Chapter 6 Deformation of solids

6.1 Stress and strains

Candidates should be able to:

1 understand that deformation is caused by tensile or compressive forces (forces and deformations will be assumed to be in one dimension only)

2 understand and use the terms load, extension, compression and limit of proportionality

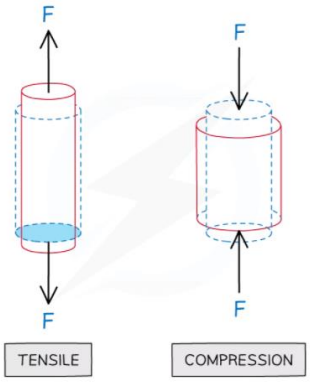
3 recall and use Hooke's law

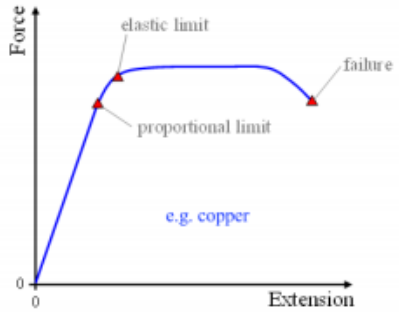
4 recall and use the formula for the spring constant $k = F / x$

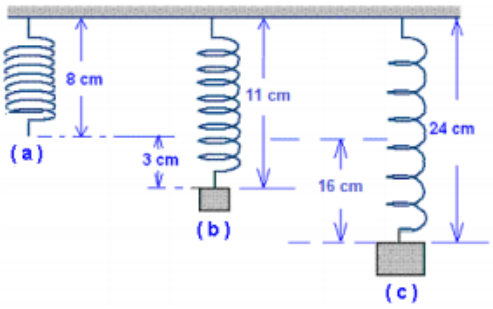
5 define and use the terms stress, strain and the Young modulus

6 describe an experiment to determine the Young modulus of a metal in the form of a wire

- Forces can deform an object.
- When an object is stretched by the force we say it is under a tensile load.
- When an object is compressed it is under compressive load.







- Recall when a tensile load is applied onto a spring, the spring will extend by x amount.
- Below is a revision of the terminology used in IGCSE/ SPM for the force-extension graph above.
- **Hooke's Law:** Springs extend in proportion to loads, as long as they are under their proportional limit.
- **Limit of proportionality:** Point and which load and extension are no longer proportional.
- **Elastic limit:** Point at which spring will not return to its original shape even after the load is removed.
- **Spring constant k:** The gradient of the graph is the spring constant which measures the stiffness of the spring in $\mathbf{Nm^{-1}}$.
- A material obeys Hooke's Law if its extension (x) is directly proportional to its applied load (F).

$$F = kx$$

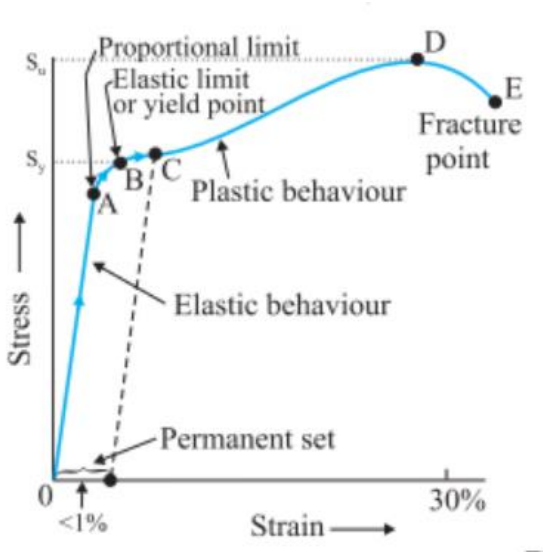
- If we normalize the tensile and compressive load with the area (divide F with A), we obtain the **stress** the object is under.

$$\sigma = \frac{F}{A}$$

- Likewise, if we normalize extension (x) with the original length of the object (L) we obtain its **strain** (ε).

