Many factors influence how far and how fast a Hot Wheels® car can go. In this experience, student teams meet as a large group to begin the problemsolving and design process. They will brainstorm possible changes they can make to their cars, experiment with the modifications, and record the results.

Procedures

- Ask students if they think the design of a car has any effect on how far and how fast a Hot Wheels car can go.
- What kinds of things can students think of that might change how far and how fast a car might travel?
- Explain to students that in this experience, they will be working in teams to modify Hot Wheel cars to determine what effect the modifications make on the performance of the car.
- To begin, divide the class into small groups. Give each group a stopwatch, Hot Wheels cars, and pieces of track for their experiment.

- Before testing the modifications to their cars, students should test the abilities of their cars without modifications.
- Have students set up their test track by creating a ramp using a 2-foot length of track and books. The bottom of the ramp should rest on a hard, smooth surface.
- Explain to students that since they are conducting scientific experiments, they must conduct controlled trials. To do this, each group should discuss and agree on variables to keep constant during their tests, including:
 - where to start the car on the ramp;
 - how to put the car in motion;
 - when to start and stop the stopwatch; and
 - how to measure distance traveled.
- Make sure students test cars using the same type of smooth surface track. To establish a consistent starting point, Use a piece of track or another object as a starting gate.
- Grades 3 5 Have students establish a consistent distance for cars to travel.
- Grades 6 8 Have students run the cars from the top of the ramp until they stop in their own.
- Have students run the cars from the top of the ramp until they stop on their own.

- Students may change only one variable at a time. If a run is not a controlled trial, students will need to run it again after making the appropriate adjustments.
- Students should use a stopwatch to measure the time needed for their group's car to run from the top of the ramp until it stops and use a yardstick or a meter stick to measure the distance the car travels.
- Students should conduct three trials, record the results on Student Data Sheet #3 on page 28, and discuss why it is important to do more than one trial.
- Next, groups should brainstorm ways to modify their cars. These modifications could include such ideas as taping coins to the cars for added weight, securing index cards in various configurations (see examples on this page), or modifying the shape of the car bodies with clay.
- Allow students to use their imaginations, but remind them that modifications should not interfere with the movement of the wheels.
- Have each group choose two modifications to implement and test.
- Students should predict whether each modification will make their car go faster or slower and travel a longer or shorter distance. They should record their predictions on Student Data Sheet #3.
- Students should implement one modification at a time and run three trails for each modification. They should record the results on **Student Data Sheet #3**.
- Have students examine their results. How have their modifications affected the results? Do the results match the group's predictions?
- Have students save their modifications if you plan to complete
 Experience 3.



Teacher Tip

To adapt this experience for different learning needs, try limiting the number of variables student teams test on Data Sheet #3. Instead of testing for both distance and speed, they might establish a constant distance and test only for speed. Student teams could also be placed in groups who test only one car modification. One group will serve as the control group and test the car with no modifications. A second group tests the car with one modification, such as adding weight to make the car heavier. The third group tests a different modification, such as changing the design of the body in some way. After the tests, groups come together to compare results. Students who have not yet learned to average numbers can determine approximate averages for speed or distance.



EXPERIENCE 2 - BUILT FOR SPEED

In this experience, students will consider how the principles of aerodynamics are reflected in the design of cars intended to go fast. As part of the design process, student teams examine Hot Wheels® cars with various modifications intended to make the car look fast to determine how these changes are reflected in the look and structure of the car. Students will create drawings showing the modifications they would make to a less aerodynamic car to make it look faster using different types of lines, shapes, colors, and space to communicate their ideas. More advanced students will create scale drawings.

The Substance of Air

To students, air may seem to be empty space, but it is not. Air is matter, made up of a mixture of gas molecules. Although air cannot be seen, it does have **mass** and takes up space.

Forces on Objects Moving Through Liquids or Gases

Thrust	The force that pushes an object forward. In the case of a car, the engine provides thrust. Thrust acts in the direction that the car is moving.
Drag	The force created by air moving over an object, slowing it down. Drag is also called air resistance and is the frictional force between a moving object and air. Parts of cars that stick out tend to increase drag. Drag acts in the direction opposite to the car's motion.
Weight	The force that pulls an object downward due to gravity. The more mass a car has, the greater its weight. Weight acts in a downward direction.
Lift	The force that pushes an object upward as it moves through the air. Air flowing under a car or parts of a car can create lift, making a car difficult to control at high speeds. Lift acts in an upward direction.

