# AS Physics Data Analysis coursework

This coursework assignment requires me analyse and evaluate data on copper and constantan given to me. It entails investigating the young's modulus of the metal and alloy. Thus I will use many methods during to complete my investigation.

## Aims:

1. To draw stress and strain graphs for the metal copper and the alloy constantan
2. To calculate the figures of young's modulus for copper and constantan
3. To discuss the physics involved

## Plan:

In this investigation I have received results for extension of copper and constantan for certain forces applied to it, for which I will analyse and calculate the young's modulus. The results I have been given are forces applied to copper and constantan, three sets of results for the metal and alloy and this can be used by averaging data to give more accurate results thus these results given to me will be used to create graphs, calculate young's modulus and analyse data for both metals so I can complete my investigation.

I will need to draw a force and extension graph for both copper and constantan, the extension shown will be the averaged value for each metal. I will also calculate the stress and strain values and plot this on a graph for both copper and constantan, I will plot these on the same graph and analyse the graph, hence I can find any patterns from the data and this will require me to draw my graphs accurately so I can correctly analyse the results to make judgements and conclusions.

I will use Microsoft Excel spreadsheet program to make tables of data, with the data I have been given. I will be using formulas to calculate average extension, stress, strain and young's modulus for copper and constantan. I will also set my tables so that all data is to two significant figures.

I have included a diagram of the set-up (Figure 1) below which was used to obtain the results I was given.

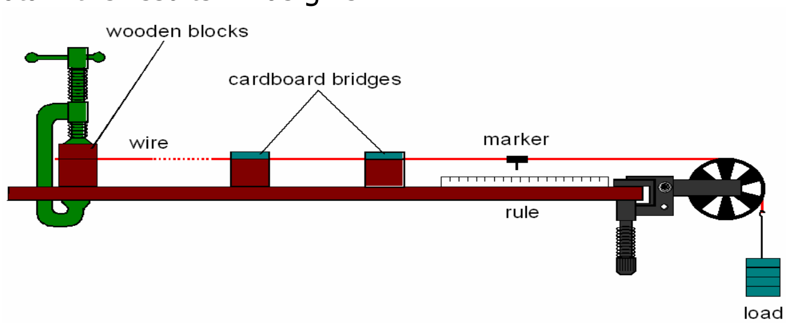


**Figure 1 (SOURCE: AS PHYSICS CDROM)**

The experiment works by a G-Clamp holding the wooden block steady, this will place pressure on the wire to keep it steady at the clamped end. The cardboard bridges keep the wire straight and in place throughout its length. The pulley allows the wire to move freely along it to keep friction minimum. As load is increased this puts pressure on wire and it may extend in length, which is the variable I will be measuring.

A micrometer has been used to measure the diameter of both copper and constantan wires, the length was measured by use of a one metre rule.

The measurements were made three times and then averaged, thus I was supplied with the following measurements:

| | CONSTANTAN | COPPER |
|---|---|---|
| DIAMETER (mm) | 0.35 | 0.37 |
| LENGTH OF WIRE (m) | 2.1 | 2.1 |

The results obtained from the experiment (diameter & length of wire, force and three sets of extension readings) will be used to calculate the following:

- Area= ∏ **r²** (where r= Radius of wire)
- Strain = **Extension ÷ Original length**
- Stress = **Force ÷ Area**
- Young's Modulus: **Stress ÷ Strain**

These calculations in turn will enable me to plot graphs. The stress over strain graphs will be analysed and linear sections used to calculate young's modulus, as both copper and constantan data will be plotted on the same graph I can find the differences between these materials in terms of young's modulus & elastic limits. Other factors I will be considering in the investigation will be differences in stiffness (Young's Modulus) of both materials and if this affects the ductility, tensile strengths and other physical aspects of the materials.

Prediction using scientific knowledge:

I would predict that the young's modulus of constantan will be higher than copper as it is an alloy and as we know alloys are generally less ductile and harder than pure metals. So hence it would take more load to create an extension for the alloy. Hence constantan would be stiffer and so this is why its young's modulus would be higher than that of copper.

