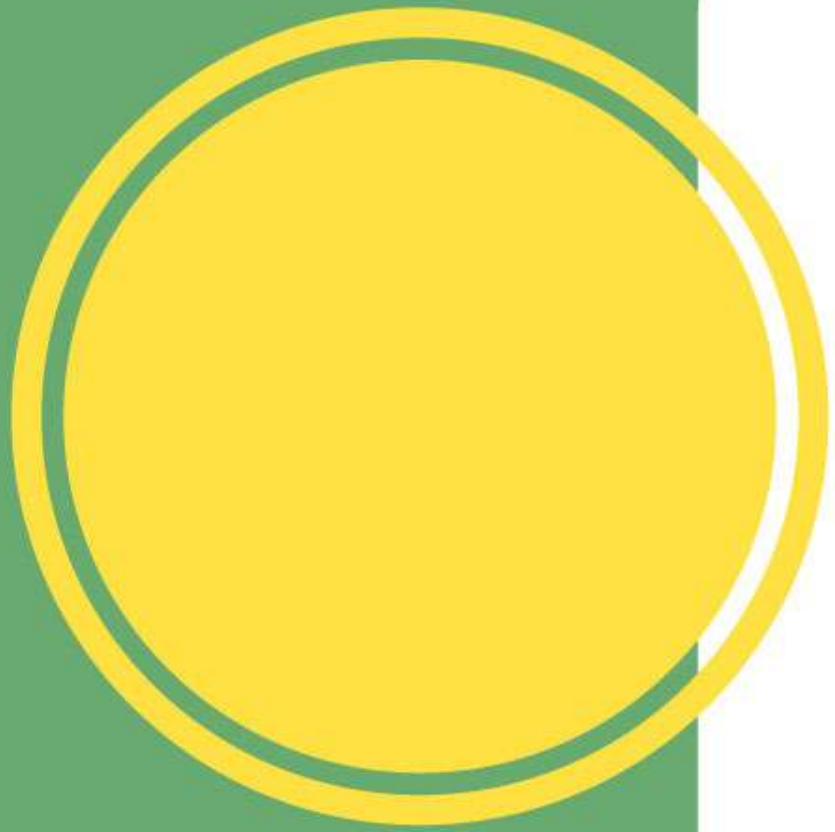


Civil Engineering

Civil Engineering

- Build safe facilities to meet societal needs
- Public works projects
  - Roads, bridges, dams, municipal water systems
- Subfields include structural, water resources, transportation, environmental, construction, geomatics engineering

Professional Aspects

- Bachelor's degree required
- Associate's degrees for technicians
- American Society of Civil Engineers
- Also International Association for Bridge and Structural Engineers (IABSE), Institute of Transportation Engineers (ITE), American Planning Association (APA)

Civil Engineering Principles

- All civil engineers must understand structures
- A structure is an arrangement of parts built to remain stable while withstanding forces.

rkriminger/Shutterstock.com

Structures

- Arrangement of parts built to remain stable while withstanding forces
- Structural loads
- Structural forces
- Structural components
- Structural materials
- Structural analysis

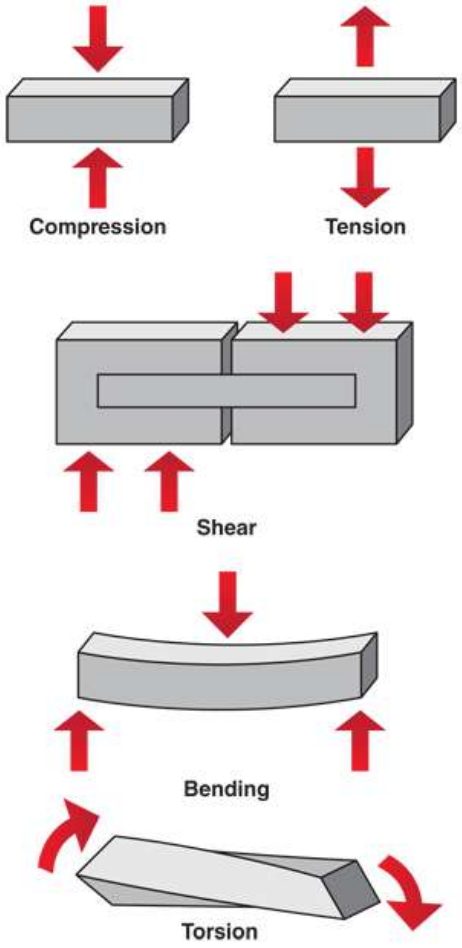
Nuttapark/Shutterstock.com

Structural Loads

- Loads are weight that must be held by structures
- Structures transmit load from structure to ground
- Static loads, dynamic loads
- AC unit on roof, snow, heavy rainfall

TFoxFoto/Shutterstock.com

Structural Forces



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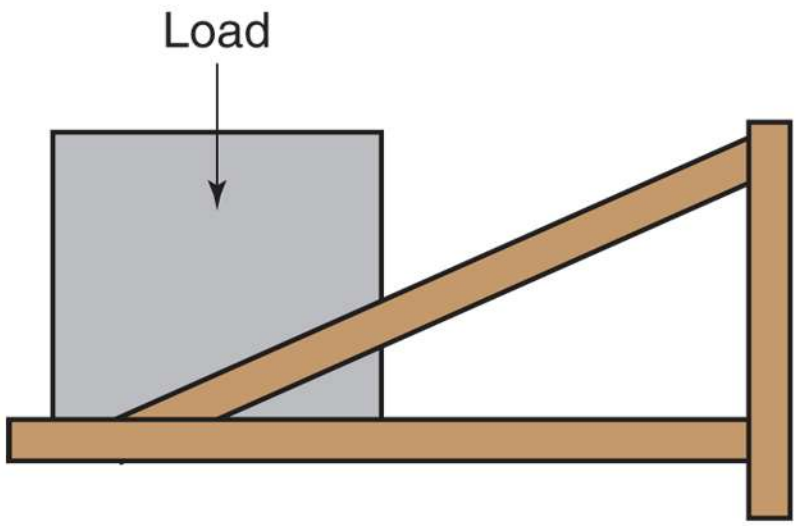
Structural Components

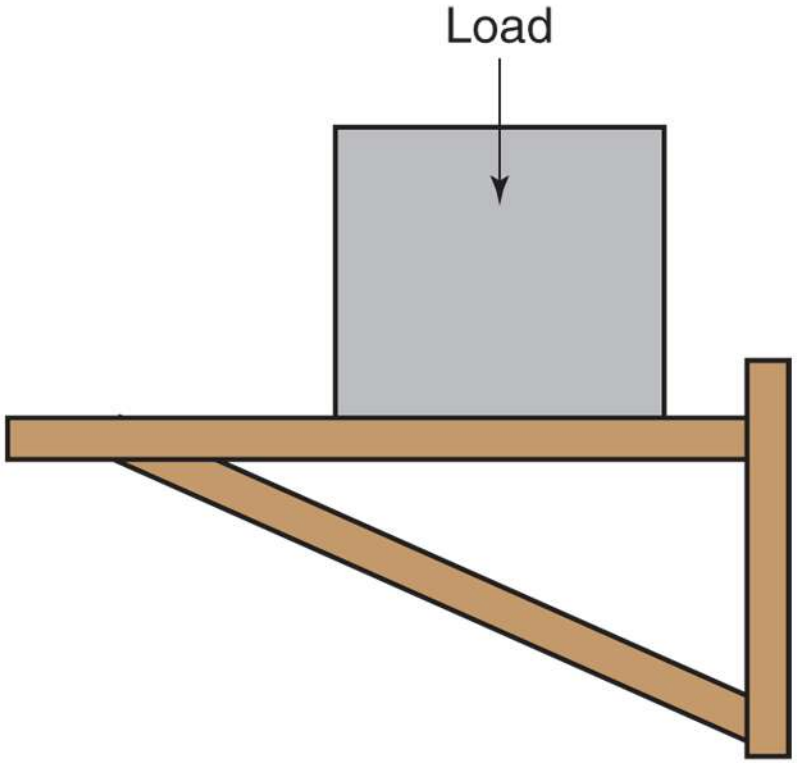
- Beams
  - Floor joist
- Columns
- Braces
  - Struts
  - Ties
- Joints

3drenderings/Shutterstock.com

Ties and Struts



Tension Tie



Compression Strut

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Structural Materials

- Stone
- Bricks
- Wood
- Concrete
- Steel
- Even Paper
- Carbon fiber
- All materials have advantages, disadvantages based on properties

Examples of real world projects

- **Cardboard Cathedral**

  After a 2011 earthquake in New Zealand, engineers built a temporary church out of 98 massive cardboard tubes. The tubes are anchored on a foundation of shipping containers. The temporary church was designed to last for 50 years, or long enough for the community to build a permanent stone church. The town will dismantle and recycle the cardboard cathedral in the year 2063—if the people haven't grown too attached to it!

- **Paper House**

  In 1922, a mechanical engineer built a vacation home out of paper. He glued newspapers together to make one-inch-thick slabs and then used the slabs to make the walls. The paper was supposed to be the insulation for the walls. But it was never covered with clapboards. Today, more than 70 years later, it's still standing!

© Rockport paper house/Guzelian

y accessible website.

Structural Analysis

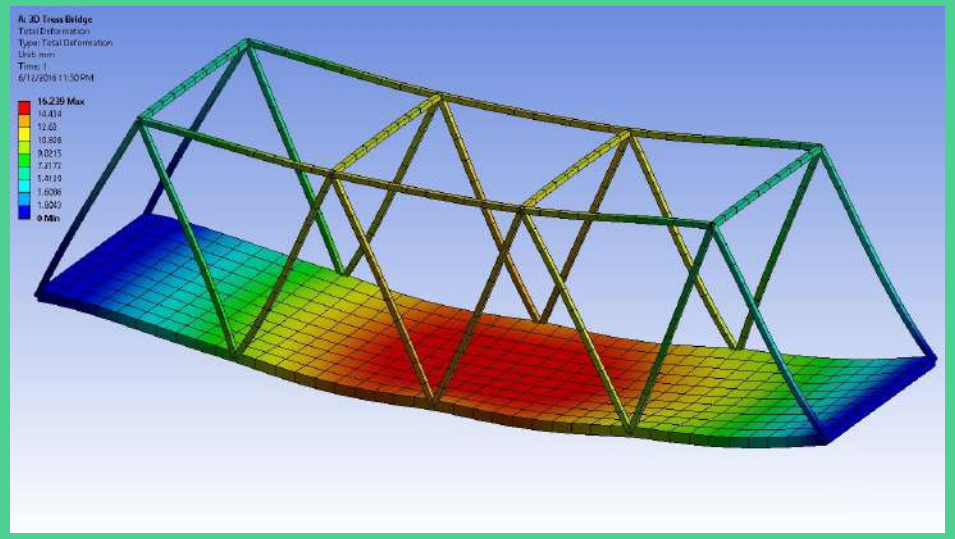
- Responsibility of structural engineer
- Ensures structure has sufficient strength (safety)
- Ensures structure is as efficient as possible (cost effective)
  - Makes best use of materials
- Incorporates physics, especially mechanics
  - Statics
  - Dynamics

Design
Civil Engineering Software

- Field specific
  - Planning
  - Drawing
  - Organization
  - Simulation
- Typically includes symbols

Force Analysis Simulations

- Simulations use computing power to quickly solve a large amount of algebraic equations.
- They help us create safer designs without having to waste expensive test materials.
- We prove the accuracy of our simulations by comparing simulated results to observations.



Civil Engineering Applications

- Bridges
- Skyscrapers
- Dams
- Tunnels

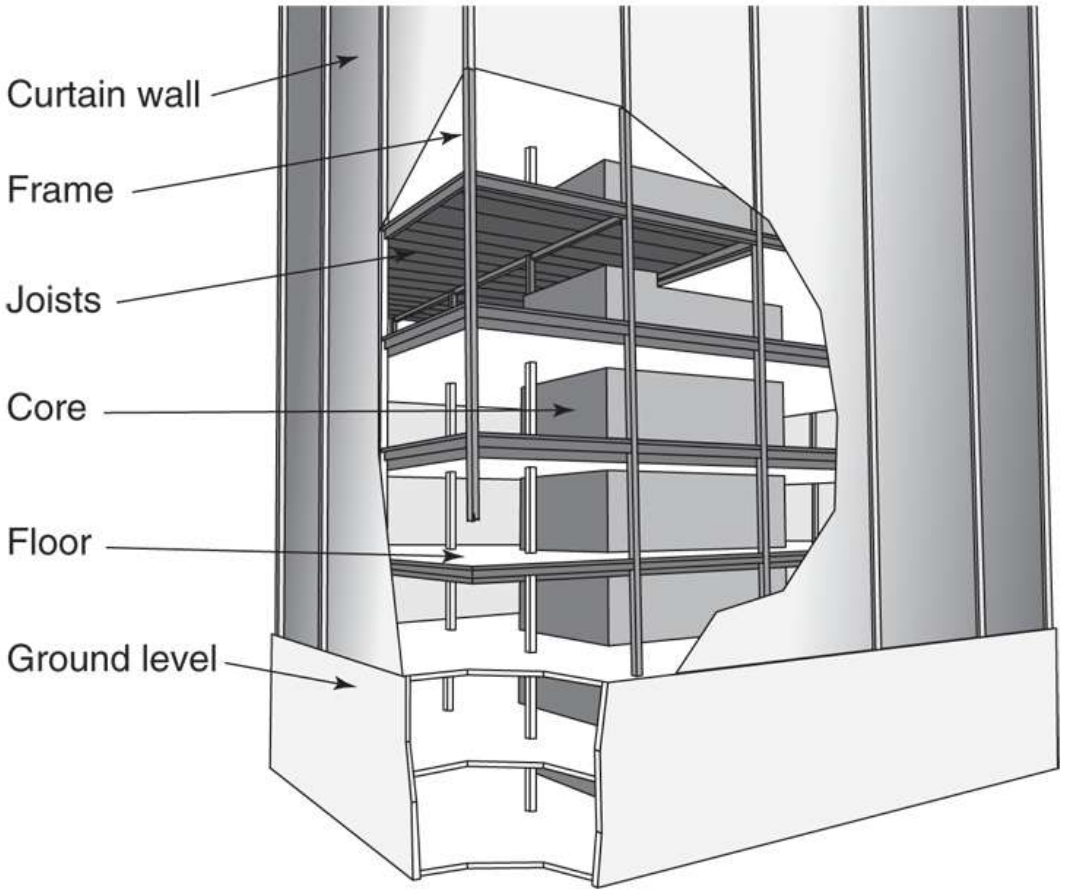
dvoevnore/Shutterstock.com

Skyscrapers and Buildings

Skyscrapers

- Structural frame (skeleton)
  - Withstands building dead load
  - Attached to footings, piers extend deep into earth
- Outer surface does not carry weight
- Central core
  - Helps resist wind
  - More resistant to earthquakes
  - Contains elevator shafts, mechanical systems