Procedures

- Show students a series of images of cars that are designed to go fast. Images can be found online through a search for images of sports cars or concept cars or from other sources.
- Ask students if the cars look like they would be fast or slow. What makes them look that way?
- Explain that car designers keep the ways that solid objects move through the air in mind. This is why fast cars tend to look alike in some ways. Certain design features help objects to move through the air more easily.
- Ask students: What is air? Record student's responses on the board.
- Have students blow on their own hands and ask them what they feel.
- Explain to students that what they feel is air pushing against their fingers. They can feel the air because it is made of matter.
- Explain that four main forces acting on a car affect how it moves through the air. These forces are **thrust**, **drag**, weight, and lift. (See "The Substance of Air" on this page.)
- Ask students which of these four forces can be affected by the design of a car. The shape of the car can have a great impact on how drag, weight, and lift affect the ability of a car to drive fast.
- Drag is one of the most important forces to consider when designing a fast car.



Careers in Racing Car Designers – Looking Fast

Auto design for all types of cars is carried out by a team whose members have training and experience in various disciplines, including art, graphic design, and transportation engineering. Design teams usually divide their work into three areas: the exterior form, the interiors, and color and trim. Exterior designers develop the shape and proportions of a car, first using manual and digital drawings, and then create clay models to scale. Full-size models, based on the small-scale models. are developed and tested. Interior designers plan and design the instrument panels, seats, doors, and all interior surface materials and trims. Other designers focus on all the colors and materials used on the car. They also create special graphics, such as stripes and decals. All designers focus on both safety features and aerodynamic design. This is especially true of designers for the racing industry, who must also consider the specifications and modifications required for each racing style. The goal is to create cars that look fast and go fast!

- Have kids think about what it is like to move in water. What happens if you smack water with a flat hand? What happens if you hit the water with the side of your hand? Objects moving through air experience similar resistance. Objects that that have a broad leading edge do not travel through air easily because the drag on them is large. Objects that have a thin or pointed leading edge move much more easily through the air because the drag on them is small.
- How easily a car moves through the air depends on the shape of the car. Cars that are boxy will have more difficulty moving through the air than cars that are wedge-shaped or curved to allow air to easily pass over them.
- Show students the images of cars with different types of body design. Which of these cars will experience more drag? Which one will move through the air more easily? Why?

What Makes a Car Fast

Aerodynamics: Aerodynamics is the study of how air moves and interacts with solid objects moving through air. For example, air resistance is a force that opposes the motion of an object through air. Air resistance increases as the speed of an object, such as a car, increases. When engineers streamline a car, they adjust the shape of the car to reduce air resistance. Cars with narrow or wedge-shaped front ends and smooth edges are more streamlined and experience less air resistance than boxy vehicles. For this reason, streamlined cars are said to be more aerodynamic than boxy cars.

Weight and mass: Weight is a measure of the force of gravity on an object. The more mass an object has, the stronger the gravity on the object, and the greater the weight of the object. A car or any object that has a small mass— and therefore a small weight—is easier to accelerate than a car or object that has a large mass and large weight.

Tires: Larger diameter wheels rotate more slowly for a given car speed and cover the road surface over a larger area so bumps are less noticeable.

Gravity: Gravity pulls every object toward the center of Earth. When a car is going downhill, the force of gravity helps accelerate the car downward. However, gravity still pulls a car downward when it is going uphill, so the car's engine must provide more power to move the car and overcome the force of gravity.

Engine: The engine of a full-size car provides the power to move the car at high speeds. The engine converts chemical potential energy into kinetic energy by burning gasoline. As gasoline is burned in an engine, the potential energy stored in the chemical bonds is released. This energy is converted into the kinetic energy of the moving pistons in the engine. The pistons move a crankshaft, and the kinetic energy of the crankshaft is transferred through different systems to power other moving parts of the car. Cars with more powerful engines have greater acceleration and/or higher top speeds.

