



For Grades 5-12
OCTOBER 2007
CHICAGO SCIENCE IN THE CITY



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September 4, 2007

Dear Teachers and Principals,

The City of Chicago, in collaboration with a dynamic group of businesses, civic, cultural and community organizations is pleased to announce Chicago's second annual *Chicago Science in the City* beginning the week of October 2, 2007. This two-week compilation of events is designed to encourage Chicagoans to explore and experience the various fields of science and to raise public awareness of the importance of science in our past, present and future. Last year's expedition was very successful and brought together 1,500 participants and 5,000 spectators to experience the kick-off event alone.


As one way of supporting *Chicago Science in the City: 2007*, we have partnered with Science Olympiad to create the **Straw Tower Challenge**. For this Challenge, we are asking that teams of students in grades 5-12 build the tallest tower possible out of a limited supply of drinking straws and tape. These towers not only have to be tall but also they must support the weight of a tennis ball. Your school can publish its results, and track the progress of other schools, on the Straw Tower Challenge website. By participating in the Challenge your school is eligible to win various prizes as well as be invited to bring their towers to one of the *Chicago Science in the City: Neighborhood Science Carnivals* for a more public display of your work.

To help you complete this Challenge, your school has been provided with two sets of tower building materials, this is enough material to involve approximately 25 to 30 students in the Challenge, and this booklet of lessons focusing on tower building and the engineering of structures. Science Olympiad designed these lessons to be used throughout the two weeks of *Chicago Science in the City: 2007* either as part of the regularly scheduled classroom instruction or during after-school or at lunch "club" time. In addition, the College of Engineering at the University of Illinois Urbana-Champaign will be providing undergraduate engineering majors to help students as they design and build their towers. These engineering mentors will be "email pals" of the students and offer help and guidance as the students strive to create the tallest tower.

If you have any questions, need additional materials, or need assistance implementing this activity, elementary schools should contact Ms. Chandra James, Office of Math & Science at 773-553-6192 and high schools should contact Dr. John F. Loehr, Department of High School Teaching and Learning at 773-535-8080 ext. 155.

Thank you in advance for your cooperation to make this effort a success. The hard work and dedication you display are always appreciated.

Sincerely,



Michael C. Lach



STRAW TOWERS

You may copy all of these pages for school use.

DESCRIPTION:

To build the tallest tower out of 50 straws that will hold a designated load for 3 seconds.

NUMBER OF PARTICIPANTS:

5-6

APPROXIMATE TIME:

120 minutes total over two weeks

MATERIALS PROVIDED:

50 drinking straws, masking tape, tennis ball, measuring tape

Optional Materials:

Scissors and a pencil; additional load items

Event Parameters:

1. The tower must be constructed using only the drinking straws and masking tape. There will be enough materials to build 3-5 towers.
2. The straws can be interconnected directly by sliding one end into another straw. Straws may be bent, cut or slit.
3. Students may not completely cover their structure with masking tape as reinforcement; tape is used at joints only. Tape may not be used to secure the tower to a table, base, ceiling or surface. You may not make a leg, brace, cone or column out of tape.
4. The tower must accommodate a standard tennis ball. The student must be able to balance the ball on the tower at the loading point for the tower to qualify.

Measuring Your Achievement:

1. Remember to measure your tower height before loading.
2. The height of the tower will be measured again once the tennis ball is placed on the structure. Use a flat surface to test the structure.
3. The tower that supports the load at the highest point is ranked first. If the tower does not support the load, it will be ranked BELOW the tower that did support the load based on tower height.
4. Once you have collected the data on your schools' towers please visit the Chicago Science in the City website and enter the data from the top 3 towers. In addition, pictures can be submitted by following the instructions posted at the site.

The Science Behind Structures:

1. Instructions for Teachers - Lists National and Illinois Standards alignment and tips for using this lesson plan.
2. Extension Activities - Optional extensions for students.
3. Implementation Schedule - A two-week calendar with suggested daily activities.
4. Tower Log - Record observations and plan, design and evaluate your structure.
5. Tower Sketch - A grid to plan your team's design.
6. Basic Tower Design - Covers legs, columns and bracing.
7. Simple Structures - How shapes like triangles and squares form the parts of a tower.
8. Analysis of Structures and Joints - Tips and engineering terms for joining your straws.

