Civil Structures Competition

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SMART Conference
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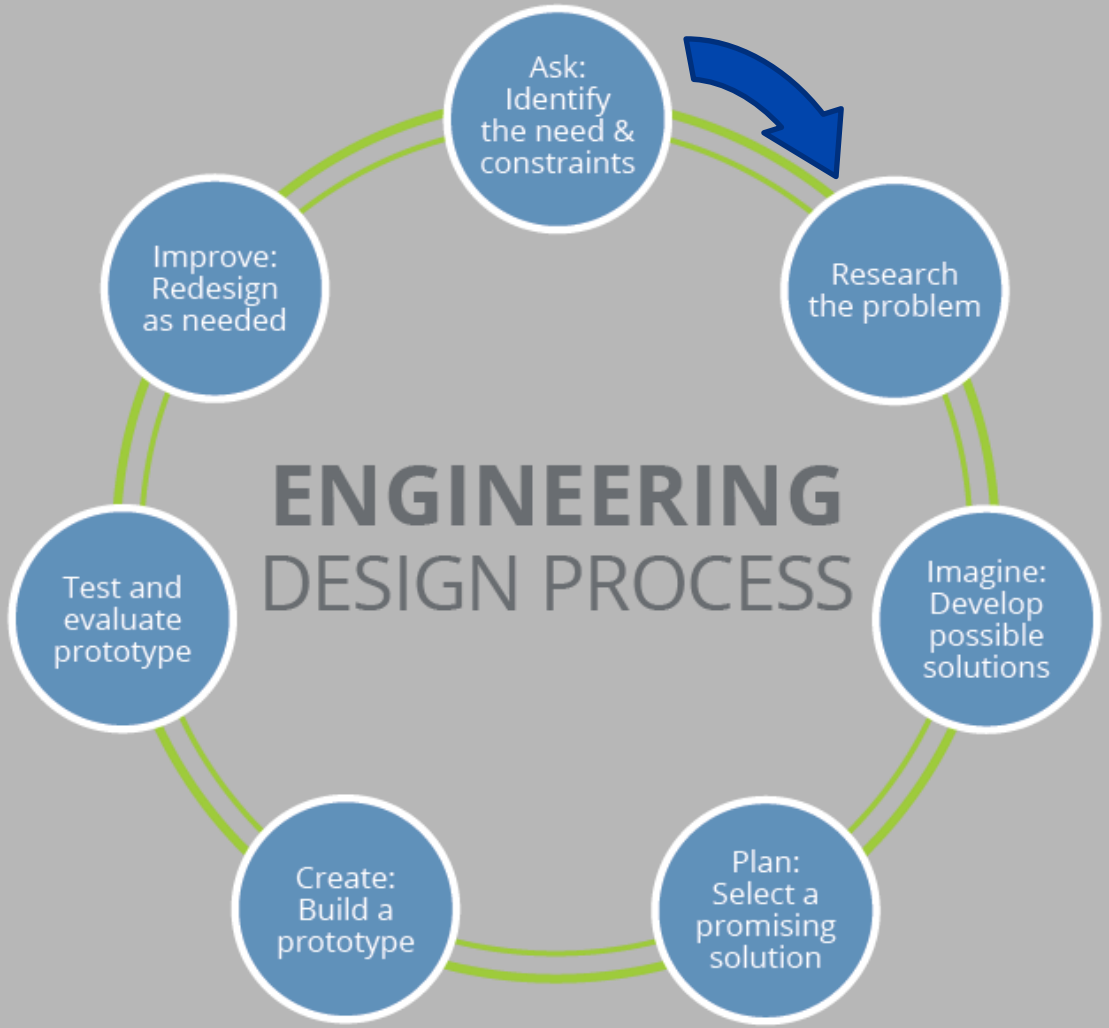
Workshop Objectives:

- At the end of the workshop you will be able to:
  - Explain the purpose of the competition
  - Provide tips and guidance on how to build a truss bridge
  - Explain Newton's Laws as they related to forces
  - Discuss the engineering notebook
  - Discuss the judging process
  - Explain the rules
  - Find additional resources

Purpose of the competition

- "Students will design and construct a model balsawood bridge from their own plans that will carry a maximum load while using as little wood as possible, stressing neatness, craftsmanship, and creativity."
- Three important activities:
  - Design → entails creating a functional and cost-effective structure that will safely carry loads
  - Construction → use elements to assemble the design
  - Aesthetics → pleasing to the eye!


Ask: Identify the need & constraints
Research the problem
Imagine: Develop possible solutions
Plan: Select a promising solution
Create: Build a prototype
Test and evaluate prototype
Improve: Redesign as needed
ENGINEERING
DESIGN PROCESS

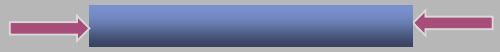
Structures

- Types:
  - Buildings
  - Foundations
  - Pipelines
  - Stadiums
  - Towers
  - Bridges
- Framing systems
  - Arches
  - Beams and frames
  - Cables
  - Towers
  - Trusses
- Design:
  - Materials
    - stone
    - steel
    - concrete
    - wood
  - Loads
    - gravity
    - wind
    - rain
    - snow
    - earthquake
  - Structural elements
    - Beam
    - column
    - tension

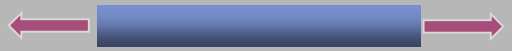
Wood Properties

http://www.pbs.org/wgbh/buildingbig/lab/forces.html

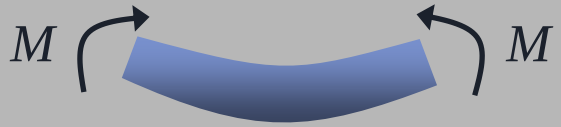
- Compression (pushing)

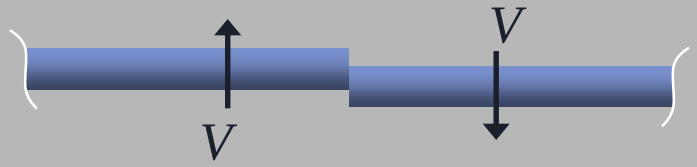


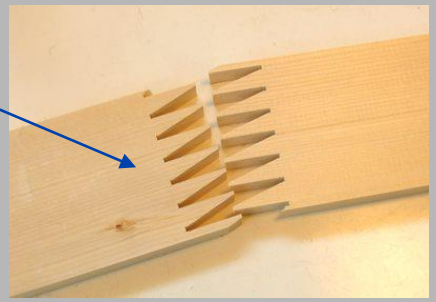
  - Hundreds of times its weight in compression, but limited by buckling: $P = p^2 * stiffness/lenght^2$
- Tension (pulling)



  - Thousands of times its weight in tension; except that this case is only as strong as the glued join, which depends on surface area glued (finger joints)
- Bending and shear (tearing)







Building Tips

- Student Introduction to Bridge Forces
- Follow with a short term activity
- Design & Sketch (To Ratio/In Accordance to Rules)
- Review & Approve (Stay Away from Max & Mins)
- Begin Building (wax paper on top of sketch)

Orient components to transmit forces as either tension or compression

Gluing

- **Only** water soluble Elmer's type white glue allowed
- Sand the joints carefully so that the members fit well
- Glue only allowed at the joints
- Verify bridge is symmetrical
- Allow to dry in a cool, moist environment.
- Do NOT place in oven or use hairdryer to speed drying
- Maximum bond strength occurs after **two weeks** of drying time.

Dimension Restrictions

The bridge MUST meet the following dimension/weight restrictions:

