Racing Spoilers:

NASCAR Engineers Use Newton's Laws of Motion

NASCAR Cup Series by Nigel Kinrade

This material was supported by funding from NV STEM Networks and is affiliated with the UNLV College of Engineering's Tech Trekker program.

Table of Contents

Unit and Project Overview

Las Vegas is known as the “Entertainment Capital of the World.” In order to live up to its name, the city has had to come up with a variety of events and shows to attract tourists and locals alike. Las Vegas Motor Speedway does just that. For more than 50 years, Las Vegas has been a host for big time car racing, and NASCAR racing has become one of the biggest events. (*WSN, Aug 8, 2019*).

This lesson is NASCAR-themed to generate interest and excitement for students. Teachers can further emphasize this theme with classroom decorations, racing related reading activities, and videos related to NASCAR cars, drivers, and races.

Students will learn science concepts on Newton’s Laws of Motion in this 7-lesson mini unit plan, which is part of the 8th grade curriculum on Forces and Interaction. The activities within each lesson will provide students with the opportunity to learn about forces in nature and how these forces result in motion. They will use their science background about Newton’s Laws of Motion and the Engineering Design Process to design the most efficient spoiler for a race car.

An easy-to-use online CAD program (Tinkercad) will allow students to design their spoilers for 3D printing.

This is a four-week unit plan that will culminate with a visit from Tech Trekker for 3D printing of the student-designed spoilers.

Teachers should request the Tech Trekker visit to coincide with Lesson 7. Requests should be made at least 3 weeks in advance.

Acknowledgements: Lessons created by educators Mignon Penalosa, Ronald Barranco and Filomena Vine, with support from Dr. Erica Marti and Paul Oko at the University of Nevada, Las Vegas.

Next Generation Science Standards

NEXT GENERATION SCIENCE STANDARDS
For States, By States

**Unless otherwise specified, "descriptions" referenced in the evidence statements could include but are not limited to written, oral, pictorial, and kinesthetic descriptions.*

MS-PS2-2 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

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.** [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [*Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions. • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. - - - - - - - - - - - - - - - - ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations.	**PS2.A: Forces and Motion** • The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. • All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.	**Stability and Change** • Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

Lessons 1 and 2 in this Unit Plan

Table from [NGSS Evidence Statements]

MS-PS2-1 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*[Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] *[Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.]*

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific ideas or principles to design an object, tool, process or system.	**PS2.A: Forces and Motion** • For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).	**Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems. - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

Lesson 3 in this Unit Plan

Table from [NGSS Evidence Statements]

MS-ETS1 Engineering Design

MS-ETS1 Engineering Design

Students who demonstrate understanding can:

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.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.
- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS-ETS1-1)

Developing and Using Models
Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.
- Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (MS-ETS1-4)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
- Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2)

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting Engineering Problems
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1)

ETS1.B: Developing Possible Solutions
- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4)
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3)
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3)
- Models of all kinds are important for testing solutions. (MS-ETS1-4)

ETS1.C: Optimizing the Design Solution
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (MS-ETS1-3)
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)

Crosscutting Concepts

Influence of Science, Engineering, and Technology on Society and the Natural World
- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ETS1-1)
- The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1)

Lessons 4 to 7 in this Unit Plan

Table from NGSS Evidence Statements

Forces and Interaction | 8th Grade Science	
Force and Motion	**Lesson One**
Questions: What is motion? What causes objects to move or stop moving? How does a fly FLY in a speeding car?	
Objective: 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.	
Phenomena: Are you sitting down as you read this? Are you sitting completely still? If you answered "yes" to either of those questions, you might be surprised to learn that you are actually moving, and you have the universe to thank for that. While certain objects, like your chair for instance, might seem at rest, everything in the world is really in constant motion; all matter in this universe is packed with atoms that vibrate with energy. The video below demonstrates the Law of Inertia, Newton's 1st Law of Motion. Students watch the video: https://www.youtube.com/watch?v=PcGIUZzWoVc	
Science 8 Knowledge Targets	***Science 8 Performance Targets***
Define motion and identify what causes an object to move by describing what must happen to make an object move or stop moving.	1. Define motion and determine that a force is needed in order to cause a change in motion. 2. Demonstrate understanding that friction is a force resisting motion. 3. Provide evidence that a moving object will continue at constant speed if no forces are acting upon it. 4. Determine that larger forces cause greater changes in motion. 5. Demonstrate understanding about the relationship between speed, position, and time. 6. Describe, using data and graphs, that the amount and direction of the force applied determines motion.

Time	*Vocabulary*
Suggested 2-4 50-minute periods **Day 1:** **A.** Students will read “Apple on a Desk” and answer the question. Teacher will facilitate TPS (see procedure below). **B.** Students, in small groups, will conduct an investigation on how forces move objects: Moving Bodies. **Days 2 and 3**: Students will use this GIZMO activity, Force and Fan Carts, to learn about Force and Motion. **Day 4:** **A.** Students will build a Table-top Hovercraft (see link below). **B.** Students will complete the Force & Motion Assessment.	motion force friction position/reference point speed
Background Information	***Materials***
Motion makes the world go 'round. Motion makes the moon go 'round too. In fact, motion makes lots of things go. When we think of motion we often think of cars, bicycles, kids running, basketballs bouncing, and airplanes flying, but motion is so much more. Motion is important to our lives and impacts so many things that we do. Motion is the changing of position or location, but motion requires a force to cause that change. Force is just a fancy word for pushing or pulling. If I push on something or pull on it, then I am applying a force to it. Force makes things move or, more accurately, makes things change their motion. *From Science Trek, sciencetrek.org*	• Student handouts and worksheets • CD • 9" balloons • Pop-top cap from soap or water bottle • Glue gun

<table>
<tr><th>Lesson Overview (Activities)</th><th>Advance Preparation</th></tr>
<tr><td>Students will start with an activity on Moving Bodies. This will help them identify changes in position leading to a definition for the word motion.

Then students will use the simulation on GIZMO on Force and Fan Carts to illustrate basic laws of force and motion. It shows a miniature cart powered only by a fan. Students can place objects (mass) on the cart, use different surfaces (friction), and change fan speeds (force). The fan can be turned off as the cart rolls to see what the results are when there is no force on the cart.</td><td>Teacher will make copies of the handouts and worksheets.

Teacher will assign the materials for the CD Hovercraft to the students.</td></tr>
<tr><td colspan="2">Procedure</td></tr>
<tr><td>Engage: Apple on a Desk. Teachers will start by uncovering students' ideas about forces. Students will read “Apple on a Desk” (see worksheet below) and then respond to the question. After the given time (usually 3 minutes), students engage in student discourse (TPS: Think-Pair-Share) by sharing their thinking with their shoulder partner.

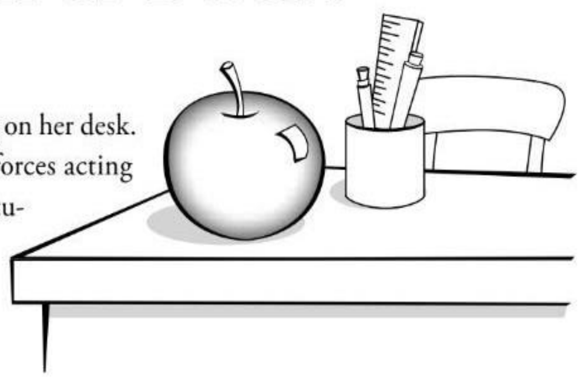
Explore:
A. Moving Bodies. Students will use the materials provided (marble, Lego man, small box, small cart) to observe how objects move.
B. Force and Fan Carts. Students will use the GIZMO simulation to determine the force needed to make an object move and change its motion.
For first time GIZMO users, click on the link below to learn how to create your teacher account and how to login for students.
How to Create & Login to GIZMO</td><td>Explain: Students will describe what makes an object move or change its motion. Students will explain how the mass of the object affects the object’s motion. Students will show that they understand the relationship between the position, time, and speed of the moving object.

Extend:
A. Students will create a CD hovercraft that will show that force is needed to make objects move.
B. Independent practice for students on the calculation of net force.

Evaluate: Force and Motion Assessment
Force and Motion</td></tr>
</table>

Suggested Assessment	***Additional Resources***
3-2-1 Countdown **Project** CD Hovercraft	**"Tablecloth Trick: Inertia"**, by Spangler ScienceTV on Youtube https://www.youtube.com/watch?v=PcGIUZzWoVc **"Apple on a Desk"**, Uncovering Student Ideas in Science, NSTA 2008 (see worksheet below) **"Moving Bodies"**, by M. Poarch 2003, Science Class.net http://science-class.net/archive/science-class/Lessons/Physics/Force_Motion/inertia.pdf **"Force and Fan Carts"**, by GIZMO https://www.explorelearning.com/index.cfm?method=cResource.dspView&ResourceID=614 **"Tabletop Hovercraft"**, by ScienceBob https://sciencebob.com/build-a-tabletop-hovercraft-2/ **"Calculating Net Force"**, abss.k12.nc.us https://www.abss.k12.nc.us/site/handlers/filedownload.ashx?moduleinstanceid=60051&dataid=106701&FileName=19.%20Calculating%20Net%20Force.pdf "Force and Motion" science-class.net Force and Motion Assessment, Science Class.net Newton + Nascar

Apple on a Desk



Mrs. Canales pointed to an apple sitting on her desk. She asked her students to describe any forces acting on the apple. This is what some of her students said.

Archie: "The only force acting on the apple is air pressure."

Sam: "There is one force acting on the apple. Gravity is the force that pulls on the apple."

Soledad: "There are two forces: the desk pushes up on the apple and gravity pulls downward on the apple."

Misha: "There are many forces acting on the apple; but, it is the holding force in the apple that keeps it on the desk."

Tess: "There are no forces acting on the apple because the desk stops any forces from acting on it."

Which student do you most agree with? ________________________

Explain your thinking. What rule or reasoning did you use to decide if there were any forces acting on the apple?

____

____

____

Forces and Interaction | 8th Grade Science	
Newton's 1st and 2nd Laws of Motion	**Lesson Two**
Question: Why do you need to slow down when making a turn or exiting the freeway?	
Objective: 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.	
Phenomena: Walk up a set of stairs, sit in a pool of rushing water, look down at the slide before you push off—*whoosh!*—and let gravity take it from there. This year, more than 85 million people around the world will visit water parks, according to the International Association of Amusement Parks. When they do, their rides will be guided by the laws of physics, the branch of science that deals with the way objects move. The Science of Summer Fun	
Science 8 Knowledge Targets	***Science 8 Performance Targets***
Identify the phenomenon under investigation, which includes the change in motion of an object.	1. Identify the purpose of the investigation, which includes providing evidence that the change in an object's motion is due to the following factors: a. balanced and unbalanced forces acting on the object; b. the mass of the object. 2. In the investigation, describe how the following factors will be determined and measured: a. the motion of the object – including a specified reference frame and appropriate units for distance and time; b. the mass of the object, including appropriate units; c. the forces acting on the object, including balanced and unbalanced forces. 3. Describe the relationship between: a. force and acceleration at constant mass; b. mass and acceleration at constant force.

Time	*Vocabulary*
Suggested 3-4 50-minute periods **Day 1:** **A.** Students will demonstrate inertia using the activity *Inertia Ring*. Links to the worksheet and video are provided below. **B.** Students will work on Force and Motion Basics from PhET (link provided) **Day 2:** **A.** Students will read *"Dropping Balls"* and then respond to the question in writing. Teacher will facilitate the TPS activity (see guide under procedure). **B.** Students will continue with the PhET simulation. **Day 3:** Students, in small groups, will teach their peers about force and motion using Jigsaw (see procedure below). **Day 4:** **A.** Students will work on the extension activity on Downforce: Under Pressure. **B.** Students will take the quiz/test.	inertia, force acceleration mass motion Law of Inertia (1st law) Law of Acceleration (2nd law)
Background Information	***Materials***
Most auto-crossers and race drivers learn the importance of balancing a car early in their careers. Learning to do it consistently and automatically is one essential part of becoming a truly good driver. While the skills for balancing a car are commonly taught in drivers' schools, the rationale behind them is not usually adequately explained. That rationale comes from simple physics. Understanding the physics of driving not only helps one be a better driver, but also increases one's enjoyment of driving. If you know the deep reasons why you ought to do certain things, you will remember the things better and move faster toward complete internalization of the skills. When a force is applied to a car, the change in motion is proportional to the force, divided by the	**For Inertia Ring:** ● Hex Nuts ● Yellow inertia rings (teacher may purchase the rings from the link found in the video, see under Additional Resources) ● Empty 2-liter soda bottle ● Worksheets **For Downforce: Under Pressure** ● Pressure-Test Spool Assembly Sheet Under Pressure Activity Sheet ● Race Car Adaptations Resource Sheet ● A Focus on Air Pressure Resource Sheet (optional) ● Recycled or reused paper (1 sheet per student)

mass of the car. This law is expressed by the famous equation $F = ma$, where F is a force, m is the mass of the car, and a is the acceleration, or change in motion, of the car. A larger force causes quicker changes in motion, and a heavier car reacts more slowly to forces. Newton's second law explains why quick cars are powerful and lightweight. The more F and the less m you have, the more a you can get.	• Straws (1 per student) • Spools (1 per student) • Index cards (1 per student) • Card stock (1 sheet per student) • Rulers • Scissors • Pencils • Markers • Completed cars
Lesson Overview (Activities)	***Advance Preparation***
Students are introduced to the concepts of force, inertia and Newton's first law of motion. Students will also learn about the kinds of forces: contact and non-contact types of forces: specifically applied, spring, drag (downforce), and frictional forces; and magnetic, electric, and gravitational forces. Students will learn the difference between speed, velocity, and acceleration, and come to see that the change in an object's motion (or acceleration) is caused by unbalanced forces. They will also learn that engineers consider and take advantage of these forces and laws of motion in their designs.	Teacher will make copies of all the worksheets needed and the materials for the Inertia Ring activity. Option: Inertia Ring activity can be a whole class demo or small group 8-minute inquiry-based lesson.