Resources:

Science in the City Homepage <http://www.chicagoscienceinthecity.org/>

University of Illinois at Urbana-Champaign College of Engineering <http://www.engr.uiuc.edu/>

Chicago Architecture Foundation <http://www.architecture.org/>

Science Olympiad Home Page <http://www.soinc.org/>



INSTRUCTIONS FOR TEACHERS

With all the excitement surrounding the construction of several new skyscrapers in Chicago (the 92-story Trump International Hotel & Tower, Santiago Calatrava's 2000-foot-tall Chicago Spire), the Science in the City "Straw Tower Challenge" reflects the rich architectural and engineering history of our great hometown. Your challenge as a teacher will be to turn a handful of straws and a roll of tape into a meaningful science activity. You might find skepticism among your students who will ask, "Can we really build a tall tower with straws?" But once presented with the materials, skyscrapers will arise from desks, floors and tabletops, reaching unexpected heights of creativity.

We at Science Olympiad have provided you with a special set of instructions, containing a detailed daily calendar, extension activities for students, a tower log, a sketch sheet and four pages of engineering tips that will help you form the building blocks of a successful tower design. (Please feel free to copy these pages for your internal school use.) Science Olympiad takes pride in aligning all its events to National Science Standards as well as State Standards, and the Straw Tower Challenge meets both:

STRAW TOWER BUILDING – The objective of this event is to design and build a straw tower with the highest structural efficiency capable of supporting a standard load. Teams should maintain and submit a log at check-in containing data to help them improve future designs.

M.E.1.b-d

E. Science and Technology – An understanding of science and technology establishes connections between the natural and designed world linking science and technology.

M.E.1 Abilities of technological design

b. Design a solution or product.

c. Implement a proposed design.

d. Evaluate completed technological designs or products.

Illinois Learning Standard 11.B concerning knowledge and application of the concepts, principles and processes of technological design.

Below are a few sample ways to utilize the following engineering tip pages. Be sure to have students record all observations in the Tower Log:

Basic Tower Design - Ask students about towers they have seen that look like the Basic Tower Design drawing (cell phone towers, electricity towers, the John Hancock Building). Identify the main parts of a tower (legs, columns, braces). Explain the job of each per the handout.

Simple Structures - Take a moment before the first lesson to assemble a few of the shapes with straws that will form the building blocks of a sample tower (square, triangle, pyramid and cube). Let the students touch and examine the shapes. Push, pull and bend the shapes to see how they react and analyze the strength of each shape. Discuss why triangles are stronger and show how they are used as reinforcing cross braces on towers. (How about making a column by bundling cables?)

Analysis of Structures - Now illustrate the concepts of what will happen when you apply stress, pressure or a load to a tower. Use your shapes as a base and test with your hand or an object. What can students do in their design to reduce strain, stress, bending or shearing? Let each student experiment with a straw.

Joints - Demonstrate and practice the proper way to wrap tape around the straws. Build a butt joint with adjoining straws for the longest section. Will it bend at the joint? Overlap the tips of two straws then tape. Is it stronger than the butt joint? Slip one straw into another and wrap the slip joint with tape. The section is shorter, but is it stronger? This exercise is vital to tower assembly and maximizing tower height.



EXTENSION ACTIVITIES

Optional Extension Activities

On all of these challenges, remember to take pictures and upload them to the Straw Towers Photo Gallery located on the Science in the City website at www.chicagoscienceinthecity.org. The website also has a Leader Board which will continuously update your progress against other schools or classrooms within your school. See how your tower stacks up against the rest!

