6.2 Elastic and plastic behaviour

Name: _____ Class: _____ Date: _____ **Total: 14 marks**

KEY WORDS elastic potential energy • thermal energy • elastic • extension • limit of proportionality

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 Key knowledge and 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.

Key knowledge: use these earlier methods

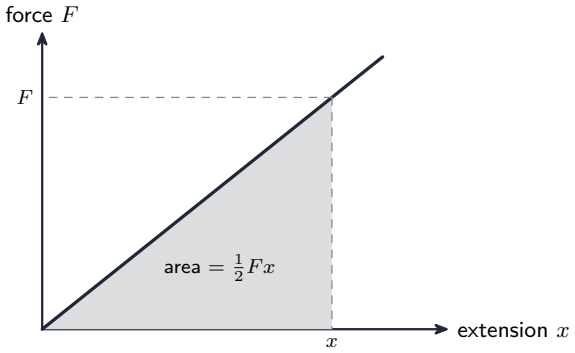
- **Force and extension**: $F = kx$ applies within the limit of proportionality. Extension is stretched length minus original length.
- **Stored elastic energy**: area under the force–extension graph. A straight line through the origin gives $E = \frac{1}{2}Fx = \frac{1}{2}kx^2$; unloading energy is the area under the unloading line.
- **Stress and strain**: $\sigma = F/A$ and $\epsilon = x/L$; Young modulus $E_Y = \sigma/\epsilon = FL/(Ax)$. For a wire of diameter d, $A = \pi d^2/4$.
- Use the gradient only over the straight region, and convert mm to m before substitution.

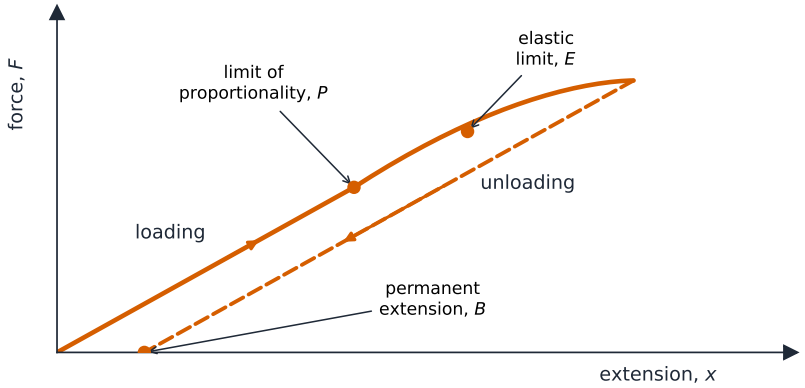
Elastic and plastic

- **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:





Hooke up to limit of proportionality · plastic beyond yield

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

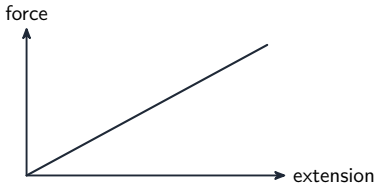
2 Practice

Now apply the methods above.

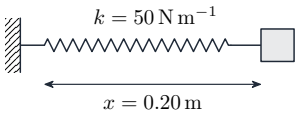
2.1 Define **elastic deformation** and **plastic deformation**. [2]

elastic plastic

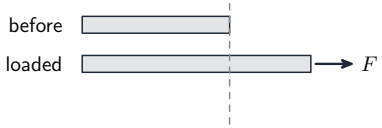
2.2 State what the **area under** a force–extension graph represents. [1]



2.3 A spring of spring constant 50 N m^{-1} is stretched by 0.20 m. Find the **elastic potential energy** stored. [2]



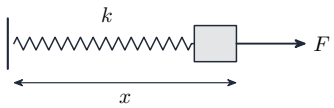
2.4 State what remains when a material stretched **past its elastic limit** has the load removed. [1]



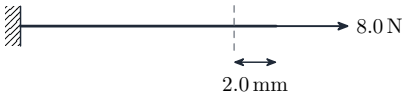
3 Exam-style questions

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

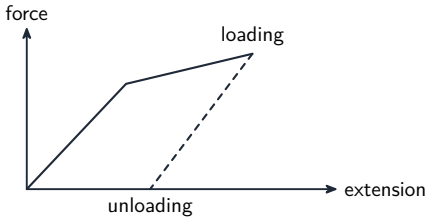
- **A** kx
- **B** $\frac{1}{2}kx$
- **C** $\frac{1}{2}kx^2$
- **D** kx^2



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]

elastic plastic

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]