Procedure	
Engage: **A. Inertia Ring.** Students will use the materials provided by the teacher (Hexnuts, empty 2-Liter soda bottle, plastic ring) to demonstrate inertia. **B. Dropping Balls.** Teachers will start by uncovering students' ideas about Newton's 2nd Law of Motion. Students will read "*Dropping Balls*" and then respond to the question. After the given time (usually 3 minutes), students will engage in discourse (TPS: Think-Pair-Share) by sharing their thinking with their shoulder partner. **Explore: Forces and Motion Basics.** In this inquiry-based lesson, students will use a simulation from PhET to learn more about the forces that act on the object and how they affect the object's motion. **There are 4 mini-lessons in the simulation: Net Force, Motion, Friction, and Acceleration.** All lessons are tied together to help students understand the effect of force and mass on the motion of an object, as well as the types of forces that we use and encounter daily. (Note: Teacher will print the student worksheets found when opening the link to the activity).	**Explain:** Teachers will facilitate small group discussion using the Jigsaw strategy. Students in groups of 4 will take turns peer-teaching a section of the lesson on **Forces and Motion Basics.** Procedure on how to do the Jigsaw is provided in the worksheet attached. **Extend: Downforce: Under Pressure.** This lesson will provide students the opportunity to learn about a kind of force race car drivers need to understand to make the cars aerodynamic. Worksheets are in the Quick Links section at the top of the page. Downforce: Under Pressure **Evaluate:** Teacher-made quiz/test. Sample Test by warwicksd.org

Suggested Assessment	***Additional Resources***
Quiz/Test	**"Inertia Ring" Demo**, adapted from Steve Spangler SICK Science (see worksheet below) **"Inertia Ring" video**, SICK Science on YouTube https://www.youtube.com/watch?v=i_8_LspALdw **"Dropping Balls"**, Uncovering Student Ideas in Science, NSTA 2008 (see worksheet below) **"Forces and Motion Basics"**, PhET Forces and Motion Basics **"JIGSAW"**, adapted from Berkeley Center for Learning and Teaching https://teaching.berkeley.edu/active-learning-strategies "**Jigsaw Worksheet**" (see worksheet below) **"Downforce: Under Pressure"**, Scholastic https://www.scholastic.com/teachers/sponsored-content/nascarspeed/17-18/downforce-under-pressure-/

Inertia Ring Demo

Procedure:

1. Balance the plastic ring in the center of the 2-liter soda bottle.

2. Balance 1 Hexnut on the plastic ring aligning it with center of the bottle (hole).

3. Pull the plastic ring fast forward or backward, and if done correctly the Hexnut will fall straight into the bottle
4. Repeat procedure 1,2 and 3 with 3 Hexnuts, then 5, and then 7.

Since the hex nuts are just sitting on the plastic ring, it shows resistance to sideways motion when the ring is pulled. However, having no place to stay, it falls straight down under the influence of gravity.

Dropping Balls

Reggie has three different types of balls. Each ball is about the same size.

Ball 1 is a wooden ball. Its mass is 28 g.

Ball 2 is a golf ball. Its mass is 46 g.

Ball 3 is a metal ball. Its mass is 110 g.

Reggie held his arm out and dropped the three balls at the same time from the same height. In what order will the balls hit the floor? Circle your prediction:

Prediction A: Ball 1, then ball 2, then ball 3.

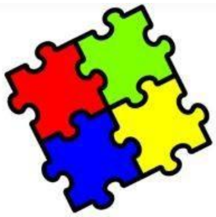
Prediction B: Ball 3, then ball 2, then ball 1.

Prediction C: Ball 2, then ball 3, then ball 1.

Prediction D: All three balls will hit the floor at about the same time.

Prediction E: Ball 3 will hit first, followed by ball 1 and ball 2 hitting the floor at the same time.

Explain your thinking. What "rule" or reasoning did you use to make your prediction?



JIGSAW

1. Students work in small groups to read information that has been organized into sections.
2. Each student in the group reads one section of the material and then shares that information with the rest of their group.
3. As they read and share information, they refer to prompts such as:
    A. What do you think each idea means?
    B. What is the big idea?
    C. How can this idea be applied to help understand the concept(s)?
    D. What questions do you have about what you read?
    E. What do you agree/not agree with?

There are various permutations of jigsaws. One such model includes expert and cooperative groups: Each group can be assigned a particular aspect/part of the overall information – they read it individually and then discuss in their small "expert" group to make sure they all understand it. New "cooperative" groups are formed made up of one-two students from each of the original expert groups. In this way, the new groups have an "expert" representative from each of the original groups so that all of the information is now represented in the new cooperative group. The "expert" has had a chance to practice sharing and hearing other viewpoints about the information in their original group, and therefore likely feels more comfortable sharing in the new group.

Forces and Interaction | 8th Grade Science	
Newton's 3rd Law of Motion and NASCARs	**Lesson Three**
Question: How does science help build the optimum race car?	
Objective: MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.	
Phenomena: Notice that when you jump from a raft into the water, you will see the raft fall back as your body moves forward. While rowing in a boat, as you move the water backward with the paddle, why does the boat move in the opposite direction? Why does a car slide back when it hits a wall? For every action there is an equal and opposite reaction. How does a rocket engine work? Why do guns kick back when they're fired? Why do muscles work in pairs? What propels us when we're swimming? And how exactly is gravity a two-way interaction? All of these questions, and many more, will be answered in this excellent video. Newton's 3rd Law of Motion	
Science 8 Knowledge Targets	***Science 8 Performance Targets***
1. Students know Newton's 3rd Law describes action and reaction forces. 2. Students know every action force has an equal and opposite reaction force.	1. Students can apply Newton's 3rd Law to a variety of real-world scenarios. 2. Students can model a system involving a collision between two objects. 3. Students can work within given criteria and constraints to design, construct, and test a solution to a problem involving the collision of two objects. 4. Students can determine how the choice of technologies used in the solution is limited by the constraints of the problem.

