Week 14

A-Level Physics

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

6. Deformation of solids

Starter Quiz · 课前小测

A-Level Physics Name: ____________________ Score: ______

1. A load of 12 N stretches a spring by 0.040 m. What is the spring constant?

   ______________ N/m

2. Past the elastic limit, an object returns to its original length when the load is removed.

   ☐ True ☐ False

3. Within Hooke's law, doubling the load doubles the extension.

   ☐ True ☐ False

4. The energy stored in a stretched material equals the _____ under the force–extension graph.

   ____

5. The straight-line law $F = kx$ holds only up to the:

   ☐ limit of proportionality

   ☐ breaking point

   ☐ plastic region

   ☐ centre of gravity

6. A spring of constant 200 $\frac{\text{N}}{\text{m}}$ is stretched by 0.10 m. How much elastic PE is stored?

   ______________ J

7. A complete statement of Hooke's law contains which of these? Select **all** that apply.

   ☐ the extension is directly proportional to the applied force

   ☐ provided the limit of proportionality is not exceeded

   ☐ the constant of proportionality is the spring constant

   ☐ provided the material is a metal

   Tick every correct option.

8. Two springs are pulled with the **same force**. The softer spring (smaller k) stores:

   ☐ more energy

   ☐ less energy

   ☐ the same energy

   ☐ no energy

9. Two identical springs (each constant k) are d in series. The combined spring constant is:

- ☐ $\frac{1}{2}k$
- ☐ $2k$
- ☐ k
- ☐ $4k$

10. When a stretched spring is released onto a mass, its elastic PE becomes ______ energy.

    ____

A-Level Physics

1. **300 N/m**

   $k = \frac{F}{x} = \frac{12}{0.040} = 300\ \frac{\text{N}}{\text{m}}.$

2. **False**

   No — in the plastic region a permanent extension stays after unloading.

3. **True**

   Yes — $F = kx$ is a straight-line (proportional) relationship, so x scales with F.

4. **area**

   Work done = area under the force–extension graph (a triangle for a Hooke material).

5. **limit of proportionality**

   Beyond the limit of proportionality the F–x graph curves and $F = kx$ no longer applies.

6. **1 J**

   $E_\text{P} = \frac{1}{2}kx^2 = \frac{1}{2} \times 200 \times 0.10^2 = 1.0$ J.

7. **the extension is directly proportional to the applied force; provided the limit of proportionality is not exceeded**

   The condition is part of the law, not an extra. Rubber obeys nothing like it, and a metal stops obeying it beyond the straight line.

8. **more energy**

   Same F, smaller k → larger extension x → larger area $\frac{1}{2}Fx$, so more energy is stored.

9. **$\frac{1}{2}k$**

   $\frac{1}{k_\text{total}} = \frac{1}{k} + \frac{1}{k} = \frac{2}{k}$, so $k_\text{total} = \frac{1}{2}k$ — the pair stretches more easily.

10. **kinetic**

    Set $\frac{1}{2}kx^2 = \frac{1}{2}mv^2$ (plus mgh if it rises) to find the speed.

A-LEVEL PHYSICS • EXERCISE SHEET

6.1 Stress and strain

Name: ______________ Class: __________ Date: ____________ **Total: 27 marks**

KEY WORDS young modulus 杨氏模量 • spring constant 劲度系数 • stress 应力 • extension 伸长量 • strain 应变

Objective

Build the skills to answer exam questions on **stress and strain** — Hooke's law, the spring constant, and the Young modulus.

You must be able to:

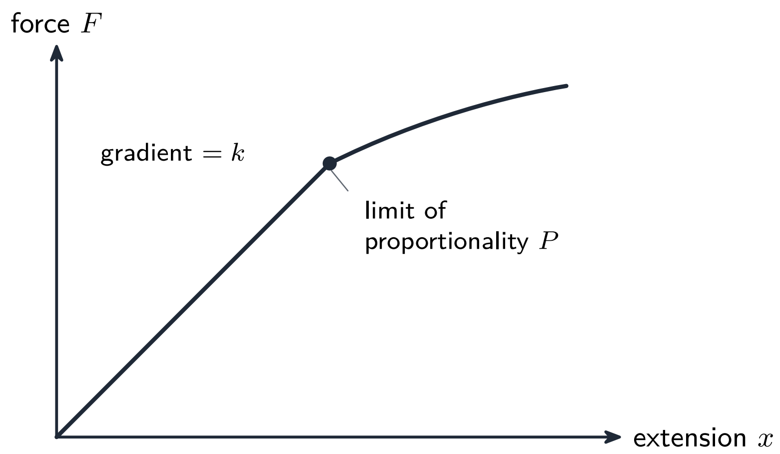
- use **Hooke's law** $F = kx$ and find k from a graph
- define and use **stress**, **strain** and the **Young modulus**
- describe the experiment to measure the **Young modulus** of a wire

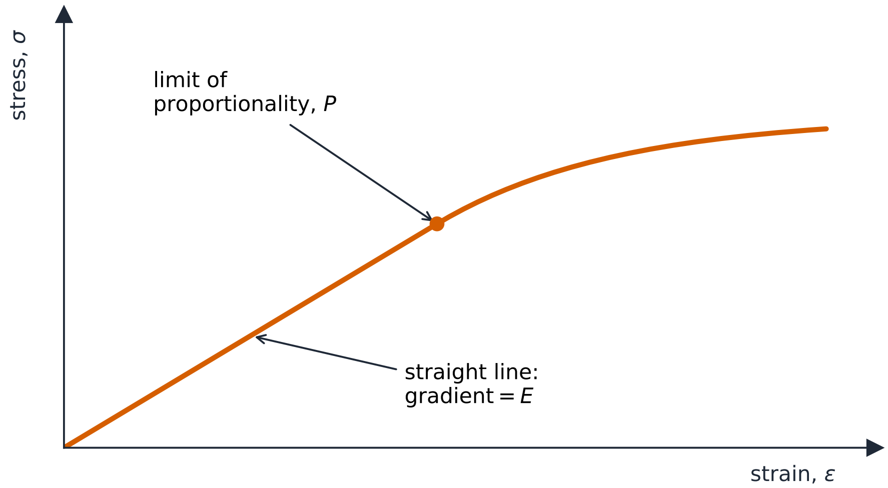
1 Worked examples

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.

Hooke's law and spring constant

For small loads, **extension is proportional to load**: $F = kx$, so the **spring constant** $k = F/x$ (unit N m^{-1}). On a force–extension graph the **gradient is** k in the straight region, up to the **limit of proportionality**:





$E = \frac{\sigma}{\varepsilon} = \frac{F/A}{\Delta L/L}$ (Hooke's law region only)

The stress-strain graph for a material

Worked example. A spring extends 4.0 cm under a 2.0 N load: $k = F/x = 2.0/0.040 = 50$ N m^{-1}.

■ **Stress, strain, Young modulus**

$$\text{stress } \sigma = \frac{F}{A} \text{ (Pa)}, \qquad \text{strain } \varepsilon = \frac{x}{L} \text{ (no unit)}, \qquad E = \frac{\sigma}{\varepsilon} \text{ (Pa)}.$$

Young modulus experiment (wire): measure the original length L and diameter ($\rightarrow$ area A); add known loads; measure the extension x (e.g. with a marker and ruler/travelling microscope); plot stress against strain; E is the gradient of the straight part.

2 Practice

Now apply the methods above.

2.1 State **Hooke's law**. [1]

2.2 A spring extends 4.0 cm when a 2.0 N load is hung from it. Find the **spring constant**. [2]

2.3 Define **stress** and **strain**. [2]

2.4 State the unit of the **Young modulus**. [1]

3 Exam-style questions

3.1 In the straight region, the **gradient** of a force–extension graph gives the: [1]

- **A** Young modulus
- **B** spring constant
- **C** stress
- **D** strain

3.2 A wire of length 2.0 m and cross-sectional area 1.0×10^{-6} m^2 stretches by 1.0 mm under a 100 N load. Calculate (a) the stress, (b) the strain, (c) the Young modulus. [4]

3.3 Describe an experiment to measure the **Young modulus** of a metal wire. [4]

3.4 Explain what is meant by the **limit of proportionality**. [1]

3.5 A wire has length L, cross-sectional area A, Young modulus E and resistivity ρ.

(a) **Define** the **Young modulus** of a material. [1]

(b) **State** an expression, in terms of some or all of L, A, E and ρ, for the resistance R_0 of the wire. [1]

