

Young's Modulus of Fishing Wire

Abstract

I have found out that there is a reduction in errors when there are accurate ways of measuring used such as using a micrometre instead of vernier calipers and using a wire with a smaller diameter means we can be more accurate with measuring the young's modulus of a fishing wire. Thus I have done this by first doing the Young's Modulus for two sets of wires and compared the results.

Introduction

Topic: I hope to find out the Young's Modulus of a fishing wire (nylon) which 0.1mm in diameter by finding out the extension length.

Background Information:

$$\text{Young's Modulus} = \frac{\text{Stress}}{\text{Strain}} \quad (\text{Nm}^{-2})$$

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} \quad (\text{Nm}^{-2})$$

$$\text{Strain} = \frac{\text{Extension Length}}{\text{Original Length}} \quad (\text{No units})$$

Young's Modulus: is the measure of elasticity therefore measuring the stiffness of a material.

Stress: is the pressure or force applied on an object.

Strain: The proportional extension of a specific wire.

Examples of this is real world includes from working out the stiffness of a bridge and other construction work on a big scale but also on cars and other accessories that doesn't have to be big.

Equipment List:

- G Clamp , 10 cm Jaw
- 2 wooden blocks
- Single Pulley on a bench clamp
- Meter ruler
- Vernier Calipers
- Tape to mark the wire
- Hanger with slotted weights
- Nylon Monofilament about 0.1 mm diameter (fishing line)
- Safety Glasses
- Clamp stand

Method

I first got my equipments and then set my work on a table, which was long (table) so I had enough length to stretch my wire. I put a pulley on a bench clamp at one end a G clamp on the other end. Then I measured out my nylon wire to a suitable length (from 180 to 200 cm). Then I took a ruler and pushed against the pulley (width wise) then using sellotape I marked the wire so the tape would be parallel to the ruler so when I eventually add weights I will be able to see how much the tape has travelled. However I put my tape near the end of my rules so if it was a meter ruler then my tape was placed around 80cm or 800mm so when the weights are added on there wouldn't be a big shift because at that length the wire is closer to the pulley. I measured the cross sectional area with a Vernier Calipers and noted it down with an approximation of the uncertainty. Then I got my nylon fishing wire and jammed it between the blocks so it wouldn't come off as it is loose when I pull it with the weights. Then I stretched out the wire (lightly) so I could measure the wire when no stress is applied. I stretched the wire and attached it to the pulley and tied a knot on to the hook so the wire wouldn't slip off. Then I hanged it off very lightly and checked that the wire would be short enough so when stretched it wouldn't reach the floor and rest on it.

Then I added weights from 1 till 5 newtons, measuring how much the tape on the ruler moved up by each time when I added up on the weights. Then I repeated this experiment 3 times so that the results would be deemed reliable.

Safety

There had to be many safety aspects for this experiment as it involved heavy weights. I had to wear safety glasses as there were wires and to prevent any wires being snapped off when put under pressure by the weights and hitting my eye. Also as soon as I put the 5th weight I would usually swiftly move backwards as there would be a tendency for the wire to snap when under that amount of stress. Also to make the experiment safer the hook for the pulley wasn't a long way from the ground so when nearer the ground there would be less energy dissipated from the weights. Also I made sure my feet weren't directly below the weights and also anyone working around me was at a considerable distance from the experiment and they were aware the experiment was going on as well.

Results

To obtain the results I performed three similar tests for the fishing wire with diameter of 0.1mm with the Vernier Calipers and the 0.08 mm wire with the micrometers.

Length (185cm \pm 2mm) Thickness (0.15mm \pm 0.1mm)

Vernier Calipers

Force(N) \pm 0.01	Displacement (mm)	Extension(mm) \pm 1mm
0	802	0
1	858	56
2	874	72
3	946	144
4	963	161
5	984	182
6	1020	218

Length (192cm \pm 2mm) Thickness (0.15mm \pm 0.1mm)

Vernier Calipers

Force(N) \pm 0.01	Displacement (mm)	Extension(mm) \pm 1mm
0	660	0
1	710	50
2	730	70
3	752	92
4	773	112
5	797	136
6	Broke	

Length (200cm \pm 2mm) Thickness (0.15mm \pm 0.1mm)

Vernier Calipers

Force(N) \pm 0.01	Displacement (mm)	Extension(mm) \pm 1mm
0	700	0
1	740	40
2	780	80
3	795	95
4	810	110
5	825	125
6	860	160

$$\text{Young's Modulus} = \frac{\text{Stress}}{\text{Strain}}$$

For this experiment I am going to use the graph to work out the Young's modulus. The below working out shows how I got the Young's Modulus for 0.1mm wire.

