

**Roof Trusses LAB**

Subject Area(s)     Physics  
Associated Unit     Wind Effects on Model Building  
Lesson Title        Lab for Truss Design and Testing

Grade Level     (11-12)  
Part #            1 of 3  
Lesson #          2 of 2  
Time Required     60-90 minutes  

Summary

The idea of this lesson plan is to teach Newton’s laws and static forces using an engineering approach. Students are to design and test a truss with specifications given by the teacher. Day 1 students are given pre-lab information on how to solve a basic structure without an internal members or webs. The students are expected to design a truss with two or three internal members. Students will be given balsa wood 4 mm x 4 mm x 93 cm. The structures will be testing using a 50.0 N Vernier Force sensor and Logger Pro software.

Engineering Connection

This is a connection into design and building part of a structure and the importance of stable structures that are not over designed but still strong. Additionally, it will show the difference between compression and tension forces.

Engineering Category

Civil Engineering

Keywords

Truss, roof, tension, compression, forces, building

Educational Standards

Science:

**Physics Texas Essential Knowledge and Skills (TEKS):**

3(B) express laws symbolically and employ mathematical procedures including vector addition and right-triangle geometry to solve physical problems;

3(D) describe the connection between physics and future careers;

4(C) demonstrate the effects of forces on the motion of objects;

4(D) develop and interpret a free-body diagram for force analysis;
Pre-Requisite Knowledge
Understanding of forces and basic trigonometry functions

Learning Objectives
After this lesson, students should be able to:
- Design and build a basic truss design
- Complete calculations on member forces in tension and compression.

Introduction / Motivation
What do engineers do? Why do engineers need to consider forces? How can engineers use a minimum amount of materials for a maximum output?

Lesson Background & Concepts for Teachers

Three different truss designs, each shown with a span of 31 cm and angle of 40 degrees.

- Truss with one web.
  Joints A - D

- Truss with three webs.
  Joints A - F
Force sensor probe testing set up is shown here. The block between the truss and sensor is a rubber block with notches on either end to help hold the sensor vertically. The bricks at the base help keep the truss from moving in the z-plane.

<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Force</td>
<td>A push or a pull</td>
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<tr>
<td>Compression</td>
<td>A force that pushes an object inward.</td>
</tr>
<tr>
<td>Tension</td>
<td>A force that pulls an object outward.</td>
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<tr>
<td>Joint</td>
<td>Point that two chords or members meet.</td>
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<tr>
<td>Chord</td>
<td>The member between two joints that is in compression or tension.</td>
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STUDENT LAB: TRUSS DESIGN AND TESTING

Background:
Truss Engineer: the design professional or organization having the responsibility for the design of the wood trusses. Additionally, the truss engineer prepares the truss design drawings, showing the slope, span and spacing, location of all joints, design loads as applicable and each reaction force and direction.

Truss Owner: shall mean the individual or organization for which the structure is designed. The owner is responsible for the review and approval of each Truss Design Drawing, evaluation of the truss engineer’s design specifications.

Truss: any of various structural frames based on the geometric rigidity of the triangle and composed of straight members subject only to longitudinal compression, tension, or both which functions as a beam or cantilever to support bridges, roofs, etc.

http://www.chamberstruss.com/terms/wtca95.htm

Purpose: Perform duties of a Truss Engineering group to design a truss for your Truss Owner (Teacher). The truss must have a slope between 25 and 45 degrees with an overall span of 25 cm. The truss must have two or three additional interior members or chords. Limited materials will be supplied to each group.

Procedure:
1. Each Truss Engineering group must submit a rough sketch of the truss that meets the Owner’s purpose. If the sketch is approved, the procedure may continue. If the sketch is not approved for non-compliance, the sketch will be rejected. After the second rejection, the Truss Engineering group will receive a 5 point deduction for each rejection, starting with the second rejection.
2. The Truss Engineering group must then make a template on wax paper and obtain the materials. Remember materials will be limited.
3. Using a sharp knife and glue, the group will construct the truss.
4. The truss is submitted back to the owner for testing. The maximum load will be will a joint or member fails.
5. The group then takes the maximum load and calculates the reaction forces and direction for each member of the truss. Each chord must be labeled as Tension or Compression.
6. Complete a full scale diagram on the back of page 6 of the laboratory report showing all joints and forces on each member in Tension or Compression.

Data:

Number of members: M = _______________
Number of nodes (joint): N = _______________

Condition to be met: M = 2N - 3
Approved Sketch: (Not drawn to scale)
Show the slope, span, spacing, location of all joints (Joint A at the peak), and maximum vertical load at Joint A.

Calculations:
Show the calculations for each joint. Use the example calculation to help you calculate the reaction force in each chord. Make sure to identify if the force is TENSION or COMPRESSION.
Calculations continued:

Conclusion:
Why is it assumed in this laboratory exercise that the sum of the forces in the x- and y-directions must equal zero? Why must the condition of \( M = 2N - 3 \) be met? What is the difference between a compression force and a tension force? What is the reaction of the chord of the truss when it is in compression or tension? Where did your truss design fail? Is it similar to the failure point of other groups in the class? What are some examples of loads that would act vertically downward on a structure? What safety features must an engineer consider when designing the load specifications for a structure?
Draw full scale truss design here, showing angles, showing angles and measurements.
Label joints, force values and show Tension and Compression.
Lesson Closure  Discuss additional relevant information that engineers need to build a structure. Review the truss designs of all groups and identify the point the structure failed. What are the overall design weaknesses?

Assessment  Evaluation of laboratory calculations and conclusion.

Lesson Extension  Have students investigate different civil engineering buildings at [http://content.asce.org/asceville/index.html](http://content.asce.org/asceville/index.html)  
Effect of Wind Loads on Building Structures Part III

Student page for truss information

Other  Discuss various ethical practices in engineering – quality of materials, maintenance of structure, and compliance of building standards.

Creator  Danielle Reynolds / Duncanville High School

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