(c) **Show that** the spring constant k_0 of the wire is given by $k_0 = \dfrac{EA}{L}$. [2]

(d) The wire is now stretched by a steadily increasing force F, staying within its limit of proportionality. In the space below, **sketch** two graphs: the variation with F of the **resistance** R of the wire, and the variation with F of its **spring constant** k. **Label** each graph and its axes. [3]

(e) A copper wire of diameter 1.6 mm has a resistance of 0.034 Ω. The resistivity of copper is 1.7×10^{-8} Ω m. **Show that** the length of the wire is about 3.8 m. [2]

(f) The Young modulus of copper is 1.3×10^{11} Pa. **Determine** the spring constant of this wire. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- the **extension is proportional to the load** (up to the limit of proportionality)

2.2

- $k = F/x$

$$k = \frac{2.0\ \text{N}}{0.040\ \text{m}} = \mathbf{50}\ \text{N m}^{\mathbf{-1}}$$

2.3

- **stress** = force per unit cross-sectional area (F/A)
- **strain** = extension per unit original length (x/L)

2.4

- **pascal**, Pa (N m^{-2})

3.1 B

- in the straight region $F = kx$, so the gradient is $F/x = k$, the **spring constant**
- **A** is the trap: the Young modulus is the gradient of a **stress–strain** graph

3.2

(a)

$$\sigma = \frac{F}{A} = \frac{100\ \text{N}}{1.0 \times 10^{-6}\ \text{m}^2} = \mathbf{1.0} \times \mathbf{10^8}\ \text{Pa}$$

(b)

$$\varepsilon = \frac{x}{L} = \frac{1.0 \times 10^{-3}\ \text{m}}{2.0\ \text{m}} = \mathbf{5.0} \times \mathbf{10^{-4}}$$

(c)

$$E = \frac{\sigma}{\varepsilon} = \frac{1.0 \times 10^8\ \text{Pa}}{5.0 \times 10^{-4}} = \mathbf{2.0} \times \mathbf{10^{11}}\ \text{Pa}$$

3.3 any four of

- measure original length L and diameter ($\rightarrow$ area A)
- hang the wire and add known loads
- measure the extension with a marker against a fixed scale
- plot stress against strain; E is the gradient of the straight part

3.4

- the point beyond which **extension is no longer proportional to load** (the F–x line stops being straight)

3.5

(a) the **ratio of stress to strain** (below the limit of proportionality)

(b) $R_0 = \rho L/A$

(c) $k = F/x$ and $E = (F/A)/(x/L) = FL/(Ax)$

- so $E = k_0 L/A \Rightarrow k_0 = EA/L$

(d)

- **resistance**: straight line of **positive** gradient from $(0, R_0)$ — stretching makes the wire longer and thinner
- **spring constant**: **horizontal** line from $(0, k_0)$ — k is constant below the limit of proportionality
- both axes labelled, each line labelled

(e) diameter 1.6 mm $\Rightarrow$ radius 0.80 mm

$$A = \pi r^2 = \pi(0.80 \times 10^{-3}\ \text{m})^2 = 2.01 \times 10^{-6}\ \text{m}^2$$

$$L = \frac{R_0 A}{\rho} = \frac{(0.034\ \Omega)(2.01 \times 10^{-6}\ \text{m}^2)}{1.7 \times 10^{-8}\ \Omega\,\text{m}} \approx \mathbf{3.8}\ \text{m}$$

(f) use $L = 3.8$ m from (e)

$$k_0 = \frac{EA}{L} = \frac{(1.3 \times 10^{11}\ \text{Pa})(2.01 \times 10^{-6}\ \text{m}^2)}{3.8\ \text{m}} = \mathbf{6.9 \times 10^4}\ \text{N m}^{-1}$$

21 A wire has an unstretched length of 2.00 m.

A stress of 1.6×10^5 Pa is applied to the wire, and the new length of the wire is 2.10 m.

