Young's Modulus: Building a Device to Measure Material Strength to Understand Interatomic Bond Stiffness

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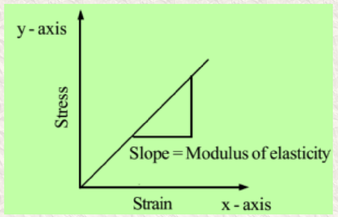
Abstract

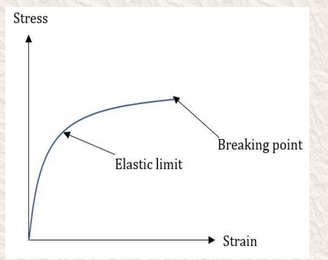
Young's Modulus is an equation that is to measure the strength in different materials. A common application of Young's Modulus is measuring the breaking point of cables. The understanding of the Young's Modulus equation and its applications is a standard part of the introductory undergraduate physics sequence. We sought to construct a lab apparatus that would enable physics undergraduate students to measure and verify the results of the Young's Modulus equation. These macroscopic measurements can then be used to further understand inter-atomic bond stiffness. This poster reviews the design, construction, and testing of a Young's Modulus lab experiment. This lab will be used by undergraduate students at Northwestern College, thus offering a further experimental application of a topic that was previously taught only theoretically..

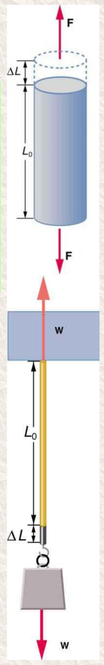
Introduction

$$Y = \frac{F_T/A}{\Delta L/L}$$

- F_T =Tension force
- A=Cross-sectional area
- L= Original length
- ΔL=Change in length
- Used to find elastic limits.
- Part of Physics 1 curriculum







Left: Two plots with the relationship of Stress and Strain.
Right: A visual example of how Young's Modulus is measured

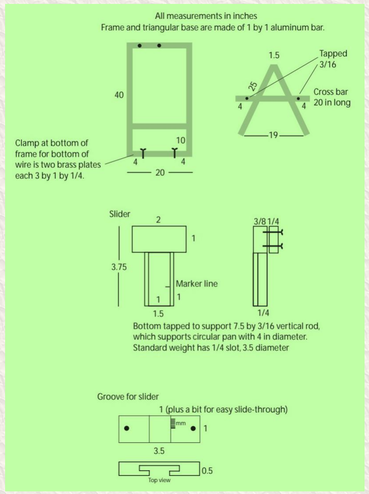
Materials and Methods

Materials

- 1inch x 1inch aluminum bars (190 inches worth)
- 3.75-inch (length) x 2-inch (width) x 3/8-inch (thickness) brass bar
- 3.5-inch x 1 inch x 0.5-inch brass bar
- 2-inch x 1-inch x ¼- inch
- 3-inch x 1-inch x ¼ -inch brass bar (2)
- ¼ inch T-30-bit metal screws 2 and 3 inches long
- 4 hand screws
- 2 nuts
- Mass hanger
- Kilogram weights

Tools

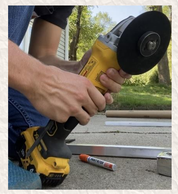
- Angle Grinder with cutting and grinding wheel
- Drill driver with metal drill bits and T-30 screw bit
- Rotary tool with cutting and grinding attachments
- Pliers
- Tape measure
- Speed square
- Paint marker



Assembly Steps

1. The frame was constructed with 2 40-inch bars and three 18-inch aluminum bars. The base was constructed with two 25-inch bars and 1 20-inch bar. A speed square was used in construction.

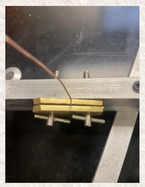
2. An angle grinder with a 4.5 inch cutting wheel was used for cutting and a 5 inch grinding wheel was used for smoothing.



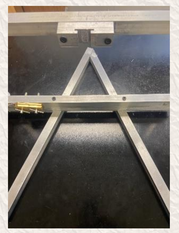
3. Measurements were made to drill holes for screws and were marked.

4. 7/32-inch holes were drilled through the bars and the bars were attached with 2-inch T-30 screws

5. The brass cable clamp was installed at the bottom and pullies were installed at the top.



6. The base was assembled using a triangle shape for stability



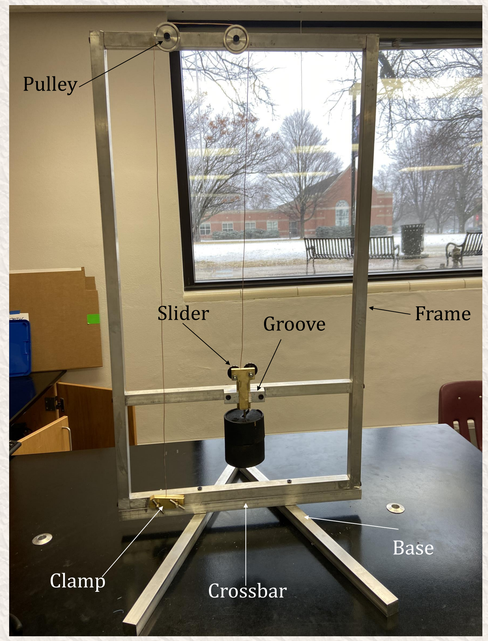
7. A length measurement device was made by cutting millimeter groves in brass.

8. The mass hanger was installed to be used to apply known force to the cable.

9. The grove was machined by the H&M Machine Shop in Lawton, Iowa

Final Construction

Below is a figure of the completed apparatus with labeled figures



Material	Stress (F_T/A)	L (m)	ΔL (m)	Measured Young's Modulus (N/m^2)	Young's Modulus (N/m^2)
Copper	2kg: $3.69x10^6$ 4kg: $7.38x10^6$	2	0.002	$3.69x10^9$	$1.1x10^{11}$
Steel	2kg: $6.04x10^6$ 4kg: $1.21x10^7$	2	0.005	$2.42x10^9$	$2x10^{11}$
Twine	2kg: $6.24x10^6$ 4kg: $1.25x10^7$	2	0.0065	$1.14x10^8$	N/A

Error is likely due to impure materials in calibration as well as cable structural issues. In future measurements we will secure cables of known material ratios.

Acknowledgements

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