NEXT ENGINEERS

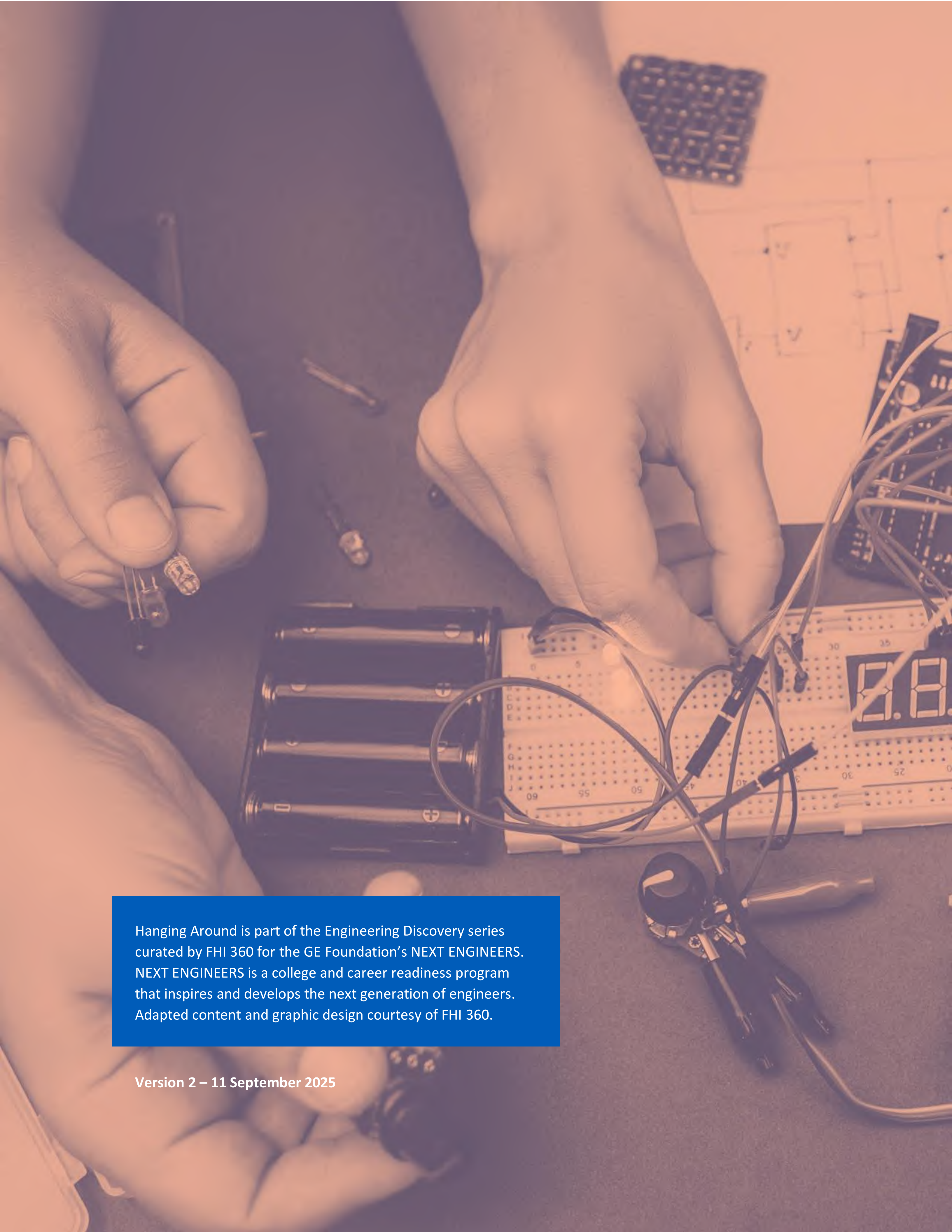
ENGINEERING DISCOVERY

Difficulty Level 1

Hanging Around

Civil Engineering
Mechanical Engineering

NEXT ENGINEERS



Hanging Around is part of the Engineering Discovery series curated by FHI 360 for the GE Foundation's NEXT ENGINEERS. NEXT ENGINEERS is a college and career readiness program that inspires and develops the next generation of engineers. Adapted content and graphic design courtesy of FHI 360.