<table>
<tr><th>Time</th><th>Vocabulary</th></tr>
<tr><td>Suggested 2-3 50-minute periods

Day 1:
A. Students will read the selection from Actively Learn or watch the BrainPop movie and complete the worksheet.
B. Students will work on Newton’s Triple Play from zunal.com (see link below)

Day 2:
A. Students will continue with Newton’s Triple Play webquest.
B. Students will summarize the laws of motion using a graphic organizer that the teacher will provide.

Day 3:
A. Students will design and drive their own NASCAR car virtually.
B. Students will take the quiz/test.</td><td>motion, force, friction, position, speed, distance, velocity, inertia, acceleration, collision, Newton</td></tr>
<tr><th>Background Information</th><th>Materials</th></tr>
<tr><td>How does downforce help a NASCAR race car?

Similar to the way that geometry and billiards are closely related, there's a lot of physics involved in NASCAR racing, or any form of auto racing, actually. If you want an easy way to remember a few of the key factors in NASCAR, just remember the three D's -- downforce, drag, and drafting.

Downforce is created by the air moving over the top of the car and pushing it down toward the track surface. Downforce increases drag. Drag is the resisting force the vehicle experiences from air pushing against it and the additional weight that downforce creates. Drivers can lessen the amount of drag that they experience on the race track by drafting. Drafting is when Driver B tucks the nose of his car almost underneath the rear bumper of Driver A's car to improve the air flow over both cars.
Sometimes you will hear this maneuver called "running nose-to-tail."

From How Stuff Works, auto.howstuffworks.com</td><td>iPads/technology
Worksheets</td></tr>
</table>

Lesson Overview (Activities)	*Advance Preparation*
Students will start with the engagement activity: Newton's 3rd law on Actively Learn or Acceleration from Brainpop. Teacher will introduce the webquest assignment, starting with the *WELCOME* page and its accompanying video. The teacher will show the *INTRODUCTION* page, and the *TASK* page. Teacher will explain the various tasks in detail. Students will work with a partner to complete the different tasks (one to three). Students will be evaluated using the online assessment (task 4).	Teachers will make copies of the handouts and worksheets (if needed) and provide the technology required. NOTE: For the webquest on Newton's Triple Play, find the attached worksheets and video clips at the bottom of the TABS (i.e. Welcome tab)
Procedure	
Engage: For the engagement activity, teacher may use either of the 2 options: **A. Newton's 3rd law.** Students will read "*Newton's third law"* from Actively Learn and answer the questions. **B. Acceleration.** This is a 3-minute video from Brainpop. After the video, the teacher will have students complete the worksheet on interpreting graphs, or the graphic organizer, which is a flow chart where students describe the changes in speed and acceleration during the stages of a skydive. **Explore:** Students will complete the different tasks of the webquest assignment found on the *PROCESS* page.	**Explain:** Students will complete a graphic organizer to summarize the laws of motion. **Extend:** Students will design and drive their own NASCAR. **Evaluate:** Teacher-made quiz/test. Sample Test by palaich.net

Suggested Assessment	*Additional Resources*
Quiz/Test	**"Acceleration",** BrainPop https://www.brainpop.com/science/motionsforcesandtime/acceleration/ **"Newton's third law"**, Actively Learn https://read.activelylearn.com/#teacher/reader/authoring/preview/538316/notes **"Newton's Triple Play",** Mignon Penalosa, zunal.com http://zunal.com/webquest.php?w=415954 **"Scary Daytona 500 Wreck"**, Cork Gaines 2/21/2020, Business Insider https://www.businessinsider.com/dale-earnhard t-jr-hates-nascar-spoilers-daytona-500-ryan-ne wman-crash-2020-2 **"Aerodynamics**", Scholastic https://www.scholastic.com/teachers/sponsored-content/nascarspeed/17-18/aerodynamics/

<table>
<tr><th colspan="2">Forces and Interaction | 8th Grade Science</th></tr>
<tr><td>Engineering Design Process:
Identifying Criteria and Constraints</td><td>Lesson Four</td></tr>
<tr><td colspan="2">Questions: When have you made something move? How can you make objects (like a toy car) go farther and faster? What forces are acting on a car as it travels a racetrack? Does the surface of the track make a difference?</td></tr>
<tr><td colspan="2">Objective: MS-ETS1-1 To integrate engineering design into the structure of science education by raising engineering design to the same level as scientific inquiry when teaching science disciplines in secondary classes. Students will use the engineering design process to work on a model car.</td></tr>
<tr><td colspan="2">Phenomena: Engineering Connection When you jump, your legs apply a force to the ground, and the ground applies an equal and opposite reaction force that propels you into the air. Rockets and other projectile devices work the same way. During launch, the burning fuel exerts a downward force, and the reaction force pushes the rocket into the air. In space, the rocket applies its rear thrusters to move forward.</td></tr>
<tr><td>Science 8 Knowledge Targets</td><td>Science 8 Performance Targets</td></tr>
<tr><td>Define the engineering design process.

Asking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, clarifying arguments and models.

1. Identifying the problem to be solved.

2. Defining the process or system boundaries and the components of the process or system.

3. Defining criteria and constraints.

Newton’s three laws and their impact on engineering design

Students knowing and using key vocabulary are important outcomes of STEM education.</td><td>1. Students perform research.

2. Students are introduced to the science of aerodynamics and understand how airflow, drag, aero-balance, and drafting influence moving objects.

3. Students learn how downforce keeps race cars on a track.

4. Students learn how engineers test the aerodynamics and performance of race cars.</td></tr>
<tr><td>Time</td><td>Vocabulary</td></tr>
<tr><td>2 50-minute class periods</td><td>position, distance, displacement, motion, speed, velocity, forces, mass, gravity, acceleration, weight, friction, momentum, drag, downforce, aerobalance, drafting, airflow</td></tr>
</table>

Background Information	***Materials***
This is a two-day lesson. Day 1 begins with a look at a famous bridge collapse to engage students in learning about the engineering design process. The remainder of the lesson is intended for a 1:1 classroom, where students have access to Chromebooks or computers to do a small online research activity about the engineering design process. On Day 2, students learn about aerodynamics and engineering with a lesson plan provided by Scholastic.com. This will provide knowledge that students will use in the final two lessons of this unit, in which they will be using the engineering design process to design and prototype race car spoilers.	• Projector to share lesson videos with class • 1:1 Chromebooks or internet-connected computers
Lesson Overview (Activities)	***Advance Preparation***
Teacher will share a video and article: Tacoma Bridge Collapse. Students will Think-Pair-Share or engage in a classroom discussion. Students will engage in online exploration of the engineering design process. Students will share out about the engineering design process. Teacher will present the aerodynamics lesson.	Teachers will review engineering design process materials in advance, and prepare a visual aid to display the steps of the engineering design process. Teachers should review the Scholastic.com lesson in advance for preparation steps for Day 2.