The young's modulus would tell me how stiff a material is when it is stretched. When a material is stretched, an increase in it length occurs (the extension) and it is proportional to the load, this means it obeys Hooke's law. When a load is applied to materials they would go under extension until their elastic limit is reached, this means if you remove the load/force applied to it then it would go back into its original length.

However if more load/force is applied and the material exceeds its elastic limit then the material yields and it becomes permanently deformed. (Adapted from Physics CD-Rom 40s).

The young's modulus can be shown on a graph of stress against strain. I have included a simple stress and strain graph (Figure2) to show how a material changes with different stress and stains added to it. (picture from **gpc.edu/~pgore/geology/geo101/ crustaldeform.php**).

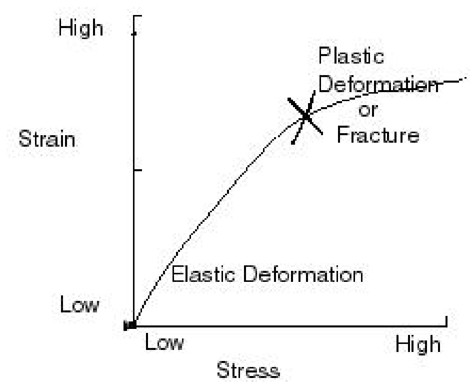


Figure 2

This graph shows how the initial linear section of the graph is when strain is proportional to stress. The part marked "X" is the elastic limit or yield point, this is the point of no return from this moment on the material in question is permanently deformed and can no longer return to its original state. The linear section however can be used to calculate the Young's modulus of the material, by stress/strain.

As I mentioned earlier that I believe the young's modulus of constantan will be higher than copper, this is because it is an alloy. Constantan "Copper with 45% nickel" (Quoted from http://www.azom.com/details.asp?ArticleID=60). The constantan alloy with added nickel gives copper extra strength, "The nickel content in these alloys also enables them to retain their strength at elevated temperatures compared to copper alloys without nickel" (Quoted from http://www.azom.com/details.asp?ArticleID=60). This statement shows that pure copper is less able to keep its strength compared to copper alloys with nickel e.g. constantan.

The structures of alloys differ to pure metals. It is this structure that causes differences in properties of alloys and pure metals. It is the presence of an other metal that makes alloys stronger than pure metals. As pure metals may have dislocations in them this makes it easy for slips to occur, as there are spaces in between atoms called dislocations, and it is easy for these atoms to slip over each other hence this is why pure metals are more ductile than alloys. As shown in figure 3, the metal alloy has its dislocation pinned, thus meaning the presence of the

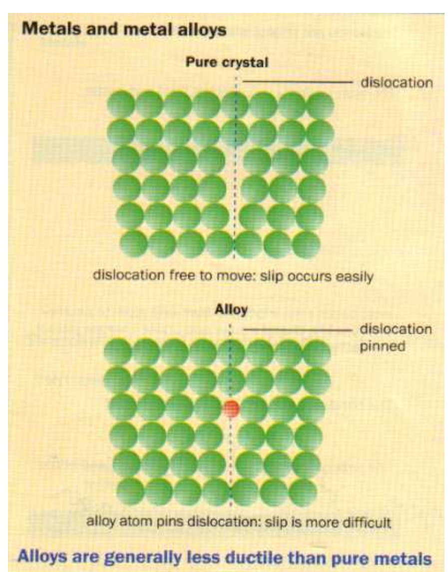


Figure 3

extra metal (e.g. so presence of nickel in copper) means that dislocations are filled in, and hence this makes it more difficult for the metal to slip making it less ductile. (Adapted from Advancing Physics AS Textbook page 116-117).

In order to work out Young's modulus I will need to calculate the stress acting on the metal and alloy wires. Stress is calculated by force/area. "The stress is force per unit area" (Quoted from Advancing physics textbook). The yield stress is the amount of stress it takes for a material to yield, this is when a metal gives before it snaps/breaks, at this point and beyond it is permanently deformed and cannot return to its original shape (also called elastic limit) and breaking stress is the amount of stress it takes to break a material. The yield and breaking stress differs between different types of materials. Figure four shows how alloys and pure metals differ.