Version 2 – 11 September 2025

Hanging Around

HANDS-ON ACTIVITY

Time	Ages	Cost	Group size (teams)	Activity type
70 minutes	11 - 18	Low	3 - 4 students	Hands-on Activity
Engineering Areas				
• Civil Engineering		• Mechanical Engineering		

Activity Description

This simple but fun activity gives students the opportunity to explore the forces involved in cantilevers by designing and building their own. Cantilevers are rigid structures that extend out horizontally. Unlike beams, however, they are only supported at one end. Common examples of cantilevers include floating shelves, balconies, and airplane wings. Many bridge designs also make use of cantilevers.

About the Engineering Design Challenge

Students work in teams of three or four to design, build, and test their own load bearing cantilever out of nothing but printing paper and masking tape. Each team will try and create a cantilever able to support the greatest mass as far out as possible They will calculate a final score for their structure as follows:

$$\text{score} = \text{mass supported (g/oz)} \times \text{distance from edge or brace (cm/in)}$$

Success Criteria

- The cantilever must support as much mass as possible but at least 75 g (2.65 oz).
- The cantilever must support this mass as far out as possible but at least 40 cm (15.75 in) from the edge of the table (or a brace point). All measurements will be taken from the edge of the table or desk (or the point where any bracing is attached) to the point from which the mass is suspended.

Constraints

- Teams must build their cantilevers out from the edge of a table or desk.
- Students may only use the materials provided.
- Students must complete their construction in 45 min or less.

STUDENT DISCOVERIES

Students will:

- Know more about engineering and engineering careers
- Learn the about the Engineering Design Process
- Participate in a team-based learning experience
- Learn about the mechanical properties of cantilevers
- Have fun experiencing engineering

Materials

Students will need blank paper and pens/pencils with which to design their structures.

The following materials will be required **per team** for this activity:

- 10 sheets of A4 or letter print paper
- A roll of masking tape (about 1.5 cm – 2 cm (0.6 in – 0.8 in) wide)
- A packet of small chocolates/sweets each of a known mass
- A tape measure or ruler
- A calculator (have someone in the team use the calculator app on a smart phone)

Facilitation Principles

Working with Youth: Facilitation Tips (https://www.nextengineers.org/resource/working-youth-facilitation-tips) is a handy summary of the key facilitation principles that volunteers need to keep in mind when demonstrating any activity with students.

Facilitator Preparation

1. Read the step-by-step instructions.
2. Collect the materials.
3. Practice doing the activity yourself to identify where students may struggle. Bring whatever objects you practice with to show students.
4. Plan when and how you will share your story and career journey in a relevant and personal way. Try to integrate your story into the demonstration as much as possible. You can find the following volunteer resources for how to tell your story on the Next Engineers website:
    a. ***I'm an Engineer! Storytelling Worksheet*** (https://www.nextengineers.org/resource/im-engineer-storytelling-worksheet)
    b. ***I Work with Great Engineers! Storytelling Worksheet*** (https://www.nextengineers.org/resource/i-work-great-engineers-storytelling-worksheet)
5. Practice asking and answering questions students may ask. See ***Frequently Asked Student Questions*** (https://www.nextengineers.org/resource/frequently-asked-student-questions).
6. Print out copies of the **Student Worksheet** (below) for each group.
7. Set up each group's materials before the start of the activity.

KEY WORDS

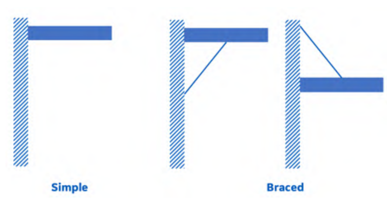
- Braced cantilever
- Cantilever
- Compression
- Constraints
- Criteria
- Engineering Design Process (EDP)
- Engineering Habits of Mind (EHM)
- Engineers
- Iteration
- Prototype
- Simple cantilever
- Tension