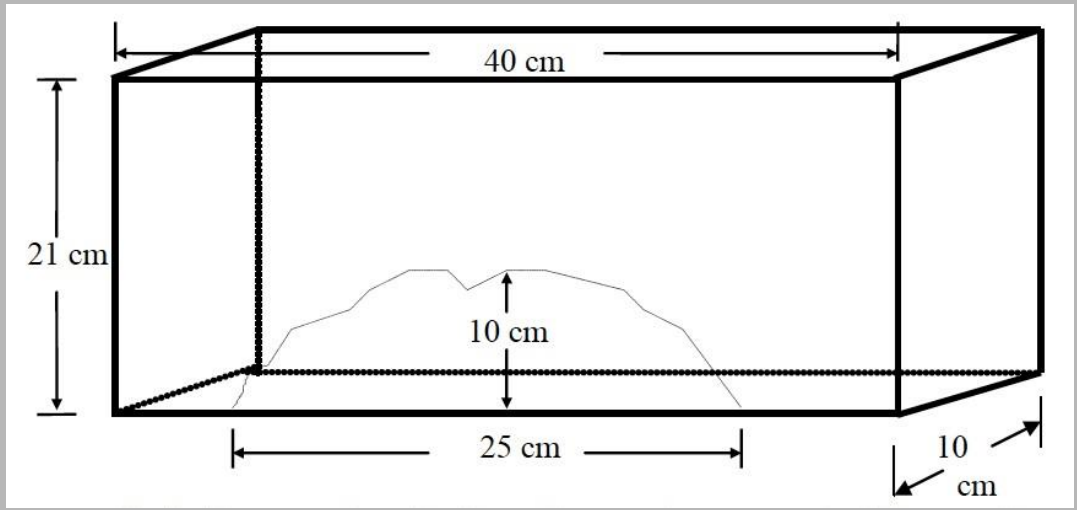
a. Maximum length = **40 cm**

b. Maximum width = **10 cm**

c. Maximum height = **21 cm**

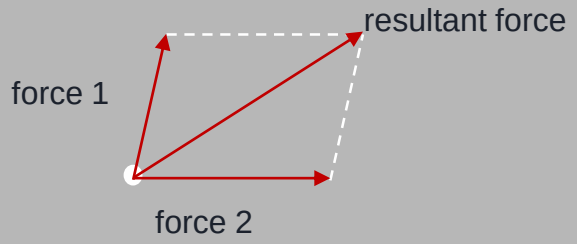
d. Minimum clearance = **10 cm**

e. Minimum span = **25 cm**



f. Maximum Bridge Weight = **95 grams**

Fundamental Principles

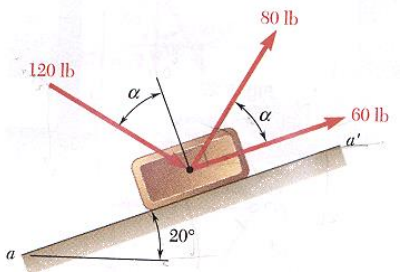


- Addition of forces

- Newton's Laws of Motion
  - If the resultant of a system of forces acting on a body is zero, the body will remain at rest (if originally at rest) or in uniform motion in a straight line (if originally in motion)
  - If the resultant of a system of forces acting on a body is not zero, the body will experience an acceleration proportional to the resultant force, $\boldsymbol{F} = m\boldsymbol{a}$
  - Forces of action and reaction between bodies in contact have same magnitude and line of action, but opposite sense

Example:

- Knowing that $\alpha = 40°$, determine the resultant of the 3 forces shown.



120lb(sin(30 °)) = - 60lb

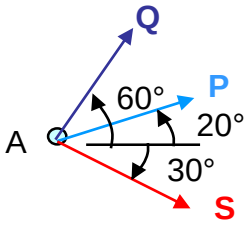
120lb

120lb(cos(30 °)) = 103.9lb

60lb(sin(20°)) = 56.4lb

60lb

60lb(cos(20°)) = 56.4lb



80lb(sin(60°)) = 69.3lb

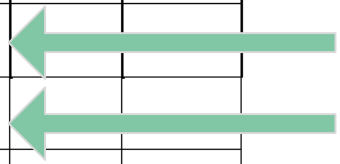
80 lb

80lb(cos(60°)) = 40lb

Engineering Notebook

Please use this rubric to assess notebook entries. An incomplete or missing notebook will lead to a 20% deduction from the total project score

