Physics TAS

Young Modulus of Copper

Objectives

-Determine the Young modulus of copper by simple experiment
-Study the relationship of strain and stress between elastic and plastic deformations of copper
-Verify a wire will not return to its original length after certain extensions

Preview Questions

1.Hooke's Law states that the elastic force is directly proportional to the extension (or compression) of the elastic body. A wire obeys Hooke's Law only if it is within its elastic limit.

2.*Elastic deformation* means a stretched wire will return to its natural length. If the wire is stretched beyond its elastic limit, it will not return to the original length and will make permanent extensions. This is called *plastic deformation*.

3.A longer wire will extend more than a shorter wire of the same cross-sectional area under the same applied force.

4.As in Q.3 , force constant can be easily affected by geometric factors such as length and cross sectional area. But the stiffness of materials depends on their Young modulus only, which is not affected by geometric factors. So force constant is not a good quantity to compare the stiffness of materials.

Apparatus

Copper wire ....1 roll

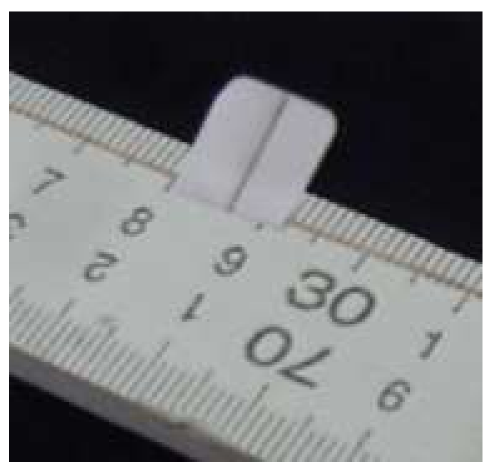
100g hangers 1

100g slotted mass ....~15

slotted mass with hanger

G-clamp 1

white label sticker................1



clamp-on pulley 1

micrometer screw gauge...........1

metre rule 2

newspaper.............several

Theory

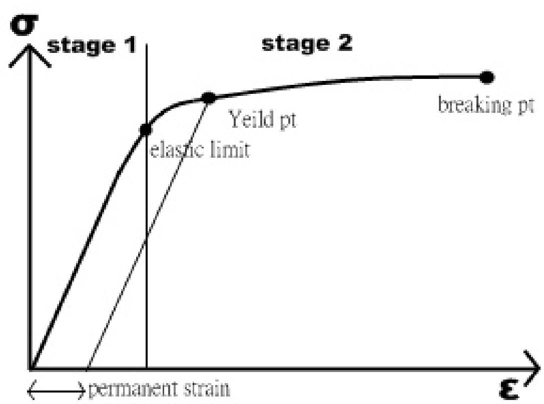
The following quantities is important for the experiment's concerns:

Stress is defined as ***σ*** =Force / Cross-sectional area **(** ***F/A*** **)**

Strain is defined as ***ε*** = Extension / Natural length **(** ***e/l*** **)**

The ratio of Stress to Strain, is the **Young modulus (*E*= *σ/ε*)**

Since a stiffer material requires larger stress to produce the same strain , a stiffer material would have a greater Young modulus (a greater slope in a graph of ***σ*** against ***ε***) .



For a non brittle material, usually there are two stages of deformation before breaking.

Stage 1 : Elastic deformation

In this stage, the wire would return to its natural length when the stress is removed. Hooke's law is usually obeyed in this stage, therefore the graph is almost a straight line.

When the wire is further stretched, it reaches the **elastic limit** and get into stage 2.

Stage 2 : Plastic deformation

In this stage, the stress is not directly proportional to the strain and and a small amount of stress can produce a large strain. If the wire passes the **yield point**, its will have permanent extension and will not return to its original length. Finally, when the wire is kept to stretched, it will break at the **breaking point.**

Procedure

Experiment 1:
Study the stress-strain behaviour of a copper wire

1.A micrometer screw gauge was used to measure the diameter of the copper wire at several points. Mean value was taken and the cross-sectional area of the wire was calculated.

2.A pulley was mounted on one side of the table. A 2 m segment of the wire was cut out and was clamped firmly by using a G-clamp which was at a distance about 1.5 m form the pulley.

3.The wire was placed over the pulley. Some newspapers were put one the ground below the pulley.

