

NEXT ENGINEERS



ENGINEERING DISCOVERY

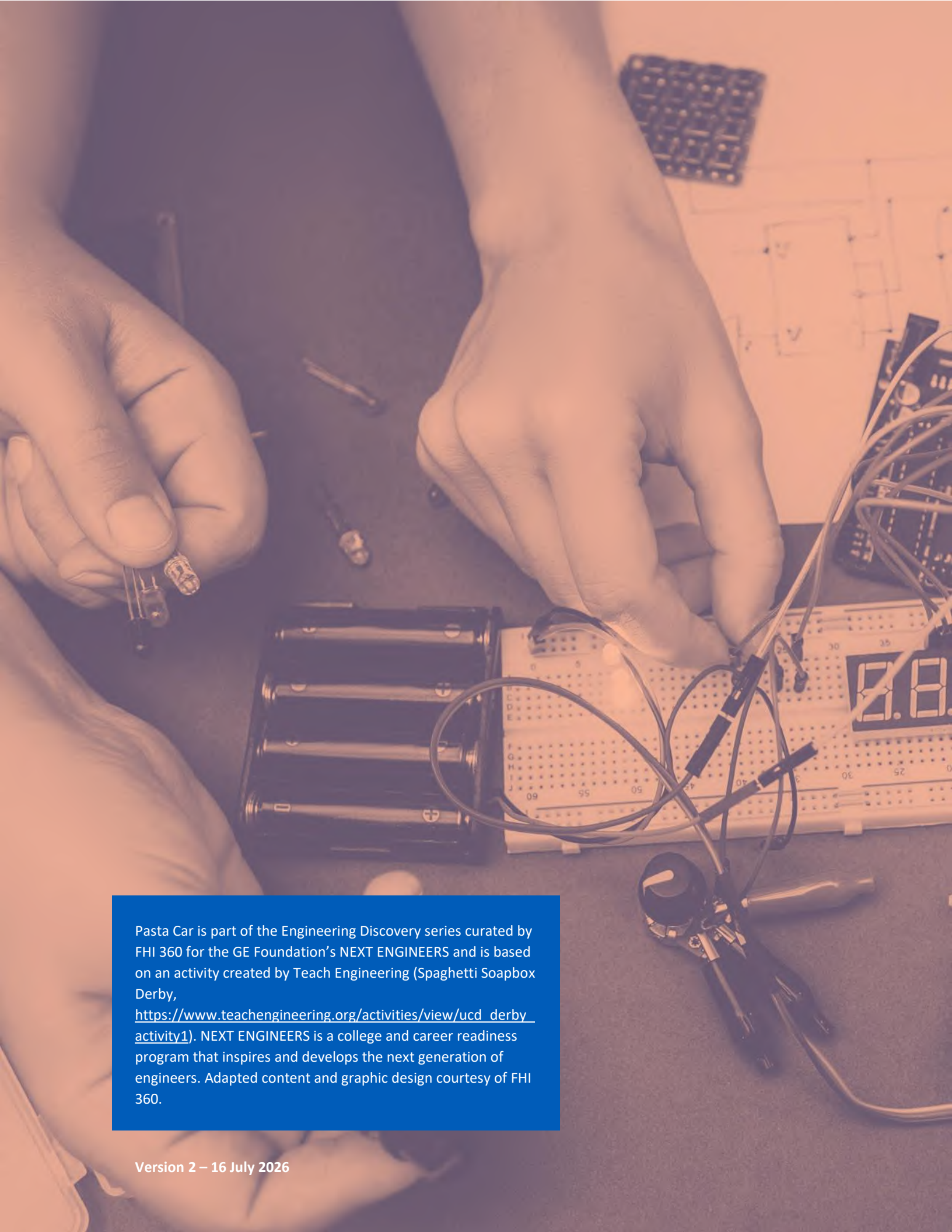
Difficulty Level **1**

Pasta Car

Mechanical Engineering
Materials Engineering



NEXT ENGINEERS



Pasta Car is part of the Engineering Discovery series curated by FHI 360 for the GE Foundation's NEXT ENGINEERS and is based on an activity created by Teach Engineering (Spaghetti Soapbox Derby, https://www.teachengineering.org/activities/view/ucd_derby_activity1). 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.



Pasta Car

HANDS-ON ACTIVITY

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

Activity Description

Parents are always telling their kids not to play with their food. In this activity, students get to do just that! In teams, students work as engineers to design and build a functional car entirely out of different kinds of pasta...oh, and glue.

About the Engineering Design Challenge

Students work as teams of mechanical engineers to design, build, and test vehicles made entirely out of dry pasta. These vehicles must be able to roll down a ramp and then coast freely as far as possible while transporting a passenger. Students must also design and build in the most efficient way possible. Therefore, each vehicle will receive a final score calculated as follows:

$$\text{score} = \frac{\text{coasting distance achieved (cm or in)}}{\text{total cost}}$$

Success Criteria

- The vehicle must coast as far as possible after rolling down a ramp (distance measured perpendicular to the bottom of the ramp – see the **Activity Background** for more details).
- The vehicle must be able to carry a passenger.
- It must be easy to insert and remove the passenger.
- The passenger must not fall out of the vehicle at any point during the journey.

Constraints

- Teams may only use the materials provided.
- Teams must remain within the specified materials budget (suggested budget is 130 - 150).
- 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
- Learn about energy conversion and friction
- Have fun experiencing engineering

Materials

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

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

- A glue gun
- A glue stick

The following additional materials must be available for teams to **purchase from a central store** (suggested prices in brackets):

- Spaghetti (3/piece)
- Penne (3/piece)
- Lasagna sheets (flat or 10/sheet)
- Rigatoni (5/piece)
- Rotelle (10/piece)
- Farfalle (optional 4/piece)
- Fusilli (optional 4/piece)
- Glue stick (30/piece)

The following additional materials will be required for the **ramp, testing, and demonstration**:

- A piece of wood or stiff board (about 35 cm (14 in) x 100 cm (39 in))
- A pile of books, bricks or other stable objects to make a tower about 45 cm (18 in) height
- A measuring tape
- An object to act as the car's passenger (e.g., a Lego mini figure, a Playmobil figure, or even a AA battery with wire arms and legs attached!)
- Your own pasta car or another small demonstration vehicle able to roll down the ramp and then coast freely.

Note: You can make the ramp larger than specified above. However, the ramp should make an angle of between 25° and 30° with the floor. If possible, find a smooth flat surface for the cars to coast over.

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 any pasta cars you have made to show students and even use these to demonstrate how well (or not!) they work.
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:



KEY WORDS

- Constraints
- Criteria
- Engineering Design Process (EDP)
- Engineering Habits of Mind (EHM)
- Engineers
- Friction
- Gravitational potential energy
- Iteration
- Kinetic energy
- Momentum
- Prototype



Spaghetti



Penne



- 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.



Rigatoni

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. - Ask students if they have ever been told not to play with their food. Say that today will be different. Today they MUST play with their food.	Activity Background
5 min	Pre-Challenge Exploration - Hold your pasta car or the demonstration vehicle at the top of the ramp and ask students to explain what will happen if you let go. - Most students will correctly predict that the car will roll down the ramp but ask them to explain why. Take a few answers. - Explain that by holding the car at the top of the ramp, we are actually holding it above the ground. If we let the car go, gravity will pull the car towards the ground. We say that the car has gravitational potential energy - potential energy because, although it is not moving yet, it has the potential to do so, and this potential exists because of gravity. <i>The heavier the car is and the higher we raise it off the ground, the more gravitational potential energy it will have.</i> - Ask students to predict what will happen to the car when it reaches the bottom of the ramp. Again most students will correctly predict that the car will coast along the ground for a while and then stop. Ask them to explain why. Take a few answers.	Ramp Passenger Pasta car or demonstration vehicle



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.