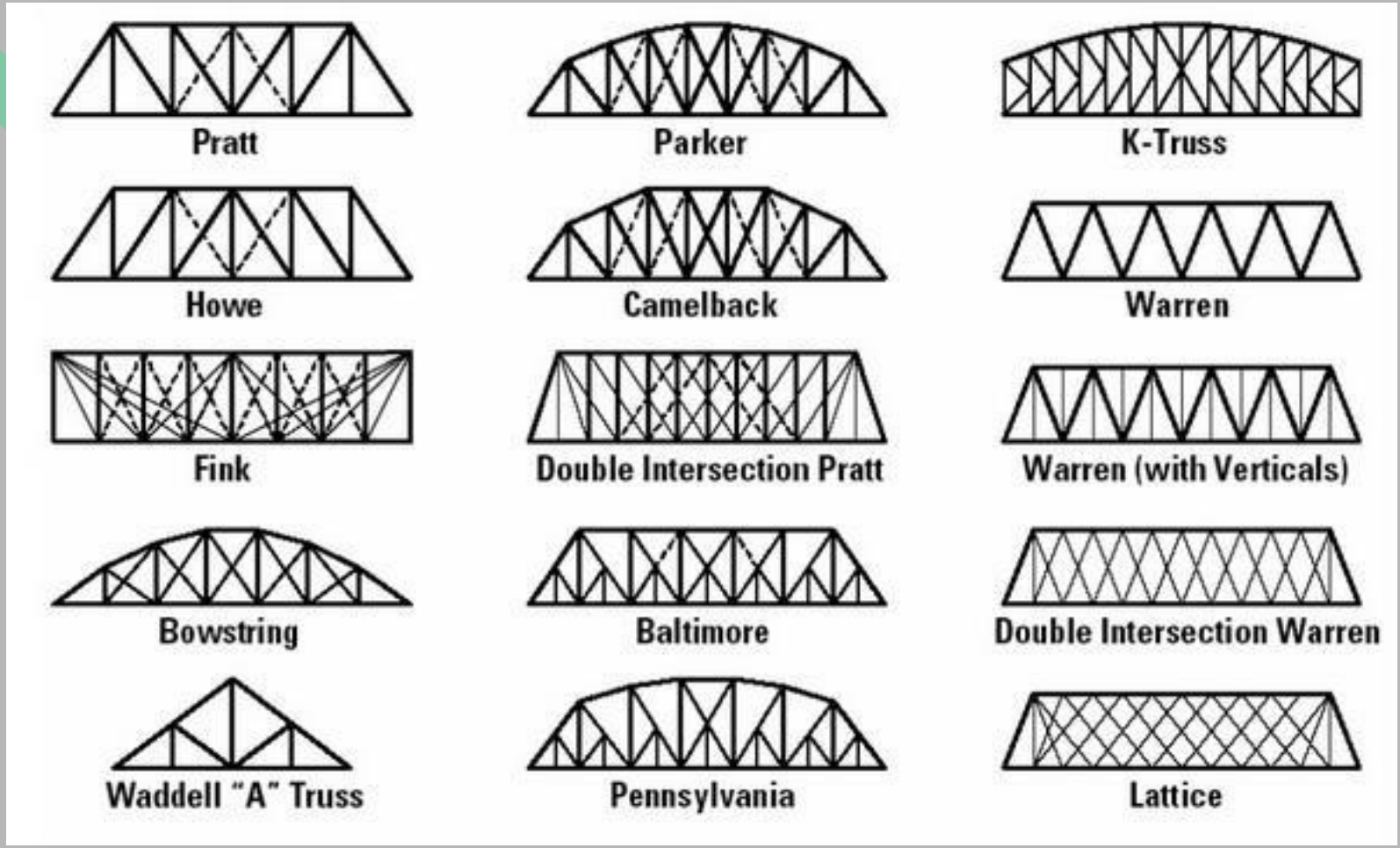
Criteria		YES	NO
1	Is the notebook properly labeled? *(Names, Grades, School, MESA Center)*		
2	Does the notebook contain a one page introduction to the project? *(On the first page of the notebook)*		
3	Are there at least 10 dated entries in the notebook?		
4	Is each entry at least half a page long?		
5	Are there at least two distinct project sketches included?		
6	Is there evidence of 1-2 applied mathematics principles?		
	TOTAL		



Does the notebook meet the requirement? (circle one) **YES** **NO**

Notebooks must meet all criteria to fulfill this requirement

Project Sketches



Math Applications

Notebooks must contain evidence of two mathematical principles as it pertains to the project.

