

6.2 Elastic and plastic behaviour

Name: _____ Class: _____ Date: _____

Total: 14 marks

KEY WORDS elastic potential energy 弹性势能 • thermal energy 热能 • elastic 弹性 • extension 伸长量
• limit of proportionality 比例极限

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 $E_P = \frac{1}{2}Fx = \frac{1}{2}kx^2$

1 Worked examples

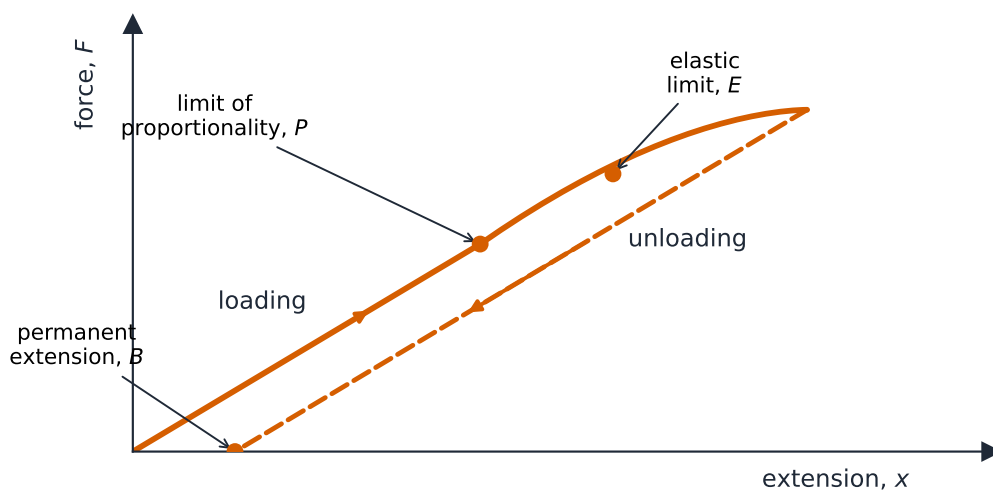
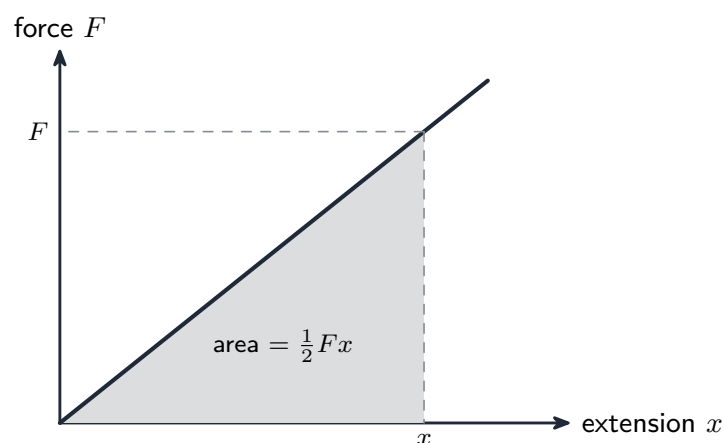
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ 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:



Hooke up to limit of proportionality · plastic beyond yield

Elastic and plastic behaviour on a force-extension graph

$$E_P = \frac{1}{2}Fx = \frac{1}{2}kx^2 = \frac{F^2}{2k}.$$

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

■ 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]

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 $E_P = \frac{1}{2}kx^2 = \frac{1}{2}(50)(0.20)^2 = 1.0 \text{ J}.$

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

3.1 $C = \frac{1}{2}kx^2.$

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

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.