

# Cardboard Tower Design Notebook

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## Instructions

The following are the instructions for completing this design notebook:

- You must document EVERYTHING
- Entries should be made by every team member (not just one person), initialed, and dated.
- All designs and changes to your design should be recorded directly into your notebook. The inclusion of all elaborate details and sketches are preferable.
- Notes and calculations should be inserted into your notebook, NOT only on loose paper.
- In the case of an error, draw a single line through the incorrect data. Do NOT erase or use correction fluid. All corrections should be initialed and dated. Use both sides of a page. Never leave any white space: "X" out or Crosshatch all unused space, and don't forget to initial and date. To insert pictures or outside information into your notebook, tape the picture into your notebook and outline with permanent ink, to note that it was there in case it falls out.
- Pictures or sketches of your design throughout the process are not just recommended, it is required.
- Include contact information of any outside advisors so that you can easily contact them again (even when you just drop by your professor's office to ask a quick question).

## Proof of Concept

### Problem Re-Statement (Recognize the Need)

- In your own words, provide a brief discussion of why we are doing this project.

This project, while teaching us about the basic of statics is valuable in the experience we get as designing a project as a team. This project is teaching us the valuable design process and skills needed for a team to successfully plan, build, and complete a large-scale project effectively as a team. This is the penultimate experience we believe we should take away from this project.

### Problem Scoping (Define the Problem)

- What are the objectives?
- What does this project need to do? Or not do?
- What variables do we need to consider?
- What questions do you need answered to ensure that you understand how to complete this design?

The objective of our project is to construct a tower than can hold the weight of a Klein unit without falling. The tower must strictly be built from glue and cardboard. Some variables to consider are any daily weight fluctuations of Mr. Klein. We need to know exactly how much weight each joint needs to support to ensure that the forces throughout the tower are distributed properly. We also need to know how much a Klein unit is roughly.

## Project Constraints (Research and Prepare)

- What are the technical requirements?

The technical requirements are that the tower must support a load of roughly 165 lbs. The tower must be constructed by cardboard and held together by glue. It needs to be roughly 8 inches wide and 24 inches in height with 8-inch members.

- What are the material requirements?

All materials must be either corrugated cardboard or file folder material.

- What do we know about things that already exist that do this?
- What kinds of things already exist that meet similar requirements?
- Reverse engineer one or more of these things. How might it be useful to complete this project?
- Use additional pages as necessary

A truss which holds up a crane is very similar to this design. By looking at the design of this truss it can help us get useful information about how to construct our own tower.

By looking at the design of the structure supporting this crane we can notice that all members are of equal length. This is something we can incorporate into our own design which helps balance the forces throughout the structure. At each joint there is a supporting guss. On top of that there are cross-sectional joining members which help nullify the cross forces on the horizontal members.



- What are the limitations we have based on our available materials?

There are many limitations to consider with cardboard. Cardboard is very flexible, its not something to be considered brittle. The disadvantage in this is that it can often bend heavily in a way of which it can't be repaired. It also is not as supportive load wise as other similar materials like wood.

Another limitation to consider is the glue we use to hold it together. While this is a strong variant of glue, glue in general is not very efficient in the long term. It could corrode away or possibly shift while drying causing unforeseen effects.

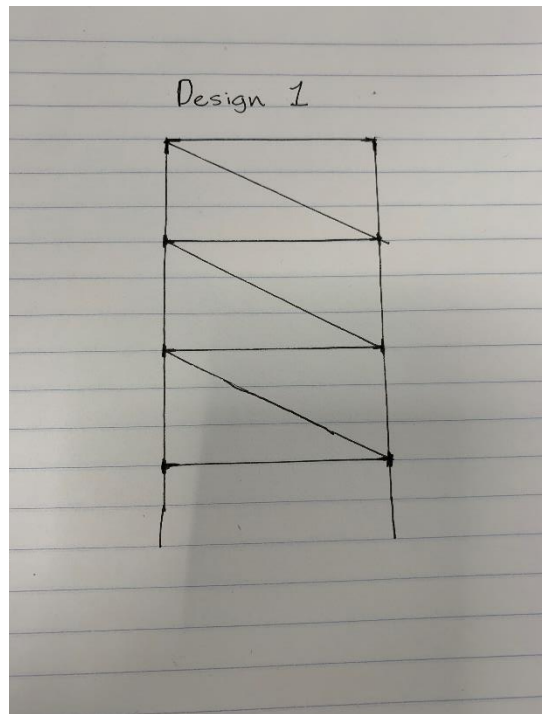
## Identify Possible Design Solutions (Conceptualize Part 1)

