Unit 8 · Elasticity

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 25

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

1 Spot the error

ANSWER U · 3

1 mm = 10^{-3} m, so 1 mm^2 = $(10^{-3})^2$ = **10^{-6} m^2**, not 10^{-3} m^2.
x = 50 × 2 ÷ (10^{-6} × 2 × 10^{11}) = **5 × 10^{-4} m** (0.5 mm), a thousand times more than he found.

MARKING SCHEME

✓ The mistake: 1 mm^2 is 10^{-6} m^2, not 10^{-3} m^2.
✓ x = FL/(AY) with the right area.
✓ x = 0.5 mm.

2 Predict, then explain

ANSWER A · 3

i. The **copper** wire: its Young's modulus is smaller.
ii. x = FL/(AY), the same F, L and A, so $x_{copper} : x_{steel} = Y_{steel} : Y_{copper}$ = 2.0 : 1.2 = **5 : 3**.
iii. E = ½Fx, the same F, so the **copper** wire, which stretches more, stores more (5/3 times as much).

MARKING SCHEME

✓ Copper stretches more.
✓ Extensions in the ratio 5 : 3 (x ∝ 1/Y).
✓ Copper stores more energy (E = ½Fx, same F).

3 Read the data

ANSWER HA · 5

i. The **5 kg** reading: the others rise by about 0.50 mm per kg, so 5 kg should give about 2.5 mm, not 2.80. The wire has gone past its elastic limit (or its proportional limit) and begun to yield.
ii. 0.50 mm per kg: F/x = 9.8 ÷ (0.50 × 10^{-3}) = 1.96 × 10^4 N/m. Y = (F/x) × L/A = 1.96 × 10^4 × 2.0 ÷ 1.96 × 10^{-7} = **2.0 × 10^{11} N/m^2**.
iii. **Steel.**
iv. **Probably not**: past the elastic limit some of the stretch is plastic, so it keeps a small permanent extension (a permanent set).

MARKING SCHEME

✓ The 5 kg reading doesn't fit.
✓ It has passed the elastic limit.
✓ 0.50 mm per kg and Y = (F/x)L/A.
✓ Y = 2.0 × 10^{11} N/m^2: steel.
✓ It keeps a permanent extension.

4 Show that

ANSWER A · 3

i. From Y = FL/(Ax), F = (YA/L) x: the force is proportional to the extension, as F = kx for a spring, with k = YA/L.
ii. k ∝ 1/L, so each half has **twice** the force constant: under the same force each half stretches half as much, since each unit of length stretches equally and there is half the length.

MARKING SCHEME

✓ F = (YA/L)x, so k = YA/L.
✓ Halving L doubles k.
✓ Reason: the same force stretches each metre equally, and there are half as many metres.

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

5 Estimate it

ANSWER A · 3

$x = FL/(AY) = 300 \times 0.45 \div (6 \times 10^{-4} \times 1.7 \times 10^{10}) = 1.3 \times 10^{-5}$ m $\approx$ **0.013 mm**: far too small to notice.

MARKING SCHEME

- ✓ $A = 6 \times 10^{-4}$ m^2, $x = FL/(AY)$.
- ✓ About 1.3×10^{-5} m.
- ✓ Too small to notice.

6 Correct the misconceptions

ANSWER U · 3

1. Steel is more elastic: it has a far larger modulus, so it needs a far greater stress for the same strain.
2. Stress is the restoring force per unit area inside a deformed body, and it can be a pull (tensile) or a sideways force (shear); pressure is a push at right angles to a surface. They share the unit N/m^2 but are not the same thing.
3. Past the elastic limit a ductile wire doesn't break at once: it yields and flows plastically, keeps a permanent set, and breaks only at the fracture point, much later.

MARKING SCHEME

- ✓ Steel is more elastic (larger modulus).
- ✓ Stress is not the same as pressure (it includes tensile and shear stress).
- ✓ Past the elastic limit it deforms plastically; it breaks later.

7 Think

ANSWER HA · 3

At each turn of the wheel, the part of the tyre touching the road is squashed and then springs back: a cycle of loading and unloading. Rubber shows elastic hysteresis: the area of the loop on its stress–strain graph is energy turned into heat in each cycle, so the tyre warms up. That heat comes from the engine's work. A rubber with a smaller loop wastes less energy each cycle, so less fuel is needed to keep the car moving.

MARKING SCHEME

- ✓ Each turn squashes and releases the tyre: a loading–unloading cycle.
- ✓ The hysteresis loop's area is heat each cycle, which warms the tyre.
- ✓ A smaller loop wastes less of the engine's work, saving fuel.

8 Make your own

ANSWER HA · 2

$x = FL/(AY)$, so $L/A = xY/F = 10^{-3} \times 2 \times 10^{11} \div 100 = 2 \times 10^{6}$ m^{-1}. For example L = 2.0 m and **$A = 1 \times 10^{-6}$ m^2** (1 mm^2): $x = 100 \times 2 \div (10^{-6} \times 2 \times 10^{11}) = 10^{-3}$ m. (Any L and A with $L/A = 2 \times 10^{6}$ m^{-1}.)

MARKING SCHEME

- ✓ $L/A = xY/F = 2 \times 10^{6}$ m^{-1}.
- ✓ A suitable L and A, checked.

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	0	6	9	10	**25**

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking