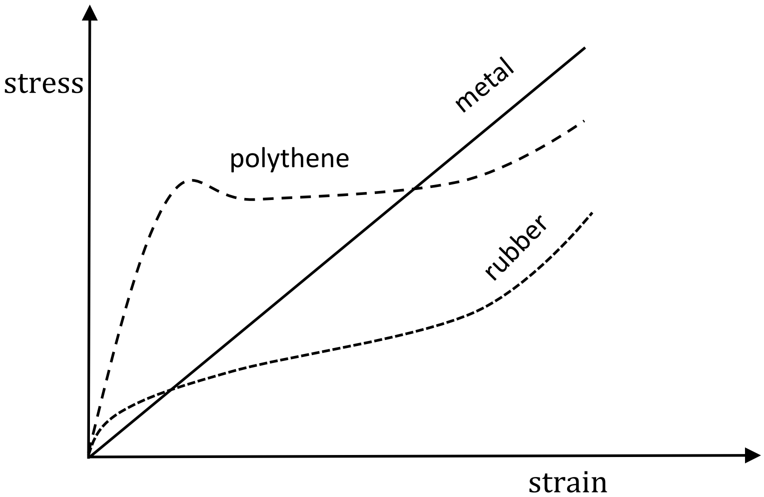
4.10.3 Stretching materials

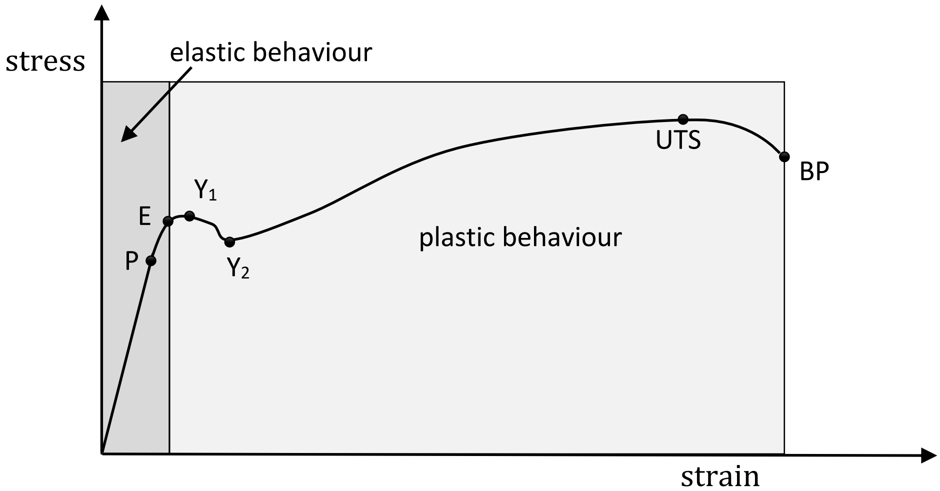
Different types of material behave differently when stretched.

videos



- Metals will stretch in a linear way up to their 'limit of proportionality'.
- Rubber stretches easily at first, then stiffens and becomes harder to stretch.
- Polythene is difficult to stretch at first, then yields and becomes much easier to stretch, before becoming stiffer again.

If we look at how metals behave when stretched beyond their limit of proportionality, we get a graph like the following:



Significant points in stretching a metal:

P – limit of proportionality, E – limit of elastic behaviour, Y_1 – yield point 1, Y_2 – yield point 2, UTS – ultimate tensile stress, BP – breaking point

Metals stretch in a linear way up to the limit of proportionality P. Metals stretched up to the elastic limit will return to their original shape once the stress is removed. Metals suddenly 'give' and rapidly stretch once the yield point 1 is exceeded. At yield point 2 the metal stiffens slightly but continues to stretch easily. The ultimate tensile stress is the maximum stress that can be applied before the wire stretches rapidly to the breaking point.

Up to the elastic limit materials will not be permanently deformed. Materials are said to behave elastically. Beyond the elastic limit materials will be permanently deformed. Materials are said to behave plastically.