How I worked out
Young's Modulus

$$\text{Young's Modulus} = \frac{F \times L}{A \times x}$$

$F = 3 \text{ N}$
 $L = 1.923 \text{ (m)}$
 $A = 1.7671459 \times 10^{-8} \text{ (m)}$
 $x = 0.079 \text{ (m)}$

$$\frac{3 \times 1.923}{1.7671459 \times 10^{-8} \times 0.079}$$

$$= 4132387510 \text{ Pa}$$

F = Force (N)

L = Actual Length (m)

A = Cross-Sectional Area of wire
(m)

x = Extension (m)

As you can see my Young's Modulus for the 0.1mm diameter nylon wire is 4132387510 Pa.

Uncertainties

My uncertainties are very big for the fishing wire used in the first experiment for the 0.1 mm which was measure by the vernier calipers and were not that precise as the micrometer. In fact the uncertainty was so much for the 0.1mm wire that the percentage uncertainty was 67% which is very high as the uncertainty was 0.1mm for a wire that was measured to be 0.15mm. However the uncertainty for the fishing wire with the diameter 0.08mm was very low in fact 0.8% as the thickness of the wire was measured to be 0.065mm with an uncertainty of 0.005mm. Therefore the uncertainty for that wire is 0.0077% which is a very small number therefore less uncertainty.

My uncertainty was decreased for measuring the extension of the 0.08mm (thickness) wire as I used a straight object (ruler) to pin the marker (the sellotape) to the meter ruler from where the previous position was. Also when measuring the extension I made sure that the G clamp and the pulleys were dead straight and opposite each other and therefore the wire wouldn't be bending one way or another.

Also to reduce the uncertainty in measuring the diameter in the wire I used a micro meter as it has a higher resolution compared to the vernier calipers.

To reduce the error in measuring how much the tape had moved up the ruler I cross referenced my findings with my friend who also used a ruler to pin down the tape to the meter ruler to get an accurate reading.

My largest uncertainty for the vernier calipers was the instrument itself as even though the thickness was 0.15mm the uncertainty was 0.01mm which is actually a huge number compared to the uncertainty of the micrometre. Thus the reason why the micrometre is another factor in reducing uncertainty when finding out the Young's Modulus.

This therefore makes my new results look way better compared to old results. However the only thing that changed in terms of uncertainties was the thickness which changed from 0.01mm to 0.005mm.

Length (193cm \pm 2mm) Thickness (0.065mm \pm 0.005mm)

Micrometer

Force(N)	Displacement (mm)	Extension(mm) \pm 1mm
0	730	0
0.2 \pm 0.0025	750	20
0.4 \pm 0.0025	760	30
0.6 \pm 0.0025	767	37
0.8 \pm 0.0025	773	43
1 \pm 0.01	780	50
1.2 \pm 0.0025	790	60
1.4 \pm 0.0025	795	65

1.6±0.0025	800	70
1.8±0.0025	807	77
2±0.01	817	87

Length (188cm ± 2mm) Thickness (0.065mm±0.005mm)
Micrometer

Force(N)	Displacement (mm)	Extension(mm) ±1mm
0	765	0
1±0.01	820	55
1.2±0.0025	833	68
1.4±0.0025	840	75
1.6±0.0025	845	80
1.8±0.0025	850	85
2±0.01	855	90

Length (203cm ± 2mm) Thickness (0.065mm±0.005mm)
Micrometer

Force(N)	Displacement (mm)	Extension(mm) ±1mm
0	700	0
1±0.01	750	50
1.2±0.0025	760	60
1.4±0.0025	767	67
1.6±0.0025	772	72
1.8±0.0025	780	80
2±0.01	785	85
3±0.01	810	110
4±0.01	850	150

The below document shows how I worked out the Young's Modulus for the 0.08 mm wire.

How I worked out
Young's Modulus

$$\text{Young's Modulus} = \frac{F \times L}{A \times x}$$

$F = 0.4 \text{ N}$
 $L = 1.9467 \text{ (m)}$
 $A = 3.31830724 \times 10^{-9} \text{ (m)}$
 $x = 0.11 \text{ (m)}$

$$\frac{0.4 \times 1.9467}{3.31830724 \times 10^{-9} \times 0.11}$$
$$= 213328922.8 \text{ Pa}$$

F = Force (N)

L = Actual Length
(m)

A = Cross-Sectional
Area of wire (m)

x = Extension (m)

As you can see the Young's Modulus for the 0.08mm diameter nylon wire is 2133289228 Pa.