### Possible Design Solution 1

- *Draw your design idea*
- *Why do you think it will work?*
- *Look around you, what do you see that is similar and might work?*
- *Justify your idea. (Use additional pages as necessary)*

This design here utilizes the cross-sectional members which will help support cross load. When we learned truss calculations, we used a design similar to this to show the advantage of having a cross sectional member which helps nullify force on the side of the tower.

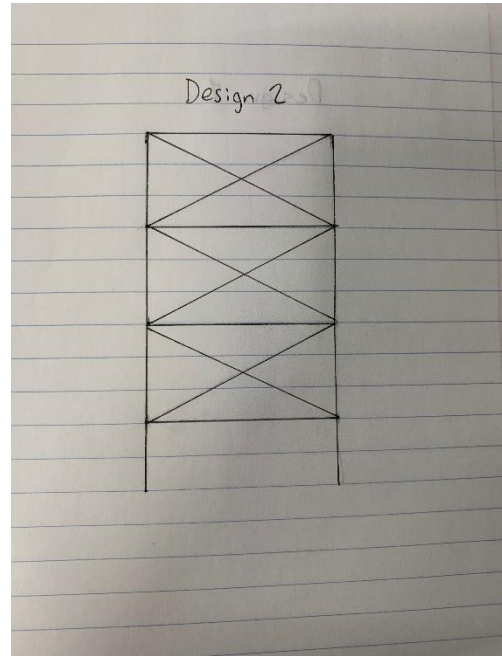
Along with that, there's even side members which will allow the force to be distributed evenly throughout the tower making it much more stable



### Possible Design Solution 2

- *Draw your design idea*
- *Why do you think it will work?*
- *Look around you, what do you see that is similar and might work?*
- *Justify your idea. (Use additional pages as necessary)*

While this design is extremely similar to design 1, we decided it would be more beneficial to add cross members in both directions. This tower has all the advantages of design 1, but the additional advantage that there is a cross sectional member nullifying side force in both directions to help make it more stable.





## Evaluate Design Strategies (Conceptualization Part 2)

- Which design will do a better job meeting the goals based on the given criteria?
- What components are necessary for completing each design?
- How did you come to your decision?
- What design idea can be completed in the time frame?
- What design idea can be completed with the budget?
- What design idea can be completed with the materials?
- Use additional pages as necessary

Design 2 is clearly more effective than design 1. The additional cross-bracing provides extra support for the tower and allows it to better achieve the goals our team has set.

We came to this decision by analyzing the constraints required and then, using truss calculations, determined the mathematical validity of our design.

Design 1 and Design 2 both require several cardboard beams, both requiring 12 horizontal beams and 4 large vertical beams. The differences lie in the manila folder diagonal cross members, where design 1 requires only 12, but design 2 requires 24. However, we feel the extra cross-sectional members will help strengthen our design.

Both designs meet the constraints regarding time, budget, and materials.

## First Cut of the design (Synthesis Part 1)

- Think about the materials involved:
  - What testing do we need to do to ensure that these materials work?
  - What do we know about the materials we have?
  - What do we know about the nature of what we are about to build?
  - What details do we need to input and consider?
  - Provide a materials list (specify amounts needed)
- Provide a detailed drawing (size and tolerances) of the projected build
- Provide a detailed time line for completion of the project
- Use additional pages as necessary

