

Exercise walk-through

6.2

Elastic and plastic behaviour

A-Level Physics

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

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**

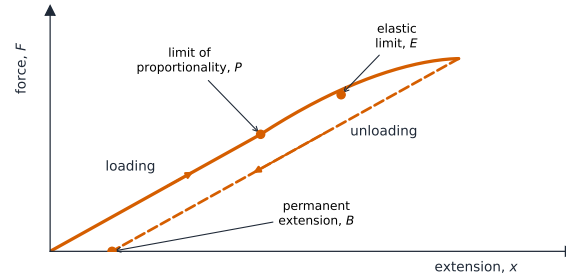
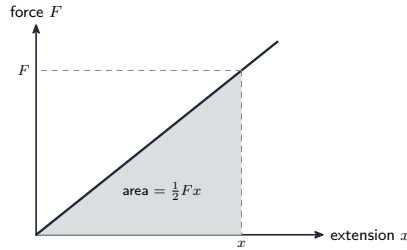
- **Force and extension:** $F = kx$ applies within the limit of proportionality. Extension is stretched length minus original length.
- **Stored elastic energy:** area under the force–extension graph. A straight line through the origin gives $E = \frac{1}{2}Fx = \frac{1}{2}kx^2$; unloading energy is 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

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

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

■ **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.

Exercises 2.1·2.2

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

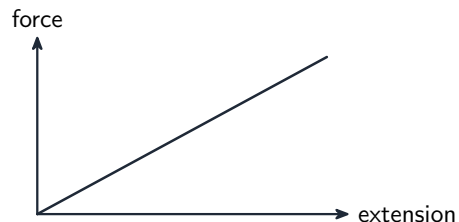
[2]

elastic

plastic

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

[1]



Exercises 2.1·2.2

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

[2]

elastic

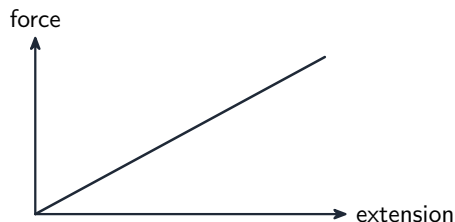
plastic

2.1

- **elastic**: the object **returns** to its original length when the load is removed
 - **plastic**: a **permanent** extension remains
-

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

[1]

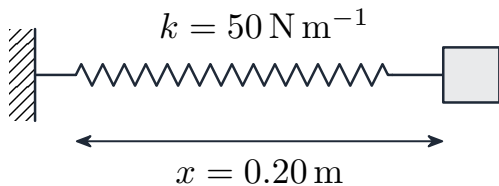


2.2

- the **work done** on the material (elastic potential energy stored, within the elastic region)

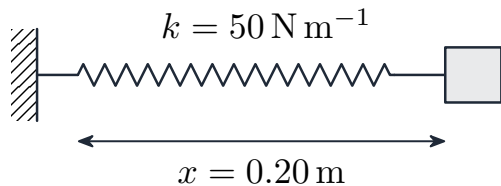
Exercise 2.3

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



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2.3

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

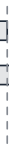
$$E_P = \frac{1}{2}kx^2 = \frac{1}{2}(50 \text{ N m}^{-1})(0.20 \text{ m})^2 = \mathbf{1.0 \text{ J}}$$

Exercises 2.4·3.1

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

before 

loaded 



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

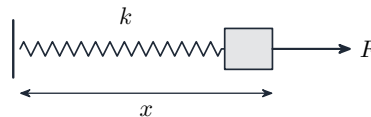
☐

A kx

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

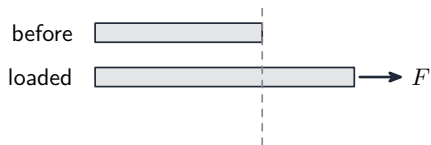
C $\frac{1}{2}kx^2$

D kx^2



Exercises 2.4·3.1

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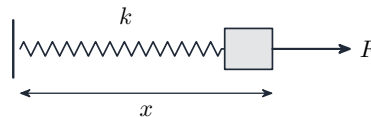


2.4

- a **permanent extension** (it does not return to its original length)

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

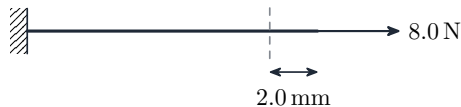


3.1 C

- elastic potential energy stored in a spring is $\frac{1}{2}kx^2$

Exercises 3.2-3.3

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]



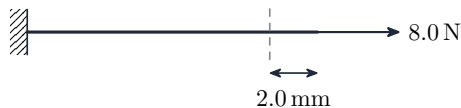
3.3 Explain the difference between **elastic** and **plastic** deformation. [2]

elastic

plastic

Exercises 3.2-3.3

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]



3.2

- $E_P = \frac{1}{2}Fx$ (because $F = kx$)

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

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

elastic

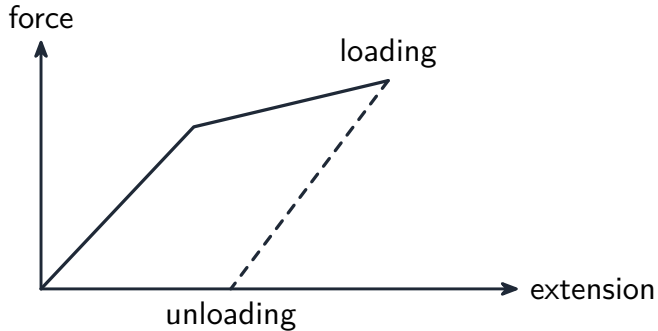
plastic

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

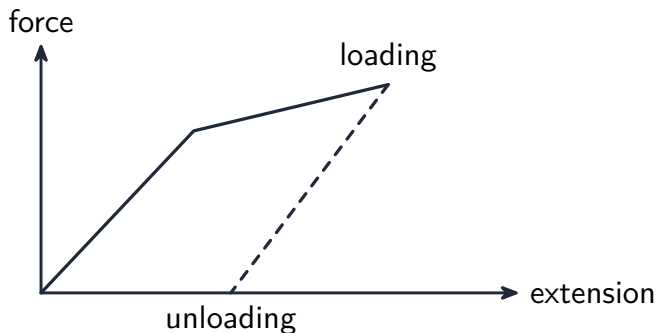
Exercise 3.4

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]



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3.4

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