Exercise walk-through

Elastic and plastic behaviour ▪ 6.2

eXercise

You must be able to

- use **elastic deformation**, **plastic deformation** and **elastic limit**
- find work done from the **area under a force–extension graph**
- use $E_P = \frac{1}{2}Fx = \frac{1}{2}kx^2$

Method — Elastic and plastic

- **Elastic deformation:** the object returns to its original length when the load is removed.
- **Plastic deformation:** a **permanent** extension remains after the load is removed (past the **elastic limit**).

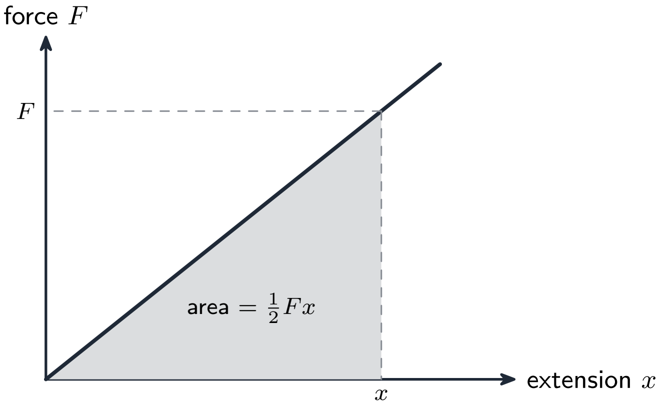
Method — Energy stored = area under the graph

The **work done** stretching a material is the **area under** its force–extension graph. For a Hooke's-law material this is a triangle:

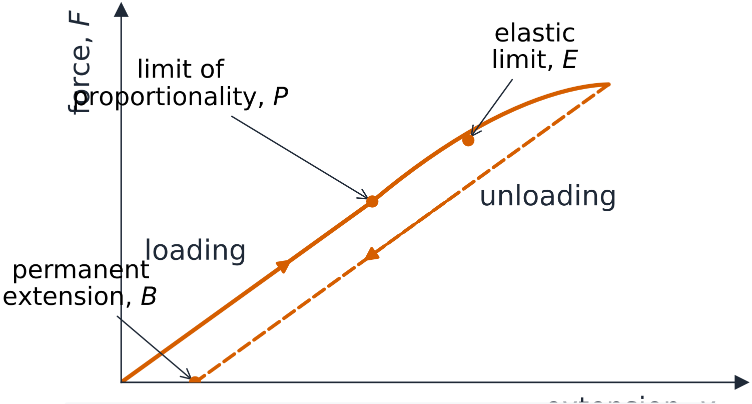
$$E_{\mathrm{P}} = \tfrac{1}{2}Fx = \tfrac{1}{2}kx^2 = \frac{F^2}{2k}.$$

Worked example. $k = 50$ N m^{-1}, $x = 0.20$ m: $E_{\mathrm{P}} = \frac{1}{2}(50)(0.20)^2 = 1.0$ J.

Method — Energy stored = area under the graph



Method — Energy stored = area under the graph



Hooke up to limit of proportionality · plastic beyond yield

Elastic and plastic behaviour on a force-extension graph

Method — Loading and unloading

Past the elastic limit, the **unloading** line is parallel to the first straight part but shifted right (a permanent extension). The area **between** the loading and unloading lines is energy turned into **thermal energy** in the material.

Practice 2.1 ▪ 2 marks

Define **elastic deformation** and **plastic deformation**.

Solution 2.1

Method: Elastic and plastic

Worked steps

Elastic — the object **returns** to its original length when the load is removed; **plastic** — a **permanent** extension remains B1 B1.

Practice 2.2 ▪ 1 mark

State what the **area under** a force–extension graph represents.

Solution 2.2

Method: Energy stored = area under the graph

Worked steps

The **work done** on the material (the elastic potential energy stored, within the elastic region) **B1**.

Practice 2.3 ▪ 2 marks

A spring of spring constant 50 N m^{-1} is stretched by 0.20 m. Find the **elastic potential energy** stored.

Solution 2.3

Method: Energy stored = area under the graph

Worked steps

$E_{\mathsf{P}} = \frac{1}{2}kx^2 = \frac{1}{2}(50)(0.20)^2 = 1.0$ J **M1** **A1**.

Practice 2.4 ▪ 1 mark

State what remains when a material stretched **past its elastic limit** has the load removed.

Solution 2.4

Method: Elastic and plastic

Worked steps

A **permanent extension** (the object does not return to its original length) B1.

Exam-style 3.1 ▪ 1 mark

The elastic potential energy in a spring of spring constant k stretched by x is:

A kx

B $\frac{1}{2}kx$

C $\frac{1}{2}kx^2$

D kx^2

Solution 3.1

Method: Loading and unloading

A kx

B $\frac{1}{2}kx$

C $\frac{1}{2}kx^2$ ✓

D kx^2

Worked steps

C — $\frac{1}{2}kx^2$.

Exam-style 3.2 ▪ 2 marks

A force of 8.0 N stretches a wire by 2.0 mm, within its limit of proportionality. Calculate the **elastic potential energy** stored.

Solution 3.2

Method: Energy stored $=$ area under the graph

Worked steps

$E_\mathrm{P} = \frac{1}{2}Fx = \frac{1}{2}(8.0)(2.0 \times 10^{-3}) = 8.0 \times 10^{-3}$ J **M1** **A1**.

Exam-style 3.3 ▪ 2 marks

Explain the difference between **elastic** and **plastic** deformation.

Solution 3.3

Worked steps

Elastic deformation is **reversible** — the material returns to its original shape **B1**; plastic deformation is **permanent** — it stays deformed after the load is removed **B1**.

Exam-style 3.4 ▪ 3 marks

A material is loaded **past** its elastic limit and then unloaded. Explain why the loading and unloading lines differ, and state what the **area between** them represents.

Solution 3.4

Method: Loading and unloading

Worked steps

Past the elastic limit some deformation is permanent, so on unloading the line returns to a **non-zero** (permanent) extension, parallel to but shifted from the loading line **B1** **B1**; the area between them is the **energy transferred to thermal energy** in the material **B1**.