1.

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

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(ii) Express the unit of the Young modulus in terms of S.I. base units. [3]

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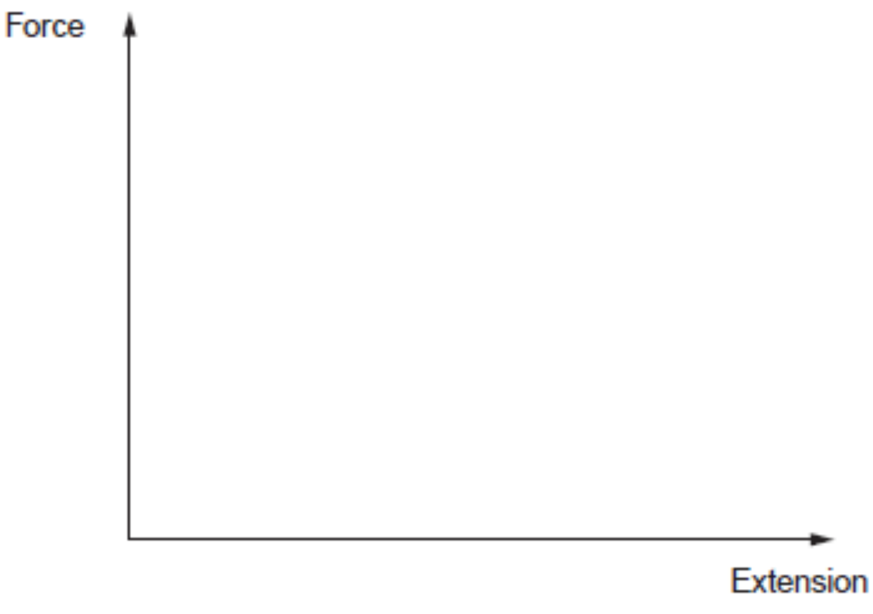
(b) (i) When a rubber band is gradually loaded and then unloaded it shows *hysteresis* and *permanent set*. Sketch, and **clearly label** a force-extension graph for rubber to illustrate these two effects. [3]



(ii) Considering the molecular structure of rubber explain why it has a much lower value of Young modulus than that of a metal. [2]

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(iii) What is the effect on the Young modulus of rubber when its temperature rises? Explain your answer. [2]

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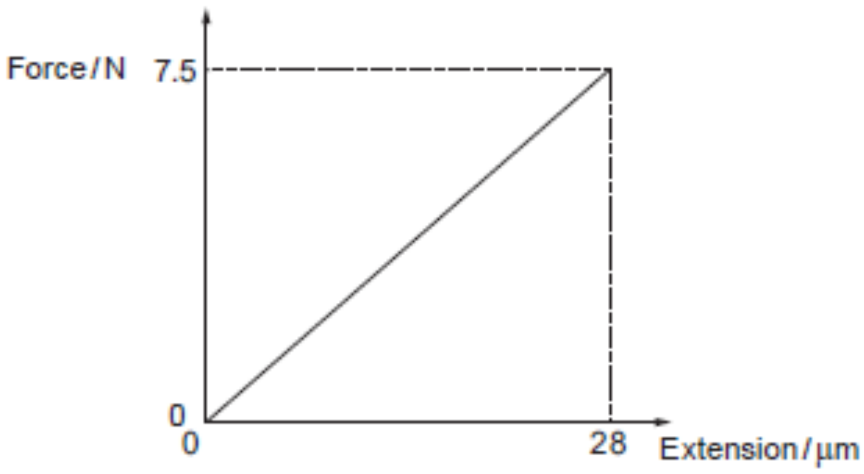
2.

1. Emily carries out an experiment to obtain a force-extension graph for a thin glass fibre. She loads the thin glass fibre until it breaks. The force-extension graph obtained is shown below.



(a) (i) Emily measures the length and diameter of the glass fibre and finds them to be 19.8 cm and 1.01 mm respectively. Suggest what measuring instruments she uses. [1]

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(ii) Determine the Young modulus of glass. [3]

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(iii) Write a risk assessment for Emily's experiment. [2]

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(iv) Determine the energy stored in the glass just before breaking point is reached. [2]

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(b) Glass is a brittle material. Describe the process by which glass fractures. [3]

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3.