- To reduce drag, car designers also try to eliminate or reduce parts that can catch air, such as rearview mirrors that stick out or open wheel wells around the tires.
- Lift can also be a problem for fast cars. The wedge shape of the car nose is similar to an airplane's wing. If air passing underneath a car creates enough lift to overcome the car's weight, it can rise off the road or be more difficult to control.
- Special design elements, such as rear spoilers, can be used to counteract lift. A spoiler is shaped like an upside down airplane wing, so air flowing around a spoiler pushes downward, and this downforce helps keep the car's wheels on the road. Designing cars lower to the ground also reduces the amount of air flowing underneath that can produce lift.

- Show students images of sports cars and discuss how the design elements help reduce drag and lift.
- Give each student a copy of the handout on page 27.
- Explain that it is their job as car designers to change the car on the paper to make it faster. They will need to decide what to change to make the card more aerodynamic and reduce drag and lift.
- Have students sketch the changes they would make over the illustration of the boxy car.
- Next, students should draw their design on a separate sheet of paper, using their sketch as a guide.
- Students should give special attention to the use of lines, shapes, and curves.
- Encourage students to complete their fast car by also designing the paint job. What styles and patterns can make a car look like it will be fast?

Common Design Elements to Increase Aerodynamic Performance



- Wedge shaped front: Allows car to slice more easily through the air
- Curved lines and edges: Allows air to move more easily over and around the car
- Spoilers and wings: Create a downward force on the car, allowing a car to benefit from greater traction
- Dams: Designed to block air moving underneath a car, reducing lift



Careers in Racing Auto Mechanic – Race Your Engine

Hot Wheels[®] cars don't have engines, but full-size cars can't go far without them! In auto racing, the engine is one of the key factors in a car's performance. A racing engine must be efficient and able to maintain high speeds, often for races that last several hours. For this reason, auto mechanics are essential members of a racing team. Race mechanics have specialized training and years of experience. They must understand how complex engines operate and be able to repair and maintain them. Mechanics also must work closely with drivers and other team members in order to help them achieve maximum speeds during a race. It takes aerodynamic design, a powerful engine, a skilled driver, and a great auto mechanic to make a car as fast as it looks!



EXPERIENCE 3 -TESTING AND REPORTING: ASSESSMENT

Students will revisit the modifications they made to the Hot Wheels[®] car in Experience 1 and evaluate the modification based on what they learned in Experience 2. Students will pick one modification and change it in a way that they think will help reduce drag to make their car go faster. Students will then test their newly modified cars against the cars modified by other groups.

S Procedures

- Have students return to their groups from Experience 1 and review their results.
- Groups should pick one of the designs that they created in Experience 1.
- Have students re-evaluate their design considering what they learned about thrust, drag, weight, and lift in Experience 2 and make modifications that they think might improve their car's speed.
- Each group should fill out the top of Student Data Sheet #4 on page 29 by describing the materials they used and the modifications they made. They should also explain how they think these modifications will affect the performance of the car.
- Next, students will prepare to compete with other groups to see which modified cars are the most successful.
- The first step is to design a controlled test, as in Experience
 1. If you have time, students can discuss the variables that need to be controlled, including how and where

to start each trial run and how to measure speed and distance traveled consistently.

- Groups should take turns running their cars on the test rack, being sure to record the results on Student
 Data Sheet #4. If a trial run is not properly controlled, it should be run again.
- Compare the outcomes for the trial runs and find which car ran the fastest.
- Students should mark their rank on Student Data Sheet #4 and discuss the results in their small groups.
- Have students discuss why they think their car performed the way it did based on the principles of aerodynamics described in Experience 2. Why was the slowest car the slowest? Why was the fastest car the fastest?
- Have each group report their results to the rest of class, including how their design affected the performance of their car.





Boxy Car

B STUDENT DATA SHEET #3

Grades 3-5

How Fast Can You Go?

Note: Complete the data collection for your unmodified car before you work on the modifications.

