How Can Race Car Bumpers Store Energy?

nsta Daily Do — FUELED BY: NASCAR KIDS

Grade Level	Topic	NGSS
MS	Kinetic Energy	PS3.A · PS3.B · PS3.C

Phenomenon

NextGen NASCAR racers use new materials in their bumpers and car doors to keep the driver safer during collisions.

Materials

Teacher Materials

- 2021 NASCAR Cup Series Crashes #1 video
  - Clip A: 0:30 to 1:25
  - Clip B: 2:00 to 2:45
  - Clip C: 6:39 to 7:50
- "Next Gen design carries legacy of safety into future" (excerpt from Next Gen design carries legacy of safety into future)
- Slideshow of Generation 5, 6, and Next Gen NASCAR racers
- Organizer for modeling collision
- Bouncing balls video
- Composition of balls
- Slow-motion video of ball dropping and deforming
- Data table
- Thermal images of point of collision between the ball and the floor
- Ball made of modeling clay

Student Materials (per group)

- Ball (golf, tennis, baseball, softball, solid rubber, hollow rubber, foam [dense], steel)
- meter stick
- Decibel Meter Sound Detector (free app for phones)
- Infrared camera or infrared thermometer (optional)
- Painter's tape

Student Materials (per student)

- "Next Gen design carries legacy of safety into future" article
- Organizer for modeling collision
- Data table

Material Management Tips

- Make copies of or provide digital access for each student to the news article excerpt and modeling organizer; make one copy per group of the data table.
- Set up a materials station with meter sticks, balls, and painter's tape for easy access by each group.
- Share app information for Decibel Meter so one student in each group has it. Encourage students to video the ball drop for slow-motion replay and analysis.
- Cue the collision, bouncing balls, and slow-motion tennis ball bounce videos.
- Determine locations for each group to collect data on a hard floor surface and with enough distance between each group for more accurate sound measurements.
- Prepare a chart or place on the board to post the investigative question, student observations, and whole-class data analysis summation.

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SCIENCE AND ENGINEERING PRACTICE(S)

Developing and Using Models

Develop a model to describe phenomena.

Planning and Carrying Out Investigations

Collect data to serve as the basis for evidence to answer scientific questions.

Analyzing and Interpreting Data

Analyze and interpret data to provide evidence for phenomena.

Constructing Explanations

Construct an explanation using models or representations.

DISCIPLINARY CORE IDEAS

Targeted Science Ideas and Engineering Ideas (when applicable)

PS3.A—Definitions of Energy.

A system of objects may also contain stored energy, depending on their relative positions.

PS3.B—Conservation of Energy and Energy Transfer

When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time.

PS3.C—Relationship Between Energy and Forces

When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (Note—This lesson focuses on energy transfers, not on forces.)

CROSSCUTTING CONCEPTS

Systems and System Models

Models can be used to represent systems and their interactions—such as inputs and outputs—and energy flows within systems

Energy and Matter

The transfer of energy can be tracked as energy flows through a designed or natural system.

Patterns

Chart, and images can be used to identify patterns in data.

SUPPORTING EQUITABLE PARTICIPATION

Interactions

One-to-one | One-to-small group | One-to-many | Small group-to-many

Modalities

How students communicate their ideas

Talk • Text • Visual: Drawing, Symbols, Table, Graph, Chart, and Gesture

Safety

NSTA encourages K–12 teachers and school leaders to promote and support the use of science activities in science instruction and work to avoid and reduce injury. Additionally, NSTA recommends teachers and school leaders visit the NSTA Safety Resource page for up-to-date information on safety issues and guidelines.

EXPERIENCE PHENOMENON

Students experience the phenomenon or problem. The teacher creates an **opportunity for students to connect** with this specific event or problem (through prior experience, interests, and curiosities) and **raise or identify a student question** to investigate.

T What is the teacher doing to support students' sensemaking?	S What are students doing to make sense of the phenomenon? (Includes teacher look-fors)
1. Introduce the Phenomenon	
Say, "Have you ever watched or been to a NASCAR race? Have you ever wondered how the drivers survive the crashes that occur at such high speeds (180–200+ mph)? Let's watch a few examples of crashes from the 2021 season. As you watch, pay close attention to the bodies of the cars just as collisions occur. Look for evidence of energy transfers and transformations." Pause after each clip (A and B) and allow students to jot down notes about their observations and questions that come to mind.	Students share experiences and ideas about how drivers survive the crashes. Students watch the video clips and note evidence of energy transfers and transformations, as well as damage to the bodies of the cars. Examples of student ideas—I noticed how loud the noise was when the collision occurred; how many times the cars spun around after impact; how far the cars kept moving after impact; smoke, screeching, crumbled bumpers, crumbled doors, flat tires, sparks, fire, torn-up turf, some parts of the cars flying off, some front and/or rear bumpers destroyed.
Give each student individual time to make note of what they observed and questioned about what happened to the body of the car and the energy transfers and transformations as collisions occurred. Ask students to turn and talk to a partner and compare the things they noticed and wondered. Have students quickly share their observations and questions. Write these on chart paper/the board for future reference.	Students share noticings and wonderings with a partner, then compare and discuss why their noticings are evidence of energy transfer and transformation. Students share observations and questions quickly as the teacher charts them. (A quick sharing strategy, popcorn share, is to have students call out ideas one at a time without repeating another student's idea or question.)

T	S
Say, "NASCAR is about managing motion energy (use the term kinetic energy if students have previous experience with it). The drivers want to go as fast as they can to win the race while staying safe. Recall that speed is an indicator of how much energy an object has. The faster it goes the more energy it has. So when the cars collide with one another or with the wall of the track, they do so with large amounts of energy, as we learned in the lesson in which we addressed the focus question of 'Why are some NASCAR crashes more dangerous than others?' With this in mind, NASCAR unveiled their Next Gen cars for 2022 that are complete redesigns. (Show pictures of Next Gen cars.) I want to share an excerpt from a news article about the Next Gen NASCAR racer that details some of the redesign for managing all that motion energy to improve safety."	Students observe the pictures on a slideshow of Generation 5, 6, and Next Gen NASCAR racers, and note any differences and listen as you prepare them for the news article excerpt.
Handout the article "Next Gen design carries legacy of safety into the future." Ask students to read and underline the safety features mentioned, paying close attention to information about the bumpers and doors, and note any questions they have in the margin. (Note—The website where the article is housed also has an audio version of the article. You may want to play this for students who are struggling readers.)	Each student reads the news article excerpt and underlines the safety features mentioned, and write questions they have in the margin.
Have students share the questions they have about how the design of the car—especially the bumpers and doors—and how the materials used to make them can increase safety for the driver by managing the motion energy. Add these questions to the chart with the video observations.	Students share questions they have about how the design of the car—especially the bumpers and doors—and how the materials used to make them can increase safety for the driver by managing (transferring and transforming) the motion energy upon impact. Examples of student ideas—How could foam be better for a bumper than metal? Why are the bumpers more integrated into the body than in previous generations of cars?
Say, "It seems that many of us are wondering how the materials used to make the bumpers and doors can transfer and transform enough of the motion energy to protect the drivers."	Some students may have questions about the difference between an energy transfer and an energy transformation. Other students can provide clarification.

T	S

INVESTIGATE

Students engage in the practices of scientists and engineers to build understanding of targeted science ideas (and engineering ideas) needed to explain the phenomenon or solve the problem.

2. Developing an initial model of energy transfer and transformation during a collision

T	S
Say, "To begin to figure out where all the motion energy goes, let's develop a model to help us think about the race car system and the flow of energy during a collision. Scientific models include the relevant components of the system and interactions among the components. You want to indicate where energy transfers and/or transformations occur based on evidence from your observations."	Each student develops an initial model to explain how energy is transferred and transformed during a collision using the model organizer, which is designed to help them consider energy before the collision, during the collision, and after the collision. (Accept all models.)
After students have worked on their initial model for a few minutes, show them Clip C from the 2021 NASCAR Cup Series Crashes #1. Ask students to raise their hand each time they see evidence of an energy transfer/ transformation. (It may be helpful to show the video clip in slow motion.)	Students watch the third clip of NASCAR collisions and raise their hand each time they see evidence of an energy transfer or transformation.
Once they have watched the clip, ask, "What evidence did you use to determine if you were observing an energy transfer or transformation? What did you observe that indicates energy transferred from the collision was also stored?" (Students may need some support in connecting the crumbled car parts to stored energy. Bringing this up now will help make the connection to the deformation of a ball to the deformation of the car parts.) "Is there anything else you might need to add to or change on your initial model?" Give students a few minutes to finish their initial models.	Randomly selected students share the evidence they observed indicating an energy transfer or transformation. Each student revises their initial model to include new or different ideas about energy transfers and transformations.