4.A label marker is sticked on the wire at a distance about 0.5 m from the pulley. A metre rule was placed below the wire and was fixed on the table by sticky tape.

5.A 100g hanger was tied to wire.

6.The length between the G-clamp and the sticker, which represents the natural length, was measured.

7.100g load was added to the hanger one by one , and the extension was recorded each time.

8.Load was kept increasing until the wire broke.

Experiment 2 :
Elastic deformation and Young modulus

1.A new wire of the same length and thickness was used and steps 1 to 7 in experiment 1 were repeated.

2.Load was added to the hanger carefully. All the load were removed each time to check whether the wire would return to the original length. Results were recorded.

3.Step 2 was repeated until the elastic limit was just exceeded.

Precautions

1.The hanger should be more than 0.5 m above the newspapers. This allows the wire to get enough space for extensions before it breaks. Also it should not be kept too high from the ground, this may cause the tiles of the floor to break.

2.The sticker should not be placed too close to the pulley. If not the wire may touch the pulley when the wire is extended. A distance of 0.4 m is preferred.

3.The load should be added to the hanger slowly and carefully. This is to avoid exerting impulse to the wire and making the masses to oscillate. Otherwise the wire may get extra extension and make the records not appropriate.

4.Records should be taken only after the sticker stops moving. This is because the wire takes time to extend itself, especially at the later stage when the wire passed the elastic limit and was near breaking.

Results

Diameter of the copper wire:

	D1	D2	D3	D4	Mean
Value (in ±0.005mm)	0.370	0.365	0.670	0.370	0.3688

Natural length of the wire=1.15m

Experiment 1:

Load(kg)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Extension (10^-3 m)	0	0.5	0.5	1	1	1.5	1.5	2.0

Load(kg)	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6
Extension (10^-3 m)	2.5	2.5	3.0	3.0	3.5	4.0	5.5	12

Load(kg)	1.7	1.8	1.9	2.0	2.1	2.2	2.3	**Broken**
Extension (10^-3 m)	19	34	46	60	77	98	125	/

Maximum load for elastic deformation=1.3 kg
Load for breaking the wire=2.3 kg

Experiment 2 :

Load(kg)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Extension (10^-3)	0	0.5	0.8	1	1.2	1.5	1.5	2

Load(kg)	0.9	1	1.1	1.2	**Elastic**	**limit**	**exceeded**	

Extension (10^-3)	2.5	2.5	3	3.5	/	/	/	

Calculations & Graphs

Maximum possible error of metre rule = 0.1 cm=0.01m
Maximum possible error of
micrometer screw gauge =0.005mm=5x10^-6 m

Cross-sectional area of the wire = 1.068x10^-7 m^2
Percentage error = 2x6.778x10^-3 =1.3557%
∴Cross-sectional area = (1.07x1 ± 0.01)x10^-7 m^2

Experiment 1

Stress - Strain relationship:

Stress (M Pa)	9.345	18.69	28.03	37.38	46.73	56.07	65.42	74.76
Strain (10^-3)	0	0.4348	0.4348	0.8696	0.8696	1.304	1.304	1.7392

Stress (M Pa)	84.11	93.45	102.8	112.1	121.5	130.8	140.1	149.5
Strain (10^-3)	2.174	2.174	2.609	2.609	3.043	3.478	4.783	10.44

Stress (M Pa)	158.9	168.2	177.6	186.9	196.3	205.6	215.0	**Broken**
Stress (10^-3)	16.52	29.57	40.00	52.61	66.96	82.61	108.7	/

Stress at elastic limit=124 M Pa
Percentage error=Percentage error of the area of the wire
=1.3557%
∴Stress at elastic limit=(124 ± 2)M Pa

Breaking stress=(215 Pa ± 3)M Pa

Experiment 2:

Stress – Strain relationship up to elastic limit:

Stress (M Pa)	9.345	18.69	28.03	37.38	46.73	56.07	65.42	74.76
Strain (10^-3)	0	0.4673	0.7477	0.9346	1.121	1.402	1.402	1.869

Stress (M Pa)	84.11	93.45	102.8	112.1	**Elastic**	**limit**	**exceeded**	
Strain (10^-3)	2.336	2.336	2.804	3.271	/	/	/	