	• Explain that the gravitational potential energy gets converted into kinetic energy (the energy of motion) as the car rolls down the ramp. <i>The more gravitational potential energy it had at the top, the more kinetic energy it will have at the bottom.</i> • Once the car gets to the bottom of the ramp, it has enough kinetic energy to keep moving. However, this kinetic energy is gradually converted to sound and heat because of friction and so the car loses its kinetic energy and eventually stops. <i>The more kinetic energy it started with and the less friction there is, the further the car will coast.</i> • Demonstrate how your own pasta car (if possible) or your demonstration vehicle coasts after rolling down the ramp you have created.	
3 min	Challenge Overview • Explain to the group that their challenge will be to design and build their own vehicle entirely out of pasta able to carry a passenger that coasts as far as possible after rolling down the ramp. Show the group the passenger they must carry and the different kinds of pasta they can build with and the cost of each. • Describe the rest of the criteria and constraints: ○ It must be easy to insert and remove the passenger. ○ The passenger cannot fall out during the journey. ○ Teams may only use the materials provided. ○ Teams cannot exceed their budget (be sure to tell teams what their exact budget is). ○ Teams must complete the challenge in the time given • Explain that the coasting distance will be measured perpendicular (at 90°) to the bottom of the ramp and that teams also need to build as efficiently as possible. Each team will receive a final score calculated as follows: $\text{score} = \frac{\text{coasting distance achieved (cm or in)}}{\text{total cost}}$	Pasta Car Passenger Pasta



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 car that details what pasta pieces will be used where.



	Finally, note that teams will not be allowed to buy anything from the central store until they have produced a design sketch of their pasta car.	
50 min	Engineering Design Challenge - Divide the group into teams and hand each team a copy of the Student Worksheet and the Engineering Design Process Summary. - Tell teams that they have 50 minutes in which to design, test, and re-design their pasta cars and do an official test to obtain their final score. - As teams work, circulate around the room encouraging them and answering any questions they might have. - Have teams consider what affect the mass of their pasta car has on its coasting performance. Also have them consider the effects of friction and how this might be reduced as well as the importance of their cars travelling in a straight line. - Encourage teams to plan their cars well so that they spend as little as possible at the central store while also testing early and often. - As teams are ready, allow them to perform ramp tests and obtain indicative test scores. - After about 40 minutes, have teams do a final ramp test to get their final score.	Building Materials Student Worksheet Engineering Design Process Summary
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



TOP TIP

When doing the ramp tests, place the back wheels of the pasta car over the back of the ramp and then gently push it forward.



Rotelle



Lasagne

Extension

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

- Increase the size and/or mass of the passenger (bigger and heavier passengers will require larger and more robust vehicles).
- Reduce the budget teams have available.
- Reduce the amount of time teams have to design and build.
- Introduce a minimum coasting distance the cars must achieve.
- Increase the slope of the ramp (this will increase the forces the car is subject to at the bottom of the ramp, requiring the car to be suitably sturdy and strong).



Key Words

- **Friction:** The force of resistance that one surface or object experiences when moving over or sliding past another.
- **Gravitational Potential Energy:** The potential energy an object has by virtue of its position above the surface of the earth.
- **Kinetic Energy:** The energy an object has by virtue of its motion.
- **Momentum:** the quantity of motion of a moving body or mass in motion, calculated as the body's mass multiplies by its velocity.
- **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

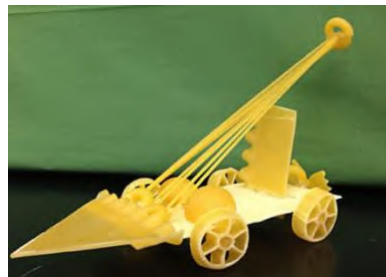
Everyone intuitively knows what will happen when a rolling object like a ball or a toy car is allowed to roll down an incline onto a smooth flat surface. As the object rolls down the incline it gains in speed. When it reaches the bottom of the ramp it will coast along the floor and eventually come to a stop.

If you want to maximize the distance over which the ball or car will coast for a given ramp, it is helpful to know some of the simple physics involved.

To begin with, to lift any object off the ground requires energy (or for work to be done). This energy is needed to overcome gravity. The heavier the object and the higher it is lifted the more energy is needed. If you let go of the object, it will fall back to the ground because of gravity.

Therefore, if you expend energy lifting an object off the ground, you can get this energy back if you drop the object again. You can think of this like depositing energy into the object and then withdrawing it again.

The energy you deposit into an object by lifting it off the ground is called **gravitational potential energy**. It is potential energy because it is stored - it only gets released if you drop the object. It is gravitational potential energy because it exists because of gravity.



