NEXT ENGINEERS

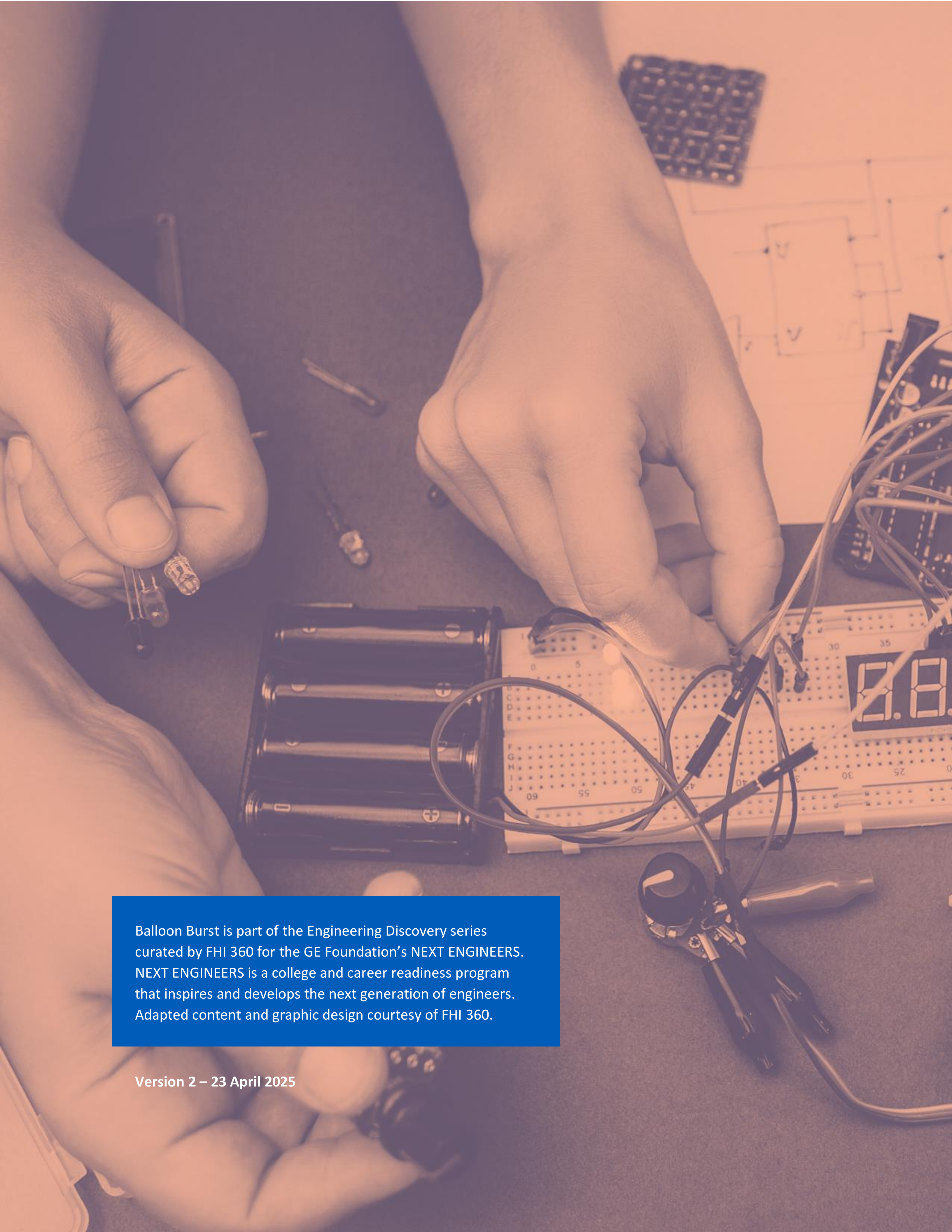
ENGINEERING DISCOVERY

Difficulty Level 1

Balloon Burst

Materials Engineering
Mechanical Engineering

NEXT ENGINEERS



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Balloon Burst

HANDS-ON ACTIVITY

Time	Ages	Cost	Group size (teams)	Activity type
60 minutes	11 - 18	Low	2 – 3 students	Hands-on Activity
Engineering Areas				
• Materials Engineering		• Mechanical Engineering		

Activity Description

This is a water balloon challenge with a difference. Students need to design a way to keep a water balloon from bursting using nothing other than balloons and some string. Obviously, water balloons will burst along the way, so this challenge is best done outside!