Skyscraper Components



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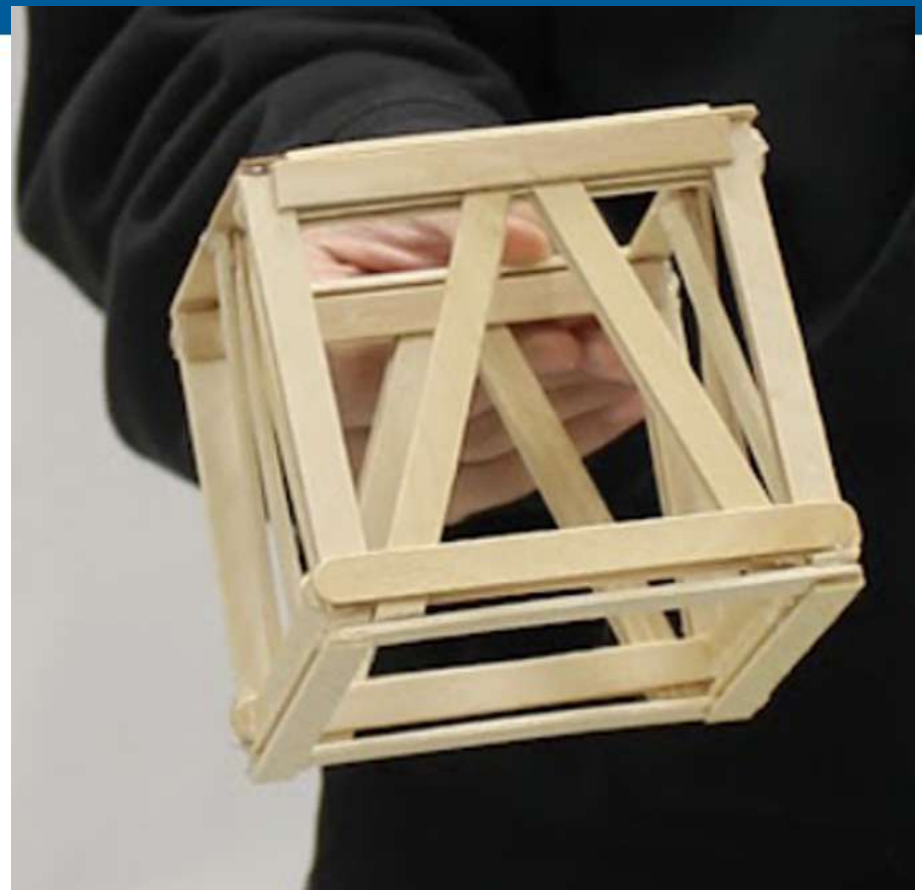
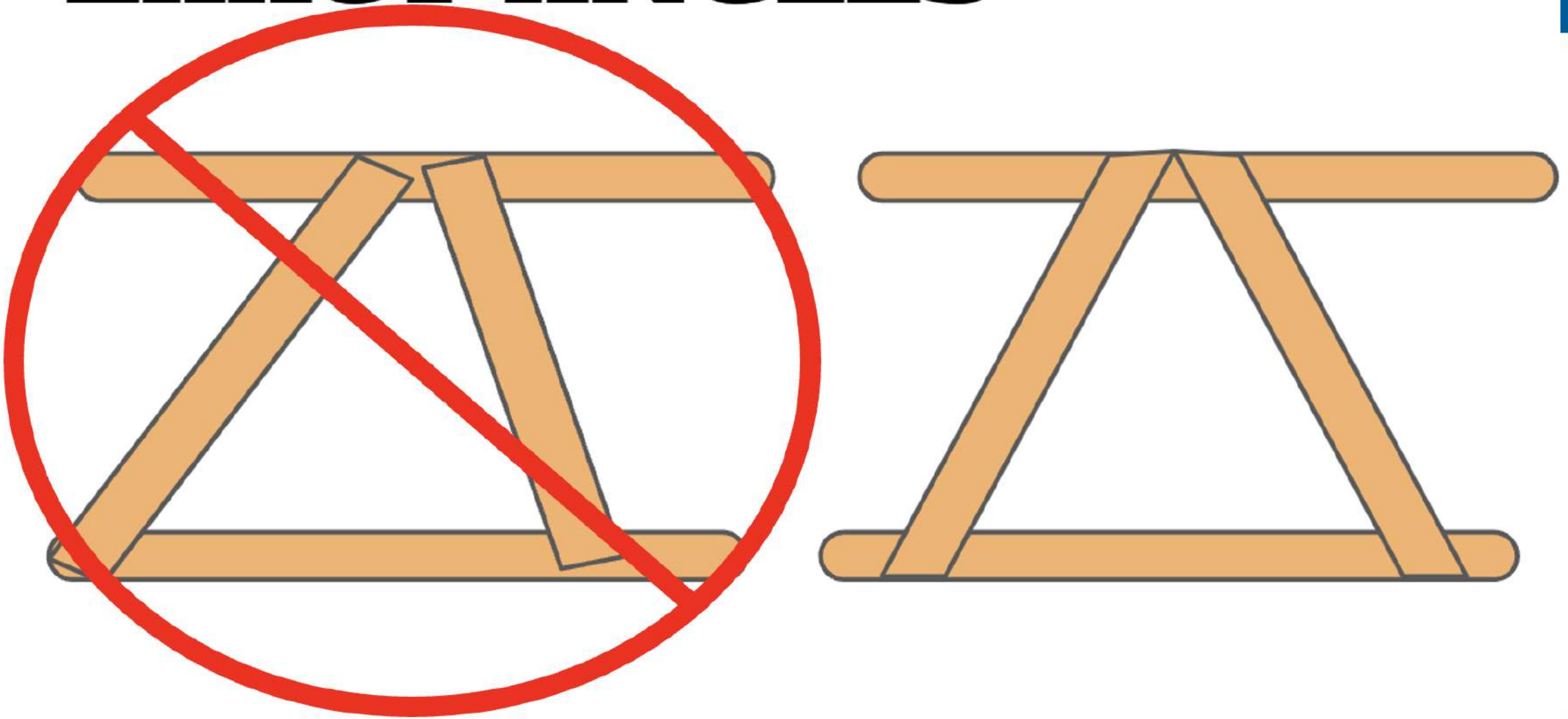
Daily Grade- Cube

- (1 popsicle stick tall each floor)
- Popsicle sticks and liquid glue only.
- NO HOT GLUE!



Popsicle Stick Tips:
EXACT ANGLES



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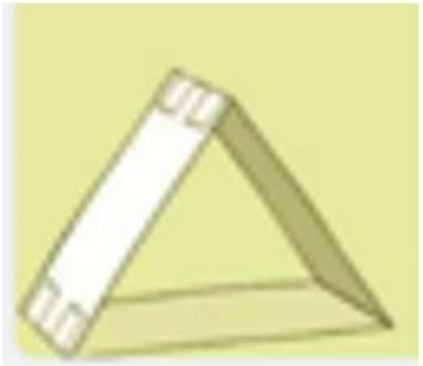


WEAKEST

This is the shape you should use in your design.

The sides of triangles are very **rigid**, which allows them to transfer force more evenly through their sides than other shapes. As a result, a triangle can withstand a lot of **strain**, making this particular shape very strong.

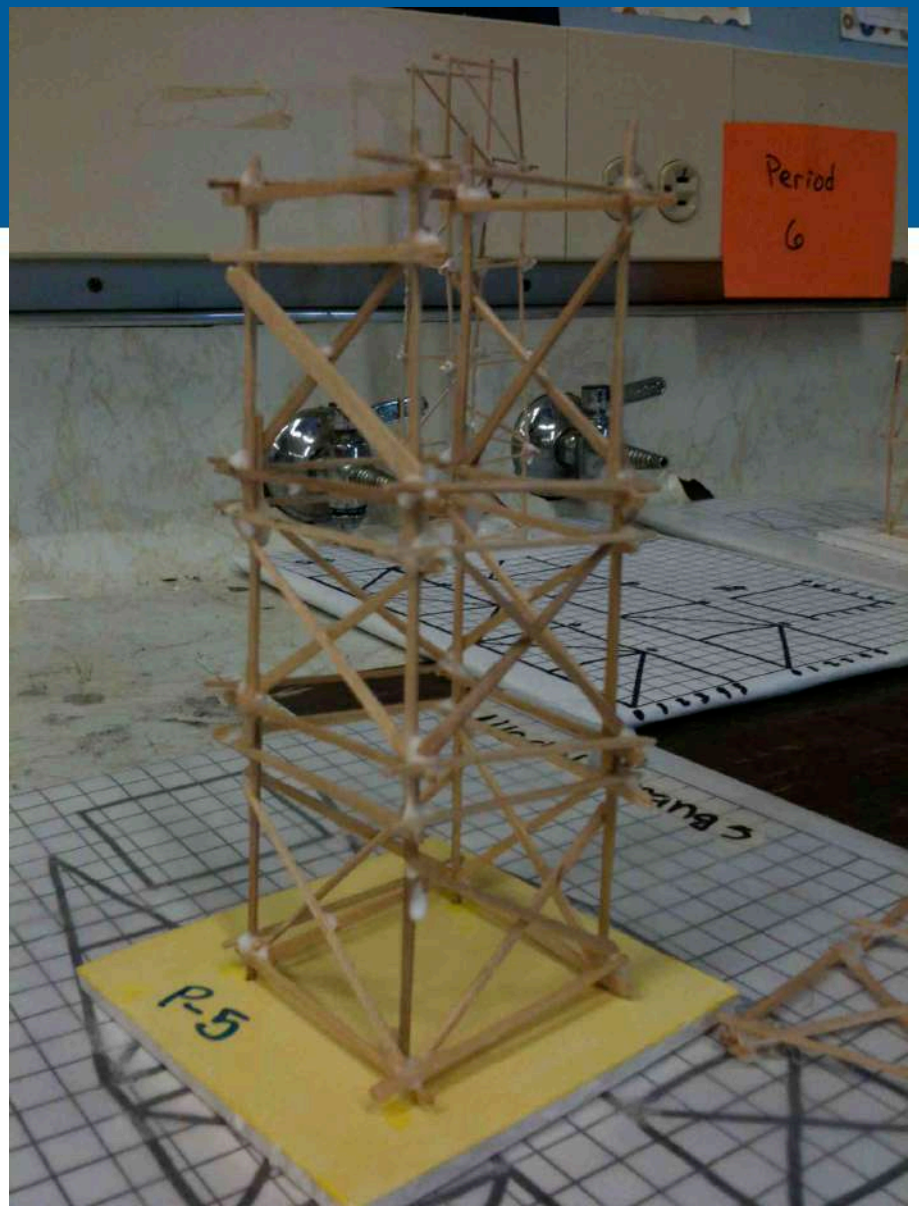
Grading

WARNING! Max weight the machine can measure is 125 lbs!

- Your cube will be weighed. Max weight will be put on it and a ratio will be calculated by taking held weight divided by weight of building
- You want **lighter** and holds more weight
- For example: holds 20 pounds and weighs 32 grams so 20/32 = .625 (62.5% grade)
- Or holds 20 pounds and weighs 12 grams so 20/12 = 1.66 (100% grade)

Daily Grade- Building

- Must build a building with **3** floors
- (1 popsicle stick tall each floor)
- Popsicle sticks and liquid glue only.
- NO HOT GLUE!