Procedure

Day 1

Engage: (20 to 30 minutes)

Tacoma Narrows Bridge Collapses! Watch the following news story from 1940. Challenge students to try to remember two details they notice about the bridge as they watch the video.

Show the video: Tacoma Bridge Collapse - 1940 | Today in History | 7 Nov 16 (3 min)

Ask the class: What details did you notice about the bridge? Allow for a few responses.

Show the article: Tacoma Narrows Bridge collapses on November 7, 1940 Play the videos contained in the article. (7 minutes)

Engage the students with a Think-Pair-Share activity or a classroom discussion with one or more of the following prompts:

- Why did the Tacoma Narrows Bridge collapse?
- How could this accident have been prevented?

Explain: Explain to students that the Tacoma Narrows Bridge disaster could have been prevented if the designers had properly used the engineering design process. *“The engineering design process is a series of steps that engineers use to find the best solution to a problem. Today we are going to learn more about these steps and how we can use the engineering design process.”* **Explore:** Students will be involved in an online exploration activity to learn about the engineering design process. Display the questions “*What is the engineering design process? What are the steps?”* on the projector or whiteboard as prompts for the students. Teacher should preview the available resources listed below to choose websites and videos that are the most appropriate for their students. Share links with the students to recommended websites on the class content management system or via email. Advanced students can be challenged to find their own resources to answer the questions. Have students take notes in their science journals or a Google doc. (10-15 minutes) With 20 minutes remaining in class, regroup students for a class discussion. Ask for volunteers or call on students to answer the prompt questions. Write the list of the engineering design process steps on the whiteboard, or display a visual aide or poster that lists the steps. Briefly go through the steps while leading a classroom discussion. Make reference to the Tacoma Narrows Bridge collapse and ask students how these steps could have prevented the disaster. **Day 2** **Extend**: Refer to the lesson plan at Scholastic.com “Engineering Aero Balance: Keep It Balanced” Students will learn about the influence that design has on a race car’s performance.
Additional Engineering Design Activities for Unit on Aerodynamics This unit is about aerodynamics and how it influences force, momentum, and speed. **For** NASCAR activities relating to Aerodynamics and accompanying reproducible worksheets and templates, Drag: Start Your Engines GRADES: 3–5, 6–8 - 1.5 Hours Downforce: Under Pressure GRADES: 3–5, 6–8 - 45 Minutes Airflow: Tunnel Testing GRADES: 3–5, 6–8 - 1 Hour

Suggested Assessments	***Additional Resources***

[Pre- Assessment] Do You Know the Science of Speed? **[Post- Assessment]** What Did You Learn About the Science of Speed?	Video Resources/ Engineering Design Sports cars Aerodynamics The One Design Change That Made NASCAR Races Faster. Motion and Forces - NASCAR Hall of Fame. https://www.pbslearningmedia.org/collection/design-squad/ Small Spoilers to Return in 2020? (NASCAR Aero Package Changes Rumored) Wings and Spoilers| Lift and Drag| How it Works **ARTICLES ONLINE** NASCAR Science / University of Cincinnati. NASCAR Racing and Forces and Motion / Cynthia Baker Woolery.

Vocabulary

The position of an object is the location of an object. If the position of the object changes you will know it has moved by the object's relationship to its surroundings. An example of position would be car 49 was behind car 29, then car 49 passed car 29. The position of car 49 has changed. **Distance** is the length of the path traveled between two places. For example, at the Bank of America 500 (the Charlotte race), the cars race for a distance of 500 miles. **Displacement** is the length between two places. When an object moves it goes from a starting position to an ending position. Measuring the length (path taken) between the starting and ending positions gives you distance. Measuring the straight length between the starting and ending positions gives you the displacement. In race cars, the engine size is called displacement and is the displaced volume of the pistons. It is piston area times the number of	**Acceleration** is the rate of change in velocity. You speed up if the acceleration and velocity point are in the same direction. You slow down (also referred to as decelerating) if the acceleration and velocity points are in opposite directions. When you accelerate or decelerate, (or even go around a turn), you change your velocity by a specific amount over a specific amount of time. In race cars, acceleration is often referred to as a multiple of (gravity) Gs. That is, a race car may accelerate or corner at two Gs. Formula one drivers often corner at five Gs, and can look like a pin ball bouncing back and forth through the turns. **Weight** is how much pull gravity has on an object. Gravity is what gives you weight. Because the moon has much less gravitational pull, I would weigh one sixth as much on the moon! **Friction** is the force that occurs when two objects rub against each other. Different materials produce different amounts of friction. Smooth pavement produces very high friction, while a gravel road creates

Pistons, times the stroke length. All Sprint Cup cars have a 358 cubic inch engine.

Motion is a change in position. Many of my students stay in motion! When the cars travel around the track position they are in motion.

Speed is how fast an object moves over a certain distance. To measure speed, you need to measure time and distance. The distance an object travels in a period of time tells you the speed. An equation to use is: speed equals distance divided by time. NASCAR race cars often top 200 miles per hour!

Velocity is the rate of motion (speed) in a specific direction.

Forces are all around us and can change an object's motion. A force is a push or a pull. When forces are equal or balanced there is no change in motion. Unequal forces cause a change in motion. Change in motion occurs when an object starts or stops moving, speeds up, slows down, or changes direction.

Mass is defined as the measure of the amount of "stuff" in something. The more mass something has, the harder it is to move or, the more sluggish it is. If we were on the moon our mass would be the same, but our weight would have changed.

Gravity is a force that tries to pull two objects toward each other. Anything that has mass also has a gravitational pull. The more massive an object is, and the closer it is, the stronger its gravitational pull.
Since force equals mass times acceleration, gravity is often referred to as acceleration. On earth, gravity is an acceleration of 32.2 feet per second squared, (9.81 m/s**2).

much less friction (try stopping fast on a gravel road). Friction slows things down, heats things up, and wears things out.

Momentum can be defined as "mass in motion." All objects have mass, so if an object is moving, then it has momentum. The amount of momentum that an object has is dependent upon two variables: how much stuff is moving, and how fast the stuff is moving. In terms of an equation, the momentum of an object is equal to the mass of the object times the velocity of the object. A NASCAR race car that weighs 3600 and is travelling at 200 mph has 720,000 lb.*miles per hour (708,000 kg*m/s).

Draft is the aerodynamic effect that when a car pushes through the air at speed, it pulls suction behind it.

Drafting is the practice of two or more cars, while racing, to run nose-to-tail, almost touching. The lead car, by displacing the air in front of it, creates a vacuum behind it, and somewhat pulls the second car along with it. With so little air pushing through its radiator, the following car may even overheat.

