6.2 Elastic and plastic behaviour

Name: ______________ Class: __________ Date: ____________ **Total: 14 marks**

Objective

Build the skills to answer exam questions on **elastic and plastic behaviour** —deformation types and elastic potential energy.

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 $E_\mathrm{P} = \frac{1}{2}Fx = \frac{1}{2}kx^2$

1 Worked examples

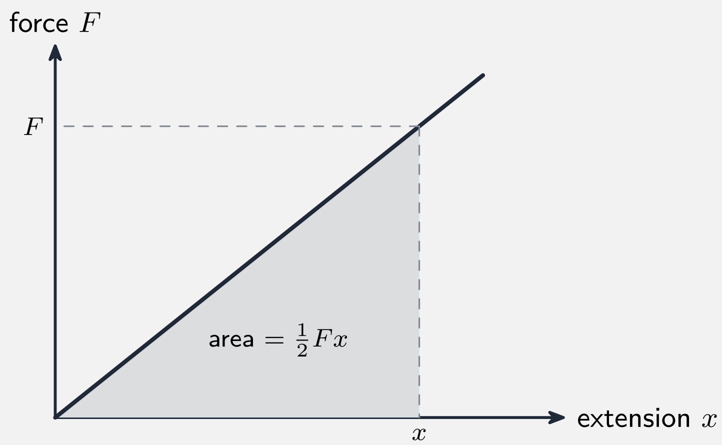
Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

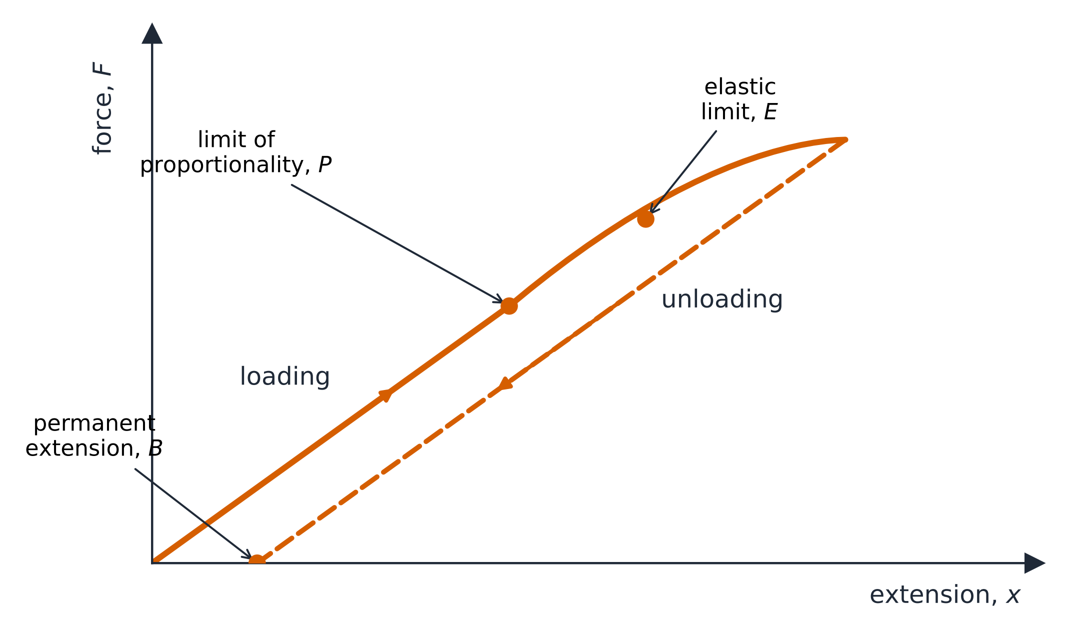
Elastic and plastic

- **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**).

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:





Elastic and plastic behaviour on a force-extension graph

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

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

■ 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.

2 Practice

Now apply the methods above.

2.1 Define **elastic deformation** and **plastic deformation**. [2]

2.2 State what the **area under** a force–extension graph represents. [1]

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

potential energy stored. [2]

2.4 State what remains when a material stretched **past its elastic limit** has the load removed. [1]

3 Exam-style questions

3.1 The elastic potential energy in a spring of spring constant k stretched by x is: [1]

- **A** kx
- **B** $\frac{1}{2}kx$
- **C** $\frac{1}{2}kx^2$
- **D** kx^2

3.2 A force of 8.0 N stretches a wire by 2.0 mm, within its limit of proportionality. Calculate the **elastic potential energy** stored. [2]

3.3 Explain the difference between **elastic** and **plastic** deformation. [2]

3.4 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. [3]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **6.2 Elastic and plastic behaviour** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/11 J25 —Q22 (elastic potential energy)
- 9702/22 J25 —Q5 (force–extension and energy)
- 9702/24 J25 —Q3 (elastic PE from a graph)
- 9702/11 N25 —Q20 (elastic and plastic behaviour)

Solutions

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

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

2.3 $E_{\mathrm{P}} = \frac{1}{2}kx^2 = \frac{1}{2}(50)(0.20)^2 = 1.0$ J.

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

3.1 **C** —$\frac{1}{2}kx^2$.

3.2 $E_{\mathrm{P}} = \frac{1}{2}Fx = \frac{1}{2}(8.0)(2.0 \times 10^{-3}) = 8.0 \times 10^{-3}$ J.

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

3.4 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; the area between them is the **energy transferred to thermal energy** in the material.