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WORKSHEETS
ATTEMPT | CHECK | CORRECT | IMPROVE

OCR A A Level Physics | Material behaviour worksheet

35-40 minutes independent practice + 15-20 minutes review | 44 marks

Specification points covered

- 3.4.2(c) Define and use stress, strain and ultimate tensile strength.
- 3.4.2(d)(ii) Use techniques and procedures to determine the Young modulus for a metal.
- 3.4.2(e) Interpret stress-strain graphs for typical ductile, brittle and polymeric materials.
- 3.4.2(f) Describe elastic and plastic deformation of materials.

How to use this worksheet

Use graph evidence and precise material language. A material can be stiff without being strong, and a strong material can still be brittle. On written questions, name the quantity that increases, decreases or remains non-zero.

1. Precision language [4 marks]

Use definitions that would be accepted in an examination answer.

(a) Define tensile stress. **[1 mark]**

(b) Define tensile strain. **[1 mark]**

(c) Define ultimate tensile strength (UTS). **[1 mark]**

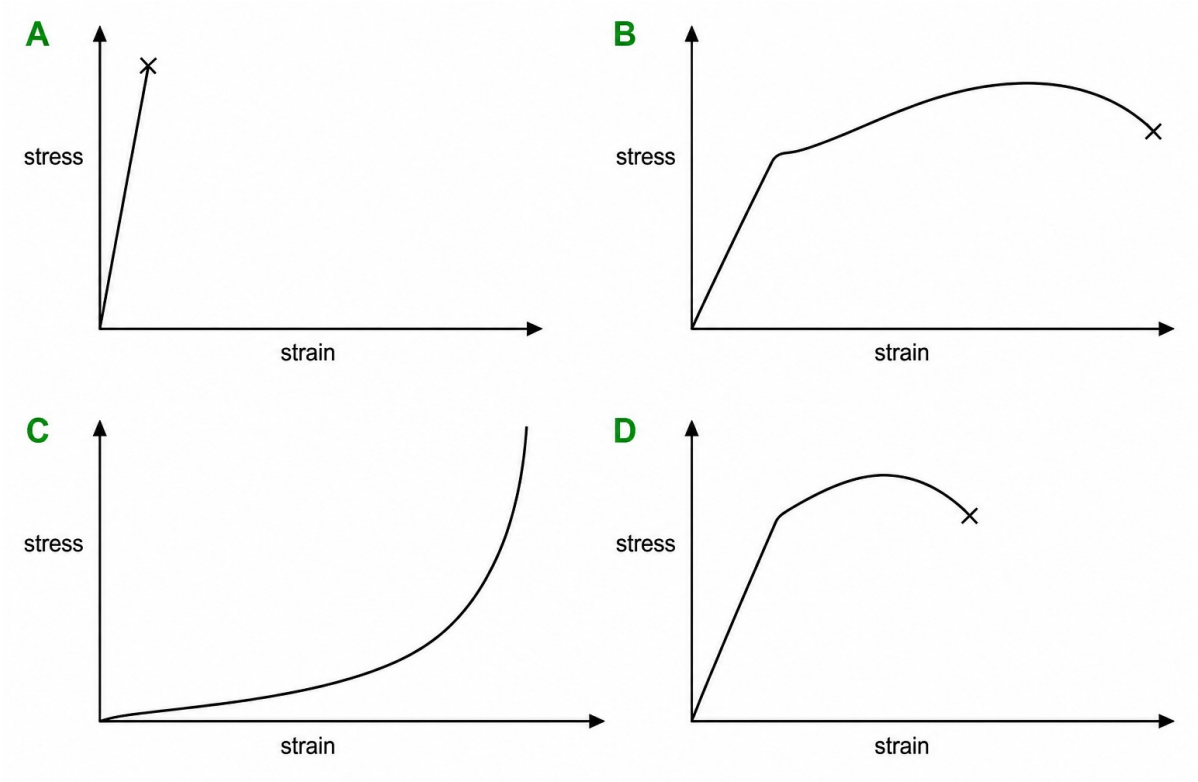
(d) Explain why the word brittle does not necessarily mean weak. **[1 mark]**

Scenario: the Aster automated warehouse robot

Engineers are selecting materials for a robot that sorts fragile parcels at high speed. Its optical window, safety link and impact pads need different combinations of stiffness, tensile strength, deformation and energy dissipation.

2. Reading stress-strain behaviour [8 marks]

The four panels use the same stress and strain scales. Crosses show fracture points. Curve C is shown only over its working range.