Team:

Modification	Distan	ce Travele	ed (cm)		Time (s)	Estimated Average Speed (cm/s)	
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2		
No modification							
Modification #1							
Modification #2							

Note: Cars should be tested over the same distance for each trial.

Describe Modification #1:	Describe Modification #2:
Predict how Modification #1 will change your car's speed	Predict how Modification #2 will change your car's speed
and distance traveled:	and distance traveled:

BSTUDENT DATA SHEET #3

Grades 6-8

How Fast Can You Go?

Note: Complete the data collection for your unmodified car before you work on the modifications.

Team: _

Modification	Distance Traveled (cm)			Time (s)			Speed (cm/s) (Distance Traveled Divided by Time)			Average Speed (cm/s)
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	
No modification										
Modification #1										
Modification #2										

Describe Modification #1:	Describe Modification #2:				
Predict how Modification #1 will change your car's speed	Predict how Modification #2 will change your car's speed				
and distance traveled:	and distance traveled:				

STUDENT DATA SHEET #4

Grades 3-5

Testing And Reporting: Assessment

Team: __

Distance Traveled (cm)			Time (s)			Estimated Average Speed (cm/s)
Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	

Note: Cars should be tested over the same distance for each trial.

Class Rank:_____

Describe your modification: _____

Predict how your modification will affect your car's speed:



Grades 6-8

Testing And Reporting: Assessment

Team: ___

Distance Traveled (cm)			Time (s)			Speed (cm/s) (Distance Traveled Divided by Time)			Average Speed (cm/s)
Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	

Class Rank:

Describe your modification: _____ Predict how your modification will affect your car's speed:

LESSON THREE



The wedge-shaped body of this funny car helps create the down force that keeps the dragster on the track at high speeds.

LESSON 3 - FARTHEST, FASTEST, AND SAFEST - INQUIRY PROJECT

Students work in teams to use what they have learned about friction, speed, potential energy, kinetic energy, the laws of motion, and aerodynamics to design and test track layouts for Hot Wheels® racers. Teams compete to create a layout that will allow their cars to move the greatest distance or the greatest speed with the best safety record. Each team must demonstrate how they worked with forces and energy transfer to reach their goal, how they documented the outcome, and how they would change their layout for better results.

Focus Questions

- What track layout will allow a Hot Wheels car to move at the highest speed or the longest distance without crashing?
- What forces are involved?
- How is potential energy converted into kinetic energy?

Objectives

Students will

- work in teams to design a Hot Wheels track layout that meets certain criteria
- draw labeled diagrams of their track layouts that explain the features of the layout
- explain how potential energy is converted into kinetic energy in their track layout
- develop a way to evaluate the success of their track layout
- build and test a track layout based on their design
- modify their track layouts based on the results of the initial tests and test the modified layouts to measure improvement
- give an oral presentation and demonstration of their track layouts during which they describe how forces and energy affected the performance of cars on the track

You will need

For each group, you will need ...

- 1 Hot Wheels car for each team
- pieces of track and connectors including curved sections of track and parts for constructing loops
- books or blocks to build a ramp and/ or hills
- 1 stopwatch
- 1 yardstick or meter stick
- strips of sandpaper and fabric to modify track surfaces and doublesided tape to attach the sandpaper and fabric
- a 3-speed launcher (optional)
- sketching paper, pencils, and markers for 2-D designs

LESSON THREE

Fast Words

constraint • criteria iteration

Academic Standards

Indiana's Academic Standards in Science, 2010 Process Standards for the Nature of

Science:

- Making observations, questions, and predictions
- Designing a test and planning and carrying out investigations using appropriate tools and technologies
- Testing predictions with multiple tests
- Keeping accurate records and communicating findings to others
- Comparing the results of an investigation with the prediction

Process Standards for the Design Process:

- Identifying a need or problem to be solved
- Brainstorming potential solutions
- Selecting a solution and the materials needed
- Creating, evaluating, and testing the solution
- Communicating the solution and evidence of results
- Communicating how to improve the solution

Content Standard 4:

• 3.4.1; 4.4.1, 4.4.2, 4.4.3, 4.4.4; 5.4.2

<u>National Standards</u> Next Generation Science Standards.