Drag is the wind resistance a car experiences when passing through air at high speeds. A resisting force exerted on a car is parallel to its air stream and opposite in direction to its motion. At full speed, only 15 horsepower (hp) is needed to spin the car parts, but over 800 hp are needed to push the air aside.

Source: https://charlotteteachers.org/wp-content/uploads/2013/03/Cwoolery_unit_20121.pdf

<table>
<tr><th colspan="2">Forces and Interaction | 8th Grade Science</th></tr>
<tr><td>Engineering Design Process: Brainstorming Solutions and Building Your Prototype</td><td>Lesson Five</td></tr>
<tr><td colspan="2">Questions: When have you made something move? How can you make objects (like a toy car) go farther and faster? What forces are acting on a car as it travels a racetrack? Does the surface of the track make a difference?</td></tr>
<tr><td colspan="2">Objective: MS-ETS1-2 / MS-PS2-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.</td></tr>
<tr><td colspan="2">Engineering Design Connection: In the natural and designed world, engineers and scientists often encounter problems evaluating competing design solutions. Unless they use a systematic process to determine how well the features of a product meet the criteria and constraints of problems that occur, the problem will not be solved. They must engage in arguments from evidence, and construct convincing arguments that support or refute claims for either explanations or solutions; they then combine the best ideas into a new solution.</td></tr>
<tr><td>Science 8 Knowledge Targets</td><td>Science 8 Performance Targets</td></tr>
<tr><td><u>Science and Engineering Practices:</u>
Engaging in Argument from Evidence and constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

1. Identifying the given design solution and associated claims and evidence

2. Identifying additional evidence

3. Evaluating and critiquing evidence

Newton’s Three Laws and their impact on Engineering Design</td><td>Students learn about engineering design with a focus on wind tunnels and engineering testing.

Students develop an understanding of: mechanical engineering and design; and aeronautical engineering testing.

Students learn: STEM skills; teamwork and collaboration; brainstorming, data analysis, and problem solving.

Students will share what they know about the science of speed.

Students will learn about drafting and the way it impacts the speed of a race car.

Students will learn how drag and downforce work together to affect a race car’s performance.

Students will learn about the influence that design has on a race car’s performance.</td></tr>
<tr><td>Time</td><td>Vocabulary</td></tr>
<tr><td>2 50-minute class periods</td><td>position, distance, displacement, motion, speed, velocity, forces, mass, gravity, acceleration,</td></tr>
</table>

	weight, friction, momentum, drag, downforce, aerobalance, drafting, airflow
Background Information	***Materials***
The Wind Tunnel Testing lesson explores how wind tunnels provide feedback to engineers about the performance and durability of products such as planes, cars, and buildings. Students work in teams to build their own model of a car, using simple materials, and test their designs in a classroom wind tunnel set up. The use of the 3D printer will be incorporated. Access the lesson from the TryEngineering website	For the wind tunnel: • Small portable fan, rectangular cardboard box with ends removed, tape to affix box to floor in fixed position. • Include a measurement (ruler, markings) to indicate the distance prototype cars move under the force of the wind. Materials (wood, plastic) to set up a ramp for testing each car on a 15 degree slope. • One set of materials for each group of students: tape, string, plastic wrap, foil, popsicle sticks, toothpicks, paperclips, paper, pencils, cardboard, one cardboard tube (from paper towel or toilet paper roll). All materials must be used so that each car weighs the same.
Lesson Overview (Activities)	***Advance Preparation***
Day 1: Students participate in Drafting: Game Changer lesson from *Scholastic.com*. **Day 2:** Students participate in simulated and model Wind Tunnel Activities.	Teachers should review the lesson plan from Scholastic.com: Drafting: Game Changer Teachers should review the lesson plan from TryEngineering.org: Wind Tunnel Activities
Procedure	
Engage: To introduce the lesson, students watch videos on Scholastic.com about drag and drift. **Explore**: Students will try out a virtual wind tunnel at the NASA Wind Tunnels or the Glenn Research Center websites. Students will connect the topic of wind tunnels with their prior understanding of how the wind affects the speed and direction of cars and airplanes.	

Explain: Students will develop explanations for what they have already observed. They will define the necessary vocabulary and connect their findings to prior knowledge. Students will also be involved in a related writing activity. **Extend:** Teams of students will build their own model cars out of everyday products and test their designs in a wind tunnel made of a fan blowing through a long cardboard box. Student teams will also evaluate their own work and that of other students. **Evaluate:** Students will observe as their team and other teams test their prototypes in the classroom wind tunnel. They use the engineering design guidelines and redesign the cars to improve performance.

Assessment	***Additional Resources***
	Video Resources The Impact of Technology: Cars: This video segment tells the story of Henry Ford's industrial revolution. America Revealed | Desktop Factory. This video profiles "MakerBot," a 3D printer that is changing the nature of manufacturing. **Online Articles** NASCAR Science / University of Cincinnati. NASCAR Racing and Forces and Motion / Cynthia Baker Woolery. **Newton's Third Law** Design Squad Nation This video from *NOVA* illustrates the significance of Newton's law to space-walking astronauts and the engineers who design their spacecrafts. NOVA | Newton's Third Law of Motion **Video Grades: 6-12.**

Forces and Interaction | 8th Grade Science	
Engineering Design Process: Designing Your Spoiler	**Lesson Six**
Question: How can I use the engineering design process to improve the performance of a race car?	
Objective: MS-ETS1-3 Students will gain hands-on experience with the engineering design process and 3-D printing by creating and evaluating designs for a race car spoiler.	
Engineering Design Connection: In the natural and designed world, engineers and scientists often encounter problems evaluating competing design solutions. Unless they use a systematic process to determine how well the features of a product meet the criteria and constraints of problems that occur, the problem will not be solved. They must engage in argument from evidence and construct convincing arguments that support or refute claims for either explanations or solutions, and then combine the best ideas into a new solution.	
Science 8 Knowledge Targets	***Science 8 Performance Targets***
Students will be familiar with all steps of the engineering design process. Students will understand the concepts of motion, force, friction, speed, drag, and drift.	1. Students will analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
Time	***Vocabulary***
Suggested 2-4 50-minute periods	motion, force, friction, position/reference point, speed
Background Information	***Materials***
In this lesson students design a spoiler for a race car, using what they have learned about aerodynamics in the previous lessons. **The suggested car to use for this lesson is a 1:24 scale model die cast race car. These are available on Amazon.com (example) or can be requested from Tech Trekker in advance.** In the final lesson of this unit, students will test their 3D printed spoilers by attaching them to the racecar and doing a speed run on a track. Students will record distance about the speed and distance achieved. This lesson uses Tinkercad, an easy-to-use online CAD program that students can use to create	• Computers with internet access (at least 1 per group) • 3-D printer with filament • Free Tinkercad Account - www.tinkercad.com • Attached Handout – 1 per pair of students • Pencils/Pens • Scratch Paper • Racecar