3. A child's jumping toy uses the compression of a spring to fire it up into the air. The spring used requires a force of 0.50 N to compress it by 1.0 cm.

(a) State Hooke's law. [1]

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(b) The toy has a mass of 20 g and the spring is compressed by 6.0 cm and then released.

(i) Calculate the velocity with which it leaves the ground. [3]

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(ii) Determine the initial acceleration of the toy as the spring extends. State any assumption you make. [2]

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(c) (i) Ignoring air resistance, determine the maximum height gained by the toy. [3]

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(ii) Determine the total time of flight. [2]

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4. 3. (a) Describe a method to investigate the force-extension properties of rubber in the form of an elastic band **as it is loaded**. You should describe how the extension of the rubber is accurately measured. [3]

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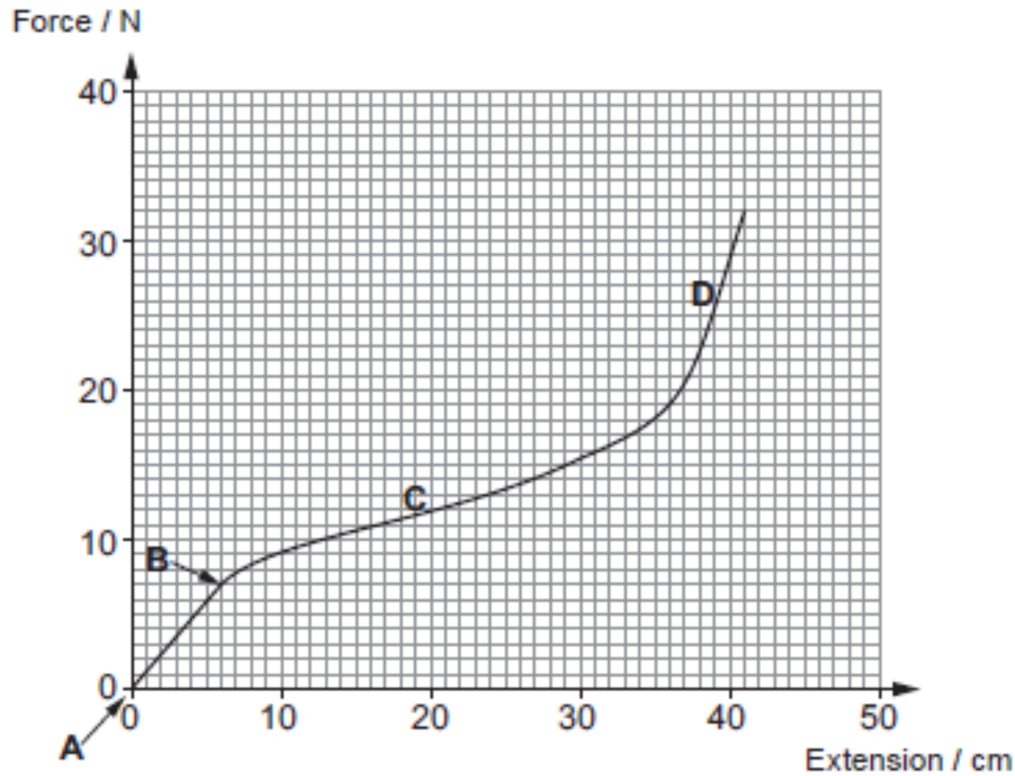
(b) The results from such an experiment for a rubber band of unstretched length 8.0 cm are plotted in a graph.