(a) Identify the brittle curve, the most ductile curve and the polymeric-elastomer curve. **[3 marks]**

(b) State one feature of curve A that shows brittle behaviour. **[1 mark]**

(c) Which curve has the greatest initial gradient? State the material property represented by this gradient. **[1 mark]**

(d) Mark the UTS on curve B with the letter U. **[1 mark]**

(e) Explain how curve B shows that the specimen is ductile rather than brittle. **[2 marks]**

3. Do not confuse stiffness with strength [5 marks]

A materials laboratory reports the approximate tensile properties below. Treat the values as results for the tested specimens.

Material	Young modulus / GPa	UTS / MPa	Strain at fracture
Borosilicate glass	70	45	0.00064
Steel alloy	200	550	0.20
Aluminium alloy	69	310	0.12
Polymeric elastomer	0.008	15	4.5

(a) Identify the stiffest material. **[1 mark]**

(b) Identify the material with the greatest tensile strength. **[1 mark]**

(c) Identify the material that reaches the greatest strain before fracture. **[1 mark]**

(d) A pupil says, 'The glass is strongest because its stress-strain graph begins with a steep line.' Explain the error using the table. **[2 marks]**

4. Elastic and plastic deformation [5 marks]

A ductile steel safety link is loaded first within its elastic region, and later beyond its elastic limit.

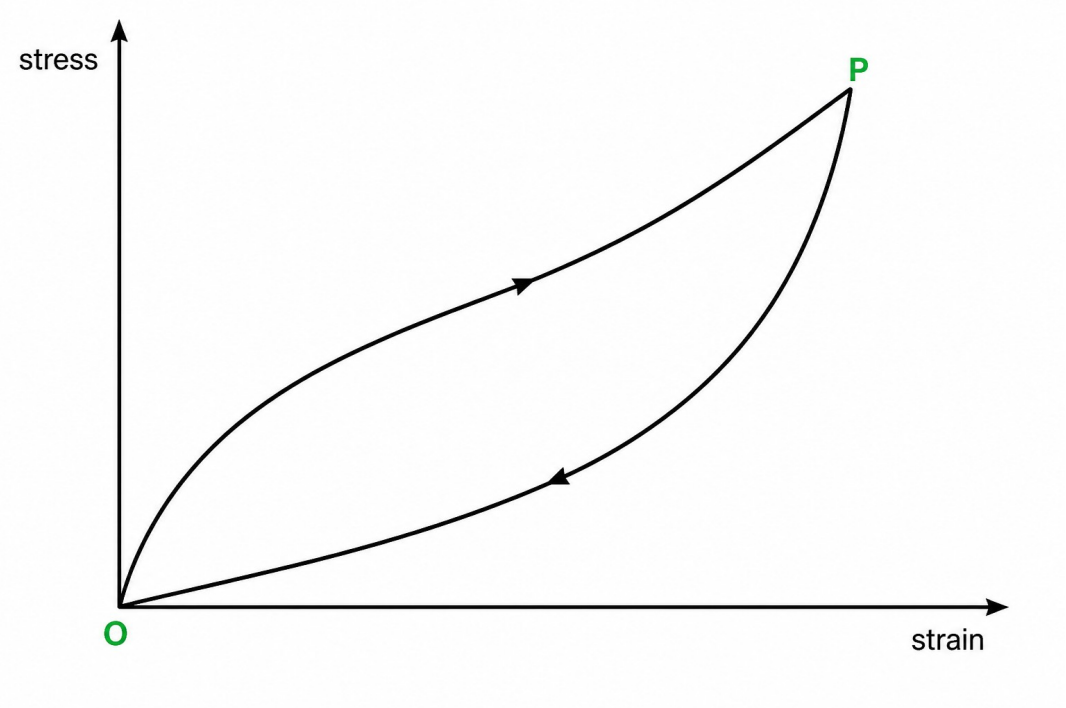
(a) Compare what happens to the link after the force is removed in the elastic case and in the plastic case. **[2 marks]**

(b) On a stress-strain graph, explain where an unloading line meets the strain axis when the link has undergone plastic deformation, and what that intercept represents. **[2 marks]**

(c) Correct this sentence: 'The stress has plastically deformed.' **[1 mark]**

5. A polymeric bumper under repeated loading [6 marks]

An elastomer bumper on the Aster warehouse robot is stretched from O to P and then allowed to return to O. The arrows show the direction of each path.



(a) Identify the loading path and the unloading path. **[2 marks]**

(b) State what the area between the two paths represents and give its SI unit. **[2 marks]**

(c) Explain why this behaviour helps the bumper reduce rebound after an impact. **[2 marks]**

6. Selecting materials for the Aster robot [6 marks]

Use curves A-D from Question 2. Select one curve for each component and justify each choice from the graph. A curve may be used once, more than once, or not at all.

