Engineering Tomorrow

Bridges Lab Worksheet

Here you will find the instructions on how to create your own bridge! Follow all the instructions for this worksheet and fill in the blanks as you go.

INTRODUCTION:

Bridges are everywhere in your daily life! All bridges are designed to hold the weight of very heavy objects. Every bridge you see has the same design fundamentals, no matter how big/small the bridge, or what the specific function is!

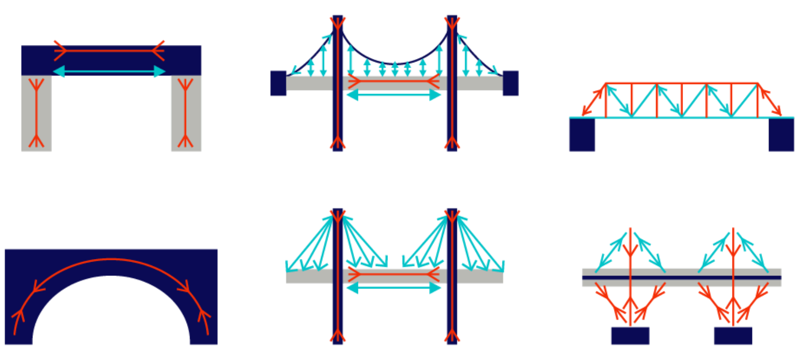
Answer Me! What problem is your team trying to solve?

Does your team want to build the strongest bridge? The most elegant? The lowest cost bridge? A bridge that can easily be built in a remote region (perhaps consider how some parts could be pre-built and shipped to aid in construction on site)?

STEP ONE: LEARN

In building your bridge, it is very important to balance **tension** and **compression** forces.

- **Tension** is a force that develops when a material is pulled or stretched
- **Compression** develops when a material is pushed inward forcing the object to become smaller or more dense



The graphic above shows how different bridge designs can balance these two forces! The more balanced your forces, the stronger your bridge will be.

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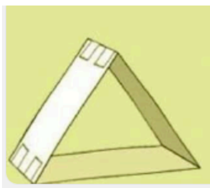
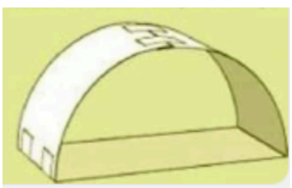
<u>Answer Me!</u> What shapes balance tension and compression forces the best?
With your team discuss the common shapes that may appear in bridges, ex. triangles/trusses, rectangular beams, and arches. How do compression and tension affect the strength of these shapes? See more info below to help answer these questions.



The sides of <u>triangles</u> are very **rigid**, or difficult to deform, which allows them to distribute force evenly through their sides. As a result, a triangle is resistant to deformation under pressure, making this particular shape very strong.



The curved shape of an <u>arch</u> carries the downward force of a load along the curving form to the base. At the same time, the ground pushes up with equal force. As a result, an arch is able to effectively distribute compression and tension forces.

STEP TWO: UNDERSTAND THE PROBLEM

In your kit, you should see popsicle sticks and thin dowel rods. You will use these materials as the structure of your bridge! Feel free to also use various classroom materials such as cardboard, tape, or hot glue. The sky's the limit here! If you are missing any materials, let your teacher know now.

Engineering is a collaborative process, and it is vital that for this lab, all team members work together. In order to organize your team, you will be splitting up your group into designated roles, which are outlined below. Although specific responsibilities will fall upon each person, please make sure that **<u>ALL</u> team members work together on every step of your project.** Take time now to decide which role each member will fulfill.

- Cost Engineer: responsible for keeping track of bridge materials and expenses & minimizing cost
- Material Engineer: responsible for determining the best materials to use in order to create a strong structure with strong connection points
- Lead Designer: responsible for determining the overall structure of the bridge, using tension and compression to make informed decisions on the desired shape

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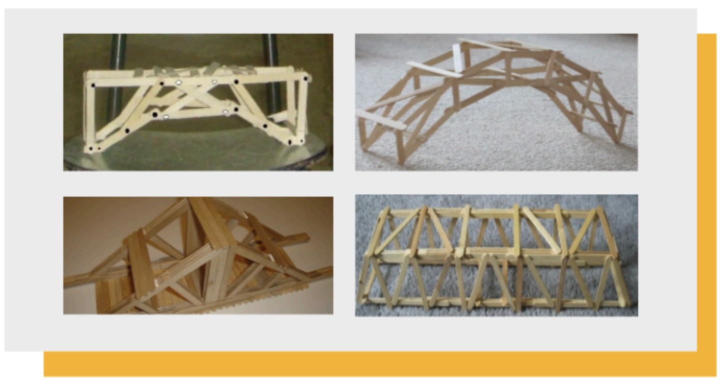
- Bridge must be **20 inches or more in length**.
- Bridge must be **4.5 inches or less in width**.
- Bridge can be as tall as you need.
- Use **materials** found at school/home or in your **ET Toolkit** to build the bridge (popsicle sticks, spaghetti, wood dowels, etc.).

Often, engineers will have to follow specific design guidelines. There are a few you must follow in this lab, and these are outlined in the red box. Make sure to keep these specifications in mind while you are designing and creating your bridge!

STEP THREE: RESEARCH & BRAINSTORMING

Do some research on different types of bridge designs. Look back on the tension and compression graphic on page 1, think about bridges you have crossed before, and see below for some examples! While these examples are made using a variety of materials and will likely not look similar to the bridges you are creating today, the same design principles can be applied to your bridge.