Pasta race car is used under fair use
<https://www.lovemylibrary.ca/event/pasta-cars/>

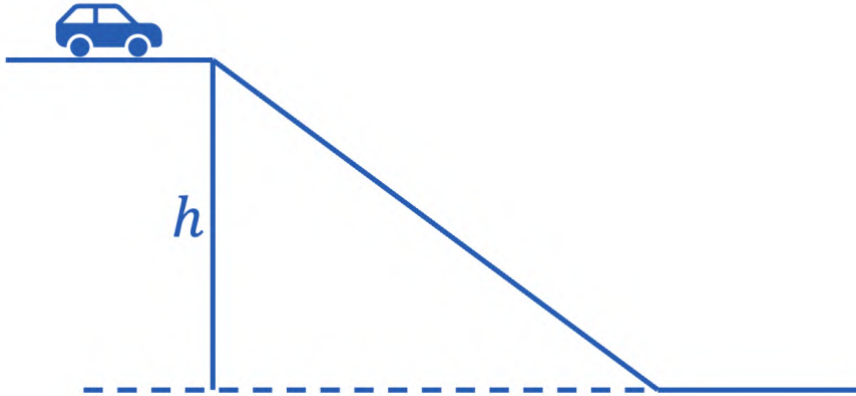


We can calculate the amount of gravitational potential energy an object has using this equation:

$$GPE = mgh$$

- m is the mass of the object in kg
- g is the acceleration due to gravity which is taken as 9.8 m/s^2 on Earth
- h is the object's vertical height above the ground in m

$$GPE = mgh$$



If you drop the object it accelerates towards the ground because of gravity, gaining in speed. Therefore, its gravitational potential energy gets converted into another kind of energy called **kinetic energy**, or the energy of motion. By the time it reaches the ground again, all of its potential energy has been converted into kinetic energy.

We can calculate the amount of kinetic energy an object has using this equation:

$$KE = \frac{1}{2}mv^2$$

- m is the mass of the object in kg
- v is the velocity (the speed) of the object in m/s



Pasta car is used under fair use
<https://www.nordangliaeducation.com/bsb-shunyi/news/2022/11/20/year-7-pasta-car-steam-challenge>



Pasta motor cycle is used under fair use
https://www.rbth.com/multimedia/2012/12/19/tiny_masterpieces_theres_more_to_pasta_than_just_cooking_21261



The same holds true when a car rolls down a ramp. It has gravitational potential energy at the top of the ramp which gets converted into kinetic energy as it rolls down. We can say that the

$$GPE_{\text{top of ramp}} = KE_{\text{bottom of ramp}}$$

Therefore, the higher the ramp or the heavier the car, the more gravitational potential energy the car will have at the top of the ramp and, thus, the greater will be its kinetic energy at the bottom of the ramp. However, the heavier the car, the more force it will experience as it leaves the ramp and hits the ground. This will mean that the car will need to be stiffer and stronger.

While it might be easy to just stick more pasta onto the car to increase its mass and hence its kinetic energy, it matters where this additional mass is added. If mass is added to only one end of the car, the car will become unbalanced. In general, it is best to keep the car's center of gravity between the axles with an even distribution of mass over each axle. You can check where the center of gravity is by trying to balance the car on your finger.

However, increasing the mass of the vehicle means that the axles and wheels need to carry more mass and, therefore, be stronger.

The conversion of energy, for example from potential to kinetic, is never perfect. Some energy is always lost, especially as heat. In the case of a car rolling down a ramp, quite a bit of energy is lost as heat due to friction. Friction is the force of resistance that one surface or object experiences when moving over or sliding past another. The wheels moving over the ramp, the axles spinning in their holes, and the car pushing through the air are all sources of friction.

The effects of friction are especially visible when the car starts to coast. At this point, there is no force pushing or pulling the car forward. The only force acting on the car is friction and so the car gradually loses all of its kinetic energy until it finally comes to a stop.

If you want the car to coast further, you either need to make sure it has more kinetic energy at the bottom of the ramp or you need to reduce the amount of friction it experiences, or both.