About the Engineering Design Challenge

Students compete in teams of two or three to design, build, and test a device to keep a water balloon from bursting when thrown as far as possible. The only materials teams can use are balloons and strings. Each device they build and test can consist of no more than five other balloons.

Success Criteria

- The balloons used can be any shape or size.
- The water balloon must contain at least 500 ml (17 oz) of water.
- Teams must record the greatest distance they can throw their water balloon WITHOUT it bursting (all the other balloons can burst). This will be their maximum recorded distance.

Constraints

- Teams may only use the materials provided.
- Only ordinary latex party balloons can be used in the challenge.
- Teams may protect their water balloon with at most five other balloons at a time.
- Teams have 45 minutes to record their greatest non-burst throw distance.

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 impacts and how to reduce the force they exert
- Have fun experiencing engineering

Materials

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

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

- About 30 standard latex party balloons (have a few extras available in case)
- 10 m (32 ft) of string
- Scissors

You will also need a tape measure with which to measure each team's distance. Alternatively, you can use masking tape or chalk to mark distance in 25 cm (10 in) increments.

For the **demonstration**, you will need

- Two raw eggs
- A few sheets of newspaper

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 facilitating 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

- Constraints
- Criteria
- Engineering Design Process (EDP)
- Engineering Habits of Mind (EHM)
- Engineers
- Force
- Impact
- Iteration
- Momentum
- Prototype
- Velocity

Four inflated balloons by FlinnScientific is used under fair use https://www.flinnsci.com/products/chemistry/models/product-12961/

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 been involved in a car accident. Ask anyone who is comfortable to describe what happened and explain how they were kept reasonably safe. • Explain that there are two main features which all modern cars use to keep passengers safe – airbags and crumple zones. Both of these help by absorbing the force of the impact (so passengers don't have to), diverting some of the forces away from the cabin (where the passengers are) and passengers and extending the duration of the impact so that the forces involved are reduced.	Activity Background
10 min	**Pre-Challenge Exploration** • Lay a few sheets of newspaper out on the ground. Hand a raw egg to a student and ask them to hold it over the newspaper at a height of about 1.5 m (5 ft). Ask the group to predict what will happen to the egg if the student lets it go. • More than likely, the group will correctly predict that the egg will break. Have the student release the egg to demonstrate. • Now have three or four other students hold a sheet of newspaper about 30 cm (12 in) above the ground. • Hand another raw egg to another student and ask them to hold it about 1.5 m (5 ft) above the newspaper. Ask the group to predict what will happen this time if the egg is released. Will it break or not. • Have the student release the egg. More than likely, the egg will not break or, if it does, it will only crack a little. • Ask students to try and explain why the egg did not break in the second case. • Take a few responses and then explain that in the second case, the egg experienced less impact force because the duration of the impact was longer. As the egg hit the newspaper, the newspaper gave way. This meant that the time taken for the egg to stop was longer. The	Two raw eggs A few sheets of newspaper

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.

TOP TIP

To save time during the challenge, pre-make about four water balloons for each team to test with. Remember each one must contain 500 ml (17 oz) of water.

