<u>Elasticity of Copper investigation</u>

In this experiment I will investigate how the extension **e** of a length of copper wire changes as the stretching force **F** is increase. The question I will be answering is: "*If a wire whose original length was **L** is subjected to a stretching force F then will the wire increase in length by the amount **e**"*

The aim of this experiment is to investigate how the extension of a length of wire is affected by the force. I will then find stress and strain after finding these variables, for which I can finally complete my objective which is to find the young's modulus for the material, in this case copper wire. My aim is to measure the extension in a piece of copper while consider safety precautions and accuracy. For the experiment I will have to also consider the accuracy of both my equipment and the degree of accuracy for my results. Furthermore I will have to find a suitable range of results so that I can form a reliable basis for my conclusion, also so to allow me to show a clear set of results on a graph so that I can identity the trend.

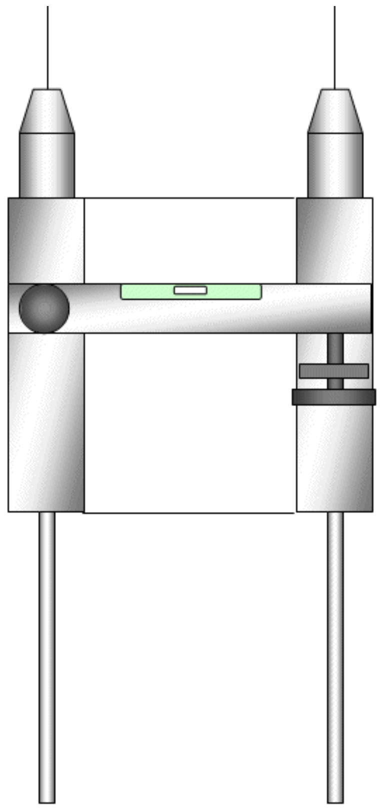
Hypothesis I predict that when a wire is subjected to a stretching force, in this case wire being pulled by the force of weight, then the wire likely to be stretched. This does depend on the material as the more flexible the material is the more possibility there is of stretching. I think that the copper wire will have a young's modulus of about 130 Gpa(GigaPascals ⁄ Kn/mm), as the secondary source has worked this out The stretching force which extends material by equal steps is called Hooke's law.

Hooke's law states that the force needed to stretch a spring is proportional to the extension of the spring from its natural length. The formula used for Hooke's law is Force, F=Ke. The K is the spring constant (measure in force by length) and e is the extension.

Based on Hooke's law theory I predict the greater the value of K is the Stiffer the spring will become. Also for the graph of **F** against ***e,*** the line should be completely straight. The gradient of the straight line from the graph when drawn will be equal to K.

This is equation for Young Modulus and should be recorded by working out the gradient for Stress and Strain on the graphs I will make for the results

$$\Upsilon = \frac{F/A}{\Delta L/L} = \frac{\text{Stress}}{\text{Strain}}$$



Searle's Apparatus

The extension of a wire under tension may be measured using searles apparatus. The micrometer attached to the control wire can be adjusted so the spirit level between the control and wire is completely horizontal. When weights are attached onto the hinge , it extends slightly causing the spirit level to drop on one side. The micrometer is then adjusted to make the spirit level horizontal again. The change in the micrometer is therefore equal to the extension of the wire. The extensions are all measured for different weights which the tension increases as well as a result of higher mass on the wire.

Stress and Strain

Strain is the deformation caused by the action of stress on a physical body. Strain is measured by calculating the change in length (termed the stretch or absolute strain) and comparing the stretch to the original length. Strain is positive if the material has gained length (in tension), and negative if it has reduced length (in compression). Strain has no units of measure but sometimes is given as a percentage. By calculating strain as a percentage we correct for the length of the object. In this experiment I will be measuring the Tension/extension instead of Compression.