Adding extra mass to increase kinetic energy is, however, also likely to increase friction within the system. There will be more force pushing the axles onto the car body and more friction between the wheels and the ground. Here, as in all of engineering, is a trade-off.

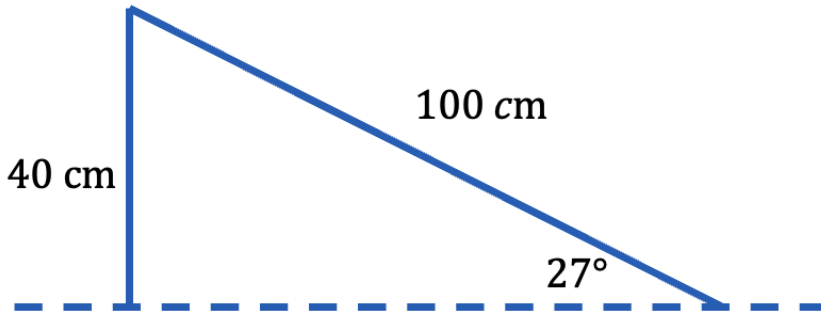
Generally, though, friction in a system like a pasta car can be reduced by ensuring that the wheels spin as freely as possible with as little wobble as possible by making sure that the:

- Axles are straight and parallel to each other
- Wheels don't rub against the sides of the car
- Wheels are perpendicular to the axis
- Axles are attached as close as possible to the center of the wheels

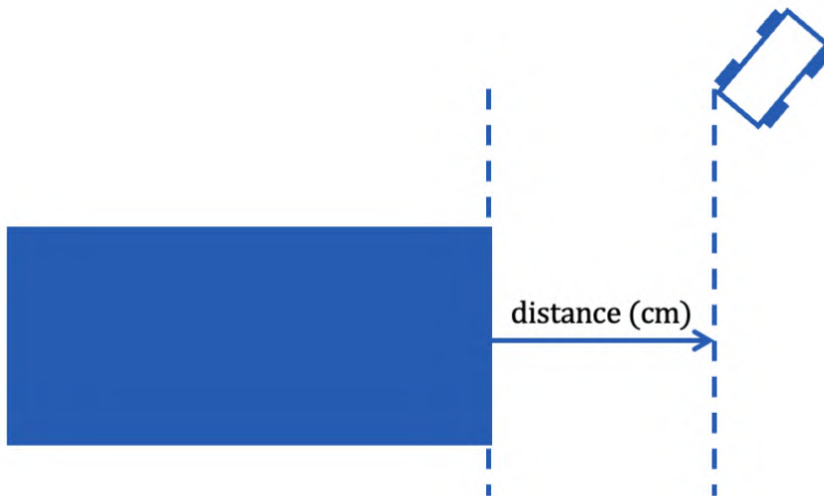


In addition, the car can be made as aerodynamic as possible although at the speeds at which the car is likely to travel and at its size, friction at the wheels will be far greater than friction through the air.

As noted above, while a 1 m (39 in) long ramp with the top about 45 cm (18 in) off the ground is suggested, you can create whatever size ramp you like. These ramp dimensions will create a ramp with at a 27° to the ground. Whatever size your ramp, make sure that the ramp angle is between 25° and 30° .



When measuring the coasting distance, make sure that you measure this distance as perpendicular to the end of the ramp. This will incentivize teams to prioritize that their cars travel as straight as possible.



Additional Resources

- **Gravitational Potential Energy** (1:58)
<https://www.youtube.com/watch?v=28MQF0RNI3g>
- **KINETIC ENERGY** (3:23)
<https://www.youtube.com/watch?v=1YeBgtH589c>
- **Gravitational Potential and Kinetic Energy** (2:03)
<https://www.youtube.com/watch?v=MYwqb8m0jkM>
- **MSC-Pasta Cars** (3:40)
<https://www.youtube.com/watch?v=JKt0w94rPGc>



References

This activity is based on **Spaghetti Soapbox Derby** originally created by **Teach Engineering** and available at:

https://www.teachengineering.org/activities/view/ucd_derby_activity1.

Visit the **Teach Engineering** (<https://www.teachengineering.org/>) website for a host of other great engineering activities and resources.





