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1225 section # 3
Desk # 7
3 July 2010

> Properly label heading with the title, your name, partner's name, course/section #, desk #, and date

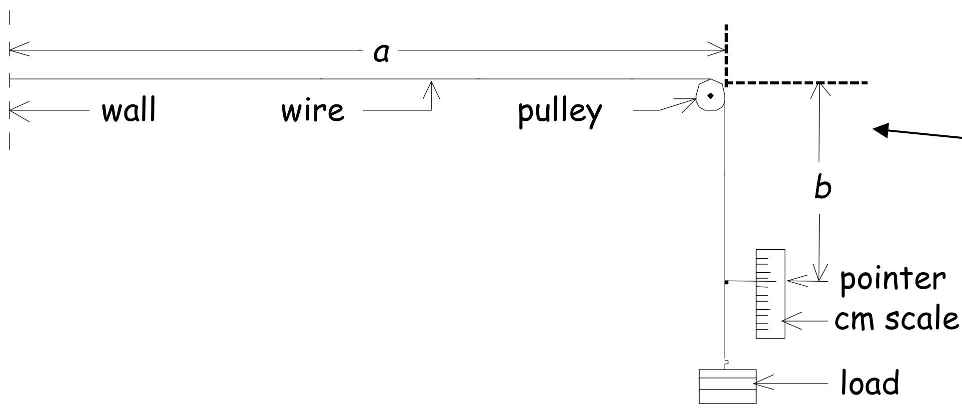
# Young's Modulus of Elasticity

Purpose To determine Young's Modulus for a metal wire.

> Describe the purpose of the lab in a form that can be answered in the conclusion

Apparatus micrometer # 7 , metric measuring tape

> List all apparatus used along with the identifying numbers




> Use diagrams and drawings to provide adequate information for other people to reproduce the experiment

Data

Table 1. Length of the wire

| | $a$ /m | $b$ /m |
|---|---|---|
| Uncertainty in reading | ± 0.03 | ± 0.01 |
| Zero reading | 0.00 | 0.00 |
| Reading | 13.54 | 2.45 |

> Record data with units and uncertainties in tables with descriptive titles

Note: $\delta a$ is larger because of the size of the attachment to the wall.
$\delta b$ is accounts for not being sure where the wire touches the pulley.

> Briefly explain how you get the value of the uncertainty

Table 2. Area of the cross section of wire

| Diameter | $d$ /mm |
|---|---|
| Zero reading | - 0.05 |
| Reading 1 | 0.54 |
| " 2 | 0.49 |
| " 3 | 0.53 |
| " 4 | 0.53 |
| " 5 | 0.55 |
| Average reading | 0.528 |
| Corrected reading | 0.578 |

> Record and correct for zero reading if available

The uncertainty of the diameter is:

$$\delta d = \frac{\text{range of } d}{2} = \frac{\max d - \min d}{2} = \frac{(0.55 - 0.49)}{2}\,\text{mm} = 0.03\,\text{mm}$$

Thus, the diameter of the wire is $d$ = (0.58 ± 0.03) mm.

If multiple measurements of the same value are taken, also consider the scatter as the uncertainty

Table 3. Stretch of the wire

| | Load $F$ /N | Pointer Position $x$ /cm |
|---|---|---|
| Uncertainty in reading | ± 0.1 | ± 0.1 |
| Reading 1 | 0.0 | 36.5 |
| Reading 2 | 20.0 | 37.3 |
| Reading 3 | 40.0 | 38.0 |
| Reading 4 | 60.0 | 38.6 |
| Reading 5 | 80.0 | 39.1 |
| Reading 6 | 100.0 | 39.7 |

