

Design-A-Beam

Subject Area(s) Math, Physics, Measurement

Associated Unit None

Associated Lesson None

Activity Title: Design-A-Beam

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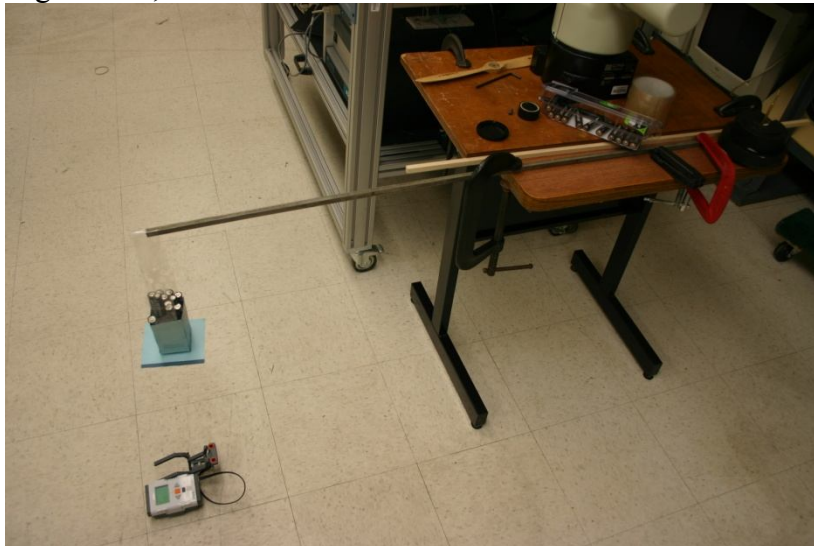


Image 1

ADA Description: An image of beam with load on end

Caption: None

Image file name: design a beam 002.jpg

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Grade Level 7 (6 - 9)

Activity Dependency: None

Time Required: 45 mins.

Group Size: 5-7

Expendable Cost per Group: US \$0

Summary

Students during this activity are learning about the measurement and mathematics behind simple structures that are seen in everyday life, such as a beam. Geometry, along with other factors and characteristics, can affect the how and the why certain structures are used. Students will be able to investigate this for themselves, as they will perform an experiment on different types of beams. Students will measure different types of beams for their cross-sectional area values, and compare them to how much they bend as a load is placed on each beam. By doing this, students will be able to investigate the ideal geometry and material for a load bearing beam.

Engineering Connection

Civil and mechanical engineers design structures of buildings and machines in order to ensure that any structure holds up under various loading conditions. Different types of materials and designs are used to ensure the durability of the structure. The stiffness of the beams used in a structure is essential to consider, which includes material and geometry considerations. Therefore, measurement and testing of beams is crucial to ensure proper structure design.

Engineering Category

Relates math concept to engineering

Keywords: Stiffness, beam, displacement, material, Lego Mindstorms NXT, data acquisition, sensor

Educational Standards

New York Math, 2010, 6.PS.3, 6.PS.5, 6.PS.12

New York Science, 2010, PS 5.1e, PS 5.2b

Pre-Requisite Knowledge

Basic geometrical shapes, decimals, area calculation, displacement, graphing

Learning Objectives

After this activity, students should be able to:

- Gain experience in basic engineering design considerations
- Observe the application of geometry and measurement data in real-life applications

Materials List

Each group needs:

- Various rectangular beams, at least 2 feet long and 1/2 in thick:
 - At least three wooden beams with square cross-sections, one slightly larger than the other
 - One metal beam (steel or aluminum) with square cross section, same size as one of the wooden beams
- Cardboard sheet
- Batteries of same size, or small weights for measurement
- Two Clamps
- Ruler or caliper

Introduction / Motivation

Let's say you are exploring the big city, and you are seeing a whole bunch of construction sites for new skyscrapers. You start to see a whole group of guys with hard hats moving around carrying materials and machines so that they could keep on building the skyscraper. At the moment, you might not see much of a building, but you might see something that looks like giant metal "sticks" that are somehow being put together (Draw a building frame). You may not realize it at that moment, but those "sticks" are really important when it comes to making sure the building stands up and stays up.

Those long "sticks" are referred to as **beams** (Draw a beam on the board with dimensions). A beam, by definition, is a long structure whose length is several times longer than any of its cross-sectional dimensions. Beams can be made of many different shapes and sizes, as well as different materials, like wood, metals, and in some machines, even plastics. Depending on what is being built, you may want to use a certain kind of material with a specified size, all of which can affect the **stiffness** of the beam, since the beam will undergo a certain amount of **deflection** when a weight is placed on it. But how do we know what size and/or what materials are better to use? How do we know that what we build won't move too much when we put weight on it? This is what we want to investigate. We have wooden beams of different sizes, and we are going to measure their sizes in order to calculate their cross-sectional areas. We are also going to put the same amount of weight on the tips of each of those beams, and measure how much the tip moves by using a Lego NXT setup with a **sensor**. Then you can draw up a graph of cross-sectional area versus deflection, and see what you get. Once you are done with that, you can take the steel beam, take a wooden beam of the same cross-section, and repeat what was done with the wooden beams before. Let's see what conclusions you can come up with when it comes to beam size and material type.