(i) Calculate the strain in the rubber at point B. [1]

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(ii) Determine the Young modulus of the rubber in the region AB. Assume the band has a total cross-sectional area of $0.050\,cm^2$. [3]

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(c) By referring to the molecular structure of rubber, explain why the gradient at C is less than the gradient at D. [3]

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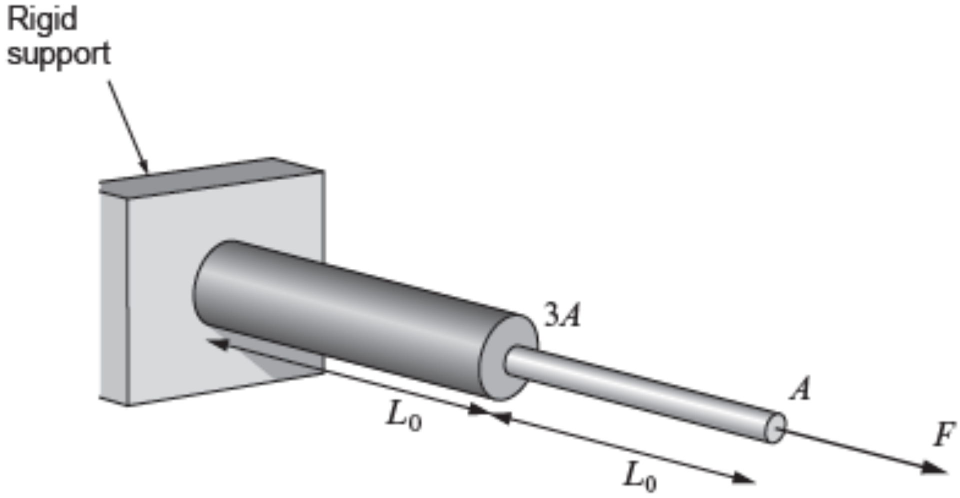
5.

5. *(a)* The bar in the figure below is made from a **single piece of metal**. It consists of two parts of equal length L_0 and cross-sectional area A and $3A$. The diagram is not drawn to scale.



(i) Show that the **total** extension, Δx_{total}, of the bar under the action of an applied force, F, as shown in the diagram, can be given by:

$$\Delta x_{total} = \frac{4FL_0}{3AE}$$

where E represents the Young modulus of the metal in the bar. [3]

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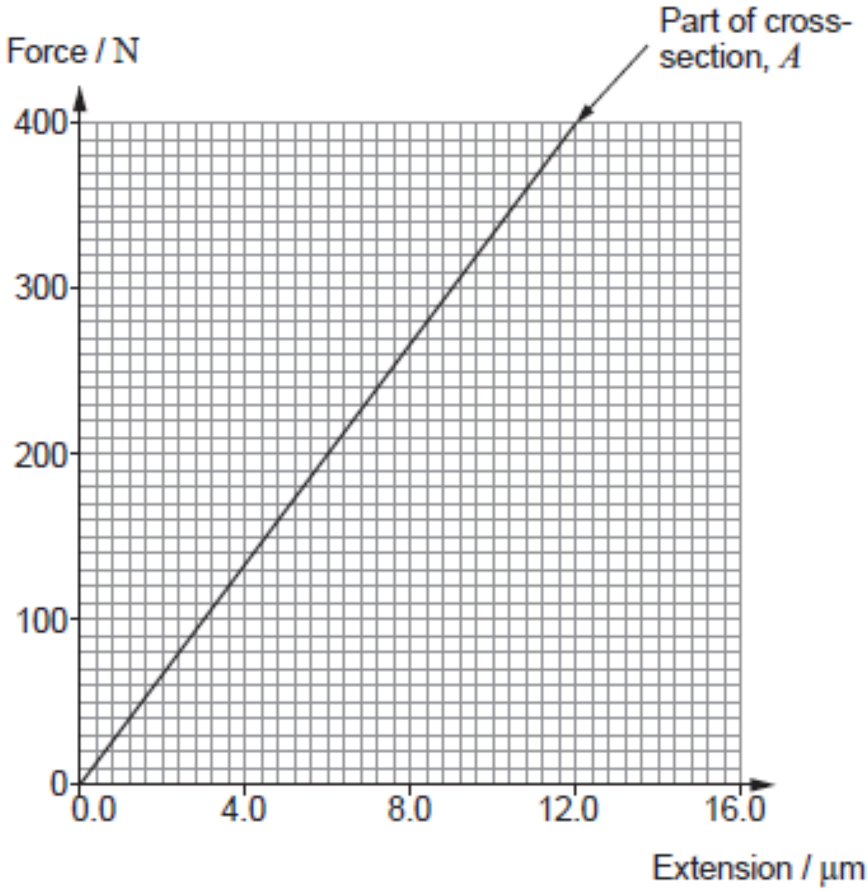
(ii) The graph shows the variation of extension with applied force for the part of cross-section, A. Draw (on the same grid) the expected force-extension graph for the segment of cross-section $3A$. [1]



