A107 Physics

Problem 13: The Material Matters!

6th Presentation

The problem

The golf ball that appears very hard, deforms and regains its shape when hit with a golf club.

Retrieved April, 2nd, 2010 from:
http://www.golfballtool.com/compression.htm

What do you recognize?

Retrieved April, 2nd, 2010 from:
http://www.golfballtool.com/compression.htm

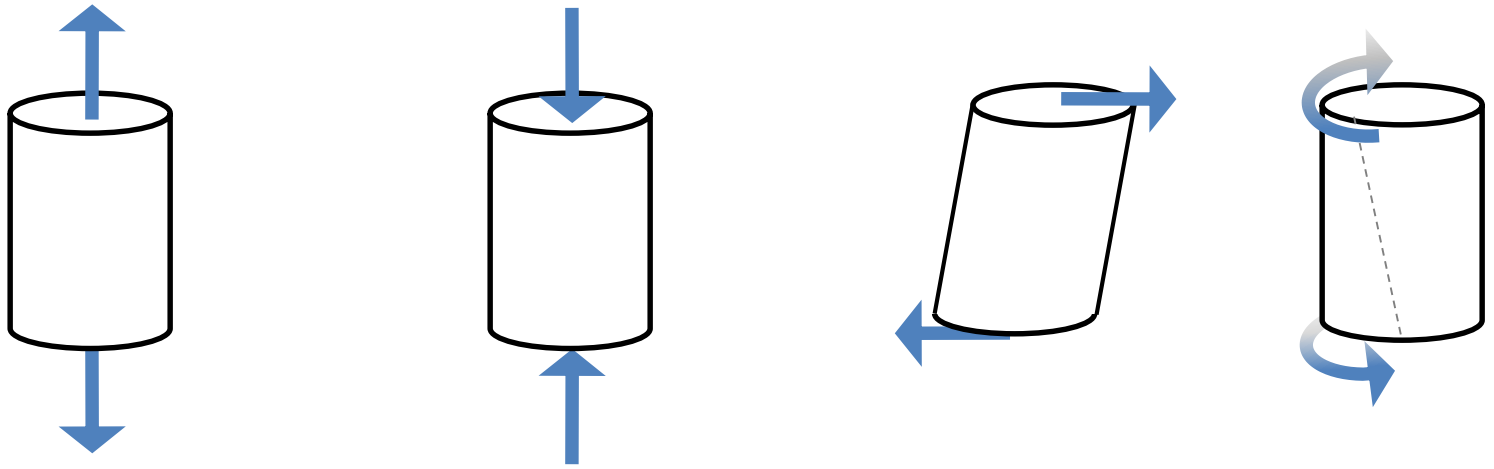
- Materials deform, regardless of how hard or strong they appear to be.
- Knowledge of a material's deformation characteristic provides useful information for its usage.

The Approach

- What are some ways to deform an object?
- How to measure the action of deformation?
- How to describe the deformation caused by a force using stress and strain?
- What is Modulus of elasticity and elastic limit?
- How to quantify the deformation using Young's modulus?
- How to identify the breaking stress for a given material and apply this to identify the breaking point for a given usage?

What are some ways to deform an object?

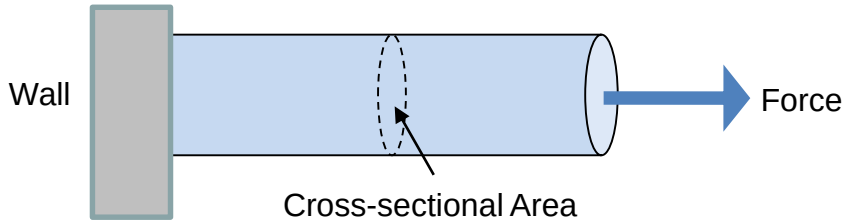
- An object may be deformed by pulling, pushing or twisting it.



- The different ways of deforming the object result in different outcomes.

How to measure the action of deformation?

- Any action that deforms an object is commonly defined in terms of **stress**.