Now, take a few minutes for each member of your group to answer the questions below that pertain to your specific role.

Cost Engineer How will your cost goals impact your design? What are ways you can reduce the cost of your bridge?	Materials Engineer How will the materials impact your design? What materials and connections will lead to the strongest bridge?	Lead Designer What shapes are the strongest to incorporate into your design? How will symmetry affect the tension and compression?
Cost Engineer:	Materials Engineer:	Lead Designer:

STEP FOUR: Design

It is time to design your bridge! The previously mentioned design specifications are listed again for your reference.

Take time to share and discuss your answers to the questions associated with each team member's role above. **Together, design a bridge that takes all team members' ideas into consideration!** Also, don't get discouraged if your design changes throughout the building process – it is rare that engineers get a perfect product on their first attempt. What matters most is a willingness to keep trying!

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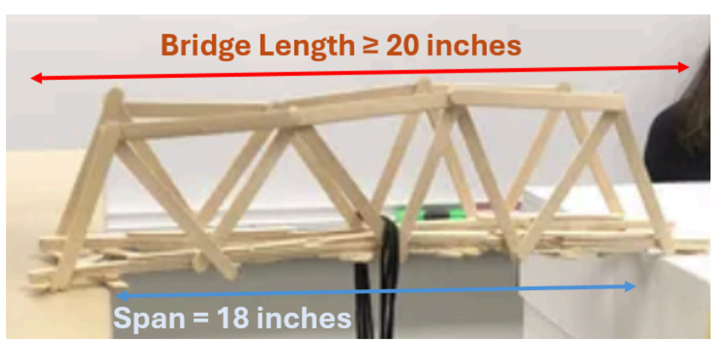

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Answer Me! Sketch your team bridge design.

STEP FIVE: BUILD

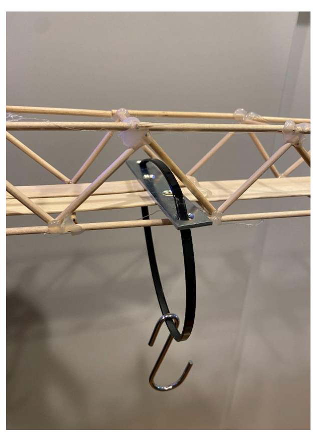
Congratulations! It is time to build your bridge! Below are some **tips for success:**

- Make sure your bridge has strong **connections** without going over budget.

- **Avoid cutting the material.** This will save you time and also reduce the risk of cracks in your material.
- After you test, you will measure the weight of your bridge to help you analyze and reflect upon your bridge performance. Your goal is to **balance weight and structural integrity**- keep this in mind as you build!

STEP SIX: TEST

To calculate the weight your bridge can hold, put a bag on your hook and load it until it breaks. Then calculate the weight of the items in the bag. If you need more help loading your bridge, scan the QR code below for a walkthrough video! Keep in mind that engineers almost always have testing restrictions. We have included some below.



- You will need two chairs or two tables to test your bridge. Set the chairs/tables up **18 inches apart**.
- Place your bridge model on the chairs/tables. Each end of the bridge should **extend at least 1 inch** beyond the chairs/tables.
- Test the strength of your bridge using a **shopping bag**. Add small items until it breaks and **calculate** the weight of all the items in the **bag**.
- Use the iterative process to build a stronger structure.

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STEP SEVEN: ANALYZE

Congratulations! Now that you have tested your bridge, it is time to analyze your results.

Maximum Weight held by bridge (lbs or kg): ___________

There are two key elements to analyze: the cost and weight of your bridge. Use the table below and fill in the highlighted columns in order to determine these two elements. If you used any outside materials or resources, you can disregard those in your calculations. **If you have a scale available to use,** disregard the last two columns of the table and simply input the total weight of your bridge into the bottom right cell.

Material	Quantity	Unit Cost	Total Cost	Unit Weight	Total Weight
Dowel Rod		$10		1.4 g	
Popsicle Stick		$10		1.3 g	
2 in. of Masking Tape		$3		0.2 g	
2 in. of Duck Tape		$5		0.3 g	
Stick of Hot Glue		$10		20 g	
Total:					

Finally, we can calculate the *structural efficiency* of your bridge! Engineers use this to reflect on how their design would perform in a real-world environment, and you can get a good idea from this too!

$$structural\ efficency = \frac{maximum\ weight}{bridge\ weight}$$

Structural Efficiency (%): ____________

Compare this value to the teams around you, and see how well your bridge did! For examples of other bridges that were built by students across the nation and their structural efficiency values- check out the site linked here or scan the QR code.

STEP EIGHT: REFLECT

Now that you have completed your bridge building process, it is time to reflect!

Answer Me! What is one thing that went well? What is one thing that did not go as planned? Would you change anything about your process?

STEP NINE: OPTIONAL EXTENSION AND REFLECTION ACTIVITIES

- Test out your bridge design and other designs using a force analysis simulation! Scan the QR code below or click here for a walkthrough.

- Explore examples of bridge design in real world examples! Check out the keynote speaker for this lab and complete the reflection questions.

Humanitarian Engineering- Try the Bridges to Prosperity Decision Matrix Activity which analyzes the needs of real world communities.

Engineering Design- Try the Bridge Failure Activity which is a case study of the Tacoma Narrows bridge collapse.

STEP TEN: STUDENT EXIT SURVEY

Once you've finished the lab, please complete the student exit survey to share your feedback.