6 Deformation of solids – Part 2

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)		
Series	串联			
Parallel	并联			
elastic limit	弹性极限			
pulley	滑轮			
diameter	直径			
micrometer	螺旋测微器			

Recall

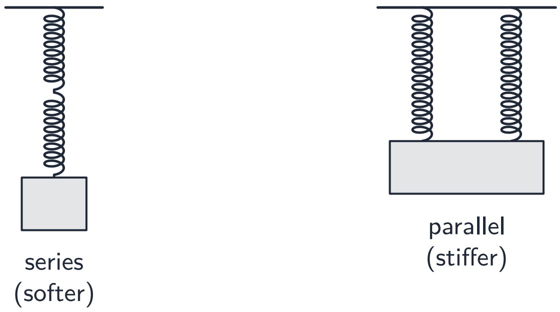
In **Part 1** you used Hooke's law ($F = kx$), stress, strain, the Young modulus, and the energy stored in a spring ($\frac{1}{2}kx^2$). Part 2 adds combining springs, what happens past the elastic limit, and the experiment to measure the Young modulus.

New ideas

Read these first. Each idea has a short worked example. Then do the Practice.

■ 1 Springs in series and parallel

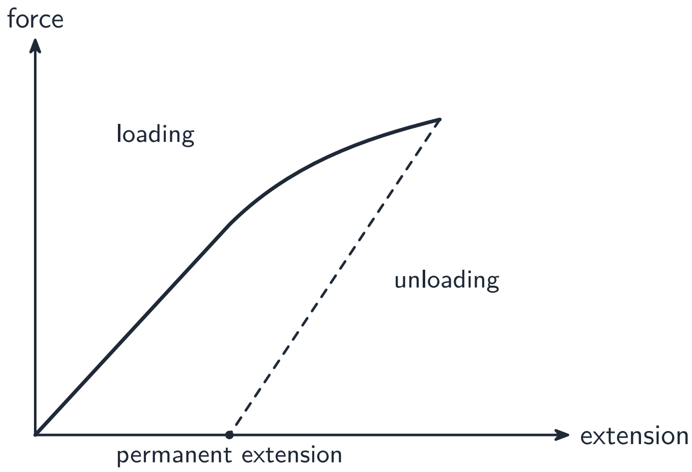
- **Series** 串联 (one below the other): the same load passes through both and the extensions add, so $\dfrac{1}{k_{\text{total}}} = \dfrac{1}{k_1} + \dfrac{1}{k_2}$ — a *softer* spring.
- **Parallel** 并联 (side by side): they share the load and stretch the same, so $k_{\text{total}} = k_1 + k_2$ — a *stiffer* spring.



Worked example. Two springs, each 20 N m^{-1}: in series $\frac{1}{k} = \frac{1}{20} + \frac{1}{20}$ so $k = 10$ N m^{-1}; in parallel $k = 20 + 20 = 40$ N m^{-1}.

■ 2 Beyond the elastic limit

Up to the limit of proportionality the force–extension line is straight. A little further the material is still **elastic** (springs back) until the **elastic limit** 弹性极限. Past that point it becomes **plastic** — when you remove the load it does **not** return to its first length; a permanent stretch is left.

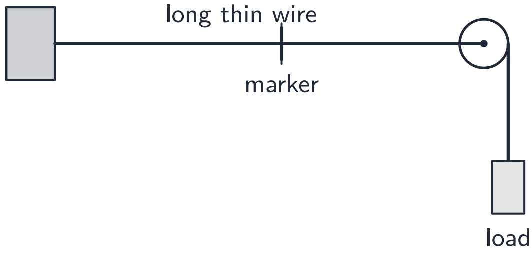


Worked example. Stretched a little, a wire springs back to its first length (elastic); pulled past its elastic limit and released, it stays — say — 2 mm longer, a permanent (plastic) stretch.

■ 3 Measuring the Young modulus

Use a long, thin wire fixed at one end and run over a **pulley** 滑轮:

1. measure the original length L_0 with a metre rule;
2. measure the **diameter** 直径 d at several places with a **micrometer** 螺旋测微器 and average it; then $A = \pi d^2/4$;
3. add loads one at a time and record the extension x;
4. plot F against x; the straight-line gradient is EA/L_0, so $E = \text{gradient} \times L_0/A$.



Worked example. If the F–x graph has gradient 9000 N m^{-1} for a wire of $L_0 = 2.0$ m and $A = 1.0 \times 10^{-7}$ m^2: $E = \text{gradient} \times \dfrac{L_0}{A} = 9000 \times \dfrac{2.0}{1.0 \times 10^{-7}} = 1.8 \times 10^{11}$ Pa.

Watch out: the area uses d^2, so a small error in the diameter has a *doubled* effect — measure d in several places and average.

Practice

6.1 Two springs each of spring constant 30 N m^{-1} are joined. Find the combined spring constant (a) in series, (b) in parallel. [2]

6.2 A wire is stretched past its elastic limit and the load is then removed. State what happens to its length. [1]

6.3 A wire of length 2.0 m and area 3.0×10^{-7} m^2 stretches 0.60 mm under a load of 18 N. Find the Young modulus ($E = FL_0/Ax$). [2]

6.4 State why a long, thin wire is chosen for the Young-modulus experiment. [1]

6.5 A wire has diameter 0.40 mm. Find its cross-sectional area ($A = \pi d^2/4$). [2]

6.6 Explain *why* an error in measuring the wire's diameter affects the Young-modulus result *twice* as much as the same percentage error in its length. [2]