prototypes to be 3D printed. Teachers can create a free teacher account on Tinkercad.com to manage their classroom. Tinkercad works with Google Classroom and supports student sign in with Google accounts. More information about creating a Tinkercad classroom can be found here: https://blog.tinkercad.com/2019/08/05/introducing-tinkercad-classroom/ Resources for teaching with Tinkercad are here: https://www.tinkercad.com/teach	
Lesson Overview (Activities)	***Advance Preparation***
The teacher will direct instruction on the Engineering Design Process and introduce the spoiler problem. The teacher will show a video and engage the class in discussion. The teacher will review the Engineering Design Process and discuss how it relates to this The students will collaboratively brainstorm ideas for spoilers. The students will use Tinkercad to create 3D prototypes of spoilers.	It is recommended that students have at least a day or more experience using Tinkercad before beginning this lesson. Upon registration, Tinkercad provides users with a small series of tutorials that help them gain familiarity with the software. Students should complete these basic tutorials before proceeding with this lesson. Further Tinkercad lesson plans are linked in the additional resources below.

Procedure

Students will be paired in groups (2-5 per group based on class size) for this lesson.

Engage:

Engineering is about solving problems! NASCAR drivers such as Dale Earnhardt Jr. have identified problems with the spoilers that the cars currently have.

Share the related article with the class: Dale Earnhardt Jr is not a fan of NASCAR's humongous spoilers and believes they helped cause Ryan Newman's scary Daytona 500 wreck

Show the following video to the class. “How Do Spoilers Actually Work?”
https://www.youtube.com/watch?v=ppoDH9VVadc

Tell students, it’s up to you and your team to help solve the problem and design a new spoiler for the car of tomorrow. We will use the engineering design process to define the process, identify our options and constraints, brainstorm solutions, select the most promising solution, and begin creating a prototype.

When the Tech Trekker kit arrives, we will 3D print our prototypes and test them on a model race car. We can then analyze the results and iterate the process until we have found the best solutions to the problem.

Explore:
Discussion: “Let’s start by defining the problem.”

- As a class, discuss what you have learned about race car spoilers and the problems with the existing NASCAR spoilers. What do we want to fix or improve?
- Give students several minutes to discuss with their groups before bringing the class together for a group discussion to define the problem.

Discussion: “Let’s identify any constraints we have.” Discuss the constraints they are working with.

- One constraint we have is that it is not practical for us to produce a full-sized spoiler for a car. We will have to test our designs on a smaller scale. We have a 1:24 model car that we can use to run tests of your spoiler designs. That means your spoilers will be about 5 inches wide.
- Another concern is the time and supplies it takes to build a prototype with a 3D printer. Tech Trekker has two 3D printers. The material will be predetermined. (Tech Trekker can specify how many spoilers can be built with the equipment, and may be able to arrange for some prototypes to be printed in advance.)

Explain:
Provide each group of students with paper and pencils.

- Tell students: “Using what you have learned about NASCAR, race car spoilers, and their effects on car performance, what ideas do you have for a new spoiler? Before moving to the computers, brainstorm some ideas with your group. Sketch possible designs on the paper.” (5 minutes)

Extend:
Students will log into Tinkercad.com to create 3D prototypes of their spoiler designs. This can be done in groups or individually as determined by the teacher.

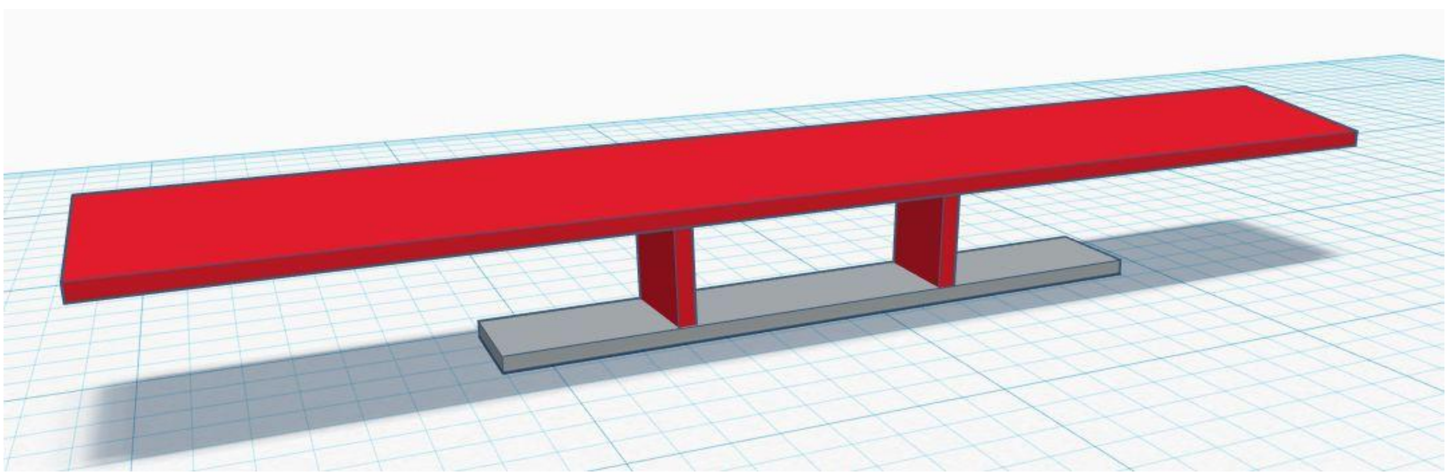
Modify this lesson as needed based on the skill level of your students and the time available. Beginner students can start by modifying the <u>example spoiler design</u> provided by Tech Trekker. Advanced students can create a design from scratch or make more elaborate designs.

Evaluate:
Ideally, each group will create multiple designs so that they can discuss the differences in the designs and select the best one for 3D printing.

Students will export their creations in STL file format.

Note to Teacher - Tech Trekker should be scheduled at least three weeks in advance, prior to the next lesson. At this point in the unit, you could email your students’ STL files to the Tech Trekker

team to have them printed in advance of their arrival. As an extension of this lesson, students can engineer the ramp and racetrack that will be used to test the cars in the next lesson using the Engineering Design Process.	
Suggested Assessment	***Additional Resources***
In this lesson, students create a prototype spoiler using Tinkercad. Teachers can view the students' work in Tinkercad to see evidence of the engineering design process. Teachers can circulate while students are brainstorming and designing to discuss their choices. Exit ticket question: How did you use the engineering design process today?	Video: The Engineering Design Process: Taco Party https://www.youtube.com/watch?v=MAhpfFt_mWM Tinkercad Lesson Plans https://www.commonsense.org/education/website/tinkercad/lesson-plans F1 Racing Car with Tinkercad x Car | 3D modeling



This sample spoiler design is provided by Tech Trekker at:
https://www.tinkercad.com/things/9hXwfonjxZH-brave-bombul-kasi/edit?sharecode=QYk6RfTakkkT8799qbz0UG97BSPPEgSVEsMc_H_pV8k

It should be suggested that students have a flat base for their spoiler, as shown in the example above, so that the spoiler can be adhered to the car using three strips of single-sided clear tape across the base.