(iii) Determine the Young modulus of the metal in the bar given that L_0 = 1.2m and $A = 2.0 \times 10^{-4}\,m^2$. [3]

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(iv) Calculate the elastic potential energy stored in the whole bar when F = 400N. [2]

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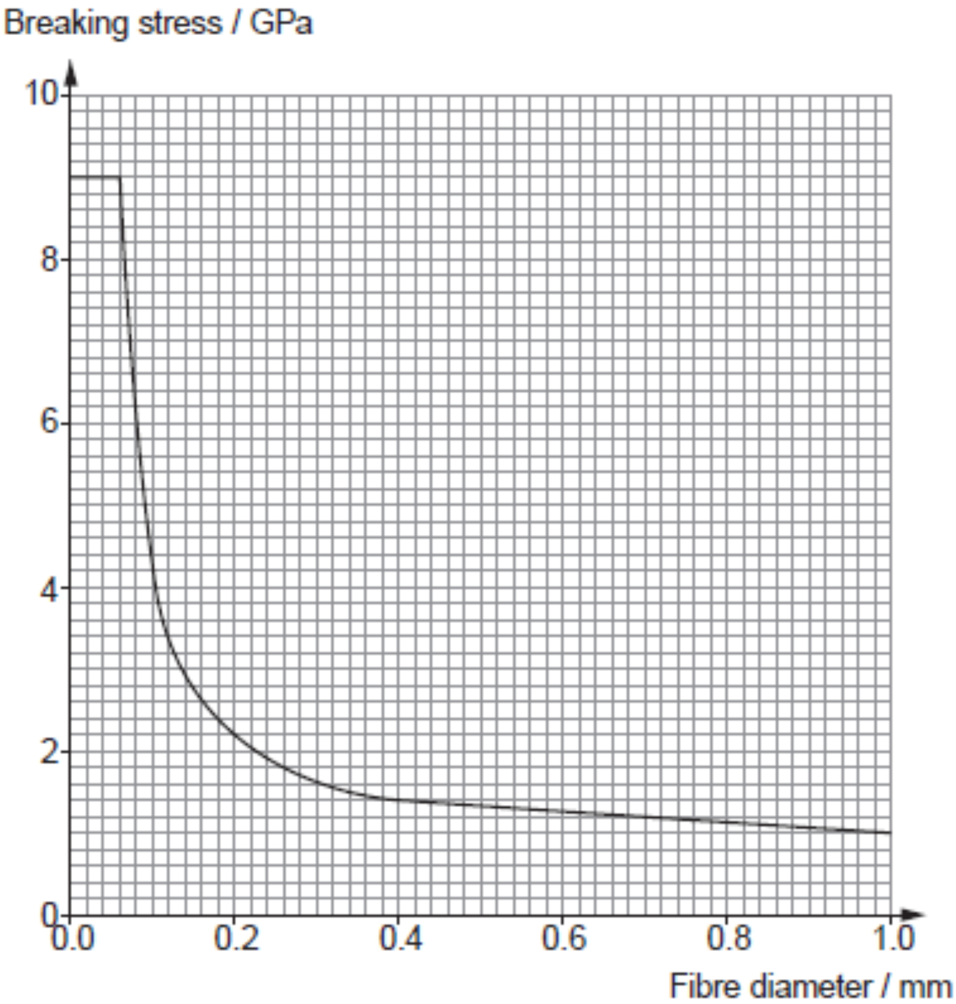
(b) Glass is a brittle material. The graph shows how the breaking stress of glass, in the form of thin fibres and rods, varies with the diameter of the fibre.



(i) Use the graph to estimate the greatest mass which can be hung from a glass fibre of diameter 0.2 mm. [3]

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(ii) Explain the term *brittle fracture* as it applies to glass and give a reason why very thin fibres have a greater breaking stress than thicker ones. [2]

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6.