Step-by-Step Instructions

Time	Instructions	Materials
5 min	**Welcome & Introductions** • Welcome students to the activity and briefly introduce yourself, noting what kind of engineer you are. • Ask students if any of them have ever stood on a balcony. What kind of structure is a balcony? Where is it supported? How does it stay up? • Explain that a balcony is an example of a cantilever. Cantilevers are rigid horizontal structures that are supported only at one end. • Hold your arm out horizontally beside or in front of you to demonstrate a very simple cantilever. Have students do this too. What do they feel? • Ask the group to describe other examples of cantilevers they have come across. Some examples might include float shelves in their home, an awning over a door or window, some bridges, and airplane wings. • Explain that some entire buildings are designed and built as cantilevers. If possible, show the images in the **Activity Background**. • If you have time, you can also play the video called *The Structures That Defy Gravity* (8:37) to see some of the world's most remarkable cantilevered structures.	Activity Background
5 min	**Pre-Challenge Exploration** • Explain to the group that their challenge will be to design and build a cantilever that can support the greatest mass at the greatest distance using nothing but paper and masking tape. • Hold up a piece of paper and ask for suggestions for how it could be used to create a cantilever. • Ask students what could be done to the paper to make is stiffer or stronger. Some options include rolling it into a cylinder or folding it into a triangle (or even a fan). • Now ask students how they can attach this stiffened structure horizontally to the edge of a table so that it remains rigid and horizontal and can support a mass. Some options include bracing it from the top and/or the bottom as shown on the right.	

TIPS FOR WORKING WITH STUDENTS

- **Be prepared** by practicing the activity beforehand. Being prepared is the best start to leading confidently and having fun.
- **Facilitate like an engineer** by reflecting during and after each session. What worked? What could be improved? How could you do things differently next time?
- **Teamwork is critical** in engineering so encourage it among students. Make sure no one dominates and everyone gets to play.
- **Give one instruction at a time** to keep a large group on task and doing what you need them to do.
- **Give regular time updates** to keep students on track.



The basic types of cantilevers

5 min	**Challenge Overview** • Remind students what their engineering design challenge is and explain that each team's structure will have a final score calculated for it as follows: $\text{score} = \text{mass supported (g/oz)} \times \text{distance from edge or brace (cm/in)}$ • Explain that the length of their cantilever will be measured as the distance from the edge of the table (or the point of attachment of any bracing) to the point at which their mass is attached. • Explain also that teams are going to need to think strategically about both the mass supported and the distance at which this mass is supported. They will need to find the right balance between these criteria.	
45 min	**Engineering Design Challenge** • Divide the group into teams and hand each team its building materials and a copy of the **Student Worksheet** and the **Engineering Design Process Summary**. Remind teams to NOT eat their delicious weights until they have calculated their final score! • Tell teams that they have 45 minutes in which to design, test, and re-design their cantilevers and have you come and measure the distance at which their load is supported in to calculate an official score. • As teams work, circulate around the room encouraging them and answering any questions they might have. • Have teams consider whether they wish to maximize the distance, supported mass, or whether they want to try and find a balance between the two. • Encourage teams to test early and often all in order to achieve the highest score possible. • As teams calculate their scores, move around the room to verify each one.	Building Materials Student Worksheet Engineering Design Process Summary

TIPS FOR MAKING CONNECTIONS

- **Give constructive feedback** to help students grow and improve.
- **Ask open-ended questions** to better understand what and how students are thinking.
- **Be respectful** by listening actively and responding openly and authentically. Give students your undivided attention and the respect you want them to give you.
- **Be honest** about what you know. Say if you don't know something. Encourage students to keep trying by sharing some of your own failures and the lessons you learned.

TOP TIP

Don't let anyone eat the chocolates or sweets until they have been used to test their cantilever and calculate its score!

10 min	**Reflection and Closing** • Give teams about four minutes to discuss the reflection questions in the Student Worksheet. • After this time, bring the group back together to discuss their answers, paying particular attention to what students learned about engineering and the engineering design process.	Student Worksheet

Extension

This activity can be extended or modified in the following ways:

- Increase the minimum mass the cantilever needs to support.
- Increase the minimum distance at which the mass needs to be supported.
- Reduce the number of pieces of paper teams have access to.
- Limit the amount of masking tape teams can make use of.