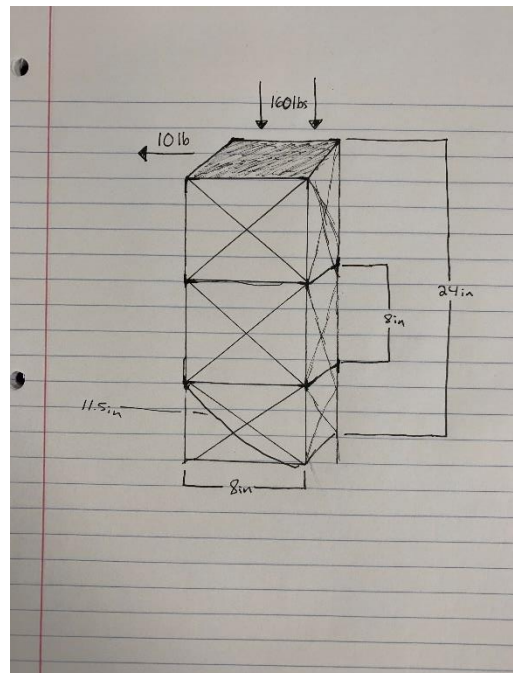
In regard to the materials involved, it is necessary that we test the materials with weights just to ensure they hold at all. We know that there is going to be a lot of load on top of the tower which will cause bowing and bending on the edges.

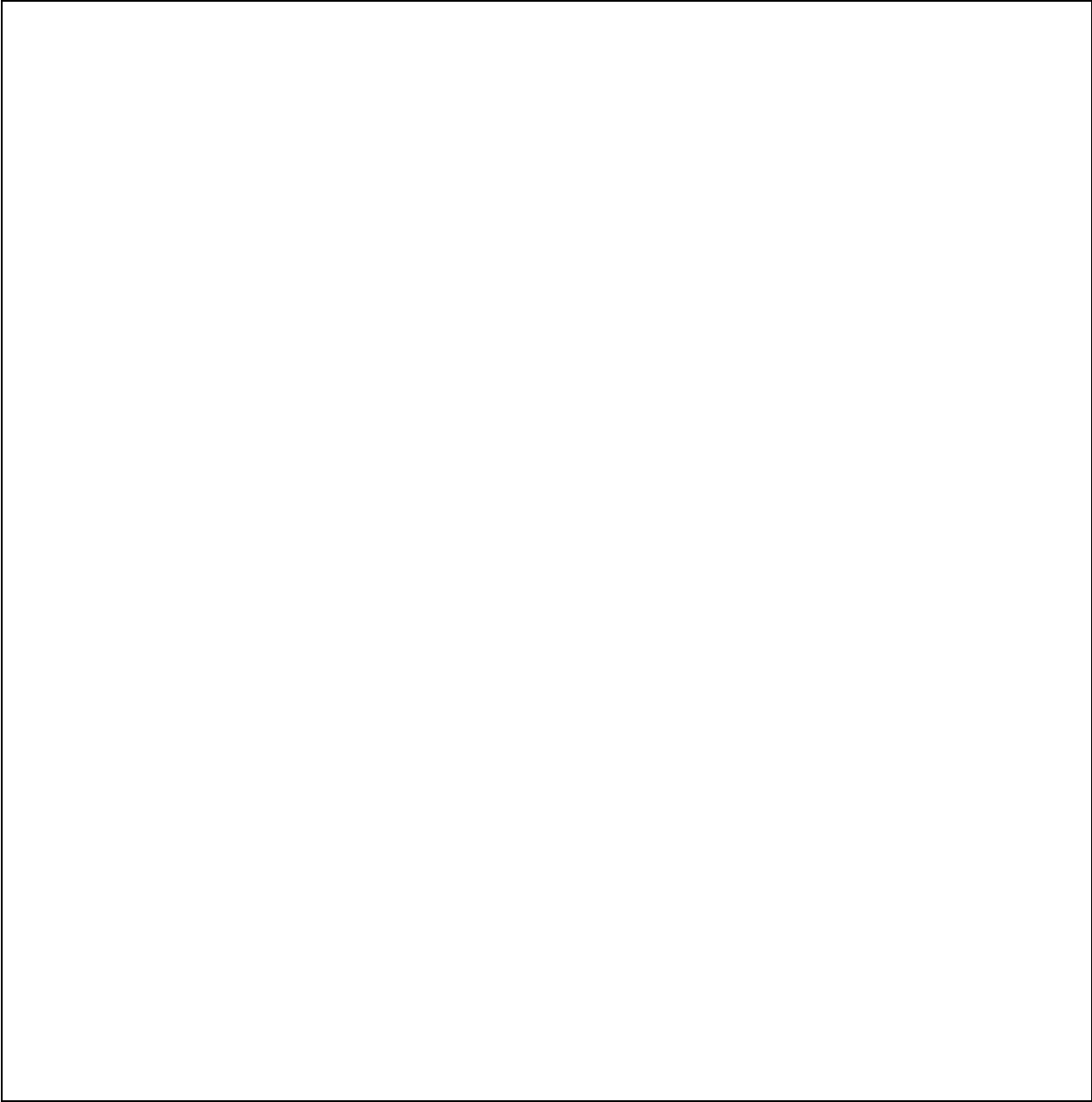
Materials wise we will need:

Both thick and thin corrugated cardboard  
Several manilla filing folders

Timeline:

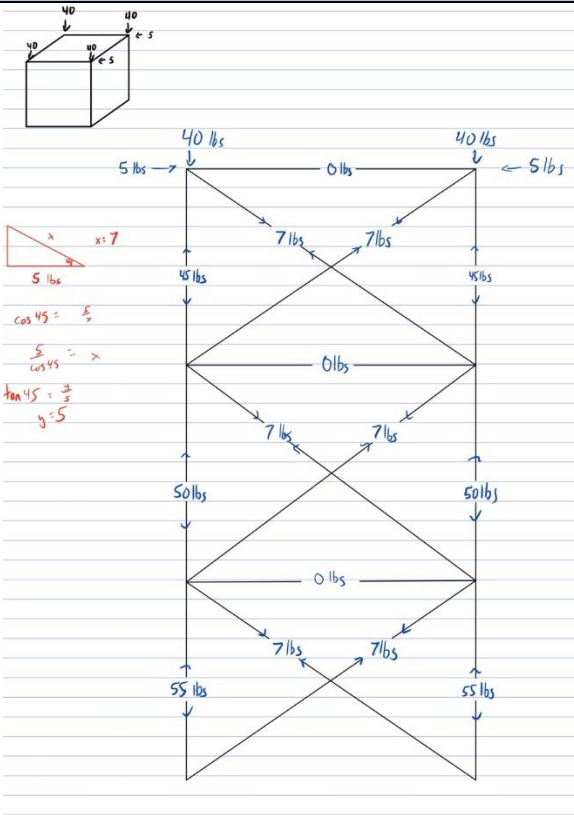
1. Layout molds for beams
2. Set glue and let dry for beams
3. Glue beams into one of four frames
4. Let glue dry in beams
5. Glue all four frames together to create tower shape
6. Cut out cross sectional members and attach to frame
7. Let glue dry throughout tower
8. Test tower in class





## Model (Synthesis Part 2)

- Using your engineering knowledge, show that your design will work.
- Math, Physics, Chemistry, Other engineering knowledge
- Justify the design and prove that it can be built.
- Use additional pages as necessary



In class we learned about truss calculations and the importance of them to designing something like a tower. By using the strategies in class we created this similar mathematical model to prove our concept of design works by balancing the forces throughout the tower. This gives us confidence in our design concept's ability to work.

## Validate Calculations (Evaluation)

- Do my model calculations make sense? Why?
- Are there other considerations I need to address? What are they?
- Did I identify the critical design parameters?

The calculations done do make sense, by using the estimated vertical and horizontal load it allows us to use the basic ideas of static forces to create our model in which nullifies the forces on each joint member creating a stable tower which mathematically speaking can hold the determined load.

What is not considered in the model is the possibility of extra force being applied to the tower, this however is something considered when designing the tower by using a factor of safety in our design.

The critical design parameters are the force that each member needs to hold and by relation the dimensions each member should be to support that force.