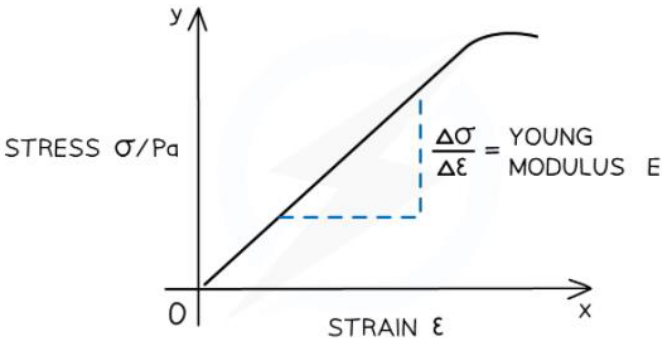
$$\varepsilon = \frac{x}{L}$$

- We can plot stress vs strain just like the way we did force vs extension

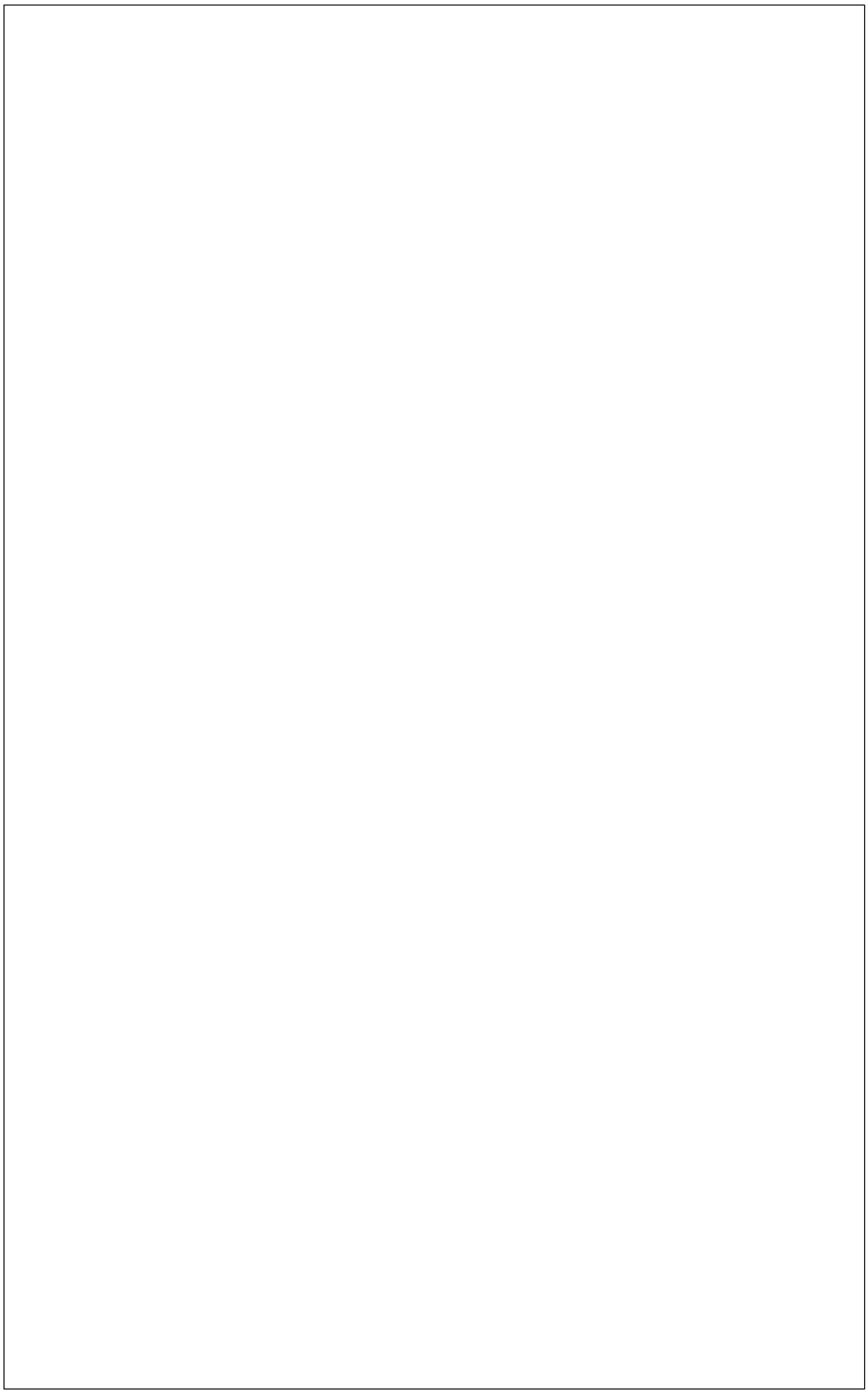


- Likewise we can find the slope of the linear part of the curve ($\frac{Stress}{Strain}$).
- The linear slope is called the Young's Modulus (E) of the object.
- E also measures the stiffness of the object.
- The SI unit is in **Pa**.

$$E = \frac{\sigma}{\varepsilon}$$



- A description of an experiment to find Young's Modulus.

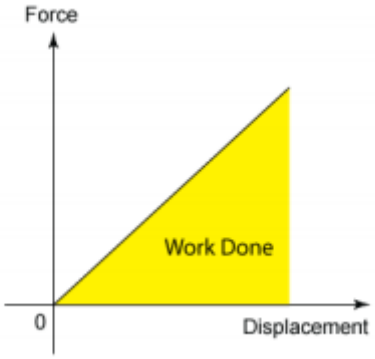


6.2 Elastic and plastic behaviour

Candidates should be able to:	
1	understand and use the terms elastic deformation, plastic deformation and elastic limit
2	understand that the area under the force–extension graph represents the work done
3	determine the elastic potential energy of a material deformed within its limit of proportionality from the area under the force–extension graph
4	recall and use $E_p = \frac{1}{2}Fx = \frac{1}{2}kx^2$ for a material deformed within its limit of proportionality

- **Elastic deformation** is the deformation that occurs before the elastic limit.
- If you removed the load before this point, the object will remove to its original shape.
- **Plastic deformation** is the deformation that occurs after the elastic limit.
- Load removal will not restore the object to its original shape.
- Recall that the **area** under a force-extension graph represents the **work done** to deform the material.
- The work done is equal to the **elastic potential energy** stored in the object (think spring).
- For an object that is deformed **within the limit of proportionality (still linear)**, the EPE can be found from

$$EPE = \frac{1}{2}Fx$$



or

$$EPE = \frac{1}{2}kx^2$$