Samochód z makaronu

MATERIAŁY DLA UCZNIÓW

Zbudujcie z makaronu samochód, który będzie najbardziej opłacalny i przejedzie najdłuższy dystans.

1

ZIDENTYFIKUJ I ZDEFINIUJ PROBLEM

Kryteria sukcesu

- Samochód powinien przejechać jak najdalej po zjechaniu z rampy.
- Samochód musi przewieźć pasażera, który nie może z niego wypaść.
- Musi być łatwo włożyć pasażera do samochodu oraz wyjmować.

Ograniczenia

- Można korzystać wyłącznie z przygotowanych materiałów.
- Należy zmieścić się w wyznaczonym budżecie na materiały.

Końcowy wynik zostanie obliczony na podstawie wzoru

$$\text{wynik} = \frac{\text{odległość przejechana przez samochód (cm)}}{\text{koszt materiałów}}$$

2

ZBIERZ INFORMACJE

Materiały

- różne rodzaje makaronu, z których każdy ma inną „cenę”,
- klej na gorąco.

? Zastanówcie się

- Przyjrzyjcie się pasażerowi, którego Wasz samochód będzie przewoził. Jak duży powinien być Wasz samochód?
- Jakie rodzaje makaronu macie do dyspozycji? Jakie mają kształty? Jak możecie wykorzystać je do zbudowania samochodu?
- Co sprawi, że po zjechaniu z rampy Wasz samochód przejedzie jak najdalej?

7

ZAPREZENTUJ LUB ZAKOMUNIKUJ ROZWIĄZANIE

Po 40 minutach musicie zakończyć budowę i wykonać końcowy test na rampie. Pamiętajcie, nie wygrywa samochód, który przejedzie najdalej tylko ten, który przejedzie najdalej w stosunku do kosztu wykonania.

6

5

TESTUJ, OCENŃ I PRZEPROJEKTUJ SWÓJ PROTOTYP

Kiedy będziecie gotowi przetestować swój samochód na rampie, poinformujcie prowadzącego. Pozwólcie samochodowi zjechać z rampy, zmierzcie odległość, jaką przejechał po jej opuszczeniu i zwróćcie uwagę na jego zachowanie.

? Zastanówcie się

- Czy jechał prosto?
- Czy pasażer wypadł?
- Czy płynnie opuścił rampę?
- Czy koła mocno się chwiały podczas jazdy? Co możecie zrobić, aby samochód poruszał się płynniej?

1
Zidentyfikuj i zdefiniuj problem

2
Zbierz informacje

3
Generuj możliwe rozwiązania

4
Utwórz prototyp

5
Testuj i oceń prototyp

6
Udoskonalaj i/lub przeprojektuj rozwiązanie

7
Zaprezentuj lub zakomunikuj rozwiązanie

Proces projektowania inżynierskiego (EDP)

3

GENERUJ MOŻLIWE ROZWIĄZANIA

Poświęćcie kilka minut na wspólną dyskusję i naszkicowanie swoich pomysłów, nawet tych najbardziej szalonych!

? Zastanówcie się

- Z czego można zbudować karoserię samochodu? A z czego wykonać koła i osie?
- Jak możecie sprawić, aby koła obracały się swobodnie?
- Jak możecie zadbać o to, aby Wasz samochód jechał prosto?
- Jak ciężki powinien być Wasz samochód? Jak długi powinien być?
- Gdzie umieścicie pasażera? Jak zadbać o to, aby nie wypadł?

4

UTWÓRZ PROTOTYP

Macie około 40 minut na zbudowanie makaronowego samochodu. Dobrym pomysłem jest rozpoczęcie testów jak najwcześniej i częste ich powtarzanie, aby na bieżąco wprowadzać zmiany i ulepszenia. Obserwujcie również, co robią inne zespoły i zastanówcie się, czy niektóre elementy ich konstrukcji mogłyby ulepszyć plan Waszego zespołu.

Jeśli będzie taka potrzeba, możecie całkowicie zmienić swój projekt. Pamiętajcie, niepowodzenia są naturalną częścią procesu i pomagają nam zrozumieć, co działa, a co nie.