Vocabulary / Definitions

Word	Definition
Beam	Basic structure whose length is several times larger than its cross-sectional dimensions
Stiffness	Resistance to change of shape of a material or structure
Sensor	Device that measures or "senses" a specific quantity (temperature, distance, level of light/darkness)
Deflection	Change in position of a point along a structure

Procedure

Before the Activity

- Setup individual group stations with at least two clamps on each station
- Make a cardboard basket for each station, or have kids cut out and make baskets.
- Setup a deflection measurement device using an ultrasonic sensor along with the NXT brick.
- Use the same amount of weight for each station, using batteries or actual experimental weights.
- For each station, place the cardboard basket on one of the beams by either using tape or a rope attached at the very tip.

With the Students

Using wooden beams only:

1. Have each group of students clamp the beam in place, with 2 feet of beam length overhanging from the table or station, as well as having the clamps evenly distributed along the beam.
2. The students should place the NXT measurement device below the basket, with the ultrasonic sensor pointing at the bottom of the basket.
3. Have the students record the initial position of the basket on the beam.
4. Have the students place weight on the platform and write down the position of the basket after the weight is placed.
5. Have the students calculate the displacement for each beam. The ruler or caliper can be used to calculate the cross-sectional area of each beam as well.
6. Using the obtained data, students can create a graph of cross-sectional area versus deflection of the set of beams.
7. Ask students for interpretation: what do they think the graph is saying about the beams tested?

Using wooden and steel beams of same cross-section:

1. Repeat steps 1-7 above.

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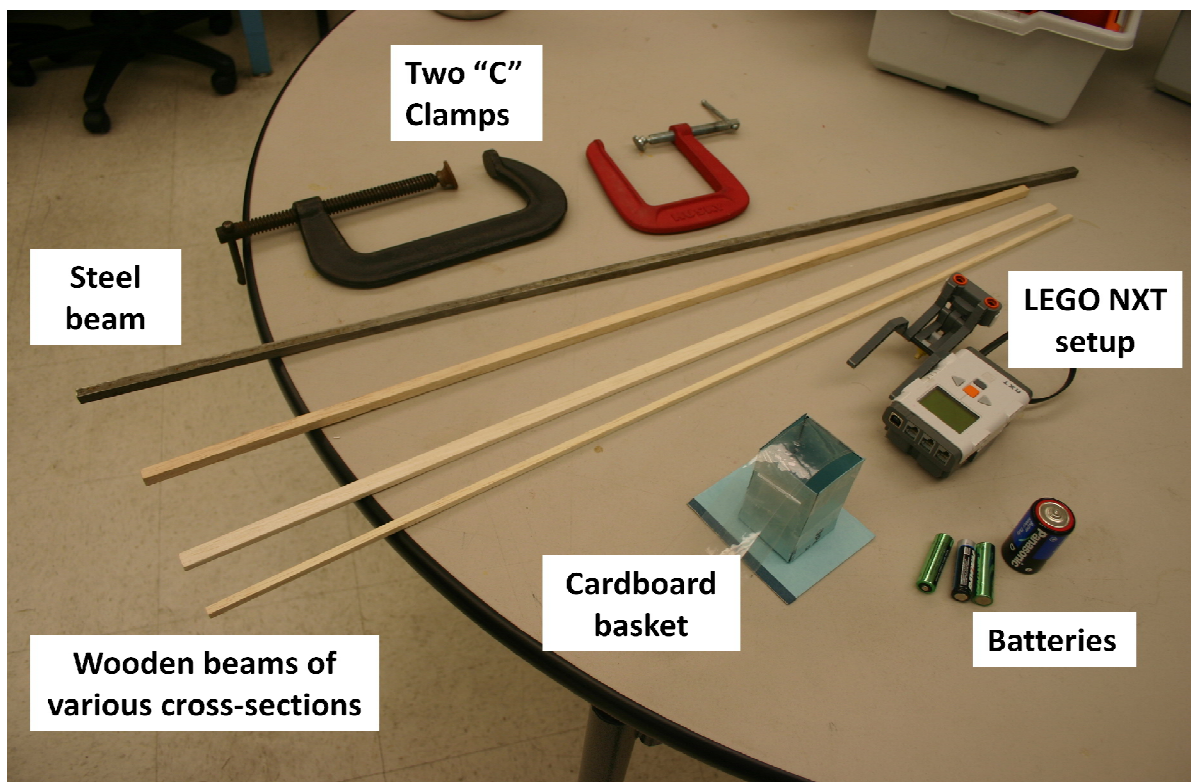


Image 2

ADA Description: An image of each of the components used for the beam deflection setup

Caption: Figure 1: Spring testing setup components

Image file name: beam setup components.jpg

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Safety Issues

- Slowly load and unload the weights to ensure the beam does not flail out and hit someone.

Troubleshooting Tips

- Ensure that the hanging weight is still when taking displacement measurements to ensure as accurate a reading as possible.
- Given that the ultrasonic sensor may not be as sensitive to detect large differences in deflection, try measurement using the centimeter scale, and/or increasing the overhang length of the beam.

Assessment

Activity Embedded Assessment

Analysis

There are two criteria that students should be evaluated on: conducting experimental measurements and the interpretation of graphical data. When conducting experimental measurements, the groups should have the similar displacement results, given that the same-size beams should be used by each group. When interpretation of data is conducted, students should be able to interpret what is seen on a graph that is drawn using their own obtained results. Students should then be able to have more insight into engineering design in terms of structures.

Activity Extensions

None

Additional Multimedia Support

None

Owner

Ronald Poveda

Contributors

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Supporting Program

AMPS Program, Polytechnic Institute of NYU

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