2015

 3-PS2-1; 4-PS3-4; 5-PS2-1; 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3; MS-PS2-2; MS-PS3-2, MS-PS3-5; MS-ETS1-1, MS-ETS1-2.



Careers In Racing Safety Crew – Putting Safety First

It is great fun to crash Hot Wheels® cars, but an accident on a real racetrack is something everyone strives to avoid. Track and car designers, equipment designers, and racetrack personnel all work to create the safest possible environment for race teams, track workers, and fans. Pit safety crews are key members of a track's safety operations. Whether they are volunteers or professionals, these crews are trained to protect racing teams, fans, and themselves. Their duties start before the race as they check equipment such as radios, fire extinguishers, and their own fires suits, helmets, and gloves. On race day, they arrive early in the morning to patrol the racetrack looking for anything that could be dangerous to drivers, pit crews, fans, or cars. During races they are alert to any potential hazard on the track. If an accident happens, they are the first ones over the wall of protective barriers that separate the pit areas from the track. They direct traffic around the accident, assist drivers, clean up oil spills, and pick up any pieces of metal, bolts, and screws that may fall off a damaged car. It's a long day for a safety crew but they have the satisfaction of knowing they've helped to make it a safe day for everyone!

Engineering Design Terms

- Criteria: Criteria are the required features or characteristics that an engineered design must have. For example, the criteria for a certain track layout may be that the layout has one curve, has a source of potential energy, can be run safely (no crashes), and can help a car move at a high speed.
- Constraint: A constraint is something that limits an engineered design. For example, a constraint on a track layout is the number of track pieces available.
- Iteration: In engineering design, an *iteration* is a new version of a design that improves on a previous design. For example, a track layout may be modified to make it safer, which is one of the criteria of the design problem.

LESSON THREE



EXPERIENCE 1 – THE CHALLENGE

The **Hot Wheels**[®] **Racing Challenge**: Like real-life racetrack designers, students use their knowledge of energy and forces, such as friction and gravity, to design a track layout that they believe will allow their cars to move as far or as fast as possible.

Procedures

- Lead a class discussion about features that a Hot Wheels track layout can have. For example, a track layout may include curves, loops, or hills. Make a list of the features on the board.
- Ask students how a Hot Wheels car can safely move through these features. Students may note that a car has to be moving fast to go through a loop, but cannot be moving too fast when going around a curve.
- Tell students that they will be working in small groups to design a track layout. Their layouts must include at least one feature listed on the board, and the layout should make their car move as fast as possible or as far as possible without crashing.

- Have students divide up based on the features they wish to include in their track layout. Be sure that the groups contain approximately equal numbers of students by dividing up large groups if necessary.
- Allow students to examine the track pieces that they will be able to use and have them discuss in their groups the goals for their track layout. Students must decide which track feature or features they will include and whether they are going to make a fast track or a long track.
- Have students draw their track designs on paper. As they work, remind them that their designs should include the way that their car will be put in motion. Ask students what form of potential energy will be converted into the kinetic energy

of their car. Some students may use gravitational potential energy and a ramp to launch their car, while other students may use elastic potential energy in a 3-speed launcher.

- Also remind students that their cars must run on their tracks without crashing. Ask them if there are sections of their track where the speed of the car needs to be reduced and ask them how they would reduce the car's speed. Putting a rough surface on a section of track will increase friction and slow the car.
- Each group should produce a final drawing of their track design with parts of the track labeled. For example, students should label the track features they are including, their source of potential energy, and any safety features they intend to use.
- After students finish drawing their track designs, have them write a description of how they will evaluate the success of their track. If students are building a fast track, they need to describe how they will measure the car's speed. If students are building a long track, they need to describe how they will measure the distance the car travels. Students can write these descriptions in their notebooks.



EXPERIENCE 2 - PUT IT TO THE TEST

Students build layouts based on their designs, conduct multiple tests of the layouts, and keep a notebook of procedures and results. They identify track designs that produce accidents and test modifications that produce better safety results. They document procedures with drawings and notes explaining the science concepts involved.