## Optimization

- Can I create a better design?
- Can I improve on any of the criteria?

It is possible to optimize the design if we were to have different limitations. Cardboard, albeit extremely useful, is not the best material to design a tower meant to hold the weight of a human body. By changing the materials, it would allow us to increase both the maximum loads and increase the factor of safety on the tower which would mean a much better outcome for consumers.

## Design Demonstration Documentation

### Document Build (Presentation Part 1)

- Use photographs and narrative to explain your building process.
- Include documentation of any changes in the design during the build process
- Include any interim test data, thoughts, etc.
- Use additional pages as necessary



Members were previously molded from pre-cut wood and one side of the frame is laid out (above) ready for gluing.



All four frames have been glued together and now it is time to glue the cross-section members onto the frame

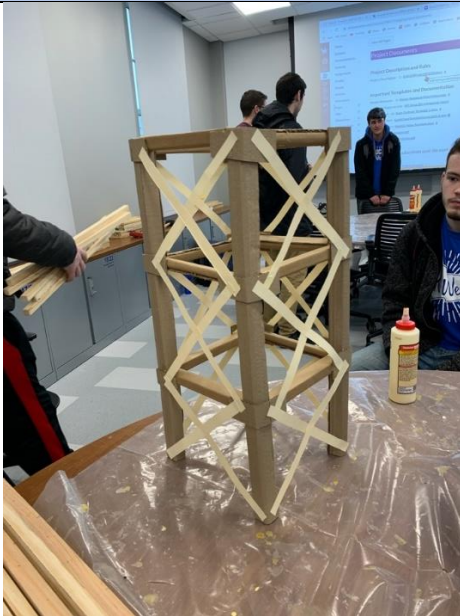


Gluing is complete and now the frame will sit to allow the glue to dry throughout the build



## Show Completed Construction (Presentation Part 2)

- Insert an image of completed build
- Provide a demonstration that the design worked
  - Photographs
  - Collected data
  - Videos, etc.







## Lessons Learned

- Provide a discussion of the major lessons learned during this design process (each team member must provide an entry)
  - About design
  - About project management
  - About working with a team

Brennen Green:

The design was interesting, and I learned the importance of documenting the entire design because it really makes you an expert over what you've created. I've learned project management can be interesting, it's fun to keep a project organized and held together in order to keep making progress towards a goal. Working as a team have always been interesting to me, so being able to do something like this and build my team cooperation skills.

Brent O'Donnell- There were many lessons to be taken away from the tower building process. Working as a team was and communicating others was the most important lesson that was expanded upon. Communicating your ideas and taking in others is not always the easiest thing if people disagree in things. However, for this project, everyone communicated well, and the process went as smooth as one could hope for. Everyone took ownership of what they needed to do and completed their section.

Jacob Compton: The major lesson I've learned through this tower project was how tasks can be split among teams evenly. I've usually dealt with an imbalance of workload on team members in projects in the past so it was nice to see the workload spread evenly among the team members evenly throughout this project. This project has also taught me about how structures are built to hold a certain amount. Since I don't usually deal with material construction or structure calculations, I have learned a lot about what holds up a structure.

Ben Browning- One of the major lessons that I learned was that was that keeping a project organized can greatly improve the product. Each team member did their own part, which allowed for everything to go smoothly. When we were designing our project, I learned how to do truss calculations, so that we would know how to build our product without it breaking. Even though our product was made from cardboard, we made our calculations correctly and it was able to hold up when testing.

Jacob Rice – One major lesson I learned regarding design was to not judge a book by its cover. We were one of the few groups that still had our doubts that the tower, made of cardboard, glue, and strips of a Manila folder, would hold a single Klein Unit (160 lbs).

Adam Reynolds – A major aspect of this project was the division of responsibilities; everyone was at work, but all on different projects, maximizing efficiency. The various responsibilities of each person made it easy to keep on schedule while also ensure everyone had a clear idea of their work. The design aspect also provided key educational experiences, especially through the detailed documentation. Every design choice must be justified in writing in order to be valid. This exercise also helped us develop a team bond, allowing us to mesh better in the future.