NEXT ENGINEERS

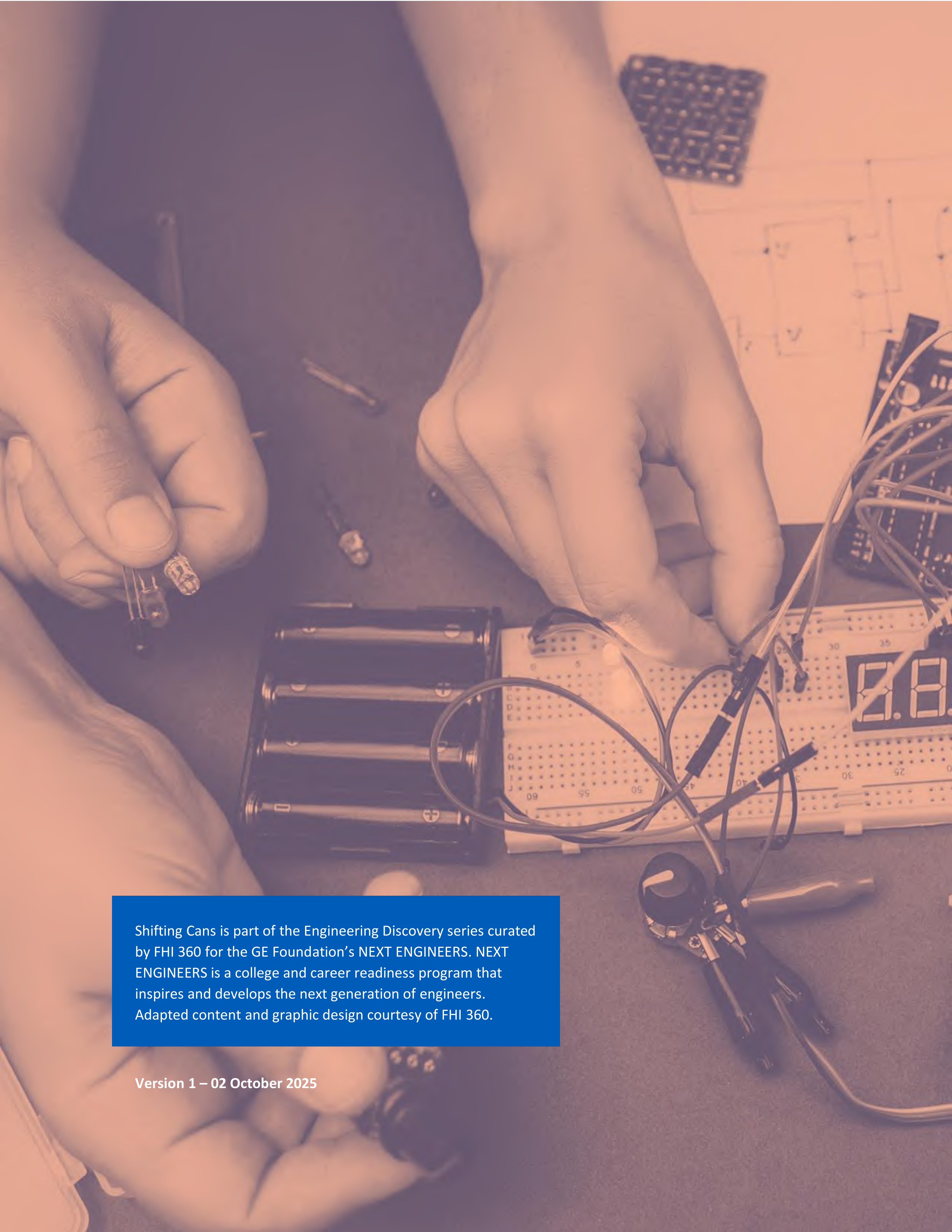
ENGINEERING DISCOVERY

Difficulty Level 1

Shifting Cans

Mechanical Engineering
Engineering Design

NEXT ENGINEERS



Shifting Cans 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 1 – 02 October 2025

Shifting Cans

HANDS-ON ACTIVITY

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

Activity Introduction

Sometimes engineers like to hang loose and just have some fun. And what could be more fun than dragging cans across the floor. But don't worry, besides being fun, there is also some serious science and engineering involved.

About the Engineering Design Challenge

In this fun and light-hearted challenge, students work in teams to design a mechanism or contraption that uses a piece of string to move two unopened soda or food cans across the floor as far as possible within a given time without the string physically touching either of the cans.

