ENGINEERING LESSON PLAN
John Schineller, Robert Gandolfo

Subject Area (s): Physics Technology

Associated Unit: Resolution of Forces

Lesson Title: Simply Supported Beam Deflection

Grade Level: 9-12

Lesson # Stand alone topic

Time Required: Two 50 minute periods

Summary: This lesson will expose students to the governing aspects that effect the deflection of a beam. They will do an activity that presents a hands-on approach to the investigation of beam deflection. This lesson will allow students to be able to infer which type of structure is more resistant to bending.

Engineering Connections:

This lesson will relate the engineering challenges that are present in designing and fabricating a bridge and/or other type of structure. Students will be taught background information, investigate the behavior of a typical beam, take data and draw conclusions. This lesson will allow students to realize the end result of an overloaded structure.

Keywords: deflection, force, Young's modulus

Educational Standards: New York State, science
Standard 1—Analysis, Inquiry, and Design
Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.
Standard 6—Interconnectedness: Common Themes
Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.
Standard 7—Interdisciplinary Problem Solving
Students will apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.

Pre-Requisite Knowledge: None

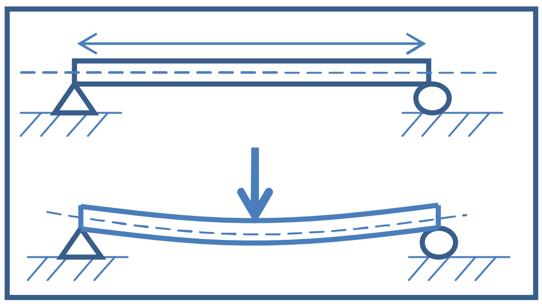
Learning Objectives:

- Students will be able to understand what variables effect the deflection of a simply supported beam.
- Students will be able to predict the deflection of a beam.

- Students will understand why a steel beam is required in certain applications rather than a wooden beam.

Introduction/ Motivation:

Demo: Lay eight pieces of 1/16 inch square sections of wood 24 inches long on a table stacked side to side. Taped both ends together forming a 24 inch long built up beam. Hold the built up beam in a vertical orientation by the taped ends. Develop that when a point force is placed at the center of its span, a simply supported beam will deflect (Relate deflection to the elongation of a spring). Point out that the top layer of wood goes into compression and that the bottom goes into tension.



A simply supported beam is a member that only supports the vertical loads at each end. No horizontal force or moment (torque) is present.

Lesson Background & Concepts for Teachers:

The equations that govern the deflection of a beam are:

$$\delta = P L^3 / 48 E I$$

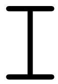
$$I = B D^3 /12$$

where:

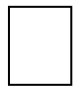
- P = the load in Newtons
- L =length of beam (mm)
- I = the moment of inertia (which is dependent on the cross section geometry of the beam) (mm^4)
- E = Young's modulus of elasticity (which is dependent on the physical composition of the beam. (N/mm^2)
- B = base of the beam (mm)
- D = height of the beam (mm)

Demo: Show three different size beams. Develop that the beam with the larger I is stiffer (more resistant to bending)

Compare an I- beam to a rectangular section



- Beam



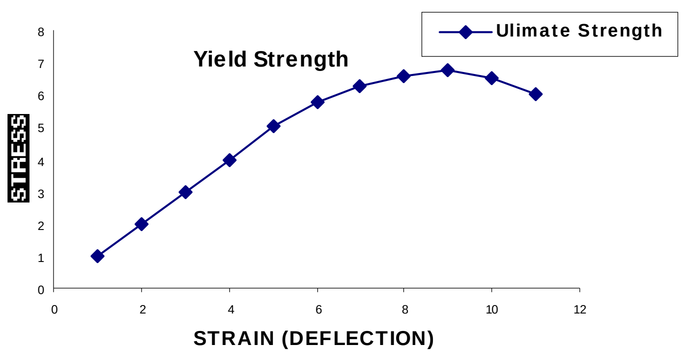
rectangular beam

- heavier

- Has a large web (d)
- Places most of the beam's mass at the flanges resulting in much larger I with less weight than a solid rectangular section

Young's Modulus of Elasticity:

Show that a graph of stress versus deflection is a linear relationship.   Relate to the behavior of the spring.



Definition:

Yield Stress- the maximum stress/ deflection a material can experience and still return to its original size, shape and strength characteristics. (Relate to the elasticity and elastic limit of a spring)

Ultimate stress – the maximum stress/ deflection at which a member will fail.

Slope - is Young's modulus

Associated Activities: DEFLECTION OF A BEAM LAB

Materials:

- 1/16 square Aluminum section 24 inches long
- meter stick
- slotted weight hangar

- slotted weights

Procedure:

1. Place the aluminum section between two supports (a stack of books will do) so that there is a 510mm (20 inch) gap between the supports.
2. Measure the distance from the table to the top of the beam (this is the no-load condition)
3. Record the height of the beam
4. Place the slotted mass hangar at mid span with a 100gram mass on it
5. Place a 100 gram mass on the hangar
6. Record the height of the beam
7. Repeat the steps 4 – 7 until the table is complete

Load (grams)	Load force (newtons)	Beam height (mm)	Deflection (mm)
0	0	0	0
100			
200			
300			
400			
500			
600			
700			
800			

8. Plot load force versus deflection and calculate the slope of a best fit line
9. Determine Young' modulus of elasticity (E) by using the slope of the line and the equation for the deflection of a beam
10. Using an average value of Young's modulus and the deflection equation calculate the deflection
11. Compare the measured to the calculated deflection

Load (Grams)	Measured deflection (mm)	Young's modulus (N/mm^2)	Calculated deflection (mm)	Error
100				
200				
300				
400				
500				
600				
700				
800				

Assessment:

Have students predict the deflection of a 30mm long aluminum beam, that is 4mm high and 6 mm wide, when loaded by a force of 200 Newton placed at the center.

Lesson Extension Activities:

1) Determine how the moment of inertia of an I- Beam can be calculated. Calculate the moment of inertia for the following I-beam
Overall height 20mm
Web height 16mm
Web thickness 2 mm
Flange width 5 mm
Flange thickness 2mm

2) List and explain ways in which the deflection of a beam can be reduced.

2) Research and describe the pros and cons of four different beams having a shape other than a rectangle or an I.

ACKNOWLEDGEMENTS

This work is supported by the Research Experience for Teachers Site Program of National Science Foundation under grant EEC-0807286: Science and Mechatronics Aided Research for Teachers (SMART). The authors are thankful to Prof Vikram Kapila, Prof Nikhil Gupta, Dr. Nguyen Q. Nguyen, Mr. Vasanth Chakravarthy Shunmugasamy, and Mr. Luong Dinh Dzung for their helpful comments and suggestions. This work was conducted in summer 2009 in the Composite Materials and Mechanics Laboratory and the Mechatronics Laboratory at the Polytechnic Institute of New York University and authors fondly acknowledge the hospitality and support of the lab personnel.