DYSKUSJA I REFLEKSJA W ZESPOLE



1. Jak bardzo Wasz pierwotny projekt był podobny do konstrukcji samochodu, którą zespół faktycznie zbudował?
2. Jeśli stwierdziliście konieczność wprowadzenia zmian w trakcie projektowania, dlaczego zdecydowaliście się je wprowadzić? Na jakich obserwacjach lub wynikach testów opieraliście się, podejmując decyzje?
3. Który samochód zbudowany przez inny zespół wydał się najbardziej efektywny lub interesujący? Dlaczego?
4. Gdybyście mogli użyć jednego dodatkowego materiału, co byście wybrali i dlaczego?
5. Czy uważasz, że wykonywanie tego ćwiczenia w zespole było bardziej satysfakcjonujące, czy wolałbyś/wolałabyś pracować nad nim sam/a? Dlaczego?
6. Czego dowiedzieliście się o inżynierii?
7. Jak myślicie, jaki związek to ćwiczenie ma z karierą inżynierską?

W DOMU



Może po powrocie do domu opowiesz swojej rodzinie o samochodzie, który zaprojektowałeś/zaprojektowałaś i zbudowałeś/zbudowałaś? Opowiedz, jak współpracowaliście w zespole podczas projektowania, budowy i testowania samochodu, jaki wynik osiągnął Wasz zespół oraz czego nauczyliście się o inżynierii.

Po tym jak już powiesz rodzinie o dzisiejszym ćwiczeniu, opowiedz im także, co ci się w nim podobało/nie podobało i co chciałbyś/chciałabyś zmienić lub dodać do tego ćwiczenia.

Jeśli chcesz, możesz także omówić z nimi niektóre pytania do dalszej refleksji.





Proces projektowania inżynierskiego

MATERIAŁY DLA UCZNIÓW

Proces projektowania inżynierskiego (EDP¹) to kluczowy proces, który stosują inżynierowie rozwiązując problemy i projektując rozwiązania.

1. Zidentyfikuj i zdefiniuj problem

Inżynierowie zaczynają od zadawania wielu pytań. Jaki problem trzeba rozwiązać? Kogo to problem? Co chcemy osiągnąć? Jakie są wymagania projektu? Jakie są ograniczenia? Jaki jest cel? Dzięki temu procesowi inżynierowie zaczynają identyfikować **kryteria** (warunki, jakie rozwiązanie musi spełniać, aby można je było uznać za skuteczne) i **ograniczenia** (granice, w ramach których muszą projektować).

2. Zbierz informacje

Inżynierowie dogłębnie analizują problem, zbierając **informacje i dane** na jego temat i na temat wszelkich istniejących rozwiązań, które można by zastosować. Aby wesprzeć badania, rozmawiają z ludźmi z wielu różnych środowisk i dziedzin.

3. Generuj możliwe rozwiązania

Teraz zaczyna się prawdziwa zabawa! Inżynierowie rozpoczynają **burzę mózgów** i opracowują jak najwięcej rozwiązań, niekiedy bardzo szalonych. To czas śmiałych pomysłów i odroczonej osądy. Ważne jest, aby rozwijać pomysły innych, jednocześnie skupiając się na sednie problemu i pamiętając o kryteriach i ograniczeniach. Na przykład, czy jeśli jest określony budżet, to czy potencjalne rozwiązanie da się opracować w ramach tego budżetu?

4. Utwórz prototyp

Inżynierowie wybierają jedno lub więcej najbardziej obiecujących rozwiązań do **prototypowania**. Prototyp to działający model, który należy poddać próbie.

5. Testuj i oceń prototyp

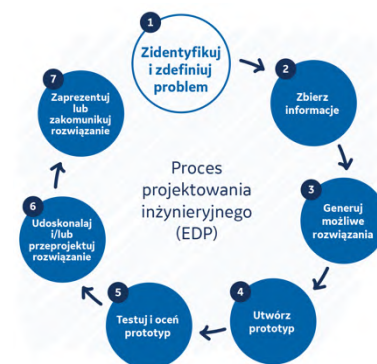
Większość prototypów **zawodzi**, ale to dobrze. Podpowiada inżynierom, na jakich pomysłach powinni się skupić. Inżynierowie muszą również zdecydować, czy projekt rzeczywiście rozwiązuje pierwotny problem.

