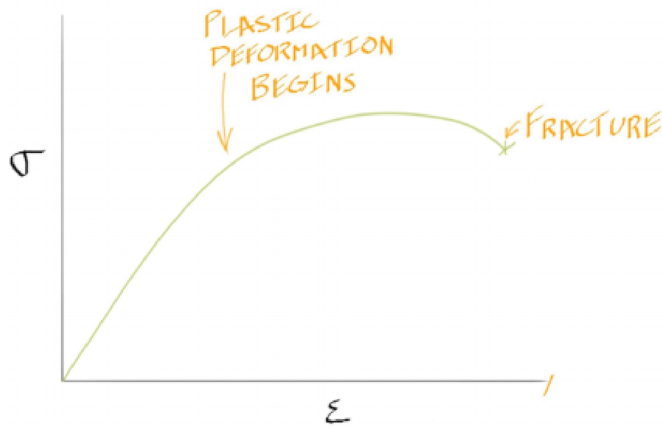
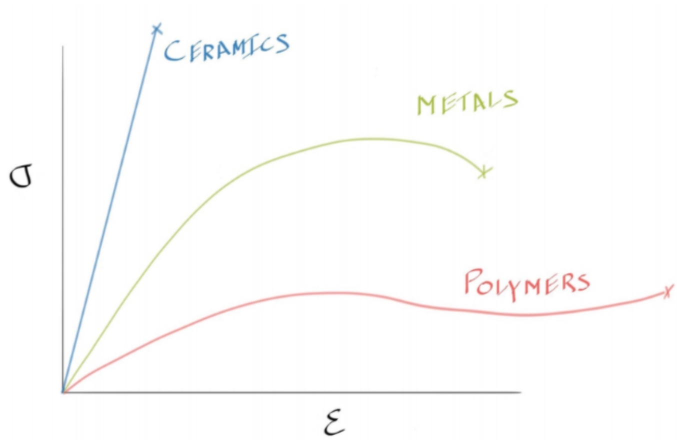
- **Chapter 3: Plastic Behaviour**

❖ PLASTIC DEFORMATION:
  - ➢ when we apply enough load to move beyond the elastic region
  - ➢ the sample dimensions will have changed
  - ➢ the atoms must move to new positions, even when the load is released
  - ➢ Tensile strain does not return to 0

❖ Plastic deformation begins close to the end of the linear elastic region.



- ➢ Stress-strain curves describe the properties of materials such as whether they are brittle, ductile and up to what stress and strain they obey Hooke's Law and have elastic and / or plastic behavior
- ➢ Each material will have a unique stress-strain curve



- Young's Modulus(highest to lowest):
  - ➔ Ceramics
  - ➔ Metals
  - ➔ Polymers
- Strength follows the same trend

CERAMICS:

★ NOTE: This is only when ceramics are loaded in **compression**

- **In tension**- ceramics are really weak
- Ceramics are brittle so the curve is linearly elastic until fracture
- Do not undergo plastic deformation at room temperature

POLYMER:

The curve dips down and then comes back up a little.

- MECHANICAL TESTING OF CERAMICS:
  - ➢ since ceramics are so strong and brittle it is very difficult to machine them into the nice tensile specimens
  - ➢ It is very challenging to align a ceramic sample exactly along the loading axis as it is likely to shatter during the machining operation.
  - ➢ Metals and polymers are relatively ductile, that is, they have high plastic strain to fracture so can use uniaxial tensile test

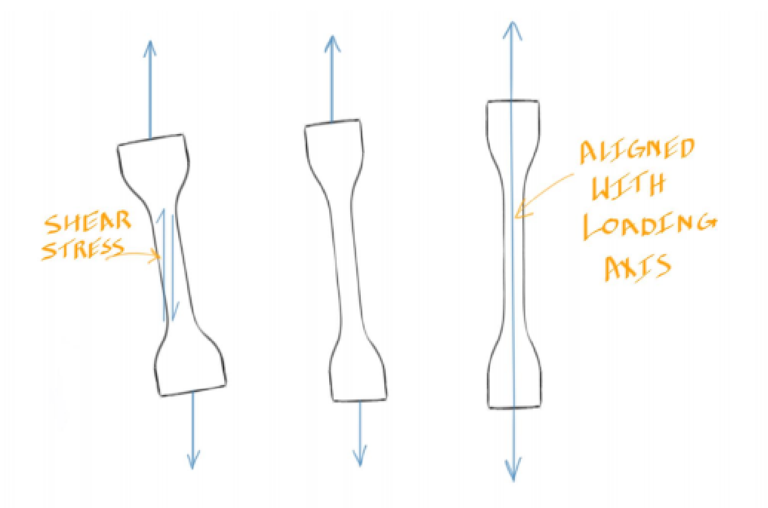


Figure 6: The challenge of aligning a sample with the tensile loading axis. Metals and polymers, even when loaded slightly off axis (exaggerated here) will deform and self-align with the loading axis. Ceramics fracture at a very low strain values while the sample is still subjected to significant shear stress.