Stress is a measure of the force per unit area within a body. This does not take into account the change in cross-sectional area as the material deforms. True stress is force per unit area taking into account the change in area.) This is a better measure than the force alone, because it corrects for the area across which the force applies. The shear stress is stress along the main axis of the material (e.g. pulling on a rope) and normal stress is across the main axis (e.g. flexing a rope). Tensile stress is shear stress which is pulling on an object. Compressive stress is shear stress which is pushing on an object. (Information from http://www.uwgb.edu/DutchS/structge/stress.htm)

Definitions:
Tension Stress*-Stress that acts to lengthen an object.*

Shear Stress *-Stress that acts parallel to a surface. It can cause one object to slide over another. It also tends to deform originally rectangular objects into parallelograms. The most general definition is that shear acts to change the angles in an object.*

Preliminary results

For this experiment I will be using Searles apparatus, which is shown on the previous page as it is very time consuming however if possible to conduct this method it would of provided a greater accuracy of results.

With these Preliminary results. All of my results seemed to be fairly reliable as they went up in fairly even progressive steps, they All appeared to follow these steps until they reached the elastic limit and then snapped.

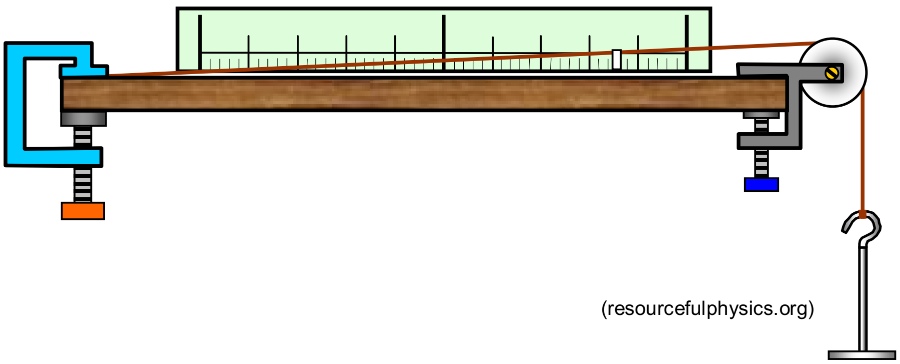
Preliminary Results

Mass	Extension
500g	2.5cm
1000g	3.0cm
1500g	3.5cm
2000g	4.5cm
2500g	6.0cm
3000g	7cm

Preliminary results

Mass	Extension
500g	2mm
1000g	4mm
1500g	5mm
2000g	7mm
2500g	17mm
3000g	18mm
3500g	25mm

Actual Apparatus used:



Fair testing

After the prelimary results and primary experiment I would say the following would be needed to make this a fair test:

- Firstly to use the same wire throughout the experiment.
- Also to make sure the experiment is done all at one time to make the results constant.
- Also to use the same equipment if I am to repeat the experiment.
- Ensure that the variables are appropriately changed

Equipment list:

> 2 pieces of copper wire
> Weights
> Tape
> 1 Metre Ruler
> Paper
> Copper wire to make Marker
> 2 Clamps
> Vernier callipers
> Writing materials.
>Pulley

Safety Issues

>Eye protection. Goggles must be warn incase the wire breaks and causes a back lash. Also there should be cardboard placed over a suitable area of the wire, should it break. Also not to lean of the wire incase of other bodily harm
>A protective material should be placed below the weights, should the load break. Most likely to be a cloth
> Clamp should be secured properly however not to tightly to cause damage to the table

Variables in the experiment:

Dependent Variables

>The Tension/Extension of the Wire
>The Stress of the wire
>The Strain across the wire

Independent Variables
>The weight load placed on the wire
>The overall length of the wire

Method:

1. In this Experiment I will be required to measure small changes in position. Firstly the clamp should be secured to the bench while holding the wire in place, horizontally, as shown in the Diagram of the apparatus.

2. After this it the wire should pass the through the pulley and attacked to the base of the weight to apply a small force to keep it in place.

3. Furthermore a Ruler was place next to the wire with another clamp so that the measurements were correct as there was minimal movement in the ruler. With the marker it significantly helped.