It is also a good idea to have a few spare ones as well.

	greater the time taken to stop something, the less force is needed to stop it. This is why if you want to stop a car or a bicycle more quickly, you have to 'hit' the brakes harder. More force is needed to stop something more quickly. • If you have time, you can play the video called *What Are Momentum and Impulse?* (5:03).	
5 min	**Challenge Overview** • Explain that in this challenge, students will work in teams to keep a water balloon from bursting as they throw it as far as possible. • However, their water balloon protection device can only be made out of balloons and string. Each device they test **may not use more than five balloons at a time.** • Teams can inflate or cut their protection balloons and it does not matter how many of these burst, so long as the water balloon does not. The team that can achieve the greatest throw distance and still have an intact water balloon will be the winner!	
50 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**. • Tell teams that they have 45 minutes in which to design, test, and re-design their water balloon protection devices and record their greatest throw distance with an intact water balloon. • As teams work, circulate around the area encouraging them and answering any questions they might have. • Encourage teams to test early and often. The best way they will learn what designs work best, will be to test them out. • You can also suggest that teams take slow motion video footage of the impact if they can. They can use this to help them analyze where and why their device might have failed. • Make sure that each team records at least three throw distances during the 45-minute build period.	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

If possible, find an outside surface that is reasonably smooth as the landing strip for the thrown balloons. Some rough concrete surfaces will cause all the balloons to burst far too easily, making this challenge harder than it needs to be.

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:

- Reduce the number balloons that can be used at any one time to create a protection device.
- Use balloons specially designed to be used as water balloons with which to protect the main balloon. These are thinner and burst more easily than ordinary party balloons.
- Implement a minimum throw distance teams need to achieve.
- Reduce the amount of string teams can use.
- Increase the amount of water the water balloon needs to hold.

Balloon exploding when hitting the ground by Raddz500 is used under fair use https://www.reddit.com/r/pics/comments/6jqebd/a_water_balloon_mid pop_when_thrown_on_the_ground/

Key Words

- **Force**: A push or a pull that causes a change in an object's velocity (its speed or direction of travel)
- **Impact**: The force applied over a certain amount of time to cause a change in momentum.
- **Momentum**: Mass in motion or the property that all moving objects with mass have, calculated as velocity times mass.
- **Velocity**: The rate and direction of motion of an object.

- **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.

Four inflated balloons by FlinnScientific is used under fair use https://www.flinnsci.com/products/chemistry/models/product-12961/

Activity Background

Who doesn't love playing with water balloons? Most of the time, the aim is to get them to burst, hopefully on or as close to someone else as possible. However, in this challenge, the object is to create a protection device made of other balloons and string to keep the water balloon from bursting when thrown.

An ordinary latex party balloon is actually quite strong. You may find that a water balloon can survive a drop of over a meter. But how far can you throw this balloon and have it remain intact?

A water balloon bursts when the force exerted on it during deceleration as it hits the ground, is greater than the elastic potential of the latex. When an object hits a hard surface like the ground, the ground hits back with an equal but opposite force.

An object in motion, like a water balloon, has momentum. The amount of momentum depends on its velocity and its mass. The greater these are, the greater its momentum.

When a water balloon hits the ground and stops, it loses all this momentum. There is a change in momentum from something to nothing. It is the force exerted on it by the ground during impact that causes this change in momentum. This impact force exerted over a certain amount of time is called **impulse**. We can say that

$$impulse = force \times time$$

or

$$J = f \times t$$

For any given collision when an object has a certain amount of initial momentum, from the equation above, we can see that if we want to reduce the force experienced by an object during the collision, we need to extend the duration of the collision. This is what an airbag in a car does. By making a collision twice as long, for example, we halve the force experienced by the passenger. A 10x longer collision means a 10x reduction in the force experienced by the passenger for the same change in momentum.

Fundamentally, therefore, the aim of this challenge is for teams to find a way to use the other balloons to cushion the impact of the water balloon, extending the duration of the impact as much as possible and absorbing as much of the force of the impact as possible so that the water balloon itself experiences far less impact force. This may well mean that one or more of the other balloons burst but their sacrifice is worth it.