(1)✏Find out what the following key terms mean:

stiffness

strength

brittle

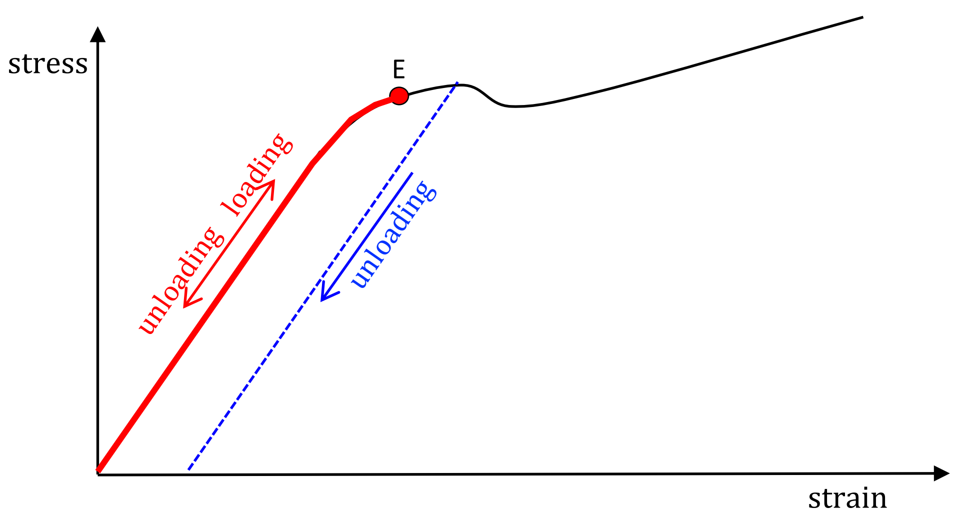
ductile

(2)✏Name a material which is strong but brittle.

(3)✏Name a material which is ductile.

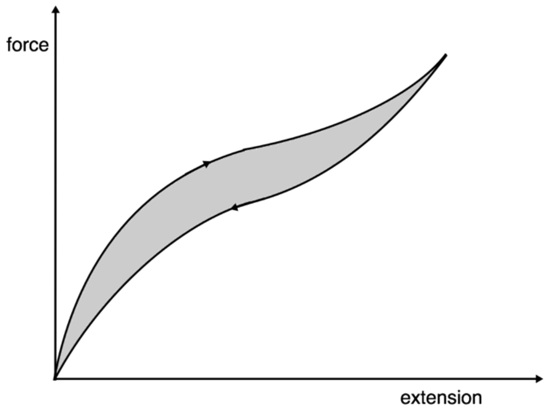
(4)✏Which is stronger – steel or copper? Explain why.

Loading and unloading materials



If we consider the graph, above, we can see that if we apply a stress to the material (called loading) it will return to its original shaped when we remove the stress (called unloading), providing we don't stretch it beyond E (the elastic limit). If we apply a greater stress beyond E, then the material will be permanently deformed and when the stress is removed (unloading) the material is permanently strained. This is represented in the diagram by the dashed line.

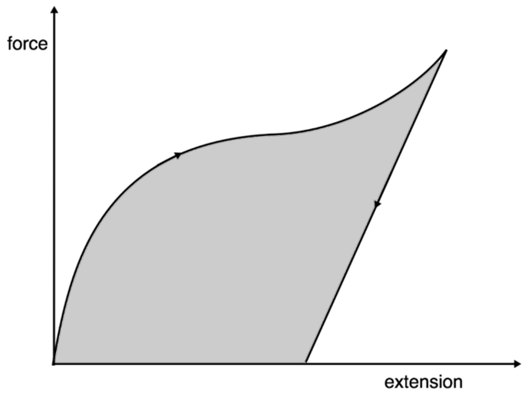
Let us consider the force-extension graph for loading and unloading rubber.



When the rubber is stretched (loading) it extends differently to when the force is removed.

The energy stored in the rubber is the area underneath the force-extension graph (see section 4.9.4). We can see that the area is greater for loading compared to unloading. The shaded area of the graph shows the difference. This 'missing' energy has gone into increasing the internal energy of the rubber, heating it up.

For materials which become permanently deformed, the 'missing' energy has gone into the internal energy of the material – both heating it and changing its structure.



The graph on the left shows the loading and unloading of polythene. The shaded area shows the work done on the polythene during loading and the energy recovered during unloading. The shaded area shows the difference and represents the energy that has gone into the internal energy of the material, heating it and changing its structure.

(5)✏If the graphs above were plotted as stress-strain graphs, what would the shaded area represent?