**Experiment**

**7**

# Young's Modulus

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## **Introduction**

From bridges and buildings to miniaturize electrical circuits, the behavior of the materials involved as they are subjected to a variety of conditions is an important aspect of design. The collapse of the Nimitz Freeway as a result of the violent forces generated by the earthquake is a sad reminder of this fact. Although solids appear to be rigid, it is possible to deform them either temporarily or permanently by applying stresses. One such stress is called a tensile stress (or tension), and the effect on a solid in general is the elongation of the dimension parallel to the stress. Below a certain "elastic limit", such behavior is predictable and is quantified by a Hooke's Law type of function (review this law before beginning). The Hooke's Law constant is called "Young's modulus", and the measurement of this constant for a steel wire will be undertaken in this experiment to further your understanding of this important topic. The goal of this lab is to measure Young’s modulus for steel.

## **Theory**

Before beginning, you should study the meaning of the modulus of elasticity (Young's modulus), and understand why it is a measure of a material's rigidity. Begin by defining each of the following terms (in your own words).

1. **Stress**: Stress is the external force applied perpendicularly to an object per cross sectional area.

For example, as I pull on a rope, I am exerting a force on the rope, thus the corresponding stress would be the force I applied over the area of a slice of that rope, which would be the area of a circle. The units for Stress are Newtons / Meter Squared.

1. **Strain**: Strain is the corresponding amount to which the object under stress deforms. Using the rope example above, the strain would the amount the rope’s length changes over its initial length before any force was applied. Strain is unitless.
2. **Tension**: Tension is the name of one of the forces acting on wires, ropes, hanging masses, and pulley systems. It if the force acting parallel to the rope when I pull on it from both ends. The units for Tension are the same as any other force, Newtons.

**Procedure**

1. Attach the 1kg mass hanger to the bottom of the wire and measure using a meter stick equipped with caliper jaws. This length is from the inside point of attachment at the top to the inside point of attachment at the bottom. Record your data in Table 1.
2. Examine the Young's Modulus apparatus and locate the leveling table. Check to see that the circular micrometer screw tip is positioned at the center of the anvil.
3. Carefully turn the micrometer screw until the table is level as evidenced by the spirit leveling bubble and record the circular micrometer reading. Note that one revolution of the disk (100 divisions) corresponds to 1 mm on the vertical scale. Why is this a micrometer reading?
4. Now add a 2 kg mass to the hanger and repeat step 3. Continue adding 2 kg masses (leveling and recording the micrometer reading after each 2 kg increment) until you have added 10 kg to the hanger.
5. Remove the 5-2 kg masses and the hanger from the wire and measure the thickness of the wire using the micrometer calipers.
6. Compare the value of Young’s Modulus obtained from the ratio stress/strain to the value obtain from you graph? Do they agree? If not, is this an indication that the experimenter needed to be extra careful in carrying out the experiment (or is it an artifact of the apparatus)? Explain.

**Data, Analysis, and Conclusions**

Now is your chance to demonstrate learning. Use the format that you have been using for the entire semester to complete the rest of this lab report. Note that I have already given you the procedure and apparatus part, and given you the outline for the theory section. What you need to do is present your data, analyze your data, and draw any relevant conclusions. When presenting your data, make sure all relevant information is given. Certainly, a table (or tables) is (are) necessary (properly formatted tables—titles, units etc.). In the Analysis section, show all relevant calculations and a properly analyzed graph is required (minimum 4 point deduction if the results of your curve fit are not used in determining Young’s Modulus).

Your conclusion must include a discussion of results, systematic errors, and an estimate of the experimental uncertainty (expressed as a percentage). **You don’t need to compare your measured value to the accepted value**.

# Data

## **Table 1.1: Initial Measurements**

Length of wire, L0 =\_\_0.8716 m

|  |  |
| --- | --- |
| **Diameter of Wire Before**  **(m)** | **Diameter of Wire After**  **(m)** |
| 0.000746 | 0.000746 |
| 0.000738 | 0.000734 |
| 0.000748 | 0.000740 |
| 0.000728 | 0.000748 |
| 0.000724 | 0.000728 |

|  |  |
| --- | --- |
| **Average Diameter of Wire Before**  **(m)** | **Average Diameter of Wire After**  **(m)** |
| 0.000737 ± 0.000005 | 0.000739 ± 0.000004 |

**Sample Calculation for Average Diameter Before:**

**Sample Calculation for Average Diameter Uncertainty Before:**

## **Table 1.2: Increasing the Tension on the Wire**

Circular Micrometer Reading with no Mass on Hanger, Li= 0.011786 m

|  |  |  |  |
| --- | --- | --- | --- |
| **Number of Masses on Hanger** | **Mass on Hanger**  **(kg)** | **Circular Micrometer Length**  **(m)** | **Change in Length**  **ΔL**  **(m)** |
| **1** | 2.04774 | 0.012020 | 0.000234 |
| **2** | 4.04823 | 0.012248 | 0.000462 |
| **3** | 6.04891 | 0.012472 | 0.000686 |
| **4** | 8.04871 | 0.012652 | 0.000866 |
| **5** | 10.04884 | 0.012850 | 0.001064 |
| **6** | 10.50686 | 0.012904 | 0.001118 |