Key Words

- **Braced cantilever**: A cantilever that is supported by a brace either from above or below.
- **Cantilever**: A rigid structure extending horizontally and only supported at one end. It can be formed as a beam, slate, truss, or slab.
- **Compression**: A force that squeezes or pushes the ends of an object together. The object is said to be in compression.
- **Simple cantilever**: A cantilever that has no supporting brace.
- **Tension**: A force that pulls the ends of an object apart. The object is said to be in tension.

- **Constraints:** Limitations of materials, time, budget, size of team, etc.
- **Criteria:** Conditions that the design must satisfy to be considered successful.
- **Engineering Design Process (EDP):** The iterative process of researching, designing, prototyping, and testing engineers use to solve problems and design solutions.
- **Engineering Habits of Mind (EHM):** Six unique ways that engineers think.
- **Engineers:** Inventors and problem-solvers of the world. Twenty-five major specialties are recognized in engineering (have a look at the infographic at https://tryengineering.org/wp-content/uploads/18-EA-381-InfographicEngineering_R2-6.pdf).
- **Iteration:** The process of repeated design, testing, and redesign.
- **Prototype:** A working model of the solution to be tested.

Activity Background

A cantilever is like a normal horizontal beam, except it is supported only at one end. If you have a floating shelf in your house, that is a cantilever. Cantilevers are used commonly in bridge, balcony, and stadium construction. The wings of an aircraft are also cantilevers.

Cantilevers can also be used to create gravity defying structures like this house in Lithuania.

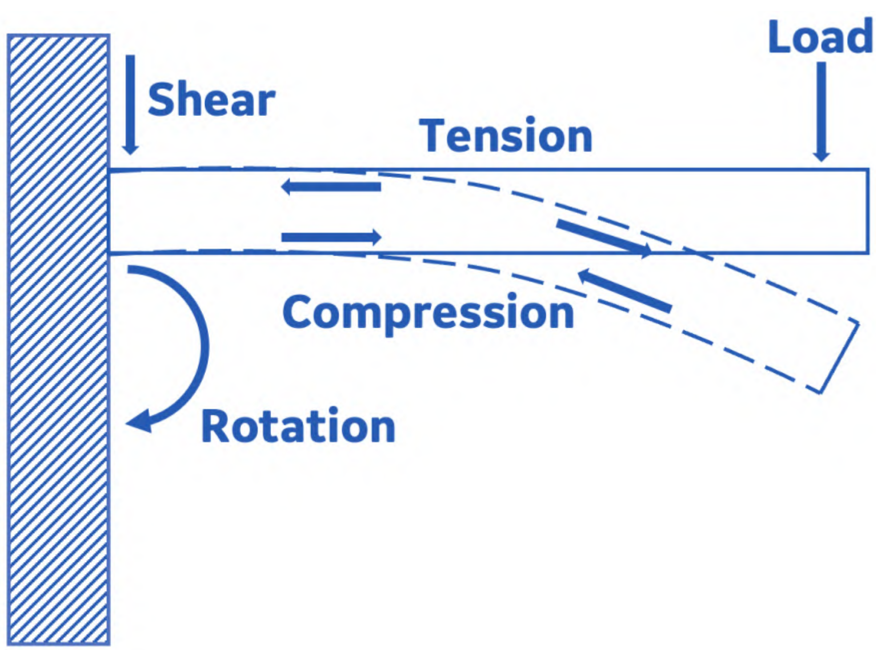
Residential House in Utriai, Lithuania by Architectural bureau G.Natkevicius and partners is used under fair use. https://architizer.com/projects/utriai/

The Lamar Construction headquarters by Integrated Architecture is used under fair use https://www.projectpresenter.com/structural-design-incorporated/projects/lamar-construction-company-corporate-headquarters/8686/show

Visit *11 Houses With Incredible Cantilevers* to see some more amazing examples.