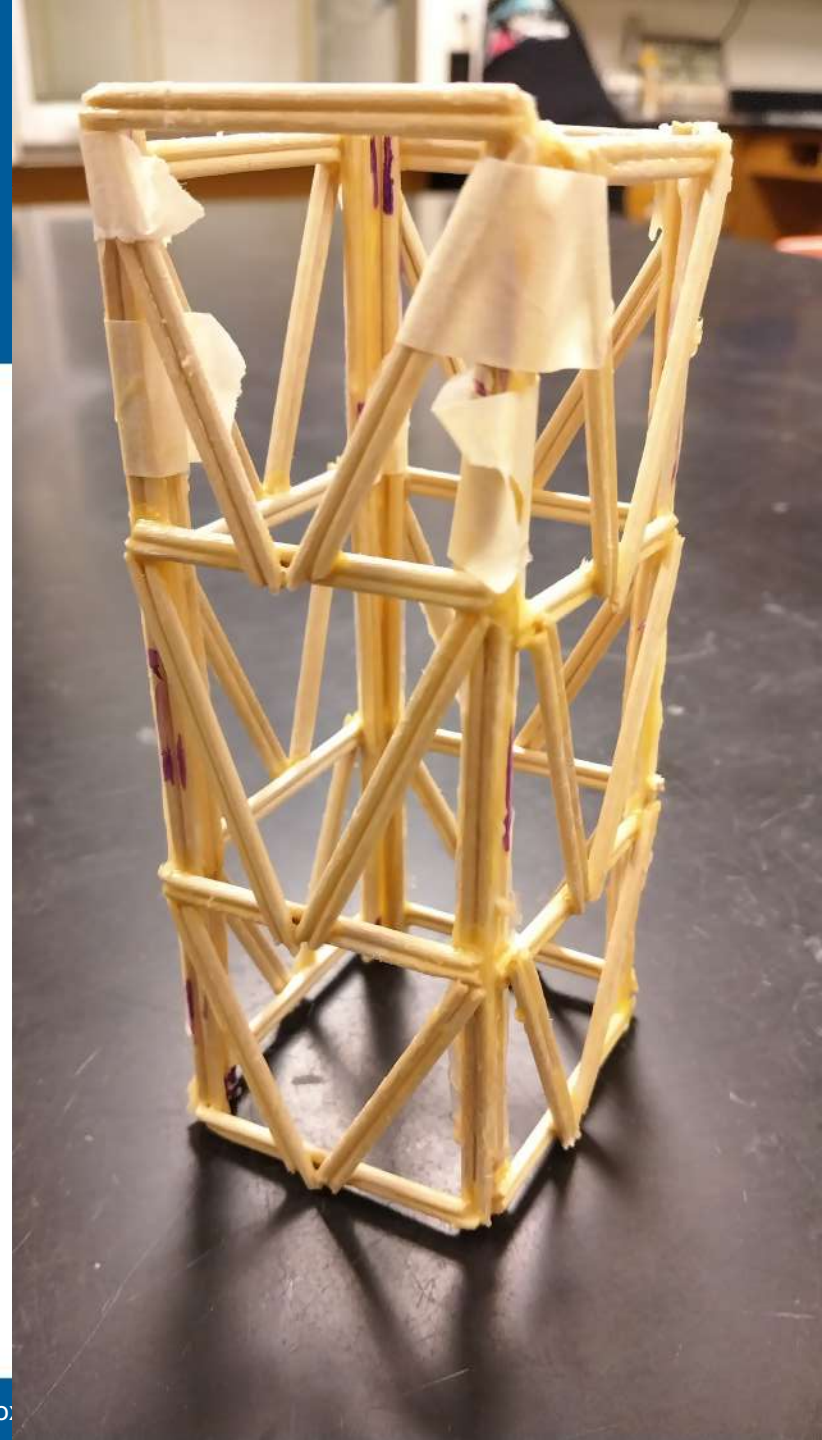
Grading

WARNING! Max weight the machine can measure is 125 lbs!

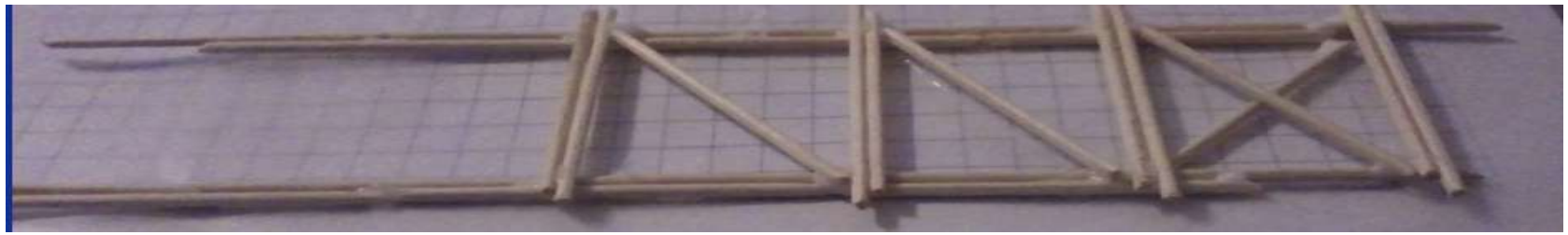
- Your building will be weighed. Max weight will be put on it and a ratio will be calculated by taking held weight divided by weight of building
- You want lighter and holds more weight
- For example: holds 20 pounds and weighs 32 grams so 20/32 = .625 (62.5% grade)
- Or holds 20 pounds and weighs 12 grams so 20/12 = 1.66 (100% grade)

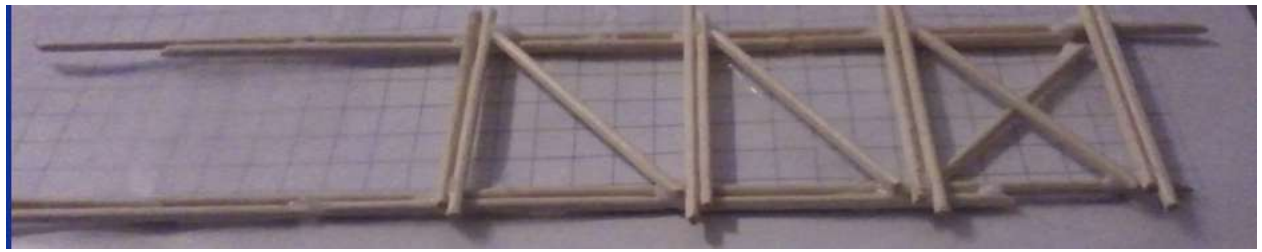
Test Grade - Building

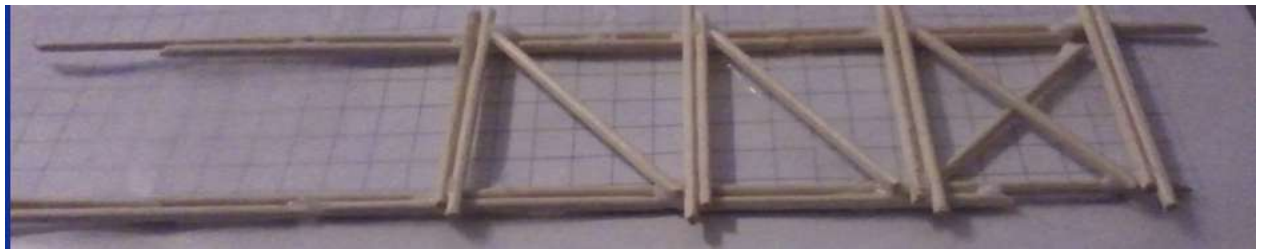
- Must have 3 floors
- (1 toothpick tall each floor)
- Wood glue only
- NO hot glue!
- NO Craft sticks!
- Masking tape helps keep it together while drying

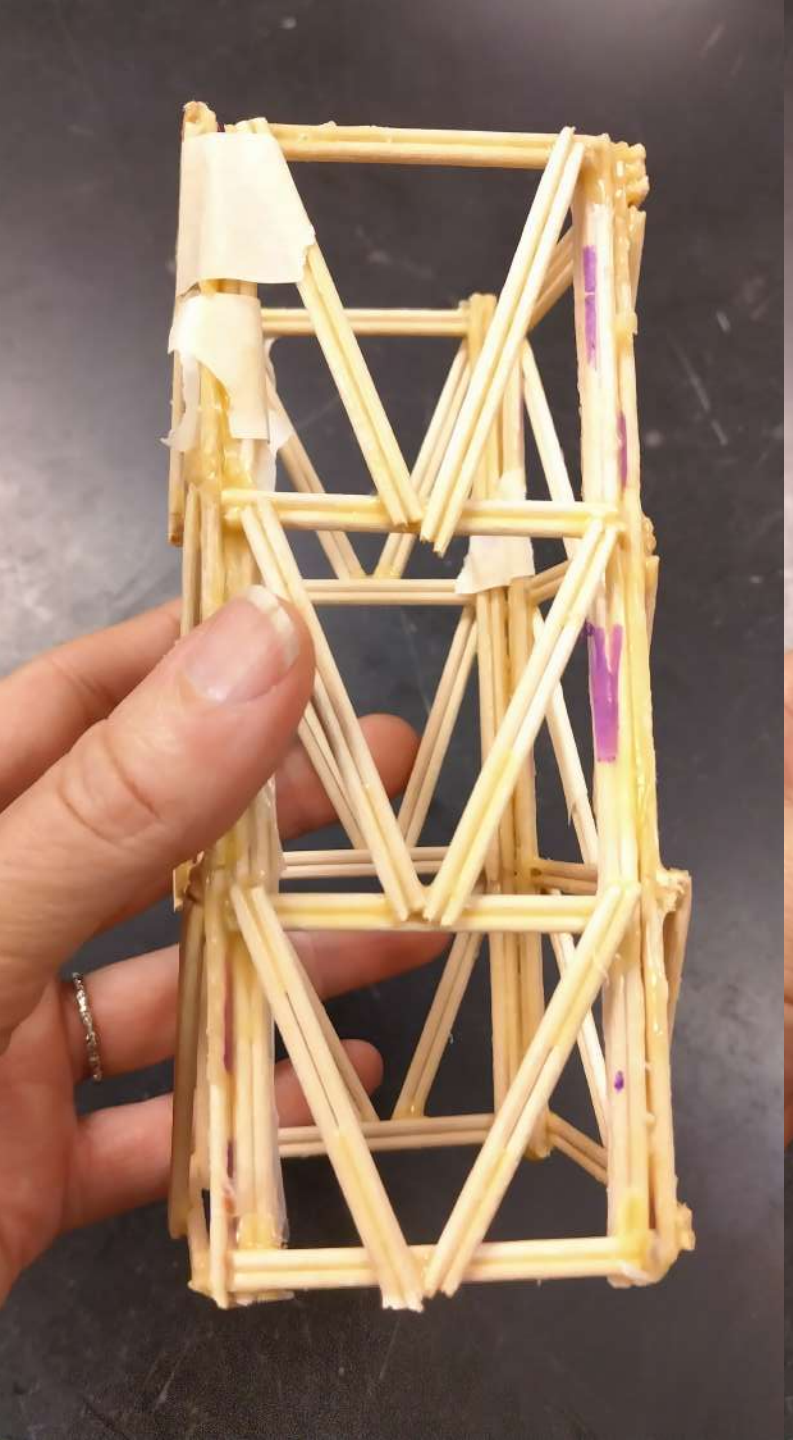
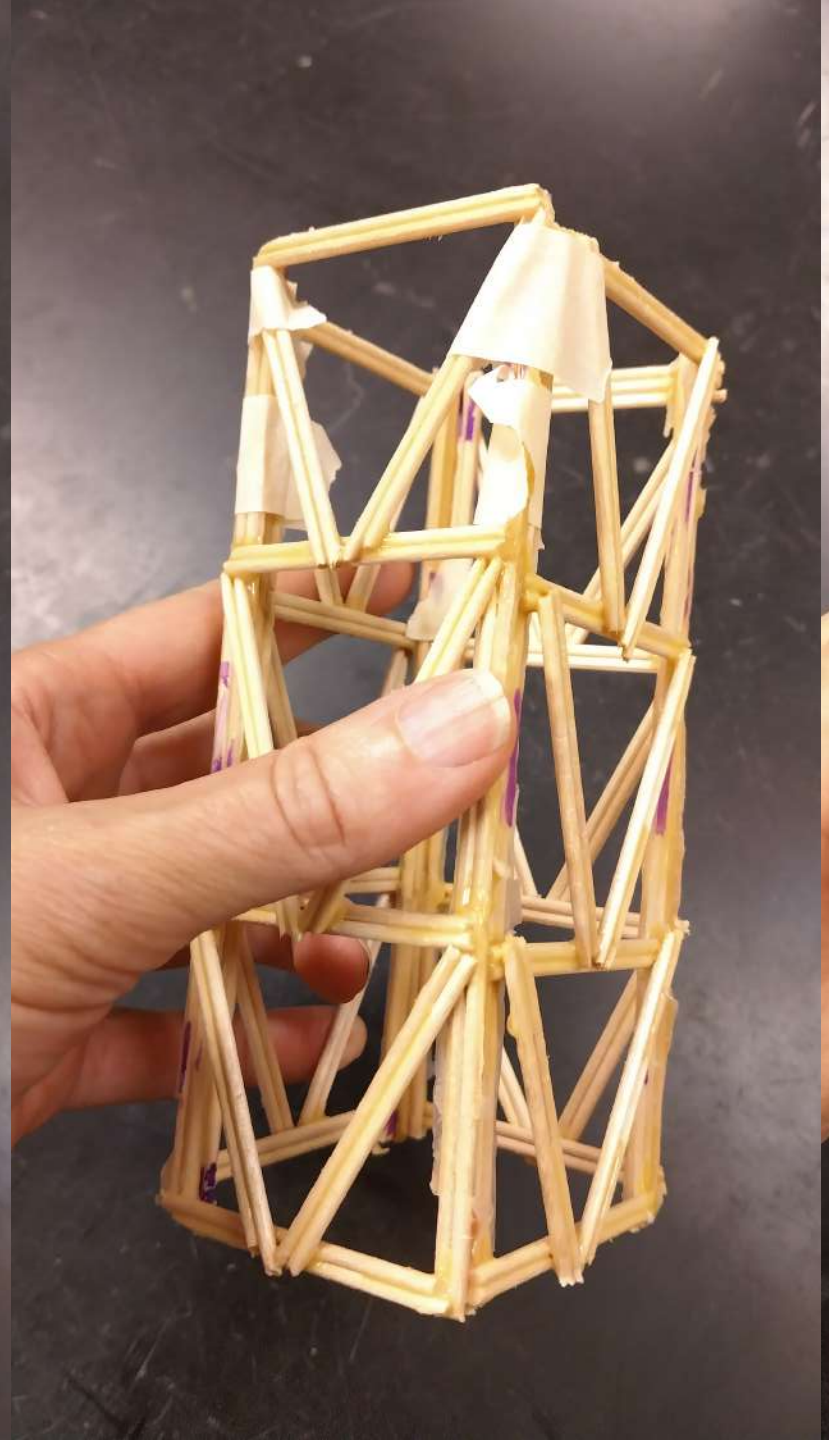
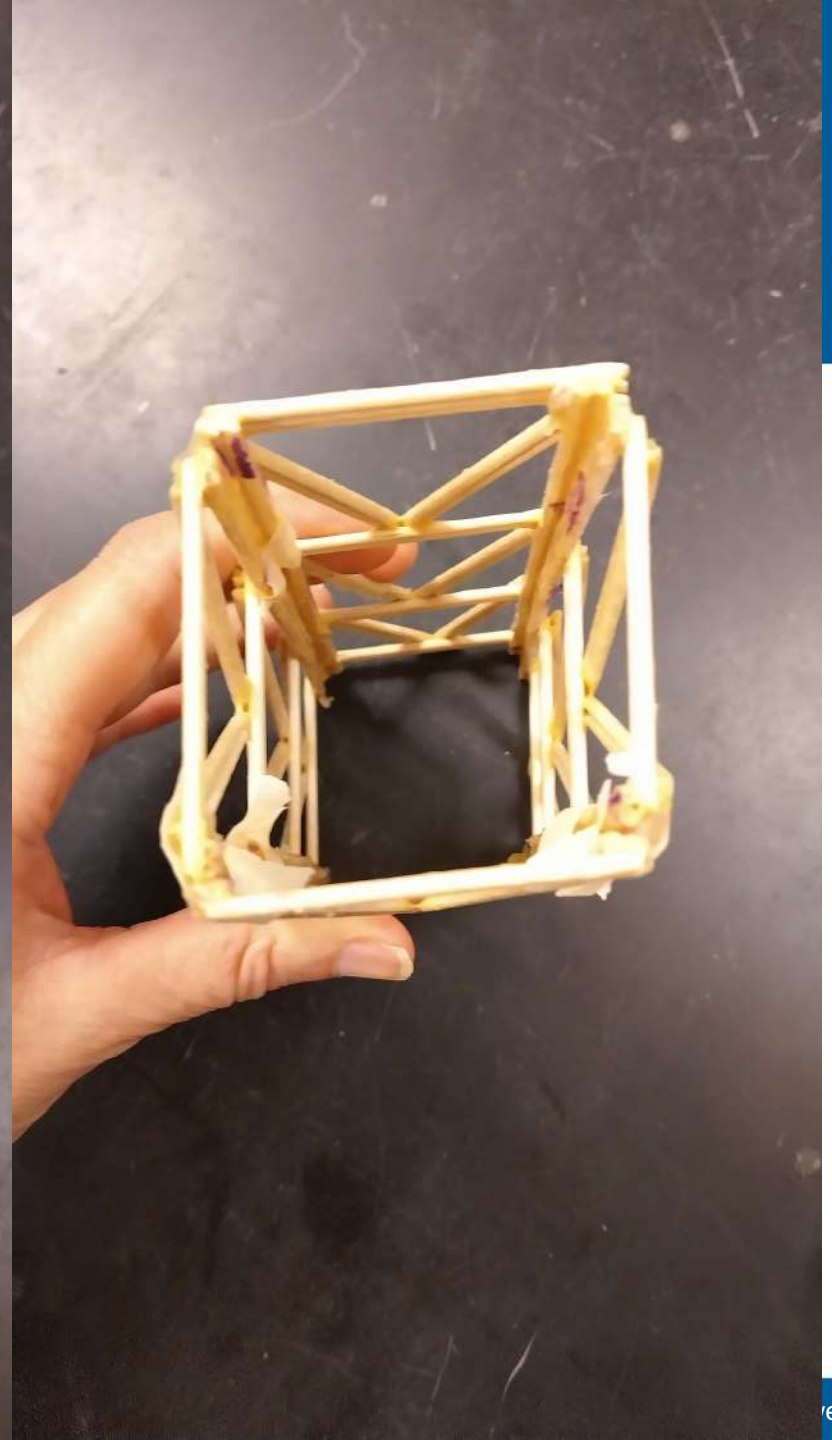


Start by making the 4 walls







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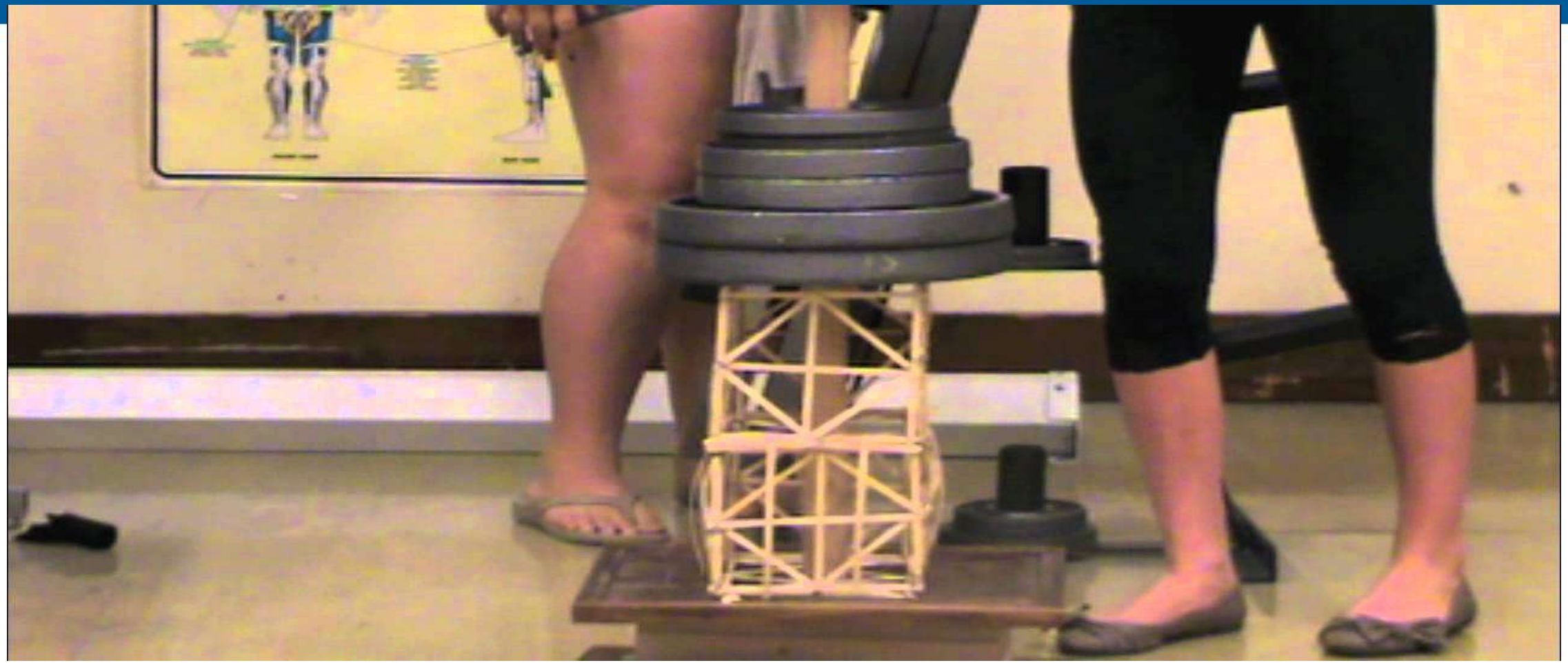
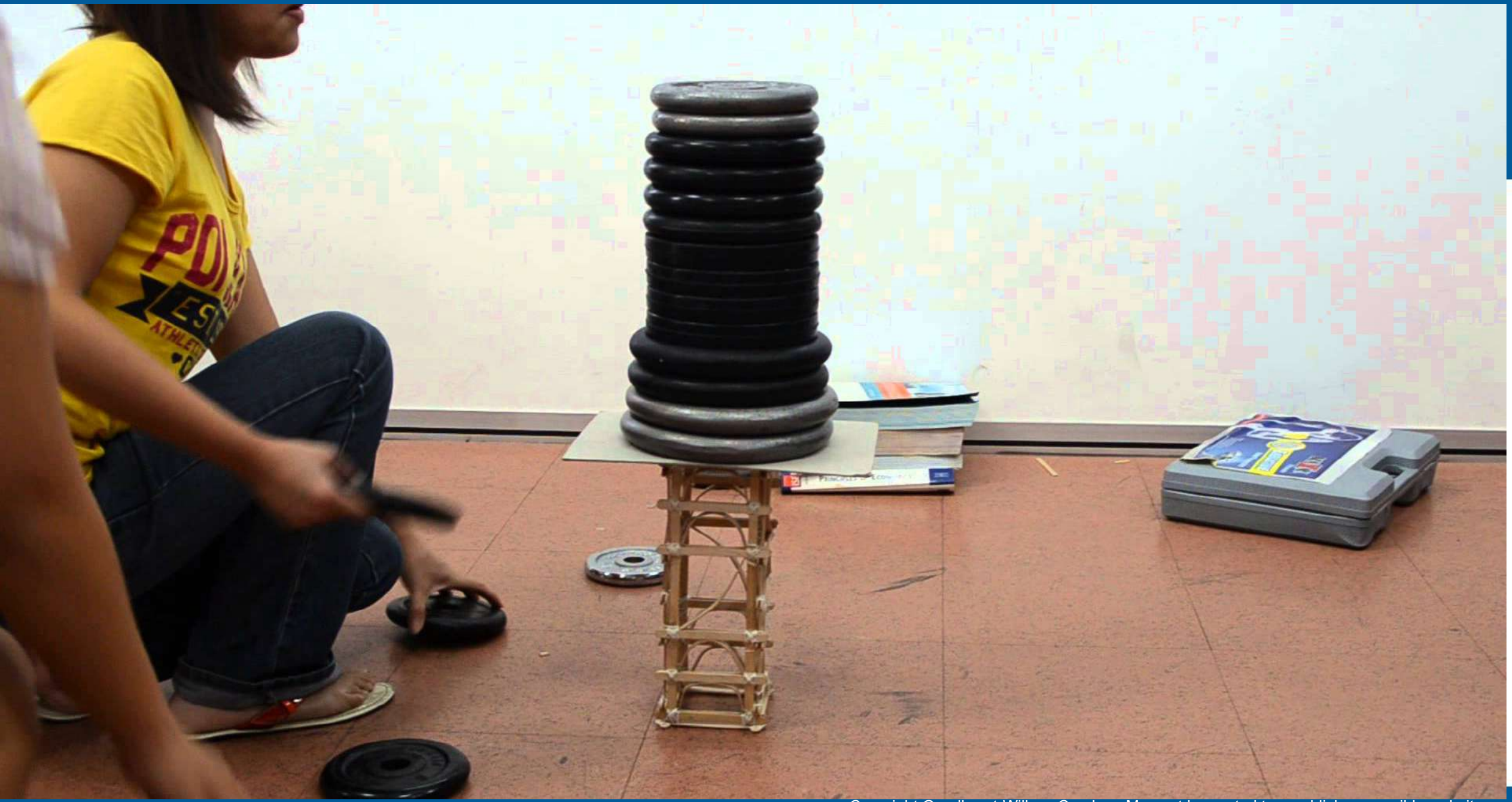
Must Hold Weight





Tips

- Overlap toothpicks so the pointed tips are reinforced.
- Use 2 toothpicks instead of only 1 – adds strength without adding too much weight.
- Use triangles for extra strength.
- Make sure your building stands level and isn’t leaning to one side.

Grades

- **EVERYONE builds their own building out of toothpicks and wood glue ONLY!**
- **I will weigh and break the building.**
- **The ratio will be your test grade!**

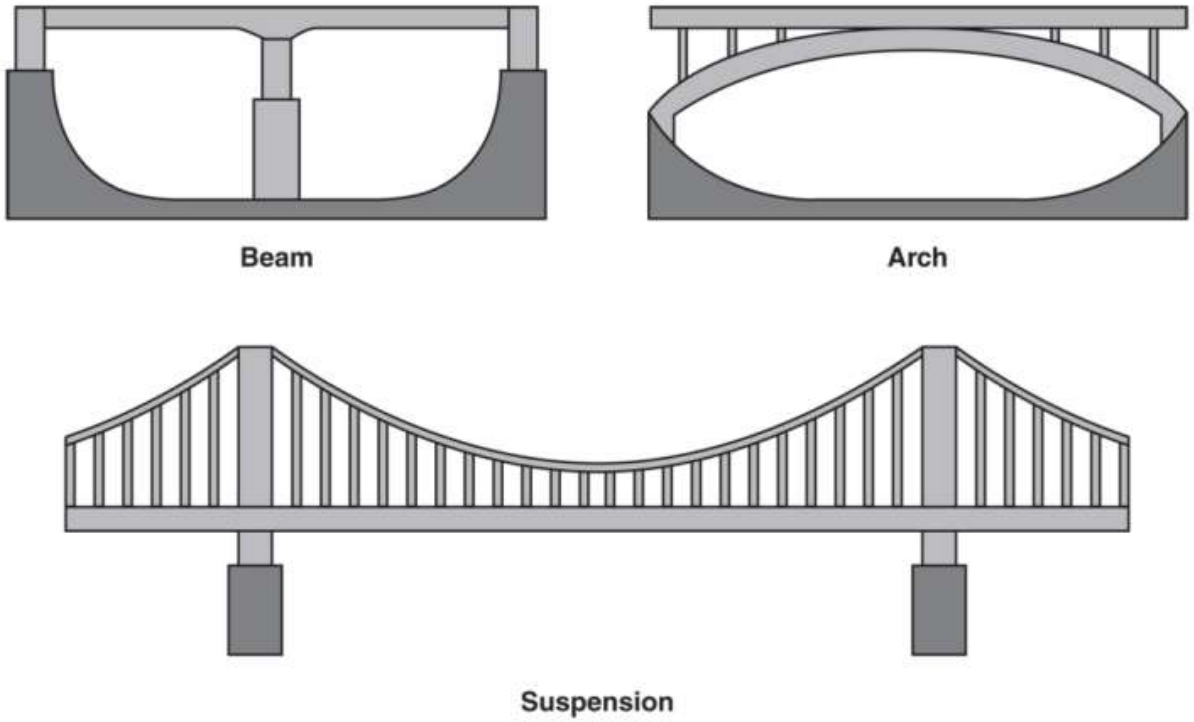
Rubric

WARNING! Max weight the machine can measure is 125 lbs!