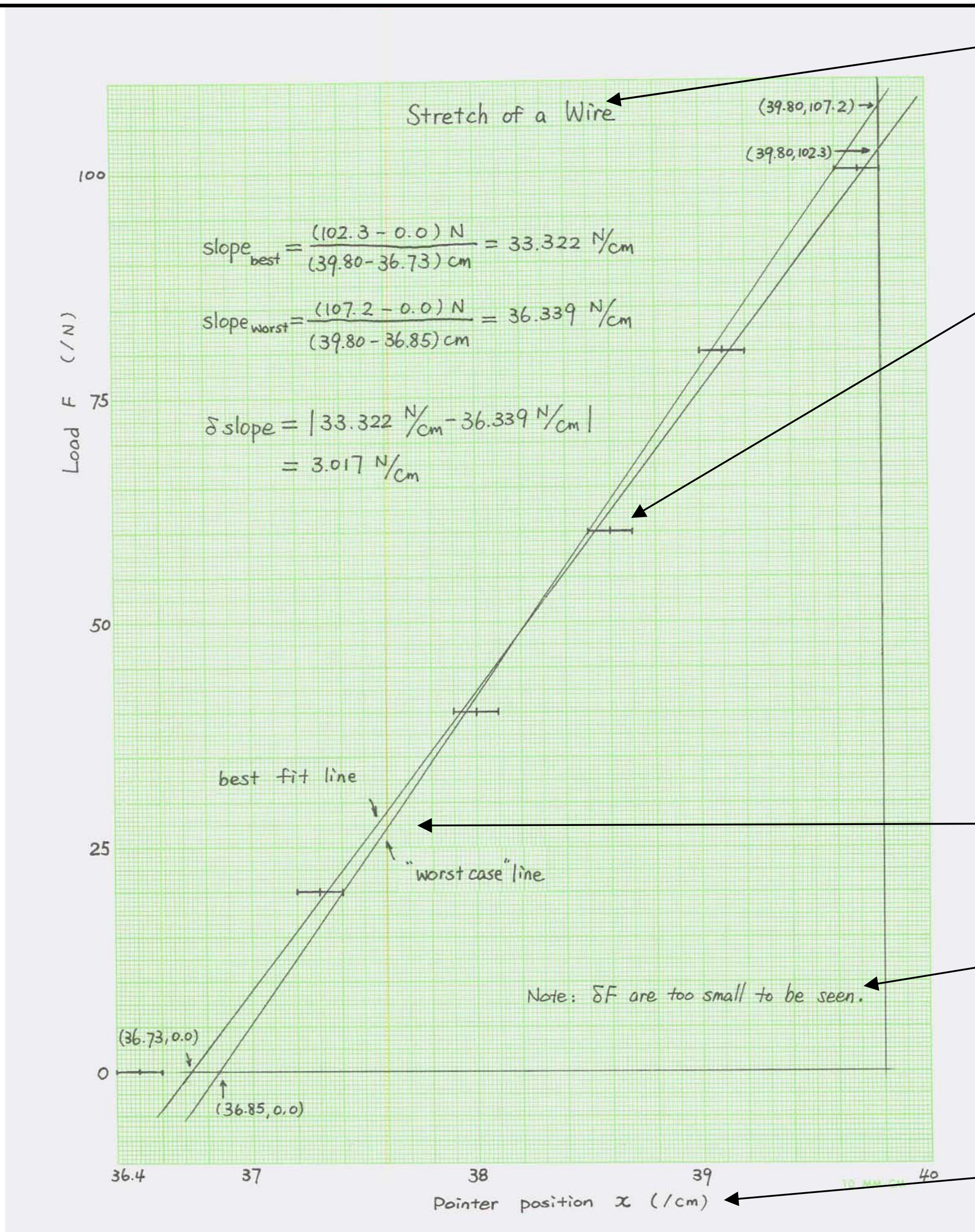
List all data points to be plotted, including any linearization steps necessary

The data are plotted in the graph "Stretch of a Wire".

Explicitly refer to any graphs in the report body to guide readers

In drawing the lines, we have ignored the first point where the load was zero. We are less confident about this point because some load is needed to overcome the slack in the wire.

Explain if any data points are excluded from the best fit line




Include a descriptive title, instead of repeating what is on each axis

Draw error bars on all points

Draw in best fit line and worst case line; calculate the slope by picking points on the lines themselves (not data points!)

Note if error bars too small

Label each axis with value names, symbols and units

## Calculations

The length of the wire is: $L = a + b = 15.99$ m.

The area of the cross section of the wire is $A = \pi r^2 = \pi d^2/4$.

See graph for slope calculations. Young's modulus of the wire is given by

$$
\begin{aligned}
E &= \frac{L}{A}\cdot\frac{\Delta F}{\Delta x} = \frac{4L}{\pi d^2}\cdot\frac{\Delta F}{\Delta x} = \frac{4L}{\pi d^2}\cdot \text{slope} \\
&= \frac{4\cdot(15.99\text{m})}{3.1416\cdot\left(0.58\times10^{-3}\text{m}\right)^2}\cdot\left(33.322\times10^2\ \frac{\text{N}}{\text{m}}\right) \\
&= 2.0167\times10^{11}\,\text{Pa}
\end{aligned}
$$

Show equations and derivations in symbols for the calculations first

Keep 5 non-zero digits in result before uncertainty analysis

## Uncertainty Analysis

The uncertainty in the total length of the wire is

$$
\begin{aligned}
\delta L &= \delta a + \delta b \\
&= 0.03\text{m} + 0.01\text{m} = 0.04\text{m}
\end{aligned}
$$