**Sample Calculation for Change in Length ΔL:**

# Analysis

## **Table 2: Young’s Modulus**

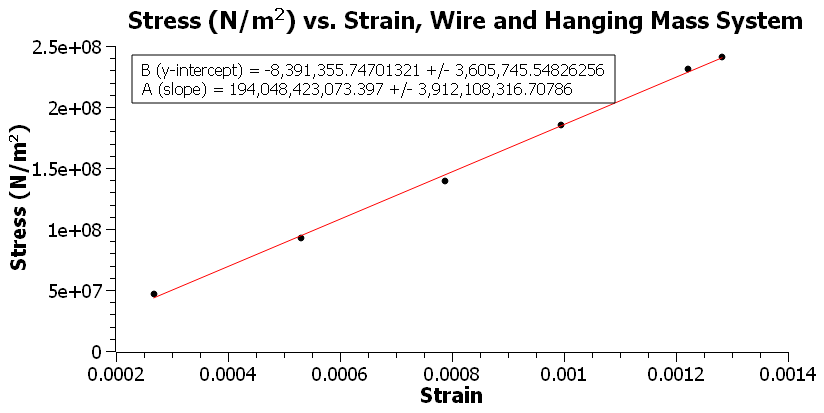
|  |  |  |  |
| --- | --- | --- | --- |
| **Number of Masses on Hanger** | **Stress**  **(N/m2)** | **Strain** | **Young’s Modulus**  **Y**  **(N/m2)** |
| **1** | 4.70 x 107 | 2.68 x 10-4 | 1.75 x 1011 |
| **2** | 9.30 x 107 | 5.30 x 10-4 | 1.75 x 1011 |
| **3** | 1.39 x 108 | 7.87 x 10-4 | 1.76 x 1011 |
| **4** | 1.85 x 108 | 9.94 x 10-4 | 1.86 x 1011 |
| **5** | 2.31 x 108 | 1.221 x 10-3 | 1.89 x 1011 |
| **6** | 2.41 x 108 | 1.283 x 10-3 | 1.88 x 1011 |

**Sample Calculation for Stress:**

**Sample Calculation for Strain:**

**Sample Calculation for Young’s Modulus:**

**Calculation for Young’s Modulus Average with Uncertainty:**



Young’s Modulus from Graph Y = **(1.94 ±0.03)×1011N/m2**

**Figure 1:** This is a plot of Stress versus Strain of a Wire and Hanging Mass System. Most of the data fits on the curve fit line and the relationship between stress of the wire and its resulting strain is linear. This region where the stress versus strain has a constant of proportionality is known as the elastic region and suggests that Young’s Modulus is verified. As mass is increased on the wire, the degree of deformation of the wire increases, thus the slope represents Young’s Modulus for the wire’s substance. The Young’s Modulus obtained from the graph is (1.94 ±0.03)×1011N/m2.

# Results

## **Table 3: Young’s Modulus Results**

|  |  |  |  |
| --- | --- | --- | --- |
| **Average Diameter of Wire Before Experiment**  **(m)** | **Average Diameter of Wire After Experiment**  **(m)** | **Average Young’s Modulus**  **Y**  **(N/m2)** | **Young’s Modulus**  **From Graph**  **Y**  **(N/m2)** |
| 0.000737 ± 0.000005 | 0.000739 ± 0.000004 | (1.82 ± 0.03) ×1011 | (1.94 ± 0.03) ×1011 |

# Conclusion

Experiment 7, Young’s Modulus served as a way to experimentally verify Young’s Modulus, summarized as the ratio of the tensile stress of an object over its tensile strength. This experiment was carried out by attaching a hanging mass to a leveled wire. The wire was the object of interest for Young’s Modulus, and to increase the perpendicular force of tension on the wire, masses were added to the hanger. With each mass added, the force of tension increased and consequently, the change in the length of the wire increased ever so slightly. These miniscule changes were recorded with a micrometer and subtracting the new measurement from the initial measurement before hanging the masses, calculated the change. With the understanding that the tensile stress was the external force of tension over the cross-sectional area, we calculated the stress with each mass added knowing the force was the mass multiplied by gravity and that the area was the slice of the wire, or better known as a disk. Tensile strain was obtained by creating a ratio of the changes in the wire over the initial length of the wire. A plot of the stress versus strain of the wire using our data would theoretically produce a linear relationship, thus verifying Young’s Modulus. Comparisons of the diameter of the wire before and experiment should also show the wire has not been deformed beyond its elastic limit, in turn verifying Young’s Modulus as well.

After conducting the experiment, the Young’s Modulus obtained from the ratio of stress over strain is (1.82 ± 0.03) ×1011 N/m2 with a percent uncertainty of 2%. This value does not agree with the Young’s Modulus calculated from the graph which is (1.94 ± 0.03) ×1011 N/m2 and with a 2% percent uncertainty as well. The experimentally obtained true value of Young’s Modulus ranges from (1.79×1011) N/m2 to (1.85 ×1011 )N/m2 which does not overlap with the true value obtained from the graph of (1.91 ×1011 )N/m2 to (1.97×1011 )N/m2. The cause of this difference in values is due to systematic errors, either to errors in the scale or damaged areas on the wire. This is an artifact of the apparatus because these errors would always be present no matter how many times we repeat the experiment with the same setup unless we replaced parts of the apparatus.

The graph of Stress versus Strain showcased a linear relationship and represented a straight line of the elastic region, thus Young’s Modulus was verified. This verification was proved further by the evidence of the diameter of the wire before and after the experiment. The average diameter of the wire before the experiment was (0.000737 ± 0.000005)m and the average diameter of the wire after the experiment was (0.000739 ± 0.000004)m. The true value of the average diameter before the experiment ranges from 0.000732m to 0.000742m which overlaps with the true value of the average diameter after the experiment of 0.000735m to 0.000743m. The evidence suggests the wire returned to its original length once the force was removed, thus verifying Young’s Modulus and the elastic region.