Introduction

In this exercise, you will calculate the Modulus of Elasticity and Moment of Inertia, and then solve a simply-supported beam problem using timber as the beam structural material.

Equipment

- (1) 2x4x8' (preferably straight, free of knots and imperfections)
- (2) end supports
- Tape measure
- Floor scale

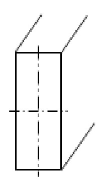
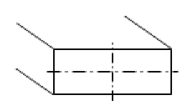
Goal

You will determine the weight of one of your classmates using nothing more than a standard 2x4 'beam' and a tape measure.

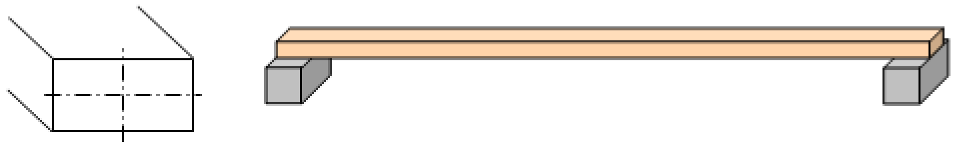
Procedure

First, calculate the beam's Moment of Inertia (I) using the formula below, and then experimentally determine the Modulus of Elasticity (E) using a person of known weight.

1. Calculate Moment of Inertia (I) using the equation below. (this is the Moment of Inertia formula for a rectangular beam).

$I_{xx} = \frac{bh^3}{12}$		
	Vertical Orientation	Horizontal Orientation
B – width of the beam (in.) h – height of the beam (in.) I – Moment of Inertia (in.^{4})		

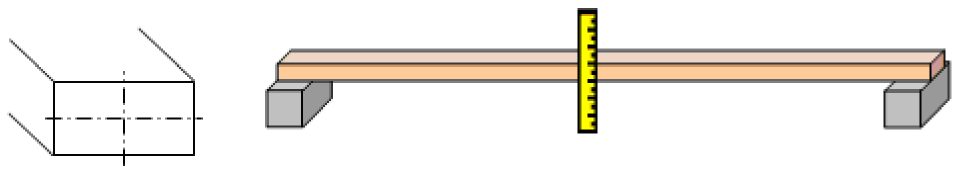
Position the beam as shown below.



2. Measure the ‘clear’ span between the supports. Record your measurement below.

   Total ‘Clear’ Span **(L)** = __________in.

3. Measure the distance between the floor and the bottom of the beam.



‘Unloaded’ Height **(H_U)** = __________in.

4. Position a volunteer (V_1) to stand carefully on the middle of the beam. Have a person on either side of the beam to help support the volunteer. Measure the distance between the floor and the bottom of the beam.

‘Loaded’ Height (H_L**)** = ___________in.

5. Calculate the maximum beam deflection (Δ_{MAX}).

   $\Delta_{MAX} = H_U - H_L$

   Δ_{MAX} = __________ in.

6. Determine the weight of volunteer (V_1) using the classroom floor scale.

   Volunteer weight **(F)** ____________ lb

7. Calculate the beam's <u>Modulus of Elasticity</u> by rearranging the equation for beam deflection below to isolate **(E)**. Show all work. Hint: the Modulus of Elasticity for Douglas Fir should be somewhere around 1.4-1.8 x 10^6, depending on how many knots or imperfections are in the 2x4, and how much moisture it has.

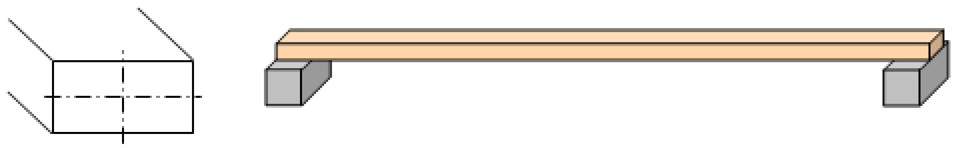
   (This is the 'beam formula' for a simply-supported beam with a single, concentrated load in the middle. F=lbs, L=inches, deflection=inches).