T	S

2. Developing an initial model of energy transfer and transformation during a collision

T	S
Say, "Set your model aside. You will return to it once you have collected data of energy transfers/transformations for different materials during a collision. To test how energy is transferred and transformed during a collision, we are going to use balls made of different materials and drop them from the same height of 1 meter. What are some measurements that you might make to compare energy transfers and transformations of balls made of different materials?" Allow students a few minutes to work with a partner/small group to share ideas about what data to collect and create a class data table template that students can draw in their science notebooks. (Or share the data table template from the Teacher Materials resource sheet.) (Note: it may be useful to show a video [0:00 to 1:09] of different balls dropping to help students think about useful measurements.)	Randomly call on students to suggest measurements to make to compare energy transfers and transformations of balls made of different materials. Students watch the video clip of different types of balls being dropped and add to or revise suggestions. Examples of student ideas—height of each rebound bounce, number of bounces, sound level, heat transfer to floor, deformation of the ball.
Remind students that this is a ball drop, and ask a volunteer to demonstrate. Ask students why it is important that each group drop the ball in the same manner.	One student volunteers to demonstrate how to drop a ball. Students suggest it is important to drop the ball in the same manner so that additional energy is not transferred to the balls.
If students suggest recording the sound the balls make when they strike the ground, ask how they could quantify it. Some students may suggest a sound meter. Share the free app that one student can download to their phone, then demonstrate how to use the decibel meter by placing it on the floor close to the drop point.	Students observe how to use the decibel meter, thermal camera, or infrared thermometer and how to video the ball as it contacts the floor, and the modeling clay ball as it collides with the floor. Students ask questions about making these measurements and discuss the observations/ measurements they will be making.

T	S
If students suggest trying to measure thermal energy transfer and if you have access to a thermal camera or an infrared thermometer, you will want to demonstrate how to make those measurements. (Thermal images are included in the Teacher Materials because this measurement is more difficult. If students suggest it would be helpful to record the ball as it collides with the floor to try to observe the deformation of the ball, then a member of each group could use their phone and place the camera perpendicular to the drop point and video the drop. Playing that video back in slow motion will show deformation in some of the balls. Although every ball will deform, it will be too slight to see for some of the balls, even with a camera. You may want to demonstrate deformation by dropping a ball made of modeling clay.	
Divide the class into the number of groups that equal the number of different types of balls you have available for testing. Each group will test a different ball, then share their data with the whole class, so that you can get many different balls tested quickly. Give each group a data table to record their data. Allow about 12 minutes for each group to conduct their tests, once they have their materials and are set up. *(Note: It is best to drop balls onto a hard flooring material like tile, wood, or concrete, and not on carpet.)*	Students form groups and determine roles. One student should be in charge of getting materials, setting up, and returning the materials. Another student should be the recorder and is given the data table to complete. If there is a third student in the group, they should be responsible for the measurements. Student groups work in their designated area and collect data for the ball they are testing.

3. Analyzing and Interpreting Data

T	S
Have groups post their data to help the class decide how to place the balls in order from most kinetic energy transferred based on first bounce to least amount of kinetic energy after the first bounce.	The recorder posts the group's data. The class works together to arrange the balls from most kinetic energy transferred to least.

T	S

You may find these questions useful for prompting student thinking as they analyze the data:

"As you look across each group's data using a ball made of a different material, what patterns could we use to determine which ball/material transferred/transformed more of its kinetic energy?" (It might be useful to start with sound. It will be intuitive for students to say that the louder the sound = more energy transformed.)

- Next, have students think about the height of the rebound. If the ball rebounded close to the drop point, would that indicate more energy was transformed/ transferred or less?
- Is there a pattern connected with the height of the rebound and the number of bounces?
- Deformation is difficult to see because the time of contact is so brief. You may want to refer to the slow-motion video you showed earlier and ask if greater energy transfer would result in more or less deformation of the ball.
- Because the thermal energy transfer data is tricky to measure, you may want to show the thermal images of the point where the ball collided with the floor as evidence that some of the kinetic energy is transformed to heat.
- Which material showed the greatest amount of kinetic energy transferred/transformed?
- What patterns do you notice about the kinds of materials that transformed/transferred the greatest amount of kinetic energy and those that transformed/ transferred the least? (You may want to project the cross-sectional pictures of the balls that are made of more than one material if students raise a question about this.)
- What claim can we make about the material used and the transformation/transfer of kinetic energy upon collision?
- If there is time, lead the whole class in developing a model of the energy transformations and transfers in the ball drop. Doing this will help many students make the transfer to their collision models.

Possible student response: Less energy, because rebound height indicates the energy that was not transferred or transformed.

Possible student response: The greater the height of the rebound, the greater the number of bounces. The same reasoning applies here. Less kinetic energy was transformed/transferred, so what remains was used to bounce back each time and transformed/transferred with each collision with the floor.

Possible student response: Greater deformation would be an indicator of greater kinetic energy transfer.

Students observe thermal images of the point where a tennis ball collided with the floor and discuss how this is an evidence of an energy transformation.

Students discuss this question in their groups and determine if their initial ordering was correct. Students provide reasoning for any rearrangement of the data posted and reach consensus as to the correct order based on their reasoning.

Answers will vary depending upon the balls tested, but should be supported by the evidence collected and with reasoning similar to this: In the ball that landed with the loudest "thud," the motion energy is transferred to the ground, transformed to thermal and sound energy, and stored in the ball as evidenced by the change in the shape (deformation) of the ball and the rebound of the ball. The ball made of _____ had the lowest rebound height, fewer bounces, made a louder sound, and had a redder thermal image, indicating more thermal energy transfer, and deformed the most; therefore, it appears to have transformed/transferred more of the kinetic energy upon collision.

Optional

Students suggest how to model the energy transformations and transfers in the ball drop.

T	S

REFLECT

Students use the new or revised science ideas they developed to help explain how or why the phenomenon occurs and/or to identify solutions to the problem.

3. Constructing an explanation

T	S
Say, "How can we use our data and our models to help us explain how the materials used to make the bumpers and doors can transfer and transform some of the motion energy to protect the drivers? How can you use our data to revise your initial model to help explain this phenomenon?"	
Ask students to revisit their initial model. These questions might be useful for helping students make the connection between the ball drop and NASCAR collisions. • How was our investigation similar to a NASCAR collision? How was it different? • How did the research and development team at NASCAR use this kind of information about materials to improve the race cars' bumpers and door protection? (You may want to refer to the news article excerpt.) • What did you notice about the energy transformations and transfers in the car collision videos? What did you observe that gave you evidence that energy was being transformed/transferred?	Each student revises his/her model to reflect their deepening understanding of energy transfers and transformations using evidence from the investigations.
Ask, "Why would it be a problem for drivers if the kinetic energy isn't quickly transformed to sound/thermal energy and/or stored by the material?" Have students share their revised model with a partner and explain how the bumper and door materials help transform/transfer motion energy during a collision and how that helps protect the drivers.	Students share their revised model with a partner and explain how the bumper and door materials help transform/transfer motion energy during a collision. Partners help each other refine their models.
As an exit slip, have students use their models, data, and text excerpt to explain how the choice of materials in the doors/bumpers keeps drivers safe.	Each student completes an exit slip.

This lesson could be one in a series of lessons building toward the following:

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.

[Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [Assessment Boundary: Assessment does not include calculations of energy.]

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AT THE RACE TRACK

Make some observations at the track.

- When a car collides with another car or with the wall, observe what happens to the car's bumper and/or door.
- See how many different energy transfers and transformations you can identify during a collision. What observations can you make that could indicate the amount of kinetic energy being transferred and transformed during a collision?
- Explain to whomever you are attending with how a more damaged car might be safer for a driver during a collision.