The fractional uncertainty of the Young's Modulus is

$$
\begin{aligned}
\frac{\delta E}{E} &= \frac{\delta L}{L} + 2\cdot\frac{\delta d}{d} + \frac{\delta \text{slope}}{\text{slope}} \\
&= \frac{0.04}{15.99} + 2\cdot\frac{0.03}{0.58} + \frac{3.017}{33.322} \\
&= 0.0025016 + 0.10345 + 0.090541 \\
&= 0.19650 \Rightarrow 20\%
\end{aligned}
$$

Calculate the uncertainty in the final result based on given propagation rules

The absolute uncertainty is

$$
\begin{aligned}
\delta E &= \frac{\delta E}{E}\cdot E = (0.19650)(2.0167\times10^{11}\text{Pa}) = 0.39628\times10^{11}\text{Pa} \\
&\Rightarrow 0.4\times10^{11}\text{Pa}
\end{aligned}
$$

## Conclusion

Young's Modulus of the steel wire was found to be $(2.0 \pm 0.4) \times 10^{11}$ Pa ($\pm$ 20 %).

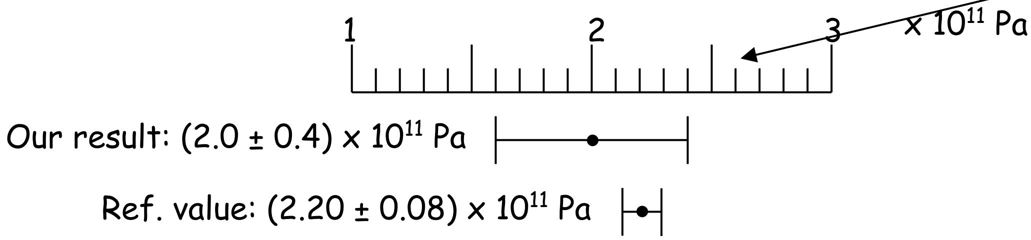
Formulate conclusions that answer to the purpose of the lab

Express final result with the correct number of decimal places for the value and the uncertainty

## Discussion

The reference value, according to Tipler, Physics for Scientists and Engineers, 3rd edition, pg 334, is $(2.20 \pm 0.08) \times 10^{11}$ Pa[1].

The diagram below shows that our result agrees with the reference value.




There are two major sources of the uncertainty: the variation of the wire diameter (10%) and the uncertainty in the slope (9%). The uncertainty in the length of the wire (0.25%) is of no importance.

To reduce the variation of the diameter, my first thought was to use a thicker wire. But this may decrease the extensions and thus increase the uncertainty in the slope. Using a longer wire or heavier loads may reduce the uncertainty in the slope, but then we are limited by the size of the room and the strength of the wire. The actual effect can only be found by trying.

Compare result with alternate or previous results while considering the uncertainty

Discuss major factors that contribute to the final uncertainty

Suggest how the experiment can be improved by targeting these factors

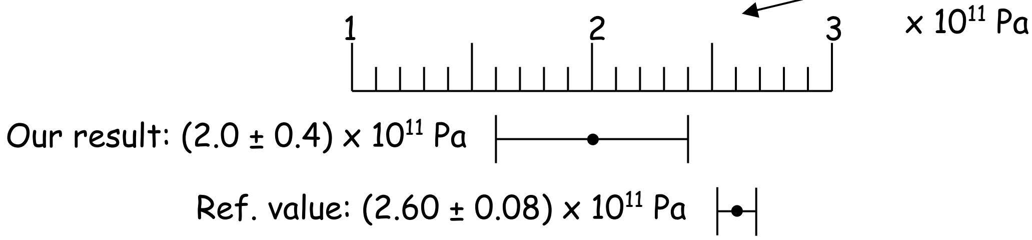
[1] These are made up values for demonstration purposes.

Discussions (Alternative example)

The reference value, according to Tipler, Physics for Scientists and Engineers, 3rd edition, pg 334, is $(2.60 \pm 0.08) \times 10^{11}$ Pa[1].

As shown in the diagram below, our result does not agree with the reference value.

> Compare result with alternate or previous results while considering the uncertainty




The possible cause for the disagreement may be that the wire we used is not the same alloy as the reference value, even though they are both steel. Temperature may also affect the value of Young's Modulus.

> Propose physical reasons that may have caused the disagreement

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[1] These are made up values for demonstration purposes.