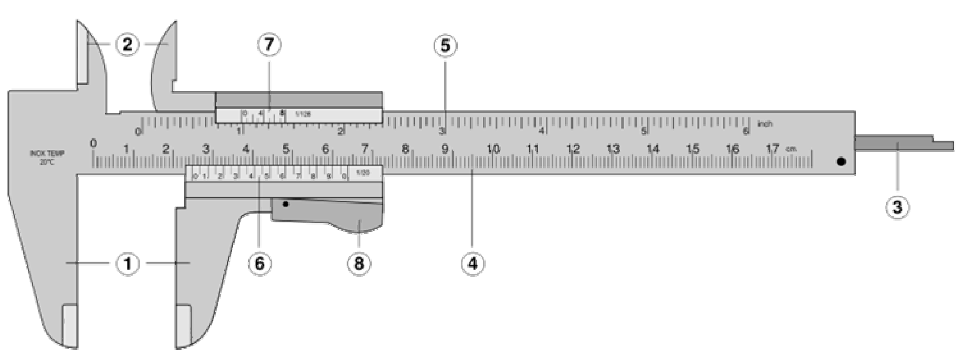
4. After this I placed small marker consisting of a small piece of tape being attacked to the Wire and as it move it could be seen how much if moved from the original point (which was recorded)

5. The loads was increased steadily while the results were recorded in each stage

The Potentional problems which may come are:

- The wire may slip from the clamp hold and result in varied results
- The exposure to the weights may not be consistent and result in wrong results

To measure the wire I used Vernier callipers



Actual Results:

For Thin Wire. Initial area of 0.37

Mass(Kg)	Force(N)	Area(Average)(m)	Extension(m)	Stress(N/m2)	Strain(e/L)
0.5kg	4.90	0.0011	0.002	4.455×10^{10}	1.2×10^{12}
1.0kg	9.80	0.0011	0.003	8.909×10^{10}	1.8×10^{12}
1.5kg	14.70	0.0011	0.005	1.336×10^{10}	2.7×10^{12}
2.0kg	19.60	0.0011	0.006	1.782×10^{11}	3.6×10^{12}
2.2kg	21.60	0.0011	0.021	1.964×10^{11}	1.27×10^{13}
2.4kg	23.52	0.0011	0.048	2.138×10^{11}	2.91×10^{13}
2.6kg	25.48	0.0011	0.082	2.316×10^{11}	4.97×10^{13}
2.8kg	27.44	0.0010	0.139	2.74×10^{11}	8.42×10^{13}
3.0kg	29.40	0.0010	0.167	2.94×10^{11}	1.01×10^{14}

Thick Wire : Initial area of 0.57

Mass(Kg)	Force(N)	Area(Average)(m)	Extension(m)	Stress(N/m2)	Strain(e/L)
0.5kg	4.90	0.0026	0.000	1.89×10^{10}	0.00×10^{12}
1.0kg	9.80	0.0026	0.000	3.77×10^{10}	0.3×10^{12}
1.5kg	14.70	0.0026	0.001	5.65×10^{10}	0.6×10^{12}
2.0kg	19.60	0.0026	0.002	7.54×10^{10}	1.2×10^{12}
2.5kg	24.5	0.0026	0.003	9.42×10^{10}	1.8×10^{12}
3.0kg	29.40	0.0026	0.005	1.13×10^{11}	2.7×10^{12}
3.5kg	34.30	0.0025	0.006	1.37×10^{11}	3.6×10^{12}
4.0kg	39.20	0.0025	0.008	1.57×10^{11}	4.5×10^{12}
4.5kg	44.10	0.0025	0.011	1.76×10^{11}	6.4×10^{12}
4.7kg	46.06	0.0025	0.021	1.84×10^{11}	1.27×10^{13}
4.9kg	48.02	0.0024	0.034	2.01×10^{11}	2.06×10^{13}
5.1kg	49.98	0.0024	0.044	2.08×10^{11}	2.70×10^{13}
5.3kg	51.94	0.0024	0.055	2.16×10^{11}	3.36×10^{13}
5.5kg	53.90	0.0023	0.065	2.34×10^{11}	3.94×10^{13}
5.7kg	55.86	0.0023	0.085	2.43×10^{11}	5.18×10^{13}
5.9kg	57.82	0.0022	0.106	2.63×10^{11}	6.42×10^{13}
6.1kg	59.78	0.0022	0.117	2.72×10^{11}	7.09×10^{13}
6.3kg	61.74	0.0021	0.145	2.94×10^{11}	8.79×10^{13}
6.5kg	63.70	0.0021	0.184	3.03×10^{11}	1.112×10^{14}

From my results table it is clear that as the mass increases if causes the length of extension to increase a significantly as it reaches its breaking point.

