6 Deformation of solids – Part 1

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
deformation	形变			
extension	伸长量			
Hooke's law	胡克定律			
spring constant	劲度系数			
limit of proportionality	比例极限			
elastic	弹性			
plastic	塑性			
Stress	应力			
strain	应变			
Young modulus	杨氏模量			
elastic potential energy	弹性势能			

Recall

At IGCSE you stretched springs. Bring this with you:

- When you stretch or squash a solid you cause **deformation** 形变.
- The **extension** 伸长量 is how much longer a spring becomes when you pull it.
- You met **Hooke's law** 胡克定律: the extension is proportional to the force, up to a point.

At AS we write this exactly and extend it to any material with stress, strain and the Young modulus.

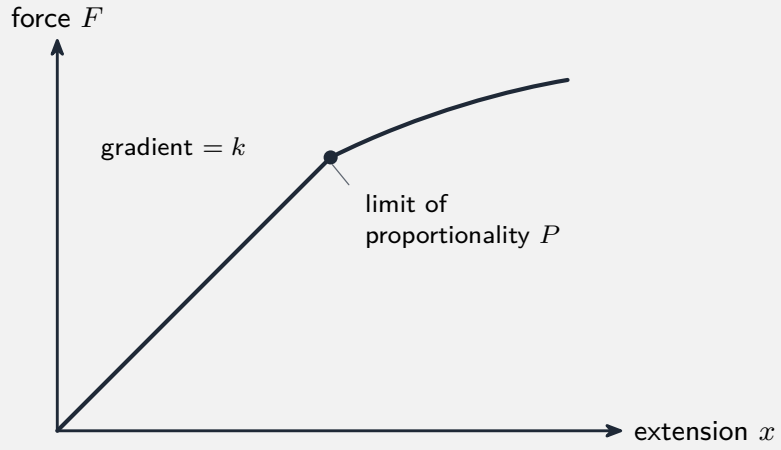
New ideas

1 Hooke's law

For a spring, force and extension are proportional:

$$F = kx,$$

where k is the **spring constant** 劲度系数 (in N m^{-1}) and x is the extension. This holds only up to the **limit of proportionality** 比例极限.



Below the **elastic** 弹性 limit a material springs back to its shape; beyond it the change is **plastic** 塑性 (permanent).

Worked example. A spring needs 6.0 N to stretch it 0.15 m: $k = \dfrac{F}{x} = \dfrac{6.0}{0.15} = 40$ N m^{-1}.

2 Stress, strain and the Young modulus

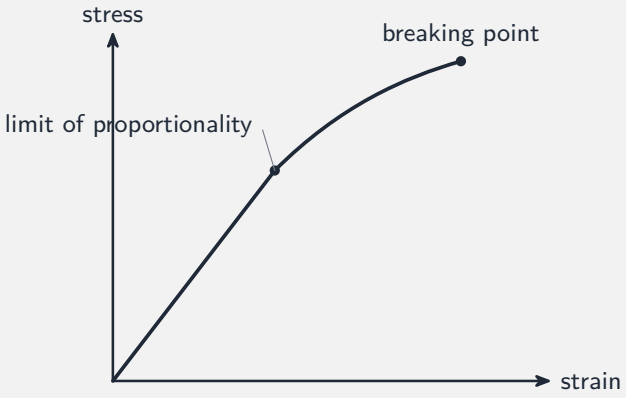
For a wire of cross-sectional area A and original length L stretched by x:

$$\text{stress } \sigma = \frac{F}{A}, \qquad \text{strain } \varepsilon = \frac{x}{L}.$$

Stress 应力 has units Pa; **strain** 应变 is just a ratio (no unit). Their ratio is the **Young modulus** 杨氏模量, a fixed number for each material:

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

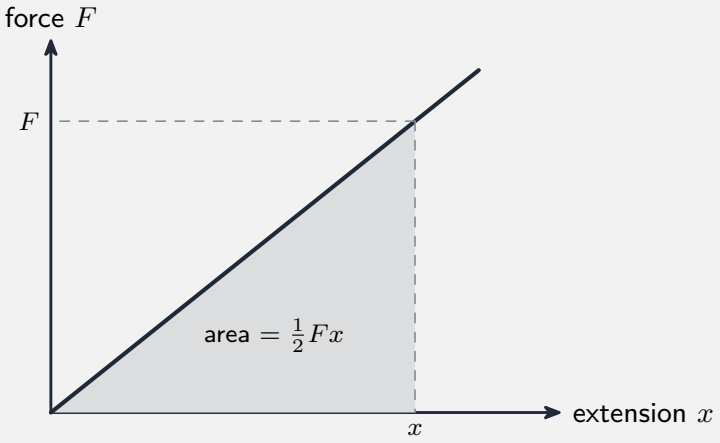
Worked example. A wire ($A = 5.0\times10^{-7}$ m^2, $L = 2.0$ m) stretches 1.0 mm under 50 N: $\sigma = \dfrac{50}{5.0\times10^{-7}} = 1.0\times10^{8}$ Pa, $\varepsilon = \dfrac{1.0\times10^{-3}}{2.0} = 5.0\times10^{-4}$, so $E = \dfrac{1.0\times10^{8}}{5.0\times10^{-4}} = 2.0\times10^{11}$ Pa.



Watch out: the Young modulus is a property of the *material*, not the wire —a thicker or longer wire of the same metal has the same E.

3 Elastic potential energy

The energy stored in a stretched spring is the area under its force–extension line — the **elastic potential energy** 弹性势能:



$$E = \tfrac{1}{2}Fx = \tfrac{1}{2}kx^2.$$

Practice

6.1 A spring has spring constant 25 N m^{-1}. Find the force needed to stretch it 0.20 m.[2]

6.2 Explain the difference between elastic and plastic behaviour. [2]

6.3 A wire of cross-sectional area 4.0×10^{-7} m^2 carries a load of 32 N. Find the stress. [2]

6.4 A 2.5 m wire stretches by 2.0 mm. Find the strain. [1]

6.5 Using the stress from 6.3 and strain from 6.4, find the Young modulus. [2]

6.6 Find the elastic potential energy stored in the spring of 6.1 when stretched 0.20 m. [2]

6.7 Challenge. Two wires are of the same material and thickness, but one is twice as long. Under the same pulling force, explain which one stretches more. [2]