- Ratio of 1.0 or better = 100%
- All other ratios will equal grade
- For example ratio of .725 = 72.5%

Bridges

- Design considerations
  - Length of span
  - Type of foundation
  - Environment
  - Available materials
- Basic components
  - Piers
  - Abutments
  - Roadway



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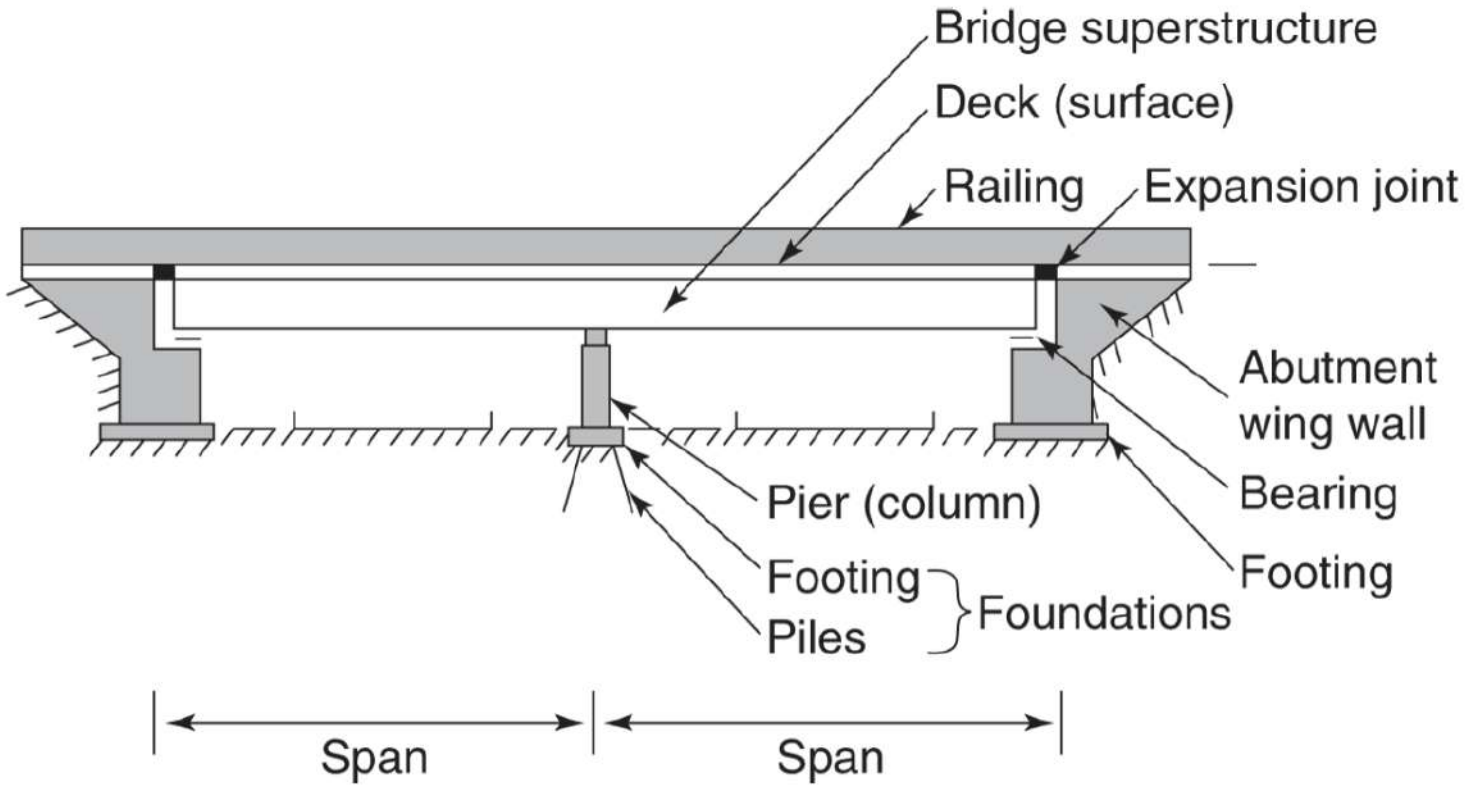
Bridge Components



Typical Bridge Elements

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Types of Beam Bridges

- Span short distances

Cantilever Bridge

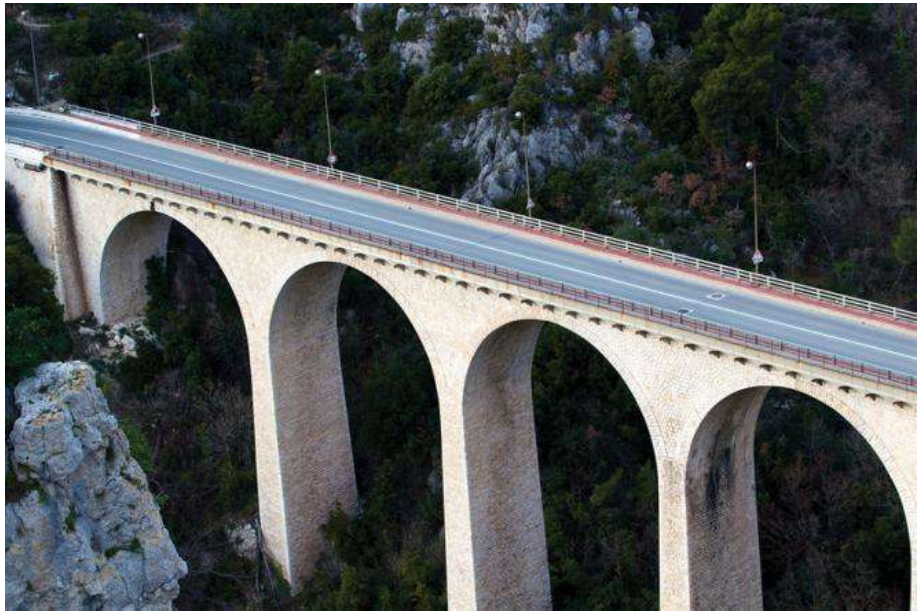
Truss Bridge

Beam Bridge

Left: StockCube/Shutterstock.com, Middle: Alexeye30/Shutterstock.com, Right: Gary Fowler/Shutterstock.com

Arch Bridges

- Rely on arch strength, rigidity
  - Structural members in compression
  - Distribute load to abutments
- Arch can support deck from above or below



Dan Costa/Shutterstock.com

Suspension Bridges

- Main section similar to inverted arch bridge
- Use tension forces
- Main components
  - Towers
  - Main cables
  - Anchorages

Specialty Bridges

- Combination bridges
- Movable bridges

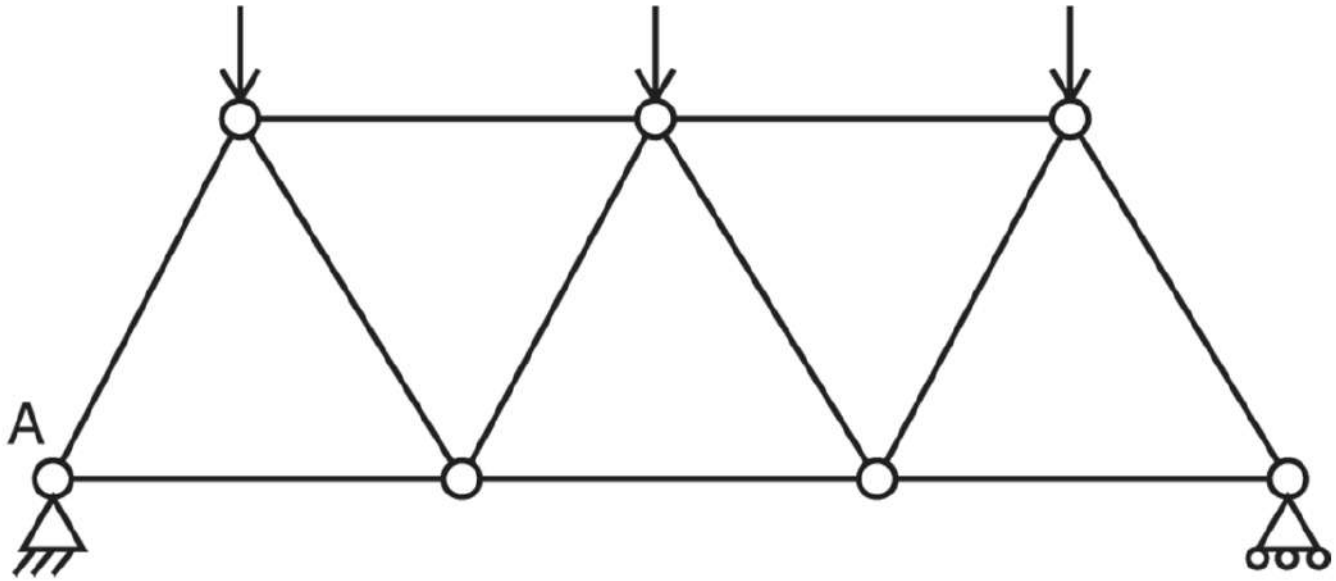
TheresaSc/Shutterstock.com

Truss Structural Analysis

- Simplest truss is triangular
- Structural members pinned together at joints
- Truss analysis
  - Begins with free body diagram
  - Determine structural stability of truss
  - Calculate reactions, internal forces
  - Complex calculations done by computer software

Free Body Diagram

- Structural members, joints
- Supports
- Loads or forces applied



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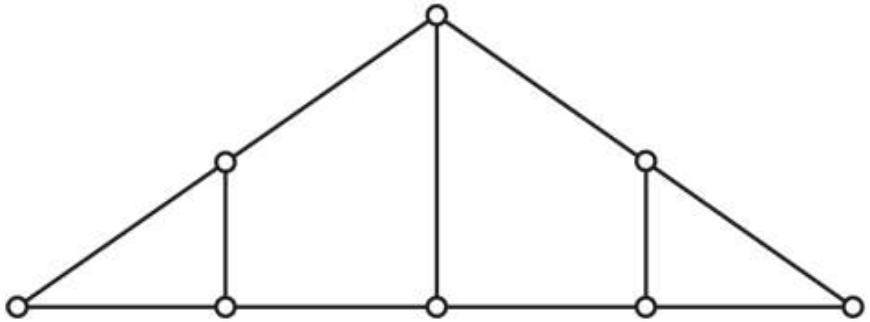
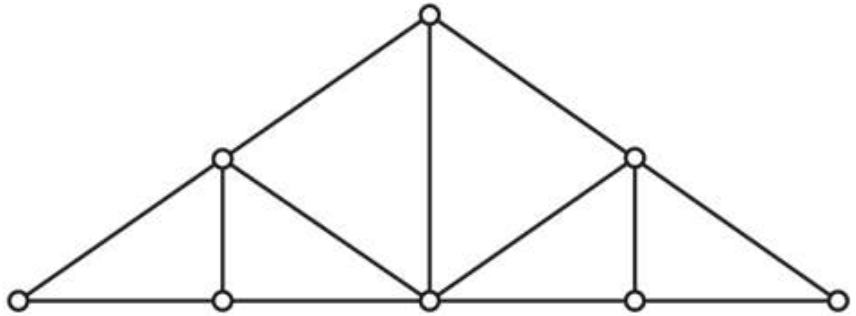
Stability Formula

- $2j = m + 3$



Unstable Truss
2j = m + 3
2 x 8 = 11 + 3
16 = 14



Stable Truss
2j = m + 3
2 x 8 = 13 + 3
16 = 16

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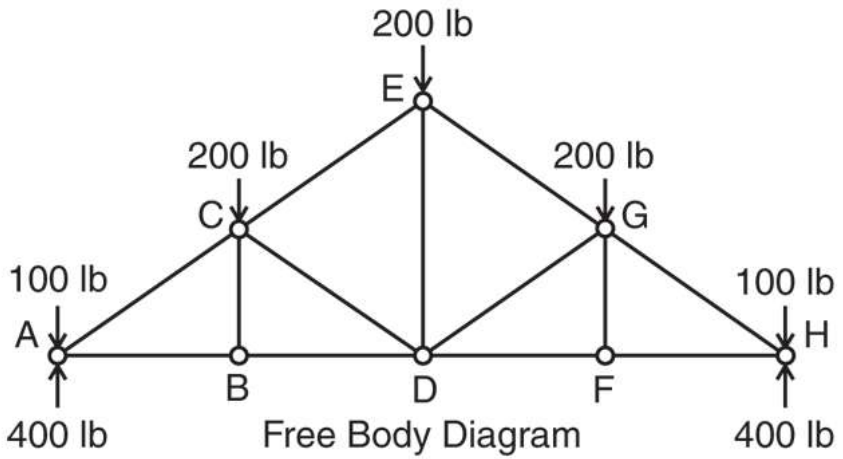
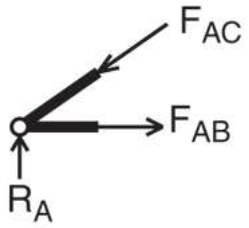
Reactions and Internal Forces