6. *(a)* Materials can be classified as *crystalline*, *amorphous* or *polymeric*. Explain the meaning of **two** of the terms in italics in terms of microscopic structure. Give **one** example of each of your chosen materials. [4]

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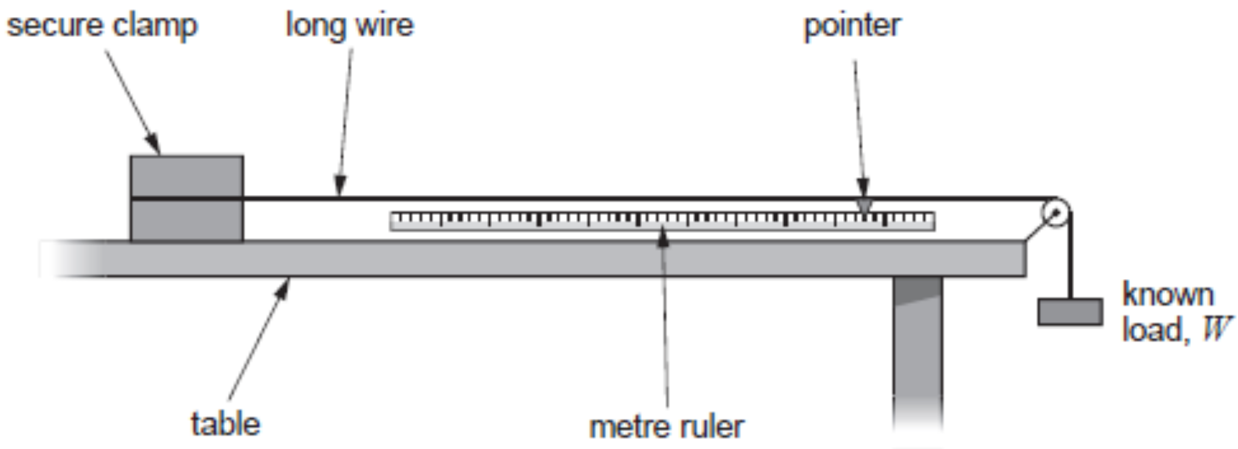
(b) The diagram shows apparatus that can be used to determine the Young modulus of a metal in the form of a wire. Describe the measurements which must be made, how they should be used to determine the Young modulus **and** precautions to minimise uncertainties.
[6 QER]



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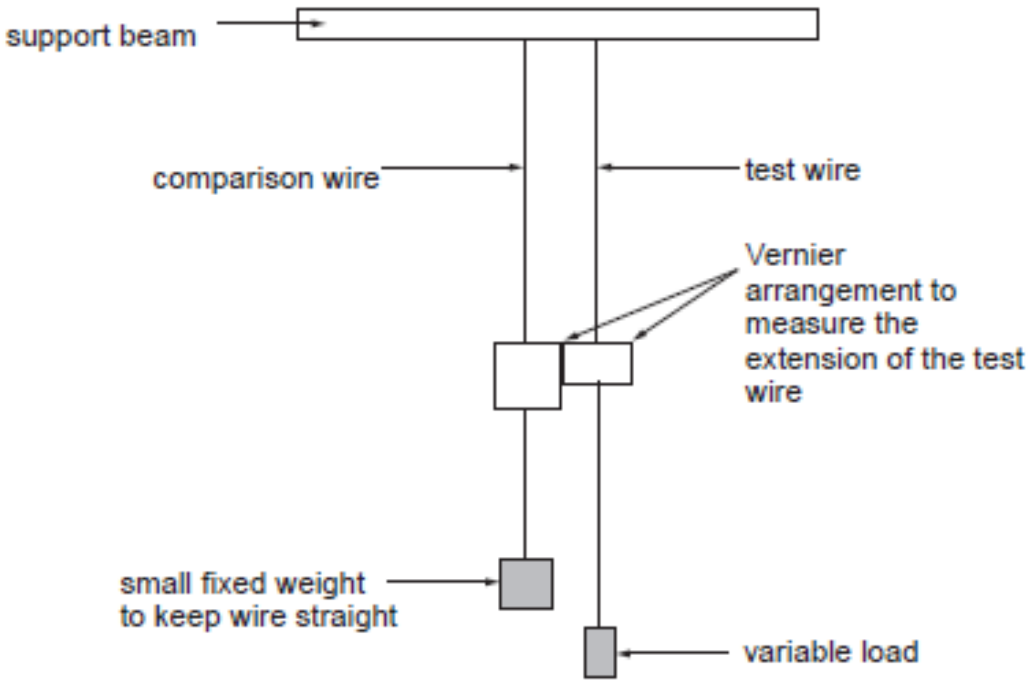
7.