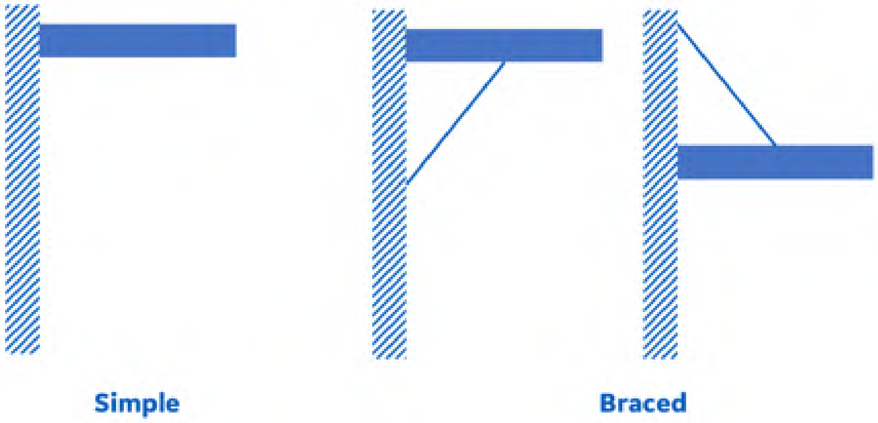
Cantilevers are excellent exemplars of four of the most important forces in civil, structural, and mechanical engineering. When placed under load, the cantilever bends. This stretches the top of the cantilever and places the top under tension while pushing the ends of the bottom of the cantilever together and placing the bottom under compression.

Also under load, the cantilever experiences a rotation force, that wants to rotate it out of its anchor as well as a shear force that wants to push the cantilever down the wall.



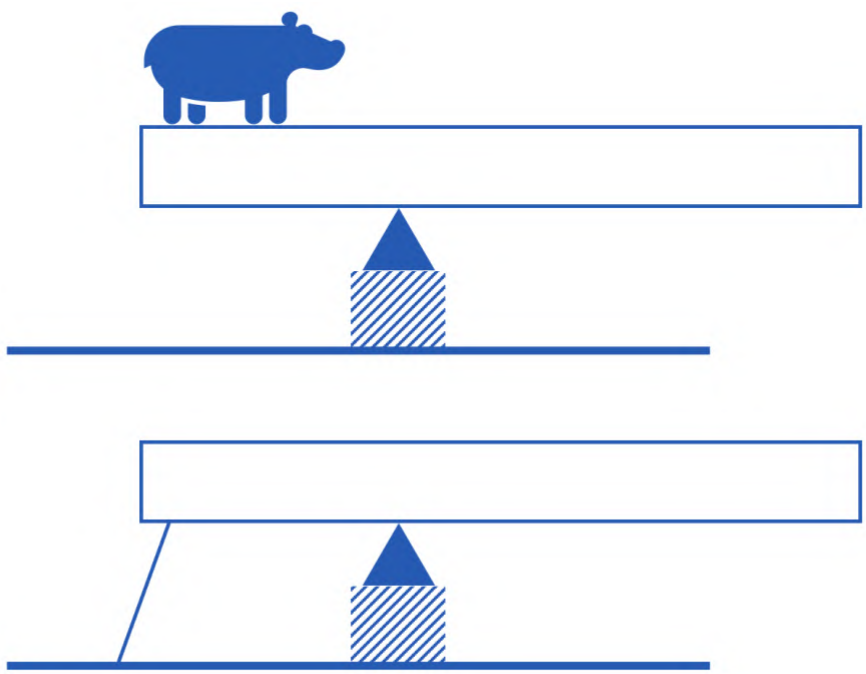
There are a few ways to anchor and stabilize a cantilever. One way is to use brute force and anchor the cantilever very securely into a wall. This is how floating shelves and balconies work. These are termed simple cantilevers.

You can also brace a cantilever from above or below. When braced from above, the brace experiences tension as the cantilever and load pulls down on it.



When braced from the bottom, the brace is under compression as the cantilever and load push on it.

Another method is to use a pivot and some sort of counter-weight. The counter-weight can either be a really heavy object or some sort of tensioned cable system.