Stress = Force acting per unit cross sectional area

$$\text{i.e. Stress (Pa or N/m}^2\text{)} = \frac{F(\text{in N})}{A(\text{in m}^2)}$$

F = applied force (unit: N)

A = cross-sectional area normal (perpendicular) to the applied force (unit: m^2)

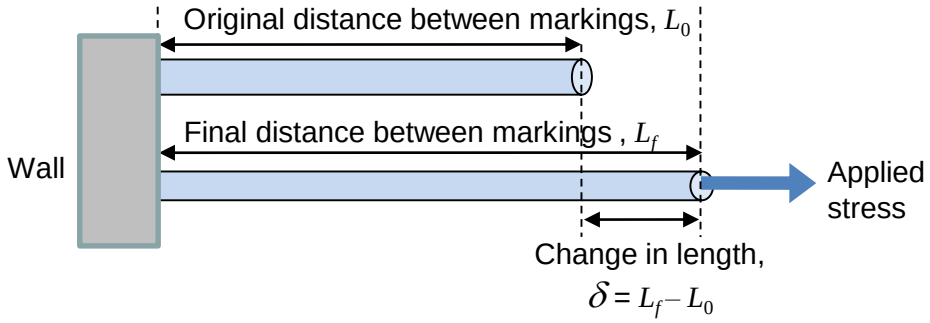
Units of stress: (Pa or N/m^2)

- Force and stress on a object can be positive or negative.
- **Forces:** Tensile force is positive and compressive force is negative
- **Stresses:** Tensile stress is positive and compressive stress is negative

How to describe the deformation caused by a force using stress and strain?

- For lengthwise deformation caused by tension and compression, we can measure it in terms of **strain**.

$$\text{Strain} = \frac{\text{change in length}}{\text{original length}} = \frac{Lf - L_o}{L_o} = \frac{\delta}{L_o}$$



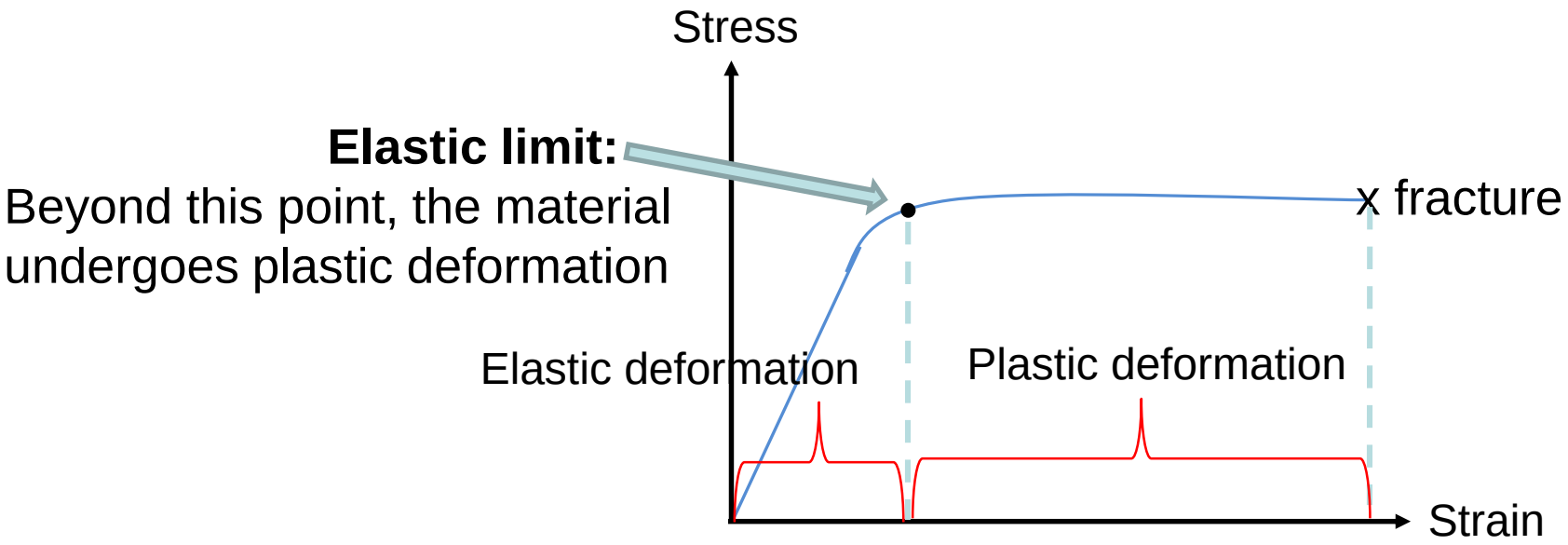
L_f = final length
L_0 = original length
δ = change in length