Rearrange the equation $\triangleleft_{MAX} \quad \frac{FL^3}{48EI}$ to solve in terms of E	
Substitute known values	
Simplify	
Solve for E	

Note: An object's Modulus of Elasticity is a material-based property and stays the same regardless of orientation (laying flat versus standing upright).

Second: Calculate a second volunteer's (V_2) weight using nothing but the same beam and the deflection formula you used above.

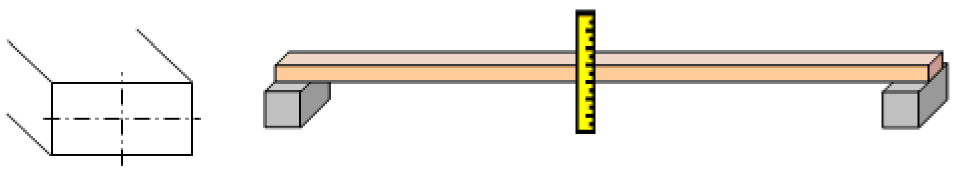
8. Position the beam as shown below.



9. Measure the 'clear' span between the supports. Record your measurement below.

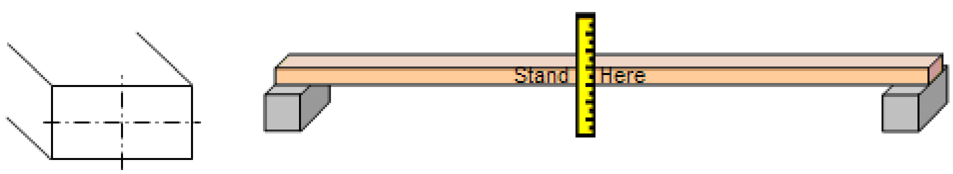
   Total Clear Span **(L)** = __________in.

10. Measure the distance between the floor and the bottom of the beam.



   'Unloaded' Height **(H_U)** = __________in.

11. Position a second volunteer (V_2) to stand carefully in the middle of the beam. Have a person on either side of the beam to help support the volunteer. Measure the distance between the floor and the bottom of the beam.



   'Loaded' Height (H_L**)** = ___________in.

12. Calculate the maximum beam deflection (Δ_{MAX}).

   $\Delta_{MAX} = H_U - H_L$

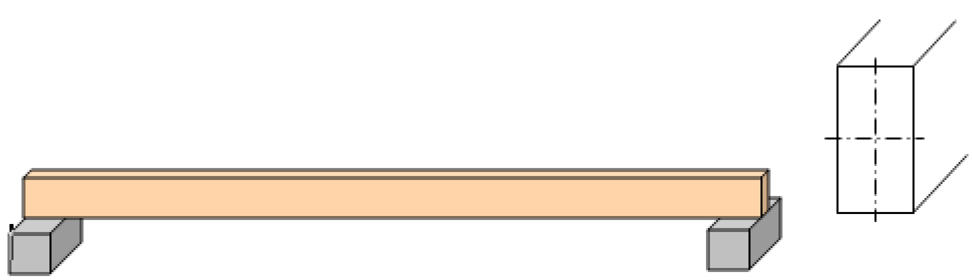
   Δ_{MAX} = __________ in.

13. Calculate the weight of volunteer (V_2) by rearranging the equation for maximum deflection to isolate **(F)**. Show all work.

Rearrange the equation $\triangleleft_{MAX} \quad \frac{FL^3}{48E\,I}$ to solve in terms of F	
Substitute known values	
Simplify	
Solve for F (the weight of volunteer V_2)	

Finally: Flip the beam to the <u>vertical orientation</u> and try to <u>predict</u> the Beam Deflection using volunteer V_2 – or another volunteer of known weight.

