LESSON 2: What happens to the shape and motion of objects when they hit each other?

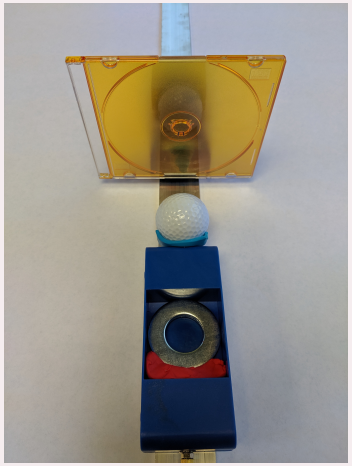
PREVIOUS LESSON

We talked about our experiences seeing things break when they collide with something else. We modeled what we thought might be happening before and after a collision where something breaks and a collision where something doesn't break. We also considered some of the factors that could have made a difference in the outcomes of these collisions. This motivated us to create a Driving Question Board (DQB) and brainstorm possible investigations we could do in order to answer our questions.

THIS LESSON

INVESTIGATION

2 days



We consider what happens to the motion and shape of objects when they collide. We investigate what happens by observing objects before and after collisions, watching collisions using slow-motion video, and noticing patterns in our data.

NEXT LESSON

We will analyze slow-motion videos of different objects colliding. We will carry out an investigation to determine if seemingly rigid objects bend when contact forces are applied to them. We will argue from evidence that rigid objects can also bend or change shape when contact forces are applied to them.

BUILDING TOWARD NGSS

MS-PS2-1, MS-PS2-2

WHAT STUDENTS WILL DO

Analyze and interpret data to provide evidence that during collisions, objects change their motion and may change their shape. Students reflect on how the motion and shape of the objects are disturbed during a sudden event, namely the collision, but it is not yet clear if the relationship between having a collision and changing motion and shape is causal or correlational.

WHAT STUDENTS WILL FIGURE OUT

All objects change their motion during collisions unless we held one object still and prevented changes in motion.

Squishy or flexible objects at least temporarily deform during a collision.

Lesson 2 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Remind students of the investigations we proposed at the end of the last lesson and prepare them for the investigations in this lesson.	A	
2	10 min	**INVESTIGATE DROPPING AND BREAKING** Explore what happens to objects during a collision by dropping hard objects on fragile but inexpensive targets and making observations.	B	Dropping and Breaking Lab
3	5 min	**DISCUSS DESIGN CHALLENGES: DROPPING AND BREAKING** Discuss challenges associated with making observations of collisions by dropping objects on fragile targets.	C-D	
4	20 min	**EXPLORE COLLISIONS: SHAPE** Investigate collisions using slow-motion video. Record data about the shape of objects before and during the collision.	E	slow-motion videos (optional), Explore Collisions: Shape Lab
5	5 min	**NAVIGATION** Motivate the next lesson by asking students to consider how collisions affect the motion of objects.	F	
				End of day 1
6	5 min	**NAVIGATION** Ask students about their investigations into the shape of objects from the previous day. Gather students' ideas about other things that might happen to objects in collisions.	G	
7	20 min	**EXPLORE COLLISIONS: MOTION** Distribute data collection handouts and demonstrate collecting data for a collision between two colliding carts. Ask students to work in stations to collect data about the motion of additional colliding objects.	H	*Exploring Collisions: Motion*, Exploring Collisions: Motion Lab
8	15 min	**INTERPRET COLLISION DATA: SHAPE AND MOTION** Discuss students' observations of shape and motion during collisions. Determine whether the shape or motion of objects always changes during collisions.	I-M	
9	5 min	**NAVIGATION** Motivate students to want to know more about the shape of objects during hard and fast collisions.	N	
				End of day 2

Lesson 2 • Materials List

	per student	per group	per class
Dropping and Breaking Lab materials		• 5 dry rice noodles • CD case • 2 graham crackers • two bricks or two heavy books • golf ball • tennis ball	
Explore Collisions: Shape Lab materials		• phone or tablet with slow-motion video capability or slow-motion videos provided with device for viewing videos	• 12 carts • 2 clay balls • 4 metal loops • 2 CD cases mounted with putty • 2 golf balls mounted with putty • 2 rubber stoppers • 6 aluminum bar tracks (3 ft x 1.5 in x ⅛ in) • tape • 36 large washers • clay
Exploring Collisions: Motion Lab materials			• 12 carts • 2 clay balls • 4 rubber stoppers • 4 metal rings • 2 golf balls • 2 CD cases • mounting putty • 6 aluminum bar tracks • tape • 36 large washers • clay
Lesson materials	• science notebook • *Exploring Collisions: Motion*	• slow-motion videos (optional)	

Materials preparation (60 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Day 1 (40 minutes):
Dropping and Breaking

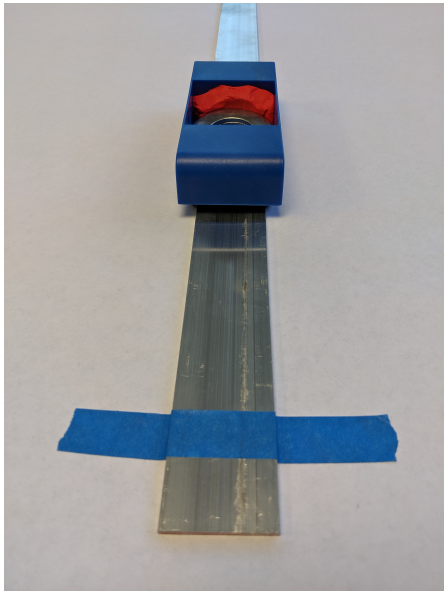
- Group size: Create six stations for groups of 5 students.

- Setup: Gather materials for 6 stations.

Exploring Collisions: Shape Lab

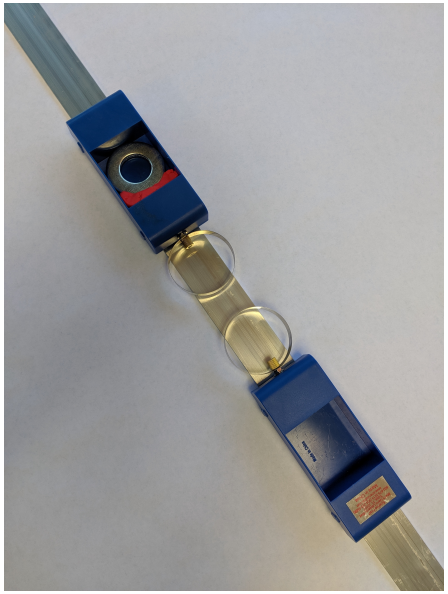
- Group size: Create six stations for groups of 5 students.
- Setup: Gather materials for 6 stations (two sets of three collisions stations). Students will rotate through three stations to test all collisions.
- If students do not have slow-motion capability on their phones, each group should have a computer or tablet to view the provided slow-motion video.

1. At each station, tape down track to guide the carts during the collision.

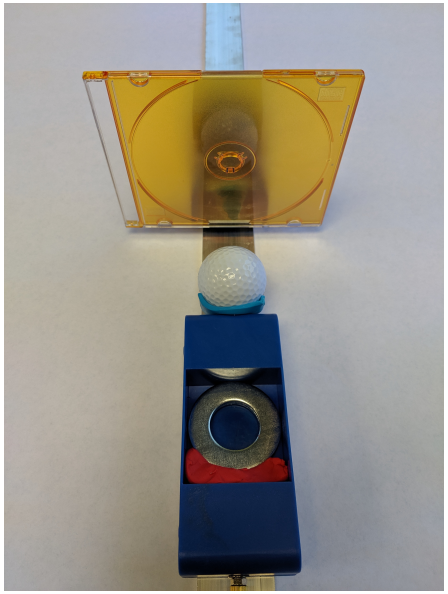


2. At the first station, attach rubber stoppers to the cart screws.

3. At the second station, attach metal hoops to the cart screws.



4. At the third station, attach the golf ball and CD case to carts with screws.



5. Repeat steps 2-4 to create stations 4, 5, and 6.

- Notes for during the lab: There should be two identical stations for each of three collision types. Students will rotate through three stations. If you have a very small class (15 students or fewer), you will need only three stations, or you can use smaller groups.
- Safety: Warn students to keep fingers out of the way when colliding cars, especially when they are holding one car still.

Day 2 (40 minutes):
Exploring Collisions: Motion

- Group size: Create six stations for groups of 5 students.
- Setup: Gather materials for 6 stations (two sets of three collisions stations). Students will rotate through three stations to test all collisions.
- You can reuse the stations from the previous day.

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students begin to develop an understanding of the effect of forces on the shape and motion of objects. Students describe what they see in the data by considering whether the effects (changes in shape or motion) correlate with or are caused by the collision. Students develop an intuitive feel for the idea that more than one force can act on an object when they compare the effects of the collision when the object is held still and when it is not held still. Students should notice that the shape of objects may change when the objects are flexible. Students may describe the rate at which motion changes in qualitative terms. For example, they may describe motion changing "quickly" or motion changing "slowly."

Where We Are NOT Going

The terms "force," "balanced force," and "unbalanced force" have not been formally introduced yet and do not need to be. Also, do not introduce the term "acceleration." The NGSS uses the language "change in motion" rather than "acceleration" for middle school students. Do not quantify the rate at which motion changes.

Students may not yet be convinced that the shape of hard objects changes during a collision. They will investigate this question in Lesson 3.

LEARNING PLAN for LESSON 2

1 · NAVIGATION

5 min

MATERIALS: science notebook

Share initial ideas. Project **slide A**. Students should consider the question on the slide (including the caveat that their answer should be short) and share their ideas with an elbow partner. Then ask 2-3 students to share their ideas with the whole class. Students may have lots of ideas about what happens to objects during a collision, but few students are likely going to be able to summarize all the things that can happen in one sentence.

Suggested prompt	Sample student response
You probably have some ideas about what happens to objects when they collide. Can you state what you think happens in one sentence?	• *I think things can break.* • *I think sometimes things don't break.* • *Sometimes things only bend but don't break.* • *Sometimes things get bumped, so they start to move.* • *Sometimes things stop.*

Gather around the DQB. Before class begins, be sure to have the DQB with questions and suggested investigations set up in the room. Gather students around the DQB and ask them to recall the collisions they had considered in the past few days and the types of investigations they wanted to do. Say, *What could we do to study this better? Let's look back at our DQB and Ideas for Investigations.*

Suggested prompt	Sample student response
Who can remind me of our suggested investigations?	• *Study what happens to the speed of objects when they collide.* • *Study which object was moving and what happens.* • *Study what happens to the motion of objects just before and just after the collision.* • *Slow down the collision with a slow-motion camera.*

Say, *Let's try to recreate some collisions to figure out what's going on!*

2 · INVESTIGATE DROPPING AND BREAKING

10 min

MATERIALS: Dropping and Breaking Lab, science notebook

Demonstrate dropping and breaking. Explain to students that they will investigate dropping some hard objects onto fragile (but inexpensive) objects in small groups. Their goal is to try to observe what makes things break and what might keep things from breaking. Students should have some freedom to test different combinations. Gather students around a demonstration area to show 1-2 types of collisions groups might try. For example, some students might suspend a rice noodle between two books and drop a golf ball on the noodle. Other students might place a graham cracker directly on the table and drop a tennis ball on the graham cracker.

SAFETY PRECAUTIONS

Remind students about safety. Students should keep track of tennis balls, golf balls, and marbles. Students should wear safety goggles in case broken pieces of objects are ejected during collisions. Also, students should not drop any object from higher than an arm's length in front of them onto the table top (about 2 feet).

Record data in notebooks. Students should try their best to make careful observations and record what they see. Encourage students to describe their tests and record what happens in a format that makes sense to them. There will likely be many challenges associated with making careful observations, so students should record those challenges.

3 · DISCUSS DESIGN CHALLENGES: DROPPING AND BREAKING

5 min

MATERIALS: science notebook

Gather student observations. Present **slide C.** Ask students to return to their seats and share what they noticed in their investigations. Listen for ideas such as

- dropping a ball from a higher height is sometimes more damaging,
- putting a fragile target on bricks may cause more damage than suspending the object across two surfaces (or maybe not),
- the targets bounced,
- the targets bent or broke, or
- balls bounced off targets.

Ask students to share any challenges. Students likely experienced challenges in conducting the investigation and making observations. Listen for ideas such as these:

- It was hard to keep track of the ball.
- It was hard to control the speed of the fall (the speed of collision).
- It was hard to aim the ball so it hit the target in a predictable spot.
- Collisions happen too fast to make good observations.

Discuss what might need to be different about the lab design. Tell students, *It sounds like it would be really helpful if we could control this collision somehow. The things I heard were...* Write ideas on the board and have students agree that we need to

- control the speed of the collision better,
- control where the ball hits the target, and
- keep the ball from flying off after the collision.

Demonstrate controlling collisions with carts. Say, *I think we can do some things to control the collision. You saw how hard it was to make observations without controlling the collision. I've got some objects stuck on the carts with putty, and the carts are on a track. I can use this to make different objects collide by running the carts into each other like this (show a crash). This looks a little bit funny, but it still should give us a way to study collisions between different kinds of objects without things flying all over the room.*

Motivate need for slow-motion video. Prompt students to share that putting things on carts can help control the collision, but it is still **too fast** to see what is happening right at the moment they make contact and immediately afterward.

Say, *I'm wondering about the surface of my CD case during the collision. What happens to it? Does it bend before it breaks? Can it bend and not break? What are some tools I could use to help me see what is happening right at the moment two objects make contact and immediately afterward? Are there any technologies we could use to help us see what is happening to the objects during that really brief event?*

Look for answers such as

- slow it down (just push them together instead of crashing them),
- try to take a photo of it as it happens,
- use a slow-motion camera, or
- use video someone else collected using a slow-motion camera.

Make predictions about the shape of objects during a collision. Present **slide D.**

Say, *It sounds like we have some good ideas about how to look at the collision a bit more slowly. Let's work with the idea of trying to get some video of the collision and then slowing it down so we could inspect the collision to really see what happens when the golf ball hits the CD case. And remember, you were thinking about some things that had to do with the shape of the object (Does it bend? break?) Record your predictions in your notebook.*

Students should record their ideas in their notebooks. Tell students that they are going to test their predictions.

4 · EXPLORE COLLISIONS: SHAPE

20 min

MATERIALS: Explore Collisions: Shape Lab, science notebook, slow-motion videos (optional)

Demonstrate data collection. Distribute *Exploring Collisions: Shape*. Tell students they will try out several different types of collisions with different materials and look for patterns in the data. Project **slide E** and demonstrate how to record data for students while you model a collision between two clay balls.

Option A: Students collect their own video. If students collect their own slow-motion video, take several minutes to show how to operate the slow-motion video functionality of their phones or tablets. You may want to project these instructions for students.

- General instructions for Android phones: https://support.google.com/googlecamera/answer/7064897?hl=en-GB
- General instructions for iPhones: https://www.howtogeek.com/346233/how-to-record-and-edit-slow-motion-videos-on-your-iphone/

Ask students to collect data at three stations. Students work in groups of 5 at stations. There should be six stations set up to accommodate a class of 30 students. Students will rotate through three of the stations. Students should record their data on their handout and tape the handout into their science notebook.

It is sometimes easier to see deformation when the carts are more massive. They may use washers to add additional mass to the carts, holding washers in place with clay.

Option B: Students record data from slow-motion video provided. If students do not have access to phones or tablets with slow-motion video recording capability, they can watch these: https://www.teachersopensciedfieldtest.org/contact-forces . Divide the students into groups depending on the number of tablets or computers available to play the videos. It's best if students can watch each video multiple times.

5 · NAVIGATION

5 min

MATERIALS: None

Prepare students for the next lesson. Say, *Today we investigated what happens to the **shape** of the objects during a collision.*

Suggested prompt	Sample student response
Did anyone notice other changes happening besides shape changes?	• *We saw some carts starting to move.* • *We saw carts bouncing.* • *We saw carts stopping.*

Say, *Tomorrow, let's look at the motion of both objects during collision.*

End of day 1

6 · NAVIGATION

5 min

MATERIALS: science notebook

Recall what we learned in the previous lesson and motivate today's lesson. Project **slide G** and ask students to look back on their notebooks from the previous lesson. Refer to student responses from the question "What else do you think might happen to objects in a collision?" that were recorded last class.

Suggested prompt	Sample student response
Last class, we thought a lot of other things besides shape changes were happening during collisions. I wonder if those things always happen. What could we do to test it out?	*We could crash the cars into each other again, and this time look at how they are moving.*

7 · EXPLORE COLLISIONS: MOTION

20 min

MATERIALS: Exploring Collisions: Motion Lab, science notebook, *Exploring Collisions: Motion*

Demonstrate data collection. Distribute *Exploring Collisions: Motion*. Tell students that they will try out several types of collisions with different materials and look for patterns in their data. Project **slide H** and demonstrate how to record data for students while you model two types of collisions. The data table is set up for you to demonstrate the collision between two clay balls. The two collision types are

- the left-hand object moves and collides with the stationary (but not restrained) right-hand object, and
- one object moves and collides with the other object that is held still.

You may wish to change the masses of the carts by adding washers and securing the washers with clay.

Ask students to collect data at three stations. Students work in groups of five. There should be six stations set up to accommodate a class of 30 students. Students will rotate through three of the stations. Students should record their data on their handouts and tape them into their science notebooks.

8 · INTERPRET COLLISION DATA: SHAPE AND MOTION

15 min

MATERIALS: science notebook

Gather students together for a class discussion. Project **slide I**. Ask students to share what they noticed during their investigations or as they watched the videos about the **shape** of objects.
Look for ideas such as

- we sometimes saw things bend,
- we sometimes didn't see anything bend or squish,
- sometimes things returned to their original shape after the collision, but sometimes not (stayed bent, squished, or broken; or bounced back), and
- sometimes things broke.

Project **slide J**. Ask students to look for a pattern in their data tables. Did they **always** see a shape change? If not, when did they **not** see a shape change? Ask 2-3 groups to share what they found.
Look for these ideas:

- With bendable things, we easily saw the shape change during a collision.
- We aren't sure if we would see a shape change with harder objects like rubber.

Write a summary statement. Ask students to write a summary statement about what happens to the shape of objects during a collision in their science notebooks. Ask 2-3 students to share their summary statements. You may wish to write a sample summary statement on the board.

Sample summary statement: **Some flexible objects at least temporarily changed shape during a collision.**

Identify patterns related to motion in a discussion. Project **slide K.** At the end of this part of the discussion, you should be able to write a short summary statement on the board that indicates how motion usually changed for both objects during a collision unless students held an object still and prevented changes.

Suggested prompt	Sample student response
What are some of the observations you saw during your investigations about motion?	• *Objects sped up.* • *Objects slowed down.* • *Objects changed the direction they were moving.* • *Objects stopped.* • *Objects started moving.* • *One object stayed still.*
We saw a lot of different things happen, didn't we? Let's take a closer look. Tell me about the data you recorded in the column "Did the motion change?" What did you see?	• *We saw a lot of changes in motion.* • *Sometimes motion didn't change.* • *Sometimes there were changes for both colliding objects, and sometimes the changes were only for one object.*
How many times did you see the motion change and how many times did you see the motion stay the same?	*Answers will vary, but students should report more data showing changing motion than motion staying the same.*

Suggested prompt	Sample student response
Do you notice any patterns? What were the conditions when the motion changed? What were the conditions when the motion didn't change?	• *In every collision, the motion of at least one of the objects changed.* • *In every collision where we didn't hold something still, the motion of both objects changed.* • *The only time the motion of an object didn't change was when we were holding the object still.*

Summarize how collisions affect the motion of objects. Ask students to consider their own data and what they have heard from their classmates about how collisions affect the motion of objects. Ask them to write a summary statement in their science notebooks answering the question "What happens to the motion of objects during a collision?" (**slide L**). Then ask 2-3 students to share what they wrote. You may wish to write a summary statement on the board.

Sample summary statement: **All objects changed their motion during collisions unless we held one object still and prevented changes in motion.**

Consider cause, effect, and correlation. Students have data about changes in motion and changes in shape during a collision. They are also likely considering that the collision **caused** the changes in shape or motion. But changes in motion don't **always** happen during collisions. There must be something slightly different that **causes** changes in motion. On the other hand, the shape of objects **always** changes during collisions, but students do not have enough evidence yet to make this claim. They will continue investigating collisions and shape changes in Lesson 3. Engage students in a discussion to help them distinguish between correlation and causation. Project **slide M**.

Suggested prompt	Sample student response
Show of hands: How many of you saw changes in shape during collisions?	*Most students should raise their hands.*
*Did you **always** see changes in shape?*	*No.*
*Now let's think back. Did we **always** see changes in motion of our objects?*	*No.*
*When did we **not** see changes in motion?*	*When we held one object still.*
Did we see changes in shape when we held an object still?	*Yes.*
*Interesting. Now let's say I'm trying to convince you that collisions **cause** changes in shape. Would you believe me?*	*Answers vary--some students may not yet believe it's true for hard objects.*
*What about changes in motion? Can we say that collisions **always cause** changes in motion? Why or why not?*	*No. Because if we held one object still, there were no changes in motion for that object. It's like there were two things happening (collision and holding) and maybe they cancelled each other out.*
But does motion change pretty often during collisions?	*Yes.*

Suggested prompt	Sample student response
When two things tend to happen together but it isn't clear if one thing caused the other to happen, we say they are correlated. Do you think collisions and change in motion are correlated?	*Yes.*

9 · NAVIGATION

5 min

MATERIALS: None

Motivate Lesson 3. Ask students to consider what evidence they might need to determine whether collisions **caused** changes in shape in every collision, including really hard objects. Listen for ideas such as

- we might think collisions caused changes in shape if we saw something really hard change shape and
- we would need a really hi-tech slow-motion camera if it was a fast push.

Project **slide N.** Tell students that tomorrow they will have the chance to look at really hard collisions that happen too fast to see without special cameras so they can gather more evidence on whether collisions always cause changes in shape or not.