<table>
<tr><th colspan="2">Forces and Interaction | 8th Grade Science</th></tr>
<tr><td>Engineering Design Process:
Testing and Analysis</td><td>Lesson Seven</td></tr>
<tr><td colspan="2">Question: How can design choices affect how fast or far a car can travel over a set distance?</td></tr>
<tr><td colspan="2">Objective: MS-ETS1-4 Using the Engineering Design Process, students will test their 3D printed spoilers and analyze the results.</td></tr>
<tr><td colspan="2">Engineering Design Connection: In the natural and designed world, engineers and scientists often encounter problems evaluating competing design solutions. Unless they use a systematic process to determine how well the features of a product meet the criteria and constraints of problems that occur, the problem will not be solved. They must engage in argument from evidence and construct convincing arguments that support or refute claims for either explanations or solutions, and then combine the best ideas into a new solution.</td></tr>
<tr><td>Science 8 Knowledge Targets</td><td>Science 8 Performance Targets</td></tr>
<tr><td>Students will gain an understanding of the Engineering Design Process and how testing and iterative design can lead to finding the best solutions to solve a problem.

Students will consider the laws of force and motion while testing their cars on the surfaces of the track (friction), along with speed of the car based on the incline of the ramp (force / gravity).</td><td>1. Students will develop a model to generate data for the iterative testing and modification of a proposed object, tool, or process, such that an optimal design can be achieved.</td></tr>
<tr><td>Time</td><td>Vocabulary</td></tr>
<tr><td>Suggested 2-4 50-minute periods</td><td>motion, force, friction, position/reference point, speed, drag</td></tr>
<tr><td>Background Information</td><td>Materials</td></tr>
<tr><td>In this lesson, students will test their 3D printed spoilers on a car and record distance about the speed and distance it achieved.

For 3D printing, students will export their creations in STL file format and share their files with the Tech Trekker team.

The design should be scaled to 3.3 inches wide to be proportionate to a 1:24 scale race car.</td><td>● Computers with internet access (1 per person or 1 per group)
● 3D printer with filament
● Free Tinkercad Account - www.tinkercad.com
● 1:24 scale model die cast cars (with spoilers removed)
● Inclined racetrack or ramp
● Clear tape (for attaching 3d printed spoilers)
● Stopwatch</td></tr>
</table>

Lesson Overview (Activities)	*Advance Preparation*
For this lesson, the UNLV Tech Trekker will be on campus to 3D print the spoilers created by students in the previous lesson. While students' spoilers are being 3D printed, the teacher will demonstrate a speed run with the class using the car without a spoiler. Students will learn how to record data and how to calculate the speed of the car. Students will analyze the results. The teacher will lead a class discussion about iterative design.	The teacher will prepare a space for race cars to be tested using an inclined ramp. If working with a large class, set up multiple tracks so more than one group of students can test at once. Determine the distance that the car will travel that can be easily timed to track speed. (15-40 feet) Ideally, conduct the tests in an outdoor space or gymnasium that allows for cars to travel a long distance before stopping. Pre-measure the area if possible. If space is limited, you can use a shorter track and omit the data point for distance travelled, and only track the speed of the car over a set distance.

Procedure

Engage:
Generate excitement by telling students today is the day they will be testing their spoilers. Show the 3D printed spoilers to the class and ask the students to point out the similarities and differences in their designs.

Explore:
Using the race car without a spoiler, demonstrate a speed run, and announce the time (in seconds) it took to travel the predetermined distance. If possible, measure the total distance the care traveled before coming to a complete stop.

Explain:
The teacher explains how to attach and remove the spoilers from the racecars. The teacher demonstrates how to record data when testing the spoilers. The students will calculate the speed of the car in fps (feet per second). This number will be used to compare this car with results of the cars with student-designed spoilers.

Extend:
In groups, students take turns using the test track with their spoiler designs and recording data about the speed and distance. You may want to assign students or aides to act as the official timekeepers.

Students groups should also consider whether the mass of their 3D printed spoiler will have an effect on the performance of the car. If possible, students should measure the mass of their spoiler.

Evaluate:
Students will analyze the results: Was the speed or distance better than the car without the spoiler?
How do their results compare with other groups? What are the differences in the designs?

Student groups will write summaries explaining the process of researching, designing, prototyping, and testing their spoilers. The class will gather for discussions about their findings: Which spoiler performed the best? The teacher will lead a class discussion about iterative design. The teacher can also show videos about iterative design (see resources below.) Teachers can extend this lesson by challenging students to return to the Engineering Design Process to improve their designs based on what they have learned through their testing and analysis.

Suggested Assessment	***Additional Resources***
Rubric to assess the design process, spoilers, and data analysis (provided)	**Video: Everything is Iterative** **https://www.youtube.com/watch?v=iAWX3KNdREs**

Engineering Design Process Project Rubric

CATEGORY	**Expert (4)**	**Proficient (3)**	**Competent (2)**	**Novice (1)**
Explore/Research	Accurate information taken from several sources in a systematic manner.	Accurate information taken from a couple of sources or not systematically.	Information taken from only one source and/or information not accurate.	Inadequate research.
Design/Imagine/Plan	Students brainstormed effectively. More than one design was imagined. Complete sketch was drawn before prototyping. Plan is complete, neat.	Students brainstormed. Sketch of one design was done on paper.	Students struggled with brainstorming. Sketch was made on paper but is lacking features, details, or professionalism.	Students did not brainstorm effectively. Plan is incomplete.
Create/Prototype	Prototype was created in Tinkercad and prepared for 3D printing. .	Prototype was completed in Tinkercad.	Prototype was planned or sketched but not fully realized in Tinkercad	Students were unable to design their prototype in Tinkercad.
Test/Improve	Clear evidence of troubleshooting, testing, and refinements based on data or scientific principles.	Clear evidence of troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence of troubleshooting, testing or refinement.
Summary	Summary provides a complete record of planning, construction, testing, and analysis. Modifications of the design were planned using reflection about the process.	Summary provides a complete record of planning, construction, testing, modifications, and reasons for modifications.	Summary provides quite a bit of detail about planning, construction, testing, modifications, and reasons for modifications.	Summary provides very little detail about several aspects of the planning, construction, and testing process.