Free Body Diagram



Free Body Diagram Detail

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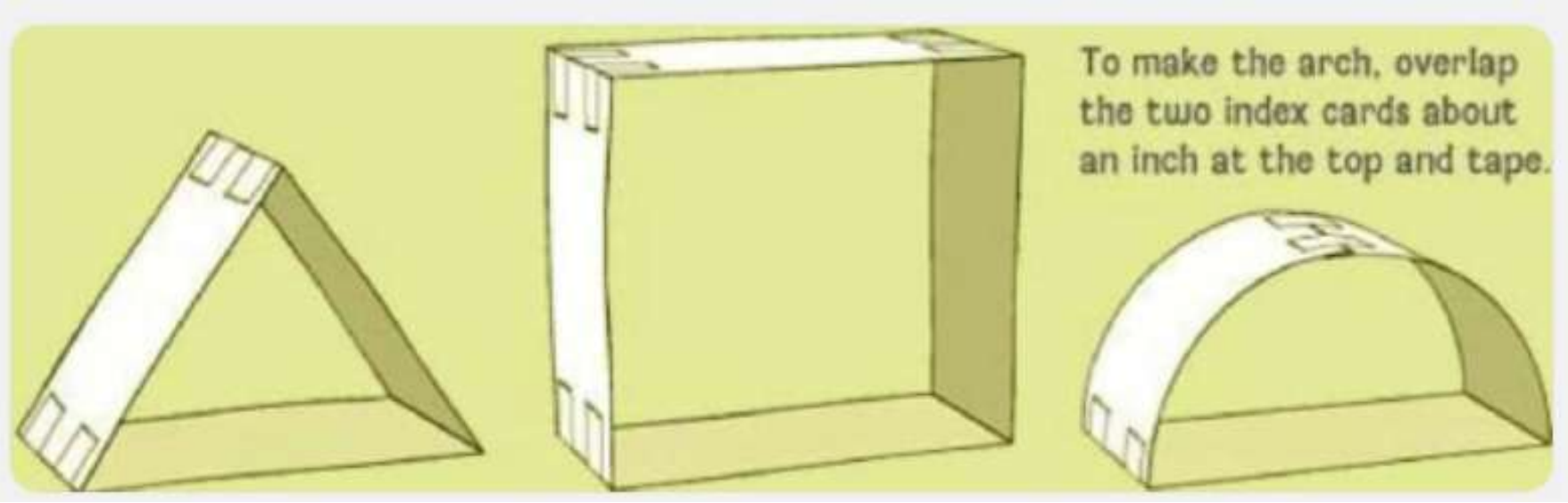
- Over 1 billion people don’t have safe year-round access to education, healthcare and markets
- Access to bridges raised average income levels 30% as farms became more efficient and access to jobs increased

So…which shape is the strongest?

BASIC SHAPES TO CONSIDER:

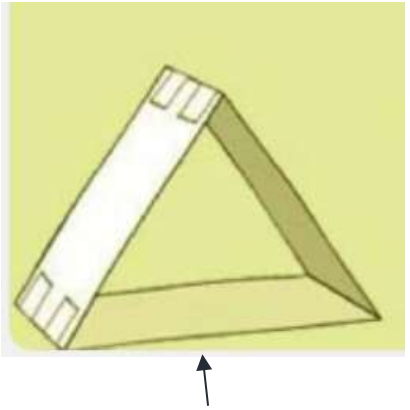
Truss/Triangle | Rectangle | Arch



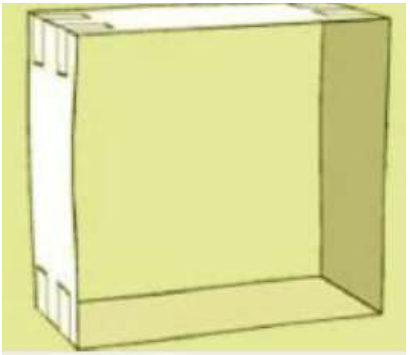
Try to make each build fall by gently pushing

Results!

STRONGEST

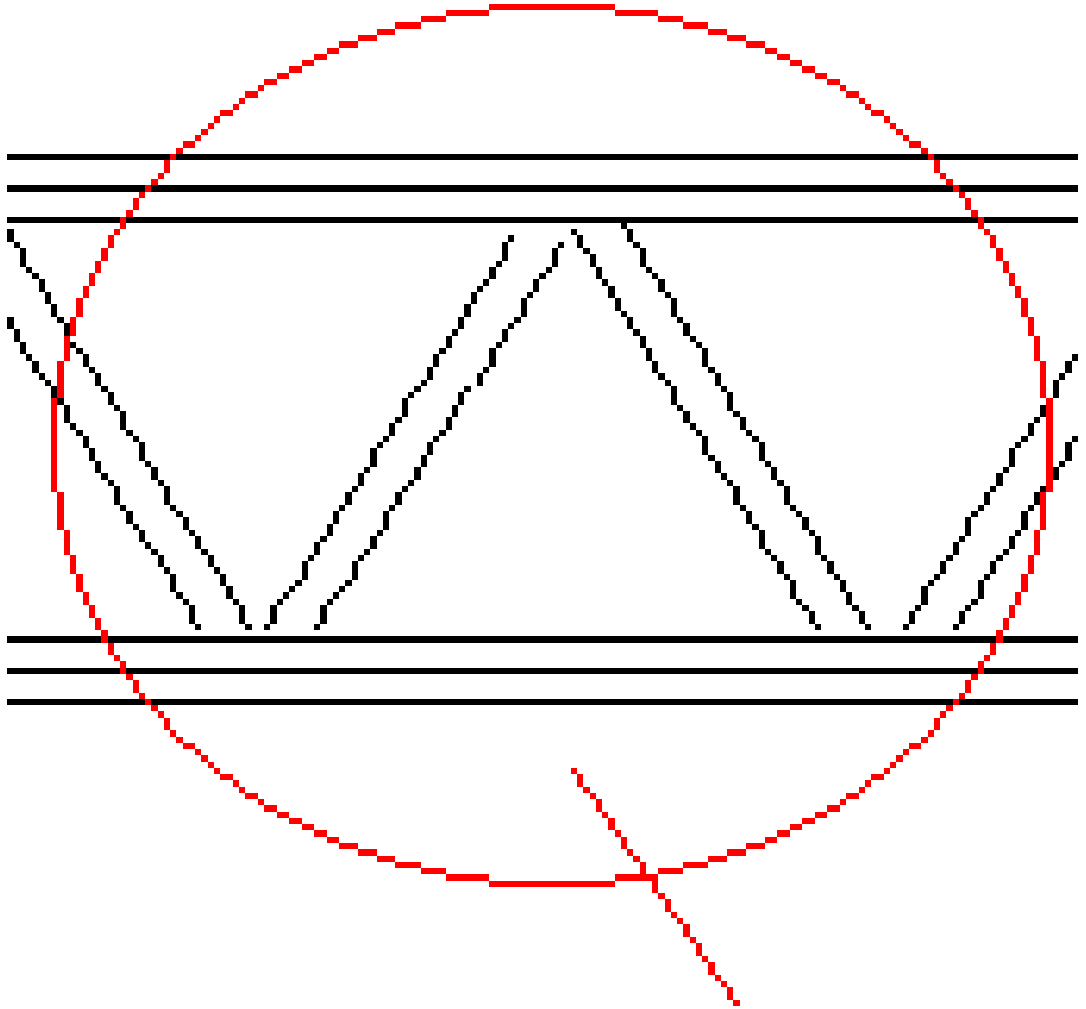


This is the shape you should use in your design.

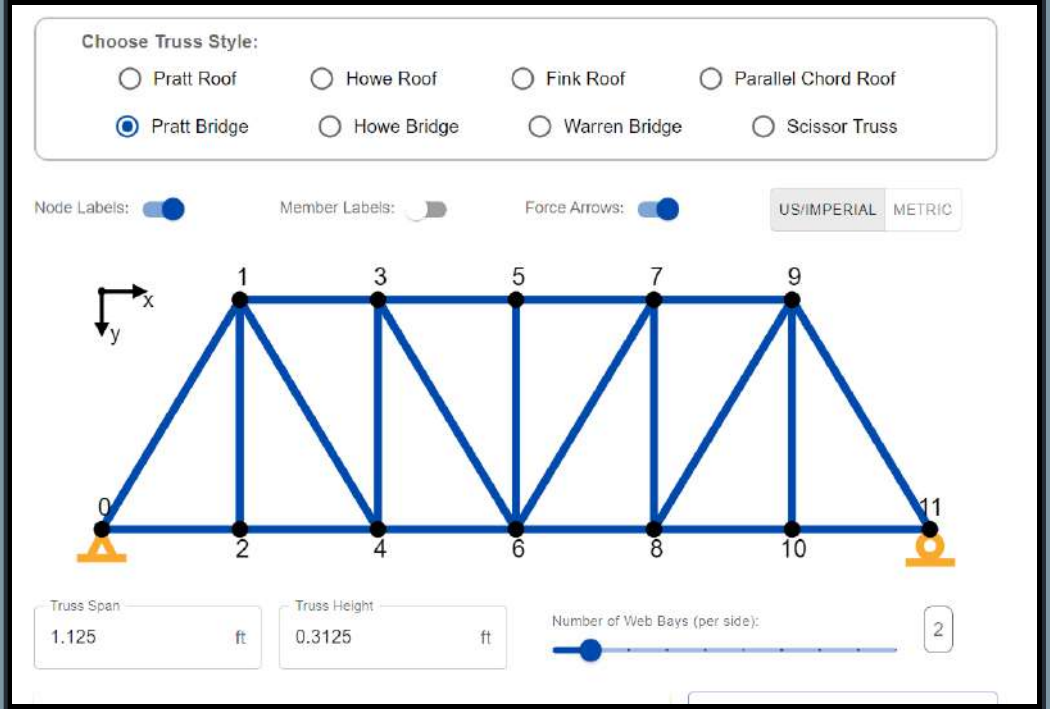


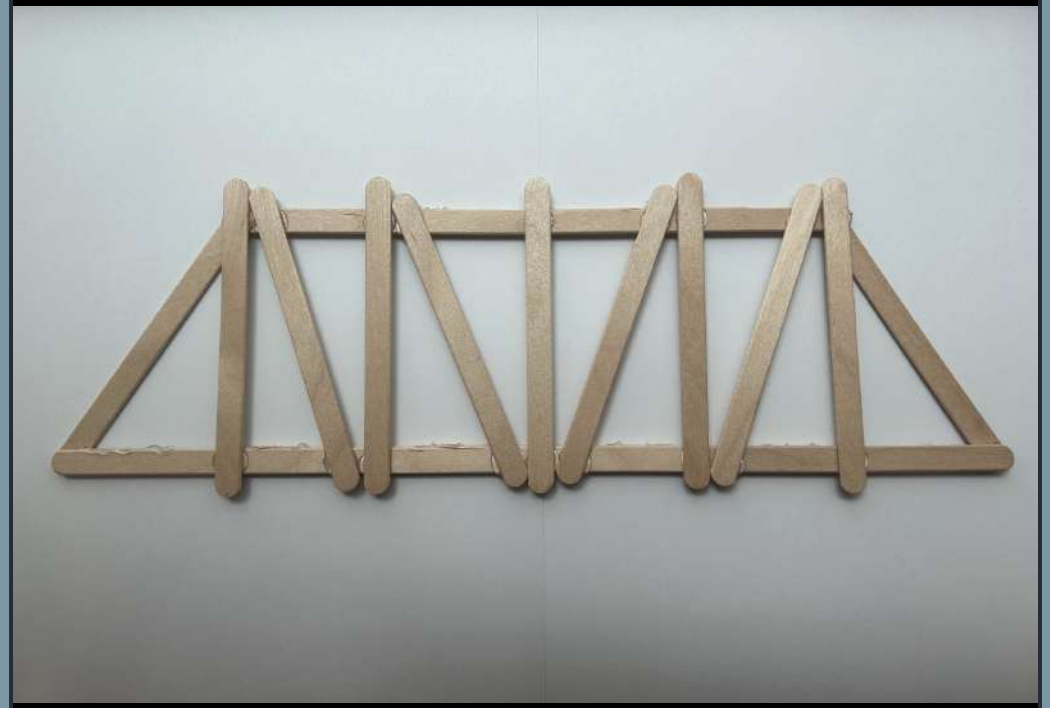
WEAKEST

The sides of triangles are very **rigid**, which allows them to transfer force more evenly through their sides than other shapes. As a result, a triangle can withstand a lot of **strain**, making this particular shape very strong.



triangular shaped sides for the bridge





Daily Grade

WARNING! Max weight the machine can measure is 125 lbs!

- You will make a bridge out of **popsicle sticks and wood glue**.
- Each of you will make your own.
- I will use the force machine to break your bridge and measure the force it can hold.