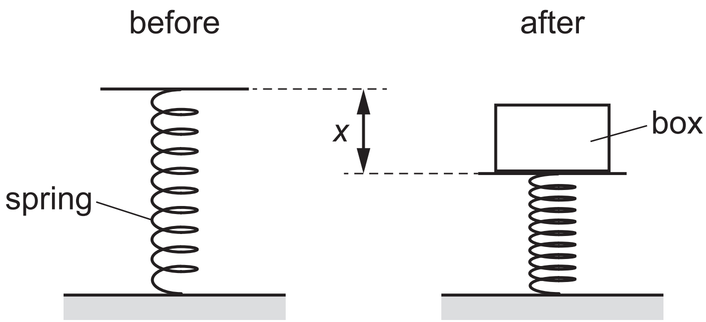
The wire obeys Hooke's law.

What is the Young modulus of the wire?

A 8.0×10^3 Pa **B** 7.8×10^4 Pa **C** 1.5×10^5 Pa **D** 3.2×10^6 Pa

A-Level Physics: **w25 12**

21 A platform is supported by a spring. A box is placed onto the platform. The diagram shows the spring before and after the box is placed onto it.



What is the term for the quantity marked as *x*?

A compression

B load

C strain

D stress

22 A copper wire has length 1.7 m and uniform diameter 0.64 mm.

The Young modulus of copper is 1.2×10^{11} Pa.

What is the spring constant of the wire?

A $2.3 \times 10^4\,\mathrm{N\,m^{-1}}$

B $9.1 \times 10^4\,\mathrm{N\,m^{-1}}$

C $4.5 \times 10^7\,\mathrm{N\,m^{-1}}$

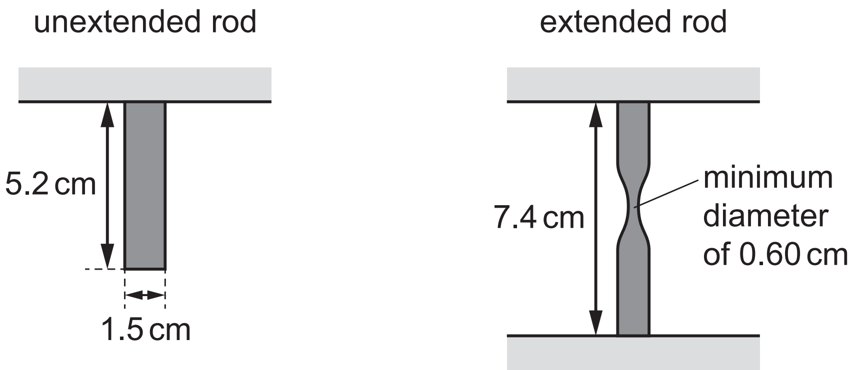
D $7.1 \times 10^7\,\mathrm{N\,m^{-1}}$

20 A cylindrical steel rod with negligible weight has a diameter of 1.5 cm and a length of 5.2 cm.

The rod is firmly attached at the top end.

The rod is firmly attached to a machine at the other end that applies a constant force of 363 N to the rod.

This causes the rod to extend to a length of 7.4 cm and to have a minimum diameter of 0.60 cm in the position shown.



What is the maximum stress acting on the steel rod when the length is 7.4 cm?

A 2.1×10^{6} Pa **B** 3.2×10^{6} Pa **C** 5.7×10^{6} Pa **D** 1.3×10^{7} Pa

23 Which expression gives the formula for the spring constant?

A Fx **B** $2Fx^2$ **C** $\dfrac{F}{x}$ **D** $\dfrac{F}{x^2}$

3 A wire has length L and cross-sectional area A. The wire is made from a metal that has Young modulus E and resistivity ρ.

(a) Define the Young modulus of a material.

....

.... [1]

(b) **(i)** State an expression, in terms of some or all of L, A, E and ρ, for the resistance R_0 of the wire.

R_0 = ... [1]

(ii) Show that the spring constant k_0 of the wire is given by

$$k_0 = \frac{EA}{L}.$$

[2]

(c) The wire is stretched, within the limit of proportionality, by a tensile force F. Assume that any changes in the cross-sectional area of the wire are negligible.

(i) On Fig. 3.1, sketch the variation with F of the resistance R of the wire.

Fig. 3.1

[1]

(ii) On Fig. 3.2, sketch the variation with F of the spring constant k of the wire.

Fig. 3.2

[1]

(d) Copper has a resistivity of $1.8 \times 10^{-8}\,\Omega\,\text{m}$ and a Young modulus of $1.3 \times 10^{11}\,\text{Pa}$.

A copper wire of diameter 1.6 mm has a resistance of $0.034\,\Omega$.