Uncertainties (Vernier Calipers)

Uncertainty in
Length:

$$\frac{2 \times 10^{-3}}{192.3 \times 10^{-2}} \times 100 = \pm 0.104\%$$

Uncertainty in
Area:

$$\frac{0.1 \times 10^{-3}}{0.15 \times 10^{-3}} \times 100 = \pm 66\%$$

Uncertainty in
Extension:

$$\frac{1 \times 10^{-3}}{218 \times 10^{-3}} \times 100 = \pm 0.46\%$$

Uncertainty in
Force:

$$\frac{0.01}{1} \times 100 = \pm 1\%$$

My Calculated
Young's modulus for
0.1mm wire:

2GPa \pm 67.56%

How I calculated my
total Uncertainty
(Vernier Calipers):

0.104 + 66 + 0.46 +
1 = 67.56. Therefore
if you have realised I
have just added up
all my uncertainties
to get a total of \pm
67.56%.

As you can see my largest factor in uncertainty is my measurement of the thickness of the wire which is 66%. This is easily the highest uncertainty in the whole experiment. As you can see below when I used a micrometer to measure the thickness of the wire you can see that my uncertainty has decreased to 7.7% which is considerably lower. However even though the micrometre represents a smaller uncertainty than vernier calipers in measuring the thickness, it still has the biggest

uncertainty therefore in conclusion the measurement that is causing my biggest uncertainty is the thickness.

Uncertainties (Micro Meter)

Uncertainty in
Length:

$$\frac{2 \times 10^{-3}}{194.7 \times 10^{-2}} \times 100 = \pm 0.103\%$$

Uncertainty in
Area:

$$\frac{0.005 \times 10^{-3}}{0.065 \times 10^{-3}} \times 100 = \pm 7.7\%$$

Uncertainty in
Extension:

$$\frac{1 \times 10^{-3}}{150 \times 10^{-3}} \times 100 = \pm 0.67\%$$

Uncertainty in
Force:

$$\frac{0.01}{1} \times 100 = \pm 1\%$$

My Calculated
Young's modulus for
0.1mm wire:

$$4\text{GPa} \pm 9.47\%$$

How I calculated my
total Uncertainty
(Micro Meter):

$$0.103 + 7.7 + 0.67 + 1 = 9.47$$

Therefore if you have realised I have just added up all my uncertainties to get a total of $\pm 9.47\%$.

Therefore my new results are more accurate than my first set of results due to the uncertainty in percentage being lower.

Analysis

My results show that as you add more newton's to the nylon wire the more the wire extends. Therefore both my graph show that as the more force is applied to the wire the more the wire extends meaning a positive correlation between the two. It also shows that the nylon wire with the diameter of 0.1mm is capable of handling a bit more than 4GPa and the wire with diameter 0.08mm is capable of handling a more than 2GPa. Therefore the wire with 0.1mm is stiffer than the wire which is 0.08mm in diameter.

I have calculated my values using the equation:

$$\text{Young's Modulus} = \frac{\text{Force (N)} \times \text{Actual Length (m)}}{\text{Cross-Sectional Area} \times \text{Extension Length (m)}}$$

However I first had to change my units of length of mm to m.

My research tells me that the Young's Modulus of Nylon varies from 2GPa to 4GPa.

http://www.engineeringtoolbox.com/young-modulus-d_417.html

This tells me that my values aren't that far off and fit onto the category of being between 2Gpa and 4Gpa.

My first set calculation's errors affect my conclusion more than my first set of results. My first sets of results were $2\text{GPa} \pm 67.56\%$. This is a very large percentage therefore it is not very good. However my second experiment had the result $4\text{GPa} \pm 9.47\%$. This is very good compared to the first percentage uncertainty however even though 9.47% does seem a large percentage, it isn't much of a problem with these numbers as they are very big. Therefore that is why my conclusion can be valid. It can also be viewed as being valid due to the reason that my set of results are very much in the range of the recognised values for the Young's Modulus of

Copper being in the region of 2-4GPa. Thus as you can see the improvements I have made to curb uncertainty in the second experiment has worked as the percentage uncertainty has decreased.

If you look at my graph under the heading: Graph showing how a change in Force affects Extension (0.08mm, Micro meter), you can see that the first point can be identified as an anomaly. Even though the tip of the uncertainty is very close to the line of best fit it still is an anomaly. This anomaly might be down to human error. To deal with this anomaly I will repeat the same test again with everything else kept same.