Bridges (TEST GRADE)

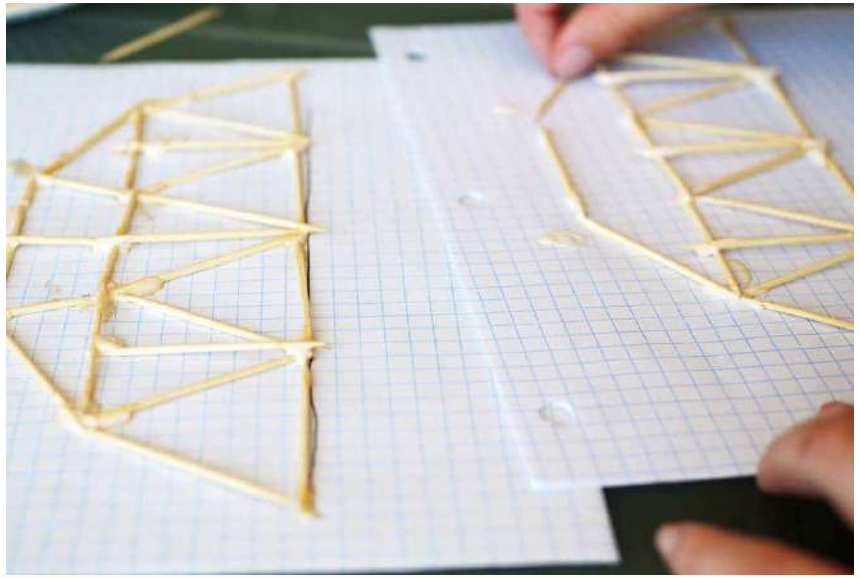
Bridge – TEST

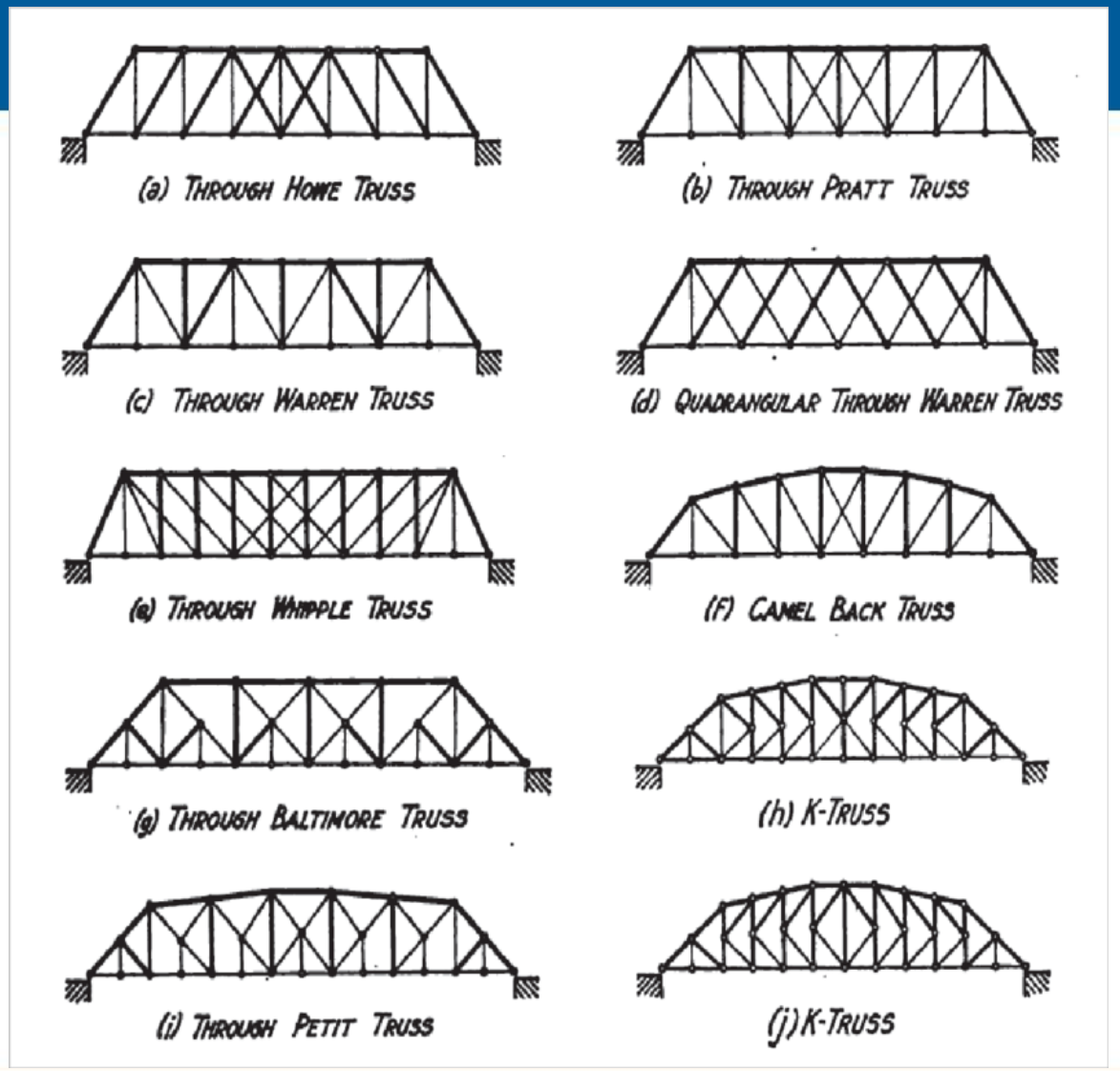
WARNING! Max weight the machine can measure is 125 lbs!

- You will build one bridge from **toothpicks and wood glue ONLY**!
- I will measure the mass of the bridge and then break it with the force machine.
- Your grade will be a ratio of weight held divided by mass of bridge.

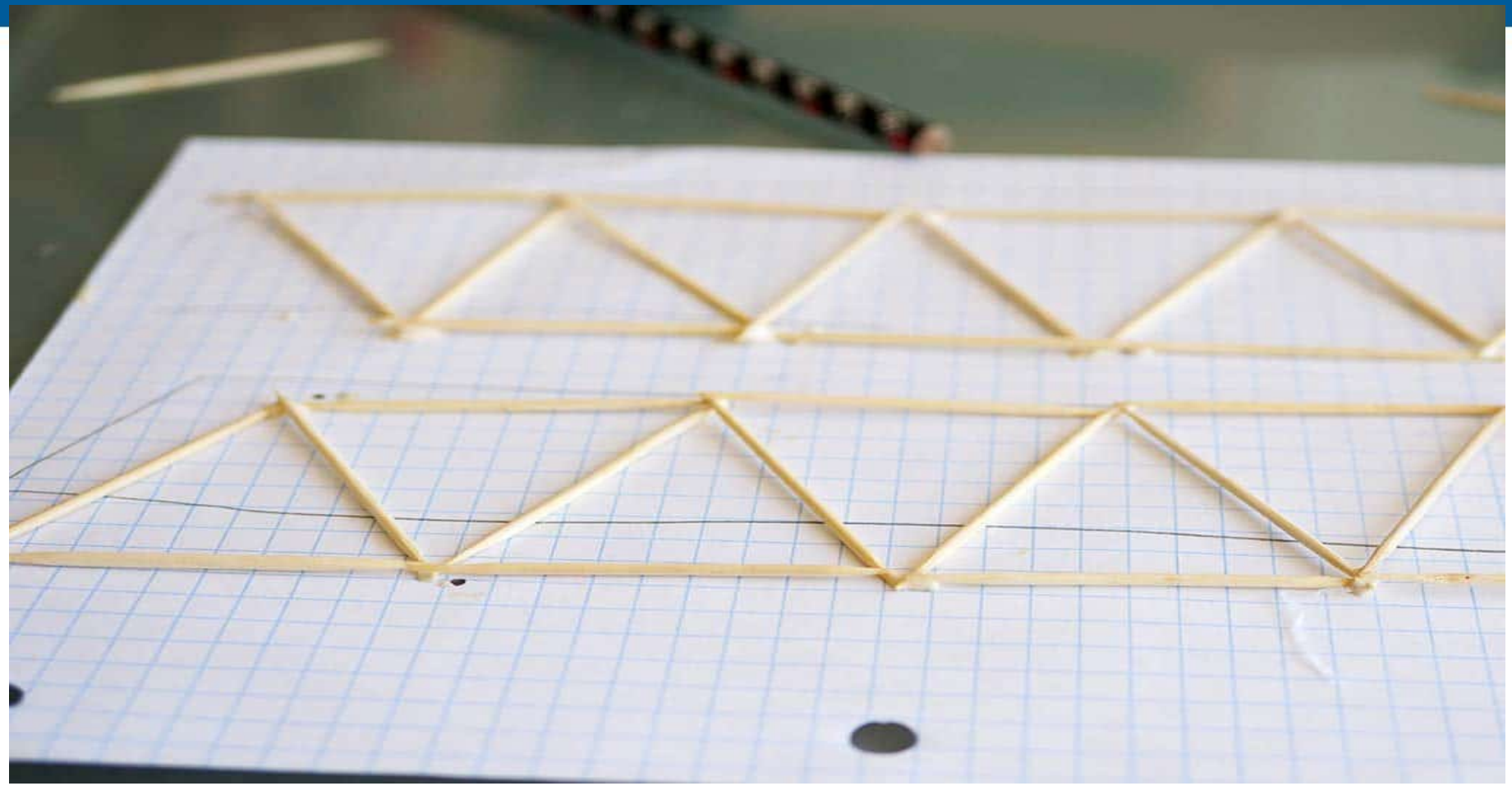
Step 1 – Draw on wax paper

- **12** inches long
- Choose a bridge design
- Use toothpicks and wood glue only



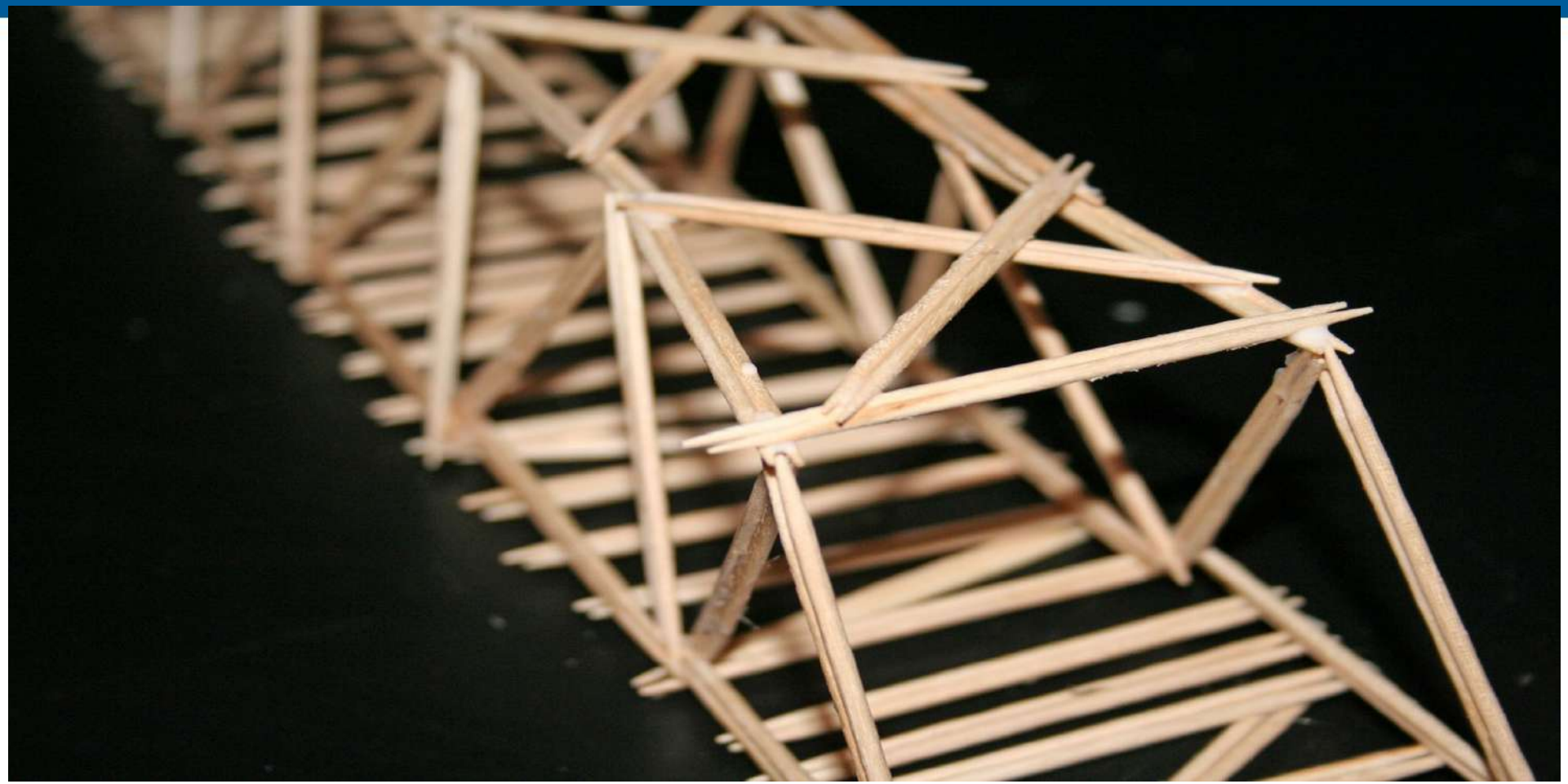


Step 2 – Build 2 walls

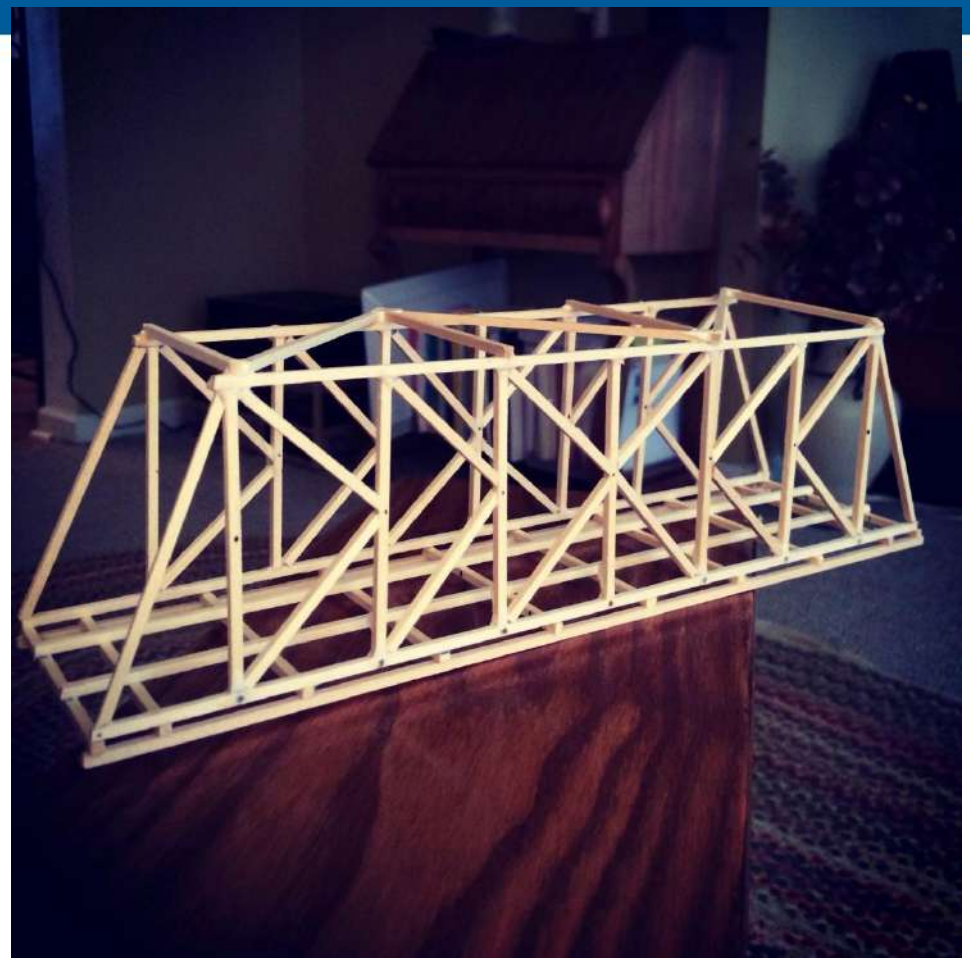


Step 3 – Build bottom

Step 4 – Build top



Glue 4 sides together



Grading

WARNING! Max weight the machine can measure is 125 lbs!