Analysis

To work out the Force I had to use the following formula:

$$Force = \frac{Weight}{Acceleration}$$

To work out the Extension I had to use the following formula:

$$Extension/Change\ in\ length: \frac{Length\ after\ weights\ added}{Original\ length\ of\ Wire}$$

After looking at the results I managed to use them apply them to the calculations and then place them into version of the table; To work out the for the two wires I had to individually get the force applied by the wire and then divide it by the cross sectional area of the wire of which it is measured in Netwons. Firstly to work out the force I had to find out the weight, Kg and then multiple it by the acceleration which was gravity. The force is Newtons. Finally to work out the cross sectional area, I used: (πd2)/4. With these two values. With all of the data I have gathered from the previous stage I was able to work out the stress by using the following formula:

$$Stress = \frac{Force\ (N)}{Area}$$

To work out the strain I had to firstly use the weight applied to the wire and the extension; the extension was acquire by taking away the original length of wire by the new length of wire, the original length of wire stayed constant. The extension was measured by taking the point at which it started at, and reading from this every time a weight was applied to the wire to see how much it had extended.

$$Strain = \frac{Extension}{Length}$$

Analysis of the Stress strain graph, Thick Wire

In my Hypothesis it stated that as the force applied to the wire steadily increase then the extension of the wire will also increase, which is proved by the graph on this. This is because there is an overall increase in stress which is consequently caused by an increase in force on the wire over a small cross sectional area as the wire is stretched therefore the tensile stress is a result of this. If we look at the start of the graph this could be shown by the steep gradient between stress and Strain. Also from this it can bee seen the stress is not the majority

We can see that the strain on the wire doesn't increase as much as the stress. This will have something to do with the length of wire that is used which has an affect on how much the wire will have extended. As you can see on the graph, the gradient begins to drop at a certain point. This is when the copper wire reaches its elastic limit.

The copper wire has begun to reach its elastic limit and suffers from plastic deformation. After this point, when a little bit of an increase in stress will then cause a huge increase in strain because of the weakness of the metal. This graph shows us that the young's modulus of this wire increases at a very quick rate at the start of the experiment, and then gradually increases at a slower rate as the wire is stretched beyond its elastic limit.

Stress/strain graph, Thin Wire

As we can see from this graph, the young's modulus of this wire is very similar to the thicker wire. The difference is that the yield point on the second graph (the point in which the wire weakens temporarily) is less significant on the thinner wire. This is because the wire is thinner to start off with so will be more ductile to the force it undergoes. There is still an elastic limit on the graph and this is in a similar position to where the elastic limit is for the thicker wire.

Evaluation

Problems with the experiment

The first problem we had with the experiment is that in the preliminary experiment the wire was considerable loose and as result the recorded data was effective making anomalies. However while conducting the experiment in more detail for the second time this was solved by attaching the wire to the Clamp directly which did work. Another problem was that I was unable to use Searle's apparatus to conduct the experiment because it was too complicated and there was insufficient place to make the wire longer than 1 m long.

The final problem that occurred was the length of wire. While doing the experiment we found it better to not measure from the end of pulley. We instead measured just before the pulley by 35cm however did not compensate for this and so therefore the overall length that we measuring decreased from 2m to 1.65m.

However, there are a few ways in which my experiment could have been improved to make the validity of the investigation a lot better. Here are a few improvements I would suggest that I make:

>Repeat readings- If I was to repeat the readings I would be able to gather a better range of results and get more reliable results. Also by repeating them I can ensure that I pick the right method to conduct the experiment with more accuracy

Also I think that I could change the length of the wire I used in repeating the experiment. with this it would allow me to get a better range of results.

Also I need to find a better way or reading indentifying the break point of the wire

Another improvement might be to use a greater range of materials which may give a better insight into the stress and strain/Young modulus theory

Finally I think that I could use a different method to record the way I get the results/readings more accurately