SProcedures

- Have groups of students build the track layouts that they designed in Experience 1. Students may need to modify their designs due to limitations of track pieces available. However, the track layouts that they build should contain at least one special feature from their original design.
- Have students test their layouts and evaluate the success of their track using the method they described in Experience 1. Each team should use one car for all trials. They should conduct at least three trial runs and record their measurements in their notebooks.
- After students have tested their initial track layouts, lead a discussion about the success of their tracks.

LESSON THREE

Ask them how the cars moved on the tracks and through the special design features. Ask them if they had problems with crashing and how they might change their track layouts to avoid crashes.

- Also ask how they might change their layouts to improve their cars' performance. Encourage students to discuss how changing their layouts may change the forces on the cars and/or change the cars' energies.
- Give students the opportunity to modify their track layouts based on the ideas discussed. Have students write a description of their modifications and explain why they made the modifications in their notebooks.
- After modifying the layouts, students should reevaluate their designs by conducting at least three more trial runs. Their new measurements should be recorded in their notebooks.
- Finally, students should write a paragraph in their notebooks that summarizes their new results and compares them to the results of the original design.



EXPERIENCE 3 - ASSESSMENT

Teams carry out a demonstration or presentation to present their inquiry project. Each team must be able to explain how they planned to use forces to reach their goals, how they tested to find the most effective layout, how they documented outcomes, and how they would change their layout, if necessary, for even better results.

Procedures

- Have each team of students present their track designs to the class.
 During the presentation, students should discuss the following:
 - Did they design a fast track or a long track?
 - What design features did they include and why did they put the track parts together in the way that they did?
 - What was their source of potential energy?
 - How was the potential energy converted into kinetic energy of the car?
- Teams should then demonstrate the performance of a Hot Wheels® car

on the track. After the demonstration, the team should discuss the following:

- How did they evaluate the success of their design? (How did they measure speed or distance?)
- What were the results of their initial design? (What was the speed of the car on the track or how far did the car travel?)
- How did gravity and friction play a role in the car's performance on the track?
- What modifications did they make to their track? Why did they make those modifications?
- If they had problems with crashing, what did they change to make the track safer?

- How did their modifications affect the car's performance on the track? (What were the results of the modified design?)
- If you could make any change, what would you do to get even better results?
- After each team has presented their design to the class, lead a class discussion on how Newton's laws of motion were observed on the tracks. Some possible observations may include: The first law was observed when the cars traveled in straight lines. They did not change direction because no sideways unbalanced force acted on them. The second law was observed when gravity pulled a car down a slope, causing it to accelerate. The second law was also observed when friction caused a car to decelerate. The third law was observed when a student pulled on the 3-speed launcher lever. As the student pulled on the lever, the lever pulled back on the student's hand.

- **aerodynamics:** In racing, the interaction between air and the resistance and forces created by a car moving through the air.
- **constraint:** Something that limits an engineered design. For example, a constraint on a track layout is the number of track pieces available.
- **criteria:** The required features or characteristics that an engineered design must include, such as for aerodynamics and safety.
- **design:** A detailed plan or drawing produced to show the look and function of an object before it is built or made.
- **drag:** The force created by air moving over an object, slowing it down. Drag is also called air resistance and is the frictional force between a moving object and air.
- **friction:** A force that resists the movement of two surfaces that are touching. In general, friction is greater when one or both surfaces are rough.
- **gravity:** A force that pulls objects together.
- iteration: A new version of an engineered design that improves on a previous design. For example, a track layout may be modified to make it safer, which is one of the criteria of the design problem.
- **kinetic energy:** The energy of motion. An object's kinetic energy depends on its mass and speed. The more kinetic energy an object has, the faster it moves.
- **lift:** The force that pushes an object upward as it moves through the air. Air flowing under a car or parts of a car can create lift, making a car difficult to control at high speeds. Lift acts in an upward direction.