- First concept: include the calculations of the magnitude of a vector at a typical joining angle, which must be labeled with a dot with red ink
  - Use Newton's Laws (see next slide) and
  - https://www.youtube.com/watch?v=RBLpMAcWHkg
- Second concept is to calculate the of mass of the bridge.

  Bridge's mass = 56 grams

  W = m *g Weight equals mass times gravitational acceleration

https://www.mathsisfun.com/measure/weight-mass.html

Weight vs. Mass

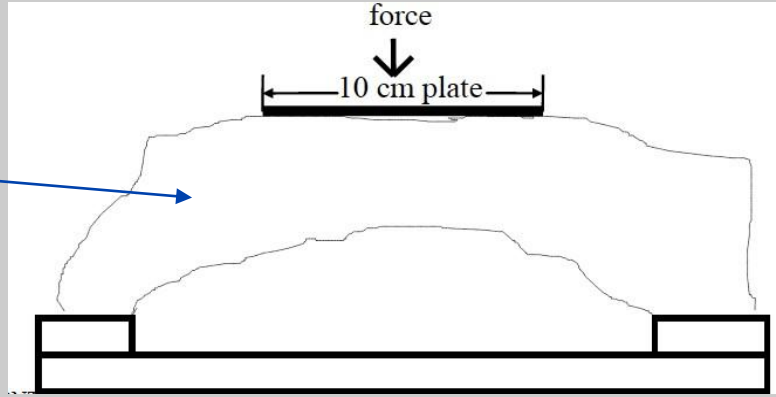
- The weight of an object is the force of gravity acting on that object (measured in newtons). Since the force of gravity depends upon altitude and position on the earth, weight is not an invariant property of a body. Also, there are two forces that affect the weight of an object: gravitational pull of the earth and the centrifugal effects associated with the rotation of the earth. So, the weight of an object can be classified as absolute or apparent. Absolute weight is based on the force of gravity alone, while apparent weight includes the effects of rotation as well. Thus, apparent weight is always less that absolute weight (except at the poles). Usually the term "weight" means "apparent weight". This is the weight of an object as measured with a spring scale. Weight is related to the mass based on Newton's second law: $W = mg$

  where g is acceleration due to gravity, and varies with elevation and latitude

  - For scientific calculations a standard international value of g has been established as: $g = 9.806650\ m/s^2$
  - For ordinary engineering purposes on or near the surface of the earth: $g = 9.81\ m/s^2$

Judging Process

1. Inspect bridge to ensure it meets all rules
2. Weigh the bridge and record its weight
3. Judge aesthetics
4. Test load carrying capacity of bridge
5. Disqualified bridges are not tested
6. Determine Strength-to-Weight Ratio: (maximum load at failure/weight)



Example: Maximum load = 120.0 pounds
Bridge weight = 20.0 grams
Ratio = 120 pounds x 454g/pound / 20g = 2724

MAX WINS

General Rules

1. Properly label bridge with team members' names, school, and MESA Center; or 10% penalty in the strength to weight score
2. No bridge kits
3. Joints must be at or within ¼" of end of at least one of the members. Members may only be glued to another stick at joints
4. No glue may extend beyond 3 mm of any joint
5. Dimension restrictions
6. Angled members must be joined at an angle of 30 degrees or more
7. Members may be carved, notched, or cut anywhere along their length
8. Pins and/or gussets are not allowed

General Rules Cont.