University of Illinois College of Engineering "Ask A Student" E-Mail Program for Straw Tower Challenge - Chicago Public Schools students



participating in the Straw Tower Challenge will be able to exchange emails with civil engineering students from the University of Illinois at Urbana-Champaign to ask questions and seek advice on their team projects. Simply access the Straw Tower Challenge portion of the Science In The City website and click on "Ask A Student." You will be directed to an email address of a UI administrator who will forward your email to an assigned mentor. CPS students will then directly communicate with the civil engineering students, who will also be attending the Science Carnivals on Saturday October 6 and 13 in the Science Olympiad booth.

Build a Chicago Landmark out of straws - Test your skill at modeling by choosing a famous Chicago building and recreate it with straws! Start with an easy geometric shape like the Sears Tower or the Hancock Tower and move on to tougher assignments like the Water Tower, the Prudential Building or even the Frank Gehry-designed band shell at Millennium Park.

Use other materials to test - Hit it out of the park! Instead of a tennis ball, test your structure with a baseball, mini basketball, football or volleyball. As you increase the load, think about the changes you will need to make to your structure to accommodate the additional weight. You can also place a cup on the top of your tower and add marbles, paper clips or pennies one by one to determine the quantity your structure will hold. Design your own Tower Log for The Cup Challenge.

Use other materials to build - Don't limit your imagination to drinking straws to build a tower. Use other materials you will commonly find around school or home, like cardboard, strips of wood, Tinker Toys, K'nex or LEGOS, to build your own creation.

Average Weights of Common Straw Towers Load Items:

Penny	2.5g
Ping Pong Ball	2.7g
Quarter	5.7g
Golf Ball	45g
Tennis Ball	58g
Apple	130g
Baseball	145g
Hockey Puck	162g
Orange	288g
Basketball	600g

IMPLEMENTATION SCHEDULE - OCTOBER 2007



Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
<p>1</p> <p>20 minutes: IDENTIFY THE PROBLEM - Introduce activity and materials, set goals. Assemble student teams and assign jobs. Log on to the SITC web site. Discuss Basic Tower Design (p.7).</p>	<p>2</p> <p>20 minutes: ANALYZE & GENERATE SOLUTIONS - Go over Simple Structures, Analysis of Structures and Joints (p. 8-10) and begin sketching out designs (p. 6). Work as a team to brainstorm shapes to hold the tennis ball atop your Straw Tower - grid, teepee, raft, shelf, basket, rooftop etc. Incorporate all ideas! Make sure you consider a way to stop the ball from rolling off. Use 10-15 straws to begin assembling 2-D and 3-D shapes: squares, triangles, cubes, pyramids (p.8).</p>	<p>3</p> <p>20 minutes: SELECT & PLAN SOLUTIONS - Settle on a design idea based on trial and error. Enter data into Tower Log (p.5) and begin testing weights on short structures. Build levels with remaining straws. Upload photos onto SITC web site.</p>	<p>4</p> <p>Extension: Try to build a Chicago landmark out of straws.</p>	<p>5</p> <p>Extension: Use other materials to build your tower.</p>	<p>6</p> <p>Science in the City Science Carnival #1</p>
<p>8</p> <p>10am - 2pm Science in the City Kickoff in Daley Plaza</p> <p>20 minutes: IMPLEMENT SOLUTION - Assemble multi-tiered or multi-level tower. Test load. Evaluate joints and discuss ways to use tape to make the strongest joints. Enter data into Tower Log.</p>	<p>9</p> <p>20 minutes: EVALUATE SOLUTION - Make adjustments and record engineering and construction successes and failures in Tower Log. Finalize design and test. Take photos!</p> <p>Extension: Use other materials to test your tower.</p>	<p>10</p> <p>20 minutes: Utilize Student and Teacher resources page. Compare your tower to others within your school to declare which is the tallest tower that holds the tennis ball. Finalize your Tower Log and turn in to teacher. Upload final photo. Congratulations on building a Straw Tower!</p>	<p>11</p>	<p>12</p>	<p>13</p> <p>Science in the City Science Carnival #3</p>



STRAW TOWER LOG

Part One - Information Collected During Construction

Date:

School Name:

Team Members

Straw Boss:

Architect:

Engineer:

Information Manager:

Construction Workers:

Number of Straws Used: _____

Number of Joints on Straw Tower: _____

Sketch your design here and label the parts of your Straw Tower

Part Two - Information Collected During Testing

Height of Tower: _____ Height at top of tennis ball: _____

Did the Straw Tower hold the tennis ball? Yes No

Part Three - Information Collected After Testing

How did the Straw Tower fail and what could you do to improve your design?