To learn more about cantilevers watch the video called *The Architecture of Cantilevers* (8:08).

Additional Resources

- ***The Structures That Defy Gravity*** (8:37)
  https://www.youtube.com/watch?v=opTiYDNaXbE
- ***11 Houses With Incredible Cantilevers***
  https://www.archdaily.com/889129/11-houses-with-incredible-cantilevers
- ***Cantilevers: Gravity-defying architectural protrusions***
  https://edition.cnn.com/style/article/cantilevers-architecture-dezeen/index.html
- ***The Architecture of Cantilevers*** (8:08)
  https://www.youtube.com/watch?v=Wwqvxzm0rio

Hanging Around

STUDENT WORKSHEET

NOTES

Challenge Overview

You are part of a team of engineers who have been given the challenge of designing and building a cantilever able to support the greatest mass possible at the greatest distance. To do this, you may only use 10 sheets of ordinary printing paper and masking tape. To see which team builds the best cantilever, you will calculate a final score for your structure as follows:

$$\text{score} = \text{mass supported (g/oz)} \times \text{distance from edge or brace (cm/in)}$$

Success Criteria

- Your cantilever must support as much mass as possible but at least 75 g (2.65 oz).
- Your cantilever must support this mass as far out as possible but at least 40 cm (15.75 in) from the edge of the table (or a brace point). All measurements will be taken from the edge of the table or desk (or the point where any bracing is attached) to the point from which the mass is suspended.

Constraints

- You must build your cantilever out from the edge of a table or desk.
- You may only use the materials provided.
- You must complete your construction in 45 min or less.

Total Time: 45 minutes

Research & Planning (2 minutes)

Remember, your cantilever may only be built using 10 sheets or ordinary printing paper and masking tape. How can you make flimsy pieces of paper stronger – strong enough to support a mass of at least 75 g (2.65 oz) and 40 cm (15.75 in) away from the edge of a table?

Think about these questions to get you started:

- What shapes could you fold your paper into to make it stronger?
- How could you attach several pieces of paper together to form as long, stable, and strong a structure as possible?
- How could you attach a structure securely to the edge of a table?

- How could you strengthen your structure to make sure it does not bend or rip away from the table when loaded?

Design Phase (3 minutes)

Before you start building anything, share ideas about how you might design and build your cantilever with your team. The more ideas, the better. Remember that crazy ideas are allowed. They are often the launchpad to the winning idea!

Draw or sketch some of your ideas on paper. Here are some questions to help get you started:

- How are you going to make your paper stronger and more stable?
- How are you going to connect pieces of paper together to achieve a longer structure?
- How are you going to attach your structure to the table?
- Are you going to use any braces to help support your structure, especially under load?
- Would it be better to use braces that attach from the top or the bottom?
- Are you going to try and increase the mass that your structure can support or the distance at which it can support a mass?
- How can you use your masking tape to strengthen and reinforce your structure?

Remember that engineers always sketch their ideas. This helps them communicate and test their thinking before committing to building anything. Make sure that you make a few design sketches of the basic approach you intend to take. Don't worry; you can also change course if your original idea does not work as planned.

Oh, and don't eat your weights – at least not yet! Use them to calculate your final score first.

Build it! Test it! (40 minutes)

Now it's time to build your cantilever. Be sure to watch what other teams are doing and consider the aspects of different designs that might be an improvement on your team's plan.

You may decide to completely change your design during the build phase if you need to. Failure is part of the process and how we learn what works and what does not.

When you are ready to start testing the strength of your cantilever, start adding the small chocolates/sweets at some point along its length. You do not need to start at the end. It can be a good idea to start loading neat the table and then to gradually move the load further out to see at which point the structure fails. Can you make your structure stronger to support a greater mass at a greater distance from the table?

AT HOME

When you get home today, why not tell your family about the paper cantilever you designed and built? Tell them about how you worked in a team to design, build, and test your cantilever, what score your team achieved, and what you learned about engineering.

After telling your family about today's activity, tell them what you liked/didn't like about it and what you would change or add to the activity.

If you like, you can also discuss some of the reflection questions with them.

