Introduction
Imagine that you just got into bed and realized that you forgot to turn off the lights. Sure, you could just get up again — but wouldn’t it be fun to build a chain reaction machine like the one above? 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. We’ve broken down these complex concepts into some simple activities. Build, reset, and try again. And most of all, have fun as you make your own unique chain reaction machine!

Design Challenge
Explore stored energy and energy transfer as you build a series of chain reactions.

Subject:
Engineering

Ages:
8+

Time:
30+ minutes

Key concepts:
Simple machines, energy transfer, stored energy, potential and kinetic energy, perseverance, cause and effect
Materials
Chain reactions can include everything from toys to kitchen utensils. Take a look at the Chain Reaction Challenge Cards at the end of this activity for some inspiration. Thinking about simple machines or motions you want to include in your device can help, but you can also just look around for items that spark your interest.

Things you can use
We included some categories to inspire you as you look for things. Choose some things from each category, but don’t limit yourself to the items on this list. Use whatever you have on hand — be creative!

<table>
<thead>
<tr>
<th>Things that roll</th>
<th>Ramps, tubes, and tracks</th>
<th>Supports and structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Marbles</td>
<td>□ Cardboard</td>
<td>□ Cardboard</td>
</tr>
<tr>
<td>□ Spools</td>
<td>□ Tubes (foam, paper or cardboard)</td>
<td>□ Kitchen utensils</td>
</tr>
<tr>
<td>□ Corks</td>
<td>□ Toy tracks and ramps</td>
<td>□ Rulers</td>
</tr>
<tr>
<td>□ Small balls (ex: golf, ping pong)</td>
<td></td>
<td>□ Chopsticks</td>
</tr>
<tr>
<td>□ Toys with wheels</td>
<td></td>
<td>□ Craft sticks</td>
</tr>
<tr>
<td>□ Bottles and cans</td>
<td></td>
<td>□ Tables, chairs, and boxes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Things to knock over</th>
<th>Connectors</th>
<th>Other useful items</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Books</td>
<td>□ Rubber bands</td>
<td>□ Scissors</td>
</tr>
<tr>
<td>□ Dominos</td>
<td>□ Pipe cleaners (chenille stems)</td>
<td>□ Hole punch</td>
</tr>
<tr>
<td>□ Containers and boxes</td>
<td>□ Tape</td>
<td>Toy figures, things that spin, things to add weight, decorations, items for a grand finale!</td>
</tr>
<tr>
<td>□ Blocks and other toys</td>
<td>□ String</td>
<td></td>
</tr>
<tr>
<td>□ Magnets</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Paper engineering
Supplies limited? Try to build with just cardboard or paper. Check out our 3D Paper Engineering guide from 2020 for 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 guide can be used 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).
Instructions

Explore

1. Sometimes it's easiest to break a chain reaction into pieces and parts. Take a look at the Chain Reaction Challenge Cards (see page 6) and choose one to try.
2. Think about the materials you can use and how you might solve the challenge on the card.
3. Once you have some ideas, sketch a design or just start building!

Make it personal...

Take a minute to work backwards and think about the story behind your device. What's your goal? Do you want to unroll a birthday message for a friend? Flip a switch? Raise a flag?

Add silly elements to your chain reaction by choosing random, unrelated items and trying to incorporate them. How could you use a kitchen spatula and a toy duck in your design, for example? What are some of your favorite things and how could you add them in?

Create and test

1. Start building the device on your Chain Reaction Challenge Card.
2. Consider the simple machines you can use as you build.
3. Engineers test, redesign, and test over and over! Ask yourself:
   • Where is this working?
   • Where is it not working?
   • What can I adjust and change to get the reaction I want?
4. Once you've met the challenge on one of the cards, you can try another one. Experiment and play around with different cards.
5. When you're ready, you can put things together into a chain reaction!