9. No material may be applied to the bridge. Ink or pencil to identify bridge builders, school, and center is ok
10. Maximum allowed weight is 95 grams
11. Top of bridge must support a 10 cm x 10 cm plate where testing load is applied
12. Bridge must have supports at least 25 cm apart, and must measure at least 10 cm above a flat surface (an imaginary “river”) at least one point (may be more than one point) between the supports
13. Project must be the original work of student(s)
14. Remember the purpose of this contest - use creativity to build the best structure within the framework of the rules

Top DQs

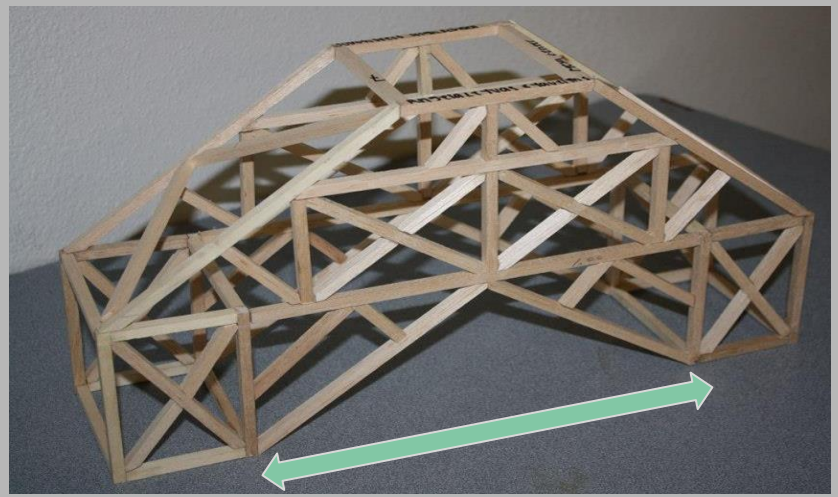
- Bridge Dimensions & Weight

- Angles

Top DQs

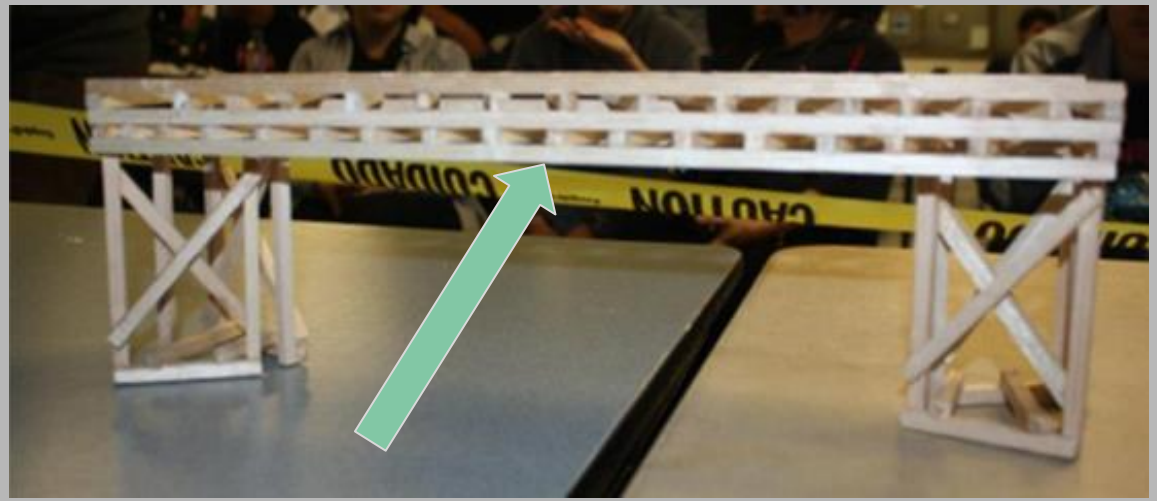
- Coating excessive glue

- Span



Top DQs

Joints must be at or within ¼" of the end of at least one of the members



Advisor Resources & Questions

MESA Curriculum

http://mesa.ucop.edu/staff/

Username/Password:

- **msp_teacher**
- **MESAdaysp@55**

Contact Info:

Jeanette Espino: Jramos@ecesd.org

Imperial Valley - Program Director

Luis E. Topete: Ltopete@mail.sdsu.edu

San Diego State - Program Director

**** Keep in mind, all centers operate differently. Event logistics and materials will vary among centers. Advisors and students are responsible in verifying information with their Center Director.*