Strain does not have a unit

- Strain on a object can be positive or negative.
- Strain is positive when objects increase in length and negative when objects decrease in length.

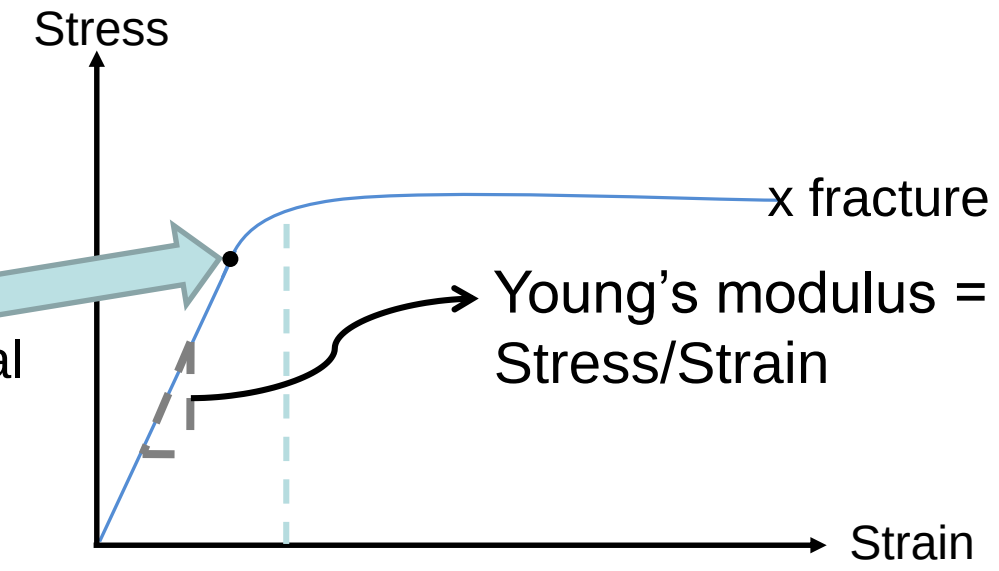
How to describe the deformation caused by a force using stress and strain?

- The stress-strain relationship describes a material's behaviour under different types of loading.
- Elastic behaviour: The material goes back to its original shape when the stress on it is removed.
- Plastic behaviour: The material does not go back to its original shape (it deforms permanently) when the stress on it is removed.



What is Modulus of elasticity and elastic limit?

- Young's modulus or Modulus of elasticity, E
  - Obtained from the slope of the stress-strain curve
  - Valid until proportional limit
  - Different materials have different values of Young's modulus