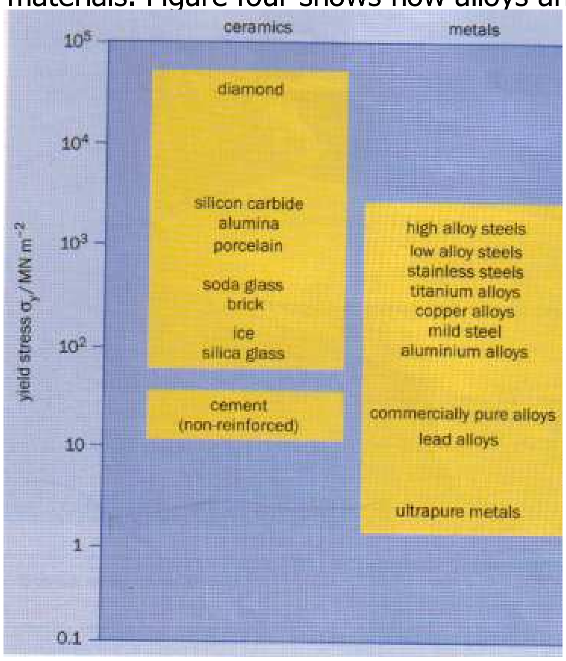


**Figure 4**

As can be seen alloy metals have a higher yield stress than pure metals, this is due to their structure makes slipping more difficult.

Apparatus:

- **Table:** To conduct experiment on
- **Wooden Blocks:** Helps to keep wire steady and in place when fixed onto the G-clamp
- **Copper & Constantan wire (3 of each):** These wires are used to conduct the experiment as we are testing how the extension of these changes with load.
- **Pulley:** A smooth running surface for the wire, over the edge of the table. Hence this will let the wire extend with force with minimal friction.
- **Masses:** These will be used to put load on the wires to give an extension reading.
- **Mass hanger:** This will hold the masses that are applied to the wires.

- **G-Clamp:** This will hold the wooden blocks in place which in turn will hold the wire in a stationary position.
- **Sellotape:** To hold the metre rule in place and to stick the marker onto the wire
- **Marker:** This will be placed along each wire before the experiment begins this will show how much the wire extends when a force is applied to it.
- **Metre rule:** Placed in a stationary position and as the marker moves when force is added to it I will be able to see the extension.

Method:

I have not specifically carried out this experiment to obtain results for this coursework, but I carried out this experiment in my first term of my AS-Level physics course and so I am able to write out a methodology for the experiment that I have received results for as it is the identical experiment. The following is a method for the experiment:

1. All equipment will need to be collected, table, wooden blocks, copper and constantan wire, pulley, masses and mass hangers, G-clamp, sellotape, marker and a metre rule.
2. Collect both copper and constantan wires together and cut to 2.1m long each using the meter rule and measure the diameter of each wire using a micrometer. Measurements of wire length in meters and wire diameter in millimetres (later converted to meters by dividing by one thousand).
3. Record the measurements of wire length and diameter. Then work out cross-sectional area of the wire by halving diameter to get the radius of each wire and then put in to the formula $\prod r^2$, to obtain the cross-sectional area of the wire.
4. I will place the meter rule on the table, using sellotape to keep it steady. The G-clamp and pulley will also be clamped to the table at this time, pulley at the end of the table and G-clamp at approximately 2 metres from the pulley (as shown in Figure 1)
5. Set up wooden bridges at ten centimetres from the G-clamp and collect copper wire and clamp it onto the G-clamp and extend the wire so it is hanging over the pulley.
6. Attach mass hanger to the end of the wire which is at the end of the pulley and then place the marker on the wire where the metre rule reads 0 centimetres.
7. Collect the two Newton masses and place on one two Newton mass on the mass hanger. Measure the extension created by increased load. (Extension from 0 centimetres on ruler, shown by marker on wire). Record extension created with this weight on a force extension table.
8. Repeat step seven by adding two Newton mass until 48N load is reached or the wire breaks (whichever is sooner).