(i) Show that the length of the wire is 3.8 m.

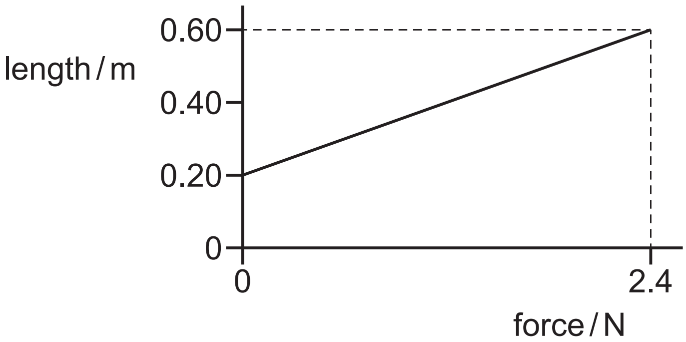
[1]

(ii) Use the equation in **(b)(ii)** to determine the spring constant of the wire.

spring constant = ... $\text{N}\,\text{m}^{-1}$ [2]

[Total: 9]

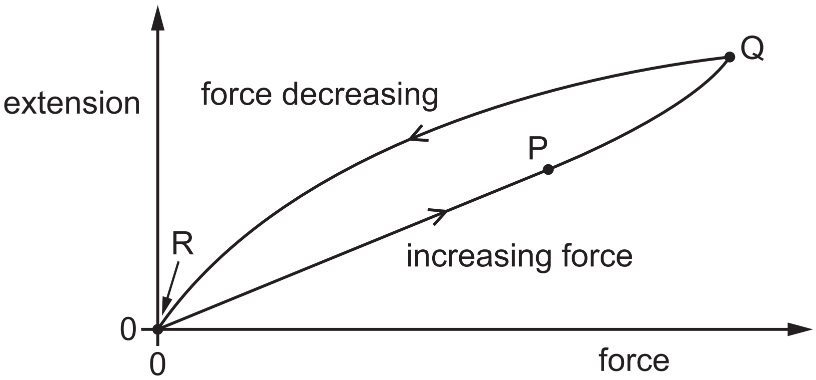
21 A student investigates a spring. The variation of the length of the spring with the force applied to the spring is shown.



What is the spring constant of the spring?

A $0.17\,\mathrm{N\,m^{-1}}$ **B** $0.25\,\mathrm{N\,m^{-1}}$ **C** $4.0\,\mathrm{N\,m^{-1}}$ **D** $6.0\,\mathrm{N\,m^{-1}}$

22 The graph shows the variation with force of the extension of a wire.



The force is gradually increased to a maximum at Q and then gradually decreased to zero at R.

Which statement is correct?

A Along the line PQ, the wire obeys Hooke's law.

B Along the line RP, the spring constant is equal to $\dfrac{\text{extension}}{\text{force}}$.

C The wire has elastic deformation at point Q.

D The work done in stretching the wire to P is equal to (force × extension) at point P.

23 A uniform metal wire of length L and diameter d has spring constant k.

What is the Young modulus of the metal?

A $\dfrac{\pi d^2}{4kL}$ **B** $\dfrac{\pi d^2}{kL}$ **C** $\dfrac{kL}{\pi d^2}$ **D** $\dfrac{4kL}{\pi d^2}$

21 A student has a copper wire and a steel wire with equal lengths and cross-sectional areas.

The student hangs identical loads on the two wires.

The extensions of the two wires are different.

The student calculates the stress, strain and Young modulus of each wire.

Which row identifies with a tick (✓) the calculated values that are equal for both wires?

	stress	strain	Young modulus
A	✓		
B		✓	
C		✓	✓
D	✓		✓

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

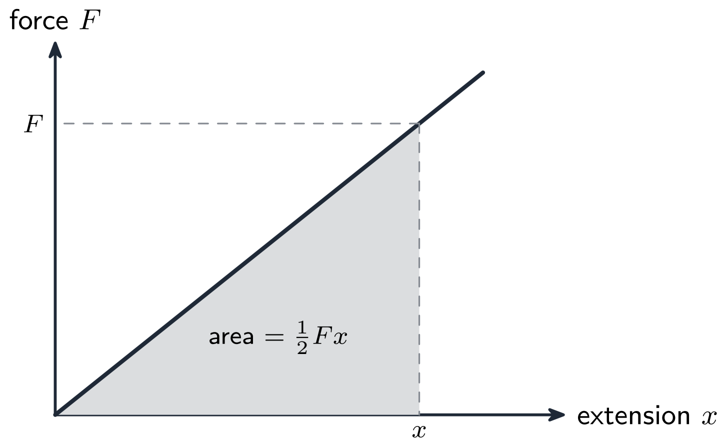
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