Simple Machines

Try it as a team

Chain reactions are a great opportunity for both in-person and virtual collaboration.
• Tag, you’re it!: Have each person or group make their own reaction and combine them together into a larger chain like The Tech’s staff did in this video, “Make a Rube Goldberg Machine!”.
  − If you are doing this in person, remember that any time you move a part of the chain reaction, it will change the results, so try to build on surfaces that are easy to combine or right next to each other.
• All together now: Even if you’re working together as a team, you can split things up so that everyone has a role.
Chain reaction

1. Now it’s time to put together everything you’ve been experimenting with. Create a chain reaction machine by connecting at least three reactions from a single starting action.

2. Use these tips as you build:
   - Think about where you are connecting each section with the others.
   - Don’t forget to test each section individually before you put them together.
   - Try adding new components in front of or behind existing sections.

3. As you build ask yourself:
   - How are these materials working? Are there other materials that would fit better?
   - Do I need to adjust where things are placed so that they run more smoothly?

4. Use what you learn from testing to improve your chain reaction machine.

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 (kinetic energy).

Here are some different ways energy might be transferred in your chain reaction:

- Gravitational potential energy
- Elastic potential energy
- Motion kinetic energy
- Sound kinetic energy

Getting frustrated?

Each time your chain reaction fails, you learn something new about how to make it better. So when you feel stuck, take a break and try one of these strategies.

- Step back and take a deep breath. Sometimes a little snack 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 making a working 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 to complete them all. This is what engineers do to make sure they meet their goals.

Sometimes it’s good to remember that failure and perseverance (not giving up) are an important part of the engineering process.
Looking for inspiration?

There are many images and videos showing “chain reactions” online. From homemade to professional, there’s lots to spark your imagination.

Here are a few of our favorites. See if you can find your own!

- **Audri’s Rube Goldberg Monster Trap**, YouTube
- **Energy Transfer Machines NBC News Learn video**, YouTube
- **Splash, Pop, Fizz: Rube Goldberg Machines**, TeachEngineering video, YouTube
- **“This Too Shall Pass”** music video on Ok Go Sandbox
- **Honda - The Cog** video, YouTube

Explore more

- **Switch it up**: Try changing one of the materials you’re using. What happens? How can you keep things moving with different components or even different simple machines?
- **More reliable**: Can you make your reaction repeat at least three times? How many times in a row can it do the same thing?
- **Self-starter**: Triggers are built-in mechanisms that release the stored energy in your device. Take a look at some of the examples below and add in a trigger to start your machine!

**Trigger**: A built-in mechanism that releases the stored energy in your device.

A trigger...

- Releases a device's stored energy *(potential energy)*.
- Is the same no matter who starts it.

Some examples:

removing a stick

flipping a latch

opening a clip

Share Your Results! Keep us posted about your design challenges on Facebook with #TheTechChallenge.
# Chain Reaction Challenge Cards

<table>
<thead>
<tr>
<th>Domino effect</th>
<th>Inclined planes</th>
<th>Pulleys</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knock over a series of items.</td>
<td>Roll something! Up or down!</td>
<td>Use string to lift or lower something.</td>
</tr>
<tr>
<td>Tip: Use tape “hinges” to keep your items in the right spot during multiple tests.</td>
<td>Tip: Have something to catch your rolling item so you don’t have to keep finding it.</td>
<td>Tip: Keep the area around strings clear and try using counterweights to slow things down.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pendulum</th>
<th>Round and round</th>
<th>Levers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swing something.</td>
<td>Spin something. Slow things down or knock them over chaotically!</td>
<td>Move, nudge, lift, or even push something.</td>
</tr>
<tr>
<td>Tip: Use stiff material instead of string to improve aim.</td>
<td>Tip: Spinning can speed things up. It can also be unpredictable, so test parts on their own first.</td>
<td>Tip: Secure with tape to keep the base in place during multiple tests.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Landing Zone</th>
<th>More motion</th>
<th>Grand finale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop or launch something.</td>
<td>What other movements and mechanisms can you think of?</td>
<td>What is your goal? What task do you want to complete?</td>
</tr>
<tr>
<td>Tip: Test where an object lands multiple times before deciding where to place the next object.</td>
<td>Tip: Take a look at some everyday objects. What motions and reactions do you see?</td>
<td>Tip: If the final action isn’t easy to reset, save yourself a messy clean-up and test the mechanism by itself.</td>
</tr>
</tbody>
</table>