3. Kiera uses the following apparatus to find the Young modulus of a metal alloy in the form of a wire.



(a) Explain how the choice of a suitable comparison wire minimises the effect of a change in temperature. [2]

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(b) Kiera uses a micrometer of resolution 0.01 mm to measure the mean diameter of the wire. She determines the mean diameter to be 0.16 mm. Calculate the cross-sectional area of the wire **in m^2**, along with its **percentage uncertainty**. [3]

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(c) Kiera then uses a metre ruler with a resolution of 1 mm to measure the initial length of the wire. She determines the length to be 1.680 m. Show, with an appropriate calculation, that the percentage uncertainty in this reading can be considered negligible. [2]

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(d) Kiera adds various masses to the test wire and measures the extension. The table shows the extension of the wire for increasing load.

Load (negligible absolute uncertainty) / N	Mean extension / mm	Absolute uncertainty in extension / mm
1.96	1.4	± 0.2
3.92	2.7	± 0.2
5.89	4.1	± 0.2
7.85	5.5	± 0.2
9.81	6.8	± 0.2

Kiera plots a graph (shown opposite) of load against extension from her data, but does not include error bars.

(i) I. **Add error bars** for the extension on the plotted points. [1]

II. Draw lines of maximum gradient and minimum gradient and determine the gradients of both lines. [3]

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(ii) Hence, calculate the mean gradient and the **percentage** uncertainty in its value. [2]

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(e) Determine the Young modulus of the metal alloy, along with its **absolute** uncertainty. Give your answer to an appropriate number of significant figures. [5]

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(f) State which of the measurements contributes most to the overall uncertainty in your answer and suggest one change Kiera could make to her experiment which would reduce the size of this uncertainty. [2]