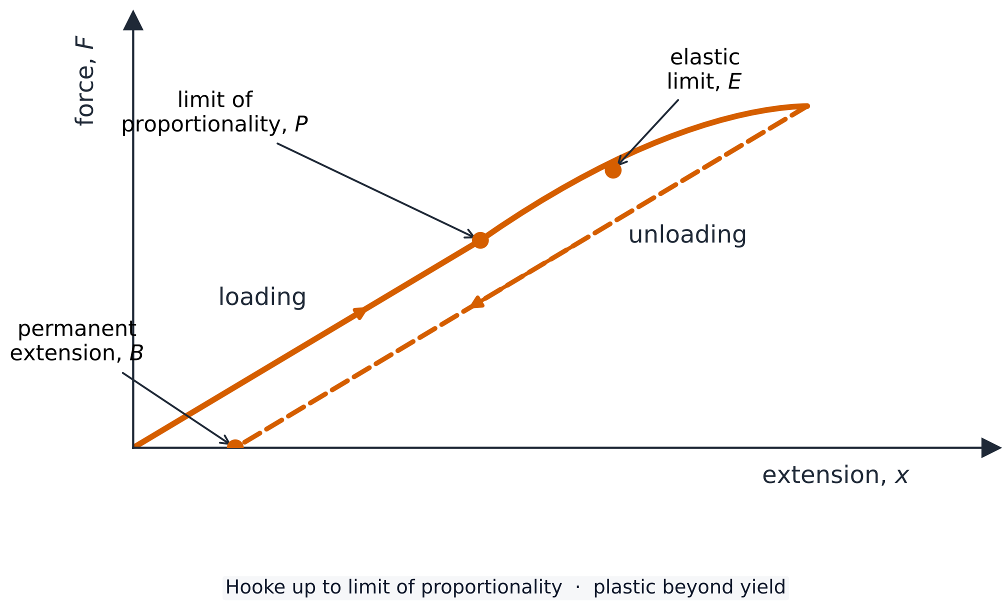
Elastic and plastic

- **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:





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

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

Each answer shows the steps, then the **result**.

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 (elastic potential energy stored, within the elastic region)

2.3

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

$$E_\mathrm{P} = \tfrac{1}{2}(50\ \mathrm{N\ m^{-1}})(0.20\ \mathrm{m})^2 = \mathbf{1.0}\ \mathrm{J}$$

2.4

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

3.1 C

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

3.2

- $E_\mathrm{P} = \frac{1}{2}Fx$ (because $F = kx$)

$$E_\mathrm{P} = \tfrac{1}{2}(8.0\ \mathrm{N})(2.0 \times 10^{-3}\ \mathrm{m}) = \mathbf{8.0 \times 10^{-3}}\ \mathrm{J}$$

3.3

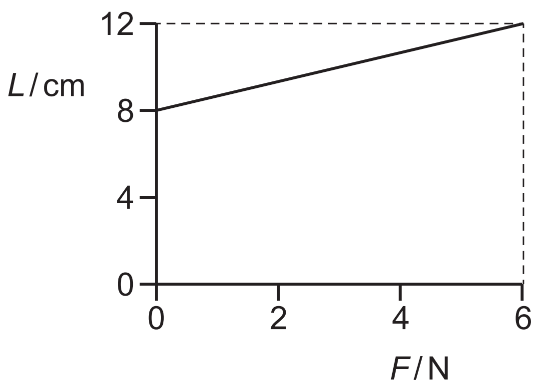
- elastic deformation is **reversible** — the material returns to its original shape
- plastic deformation is **permanent** — it stays deformed after the load is removed

3.4

- past the elastic limit some deformation is permanent, so 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