Where did the Straw Tower fail? (list location of failure and ID on drawing above)

What one thing would you change about the design next time?

Jobs - Each member of the team should choose a job from the following list:

Straw Boss - Serve as the Project Manager and supervise the project, making sure the job is getting built on time.

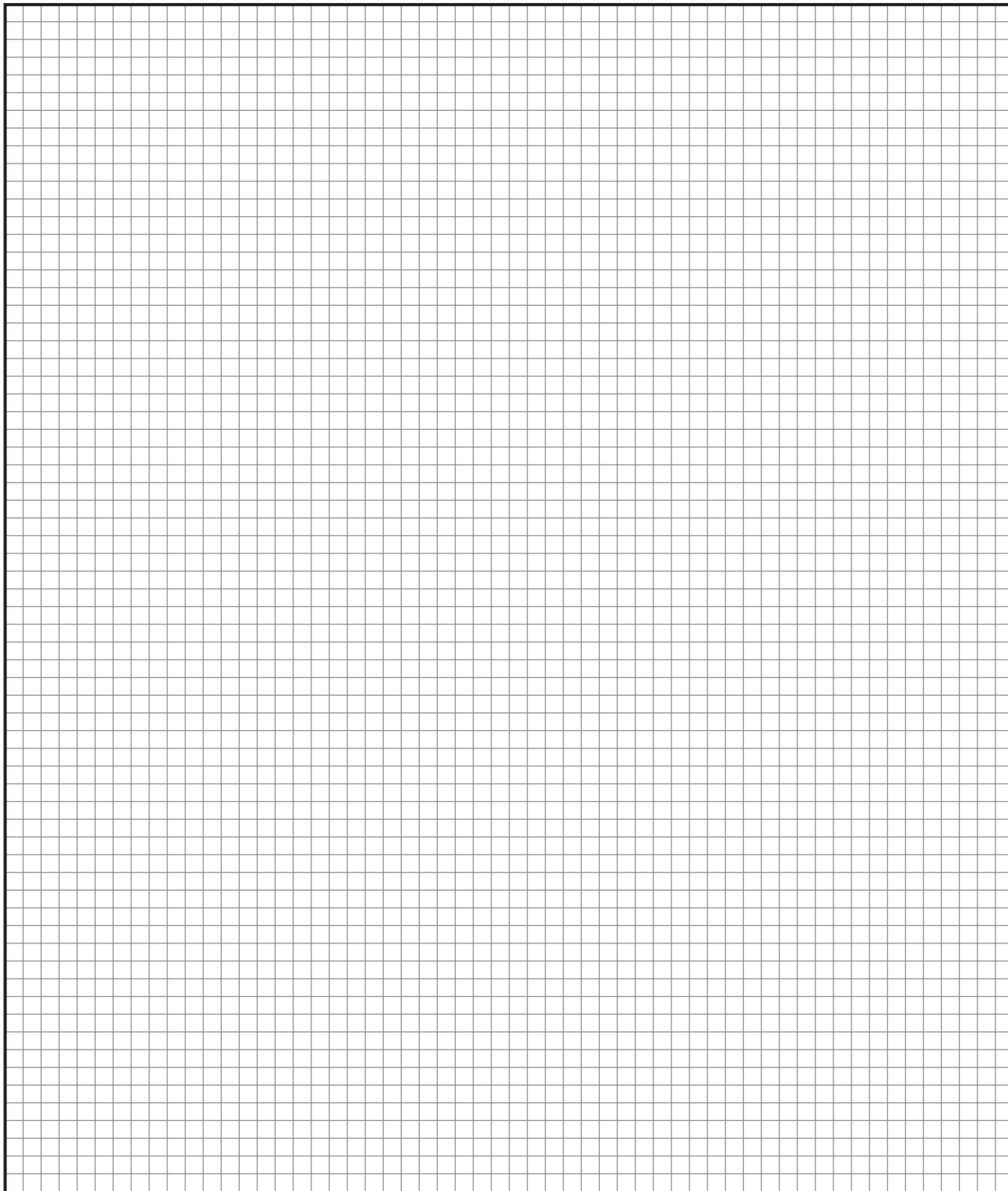
Architect - Complete the drawings and sketch out the design of the tower.