Fair Test:

- For each wire test it three times and average the results, with same conditions each time
- Carry it out all experimental work on the same day, same conditions and using all of the same apparatus.
- Keep metre stick stationary for every test, so to keep extension values fair for every test.
- Do not alter the position of G-clamp, Pulley, metre rule, wooden blocks and table during all the experiments have been completed
- Use all wire from same roll and the copper and constantan must be manufactured by the same company.

Safety:

- When adding masses to the mass hanger be sure not to step in the falling range of the masses as they could injure feet
- Wear goggles while conducting the experiment as when the wire snaps it could take to the air in any direction and hit the eye.

Results:

The results I have been given were given to me on paper format, I have entered these results into the spreadsheet program Microsoft excel and calculated additional calculations to help me plot graphs. The results for copper and constantan are shown on the next two pages.

In the data given to me I received the extension readings in millimetres, however it is required to be in metres. The conversion process used to convert millimetres to metres is shown below:

| | | |
|---|---|---|
| **e.g. 33mm >** | **(÷ 1000) >** | **Value of 0.033m achieved** |

Also needed to be calculated is cross sectional area of the wires copper and constantan, needed to calculate stress which in turn is used to calculate young's modulus. The "r" value is radius, which is half the diameter, so it is divided by two to give the radius. The calculations I did for cross sectional areas of both wires is shown below:

| | |
|---|---|
| **Cross sectional area = $\prod r^2$** | **Cross sectional area= $\prod r^2$** |
| Copper "r"= 0.37/2= 0.185mm | Constantan "r" = 0.35/2= 0.175mm |
| **Conversion to m= 1.85E-4** | Conversion to m= 1.75E-4 |
| **Calculations= $\prod (0.000185^2)$ = 1.08e-7m²** | Calculations= **$\prod (0.000175^2)$ = 9.62e-8m²** |

The stress can now be calculated by force “F” divided by cross sectional area “A”. The strain is simply average extension “E” divided by length. The average extension value was calculated by the formula =AVERAGE(cell address: cell address), this is the mean extension values. The length value “L” was a constant at 2.1metres.

| | COPPER | | | | | | |
|---|---|---|---|---|---|---|---|
| Force (N) | Extension (m) | Extension (m) | Extension (m) | Average Extension (m) | Stress (F/A) | Strain (E/L) | Young's Modulus |
| 0 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.00E+00 | 0.000E+00 | 0.00E+00 | 0.00E+00 |
| 2 | 0.000E+00 | 0.000E+00 | 0.000E+00 | 0.00E+00 | 1.860E+07 | 0.00E+00 | 0.00E+00 |
| 4 | 1.000E-03 | 1.000E-03 | 2.000E-03 | 1.33E-03 | 3.720E+07 | 6.35E-04 | 5.86E+10 |
| 6 | 3.000E-03 | 2.000E-03 | 3.000E-03 | 2.67E-03 | 5.580E+07 | 1.27E-03 | 4.39E+10 |
| 8 | 4.000E-03 | 3.000E-03 | 3.000E-03 | 3.33E-03 | 7.440E+07 | 1.59E-03 | 4.69E+10 |
| 10 | 5.000E-03 | 4.000E-03 | 4.000E-03 | 4.33E-03 | 9.301E+07 | 2.06E-03 | 4.51E+10 |
| 12 | 6.000E-03 | 5.000E-03 | 5.000E-03 | 5.33E-03 | 1.116E+08 | 2.54E-03 | 4.39E+10 |
| 14 | 7.000E-03 | 5.000E-03 | 5.000E-03 | 5.67E-03 | 1.302E+08 | 2.70E-03 | 4.83E+10 |
| 16 | 9.000E-03 | 6.000E-03 | 6.000E-03 | 7.00E-03 | 1.488E+08 | 3.33E-03 | 4.46E+10 |
| 18 | 1.100E-02 | 7.000E-03 | 1.000E-02 | 9.33E-03 | 1.674E+08 | 4.44E-03 | 3.77E+10 |
| 20 | 1.600E-02 | 1.000E-02 | 1.200E-02 | 1.27E-02 | 1.860E+08 | 6.03E-03 | 3.08E+10 |
| 22 | 2.200E-02 | 1.500E-02 | 4.500E-02 | 2.73E-02 | 2.046E+08 | 1.30E-02 | 1.57E+10 |
| 24 | 9.600E-02 | 3.200E-02 | 1.400E-01 | 8.93E-02 | 2.232E+08 | 4.25E-02 | 5.25E+09 |
| 26 | BROKE | 4.300E-02 | BROKE | 4.300E-02 | 2.418E+08 | 2.05E-02 | 1.18E+10 |
| 28 | BROKE | BROKE | BROKE | BROKE | BROKE | BROKE | BROKE |

