Unit 8 · Elasticity

ANSWER KEY · FOR TEACHERS

Full marks 32

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. elasticity
2. plasticity
3. stress
4. strain
5. Hooke's law
6. Poisson's ratio
7. bulk modulus
8. rigidity

Each carries 0.5 mark. **K · 4**

2 Label the diagram

1. elastic
2. strain hardening
3. stress ∝ strain
4. necking

Each carries 0.5 mark. **K · 2**

3 Multiple choice

i. **b.** N/m^2 **K · 1**

Y = stress ÷ strain; strain has no unit, so Y has the unit of stress, N/m^2 (Pa).

ii. **b.** steel, because it is much harder to deform **U · 1**

"More elastic" means a larger modulus: a greater stress is needed for the same strain. Steel's Y is about 2×10^{11} N/m^2, rubber's only 10^6 to 10^7 N/m^2.

iii. **c.** four times as much **A · 1**

$x = FL/(AY)$ and $A = \pi d^2/4$: half the diameter gives a quarter of the area, so four times the extension.

iv. **c.** 0.05 J **A · 1**

$E = \frac{1}{2}Fx = \frac{1}{2} \times 50 \times 0.002 = 0.05$ J.

v. **b.** a modulus of rigidity **U · 1**

A liquid or gas at rest can't hold a shearing stress: it flows. So only solids have a modulus of rigidity; all three states have a bulk modulus.

4 Short answers

a. **MARKING SCHEME** **U · 2**

- ✓ Ductile: a long plastic region, stretches much before breaking, with an example.
- ✓ Brittle: breaks just past the elastic limit, with an example.

b. **MARKING SCHEME** **U · 2**

- ✓ Elastic fatigue: repeated stress cycles weaken the material.
- ✓ Tiny cracks grow each cycle until it breaks below the breaking stress.

c. **MARKING SCHEME** **A · 3**

- ✓ $A = 7.85 \times 10^{-7}$ m^2 and $F = 98$ N.
- ✓ $x = FL/(AY)$.
- ✓ $x = 1.25$ mm.

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5 Long answer

ANSWER U · 4

Two equal wires hang from the same support: a reference wire with a fixed load, and the test wire, to which a hanger is added. A spirit level and a micrometer screw between the two measure the extension of the test wire, so any sag of the support or change of temperature affects both wires and cancels.

The original length L is measured with a metre rule and the diameter d with a screw gauge at several places ($A = \pi d^2/4$). Loads are added step by step and the extension x read each time; then they are removed step by step and read again.

A graph of load F against extension x is a straight line; its slope is F/x, so $Y = \frac{FL}{Ax} = \text{slope} \times \frac{L}{A}$.

Precautions (any two): the wire is free of kinks; the loads stay within the elastic limit; the diameter is measured at several places; readings are taken while loading and unloading, after waiting a moment for each load.

MARKING SCHEME

- ✓ Test and reference wires from one support, so sag and temperature cancel.
- ✓ L, d ($A = \pi d^2/4$) and the extensions for each load measured.
- ✓ $Y = FL/(Ax) = \text{slope} \times L/A$.
- ✓ Any two precautions.

6 Numerical problems

a. **ANSWER** A · 4

i. $A = \pi \times (5 \times 10^{-3})^2 = 7.85 \times 10^{-5}$ m^2; stress $= 600 \div 7.85 \times 10^{-5} =$ **7.6×10^6 N/m^2**.

ii. strain = stress ÷ Y $= 7.64 \times 10^6 \div 3 \times 10^9 =$ **2.5×10^{-3}**; extension $= 2.55 \times 10^{-3} \times 10 =$ **0.0255 m** (about 2.5 cm).

iii. $E = \frac{1}{2}Fx = \frac{1}{2} \times 600 \times 0.0255 =$ **7.6 J**.

MARKING SCHEME

- ✓ Stress 7.6×10^6 N/m^2.
- ✓ Strain 2.5×10^{-3}.
- ✓ Extension 2.5 cm.
- ✓ Energy 7.6 J.

b. **ANSWER** A · 3

$B = P \div (\Delta V/V)$, so $\Delta V/V = P/B = 2.2 \times 10^7 \div 2.2 \times 10^9 = 0.01$ (1%).

$\Delta V = 0.01 \times 1000$ cm$^3 =$ **10 cm^3**.

MARKING SCHEME

- ✓ $\Delta V/V = P/B$.
- ✓ 0.01, or 1%.
- ✓ $\Delta V = 10$ cm^3.

7 Think

ANSWER HA · 3

$x = FL/(AY) \propto L/d^2$. For Q: $2/2^2 = \frac{1}{2}$, so **P stretches twice as much** as Q.

The breaking depends on the stress, F/A, not the length: Q has four times the area, so a quarter of the stress. **P is nearer to breaking.**

MARKING SCHEME

- ✓ $x \propto L/d^2$, so Q stretches half as much as P.
- ✓ Breaking depends on stress F/A, not length.
- ✓ Q's stress is a quarter of P's, so P is nearer to breaking.

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8 Activity: Does a rubber band obey Hooke's law?

(not marked)

WHAT STUDENTS SHOULD FIND

The graph is not a straight line: rubber does not obey Hooke's law well (it is an elastomer). The unloading lengths are a little longer than the loading ones for the same load: the band shows elastic hysteresis (and an elastic after-effect: it takes time to come back). A steel spring done the same way gives a straight line, with the same lengths both ways.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Tensegrity — Floating in Balance** (exhibit): Find the parts that pull and the parts that push: the strings are under tensile stress, the rods under compressive stress.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	7	10	12	3	**32**

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