

6 Deformation of solids – Part 2

Name: _____ Class: _____ Date: _____

Vocabulary

Write each word three times.

English	Write it 3 times (English)		
Series	_____	_____	_____
Parallel	_____	_____	_____
elastic limit	_____	_____	_____
pulley	_____	_____	_____
diameter	_____	_____	_____
micrometer	_____	_____	_____

Recall

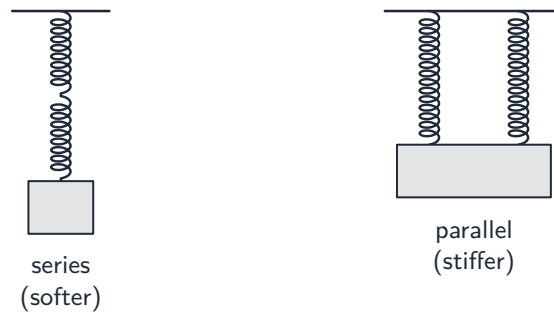
In **Part 1** you used Hooke's law ($F = kx$), stress, strain, the Young modulus, and the energy stored in a spring ($\frac{1}{2}kx^2$). Part 2 adds combining springs, what happens past the elastic limit, and the experiment to measure the Young modulus.

New ideas

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

■ 1 Springs in series and parallel

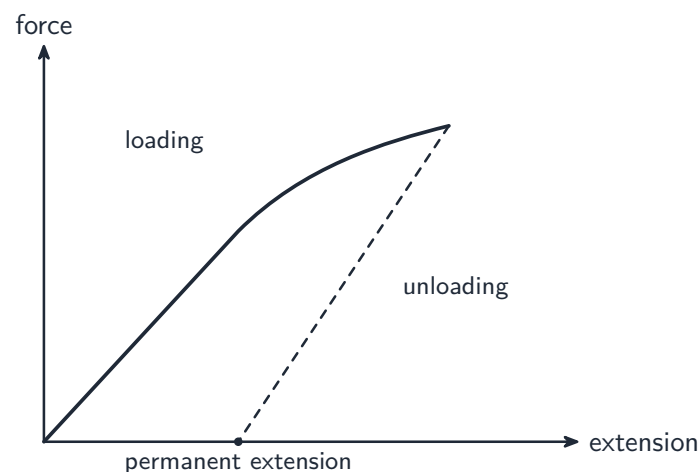
- **Series** (one below the other): the same load passes through both and the extensions add, so $\frac{1}{k_{\text{total}}} = \frac{1}{k_1} + \frac{1}{k_2}$ – a *softer* spring.
- **Parallel** (side by side): they share the load and stretch the same, so $k_{\text{total}} = k_1 + k_2$ – a *stiffer* spring.



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

■ 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**. Past that point it becomes **plastic** – when you remove the load it does **not** return to its first length; a permanent stretch is left.

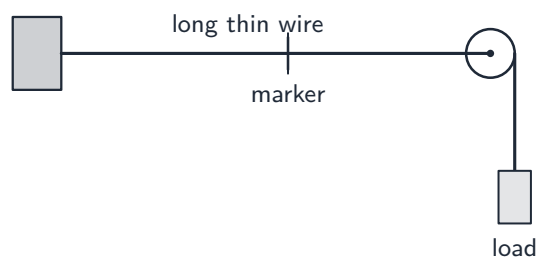


Worked example. Stretched a little, a wire springs back to its first length (elastic); pulled past its elastic limit and released, it stays – say – 2 mm longer, a permanent (plastic) stretch.

■ 3 Measuring the Young modulus

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

1. measure the original length L_0 with a metre rule;
2. measure the **diameter** d at several places with a **micrometer** 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 $L_0 = 2.0 \text{ m}$ and $A = 1.0 \times 10^{-7} \text{ m}^2$: $E = \text{gradient} \times \frac{L_0}{A} = 9000 \times \frac{2.0}{1.0 \times 10^{-7}} = 1.8 \times 10^{11} \text{ Pa}$.

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 $3.0 \times 10^{-7} \text{ m}^2$ 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]