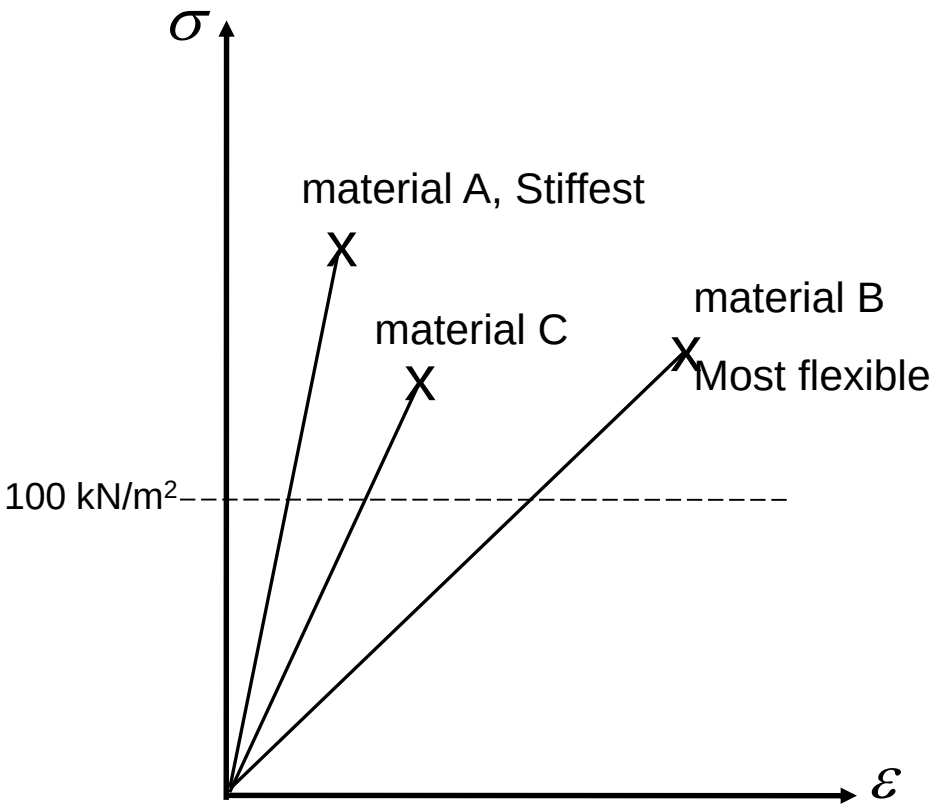
Proportional limit: Stress is proportional to strain up to this point.

Note: Young modulus is calculated from the linear portion of the stress-strain graph.

How to quantify the deformation using Young's modulus?

- Stiffness/Flexibility (Depends on the Young's modulus of the material)
- The higher the Young's modulus, the stiffer will be the material.
- A material with lower Young's modulus is more flexible than a material with higher Young's modulus.

How to quantify the deformation using Young's modulus?



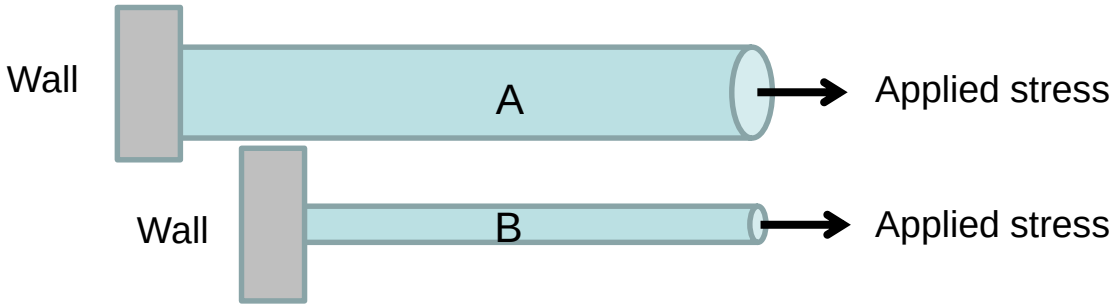
- Material A is the stiffest as its strain is the least for the same applied stress. This corresponds to the largest Young's modulus. It also has the highest strength as it fractures at the highest stress.
- Material B is the most flexible as its strain is the largest for the same applied stress. It corresponds to the lowest Young's modulus.

Learning points

- Mechanical force causes all solid materials to deform.
- Deformation caused by a force on an object can be described using stress and strain.
- Solid materials subjected to a force undergo either extension or compression respectively.
- Material behaviour can be described using a stress-strain relationship.
- When the stress-strain relationship for a material is linear, the gradient of the stress-strain graph represents the material's Young's modulus.
- Knowledge of a material's deformation characteristic provides useful information for its usage.

Discussion

Consider two metal bars, A and B made of the same material, with the different length and thickness. Both are subjected to the same amount of stress due to some tension force acting on them.



Will the strain on A be greater than, less than or the same as that on B? Explain your answer.