Additional Resources

- ***Crumple Zone Explained*** (1:34) https://www.youtube.com/watch?v=YO2vxMIqg8k
- ***Momentum and Impulse Explained*** (7:49) https://www.youtube.com/watch?v=LvsXxd3DM9w
- ***What Are Momentum and Impulse?*** (5:03) https://www.youtube.com/watch?v=CbcXSqia-Jg

Balloon Burst

STUDENT WORKSHEET

Challenge Overview

You are part of a team of engineers who have been given the challenge of designing and building a device to keep a water balloon from bursting when thrown. The aim is to be able achieve the greatest throw distance possible without the water balloon bursting. The tricky bit is that the protection device can only be made out of five other balloons and some string. These other balloons can be deflated, inflated, or cut up.

Success Criteria

- The balloons used can be any shape or size.
- The water balloon must contain at least 500 ml (17 oz) of water.
- You must record the greatest distance you can throw your water balloon WITHOUT it bursting (all the other balloons can burst). This will be your maximum recorded distance.

Constraints

- You may only use the materials provided.
- Only ordinary latex party balloons can be used.
- You may protect your water balloon with at most five other balloons at a time.
- You have 45 minutes to record your greatest throw non-burst throw distance.

Total Time: 45 minutes

Research & Planning (2 minutes)

Remember, your water balloon protection device may only be built using five other balloons and some string. Your other balloons can be deflated, inflated, or cut.

Think about these questions to get you started:

- How likely is an inflated balloon to burst when it hits the ground?
- Does it make a difference whether a balloon is inflated a lot or a little?
- How can several balloons be kept together and around a water balloon to protect it?

NOTES

Design Phase (3 minutes)

Before you start building anything, share ideas about how you might design and build your protection device with your team. The more ideas, the better. Remember 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:

- Are you going to inflate some or all of your balloons?
- How might you create a protective 'cage' for your water balloon?
- What kind of shapes could you make with a cut up balloon?
- How might you make your water balloon stronger so that it can withstand more impact force?

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.

Build it! Test it! (40 minutes)

Now it's time to build your protection device. 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 your balloon protection device. Remember that you can use at most five other balloons at a time. It is a good idea to start with short throws to see how well your device performs and increase the distance bit by bit to see at what distance your device fails and the water balloon bursts. Remember, the further you throw, the greater the momentum of your water balloon and so the greater the force it will experience on impact. You may need to replace one or more of your 'protection balloons' along the way.

Can you make your device better and able to protect your water balloon at ever greater distances?

To help you analyze your tests, take videos of your impacts. If you can, take slow motion video. This will help you to see things more clearly. Here are some questions you should ask yourself after each test:

- Did our device fail at a particular point? Is there a way we can reinforce or redesign this part of it?
- Can we make sure that the device lands on the side we need or want it to?
- Can we increase the strength of the water balloon in some way?
- Can we keep the water balloon from bouncing around too much?
- Is there a way we can transfer more impact force to the protection balloons and away from the water balloon?

AT HOME

When you get home today, why not tell your family about the water balloon protection device you designed and built? Tell them about how you worked in a team to design, build, and test your device, what maximum throw distance you 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.

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

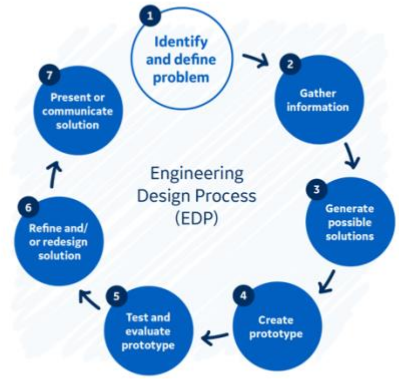
As a team, discuss the following questions:

1. How similar was your original design to the actual protection device your team built?
2. If you found you needed to make changes during the build phase, why did you decide to make these changes?
3. Which protection device that another team built was the most effective or interesting to you? Why?
4. If you could have used one additional material, what would you choose and why?
5. 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?
6. What did you learn about engineering?
7. 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

Balloon Burst 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

This is a different water balloon challenge. Students need to design a way to keep a water balloon from bursting when thrown as far as possible, using nothing other than balloons and some string. The team able to throw their water balloon the furthest without bursting will be the winner.

The criteria and constraints for this challenge are as follows:

- Success criteria
  - The balloons used can be any shape or size.
  - The water balloon must contain at least 500 ml (17 oz) of water.
  - Teams must record the greatest distance they can throw their water balloon WITHOUT it bursting (all the other balloons can burst). This will be their maximum recorded distance.
- Constraints
  - Teams may only use the materials provided.
  - Only ordinary latex party balloons can be used in the challenge.
  - Teams may protect their water balloon with at most five other balloons at a time.
  - Teams have 45 minutes to record their greatest non-burst throw distance.

Possible design solutions

There are many possible design options for this challenge. Teams may build a structure that encloses their water balloon like a cage, or they could design more of a flat bed to protect their water balloon. However, this design needs to be thrown carefully.

Teams also need to decide whether they will inflate all, some, or none of their protection balloons. If they do inflate any, have teams decide how much will they inflate them. Lower inflation may mean that these balloons do not burst as easily, but they also may not offer as much protection. Teams need to decide how they will attach their water balloon to the protection balloons. It is no good if their water balloon flies out.

FACILITATION NOTE

This challenge is customizable in terms of the type of balloons used, the size of the water balloon, the other materials that can be used, and the minimum throw distance teams must achieve. Check with the activity facilitator as to what specific criteria have been set for the challenge.

FACILITATION NOTE

One reasonably effective strategy is to cut open a protection balloon and insert the water balloon inside. If there are teams struggling with this challenge, you can point them in this direction.

Teams will also need to think about how far they plan to throw their water balloon. Remember, there is no winning for the furthest throw. The water balloon must survive. The further the throw, the greater the forces the water balloon will be subject to. This trade-off between distance and force needs to be managed.

Key design questions

Before teams start building anything, encourage them to share ideas about how they might design and build their protection device. The more ideas they can come up with, the better. Remind them that crazy ideas are allowed. Also remind them that the best way to think through, share, and explain their ideas is through design sketches.

Here are some questions you can have teams think about as they design.

- Are they going to design more of a ‘cage’ or a ‘bed’ protection device? What are the inherent trade-offs of each approach?
- Are they going to inflate some or all of their balloons? If so, by how much?
- Could they cut one or more protection balloons up? What kind of shapes could they create?
- How might they make their water balloon stronger so that it can withstand more impact force?

Key testing questions

Suggest to teams that they start their testing with shorter throws and then gradually increase the distance to discover the failure point – the point at which their water ballon bursts. Remind them that the other protection balloons are designed to burst, so this bursting does not indicate a failure of their design.

Also, if teams have a smart phone able to take slow motion video, you can suggest that they take videos of their contraptions as they hit the ground to try and learn when and why their water balloon bursts.

While testing their devices, here are some questions teams should think about.

- Did their device fail at a particular point? Is there a way we can reinforce or redesign this part of it?
- Can they make sure that the device lands on the side they need or want it to?
- Can they increase the strength of the water balloon in some way?
- Can they keep the water balloon from bouncing around too much after hitting the ground?
- Is there a way they can transfer more of the impact force to the protection balloons and away from the water balloon?

Remind teams that if something goes wrong or their design does not work as they expected, this is just an opportunity to improve – to learn, redesign, and, retest.

FACILITATION NOTE

Encourage teams to draw their ideas and designs first. Explain that design sketches are some of the first prototypes that engineers produce. A design sketch is very useful for thinking through a design and discovering any obvious problems. A little time invested upfront in a sketch can save loads of time later on.