- **potential energy:** The energy an object has because of its position. An object's potential energy increases is greater when it is higher off the ground.
- **predict:** To estimate that a specific thing will happen in a certain way in the future or will be a consequence of some action or force.
- **speed:** The distance an object travels per unit of time, such as miles per hour.
- **surface:** The outside material or upper layer of something, such as a track or a road.
- **thrust:** The force that pushes an object forward. In the case of a car, the engine provides thrust. Thrust acts in the direction that the car is moving.
- **variable:** An element, feature, or factor that is likely to vary or change or that can be varied or changed according to a design plan.
- weight: The force that pulls an object downward due to gravity. The more mass a car has, the greater its weight. Weight acts in a downward direction.

Auto Racing

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Hot Wheels[®] Speedometry[™] Math and Science Curriculum: www.hotwheels. com/en-us/speedometry.com

These Grade 4 on-line lesson plans encourage inquiry and STEM learning through play and handson activities. Co-created with researchers at the Rossier School of Education, University of Southern California, lesson plans are linked to Texas state standards, Common Core State Standards (CCSS), and Next Generation Science Standards (NGSS).

Academic Standards

This unit of study addresses specific state and national academic standards in science, visual arts, and language arts.

Indiana's Academic Standards

Science, 2010

This unit addresses Indiana Process Standards for The Nature of Science and The Design Process and integrates them with Content Standard 1: Physical Science and Content Standard 4: Science, Engineering and Technology.

Process Standards for the Nature of Science include:

- Making observations, questions, and predictions
- Designing a test and planning and carrying out investigations using appropriate tools and technologies
- Testing predictions with multiple tests
- Keeping accurate records and communicating findings to others
- Comparing the results of an investigation with the prediction

Process Standards for the Design Process include:

- Identifying a need or problem to be solved
- · Brainstorming potential solutions
- Selecting a solution and the materials needed
- Creating, evaluating, and testing the solution
- Communicating the solution and evidence of results
- Communicating how to improve the solution

Content Standards:

• 3.4.1 Choose and use the appropriate tools to estimate and measure length, mass, and temperature in SI units.

- 3.4.2 Define the uses and types of simple machines and utilize simple machines in the solution to a "real world" problem.
- 4.4.1 Investigate transportation systems and devices that operate on or in land, water, air, and space and recognize the forces (lift, drag, thrust, and gravity) that affect their motion.
- 4.4.2 Make appropriate measurements to compare the speeds of objects in terms of the distance traveled in a given amount of time or the time required to travel a given distance.
- 4.4.3 Investigate how changes in speed or direction are caused by forces: the greater the force exerted on an object, the greater the change.
- 4.4.4 Define a problem in the context of motion and transportation. Propose a solution to this problem by evaluating, reevaluating, and testing the design. Gather evidence about how well the design meets the needs of the problem. Document the design so that it can be easily replicated.
- 5.4.2 Investigate the purpose of prototypes and models when designing a solution to a problem and how limitations in cost and design might affect their construction.

English Language Arts, 2014

This unit addresses academic standards in the area of Speaking and Listening, including

Discussion and Collaboration:

 3.SL.2.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) on grade-appropriate topics and texts, building on others' ideas and expressing personal ideas clearly.

- 3.SL.2.3 Demonstrate knowledge and us of agreedupon rules for discussions and identify and serve in roles for small group discussions on projects.
- 3.SL.2.5 Explain personal ideas and understanding in reference to the discussion.
- 4.SL.2.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) on grade-appropriate topics and texts, building on others' ideas and expressing personal ideas clearly.
- 4.SL.2.3 Demonstrate knowledge and us of agreedupon rules for discussions and carry out assigned roles.
- 4.SL.2.5 Review the key ideas expressed and explain personal ideas in reference to the discussion.
- 5.SL.2.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) on grade-appropriate topics and texts, building on others' ideas and expressing personal ideas clearly.
- 5.SL.2.3 Establish and follow agreed-upon rules for discussion.
- 5.SL.2.5 Review the key ideas expressed and draw conclusions in reference to information and knowledge gained from the discussions.

Presentation of Knowledge and Ideas:

 3.SL.4.2 Create oral presentations that maintain a clear focus, using various media when appropriate to emphasize or enhance certain facts or details.

- 4.SL.4.2 Create oral presentations that maintain a clear focus, using multimedia to enhance the development of main ideas and themes that engage the audience.
- 5.SL.4.2 Create engaging presentations that include multimedia components and visual displays when appropriate to enhance the development of main ideas or themes.