14. Using the information you collected and calculated in steps 1 – 13, <u>predict</u> the maximum deflection of the beam if volunteer (V_2) is positioned to stand on the beam in a vertical orientation. Hint: first calculate the new Moment of Inertia (I) using the formula on page 1.



$\Delta_{MAX} = \frac{FL^3}{48EI}$	
Substitute known values	
Simplify	
Solve for deflection	

15. Then, have volunteer (V_2) carefully stand in the middle of the beam. Place a person on either side of the beam to help support the volunteer. Measure the actual deflection ($H_U - H_L$) and compare the results with your pre-calculated value. How did you do?

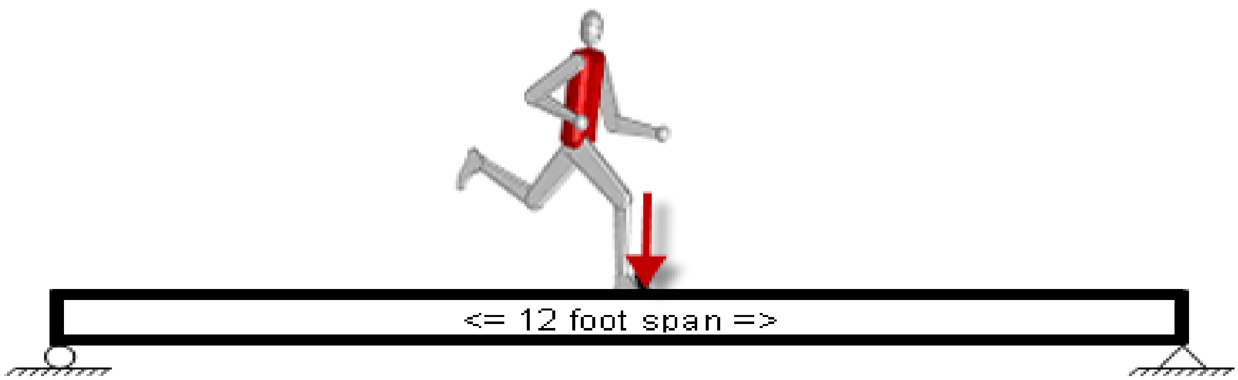
Calculated deflection: ______________

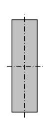
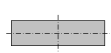
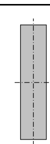
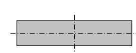
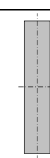
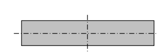
Measured deflection: ______________

Instructor signature: ____________________________________ Date: ______________

Homework instructions: Complete problems #16-18 by the due date. Deliverables: you may fill-in the table and answer the questions directly on these 2 pages - and scan and email. Submit the MDSolids printouts (#16) and the Excel graph (#17) as email attachments. (100 points total)

16. (45 points) Using MDSolids software (free download), complete the table below by calculating the cross-sectional area, Moment of Inertia, and beam deflection, given a load of **250 lbs**, a Modulus of Elasticity of **1,510,000 psi**, and a span of **12 ft**. You may directly fill-in the chart below. Attach the applicable printouts from MDSolids.



Beam	**A**	**B**	**C**	**D**	**E**	**F**
Common Name	**2x6**	**2x6**	**2x8**	**2x8**	**2x10**	**2x10**
Actual Dimensions (in.)	1.5 x 5.5	1.5 x 5.5	1.5 x 7.25	1.5 x 7.25	1.5 x 9.25	1.5 x 9.25
Vertical or Horizontal Orientation						
Cross-Sectional Area (in.^{2})						
Moment of Inertia (in.^{4})						
Beam Deflection (in.)						

17. (45 points) Using Excel, create a Deflection vs. Moment of Inertia graph using the data from the table above. Place ‘Beam Deflection’ on the Y-axis and ‘Moment of Inertia’ on the X-axis. What is the relationship between moment of inertia and beam deflection?

18. (10 points) How could you increase the Moment of Inertia (I) of a beam without increasing its cross-sectional area?