20 A spring is fixed at one end. The length L of the spring is increased by applying a tensile force F to the other end.

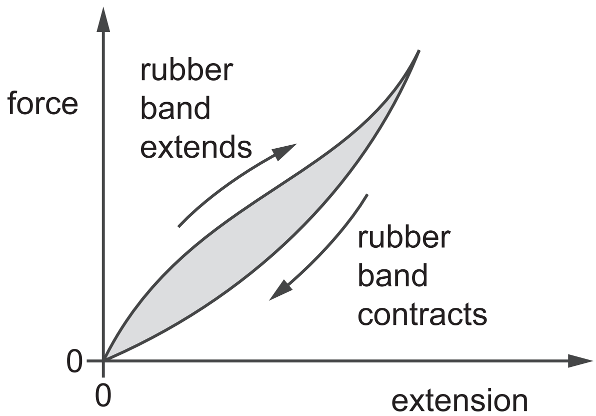
The graph shows the variation of L with F.



What is the elastic potential energy of the spring when F is 6.0 N?

A 0.12 J **B** 0.24 J **C** 0.36 J **D** 0.60 J

23 The diagram shows a force–extension graph for a rubber band as the band is extended and then the stretching force is decreased to zero.



What can be deduced from the graph?

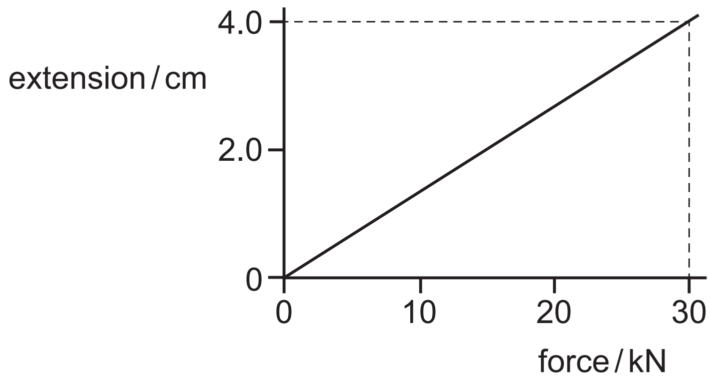
A The rubber band does **not** return to its original length when the force is decreased to zero.

B The rubber band obeys Hooke's law for the extensions shown.

C The rubber band remains elastic for the extensions shown.

D The shaded area represents the work done in extending the rubber band.

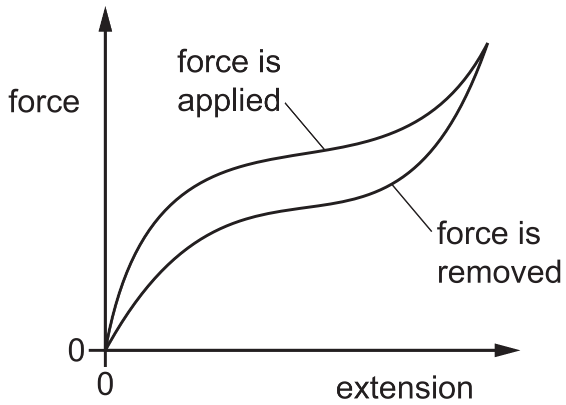
23 The graph shows how the extension of a spring varies with the force used to stretch it.



What is the elastic potential energy of the spring when the extension is 4.0 cm?

A 60 J **B** 120 J **C** 600 J **D** 1200 J

21 The graph shows the variation in extension with force for a sample of rubber.



The top line shows the variation in extension as a force is applied.

The bottom line shows the variation in extension as the force is removed.

What is represented by the area between the two lines?

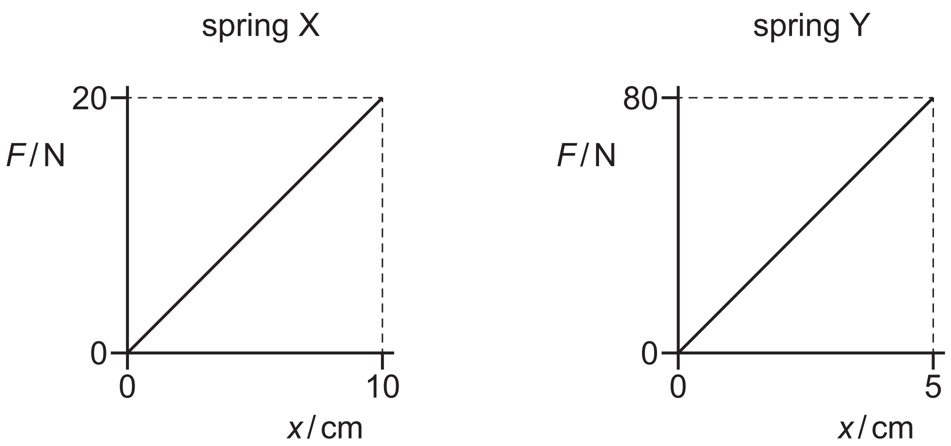
A the work done as the force is applied

B the work done as the force is applied minus the work done as the force is removed

C the work done as the force is removed

D the work done as the force is removed plus the work done as the force is applied

22 Two springs X and Y stretch elastically. The graphs show the variation with extension x of the force F applied to each spring.



Which statement is correct?

A When each spring is given the same extension, the energy stored in Y is 4 times the energy stored in X.

B When each spring is given the same extension, the energy stored in Y is 8 times the energy stored in X.

C When the same force is applied to each spring, the energy stored in Y is 4 times the energy stored in X.

D When the same force is applied to each spring, the energy stored in Y is 8 times the energy stored in X.

23 Which phrase describes the strain at the elastic limit on a stress–strain graph?

A the maximum strain below which Hooke's law is obeyed

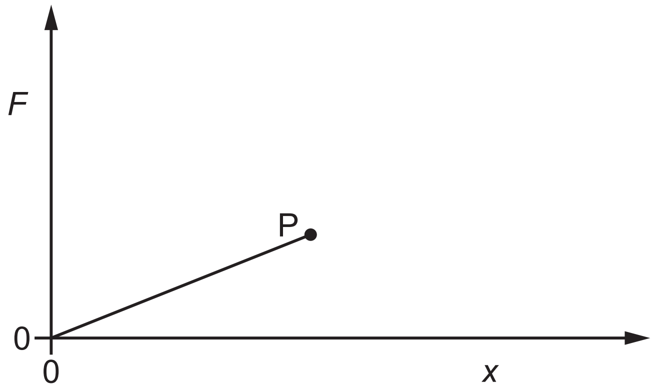
B the maximum strain below which the deformation is plastic

C the minimum strain above which Hooke's law is obeyed

D the minimum strain above which the deformation is plastic

23 A wire of length L is stretched to determine its limit of proportionality.

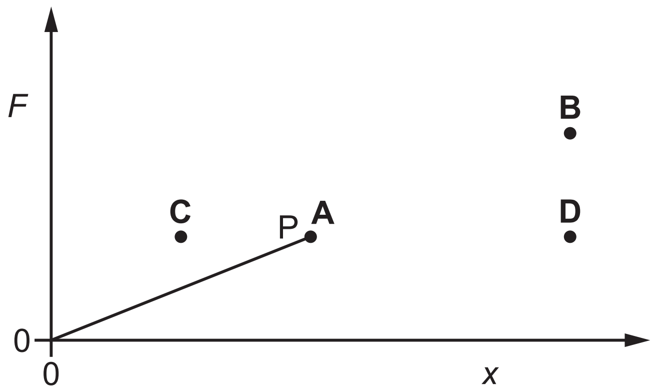
The graph shows the variation of the extension x with the force F applied to the wire.



The limit of proportionality is shown by point P on the graph.

The experiment is repeated with another wire of length $2L$ but of the same material and same diameter as the first wire.

Which point on the graph shows the limit of proportionality for the new wire?



18 A spring of unstretched length 0.10 m is suspended vertically from a support.

A weight of 2.0 N is attached to the bottom of the spring and its length increases to 0.15 m.

An additional weight of 4.0 N is then added to the bottom of the spring.

The spring obeys Hooke's law.

How much extra elastic potential energy is stored in the spring due to the addition of the 4.0 N weight?

A 0.067 J **B** 0.13 J **C** 0.20 J **D** 0.40 J

19 A wire is extended by a tensile force so that its deformation is elastic.

What is meant by elastic deformation?

A The extension of the wire is proportional to the tensile force.

B The extension of the wire is **not** proportional to the tensile force.

C When the tensile force is removed, the wire does **not** return to its original length.

D When the tensile force is removed, the wire returns to its original length.