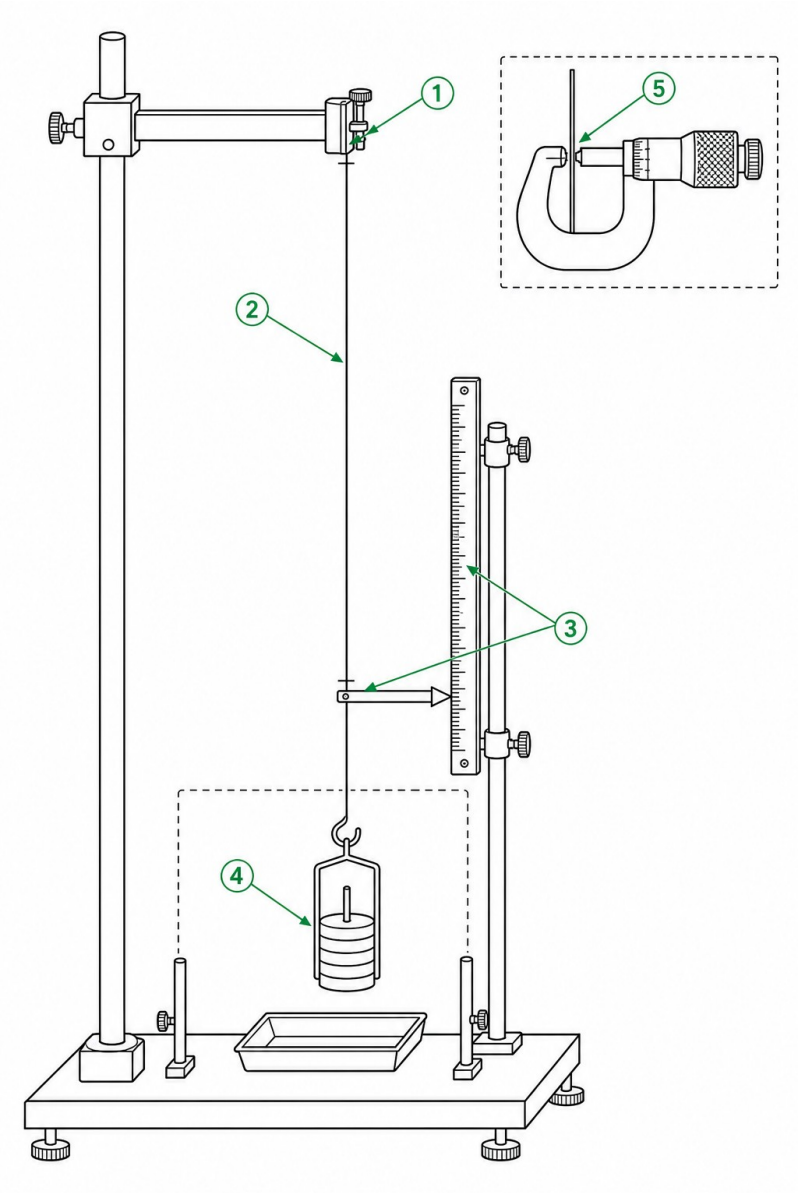
(a) An optical inspection window is protected from impact but must be stiff and retain its dimensions during normal operation. **[2 marks]**

(b) A sacrificial catch link must deform substantially before fracture so that detached parts remain connected after an overload. **[2 marks]**

(c) A reusable impact pad must undergo a very large reversible strain and dissipate energy during each impact. **[2 marks]**

7. Determining Young modulus experimentally [6 marks]

A technician uses the direct tensile arrangement below to determine the Young modulus of a metal wire.



Use the scaffold to plan. Your final answer on the next page must read as one coherent method and analysis.

Planning area	Questions to answer in your method
Measurements	Which original length and diameter are needed? Which instruments are suitable? Where and how often will diameter be measured?
Loading and extension	How will force be increased and calculated? How will extension be obtained while the wire remains suitable for the analysis?
Analysis	Which graph will be plotted? How will its gradient be used with the specimen dimensions to calculate E?
Quality and safety	How will reliability be improved? What hazards arise from the wire and falling masses?

7 continued. Describe how to obtain a reliable value for Young modulus. Include measurements and instruments, at least three diameter positions and averaging, loading and extension, graph analysis, validity and safety. **[6 marks]**

8. Diagnosing a weak practical method [4 marks]

A pupil takes one calliper reading of a thin wire to the nearest 0.1 mm, adds a single large load, continues after a permanent extension appears, then plots ΔL vertically against F horizontally and states that the gradient is E.

(a) Give four specific corrections to this method or analysis. **[4 marks]**

Review and improve

- ☐ I can distinguish stiffness, strength and fracture strain.
- ☐ I can interpret brittle, ductile and polymeric stress-strain curves.
- ☐ I can plan a reliable Young modulus experiment and explain its graph analysis.