**Table 1**

| | CONSTANTAN | | | | | | |
|---|---|---|---|---|---|---|---|
| Force (N) | Extension (m) | Extension (m) | Extension (m) | Average Extension (m) | Stress (Pa) F/A | Strain (Ratio) E/L | Young's Modulus |
| 0 | 0 | 0 | 0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 2 | 0 | 0 | 0 | 0.00E+00 | 2.08E+07 | 0.00E+00 | 0.00E+00 |
| 4 | 2.00E-03 | 1.00E-03 | 1.00E-03 | 1.33E-03 | 4.16E+07 | 6.35E-04 | 6.55E+10 |
| 6 | 3.00E-03 | 1.00E-03 | 1.00E-03 | 1.67E-03 | 6.24E+07 | 7.94E-04 | 7.86E+10 |
| 8 | 4.00E-03 | 2.00E-03 | 2.00E-03 | 2.67E-03 | 8.32E+07 | 1.27E-03 | 6.55E+10 |
| 10 | 4.00E-03 | 3.00E-03 | 3.00E-03 | 3.33E-03 | 1.04E+08 | 1.59E-03 | 6.55E+10 |
| 12 | 5.00E-03 | 3.00E-03 | 4.00E-03 | 4.00E-03 | 1.25E+08 | 1.90E-03 | 6.55E+10 |
| 14 | 5.00E-03 | 4.00E-03 | 5.00E-03 | 4.67E-03 | 1.46E+08 | 2.22E-03 | 6.55E+10 |
| 16 | 6.00E-03 | 4.00E-03 | 5.00E-03 | 5.00E-03 | 1.66E+08 | 2.38E-03 | 6.98E+10 |
| 18 | 8.00E-03 | 4.00E-03 | 5.00E-03 | 5.67E-03 | 1.87E+08 | 2.70E-03 | 6.93E+10 |
| 20 | 8.00E-03 | 4.00E-03 | 6.00E-03 | 6.00E-03 | 2.08E+08 | 2.86E-03 | 7.28E+10 |
| 22 | 8.00E-03 | 5.00E-03 | 7.00E-03 | 6.67E-03 | 2.29E+08 | 3.17E-03 | 7.20E+10 |
| 24 | 8.00E-03 | 6.00E-03 | 9.00E-03 | 7.67E-03 | 2.49E+08 | 3.65E-03 | 6.83E+10 |
| 26 | 9.00E-03 | 7.00E-03 | 9.00E-03 | 8.33E-03 | 2.70E+08 | 3.97E-03 | 6.81E+10 |
| 28 | 1.00E-02 | 7.00E-03 | 1.10E-02 | 9.33E-03 | 2.91E+08 | 4.44E-03 | 6.55E+10 |
| 30 | 1.10E-02 | 9.00E-03 | 1.20E-02 | 1.07E-02 | 3.12E+08 | 5.08E-03 | 6.14E+10 |
| 32 | 1.40E-02 | 1.00E-02 | 1.40E-02 | 1.27E-02 | 3.33E+08 | 6.03E-03 | 5.51E+10 |
| 34 | 1.80E-02 | 1.50E-02 | 1.70E-02 | 1.67E-02 | 3.53E+08 | 7.94E-03 | 4.45E+10 |
| 36 | 3.80E-02 | 1.50E-02 | 2.00E-02 | 2.43E-02 | 3.74E+08 | 1.16E-02 | 3.23E+10 |
| 38 | 4.70E-02 | 2.00E-02 | 3.00E-02 | 3.23E-02 | 3.95E+08 | 1.54E-02 | 2.57E+10 |
| 40 | 7.80E-02 | 3.40E-02 | 6.70E-02 | 5.97E-02 | 4.16E+08 | 2.84E-02 | 1.46E+10 |
| 42 | 8.20E-02 | 9.40E-02 | 9.20E-02 | 8.93E-02 | 4.37E+08 | 4.25E-02 | 1.03E+10 |
| 44 | 1.37E-01 | 1.07E-01 | BROKE | 1.22E-01 | 4.57E+08 | 5.81E-02 | 7.87E+09 |
| 46 | 1.51E-01 | 1.67E-01 | BROKE | 1.59E-01 | 4.78E+08 | 7.57E-02 | 6.31E+09 |
| 48 | BROKE | BROKE | BROKE | BROKE | BROKE | BROKE | BROKE |

