Young Modulus

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Learning Outcome

I highly recommend you to finish this checklist to determine whether you've achieved the learning objectives.

- ☐ define and use *stress, strain* and the *Young Modulus*
- ☐ describe an experiment to measure the Young Modulus
- ☐ calculate the energy stored in a deformed materials, from both Hooke's Law and Young Modulus perspective.

Leadin

Young is not Yang in Chinese, the first time I saw, I mistakenly regard it as a Chinese Scientist. But actually, he is TThomas Young, British scientist, and we will study his famous Double Slit Experiment later.

Figure 1: Thomas Young
1713-1929

Determine the stiffness of any materials

The stiffness of a spring can be determined through the force applied on it divided by the extension caused by that force, so what is the stiffness of an material itself?[1]? Is force divided by extension enough for determine the stiffness of material?

The answer is definely no, because very obviously, two wires with different *cross-sectional area*[2] will have different applying force to stretch them to same extention, not to mention when the orginial length can vary. Therefore, to avoide the influence of shape and length. Two concept has been introduced, *Stress* and *Strain*

[1] The shape should not be a factor, the question is that, we want the stiffness of 'material' not just a single object made from that material

[2] def:

Stress

Stress is defined as __________________________. If expressed in formula:

Summary

$$\text{stress} = \underline{\qquad\qquad\qquad}$$

$$\sigma = {}^{F}/_{A}$$

The unit for stress σ is _______________, the SI base unit is _______________.

Task

Try to compare stress with pressure, in physical meaning.

By calculating the **Force Per Unit Area**, we can exclude the influence of the cross-sectional area.

Strain

The next factor is the length of the wire itself. Obviously, forces with same magnitude will not incur same extension on a longer and a shorter wire. A way to solve this problem is considering the "the proportion relative to original length", which is the *Strain* in this case.

Summary

Strain is defined as ____.

strain = ―――――――――

$$\varepsilon = x/L$$

The unit for strain is _______________.

You may find that the basic route of studying the stiffness of materials resembles that in studying the spring, but cross-sectional area and orginial length are taken inton consideration. The two concept of force and extension can now be transformed to the two counterparts:stress and strain.

Young Modulus

The whole experiment is set up as in Fig 2. After the orginial length and

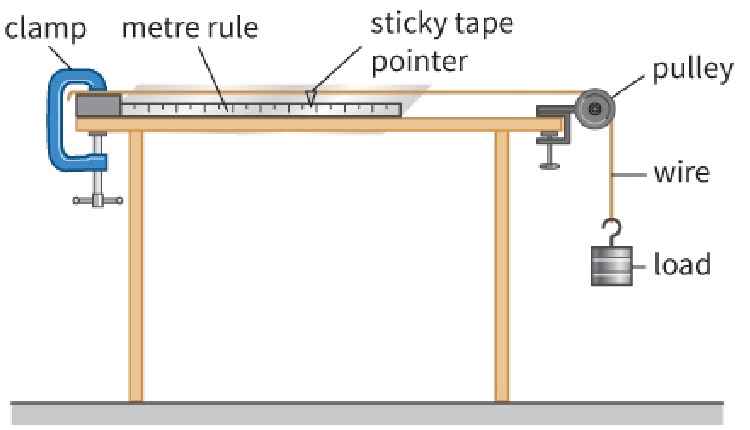
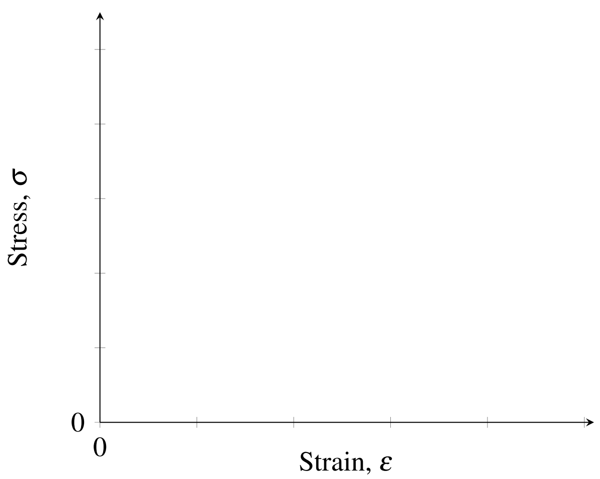


Figure 2: Stretching a wire in the laboratory

cross-sectional area are measured. Instead of Force versus Extension, A Stress versus Strain diagram is used.



Remember, how the spring constant, k, can be inferred from the F-x graph? It is the _______________ of the graph, apply the same method, A new physical quantities can be deduced - *Young Modulus*.

Summary

Young Modulus is ____.

$$E = \underline{\hspace{4cm}} = \frac{F \cdot L}{A \cdot x}$$

The unit for Young Modulus is _______________. and usually for metal materials, G is more frequently used, the SI base unit is _______________.

Plastic vs Elastic

Studying the graph of σ-ε of a wire, the following graph is often obtained.

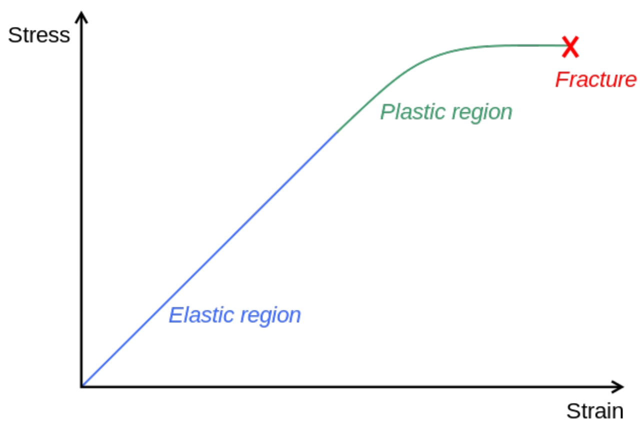


Figure 3: A Stress-Strain Curve for a Ductile Material

In elastic region, the wire actually obeys Hooke's Law; while in plastic region, some of the chemical bondings have been permanently destroyed, so deformation of the wire could not be reversed.

Task

In Fig.3, label the *limit of proportionality*

Elastic Potential Energy

If elastic deformation happens in an object, the energy is stored in the object, and when the object restores to its original state, such energy is released.

Summary

Elastic Potential Energy is

e.p.e. in spring

Since work done by a force is defined as the area under F-x graph.

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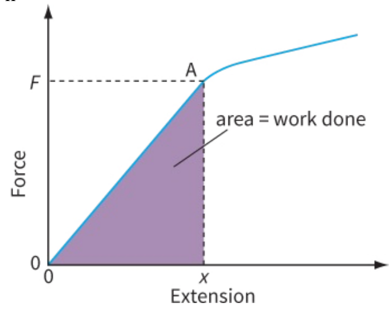

Task

Calculate the work done by your hand when a spring with spring constant k is stretched to Δx.

So the elastic potential energy stored in a spring is calcuated by

$$\text{e.p.e.} = {}^1\!/_2 \cdot k\Delta x^2$$

e.p.e. in wire

This section is no longer be required. If the same process is applied, what are the unit for ${}^1\!/_2 \cdot E\varepsilon^2$?