Engineer - Manages building the tower and testing the load.

Information Manager - In charge of all information related to the construction project; complete the Tower Log and take photos of all progress.

Construction Workers - Members of the crew will build all parts of the tower.

SKETCH YOUR TOWER



BASIC TOWER DESIGN

Note to Teachers: The following four pages provide an overview of the components necessary to build successful Straw Towers. Use these tips as instructional tools to correspond with the activities listed on the Instructions for Teachers on Page 2 and the Implementation Schedule on Page 4.

The object is to support a load at some height above the base.

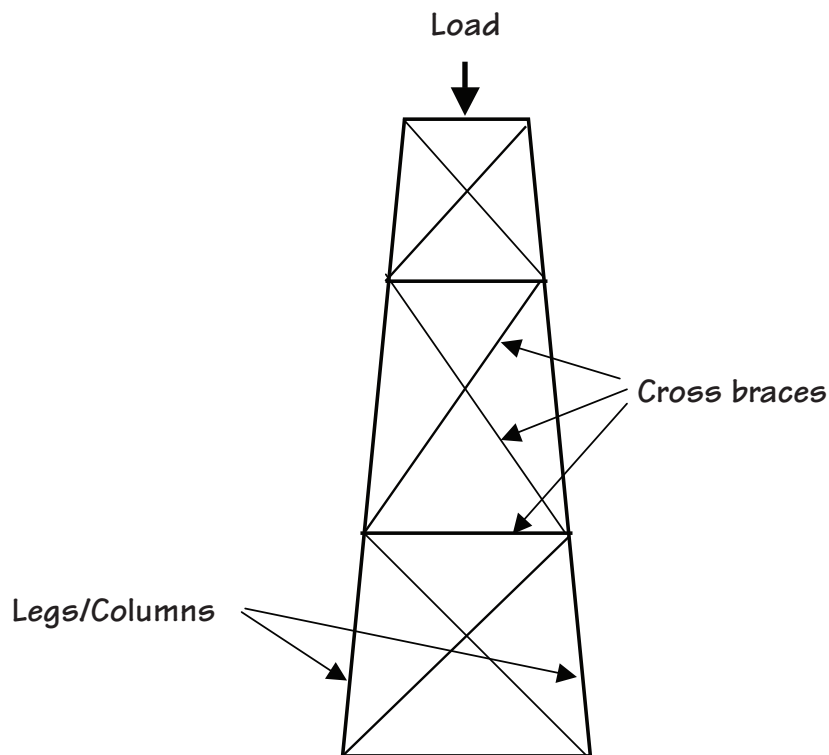
A tower is made up of:

Legs or Columns – Vertical members

- Extend from the base to the top of the tower
- Support the load
- Need to be strong in compression
- Bend easily because they are long and slender

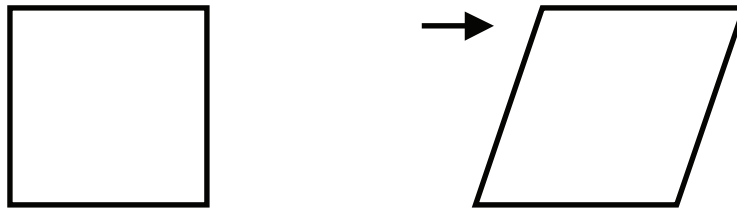
Cross Braces – Horizontal/Diagonal members

- Connect one leg to another
- “Break” the legs up into shorter and stronger members
- Prevent the legs from bending
- May be under compression or tension
- Have very little stress as long as the legs remain straight