**Table 2**

## Graph one: How average extension changes with force for copper and constantan (Hooke's law)

The graph shows how average extension changes with force for Copper and Constantan. The initial part of each curve is linear, thus showing where the extension is proportional to load, on copper the yield stress is reached at 16N and constantan reaches its yield stress at 32N. As can be seen by the graph that constantan extends more than copper and more force is needed with constantan to create a certain extension than is needed with copper for example constantan needs a force of 35N for a 0.02m extension whereas copper only needs a force of 21N for the same extension, this would be due to its atomic arrangement. Constantan is an alloy and so for slipping to occur it is more difficult than for the pure metal copper, due to dislocations being filled up with the nickel atoms in constantan and so dislocations are pinned hence why the greater force is needed for equal extension of constantan compared to copper.

The constantan wire diameter was given to be 0.00035m compared to the copper diameter being 0.00037m. This is a major factor in the behaviour of the wire as stress is force per unit area. With the cross sectional areas of the wires being different (copper= $1.076x10\text{-}7m^2$ and constantan = $0.962x10\text{-}7m^2$), the cross sectional area of constantan being smaller means that the forces acting on the area of constantan wire are grater than the copper wire, so in theory this should put more pressure on the constantan wire and cause it to yield and break easier, however this is not the case due to it being an alloy and it is stronger as its dislocations are pinned.

The graph shows that the breaking stress of both materials is also different, with constantan having a breaking stress of 46N and copper at 24N. Hence we can deduce from the information that constantan can handle more stress than copper even though the wire diameter of constantan was 0.002m smaller and that the constantan wire is able to extend more than copper when equal and grater forces are applied to it.

I have found out from my graph one analysis that it shows my prediction may be correct of the young's modulus of constantan being greater than copper. I can state this as stress it is part of the young's modulus equation, it is a key component needed to calculate young's modulus of a material, with constantan being more resistant to stress forces acting on it than copper it can be said that the overall Young's modulus may be higher.

## Graph two: Stress and strain graph for copper and constantan

The second graph I will analyse is a stress and strain graph for copper and constantan. I have made the scale as large as possible so to show the shape of the curve as large as possible so any anomalous points clearly and it will take advantage of the whole page so to use my resources carefully. For this graph a curve will be needed for both sets of data to show how stress changes with strain and to see the yield point graphically. It will be accurate as the points will be plotted carefully with due care to ensure an accurate graph and the scale will be relevant as to show the best possible curve. It will need to be neat to show the best possible curve and most accurate in order to correctly analyse it.

The graph shows that the initial linear section is when strain is proportional to stress. So for constantan stress is proportional to strain up until 3.33x10+8 Pa (stress) and 6.03x10-3 (strain) and copper 1.674x10+8 (stress) and 4.44x10-3 (strain), this can be seen on the graph as the yield point and it can be clearly seen that the yield point of constantan has a higher stress and strain value, hence greater forces are needed for it to yield. This may be due to the atom arrangement in alloys compared to pure metals. In pure metals there are many dislocations and slipping could occur easily (as shown in figure 3) that these dislocations in pure metals make them more ductile. However alloys have other elements contained in the atomic structure, like constantan which has nickel to fill these dislocations making it stronger, as slipping is more difficult. In alloys the forces between particles are stronger which makes it more difficult to yield or break.