- Lighter and holds more weight
- For example: holds 20 pounds and weighs 32 grams so 20/32 = .625 (62.5% grade)
- Or holds 20 pounds and weighs 12 grams so 20/12 = 1.66 (100% grade)

Rubric

- Ratio of 1.0 or better = 100%
- All other ratios will equal grade
- For example ratio of .725 = 72.5%

Tips

- Overlap toothpicks so the pointed tips are reinforced.
- Use 2 toothpicks instead of only 1 – adds strength without adding too much weight.
- Use triangles for extra strength.
- Make sure your bridge stands level and isn’t leaning to one side.

Paper Table: Materials

- 10 pieces of Paper
- Masking Tape (1 meter)
- Board for top

Rules

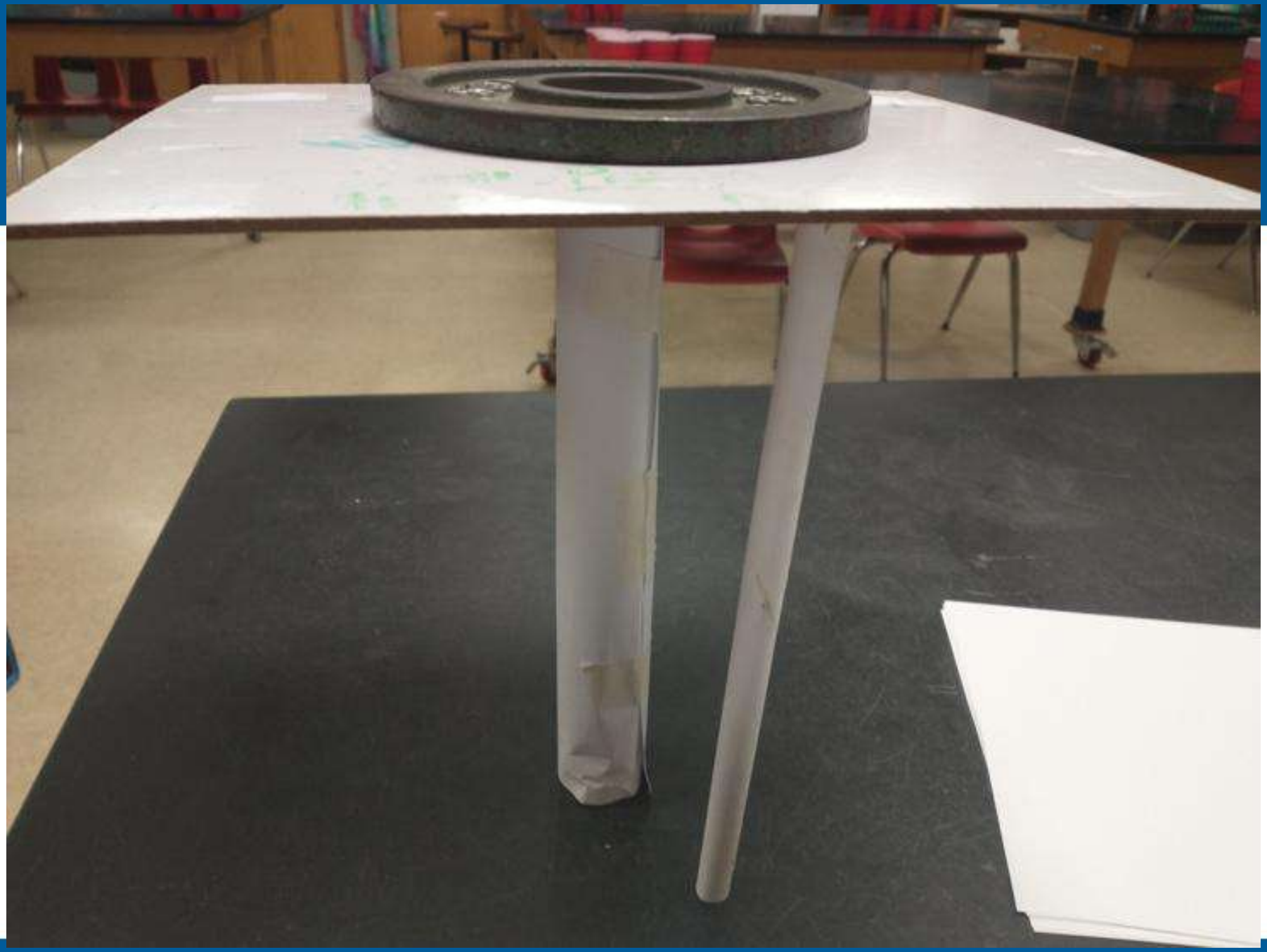
- Must build a table and hold the most weight possible.
- You will make beams to hold up a flat top.
- More weight – higher grade

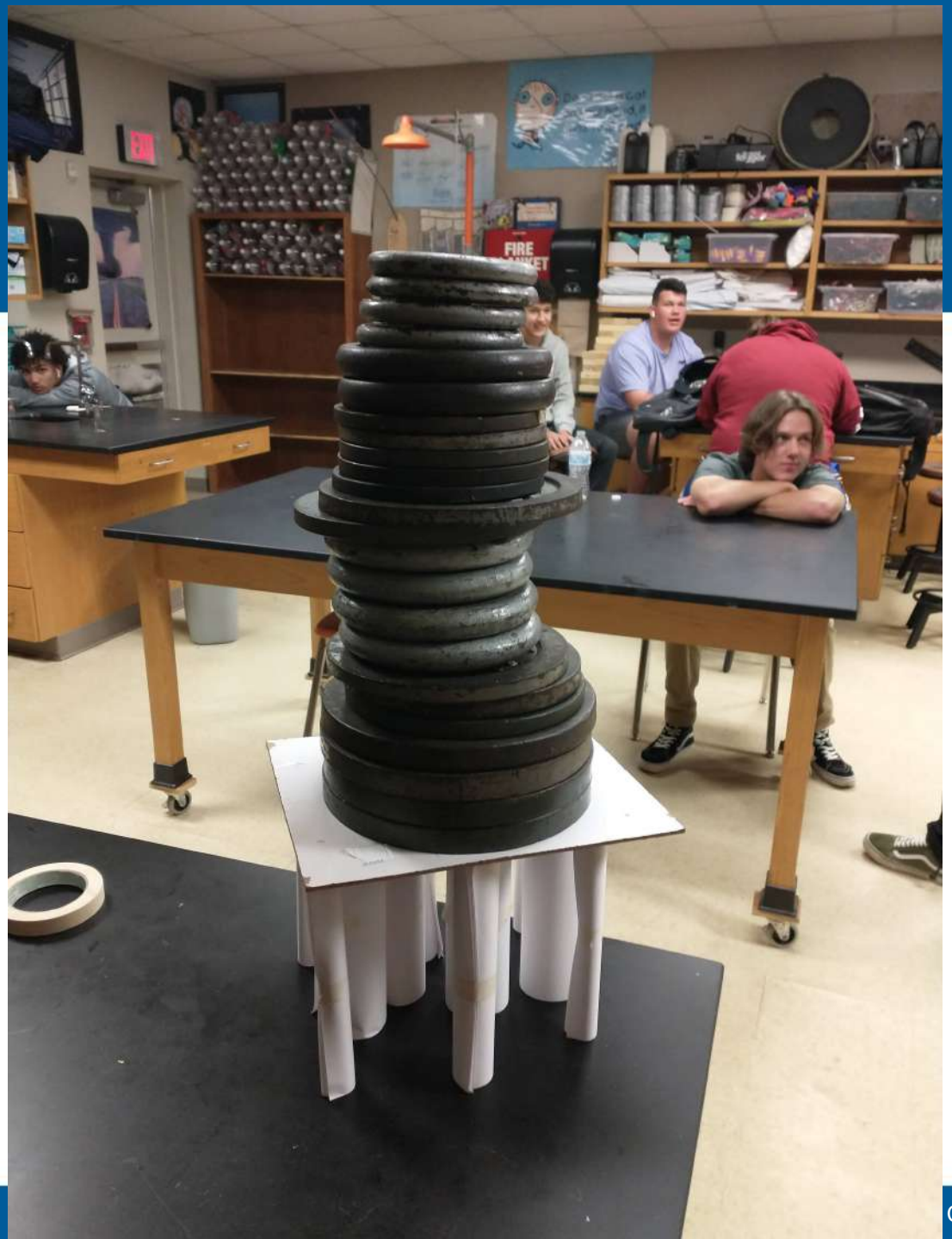
- You will receive 10 sheets of plain paper, 1 strip of tape, and 1 board.
- You will make columns / beams that will support the board.
- Each column must stand 11 inches high (so roll or fold the paper Hot Dog not Hamburger).
- You will then put weight on the board.
- Each pound equals 1 point so a 100% will have to hold 100 pounds.
- You can try as many times as you like and receive the highest grade.
- Each time you try, you will receive 10 more sheets of paper and a strip of tape.

Things to consider:

- You can roll all 10 pieces of paper into 1 column. It will be very strong but not easy to balance.
- You can roll the 10 pieces of paper into 10 columns. It will be very balanced but not very strong.

- *TIP: Using paper shapes such as tubes will increase the amount of weight the table can support and will **distribute** or divide a load.*
- *TIP: Roll papers tight to make strong tubes. It takes more **force**, or impact or pressure, to crumple a paper when it is shaped as a tube.*





Rubric

- Table holds 100 pounds – 100
- Table holds 90 pounds – 90
- Table holds 80 pounds – 80
- Table holds 70 pounds – 70
- Table holds 60 pounds – 60
- Table holds 50 pounds – 50
- Table holds 40 pounds – 40
- Table holds 30 pounds – 30
- Table holds 20 pounds – 20
- Table holds 10 pounds – 10

Hurricane Katrina (DAILY GRADE)

Your challenge is to build a freestanding tower that can support a tennis ball 12 inches (1 ruler) off the ground while (on top) withstanding the wind from a fan.

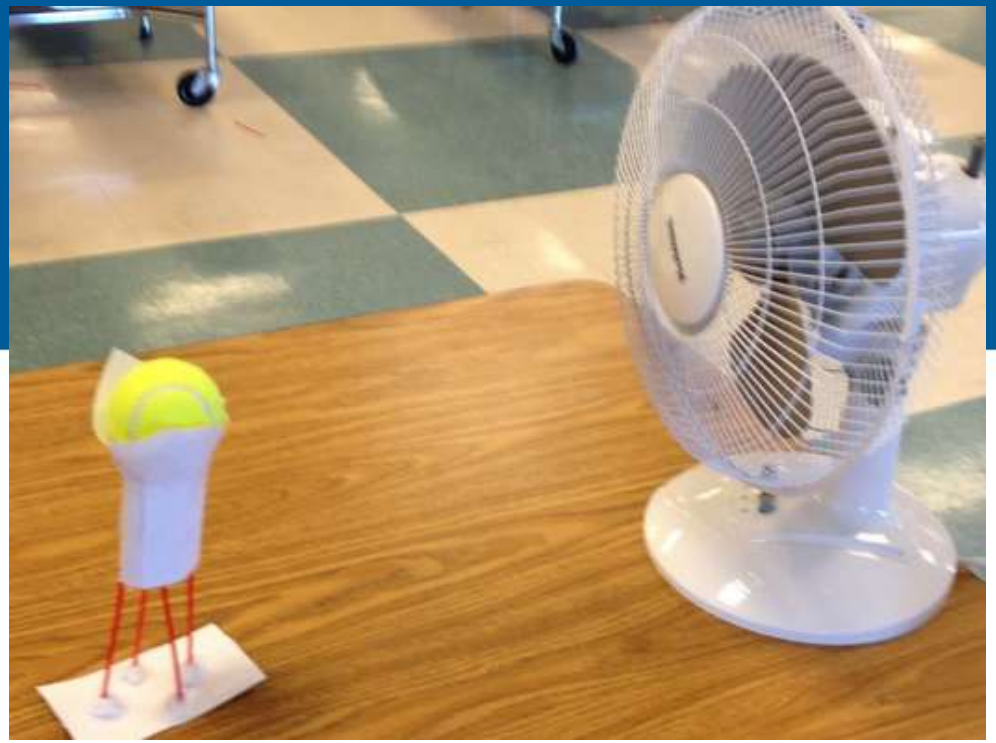
Instructions and Materials

Materials available to build your tower:

- Copy Paper / Cardstock
- Straws
- Masking Tape
- Toothpicks
- Cardboard
- Any in room

Grading:
Tower that withstands the fan on high.
Less weight = higher grade

Remember, the tower needs to be freestanding – that means you can't tape the tower to the floor!



Rubric

- 7 grams or less = 100
- 8 grams = 90
- 9 grams = 80
- 10 & greater grams = 70

Everyone builds one