Students must also design and build in the most efficient way possible. Therefore, each contraption will receive a final score calculated as follows:

$$\text{score} = \frac{\text{total time (s)}}{\text{total cost}}$$

Success Criteria

- Both cans must be moved a distance of 10 m (33 ft) as quickly as possible.
- The cans must start at rest.
- The cans must both remain upright (if even one falls over, the test must start again).
- The string must form part of the mechanism to move the cans.

Constraints

- The string may not touch either of the cans at any stage in any way.
- Students may not touch the cans once the test begins.
- The bottom of the can(s) must remain in contact with the floor
- Teams may only use the materials provided.
- Teams must remain within the specified materials budget (suggested budget is 20 credits).
- Teams must complete the activity in the time allocated.

STUDENT DISCOVERIES

Students will:

- Know more about engineering and engineering careers
- Learn about the Engineering Design Process
- Participate in a team-based learning experience
- Have an opportunity to be creative in solving a problem
- Have fun experiencing engineering

Materials

Students will need blank paper and pens/pencils with which to sketch their can moving designs.

The following materials will be required **per team of 3 – 4 students**:

- 10 m string
- Three unopened soda or food cans
- Scissors

Make the following materials available to teams **to purchase from a central store** (suggested prices in brackets)

- Additional 1 m string (8 credits
- Popsicle sticks (6 credits per stick)
- Clothes pegs (6 credits per peg)
- Paper clips (4 credits per clip)
- Printer paper (3 credits per sheet)
- 5 cm (2 in) strips of masking tape (5 credits per strip)
- Rubber bands (8 credits per band)

The following materials will be required for testing:

- Stopwatch or timer
- Measuring tape
- Strips of masking tape to mark the start and finish lines.

Note: You should conduct the tests on smooth level floor (wood, tiles, or linoleum is ideal)

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. Consider bringing your own contraptions to the activity and seeing if you can beat the times set by the student teams.
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 activity 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)

KEY WORDS

- Compression
- Constraints
- Criteria
- Dynamic friction
- Engineering Design Process (EDP)
- Engineering Habits of Mind (EHM)
- Engineers
- Force
- Iteration
- Prototype
- Static friction
- Tension

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.

Step-by-Step Instructions

Time	Instructions	Materials
2 min	**Welcome & Introductions** • Welcome students to the activity and briefly introduce yourself, noting what kind of engineer you are. • Explain briefly how and why you became an engineer and describe some of the things that you work on day-to-day • Explain that in today's challenge, students will work as engineers and use the engineering design process to come up with solutions to a very important and pressing problem – how to move two unopened cans across the floor as quickly as possible with a piece of string but without the string physically touching either can in any way.	Activity Background
5 min	**Pre-Challenge Exploration** • Divide students into the teams for the challenge and give each team its materials. • Ask students to use their string to move one of their cans. • Teams are very likely to tie the string around the can and then pull the can. • Explain that string can only move the can if it pulls it i.e., by transferring the force in the string to the can. String is very weak in **compression**. If you push on the end of a piece of string it folds and cannot transfer that pushing forcing to another object. • However, string is strong in **tension**. It can be used to pull an object because it can effectively transfer the force to the can. • Ask teams to investigate the **force** required to move one can and then two cans upright across the floor. Is more force required to get the cans moving or keep them moving? • Explain that friction opposes the motion of the cans. Explain also that, while friction is always present, it is greater when the cans are stationary (called **static friction**) than when the	Activity Background Team materials

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.

<table>
<tr>
<td></td>
<td>cans are moving (kinetic or dynamic friction). This is why it is always harder to get an object to start sliding than to keep it sliding.</td>
<td></td>
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<tr>
<td>3 min</td>
<td>Challenge Overview

Explain to the group that their challenge is to design and build a contraption that uses a piece of string to move two cans across the floor without the string physically touching either can.
Explain that the success criteria are that:

Both cans must be moved a distance of 10 m (33 ft) as quickly as possible.
The cans must start at rest.
The cans must both remain standing upright (if even one falls over, the test must start again).
The string must form part of the mechanism to move the cans.

Explain that the constraints are that:

The string may not touch either of the cans at any stage.
Students may not touch the cans at all once the test begins.
The cans may not be lifted in any way.
Teams may only use the materials provided.
Teams must remain within the specified materials budget (suggested budget is 15 - 20).
Teams must complete the activity in the time allocated.

Explain that teams will need to design as efficiently as possible. They will receive a final score calculated as follows:

$$\text{score} = \frac{\text{total time (s)}}{\text{total cost}}$$

Finally, note that teams will not be allowed to buy anything from the central store until they have produced a design sketch of their can shifting contraption.
</td>
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<tr>
<td>35 min</td>
<td>Engineering Design Challenge

Hand each team a copy of the Student Worksheet, the Engineering Design Process Summary.
Tell teams that they have about 25 minutes in which to design and test their can shifting contraptions before they need to conduct a final test.
</td>
<td>Building Materials

Student Worksheet

Engineering Design Process Summary</td>
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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 allow teams to buy materials from the central store until they have produced a sketch of their contraption that details what materials they plan on using.

	• As teams work, circulate around the room encouraging them and answering any questions they might have.
	• Have teams think about:
	  ○ How they will arrange their two cans – one on top of the other, side-by-side, one behind the other or some other arrangement
	  ○ How they can transfer the pulling force from the string to the cans without the string touching either can at all.
	  ○ How they can ensure that their contraption is strong enough to not break as they start moving their cans i.e., when they need to overcome static friction.
	  ○ How they can make sure that their cans both stay upright.
	• After about 25 minutes invite teams to come and test their contraptions with you and get a final score.	

10 min	**Reflection and Closing** • Give teams about five 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:

- Require teams to cover the distance in a maximum time.
- Require teams to move heavier or larger objects.
- Require teams to partner with one to three other teams to create a "can train" that needs to be moved.
- Open the cans to increase the jeopardy if they tip over.
- Reduce the amount of time teams have to design and build.
- Reduce the budget that teams have available.
- Conduct the test on a carpeted floor or a floor with a rough surface.

Key Words

- **Compression**: when a physical force presses inwards on an object, causing it to become more compacted
- **Dynamic friction**: the force that opposes the motion of an object that is sliding across a surface
- **Force**: a push or a pull that acts on an object and can cause the object to change its motion i.e., change direction or speed up/slow down.

TOP TIP

Instead of having teams test their contraptions individually, you can run the test as a race.

In this case, if any two cans collide, both teams should be disqualified or penalised a set amount of time.

EXTENSION

If you have an additional 20 – 25 minutes available for this activity, it is suggested that you end by having teams join with one or two other teams to move a "can train" consisting of all their cans. They can design a new contraption, combine their existing ideas, or extend one team's idea.

- **Kinetic friction**: the force that prevents an object from moving when at rest on a surface.
- **Tension**: when a physical force pulls apart or stretches 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.

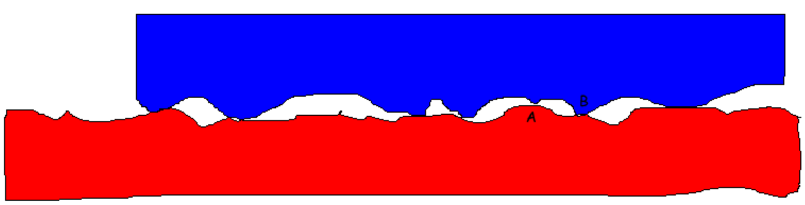
Activity Background

Although this might not seem like a serious challenge (after all, who needs to drag cans across the floor with a piece of string), it does involve some important engineering principles. The most important of these is friction.

Friction is a force that acts in opposition to the motion of an object. Friction is fundamental and essential to how we live our lives. Just think of all the things that would be difficult or impossible if you kept moving off in different directions. You could not walk or run. You would find it hard to sit on a chair. Vehicles of all types would be practically impossible to control.

This is not to say that friction is not sometimes a problem (your shoes wear out and it can be hard to move the furniture around your house) but overall, friction is far more friend than foe.

Friction results from the fact that no surface, no matter how smooth it looks or feels, is actually perfectly smooth. At the microscopic level, every surface has ridges and valleys. When two surfaces are in contact, these ridges and valleys interact and hook on each other. At the atomic level, the molecules at the surface of each object for intermolecular bonds with each other.

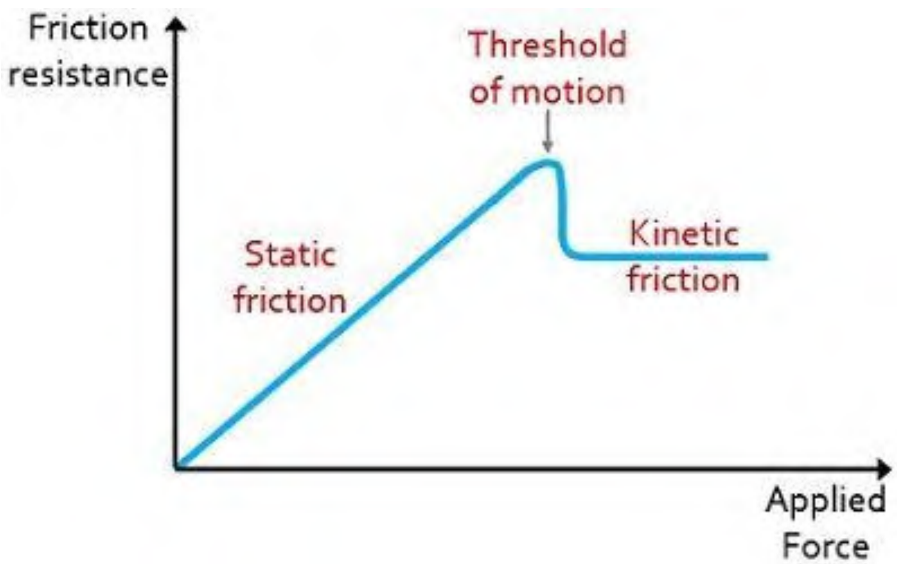


Two surfaces in contact at a microscopic level by High Point University is used under fair use https://physics.highpoint.edu/~jregester/potl/Mechanics/Friction/FrictionA.htm

The overall amount of friction depends on the “roughness” of the surfaces as well as the force with which they are pressed together. As roughness and force increase, so does friction. This means that placing one can on top of the other will increase the friction experienced by the bottom can, but this arrangement is likely to be easier to design for.

Importantly for this activity, there are two main types of friction – static and kinetic (or dynamic) friction. Static friction is friction that prevents an object at rest from starting to move. Once the object is moving it experiences kinetic friction.

For any combination of surfaces, static friction is always greater than kinetic friction. You will know from experience that more force is needed to get a heavy object (like a couch or box) to start sliding across the floor than to keep it sliding. The graph below illustrates this. There comes a point (called the breakaway point) as the object starts moving where the friction force suddenly drops and then remains constant. This is the change from static to kinetic friction and is experienced as the jerk when an object starts moving.



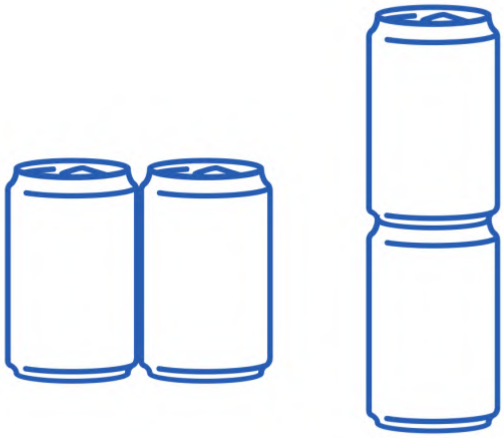
Graph of friction vs applied force for static and kinetic friction by Circuit Globe is used under fair use https://circuitglobe.com/difference-between-static-and-kinetic-friction.html

For more details on friction watch the video called *Friction - Physics 101* (19:47).

Now because of the sudden change from static to kinetic friction and the associated jerk forward, teams are going to need to think about how they can apply a force to their cans so that they do not tip over as they start moving. Placing one can on top of the other is going to be particularly susceptible to tipping. Apply the pulling force at the top of a can is may cause it to tip over. Applying it at the bottom might help prevent this.

Teams will also need to consider the optimal arrangement of their cans. Indeed this assumes that they will move both cans together. There is no restriction on them shifting one can at a time, but this will either take far longer or need far more materials.

There are three basic arrangements possible – one can on top of the other; the cans side-by-side, one can behind the other. All three come with their own pros and cons in terms of overall friction, inherent stability and the amount of materials required.

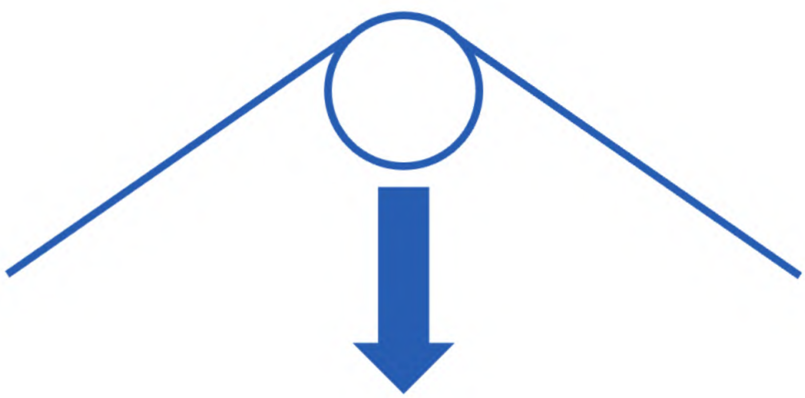


Further, teams might want to think if any of their materials offer less friction with the floor than the bottom of a can. Less friction means less force needs to be applied which means that their contraption does not need to be as strong or will accelerate faster for the same force.

Another decision teams need to make is whether to cut their string into pieces or not. Dragging cans with the force exerted by a single piece of string is fine but more control and stability can be achieved if there are two or more strings pulling on the cans. However, to gain this control and stability, the forces in the multiple strings need to be balanced. Unbalanced forces can cause the cans to move off to the left of the right.

Teams will also need to decide on a way that they can transfer the pulling force applied to the string to the cans WITHOUT the string touching either can in any way.

Finally, some very adventurous teams may design and build a slingshot device. There is nothing in the rules that states that the cans need to be dragged the entire distance. If they can stay upright, they can be slingshot over the distance.



Additional Resources

- ***Stretching and Compressing*** (3:31)
  https://www.youtube.com/watch?v=8wUYxbnEC0k
- ***Why Is Static Friction Greater Than Kinetic Friction?*** (3:29)
  https://www.youtube.com/watch?v=j12JZC-UCC8
- ***Introduction to Static and Kinetic Friction by Bobby*** (4:03)
  https://www.youtube.com/watch?v=i-DdiI7gFoM
- ***Friction - Physics 101*** (19:47)
  https://www.youtube.com/watch?v=fCe6UyNyPTg

Shifting Cans

STUDENT WORKSHEET

Challenge Overview

In this challenge, you get to drag a pair of cans across the floor. Exciting huh!?

Well, there will be a little more engineering involved that just tying a piece of string to the cans and pulling. For one thing, the string is not allowed to physically touch either can at all. You also need to move the cans 10 m (33 ft) as quickly as possible and build your contraption in the most cost efficient way possible. You will receive a final score calculated as follows:

$$\text{score} = \frac{\text{total time (s)}}{\text{total cost}}$$

Success Criteria

- Both cans must be moved a distance of 10 m (33 ft) as quickly as possible.
- The cans must start at rest.
- The cans must both remain standing upright (if even one falls over, the test must start again).
- The string must form part of your mechanism to move the cans.

Constraints

- The string may not touch either of the cans at any stage.
- You may not touch the cans once the test begins.
- The cans may not be lifted in any way.
- You may only use the materials provided.
- You must remain within the specified materials budget (suggested budget is 15 - 20).
- You must complete the activity in the time allocated.

Total Time: 35 minutes

Research & Planning (2 minutes)

Basically, you need to build something that allows you to move two cans across the floor with a piece of string but without the string touching the cans. Have a look at the central store to see what other materials you can use. Here are some questions to kickstart your thinking.

NOTES

- It is clear that you will need to pull the cans in some way. How can you transfer this pulling force to the cans?
- Will you move one can at a time or both cans at once?
- How will you arrange the cans if you move them both at once?
- How can you make most efficient use of the materials available to achieve these aims?

Design Phase (3 minutes)

Before you start building anything, share ideas about how you might design and build your contraption 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 to help you think through the different options. Engineers always sketch their ideas. This helps them communicate and test their thinking before committing to building anything. You will not be allowed to buy any materials from the central store until you have a fairly detailed sketch of what you plan to build. Don't worry; you can also change course if your original idea does not work as planned.

Here are some questions to help get you started:

- How will you arrange the cans?
- How can you "attach" the string to the cans?
- How can you make sure that your contraption is strong enough to withstand the force needed to overcome friction (first static friction and then kinetic friction) as you apply the force needed to move them?
- How might you control and stabilize the cans as you move them? Remember that both cans must remain upright for the whole distance.

Build it! Test it! (30 minutes)

Now it's time to build and test your can shifting contraption. It's a good idea to test early and often so that you can make changes and improvements along the way. Also, 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.

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

- Did our contraption break in any way? Where are the weak points and how can we fix these?
- Did the string touch the cans in any way? How can this be prevented?
- Did the cans fall over? Why did this happen? How can this be prevented?
- Can we optimize the application of force to the cans? Would it be better to accelerate more slowly in the beginning and then pick up speed?

When you are ready for an official test, let your facilitator know. Position your cans behind the starting line and get ready. Remember, if something goes wrong or

AT HOME

When you get home today, why not tell your family about the how you were able to drag a pair of cans across the floor? Tell them about how you worked in a team to design, build, and test your contraption, 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.

EXTENSION

If you have time, why not join forces with one or two other teams to see if you can move a "can train" consisting of all your cans. You can design a new contraption, combine your different existing ideas, or extend one team's idea.

your design does not work quite as you expected, this is just an opportunity to improve. Learn, redesign, and retest.

Reflection

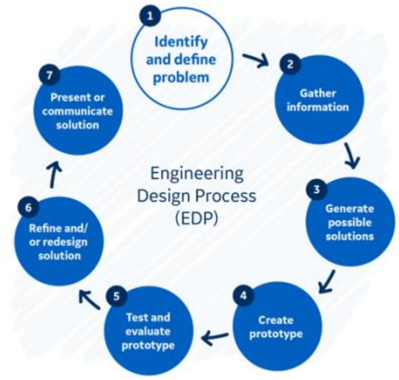
As a team, discuss the following questions:

1. How similar was your original design to the actual can shifting contraption 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. Which contraption 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

Shifting Cans 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 to design, build, and test a string contraption that allows them to move two cans over a distance as quickly as possible without the string touching the cans in any way. Teams also need to build the most cost efficient contraption possible and will receive a final score calculated as follows:

$$\text{score} = \frac{\text{total time (s)}}{\text{total cost}}$$

- Success criteria
  - Both cans must be moved a distance of 10 m (33 ft) as quickly as possible.
  - The cans must start at rest.
  - The cans must both remain standing upright (if even one falls over, the test must start again).
  - The string must form part of the mechanism to move the cans.
- Constraints
  - The string may not touch either of the cans at any stage.
  - Students may not touch the cans once the test begins.
  - The cans may not be lifted in any way.
  - Teams may only use the materials provided.
  - Teams must remain within the specified materials budget (suggested budget is 15 - 20).
  - Teams must complete the activity in the time allocated.

Possible design solutions

The most obvious design solution is a contraption that attaches to the can(s) and string, but keeps the string from touching the cans. The string is then pulled to drag the cans across the ground.

Another option might be to build some sort of slingshot that catapults the cans over the 10 m (33 ft) distance.

In both cases, teams need to figure out how to keep the cans from falling over by looking at where the force from the string is applied, how much force is applied to overcome static and then kinetic friction, and whether force is applied to the cans at one point or more.

FACILITATION NOTE

This challenge is customizable in terms of the objects to be shifted, the surface over which they need to be moved, the budget teams are allowed to spend and the time available. Therefore, it is a good idea to check with the lead facilitator as to what specific criteria and constraints they have decided to impose.

FACILITATION NOTE

A design option teams may overlook is the slingshot. While this is risky, it can move the cans over the 10 m (33 ft) distance very quickly, assuming the cans don't fall over before the end.

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 will need to produce a sketch of their design before they can buy materials from the central store.

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

1. Will they move both cans together or not?
2. If moved together, how will the cans be arranged – one on top of the other, side-by-side, or one behind the other?
3. Can the friction between the can(s) and surface be reduced in any way?
4. What kind of device will allow them to transfer the force in a piece of string to the cans to move them without the string touching the cans?
5. How can they make sure that your contraption is strong enough to withstand the force needed to overcome friction (first static friction and then kinetic friction) as they apply the force needed to move their cans.
6. How can the cans be moved as quickly as possible but without them falling over?

Key testing questions

As teams build, encourage them to test early and often. They can do their own tests to check their contraption and their pulling technique before the go forward for an official times test.

Here are some questions you may ask while teams test and iterate:

- Did their contraption break in any way? Where are the weak points and how can we fix these?
- Did the string touch the cans in any way? How can this be prevented?
- Did the cans fall over? Why did this happen? How can this be prevented?
- Can they optimize the application of force to the cans? Would it be better to accelerate more slowly in the beginning and then pick up speed?

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.

Also emphasize that teams will be unable to buy any materials until they have a fairly detailed sketch.

EXTENSION

If teams finish early or there is additional time, have teams join one or two other teams to move a "can train" consisting of all their cans. They can design a new contraption, combine their existing ideas, or extend team's idea.