The graph also shows the breaking point of each wire, copper being 2.418x10+8 Pa (Stress) and 2.05x10-2 (strain) and constantan being 4.78x10+8 Pa (stress) and 7.57x10-2 (strain) and it can be seen on the graph that constantan needs a huge amount more stress and strain force for it to break. Again this is due to it properties as an alloy, which makes it have a high young's modulus.

The young's modulus is how stiff a material is. In metals the atoms are ionised and free electrons in between the ions. It is this negative charge of the electrons that gules the ions collectively. The ions are able to slip however. When a metal experiences stretching forces then this pulls the bonds apart and gaps open up a little, this is the elastic extensibility of a metal and is 0.1% in metals. However in alloys this may be less as atoms are even closer together therefore have stronger forces of attraction and so may not encounter elastic extensibility as much and therefore is more stable, hence why constantan may have a higher young's modulus and can withstand higher forces of stress and strain acting on it.

This also helps me prove my prediction of the young's modulus of constantan will be higher than copper due to it being an alloy, the graph clearly shows the constantan is able to withstand greater forces acting on it and therefore could have a higher young's modulus. To calculate the young's modulus I will analyse the linear section using graph three.

Graph three/ four: Linear expansion of stress and strain graph for copper and constantan/ graph showing error bars to 3% error.

Graph three is only the linear section of graph two, it is enlarged so I am able to calculate the young's modulus of both metals, hence so my prediction can be analysed. I will be calculating the young's modulus by taking the change in stress divided by change in strain of the linear points for both copper and constantan and using graph four I will analyse the error percentage on the graph to 3%.

| MATERIAL | YOUNG'S MODULUS |
|---|---|
| Copper | 1.86x10+8/6.35x10-4= 2.93x10+11 pa |
| Constantan | 3.33x10+8/6.35x10-4= 5.25x10+11 pa |

**Table 3**

As can be seen by the results constantan has a higher young's modulus value, thus my prediction was correct. Due to the difference in Young's modulus this means that the metal copper and alloy constantan would react slightly different stress and strain forces are applied to it. As can be seen in the table three the Young's modulus of constantan is higher, this can be also seen on graph three as all points for constantan is above copper, thus the higher stress and strain resistance of constantan.

The line of best fit for constantan shows higher stress and strain than for the line of best fit for copper. This means there is little strain for the large stress forces applied to constantan and copper, so the material is stiff and hard to stretch. I can state that constantan is harder to stretch than copper as the line of best fit is steeper. All the points on graph three show the elastic reigns of copper and constantan, hence if forces on the wire at that time are removed then the material will return to its normal length.

Graph four shows error percentage range to 3%. This is acceptable for A-level experiment. The general trend shown is positive correlation and that the higher the stress and strain values for copper or constantan is, shows the error markings to be higher, thus meaning as the experiment is carried out as the forces applied to the materials increase the results become less accurate. The error rate may increase due to the forces acting on the wire being so great that it is close to its yield stress point and so becomes less stable.

However there are many anomalous points which lie totally off the general trend of the graph. I have marked points one, two and three (on graph four) as three anomalous points I will analyse. Point one is situated below the line of best fit for copper, it is an considerable anomalous point as it is well below the line of best fit, this means during the collecting data stage an inaccurate reading must have taken place or the weight of the mass been incorrect. Other factors that could have made this point anomalous is that not enough time was taken before a reading was taken, so when a force was applied to the copper at this point it may have still been extending while the reading was taken so the results became inaccurate. Kinks in parts of the wire could also be a factor as this would affect how parts of the wire react to different forces acting on it. This may have also happened to point two for constantan, which was in the same situation as copper. The point three showing a region of seven points of constantan, is a range of points which are slightly off the line of best fit, this may be due to kinks in the wire which caused it to react differently to forces added during these seven points, inaccurate readings could have taken place where not enough time was taken again to let the force applied take its full effect on the wire.