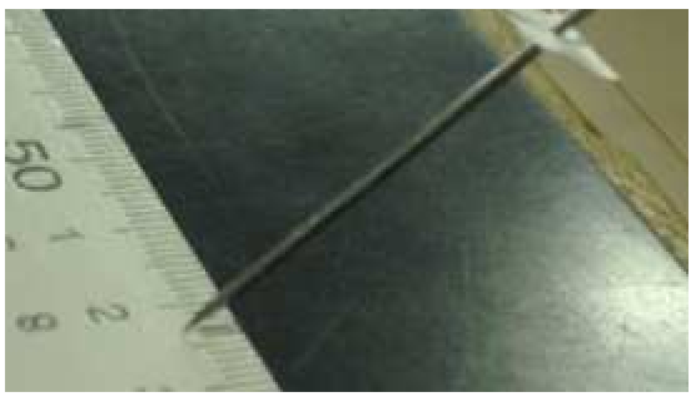
Mean of the stress=60.7 M Pa

Mean of the strain=1.56x10^-3
Slope of the best-fit line=38.9 G Pa
Maximum slope=42.2 G Pa
Minimum slope=30.0 G Pa
Mean error=(38.9-36.1)=2.8 G Pa
∴Young modulus of the copper wire=(38.9 ± 2.8)G Pa

Errors and Difficulties

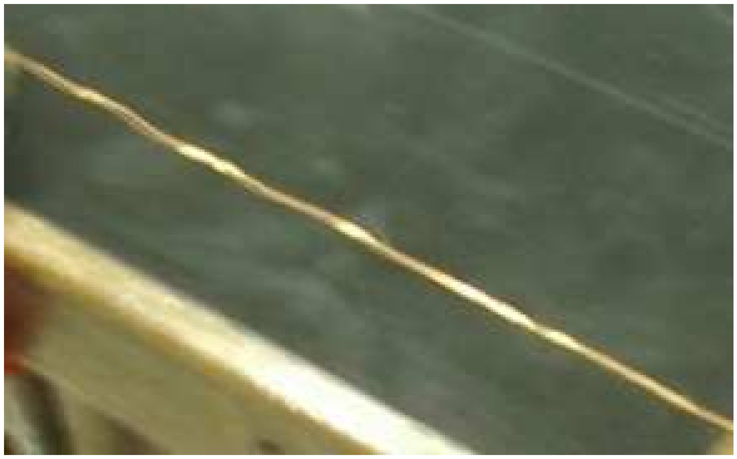
1.There were systematic errors in this experiment. The masses were not weighted to check what its actual weight is. The wire may not be made of pure copper. The air temperature may vary due to air-conditioners. Besides, gravitational acceleration is taken as 10ms^-2 instead of 9.8ms^-2

2.There was a random error in viewing the sticker. Since the sticker had a few distance from the ruler, errors due to parallax would arise if we view form a little bit right or left. So it is difficult to obtain the precise value. To improve this, a nail can be added onto the sticker. The nail was more stable



and gave readings very sharply.

3.At the beginning of the experiment, the wire is very uneven. The first few extensions we taken may be only due to the reform of the wire into a straight shape.(just like stretching a spring into a straight wire)



Discussion

1.Near the breaking point, the shape of the wire is very narrow.

2.During elastic deformation, the hanger falls and loses gravitational potential energy. This energy change to elastic potential energy. If the wire is unloaded, the energy will be restored to GPE and the wire will return to is original length.

3.During plastic deformation, the loss of gravitational potential energy becomes the work done to increase the length of the wire (increase the separations of the particles in the wire). This energy would not be restored even the wire is unloaded.

4.Double of the amount of the load is required to break the wires.

Conclusion

To obtain the Young modulus of the copper wire by this experiment is convenient. A few apparatus and steps are needed, and it only involves easy calculations. But by comparing to the actual value(124G Pa), the result we get (38.9 G Pa) has a great difference from it.

This may due to the experiment is done in several assumptions and estimations. We assumed g=10ms^-2 and the wire is made of pure copper. We neglected environmental factors and assumed the wire was stretched evenly in every parts.

In short, although the experiment is not accurate enough, it provides a good chance for students to practice what they have learned. It is quite shocked that a very thin and long wire can withstand more than 2 kg load.

The End