6. Udoskonalaj i/lub przeprojektuj rozwiązanie

Po zdobyciu wiedzy w wyniku testów inżynierowie **projektują na nowo i ponownie testują** dopóty, dopóki nie znajdą optymalnego rozwiązania – takiego, które równoważy kryteria i ograniczenia.

7. Zaprezentuj lub zakomunikuj rozwiązanie

W końcu inżynierowie dochodzą do punktu, w którym są zadowoleni ze swojego rozwiązania. Nie musi być ono idealne, ale powinno „**zadowalać**” – spełniać kryteria w ramach ograniczeń. Inżynierowie następnie dzielą się swoimi rozwiązaniami z innymi.



¹ Źródło <https://www.teachengineering.org/design/designprocess>



Pasta Car 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 cars made entirely out of dry pasta. While safely carrying a passenger, these cars must roll down a ramp and then coast as far as possible. However, teams also need to consider material efficiency. They will need to buy all the pasta they use from a central store with a limited budget. Each team will then get a score calculated as follows:

$$\text{score} = \frac{\text{coasting distance achieved (cm or in)}}{\text{total cost}}$$

- Success criteria
 - The vehicle must coast as far as possible after rolling down a ramp.
 - The vehicle must be able to carry a passenger.
 - It must be easy to insert and remove the passenger.
 - The passenger must not fall out of the vehicle at any point during the journey.
- Constraints
 - Teams may only use the materials provided.
 - Teams must remain within the specified materials budget (suggested budget is 130 - 150).
 - Teams must complete the activity in the time allocated.

Possible design solutions

The three key challenges in this activity are to create a vehicle that:

1. Has an optimal and balanced mass to maximize the amount of kinetic energy it has at the bottom of the slope
2. Is able to roll as straight as possible, both down the ramp and while coasting
3. Minimizes friction - especially between the axle and the body and between the wheels and the ground

Very light cars are unlikely to have enough kinetic energy to coast very far. However, the heavier the car becomes, the greater the friction it will experience and the more robust it will need to be. Leaving the bottom of the ramp can cause



FACILITATION NOTE

This challenge is customizable in terms of the exact passenger the cars need to carry, the budget teams are allowed to spend, and the size and slope of the ramp. 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

An important factor some teams may overlook is the size of the car. Cars with a longer wheel base tend to roll straighter. Any misalignment between the front and rear wheels is more accentuated the shorter the wheel base.



poorly constructed cars to break. Heavier cars will also tend to roll straighter due to their increased momentum.

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:

- How big will you make your car? Are there benefits to a bigger or smaller car, especially in terms of the distance between the axles?
- What will you use for the body of your car?
- What will you use for the wheels and axles? How will you connect the wheels to the axles? How long will you make your axles?
- How long will your wheelbase (the distance between the front and back axles) be? What effect does the wheelbase have on the car's performance? Are longer cars better?
- How can you make sure that your wheels spin freely with as little friction and wobble as possible?
- What can you do to make sure that your pasta car travels as straight as possible down the ramp and while coasting?
- How heavy do you think you should make your car? Can you make it too heavy?
- If you do add extra mass to your car, where do you think you should add it – the front, the back, or the middle?
- Where do you think you should place the passenger?
- How will you keep the passenger from falling out during the journey?

Key testing questions

As teams build, encourage them to test early and often. They can test how far their cars coast on the ground just by giving it a push, but they will also need to do some tests on the ramp. In particular, they need to check that their passenger does not fall out of the car - especially as the car hits the ground.

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

- Does your pasta car roll straight? If not, in which direction does it turn? Why do you think this is?
- Does the passenger fall out at any stage of the journey? How can they be better secured while still making it easy to get them in and out?
- How smoothly does your car leave the bottom of the ramp? Does this cause your car to lose lots of energy?
- Is there a difference in performance when the car rolls 'forwards' or 'backwards'? Why might this be?
- How have you distributed the car's mass? Is it evenly distributed or concentrated? What are the benefits in each case?
- Do the wheels wobble when the car moves? How can you reduce the amount of wobble?



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.