These anomalous points could have been caused by kinks in the wire, there could be parts of the wire which are weaker or stronger (notches) and these would extend differently compared to the rest of the wire, hence causing anomalous points in the graphed data.

## Evaluation

I have concluded that my prediction was correct as this was shown by my calculations and can be seen in the graphs I have drawn that constantan has a higher young's modulus than copper.

The experiment was reliable as I believe the experiment was carried out under all the fair test conditions. Also with the experiment having been repeated three times this would level out any extreme values or inaccurate readings as I took the average of extensions to plot my graphs and analyse the data. It was also reliable as data on the material length and diameter were taken accurately and repeated three times and averaged, so the diameter and length of each wire was taken three times and averaged, so I received the average value. The diameter of each wire was made using a micrometer, the error in a micrometer is +/- 5%, so the diameter measurement could have been wrong by approximately 5%. The length of the wire was measured using a metre rule, which would have an uncertainty of 0.5mm, thus the wire length could have actually been +/- 2.1m. In addition the calculation on Young's modulus could have also been inaccurate as I calculated it using my line of best fit, as this was drawn by my interpretation of what the line of best fit is then it could be human error that Young's modulus may have been incorrect. The Young's modulus of copper is 3x10+10 and constantan is 6.4x10+10, however my calculations show copper to be 2.93x10+11 and constantan to be 5.25x10+11, these were close to the real values, however as this was a basic school based experiment and the real values were taken under perfect conditions and all factors accounted for then my values for Young's modulus were accurate as they were close to the real values. My values may have been less accurate due to the fact that I have not accounted for the friction of the pulley system acting on the wire and thus this would have affected the school based experiments values.

The wire length used was 2.1m in length, this was better than wire of half its length as it let the wire extend to its full potential rather than a wire of half its length extending and breaking within a few readings of force and hence less results makes the experiment less reliable as the more results there are the more data there is and hence more accuracy. Also the 2.1m wire was used this made calculations more difficult than if wire was 1m in length, however measuring extension it was easier as it would be larger as the wire is longer so more of it stretches.

I have concluded that my prediction was correct as this was shown by my calculations and can be seen in the graphs I have drawn that constantan has a higher young's modulus than copper.

I will now evaluate the accuracy of the data given to me and calculations I have made myself. I have set the my percentage error to be 5%, so if the percentage error is above 5% then I believe this is not accurate enough for an A-level experiment.

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| Percentage error in measurements<br><br>**% error=**<br><br>**(Error in measure/measurement) x 100** | Area of wire<br>Smallest measurements: 0.005x10-3m (Micrometer) and 0.35x10-3m (smallest recorded measurement).<br><br>(0.005x10-3/0.35x10-3) x100<br>= **1.43% error**<br><br>The error percentage maximum I set was 5%, I have worked out the error percentage of area of wire to be 1.43%, and therefore this is acceptable. |
| Original Length<br><br>Length of wire taken as 2.1m<br><br>The error in measure of metre rule is 5mm (5x10-3m)<br><br>(0.005/2.1) x100<br><br>= 0.238095238%<br><br>= **0.24% error**<br><br>This error is acceptable as it is well below the 5% error maximum I set, | Force<br><br>Mass= 100g each, but 2N intervals in force, so 200g mass for each interval. The mass error is between 99-101g, so +/- 1g. As two were used then 1x2= +/-2g error.<br><br>(2/200) x100<br><br>= **1% error**<br><br>As my error maximum was set to 5%, a 1% error for force is acceptable. |

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| so this was seen to be literally an error free measurement. | |

Bibliography


- http://www.york.ac.uk/depts/chem/course/studhand/solids.html- found out composition of copper and constantan. (7/10)

- http://www.azom.com/details.asp?ArticleID=60- information on copper alloys (5/10)

- AS physics text book: very useful, chapter 4-5 are very useful and contained lots of information on the physics theory of my investigation (9/10)

- AS-physics CD-ROM: provided guides on how to set out coursework and information on the experiment hat this coursework was based on. (8/10)

- AS Physics teacher: Miss Bottomly: Very helpful. Introduced coursework, hence this would not have been possible without teachers help. (10/10)


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