MA1 Experiment: Young's modulus of copper

Objective: To investigate the Hooke's law and measure the Young's modulus

Apparatus: Searle's apparatus, micrometer screw gauge, slotted mass with 15x0.1kg, 8-meter tape.

Procedure and results:

1. Set up the Searle's apparatus as shown. The wire on the left is the reference wire and the wire on the right is under study. The two wires are the same material to allow for any temperature change and must be kept taut by weights hung at the ends. The wires are connected to a frame carrying a spirit level and a micrometer with screw is used to make the frame horizontal for the reference state.

2. Load extra mass m on the right wire in steps and record the extension e of the wire. The extension e of the wire is the amount by which the micrometer needs to be adjusted to bring the spirit level back to the horizontal. Tabulate the results:

<table>
<thead>
<tr>
<th>Load m /kg</th>
<th>extension e /m</th>
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Plot a graph of load against extension acting on the wire.

PQ1. What is the shape of the graph?
PQ2. What do you deduce from the shape of the graph?

Slope of load-extension graph = ________________ kgm\(^{-1}\)

3. Unload all the extra mass m and note the spirit level.

PQ3. What do you notice from the spirit level?

4. Measure the original length of the wire.

original length of the wire = _______________________________m

Strain = \( \frac{extension}{original\ length} \)
5. Use a micrometer screw gauge to measure the diameter of the wire at 3 or 4 different points along its length and take the mean value.

<table>
<thead>
<tr>
<th>diameter of wire</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>mean</th>
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<tbody>
<tr>
<td>d /m</td>
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PQ4. Why does the wire measure at different parts of the wire?

6. Young’s modulus $E$ is given by

$$E = \frac{\text{stress}}{\text{strain}} = \frac{\sigma}{\epsilon} = \frac{F}{A e l}$$

where $F$ is the tension in the wire and $A$ is the cross-sectional area.

Also, $F = mg$ and $A = \frac{1}{4} \pi l^2$

Show that $E = \text{slope} \times \frac{4gl}{\pi l^2}$

Calculate the Young’s modulus of the wire

Young’s modulus = ___________________________ Pa

7. Error estimation

Draw lines of maximum and minimum slope through the points of the graph. Find the slopes and take the larger deviation from the slope of the best-fitted graph as the error.

Also, estimate the possible error in the measuring the length and diameter.

Error in slope = _______________  ⇒ % error in slope = _______________

Error in l = _______________  ⇒ % error in l = _______________

Error in d = _______________  ⇒ % error in d = _______________

Show that % error in $E$ = % error in slope + % error in l + 2 x (% error in d)

Calculate the % error in $E$ and error in $E$

Questions:
1. State the Hooke’s law
2. Does the Young’s modulus depend on the size of the wire?
3. What is order of magnitude of Young’s modulus?
4. How can you reduce the percentage error in this experiment?