HINT

Just as a bundle of sticks is stronger than a single stick, so multiple pieces of paper are stronger than a single piece of paper where they are combined into a single shape or when many smaller shapes are bundled together.

Here are some questions you should ask yourself after each test:

- Did our structure fail at a particular point? Is there a way we can reinforce this point?
- Can we add a brace to help support our cantilever? Remember that you will measure your distance from the point at which this brace connects to the cantilever?
- Is adding a brace worth the sacrifice in distance?
- Is it better to add a greater mass at a lesser distance or a lesser mass at a greater distance. Which approach gives us the greatest score

Remember, if something goes wrong or your design does not work quite as you expected, this is just an opportunity to improve. Learn, redesign, and retest.

Reflection

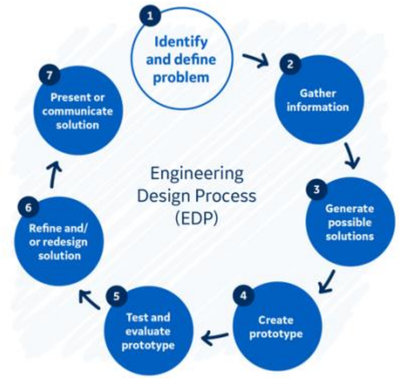
As a team, discuss the following questions:

1. How similar was your original design to the actual cantilever structure your team built?
2. If you found you needed to make changes during the construction phase, why did you decide to make these changes?
3. Was your cantilever able to meet both criteria of minimum mass and minimum distance?
4. Which cantilever that another team built was the most effective or interesting to you? Why?
5. If you could have used one additional material, what would you choose and why?
6. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?
7. What did you learn about engineering?
8. How do you think the activity relates to a career in engineering?

The Engineering Design Process

STUDENT HANDOUT

The engineering design process (EDP[1]) is the key process engineers follow when they solve problems and design solutions.



1. Identify and define the problem

Engineers start by asking lots of questions. What problem must be solved? Who has the problem? What do we want to accomplish? What are the project requirements? What are the limitations? What is the goal? Through this process, engineers start to identify the **criteria** (the conditions the solution must satisfy to be considered successful) and the **constraints** (the limitations they need to design within).

2. Gather information

Engineers dig deep into the problem by collecting **information and data** about the problem and any existing solutions that might be adaptable. They talk to people from many different backgrounds and specialties to assist with this research.

3. Generate possible solutions

Now the fun really starts! Engineers start to **brainstorm** ideas and develop as many solutions as possible, sometimes even crazy ones. This is the time for wild ideas and deferred judgment. It is important to build on the ideas of others while staying focused on the core problem and keeping the criteria and constraints in mind. For example, if there is a budget, can the potential solution be developed within that budget?

4. Create a prototype

Engineers choose one or more of the most promising solutions to **prototype**. A prototype is a working model to be tested.

5. Test and evaluate the prototype

Most prototypes **fail**, but that is good. It tells engineers which ideas they should focus on. Engineers also need to decide if the design really does solve the original problem.

6. Refine and/or redesign the solution

After learning through testing, engineers **redesign and retest** until they have the best solution possible – one that balances the criteria and constraints.

7. Present or communicate the solution

Finally, engineers reach a point where they are satisfied with their solution. It does not need to be perfect, but it should '**satisfice**' - meet the criteria within the constraints. Engineers now communicate their solution to others.

[1] Adapted from https://www.teachengineering.org/design/designprocess

Hanging Around Volunteer Guide

This guide highlights some important information, questions, and principles to help you support teams in this challenge. Start by watching a video that explains some of the *Principles for Supporting Young Engineers* (9:40) and then *An Introduction to the Design Challenges* (6:08). You can also read about some general *facilitation tips* when working with youth.

