CLASS CRUNCH LABS

TEACHER GUIDE

Forces and Motion: Unit 1

OVERVIEW

It's time to put your game face on, because in this unit, we're going to explore the concepts of forces and motion through the sports your students love. Along the way, we'll observe phenomena, ask questions, analyze data, perform hands-on investigations, create model diagrams, take a virtual field trip, do an engineering design challenge, break some eggs and even smash a watermelon or two! In the end, students will gain an understanding of how to answer this overarching unit question:

UNIT QUESTION

How do I get better at any ball sport using the science of forces and motion?

UNIT AT A GLANCE:

LESSON 1

Anchoring Phenomenon

90min (2 days)

LESSON 2

Newton's 1st Law Investigation

90min (2 days)

LESSON 3

Newton's 2nd Law Investigation

90min (2 days)

LESSON 4

Tying it all Together

90min (2 days)

LESSON 5

Design Challenge

90min - 225min (2 days)

This unit is designed to align with the Next Generation Science Standard:
MS-PS2-2: MOTION AND STABILITY: FORCES AND INTERACTIONS

NGSS STANDARDS ALIGNMENT

MS-PS2-2: MOTION AND STABILITY: FORCES AND INTERACTIONS

PERFORMANCE EXPECTATION

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.

DISCIPLINARY CORE IDEAS

- 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 a 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.

CROSSCUTTING CONCEPTS

Explanations of stability and change in natural or design systems can be constructed by examining the changes over time and forces at different scales.

SCIENCE AND ENGINEERING PRACTICES

- 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.
- Science knowledge is based upon logical and conceptual connections between evidence and explanations.

LESSON 1

Why do different balls from different sports travel different distances?

LESSON 1 Why do different balls from different sports travel different distances? DAY 1

Resource	Teacher Will...	Students Will...
15 MIN **Introductory slides 1-4** ↳ **Video** **Mark's Surprise!** ↳ **Video** **Sports montage Anchoring phenomenon**	SLIDE 1: Begin with an intentionally dull introductory slide to trick students into thinking this lesson is going to be boring. Have some fun with this if you'd like - you could even do your best rendition of the teacher from Ferris Bueller so no one will expect what's coming on the next slide... SLIDE 2: ...an embedded video with an exciting surprise message from Mark. **Play Mark's surprise video** SLIDE 3: "Surprise!! Mark Rober's here to crash our classroom!" Ask students if they know who Mark Rober is and have a few talk about him to the class. SLIDE 4: "Mark sent us this video about sports that he wants us to watch and help him figure out. Pay attention to what you notice (observations) and what you wonder (questions) about the phenomena you see in the video. Look for similarities and differences between all of the sports." **Play anchoring phenomenon video**	• Mistakenly think this is going to be boring... • Watch Mark's surprise video • Realize this is going to be interesting... • Share what they know about Mark Rober with the class • Watch the anchoring phenomenon video
Worksheet **Notice and Wonder Chart**	"We are going to re-watch the video and this time, record what you notice (observations) and what you wonder about the phenomenon. (questions)." • Hand out the Notice and Wonder Chart • Replay anchoring phenomenon video *Ask students to share what they wrote with the class out loud. Record similarities, differences and patterns on the white board, digitally or somewhere you can refer back to later. Listen for and pointedly amplify ideas about "all the balls were struck", forces or pushes & pulls, motion, speed, distance, mass or weight, balls changing direction, balls or bats speeding up or slowing down, etc.*	• Watch the anchoring phenomenon video again • Record questions and observations on the Notice and Wonder chart • Engage in class discussion sharing their questions and observations

LESSON 1 Why do different balls from different sports travel different distances? DAY 1

Resource	Teacher Will...	Students Will...
15 MIN **Slide 5** ↳ **Data Slide** **Ball Sports Data Sheet** for students to fill out with observations.	SLIDE 5: "We made a lot of observations and have lots of questions about these sports that we just observed. I have some data that might help us recognize more patterns in the observations we made. Today, we'll be taking a look at data from: baseball, golf, football, cricket, softball and soccer." **Hand out Ball Sports Data Sheet** Ask students to spend 10 minutes recording noticings and wonderings about the data on the handout in pairs or small groups. Ask students to share what they noticed and wondered aloud about the data table with the rest of the class. Record some ideas on the whiteboard, digitally, or somewhere you can refer back to later. This can be added to the list that was started from the video. Some possible prompts include: "Do you recognize patterns in these data that are the same or similar to our observations of the video? Do you see any new patterns?" Listen for patterns that students identify including: different balls going different distances, different sports having different masses of balls, different sports having different masses of hitting devices.	• Read and analyze the Ball Sports Data Sheet • Record their noticings and wonderings about the data on the Data Sheet Handout • Share their noticings and wonderings out loud with the rest of the class
15 MIN **Slide 6** ↳ **Example model** **Worksheet** **Sports Model Sheet**	SLIDE 6: "Next, we are going to make models of these sports. But before we do, let's first talk about what a model is. Models use symbols, words, and images to visually represent our science thinking." *Show the sample model in the slide deck.* **Hand out Sports Model Worksheet** SLIDE 7: "Now it's your turn. Choose one of the ball sports from the worksheet to analyze - whichever sport you're most familiar with. Using the video, the data set and your own experiences: **Create a model explaining how to get a ball to move in the direction you want it to go when it is struck in your chosen sport.**" "Your model should include symbols, words, and images to explain: the objects involved (components & parts), how the objects interact with each other (interactions / relationships), and forces (pushes or pulls). Why doesn't the ball in your sport travel the same distance each time it is hit?"	• Choose their own sport to analyze • Create an initial model of their chosen sport using the Sports Model Worksheet

LESSON 1 Why do different balls from different sports travel different distances? DAY 2

Resource	Teacher Will...	Students Will...
10 MIN Slides 8-9 Worksheet Sports Model Sheet	SLIDE 8: Quick recap of yesterday's lesson. SLIDE 9: "Let's compare our sports model sheets from yesterday." Break students into pairs or small groups with different sports to compare their models. Let students know that they should be looking for things that are similar or different so they can try to identify patterns. Ask your students to share the similarities, differences and patterns they identified aloud to the entire class. Record some ideas (as well as any questions students are still unsure about) on the white board, digitally or somewhere you can refer back to later. Listen for examples like: "the models all show striking/hitting/kicking" the ball to make the ball change direction", "the models all show people hitting really hard to make the ball go fast." Note: Let your students know that if they have questions or are unsure about something, write those questions down! There is a lot we still don't understand at this point, but recording these questions	• Compare their initial sports models in pairs or small groups • Identify similarities and differences between their models • Share their observations out loud with the rest of the class
5 MIN Video Hero Video: Scene 1	SLIDE 10: "Let's check back in with Mark Rober to see why he sent us all this sports data." **Play Hero Video: Scene 1** "As a class, how can we help Mark, Maynard and Emily with their big question: **"What is the best way to hit a homerun every time?** Do you think this question relates to what we've been discussing and observing thus far? Let's see if we can use the similarities, differences and patterns we've been talking about to explain how to hit a homerun every time. Lead a consensus conversation with the class soliciting student ideas of the best way to hit a homerun every time and record them on the white board, digitally or somewhere you can refer back to later. Look for areas where the class agrees and disagrees about forces in baseball.	• Watch the Hero Video • Share their ideas about the best way to hit a homerun every time.

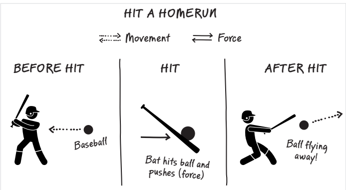
LESSON 1 Why do different balls from different sports travel different distances? DAY 2

Resource

15 MIN

Slide 11

↳ Model



Teacher Will...

SLIDE 11: "Now we're going to take these ideas to draw a model for baseball."

Record student ideas to draw an initial classroom consensus model (see Figure 1 below). Make sure to include: the bat, the ball, the batter, motion of objects, force arrows, distance traveled.

Draw arrows to represent forces and label the arrows for clarity. This is a good opportunity to introduce the idea of clear communication in science (ex. labeling arrows, units of measurement, etc.).

Support students in differentiating between force arrows and motion arrows though color coding or labels or using a different symbol for motion.

Note: During consensus building it is important for all students to be engaged in the conversation, even if as a listener. One way to support this is to physically re-arrange students into a "scientist circle" where everyone sits together in a circle or semicircle with their notes or models and with limited distractions. This can help allow more voices to be heard.

Students Will...

- Share ideas aloud with the class to contribute to the classroom consensus model
- Sit in a scientist circle to engage in focused consensus discussion
- Share ideas about how to hit a homerun and how the teacher can represent those ideas on the consensus model

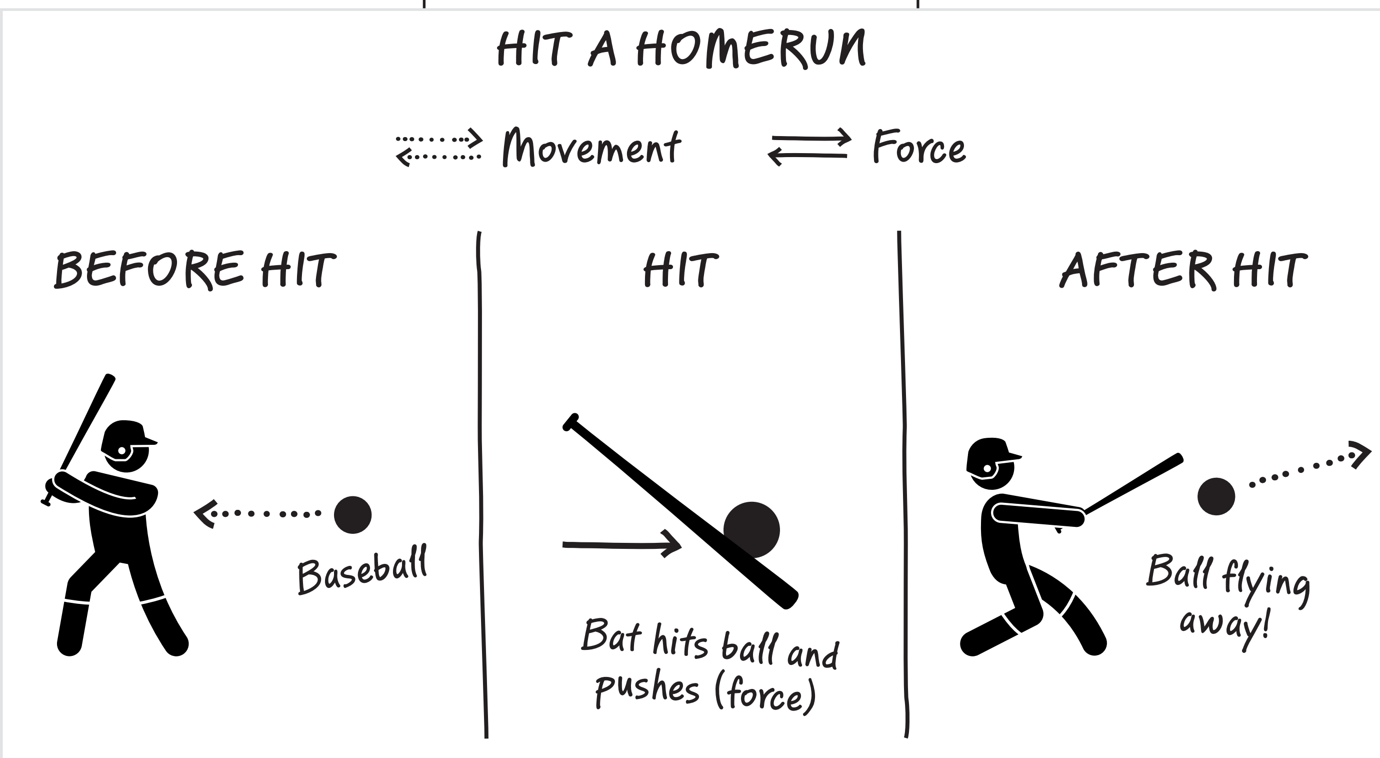
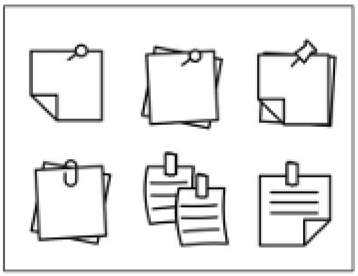


Figure 1: Initial Classroom Consensus Model

LESSON 1 Why do different balls from different sports travel different distances? DAY 2

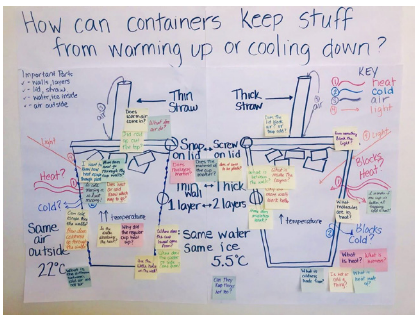
Resource	Teacher Will...	Students Will...
15 MIN Slide 12	SLIDE 12: “We made a lot of progress together as a class on a baseball model that could help Mark and team hit a homerun every time, but still don’t have all the information yet. We’ve explored different sports together, and we still have a lot of questions to explore. So let’s get into it.	
Class Tool  Driving Question Board	Guide the class in developing a Driving Question Board. The goal is to facilitate the students to share their remaining unanswered questions about baseball as well as their chosen sports on their individual models to drive the learning forward. As students share their questions, show them you value their thinking by pulling out their questions to lead to the overarching question for the unit and write it at the top of the Driving Question Board: “**How can I get better at any ball sport using the science of forces and motion?**”	• Participate in a Driving Question Board exercise • Record their questions in a shared area in the class

The Driving Question Board is a tool used to generate, keep track of, and revisit student questions that drive the investigation of the anchoring phenomenon and related phenomena. It is a visual representation of the class’s shared mission of learning in the unit. It is publicly displayed to serve as a learning resource for the community and should be easily accessible to students to see and add to during the unit. It lets students see that their questions are driving the learning.

Quick Set-up:

- Use a large sheet of poster board or chart paper. At the top, write the unit question: How can I get better at any ball sport using the science of forces and motion?
- Find a space in the classroom for the Driving Question Board that students can easily walk up to and reach to add their questions and read what their peers post over the course of the unit.
- Encourage students to add their ideas to the board. Collect questions on post its, note cards, paper, etc. or digitally using Google Form, FigJam or another digital tool.
- Add new ideas to the poster as students come up with them.

Example:



END OF DAY 2 - LESSON 1

LESSON 2

Why do objects move the way they do
when they're hit by a force ?

LESSON 2 Why do objects move the way they do when they're hit by a force? DAY 3

Resource

20 MIN

Demo

Egg in cup challenge

Worksheet

Stability and Change Worksheet

Teacher Video

Egg-in-Cup "How To" from Science Bob

Psst... for expert tips and tricks on how to facilitate the Egg-in-Cup challenge in your classroom, be sure to check out the "how to" video from our science teacher-in-residence, Science Bob!

Teacher Will...

SLIDE 13: Quick recap of yesterday's lesson.

SLIDE 14: "Now we've been talking about motion, but there's no better way to learn about motion than to watch it in action... and we're going to do it with this RAW EGG! How many of you have seen this before?"

"Here's the challenge: can you get the egg into the cup without touching the egg or the cup? Who thinks the egg will break?!?"

Materials for demo:
- Raw eggs
- A cup (clear plastic or glass)
- A lightweight disc (ex. paper plate)
- Cardboard tube (ex. toilet paper roll)
- Water

Invite a student to come up to the front of the class and try the challenge. Make sure there is no water in the cup at this point.

Chances are, the student will whack the disk and everything will fall down on the table and the egg will break. After the failed test, ask the class why this experiment didn't work?

Hand out Stability and Change Worksheet

Ask students to identify what changed and what stayed the same in the system and record it on their worksheet. Once finished, ask students what we can do differently to get the egg to fall into the cup, leading toward the idea to add water to the cup.

Reset the experiment and fill the glass with water. Invite another student to try the challenge at the front of the class. This time, it should work!

Ask students to record what happened on their Stability and Change worksheet. Lead a classroom discussion about what we observed in our experiment – using the cross-cutting concepts of change and stability.

Students Will...

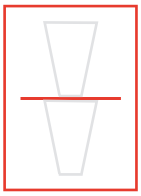
- Share hypotheses about what will happen in the Egg-in-Cup challenge
- Volunteer to participate in the Egg-in-Cup challenge in front of the class
- Complete the Stability and Change Worksheet
- Identify what changed and what stayed the same in the Egg-in-Cup system
- Share their observations out loud with the rest of the class

LESSON 2 Why do objects move the way they do when they're hit by a force? DAY 3

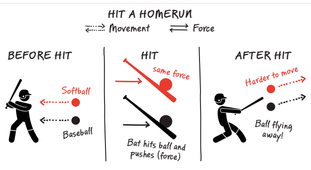
Resource	Teacher Will...	Students Will...
5 MIN **Video** **Hero Video: Scene 2**	SLIDE 15: "Let's check back in with Mark, Emily and Maynard to see what they're finding out about hitting a homerun every time." **Play Hero Video: Scene 2**	• Watch Hero Video: Scene 2
20 MIN **Worksheet** **Tablecloth Model Template Worksheet**	SLIDE 16: **Hand out the Tablecloth Model Template Worksheet** Ask students to individually or collaboratively use the model template to explain: • What objects will likely move when the tablecloth is pulled out. • What objects will likely not move when the tablecloth is pulled out. • Force arrows (including at least one example of where forces are not balanced) • Explain their reasoning. *Note: This is designed as a formative assessment opportunity to see how students can use a model to synthesize what we are learning together. At this point, what we expect students to capture and understand is that for something to move, there must be unbalanced forces acting on it. The unbalanced forces caused the objects with less mass to have a larger change in motion. The objects with more mass are less likely to move with that same force applied.* *Note: Although we as teachers understand this is the concept of inertia, it is not necessary for students to use that vocabulary word at this time. It is sufficient for them to describe the concept in their own words. If it does become a word we learn, consider adding it to a word wall in the classroom for students to reference later.*	• Work on the Tablecloth Model Template Worksheet individually or in pairs • Share their reasoning out loud with the rest of the class

END OF DAY 3

LESSON 2 Why do objects move the way they do when they're hit by a force? DAY 4

Resource	Teacher Will...	Students Will...
20 MIN Video **Maynard's Activity Video Sequence** Activity  **Newton's Tower** Teacher Video **Newton's Tower "How To" from Science Bob** **Psst...** for expert tips and tricks on how to facilitate the Newton's Tower activity in your classroom, be sure to check out the "how to" video from our science teacher-in-residence, Science Bob!	SLIDE 17: Quick recap of yesterday's lesson. SLIDE 18: **Play Maynard's Video Part 1** SLIDE 19: "We just witnessed a discrepant event - which means a demonstration with an unexpected outcome. I'm going to pass out the materials to you to see if you can figure out why the two sets up cups behaved differently." Hand out Initial Materials for Newton's Tower Activity to students in pairs or small groups: - 2 cups (paper or plastic) - Index card - String Ask students to share what they observed in their experiments out loud with the class. See if they can explain Maynard's discrepant event. Look for suggestions to add mass to the cups. SLIDE 20: **Play Maynard's Video - Part 2** SLIDE 21: **Hand out Remaining Materials for Newton's Tower Activity** - Extra cups (paper or plastic) - Extra Index cards - Extra String - Weights (ex. marbles) Ask students to share what they observed in their experiments out loud with the class. SLIDE 22: **Play Maynard's Activity Video Sequence - Part 3** Facilitate a classroom discussion about what we observed. See if students can relate what they observed back to the Egg-in-Cup challenge from yesterday.	• Watch Maynard's Activity Video - Part 1 • Use the provided materials to try to get 2 cups to stack working in pairs or small groups. • Watch Maynard's Activity Video - Part 2 • Optimize their towers to try to make the most cups fall into a stack. • Watch Maynard's Activity Video - Part 3 • Share their observations and ideas out loud with the rest of the class

LESSON 2 Why do objects move the way they do when they're hit by a force? DAY 4

Resource	Teacher Will...	Students Will...
20 MIN **Model** 	SLIDE 23: Lead a class discussion around the class model of baseball home runs and ask students to share thinking about what we can add to the model now. This conversation should lead to adding information about the mass of the ball and the unbalanced force on the baseball that causes it to change motion. The largest unbalanced force causing the change in motion is the bat hitting the ball. Use a different color when adding new information to the class consensus model and ask students to use a new color on their initial models as well. This will allow you and the students to see how their thinking has changed over time. *Note: In middle school, the focus of these changes in motion is intentionally constrained to one-dimension at a time. Although there are more forces acting on the ball such as gravity and air resistance, we are primarily focused on the largest change in motion that results from the unbalanced force of the bat hitting the ball. Asking students to include these additional concepts could be a way to differentiate for more advanced students.*	• Participate in a classroom discussion about what we can add to the baseball classroom consensus model • Return to their initial models of their chosen sports from Lesson 1 and add new information about the mass of the object moving and the unbalanced forces that cause the change in motion.

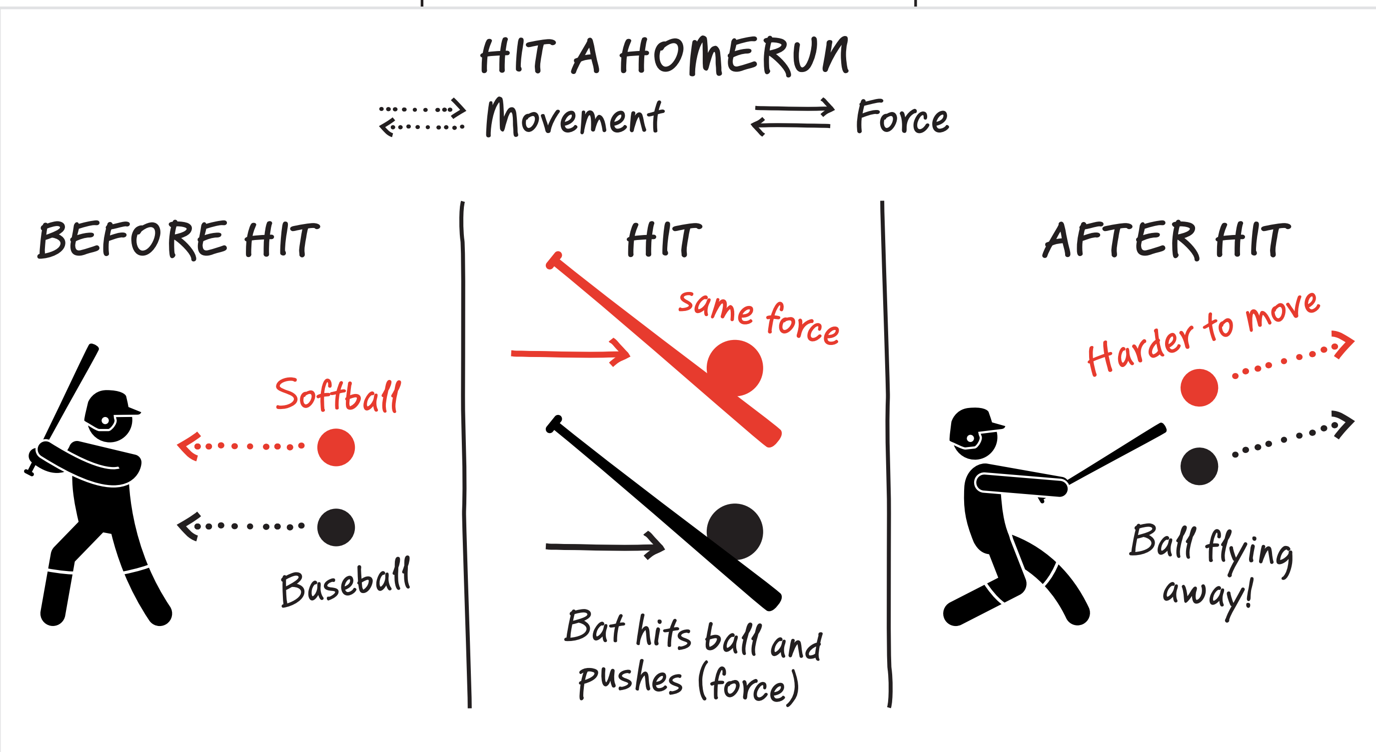


Figure 2: Classroom Consensus Model - Lesson 2

END OF DAY 4

LESSON 3

Why do objects move the way they do when they're hit by different forces?

LESSON 3 Why do objects move the way they do when they're hit by different forces? DAY 5

Resource	Teacher Will...	Students Will...
2 MIN Slide 24-29	SLIDE 24: Quick recap of yesterday's lesson. "Last class we were asking questions about how different forces affect the change in motion of an object. I think that we have some pretty big questions right now that are worthy of a scientific investigation."	
45 MIN Video Emily's Ball & Ramp Video Sequence Activity Ball & Ramp Worksheet Ball & Ramp Worksheet Teacher Video Newton's Tower "How To" from Science Bob Psst... for expert tips and tricks on how to facilitate the Newton's Tower activity in your classroom, be sure to check out the "how to" video from our science teacher-in-residence, Science Bob!	SLIDE 25: **Play Emily's Video - Part 1** • Hand out Ball & Ramp Worksheet • Hand out Materials for Ball & Ramp Investigations (see next page) "Before we dive into this investigation, we need to talk about how to make this a 'fair test'. In science, things that we carefully change in an experiment are called variables. What are some things I can change in this set up to make the cup move differently? Or What variables can we change in this experiment? Allow students to share their thinking but listen for and highlight: • Size / mass of the marble • Mass of the cup • Height of the ramp "Now to make this test fair, how many variables should we change at once?" If students don't know that we can only change one variable, this is a great opportunity to lead a discussion about that as well as what should remain the same across each test. In science we have a rule that we only change one thing at a time to make sure it is a fair experiment. SLIDES 26 - 28: Facilitate the Ball & Ramp Investigation (see next page) SLIDE 29: **Play Emily's Video - Part 2**	• Watch Emily's Ball & Ramp Video - Part 1 • Participate in a classroom discussion about identifying variables • Construct the Ball & Ramp apparatus in pairs or small groups. • Design and craft two "cup mascots" with different masses • Identify a variable to test using the Ball & Ramp system • Record data of their findings from their initial variable test • Conduct an investigation to identify the factors that affect different changes in motion. • Refer to the Ball & Ramp Worksheet for guidance • Use evidence from their investigation to explain science concepts related to force, mass, speed and change in motion. • Watch Emily's Ball & Ramp Video - Part 2

LESSON 3 Why do objects move the way they do when they're hit by different forces? DAY 5

Objective: Roll objects of different masses down an adjustable ramp to try to push a "cup mascot" into a "goal zone".

Bill of Materials:

- (2) Cups (paper or plastic)
- (3) Rolling objects with different masses
- Ramp with side rails (ex. yardstick with wooden dowels glued down the sides)
- Ruler
- Object for raising / lowering ramp (ex. large roll of tape)
- Masking Tape
- Scissors
- Decorations (e.g. googly eyes, pom-poms)
- Weights (e.g. washers, pennies)
- Clamp (optional)
- Glue gun (optional)

Students will:

- Prepare each cup by cutting a hole in one side big enough for the rolling objects to enter
- Design cup mascots! Add decorations and weights (with glue or tape) to each cup so that they have different masses.
- Tape one end of the ramp to the table so it lays horizontal
- Raise and lower the horizontal ramp by sliding an object underneath it (ex. large roll of tape)
- Measure the height of the ramp with the ruler (Optional: attach a clamp to the base of the ruler so it stays upright)
- Create the "goal zone" by placing 1 strip of masking tape about 10 inches from the base of the ramp and a parallel strip of tape about 5 inches from the first strip (make sure the cup just barely fits between the two pieces of tape)
- Place a cup mascot at the bottom of the ramp and get ready to conduct an investigation and record the results!

Teacher Prompts:

- How did the starting position affect how far the cup went?
- How did the ramp height affect how far the cup went?
- How do you explain the difference between the two?
- How did the weighted cup compare in how far it went?
- What did you have to do to make the weighted cup still make it to the landing zone?
- A "force" is how hard something pulls or pushes. How did raising the height of the cup affect the force exerted on the cup?
- The "mass" is how much stuff is in an object. On Earth, more mass means an object is heavier due to the force of gravity. A heavier thing we could consider to have more mass. How did the cup's mass affect how far it traveled?
- We only witnessed how far the cup traveled but didn't measure the speed directly. Which positions and heights do you think created more speed?

Students learning outcomes:

- At the end of the investigation, students should be able to use evidence from their investigation to explain some or all of the following concepts through guided discussion:
- More force will move the cup more
- If the same force is applied on different objects, the objects with less mass have a larger change in motion. More mass will experience a smaller change in motion.
- The object with more mass creates more force.
- More force can mean a larger change in motion.
- The object with more mass and more speed will create more force.

END OF DAY 5

LESSON 3 Why do objects move the way they do when they're hit by different forces? DAY 6

Resource	Teacher Will...	Students Will...
5 MIN Slides	SLIDE 30: Quick recap of yesterday's lesson.	
5 MIN Video Hero Video - Scene 3	SLIDE 31: **Play Hero Video - Scene 3** "We are starting to figure out some really cool stuff! Let's think about how the videos we just watched might help us make more sense of the investigation we did with the ramp."	• Watch Hero Video - Scene 3
10 MIN Worksheet Mapping Worksheet	SLIDE 32: **Hand out Mapping Worksheet** This activity helps students draw comparisons between different events to find patterns and understand the science concepts behind them. Helpful prompts: "One variable that we changed in the ball & ramp investigation was..." "The part of the video related to that variable was..." "The variable in the investigation and the video are related to each other because..." As students work on the handout, they should be forming the following connections: 1. The balls from the ramp investigation relate to the objects being slingshot 2. The higher the ramp and the more massive the balls, the more force was delivered. Just like the slingshot being pulled back more. Refer to the Mapping Worksheet Answer Key to help guide students who are getting stuck	• Map comparisons between the hero video slingshot experiment and the ball & ramp investigation using the Mapping Worksheet. • Build an understanding of these ideas: 1) The greater the mass of the object, the greater the force needed to achieve a same change in motion and 2) For any given object, a larger force causes a larger change in motion.

LESSON 3 Mapping Excercise Answer Key DAY 6

Ball & Ramp Investigation


Slingshot Experiment

Select an independent variable (one that was changed) from the Ball & Ramp Investigation:	Which variable from the Slingshot Experiment best relates to this variable?
Ramp Height	**Slingshot force**

Explain your reasoning:

Adjusting the height of the ramp and pulling back the slingshot both provided the force that pushed the objects. The higher the ramp, the more force that was delivered and the farther the slingshot pull, the more force was delivered.

Select another independent variable (one that was changed) from the Ball & Ramp Investigation:	Which variable from the Slingshot Experiment best relates to this variable?
Cup masscot with different mass	**Object (Phat Gus, Laptop, Diamond Play Button) mass**

Explain your reasoning:

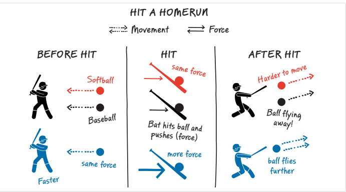
These are all objects with different masses. An object with more mass resists its change in motion more than an object with less mass. More force is required to move an object with more mass the same distance as an object with less mass.

Select another independent variable (one that was changed) from the Ball & Ramp Investigation:	Which variable from the Slingshot Experiment best relates to this variable?
Balls with different masses	**Slingshot force**

Explain your reasoning:

Increasing the mass of the ball and pulling back the slingshot farther both provided more force that pushed the objects further. The larger the mass of the ball, the more force that was delivered and the farther the slingshot pull, the more force was delivered.

LESSON 3 Why do objects move the way they do when they're hit by different forces? DAY 6

Resource	Teacher Will...	Students Will...
5 MIN Video Hero Video - Scene 4	SLIDE 33: **Play Hero Video - Scene 4** Facilitate a classroom discussion where students map what they learned about speed in the hero video back to the ball & ramp investigation.	• Watch Hero Video - Scene 4 • Participate in a classroom discussion about the concept of speed as it relates back to the ball & ramp investigation
10 MIN Model 	SLIDE 34: Revisit the classroom consensus model of hitting a baseball homerun and ask students to share thinking about what we can add to the model now. This conversation should lead to adding information about how hitting the ball with more force will lead to the ball going further and adding information about the speed of the bat leading to more force on the ball. *Use a different color when adding new information to the class consensus model and ask students to use a new color on their initial models as well. This will allow students to see how their thinking has changed over time.*	• Participate in a classroom discussion about what we can add to the baseball classroom consensus model • Return to their models of their chosen sports from and add new information about speed.

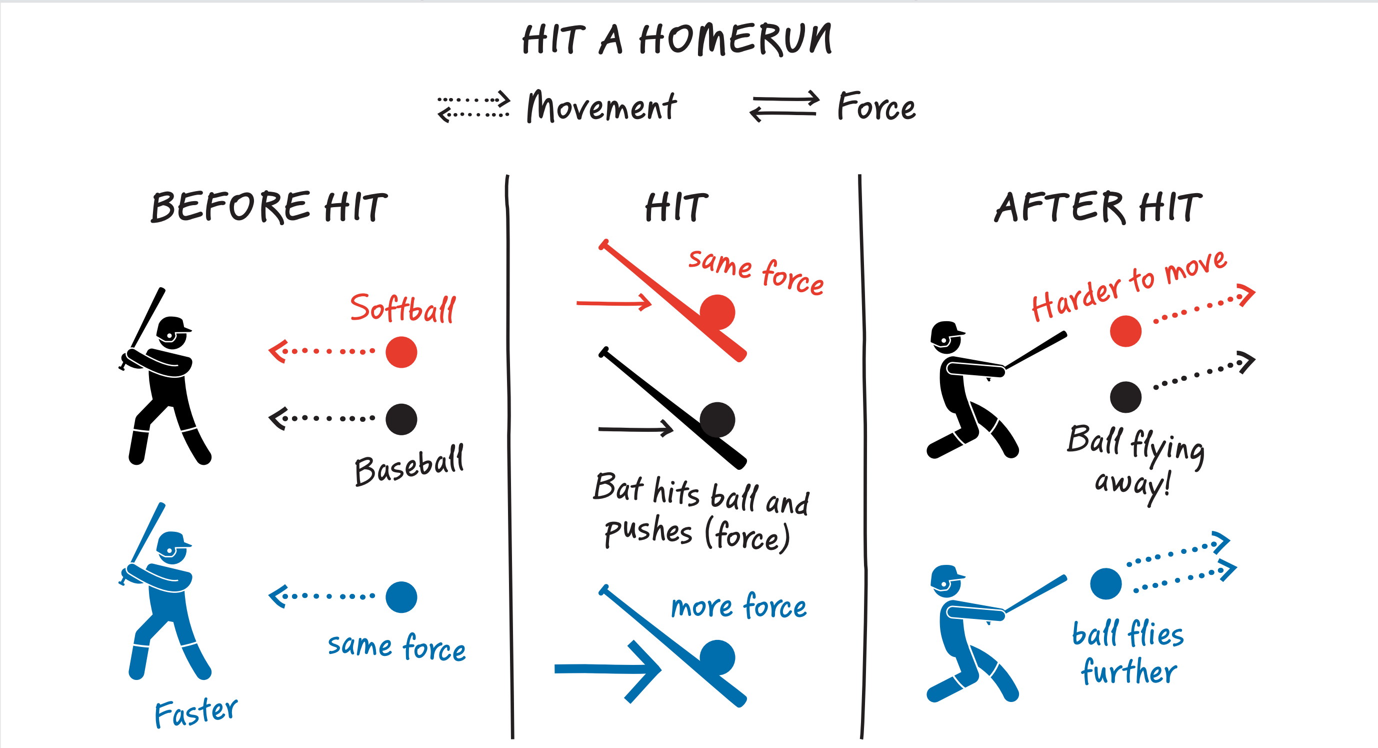


Figure 3: Classroom Consensus Model - Lesson 4

END OF DAY 6

LESSON 4

How do I get better at any ball sport using the science of forces and motion?

LESSON 4 How do I get better at any ball sport using the science of forces and motion? DAY 7

Resource	Teacher Will...	Students Will...
20 MIN Slide 35 Handouts Sports Model Worksheet & Sports Ball Data Sheet	SLIDE 35: Quick recap of yesterday's lesson. Prompt: "Now that we have a final consensus model about baseball, let's look back at the data set we started the unit with and see if we can use it to add more information to your model"" Instruct students to revise their Sports Model Sheet. Tip: Encourage students to use a new color on their initial models when adding new information. This will allow students to see how their thinking has changed over time. Refer students back to the Ball Sports Data Sheet. Note: we are scaffolding the Science & Engineering Practice of Analyzing and Interpreting Data to provide evidence for phenomena at this point. Students may need some support looking for patterns in the data related to the unit.	• Iterate on their initial models of their chosen sport by adding information about how hitting the ball with more force and speed will make it go further. • Analyze the original sports data set to provide evidence to include in their model.
10 MIN Video Hero Video - Scene 5	SLIDE 36: Play Hero Video - Scene 5 Lead real-world application career conversation. (Ex. "How did Julie Bellerose use forces in her career and development of the DART Spacecraft?") Fun tip: Google "dart spacecraft" and watch what happens to your screen.	• **Watch Hero Video - Scene 5** • Participate in classroom discussion about a real-world career application of forces and motion
15 MIN Video Hero Video - Scene 5	SLIDE 37: Play Hero Video - Scene 6 Lead discussion about the design solution in the video. Sample prompts: "How did the team build a homerun device? What factors did they consider to make it consistently hit home runs?" How could Mark Rober's "homerun machine" design be improved?	• **Watch Hero Video - Scene 6** • Participate in classroom discussion about the design solution in the video

END OF DAY 7

LESSON 4 How do I get better at any ball sport using the science of forces and motion? DAY 8

Resource	Teacher Will...	Students Will...
20 MIN Worksheet Notice and Wonder Chart	SLIDE 38: Quick recap of yesterday's lesson Prompt: Today we are going to revisit Lesson 1, verifying that we have answered all of our initial questions - and identifying unanswered ones that could prompt further investigation. Look back at the questions from the initial "Notice and Wonder Chart" Help students identify what we can answer and what questions we still need to figure out Tip: This process can be done more frequently as needed to help students realize we are making progress on the questions they asked at the beginning of the unit.	• Look at their "Notice and Wonder Charts" • Evaluate answers and remaining questions
25 MIN Worksheet Explanation Worksheet	SLIDE 39: **Distribute the "Explanation Worksheet" to students** Prompt: "Use this worksheet to construct an explanation of how you would get a perfect hit in your sport of choice every time. In your explanation include information about how you could optimize the hit using forces. Use your model that you have been revising as evidence to support your thinking." *Note: we are building towards the Science & Engineering Practice of Constructing Explanations & Designing Solutions: Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.*	• Fill out the "Explanation Worksheet" • Consider the model they have been revising throughout the unit to support their thinking on the explanation handout.
15 MIN Assessment Video Interactive multiple-choice quiz video	To round out the completion of the unit, evaluate your students' learnings with the provided interactive assessment video. This is a multiple-choice quiz reviewing the scientific principles covered in the unit, hosted by Maynard. **Assign the assessment video to individual students on a computer or tablet**	• Complete the assessment video by tapping on the screen to select answers • Listen to explanations of correct and incorrect answers that help solidify understanding

END OF DAY 8

LESSON 5

Engineering Design Challenge:
Build your own "home run hitting machine"

LESSON 5 How can we design our own “homerun machine” to meet specific criteria & constraints? **DAY 9-13**

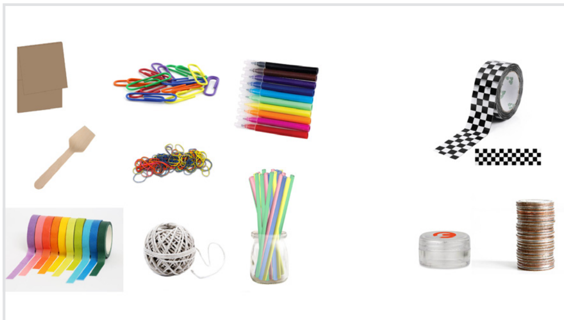
3-5 DAYS

ENGINEERING DESIGN CHALLENGE

The design challenge is the exciting culmination of our unit - this is the fun part where we all get to feel like Mark Rober and invent our own homerun machines!

This is an open-ended challenge that combines knowledge of Newton’s first and second laws to create their own “homerun machine”. Groups will be creating unique designs that achieve the task of sliding objects as close to a target as possible, incorporating their knowledge of force, mass, and speed.

In this 2-5 day lesson, we give students the opportunity to engage with the engineering design process, alongside NGSS performance expectations.



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.

NOTE: We use pucks instead of balls to specifically constrain the motion as close to 1 dimension - as projectile motion in 2-dimensions falls beyond the scope of MS standards.

LESSON 5 How can we design our own "homerun machine" to meet specific criteria & constraints? DAY 9

Resource	Teacher Will...	Students Will...
45 MIN **Slide 40** ↳ **Video** **Mark's Design Challenge Kickoff**	SLIDE 40: **Play Mark's Design Challenge Kickoff video** Prompt: "We are going to be developing our own homerun machines! Let's see if we can apply what we have learned about forces and motion to complete Mark's engineering design challenge." See next page for full set-up instructions. Kickoff with a Teacher Demonstration Step 1: Set up two short pieces of tape 6 feet apart from each other on the ground or table. Step 2: Demonstrate flinging a bottle cap ("puck") with your finger from one piece of tape to the other. Step 3: Explain to students that instead of using a finger to fling the puck, they will be building their own machines.	• Look at their "Notice and Wonder Charts" • Evaluate answers and remaining questions
Hand out **Design Challenge Worksheet**	**Distribute the "Design Challenge Worksheet" to students** Split the class up into small groups of 2-3 students. Prompt: "Oh yeah, one more thing - Mark and his team wanna see what you create, so make sure to document your work! On presentation day you will demonstrate your machines in front of the class Provide students presentation day deadline	• Read through the design challenge handout in their groups • Break into small groups
Build Materials	**Distribute the Build Materials to each group of students** SLIDE 41: Review the criteria and constraints of this engineering design challenge with the class and answer any questions students may have aloud in front of the rest of the class before everyone begins. Ask student to begin sketching their ideas with the remaining classroom time	• Review the build materials • Participate in a classroom discussion about the criteria and constraints of this design challenge • Start sketching their ideas

LESSON 5 How can we design our own "homerun machine" to meet specific criteria & constraints? **DAY 9**

ENGINEERING DESIGN CHALLENGE

Objective: Design and decorate a "homerun machine" that can fling 3 objects of different masses the same distance each time.

Bill of Materials:

- 4 rubber bands
- 6 popsicle sticks
- Tape
- 12" yarn
- 2 plastic spoons
- 2 clothespins
- 1 binder clip
- 12" x 12" cardboard sheets
- 4 straws
- 4 brads
- 4 paper clips
- Glue stick
- Miscellaneous craft supplies (ex. Markers, paint, glitter, googly eyes, etc.)

Tools:

- Hot glue gun
- Hot glue
- Scissors (cannot be part of the final design)

Teacher Preparation:

Prepare the pucks
Each team will receive 3 pucks of 3 different masses:

- Puck 1: Empty bottle cap
- Puck 2: Bottle cap with 3 pennies glued inside
- Puck 3: Bottle cap with 6 pennies glued inside

Set up the playing fields

- For each team, set up 2 strips of tape 6 feet apart from each other in separate areas of the classroom or in the hallway
- Set up a "final challenge" playing field in the front of the classroom with 2 strips of tape 6 feet apart from one another for the last day.

Criteria:

- At the end of the investigation, students The target will be 6 feet from the starting point.
- The device should be able to move objects of different masses while not taking longer than 1 minute between shots to modify the device.
- The device will need to be mobile to move to the "official" challenge field for the final implementation.
- Optional: You can offer bonus points for special challenges like "who can fling the pucks the farthest"?

Constriants:

- Students may only use the materials provided
- # of days to design and develop the solution (to be specified by the teacher)

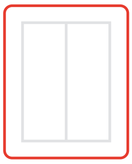
Teacher Video

Design Challenge "How To" from Science Bob

Psst... for expert tips and tricks on how to facilitate the Newton's Tower activity in your classroom, be sure to check out the "how to" video from our science teacher-in-residence, Science Bob!

END OF DAY 9

LESSON 5 How can we design our own "homerun machine" to meet specific criteria & constraints? DAY 10-12

Resource	Teacher Will...	Students Will...
1-3 DAYS Hand out  Design Challenge Worksheet Build Materials	After setting up the challenge on the first day, the next 1-2 days will be spent designing and building each team's machines, in preparation for presentation day. Note: You may choose to split up the deadline across multiple days where groups demonstrate incremental progress to the class. Make sure all groups have their materials and space to test their machines Check in on student's progress across the build days and answer questions Make sure students complete the reflection questions in their student guide to prepare them for the big presentation day!	• Sketch and design machine ideas • Build and refine their machines • Conduct test launches • Record their process and results in their guide / handouts
 Student Presentations	You made it... get ready for the big day! It's presentation day. This should be a fun celebration of all students creations in front of the class. The teacher will review the rules for everyone, which should be familiar by now. Prompt: "Today's the big day! Each group will get 6 total attempts in front of the class to demonstrate their designs. 3 per puck." Set-up the official presentation field in the center of the class (on table or floor) - with a tape starting line and target line 6 feet apart Randomly select an order for the groups to present (can be fun to ceremoniously draw their team names out of a hat) Have each team share aloud scientific explanations of their machines using the concepts of force, mass, speed and change in motion. Draw a results chart on the whiteboard, to increase the excitement, where each's teams trials will be recorded and displayed. (Optional) take pictures of each design and video clips of their trials, to be shared with Class CrunchLabs (we wanna see them!)	• Take turns presenting to the class • Introduce their machine name. • Describe their process... what they built, what didn't work, how they chose their approach. • Explain how they met the criteria and constraints • Communicate what they might explore next if they had more time or other materials. • Compete in the final classroom challenge. • Launch their pucks! 2 tries for each puck (6 total) • Record results • Comment on their own results and the results of their peers.

END OF UNIT

THANK YOU!

Thank you for taking the time to review this Teacher Guide for Unit 1: Forces & Motion. Class CrunchLabs is in Beta and we are looking for educator feedback to make it the best it can be!

Send us your feedback!

Visit crunchlabs.com/class to fill out a brief survey and find information about signing up to be a beta tester.