SIMPLE STRUCTURES

Square

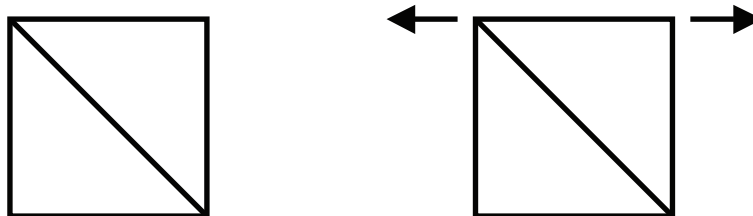


Use 4 drinking straws and tape to form a square. Stand the square on edge and apply a downward force to the top of it. The square deforms easily due to the weakness (in rotation) of the corner joints.

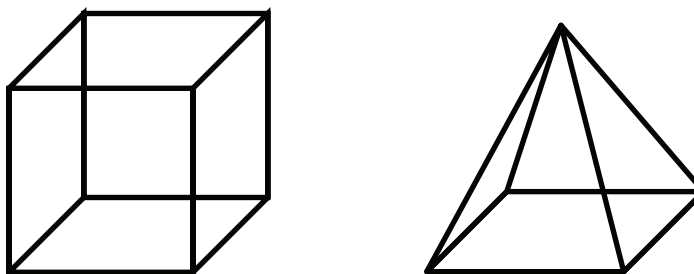
Triangle



Make a triangle in the same manner using 3 straws and tape and test it as you did the square. The triangle won't change shape unless you push hard enough for either a joint or one of the straws to break.



Fortunately a 4-sided figure can be changed into 2 triangles by connecting 2 opposite corners together. Add a rigid cross brace to the square and test it again. Now it is much stronger.



Use squares and triangles as a base to form pyramids and cubes which will be the building blocks of your Straw Tower.

ANALYSIS OF STRUCTURES

Definitions

Joint – The place where 2 or more members are connected together.

Member – A part of a structure that connects 2 joints.

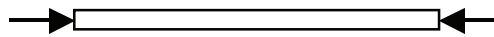
Strain – The deformation or change of shape that is the result of applied stress.

Stress – The force applied to an object that tries to change its shape. There are 5 different forms of stress:

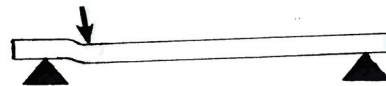
Bending – Stress that tends to deform an object from a straight line.



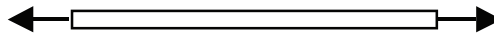
Compression – Stress that tends to compress an object together.



Shear – Stress that tends to make two parts of an object slide past each other.



Tension – Stress that tends to pull an object apart.



Torsion – Stress that tends to twist an object around an axis.

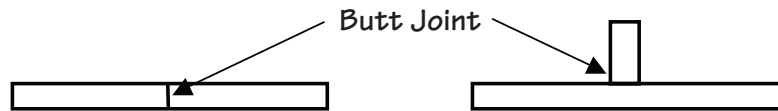


For our simplified analysis we will only consider bending, compression, and tension.

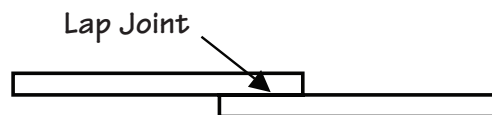
JOINTS

A joint is where 2 or more members are joined together;

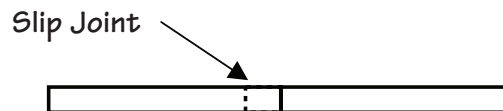
Butt Joint – Pieces are joined end to end



Lap Joint – Pieces are overlapped



Slip Joint – One piece is slipped into the other



The strength depends on the type of joint and material used to hold it together.

You can use tape to hold butt and lap joints together.

A lap joint can be held together with string or tape used as glue.

Strength of Taped Joints

Butt Joint

Bending – Medium
Compression – Strong
Tension – Weak

Lap Joint

Bending – Medium
Compression – Medium
Tension – Medium

Slip Joint

Bending – Weak
Compression – Medium
Tension – Weak