The design challenge

In this activity, students work in teams of three or four to design, build, and test their own load bearing cantilever out of nothing but printing paper and masking tape. Each team will try and create a cantilever able to support the greatest mass as far out as possible They will calculate a final score for their structure as follows:

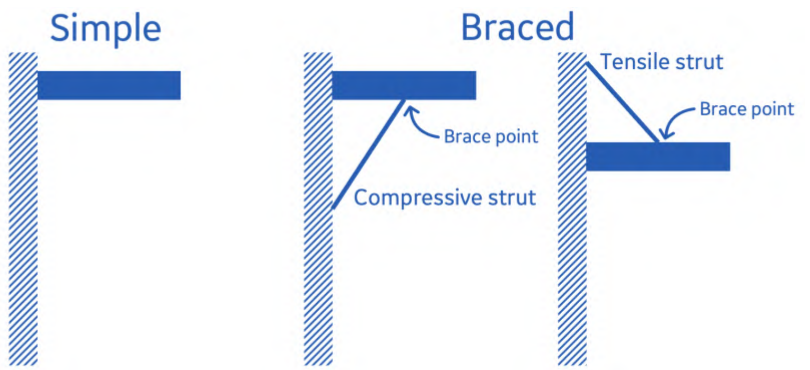
$$\text{score} = \text{mass supported (g/oz)} \times \text{distance from edge or brace (cm/in)}$$

The criteria and constraints for this challenge are reasonably simple.

- Success criteria
  - The cantilever must support as much mass as possible but at least 75 g (2.65 oz).
  - The cantilever must support this mass as far out as possible but at least 40 cm (15.75 in) from the edge of the table (or a brace point). All measurements will be taken from the edge of the table or desk (or the point where any bracing is attached) to the point from which the mass is suspended.
- Constraints
  - Teams must build their cantilevers out from the edge of a table or desk.
  - Students may only use the materials provided.
  - Students must complete their construction in 45 min or less.

Possible design solutions

It is almost inevitable that teams will build a braced rather than simple cantilever. If they build a braced cantilever, they will need to decide whether to use a compressive or tensile strut i.e., whether to brace from below or above.



FACILITATION NOTE

This challenge is customizable in terms of the minimum requirements for the mass to be supported and the minimum distance at which it must be supported. Check with the facilitator as to what criteria they have put in place.

FACILITATION NOTE

It may be tempting for teams to simply wrap their cantilever in copious amounts of masking tape. If necessary, illustrate how making tape is weak under compression but strong under tension. Suggest that this property might make their tape more useful to them in other ways, like as a tensile strut, leaving more paper to create a reinforced cantilever beam.

In addition, they will need to decide on the cross-sectional shape of their cantilever and strut. Here are some of the possible cross-sections they could choose from.

Finally, teams might decide to internally reinforce their cantilever and/or strut as in the examples below. Many pieces of paper working together are stronger than one.

Key design questions

Encourage teams to pause and share their ideas before jumping straight into building. The more ideas, the better—and crazy ideas are welcome! Also, remind them that they should produce a sketch of their design before they start building anything. Explain that sketches are a great way to test out different designs quickly and cheaply.

Here are some questions you can ask to help their design process:

- What shapes can they create that are strong and stiff? What shapes are beams they have seen in buildings and other structures.
- How are they going to attach their structure to the table?
- Is there a way they can reinforce their cantilever internally in some way?
- How can they support or strengthen that part of the cantilever that extends beyond the edge of the table either from the top or the bottom?
- How important is the position from which the mass is suspended?

Key testing questions

As teams build, encourage them to test early and often. Here are some questions you can ask while teams test and iterate:

- Are there any particular weak points in their system? How could they strengthen or reinforce these?
- Can they add a brace to help support their cantilever? Remember that you will measure your distance from the point at which this brace connects to the cantilever so, is adding a brace worth the sacrifice in distance?
- Are there any other cantilever (or strut) cross-sectional shapes they could try or ways to internally reinforce their cantilever?

FACILITATION NOTE

Strongly encourage teams to draw their design ideas on paper first.

If possible, explain why engineers draw sketches of their designs before they build by relating your own experience.

FACILITATION NOTE

Just as a bundle of sticks is stronger than a single stick, so multiple pieces of paper are stronger than a single piece of paper where they are combined into a single shape or when many smaller shapes are bundled together.

- Is there any advantage in sacrificing mass for greater distance or distance for greater mass? Where is the sweet spot in order to get the highest score?