Visual Arts, 2010

Content Standard 7: Understand and apply elements and principles of design in personal works of art, utilizing a variety of media, tools, and processes.

- 3.7.1 Apply elements (line, shape, form, texture, color, and space) and principles (repetition, variety, rhythm, proportion, movement, balance, emphasis) in artwork that effectively communicate ideas.
- 3.7.2 Identify and discriminate between types of lines (characteristics and qualities), shapes (geometric and organic), textures (tactile and visual), colors (primary, secondary, complementary), and space (placement, overlapping, negative, positive, size) in own work and the works of others.
- 4.7.1 Apply elements (line, shape, form, texture, color, and space) and principles (repetition, variety, rhythm, proportion, movement, balance, emphasis) in work that effectively communicate ideas.
- 4.7.2 Identify and discriminate between types of lines (characteristics, quality), shapes (geometric and organic), textures (tactile and visual), colors (primary, secondary,

complementary, tints, and shades), space (placement, perspective, overlap, negative, positive, size), balance (symmetrical, asymmetrical, radial), and the use of proportion, rhythm, variety, repetition, and movement in own work and the works of others.

- 5.7.1 Apply elements (line, shape, form, texture, color, and space) and principles (repetition, variety, rhythm, proportion, movement, balance, emphasis, and unity) in work that effectively communicate ideas.
- 5.7.2 Identify and discriminate between types of lines (characteristics, quality), shapes (geometric and organic), textures (tactile and visual), colors (primary, secondary, complementary, intermediates, neutrals, tints, tones, shades, and values), space (background, middle ground, foreground, placement, perspective, overlap, negative, converging lines, positive, size, color), balance (symmetrical, asymmetrical, radial), and the use of proportion, rhythm, variety, repetition, and movement in own work and the works of others.

National Standards

Next Generation Science Standards, 2014

- 3-PS2-1 Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.
- 4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.

- 4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
- 5-PS2-1 Support an argument that the gravitational force exerted by Earth on objects is directed down.
- 3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
- MS-PS2-2 Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
- MS-PS3-1 Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
- MS-PS3-2 Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
- MS-PS3-5 Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes,

energy is transferred to or from the object.

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

<u>National Standards for Arts</u> Education – Visual Arts. 2014

Creating/ Process Component: Investigate, Plan, Make

Anchor Standard 1: Generate and conceptualize artistic ideas and work

- VA:Cr1.1.3a Elaborate on an imaginative idea.
- VA:Cr1.1.4a Brainstorm multiple approaches to a creative art or design problem.
- VA:Cr1.2.2a Make art or deign with various materials and tools to explore personal interests, questions, and curiosity.
- VA:Cr1.2.3a Apply knowledge of available resources, tools, and technologies to investigate personal ideas through the artmaking process.
- VA:Cr1.2.4a Collaborate set goals and create artwork that is meaningful and has a purpose to the makers.

<u>National Common Core State</u> <u>Standards – English Language</u> Arts

Language Arts:

- L.3.4 Determine or clarify the meaning of unknown and multiple-meaning word and phrases based on Grade 3 reading and content, choosing flexibly from a range of strategies.
- W.3.2 Write informative/ explanatory texts to examine a topic and convey ideas and information clearly.
- W.3.7 Conduct short research projects that build knowledge about a topic.
- SL.3.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on Grade 3 topics and texts, building on others' ideas and expressing their own clearly.
- SL.3.3 Ask and answer questions about information from a speaker, offering appropriate elaboration and detail.
- SL.3.4 Report on a topic or text, tell a story, or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace.
- W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic.
- L.4.4 Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on Grade 4 reading and content, choosing flexibly from a range of strategies.

- SL.4.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on Grade 4 topics and texts, building on others' ideas and expressing their own clearly.
- W.5.7 Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic.
- W.5.8 Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources.
- L.5.4 Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on Grade 5 reading and content, choosing flexibly from a range of strategies.
- SL.5.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on Grade 5 topics and texts, building on others' ideas and expressing their own clearly.
- SL.5.4 Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.
- SL.5.5 Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes.