LESSON

Exploring Chain Reactions

Grade Levels: 2-12
The Tech Challenge 2022
Duration: Two 60 min sessions

Students will explore stored energy and energy transfer as they build a series of chain reactions.

Outline

Session One	60 min
Teams are introduced to chain reaction machines and build a simple machine that works three times in a row.	
Session Two	**60 min**
Teams build a chain reaction machine that includes three simple machines and three energy transfers.	

Lab Connections:
Physics of Roller Coasters
Advanced Physics of Roller Coasters

Grade Levels: 2-12

Duration: Two sessions, 60 min each

Concepts/Skills
Simple machines, energy transfer, potential and kinetic energy, cause and effect

Objectives
Students will:
- Explore simple machines and energy transfer by building several components of a chain reaction.
- Identify the ways that energy is transferred and stored in a chain reaction.
- Iterate and improve designs based on testing and observation of failure points.

Materials and Preparation

Look for items that match the categories; see the suggestions below for ideas. Try to provide several different types of items for each category, be creative!

Materials

(per class of ~32 students)					*(1 per team)*
Things that Roll *(30-40 items)*	**Ramps, tubes, and tracks** *(20-30 items)*	**Supports and structure** *(30-40 total)*	**Thing to knock over** *(40-50 total)*	**Connectors** *(50-60 items)*	**Tools** *(1 per team)*
◻ Bottles and cans ◻ Corks ◻ Marbles or small balls ◻ Spools ◻ Springs	◻ Cardboard ◻ Straws ◻ Toy tracks ◻ Tubes (foam, paper, cardboard)	◻ Building blocks ◻ Chopsticks ◻ Craft sticks ◻ Rulers or yardsticks ◻ Utensils	◻ Books ◻ Containers and boxes ◻ Dominos ◻ Thin blocks and other toys	◻ Magnets ◻ Pipe cleaners (chenille stems) ◻ Rubber bands ◻ String ◻ Twist ties	◻ **Chain Reaction Cards** (1 set) ◻ Hole punch ◻ Paper ◻ Pencil ◻ Scissors ◻ Tape

Paper Engineering

- Limited materials? Try building with only cardboard or paper. Check out our **Paper Engineering lesson** for more tips on folding paper. See if you can use it to make paper chutes, springs, funnels, or even trap doors!

The Tech Challenge

This activity was created to prepare students for the 2022 Tech Challenge: Kinetic Commotion, presented by Amazon.

This lesson will...

- Give students experience with building simple machines.
- Familiarize them with stored energy and energy transfer.
- Introduce students to triggers (release mechanisms).

To learn more about this year's Tech Challenge, go to **thetech.org/thetechchallenge**

Preparation

1. Print and cut the **Chain Reaction Cards.** Each team will need one set of cards.
   - ***Note***: With beginning engineers it may be helpful to start with just a few cards for Design Challenge Part One.
2. Set up material bins for students to access and exchange items throughout their build time. Group items in categories.
3. If working on the activity over several sessions, provide bins or bags for the teams to store their materials. Remind teams to measure and keep records about their devices so that they can ease the set-up process.
4. Think about where teams will be able to work. This activity benefits from students being able to spread out and build across different types of furniture, across heights, and in other unconventional spaces. If there are any areas that would be dangerous to build in, like in front of a door, be sure to mark the area off.
5. Decide how you will introduce the idea of a chain reaction to students – a small demo, a video, or another way, and prepare the necessary materials. See our **Get Inspired** tip for options.
6. Plan to have students work in groups of three to five.

Distance Learning Adaptation

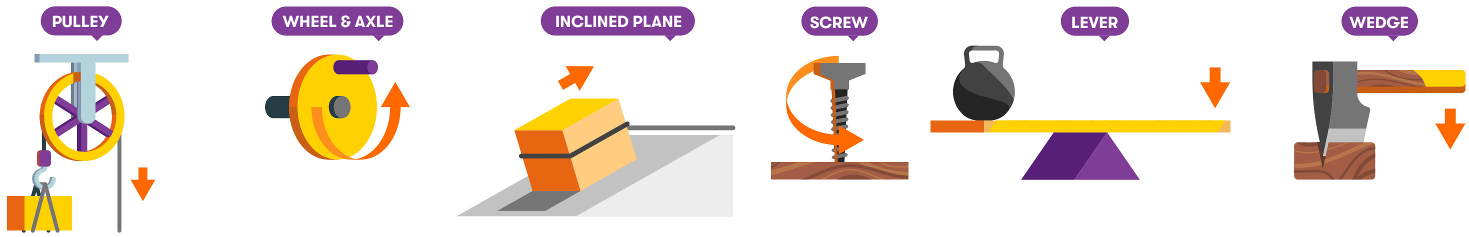
In a virtual setting, share **The Tech Interactive at Home version** of the activity with students asynchronously.

- If you are able to schedule synchronous sessions, do the first parts of the activity together as a class and have students finish the remainder on their own, before sharing virtually or in a synchronous video call.
- For more tips on adapting Design Challenges to a virtual setting see our **Educator Tips for Remote STEM Learning.**

Background Information

Chain reaction machines are made up of everyday objects and designed to accomplish a simple task in a silly and complicated way. Movement is created by storing and transferring **energy**, while using gravity and simple machines like levers and pulleys to help it along. Chain reaction machines can take significant time to set up and run depending on how many transfers are included.

Simple Machines



Simple Machine Building Tips

If students get stuck while building, share some of these tips.

- **Material Considerations**
  - Adjust motion of pulleys, launchers, and more by considering heavier materials or counterweights.
  - Think outside the box – changing the material or way it's connected can produce different results.
- **Securing Items**
  - Use tape "hinges" to hold items together or in place.
  - Attach ramps or base items to the ground or build area.
  - Set up frames or boundaries to ensure objects roll, swing, or fall within a safe area.
- **Fine-tuning**
  - Think about where the object is coming from as well as where it's landing.
  - If an object keeps landing in the same spot, consider if the landing zone is easier to adjust than the launching point.
  - Test where the object ends multiple times before deciding where to place the next object.
- **Testing and Resetting**
  - Test each simple machine many times on its own before adding on.
  - Test mechanisms and machines without extra items or the final action to prevent messy cleanups and resets.
  - Have something to catch rolling or chaotically moving items to not lose them.

Lab Connection

Exploring Chain Reactions builds on the connection between **potential** and **kinetic** energy that students explore in the **Physics of Roller Coasters** and **Advanced Physics of Roller Coasters** labs at The Tech Interactive. The student-built roller coasters focused on using a hill to transform potential energy into kinetic energy. In this activity, students will focus on finding different ways to transform energy several times.

Frame the Activity

Frame the Activity	20 min total
Activate Prior Knowledge	20 min
Design Challenge Part 1	**40 min total**
Brainstorm	10 min
Prototype (Build and Test)	15 min
Share Solutions	10 min
Debrief	5 min

Activate Prior Knowledge *(20 min)*

1. Show students a few samples of chain reaction machines to introduce the concept.
   - Try to include varied examples that involve lots of different materials and types of energy transfers.

Get Inspired

There are many images and videos showing "chain reactions" online. From homemade to professional, there's lots to spark imagination.

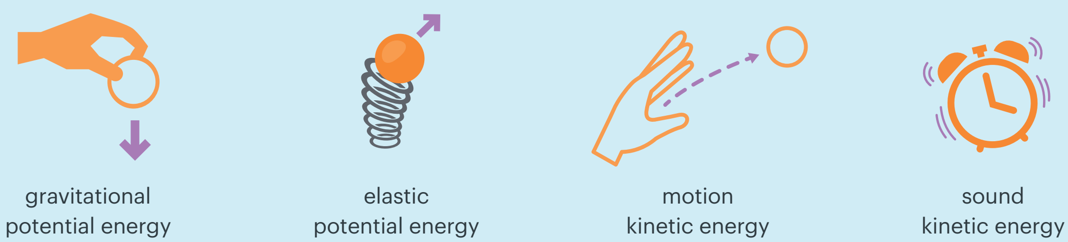
- **"Tech Topple Reactica 2023,"** Flash Domino Youtube video *(6:41 min)*
- **"Audri's Rube Goldberg Monster Trap,"** Littlepythagoras YouTube video *(4:05 min)*
- **"Energy Transfer Machines,"** NBC News Learn YouTube video *(4:52 min)*
- **"Splash, Pop, Fizz: Rube Goldberg Machines,"** TeachEngineering YouTube video *(2:03 min)*
- **"This Too Shall Pass,"** OK Go Sandbox YouTube music video *(3:54 min)*
- **"Honda - The Cog,"** WebRides TV YouTube video *(2:00 min)*

2. Have students get into teams of 3-5 and discuss what they noticed about the chain reaction examples, focusing specifically on where there might have been different kinds of energy.
   - If students have already attended the **Physics of Roller Coasters** or **Advanced Physics of Roller Coasters** lab at The Tech Interactive, have them discuss some of these questions:
     - *Where were potential and kinetic energy present in your roller coaster?*
     - *Did you notice the same form of potential or kinetic energy in a chain reaction machine?*
     - **Advanced Physics of Roller Coasters**
       - *How was the total amount of energy limited in your roller coaster and what, if any, limits might apply to a chain reaction machine?*
3. Lead a class discussion around how a chain reaction machine includes different types of energy and transforms or transfers energy between different simple machines.
   - *Where was energy transferred from one section to another?*
     - *What types of energy were involved?*
   - *How can you change the amount of energy in the chain reaction machine?*
   - *How could one type of energy be transformed into another?*
   - *What kind of simple tasks were completed through the chain reaction machine?*

- For advanced engineers:
  - *How does conservation of energy apply to a chain reaction machine?*
  - *What are examples of how Newton's first law of motion applies to a chain reaction machine?*
  - *How might engineers optimize a chain reaction machine?*

For Beginning Engineers
Support beginning engineers' understanding of energy transfers by providing or demonstrating some examples shown below.

Energy transfer
A chain reaction is a great example of energy being transferred from one item to another. When your chain reaction device runs, energy will be transferred from stored energy (potential energy) to motion energy (kinetic energy).
Here are some different ways energy might be transferred in your chain reaction.



Design Challenge Part 1

Brainstorm *(10 min)*

1. Let students know that they will be exploring how to build different types of simple machines today.
2. Distribute a set of Chain Reaction Cards to each team of three to five students.
   - Each team will pick one **Chain Reaction Challenge Card** and try to build that machine.
   - Explain they will be trying to build something that works three times in a row.
3. Let teams explore the materials and brainstorm how they will create the simple machine on their card.
4. Encourage teams to take notes about which materials they want to use and how they might set up their machine using sketches and diagrams.

Prototype (Build and Test) *(15 min)*

1. Let teams begin building their first simple machine. Encourage teams to test early and often.
2. During the prototyping time, support teams with open-ended questions to guide the process.
3. Provide reminders on time.
   - If a team has finished their simple machine and there is build time left, have them take another **Chain Reaction Challenge Card** and build a new design.
4. When build time is up, teams should reset their machines so they can share them in the next section.

Sample Prototype Questions

Just Getting Started

- *How are you determining which materials to use?*
- *How does your device transfer energy between the different sections?*
- *Are you inspired by any real world machines?*

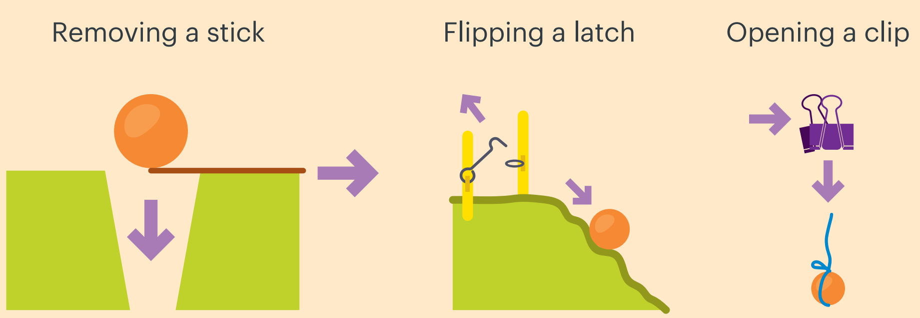
Problem-Solving After Testing

- *Did you notice any* ***failure points*** *during testing? What caused the failure?*
- *What are some ideas you have to change your design?*
- *Does your design have the right amount of potential energy? Kinetic energy?*
- *How can you* ***optimize*** *your simple machine?*

For Advanced Engineers: Trigger

Have advanced engineers design a **trigger** to set off their device.
Trigger: a built-in mechanism that releases the stored energy at the start of the machine.
A trigger:

- Releases stored energy (potential energy) to start the chain reaction machine.
- Is the same no matter who activates it.
- Could be:



Have engineers spend about five to seven minutes brainstorming and building types of triggers during the prototype time. Teams should think about what kinds of materials will work as part of a trigger and try sample building to refine their trigger idea. Support teams with open-ended questions:

- *Which materials already store potential energy or could support storing energy?*
- *What item will be storing the potential energy?*
- *Does the trigger always work the same or is there possible variation between team members setting it off?*
- *Can you design a trigger that sets itself off reliably?*

Share Solutions *(10 min)*

1. At the end of the time limit, have learners stop working even if they haven't been able to complete their design.
2. Have each team demonstrate their simple machine while sharing what they built and why.
   - When demonstrating the machine, it may be useful to limit the number of resets that students can make if their machine does not run as expected. *For example:* Limit teams to three tries with a reset time of 30 seconds.
3. Keep the sharing simple and focused. Have learners give each other positive feedback on their designs. Encourage them to tell the presenting team one thing they liked or noticed.

Sharing Prompts

Possible sharing prompts could include:

- *Tell us about your chain reaction machine.*
- *What changes did you have to make while working?*
- *What trade-offs did you make to optimize your design?*
- *What would you change or add if you had more time?*

Debrief *(5 min)*

1. Have students reflect on the first part of the challenge and prepare for the next session by discussing in their teams. Debrief questions could include:
   - *What types of energy did your design use? Could you use other types?*
   - *What types of energy did other teams use?*
   - *How might simple machines be connected together?*
2. Give teams time to measure, draw, or take pictures of their current simple machine set-up so they can recreate their design during Session Two.

Design Challenge Part 2

Design Challenge Part 2	60 min total
Introduce the Design Scenario	5 min
Prototype (Build and Test)	25 min
Share Solutions	15 min
Debrief	15 min

Introduce the Design Scenario *(5 min)*

1. Introduce the design scenario.

Imagine all the small things you have to do before you go to bed at night… maybe you turn off the lights, close a door, or pack your backpack for the next day. You can use your engineering skills to build a chain reaction machine that does the small things for you! Today your engineering team will work together to solve a simple problem using a complex chain reaction machine!

Additional Design Scenarios

- Design a video commercial advertising a custom toy or product (similar to the "Honda – The Cog" video in the **Get Inspired** tip).
- Design a custom amusement park ride that would transport the rider across the park.
- Design a "band" that makes sounds to create a custom theme song for the team.

2. Introduce the new constraints and criteria for success.

Design Problem	Create a chain reaction machine to complete a task using energy transfer.	
Criteria	• Includes at least three different simple machines. • Includes three different places where energy is transferred from one object to another. • Must complete at least one simple task.	 3 3
Constraints	• No human help – once the chain reaction machine is started, team members cannot interfere. • Use only the materials provided.	

Prototype (Build and Test) *(15 min)*

1. Teams can rebuild or reset their simple machine(s) from the first session or they can start over with a new design.

For Advanced Engineers: Trigger

To help scaffold designs for beginning engineers, continue to use the **Chain Reaction Challenge Card** set as inspiration. Have each team reset their machine from Session One. Then pull an additional challenge card and design a second simple machine. Teams can then work to connect their machines together. Repeat the process of drawing a card and making connections as time allows.

2. Encourage teams to test early and often. They should check each section individually and then begin to connect them together. This ensures that each step works before teams create a longer chain reaction machine.
3. During the prototyping time, support teams with open-ended questions to guide the process:

Sample Prototype Questions

Problem-Solving After Testing

- *How did your chain reaction machine perform during testing?*
- *What trade-offs might you need to make to optimize your design?*
- *What are some ideas you have to change your design?*
- *Did you notice something in another design that you want to try?*

Pushing Designs Further

- *What can your team try to make this design more creative or silly?*
- *Could your team's chain reaction machine include another type of energy transfer?*

4. Provide reminders on time and encourage teams to test their chain reaction machine often as they add more energy transfers. Before build time is up, warn teams that they should reset their machines for the next section.

How to Support Perseverance

Each time a team's chain reaction fails, they are learning something new about how to make it better. If teams feel stuck, encourage one of these strategies:

- Step back, take a deep breath, sometimes a little break is all you need!
- Look at things in a different way, from up above, or down on the floor, maybe even upside down.
- Resetting and trying again is a big part of a chain reaction. Secure objects in place with tape once you've figured out exactly where you need them.
- As you build, you might have to make tradeoffs. You might give up one material to use another or compromise on the number of reactions because you don't have time. This is what engineers do to make sure they meet their goals.

Remember that failure and perseverance are important parts of the engineering process. Check out the **Explore Design Challenge Learning** page and the **Innovator Mindsets Tech Tip** for ideas on how to help learners become creative problem solvers and persevere through challenges.

Share Solutions *(15 min)*

1. At the end of the time limit, have learners stop working even if they haven't been able to complete their design.
2. Have each team demonstrate their simple machine while sharing what they built and why.
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- *What would you change or add if you had more time?*

Debrief *(5 min)*

1. Have students reflect on what they learned from the building and iterating process and the larger engineering concepts and real-world applications.
2. Lead a short debrief with some of these questions.

   Design Process
   - *From what you observed, what makes devices more reliable?*
   - *Did you notice anything that a lot of teams did while working? (e.g., a brainstorm, iterating after testing, trying something new when an idea didn't work)*
   - *What are some features that worked well in many devices? What are some features that did not work as well?*

   Science Concepts
   - *What similarities and did you notice about how different devices transferred energy?*
   - *What type of materials were the most common to store potential energy?*
   - *How might knowledge of energy transfer help other kinds of scientists or engineers?*
3. For advanced engineers:
   - *How or where are conservation of energy and Newton's first law of motion related to this experiment?*

Extensions

Iteration is an important part of the design process.

- **More reactions**: Let teams select one card from the **Chain Reactions Challenge Cards** and add that type of simple machine to their design somewhere.
- **Multitasking**: Challenge teams complete two different simple tasks with one chain reaction machine.
- **Self-starter**: Teams can design a trigger to set off their chain reaction. For advanced teams that designed one already, challenge them to change the trigger based on one of the **Chain Reaction Challenge Cards.**

Career Connection: Mechanical Engineer

Mechanical engineers can work in a wide range of fields and rely on the innovation design process to create, test, and iterate on prototypes. While they are commonly found collaborating with others in industries like construction, aerospace, and manufacturing, mechanical engineers learn skills that can be applied in many other fields such as product design, patent law, or even at interactive science centers like The Tech!

To learn more about Mechanical Engineering skills and career path options check out the resources below:

- **Meet an Expert:** One example of someone using mechanical engineering skills and processes in a creative way is Alex Huang. Alex is a chain reaction specialist and showcases amazing domino and chain reaction builds on his **"Flash Domino"** YouTube channel and **Flash Domino** website. The Tech Interactive has partnered with Alex to host his annual chain reaction event Reactica for several years. Check out Alex's **"Chain Reaction Machines"** YouTube playlist to see more about the annual event.
- **Research**: Mechanical Engineers can participate in many industries. Check out a few other ways mechanical engineers can apply their skills in a variety of industries.
  - Many games rely on mechanical engineering and devices to control and run the system. Pinball games are a great example of mechanical systems. **The Pinball Museum of Alameda** hosts many machines and features the history of the pinball industry.
  - Toy design is another unique industry where mechanical engineers can be found. Fans of LEGO™ know there is a lot of effort and thought put into each set. Learn more about what it takes to be a LEGO™ designer, check out **"Have You Got What it Takes to Be a Lego Designer"** on YouTube.
- **Try it:** Mechanical engineers use a variety of skills depending on their job function. Try building your **own pinball machine at home** using cardboard to get into the spirit of toy design. Or check out free design courses on sites like **Udemy** to learn how to create models to design your own mechanical systems.

Standards Connections

Next Generation Science Standards

Grade	Performance Expectation	Description
2	2-PS1-2	Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.
3	3-PS2-2	Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.
4	4-PS3-4	Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
6-8	MS-PS3-5	Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
	MS-ES1-2	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
9-12	HS-PS3-3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
Related Standards		K-2-ETS1-2, 3-PS2-1, 4-PS3-3, 5-PS2-1, 3-5-ETS, MS-PS3-5, MS-ETS, HS-ETS1
Science and Engineering Practices		Asking Questions and Defining Problems Planning and Carrying Out Investigations
Cross Cutting Concepts		Patterns | Cause and Effect | Structure and Function

Vocabulary

- **Conservation of energy**: Energy cannot be created or destroyed; it may be transformed from one form into another, or transferred from one place to another, but the total amount of energy never changes
- **Elastic potential energy:** Potential energy created by deforming an elastic object like a rubber band or a bouncy ball
- **Energy:** The ability to do work
- **Failure point:** A place where the design or system fails
- **Force:** An influence (push or pull) on a body or system, causing a change in movement or shape
- **Gravitational potential energy:** Potential energy due to elevated position; this depends only on vertical displacement and not the path taken to get there; the value is always relative to some reference level
- **Kinetic energy:** The energy of motion; an object in any form of motion has kinetic energy (e.g., running, walking, dancing, flying, etc.)
- **Newton's first law of motion:** An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force
- **Optimization:** The process of iterating, refining, and making trade-offs until a solution is found that best meets the criteria within given constraints
- **Potential energy:** The energy of position; energy that is stored and held in readiness or waiting to move (e.g., a ball held in the air, sitting still, waiting motionless)
- **Spring potential energy:** Potential energy created by deforming a spring
- **Trade-off:** A situation in which you must choose between or balance two things that are opposite or cannot be had at the same time
- **Trigger (release mechanism):** A built-in mechanism that releases the stored energy in a device

The Tech Challenge
Presented by Amazon

Chain Reaction Challenge Cards

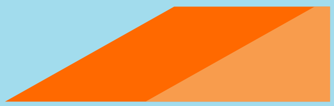
Domino effect

Knock over a series of items.

Tip: Use tape "hinges" to keep your items in the right spot during multiple tests.

Inclined planes

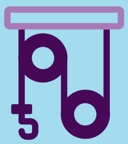
Roll something! Up or down!



Tip: Have something to catch your rolling item so you don't have to keep finding it.

Pulleys

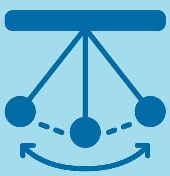
Use string to lift or lower something.



Tip: Keep the area around strings clear and try using counterweights to slow things down.

Pendulum

Swing something.



Tip: Use stiff material instead of string to improve aim.

Round and round

Spin something. Slow things down or knock them over chaotically!

Tip: Spinning can speed things up. It can also be unpredictable, so test parts on their own first.

Levers

Move, nudge, lift, or even push something.

Tip: Secure with tape to keep the base in place during multiple tests.

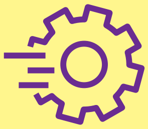
Landing Zone

Drop or launch something.

Tip: Test where an object lands multiple times before deciding where to place the next object.

BONUS: More motion

What other movements and mechanisms can you think of?



Tip: Take a look at some everyday objects. What motions and reactions do you see?

BONUS: Grand finale

What is your goal? What task do you want to complete?

Tip: If the final action isn't easy to reset, save yourself a messy clean-up and test the mechanism by itself.