Robogals Science Challenge

Minor Challenge Set #4
STEM Field: Civil Engineering
Level: Senior
Challenge Name: Build The Tallest Tower
Project Cost: 0-20 USD
Materials Required:

- Maximum 30 pieces of paper (printer paper, notebook paper, graph paper allowed) of A4 size (210 mm x 297 mm, or equivalently 8.5 in x 11 in)
- 1 roll of one-sided, clear tape (office tape or masking tape allowed)
    - Note: Double-sided tape is **not** allowed
- Tools:
    - Scissors
    - Ruler, and/or tape measure
    - Pen, and/or pencil
    - Drafting paper to design or plan how to construct your tower
    - Stopwatch
- Unopened can(s) of food, up to a total weight of 400-500 grams (or equivalently 14-17 ounces). You may like to use different sizes of cans of food when testing the tower.
- Horizontal, even surface for testing, for example: table, floor

Safety:

- Do **not** use any glass materials for testing as they can shatter if they fall off your tower
- Be careful when handling scissors or sharp edges of paper

Duration:

- The challenge takes approximately 2-3 hours to finish, however, the time guideline is an estimation only, and students and mentors can complete the tasks around their schedules
- It is recommended students attempt to build the tower individually, or in pairs. Adults assistance is recommended for testing, and calculating materials cost at the end of the challenge

Introduction:

Throughout the world, engineers have designed many observation towers. For example, in the pictures below, from left to right, we have the Shanghai Tower (China), Space Needle (USA), and the Eiffel Tower (France).

This challenge is all about building the tallest tower possible with a limited amount of materials! Your tower is built using only paper and tape, but it must also support a can of food at the top.

For some inspirations, you can check out previous designs from the 2021 Fluor Engineering Challenge here:

Tallest Tower: 2021 Fluor Engineering Challenge

We will give some background information in the Instructions section. You are encouraged to do your own research if you need more ideas on how to design, and build towers.

This is an engineering design project, which means you are encouraged to start by **identifying** the problem, **developing** possible solutions, **making** prototypes, **testing** and **evaluating** your prototypes, then finally, **improve** on the design.

Your design does NOT need to be perfect from the first try! You are encouraged to build individual components of the tower, test, make necessary modifications, before combining all components into one final complete tower.

Instructions:

This is an engineering design project. There are no specific instructions on how to build your tower – you have the total freedom to design, and build! There are some design, and testing specifications you will need to adhere to, which are listed below. There are also scoring guidelines, which you need to follow to calculate the score of your project.

Design specifications:

- You are allowed to fold, bend, and cut the paper. However, if you only use half a sheet of paper in the final design, when calculating the materials cost, you must still count the entire sheet of paper

- You are allowed to build individual parts of the tower, test each part, before connecting parts together in the final design
- You cannot use any tools such as pen, pencil, or ruler as part of the final tower design. Only paper and tape count!
- For this challenge, materials used to test individual parts do **not** count towards the final material cost. However, in real life, depending on the project, the testing materials may be counted towards the cost of the whole project!

Here is a rough plan of four steps you can follow as you work through your engineering project.

Step 1: Design

It is a good idea to brainstorm how you want to build the tower. Try sketching your designs on paper. Remember to take into account the amount of paper you need to build the tower, and the weight of food the tower can support.

Here are some starting points to help with your design:

- Consider starting with a strong, wide base for the tower to sit on. For example, the Eiffel tower has a four-legged base, making it stronger.
- **Beams** are long, skinny elements used to make structures like towers and bridges.
- **Truss** is a structure that is made up of connected elements to form a series of triangles. Generally, trusses are used to strengthen the structure of towers and bridges. The Eiffel Tower, for example, is made up of a network of triangular shapes.
- The shape of a beam can affect its strength. For example, it is very easy to bend a flat piece of paper. It becomes much harder to bend the paper if you fold it in half multiple times, or roll it into a tube.

The pictures below are three examples of paper towers that comply with the design specifications.

Step 2: Build

It's time to build your tower!

You can build each part of the tower individually, for example, single beams, or connections between beams of the tower, before you try to build the entire tower.

You may also want to test your tower as you build it, for example, pressing on it gently to make sure the tower is sturdy enough. Remember that your design may not work as you had planned, and that is okay!

Step 3: Testing

When you have completed your tower, you can tape it to a flat surface. Then, gently placing a can of food. You can use different cans of food of different weights. Try adding more weights until your tower breaks.

Note that if the tower collapses, the food cans will fall down, so be careful when testing!

Here are some testing guidelines you need to follow to test your tower design.

Testing guidelines:

- The can must **not** be taped to your tower.
- Your tower can only be taped on the surface it rests on. You cannot tape the tower to anything else, or supported by a person
- The can of food must stay for 15 seconds to be counted as a successful test. You cannot touch, or modify the tower during this testing time of 15 seconds.
- When measuring the height of the tower, ensure you are measuring from the flat surface it rests on.

After testing your prototypes, you may need to do some troubleshooting and modify the design. Here are some troubleshooting steps that may help you:

- If the tower is falling easily, then the base may not be wide enough, or the tower is unbalanced.
- If the tower bends when you put the can of food at the top, then the structure may not support the weight evenly. You may need to support the structure.

Step 4: Calculating Score

You will now calculate the total score for your tower design, follow the scoring guidelines below.

Scoring guidelines:

- Height of the tower (you can round up to the nearest whole number):
    - Between 0-5 cm (inch): +5 points
    - Between 6-10 cm (inch): +10 points
    - Between 10-15 cm (inch): +15 points
    - Above 15cm (inch): +20 points
- Weight of the can of food the tower can support:
    - Between 0-100 grams (pounds): +5 points
    - Between 100-250 grams (pounds): +10 points
    - Between 250-400 grams (pounds): +15 points
    - Above 400 grams: +20 points
- Materials cost:
    - Each piece, or sheet of paper used: -2 points
    - Tape (regardless of amount used): -3 points

Extension - Triangles in Structures

We briefly talked about how truss is a network of triangular shapes. Learn more about how architects use triangles in their designs with this Google Earth activity. This is a presentation on Google Earth, featuring how triangles are incorporated in designs of buildings around the world.

Google Earth - Triangular Structures

Reflection Questions:

- Are there any improvements you would make to this challenge?
- What real world application/s can you apply this challenge to?
- What are the key science and engineering concepts that relate to this challenge?

- What is the total score for your tower design? Include a breakdown of the points you earned from each category, based on the scoring guideline.
- What did you find difficult about building a paper tower? How did you overcome this challenge?
- If you have more materials to build the tower, which materials do you also want to use to build the tower? How will this improve your tower design?

Submission Guidelines:

- Submit photos of your tower design, and the paper tower you built. Include a short summary that addresses the reflection questions.

> Note: Remember, if you want to upload pictures of your Minor Challenge that also include you, please check if it is OK with your parent or guardian first.

- The submission form is on the Minor Challenges page: https://sciencechallenge.org.au/index.php/minor-challenges/
  Fill out the details and make sure you upload your submission.

Learn More! Resources:

- If you enjoyed this challenge, you may like to read more about what architects and civil engineers work on:

  Architect:
  https://careerdiscovery.sciencebuddies.org/science-engineering-careers/engineering/architect

  Civil engineer:
  https://careerdiscovery.sciencebuddies.org/science-engineering-careers/engineering/civil-engineers

Bibliography:

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