BEND TEST(CERAMICS):

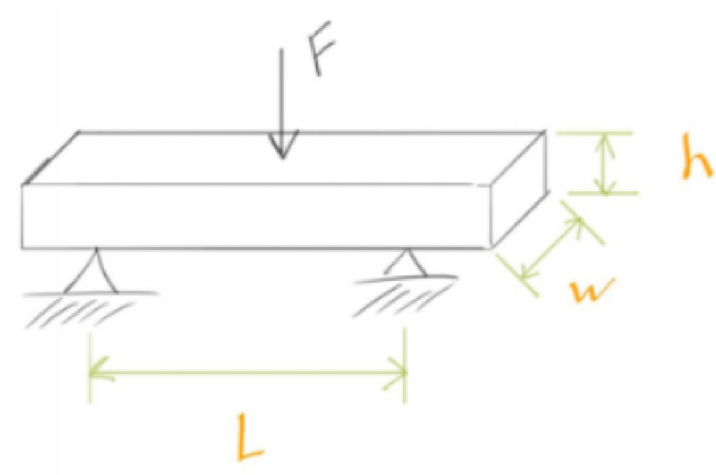


Figure 7: A cartoon sketch of a three point bend test on a rectangular cross-section beam.

- The **lower** surface of a beam loaded as shown will be in **tension**, while the **top** surface will be in **compression**.
- The stress state on the top and bottom surfaces actually have opposite signs.
- Since ceramics perform poorly in tension, the beam will fracture first on the lower surface, specifically near the middle, underneath where the load is applied.

$$\sigma = \frac{3FL}{2wh^2}$$

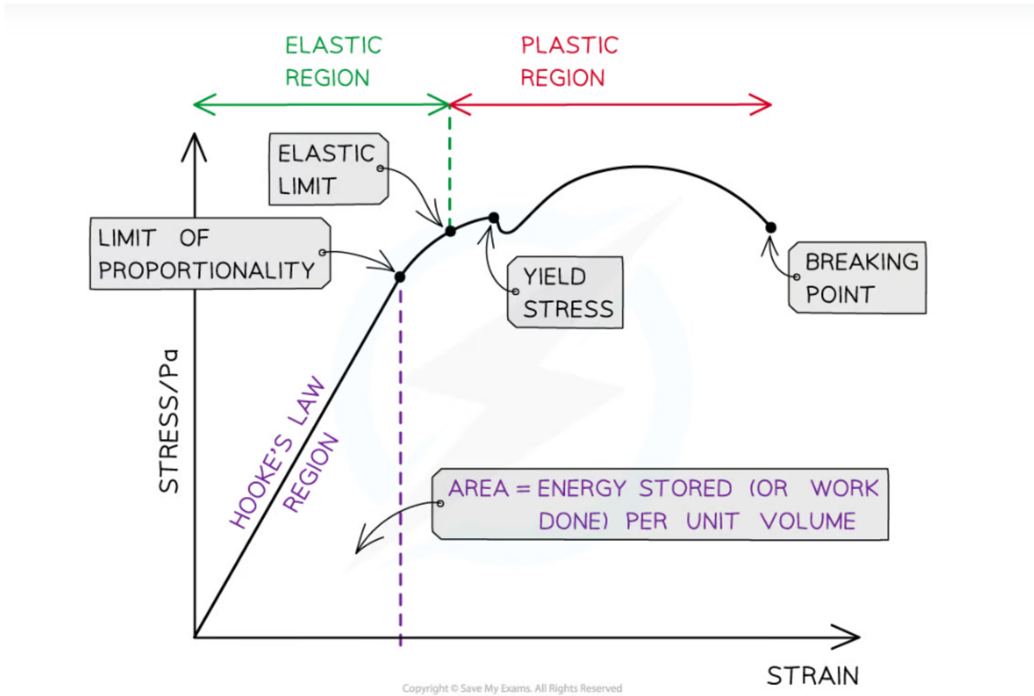
- BALANCING ON A THIN SHEET OF GLASS:

Why is tempered glass stronger than conventional glass?

- When the glass is at a high temperature the surfaces are rapidly cooled.
- There are 3-dimensional networks of bonds within the glass.
- At elevated temperatures the molecules are further apart
- When the surfaces are rapidly cooled some of this excess volume from the higher temperature is locked into the glass.
- The central portion of the glass however continues to cool more slowly
- The molecules are better able to organize and achieve a smaller final volume.
- The final piece of tempered glass, once it has cooled, contains residual stresses.
- The surfaces are being pushed together as the center tries to contract.
- The surfaces are therefore in residual compression, while the center is in residual tension.
- Since ceramics are strong in compression, the glass does not break

- Why does tempered glass break into small pieces if it does fracture?
  This is because the residual strain energy in the glass attempts to convert to surface energy in the form of new surfaces during fracture.

BOTTOM LINE:



- Yield Stress: The force per unit area at which the material extends plastically for no / a small increase in stress
- The elastic strain energy stored per unit volume is the area under the Hooke's Law (straight line) region of the graph
- Breaking point: The stress at this point is the breaking stress. This is the maximum stress a material can stand before it fractures
- Elastic region: The region of the graph up till the elastic limit. In this region, the material will return to its original shape when the applied force is removed
- Plastic region: The region of the graph after the elastic limit. In this region, the material has deformed permanently and will not return to its original shape when the applied force is removed