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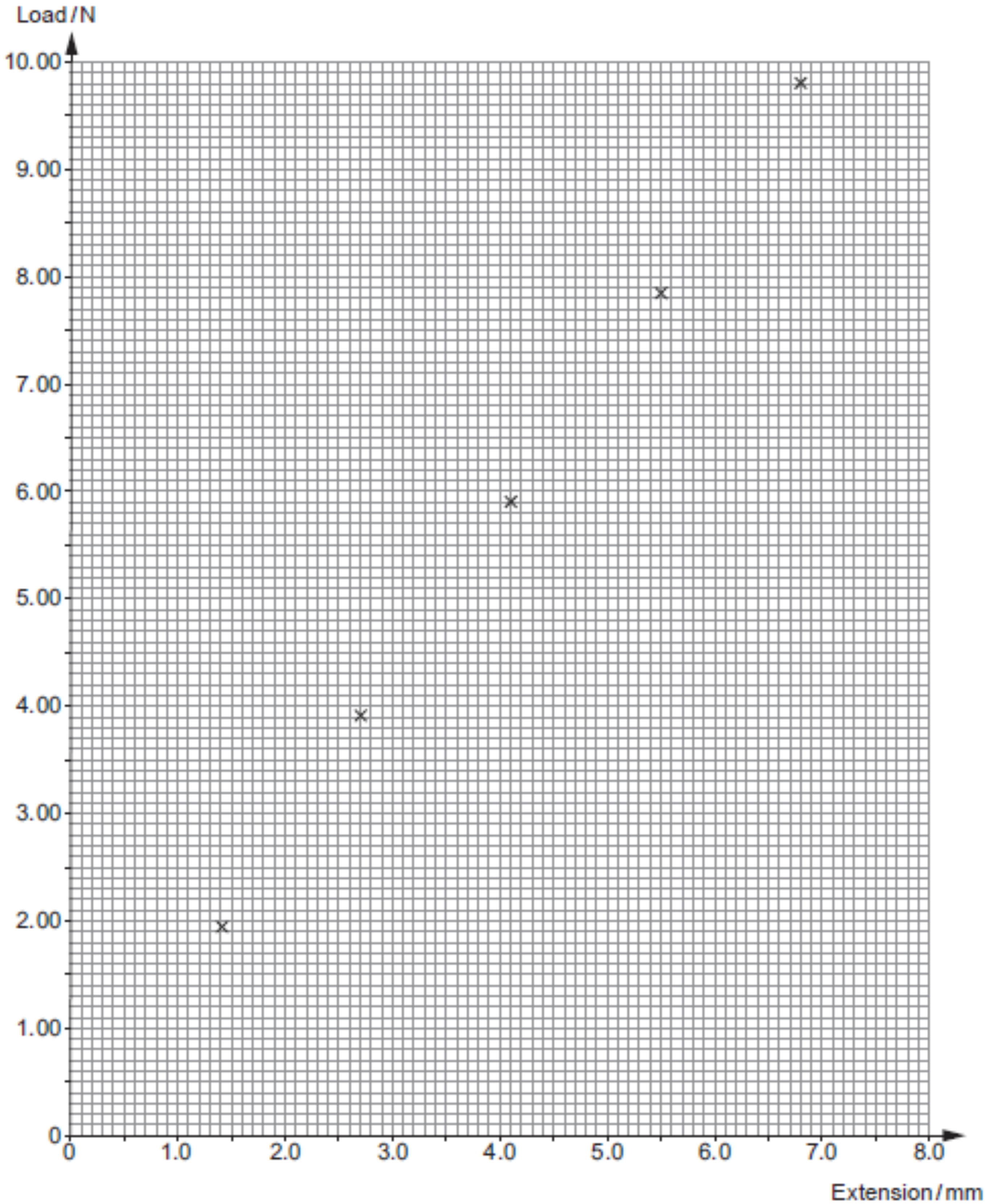
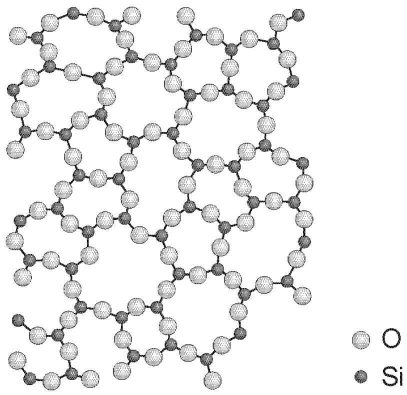


8.

(a) The picture shows the microscopic structure of glass, an amorphous solid.



Explain the following macroscopic properties of glass.

(i) Glass fibres are brittle, showing no plastic deformation before fracture. [2]

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(ii) A sheet of glass can be fractured accurately and cleanly if its surface is scratched and then the glass is bent slightly. [You may wish to draw a labelled diagram to support your answer.] [2]

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(iii) During production, car windscreens are strengthened by using jets of cold air to cool the outer surfaces of the hot glass. This causes the outside to contract quickly while the inside remains soft. Later, the inside cools and contracts. Explain how this process makes the windscreen difficult to break. [2]

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(b) Advanced aircraft and spacecraft applications require aluminium based alloys which are able to operate under extremely diverse conditions. The properties of three of these alloys are given in the table.

Aluminium alloy	Young modulus / GPa	Yield strength / MPa	Maximum tensile strain / %
Alloy A	80	800	9
Alloy B	80	1000	5
Alloy C	60	600	15

The graph opposite shows the stress against strain graph for **alloy A**.

(i) Use information from the graph to confirm that the Young modulus of alloy A is 80 GPa. [1]

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(ii) Alloy A is in the form of a cylinder of length 2.5 m and diameter 2.5 mm. Determine the work done to stretch this alloy to breaking point. [3]

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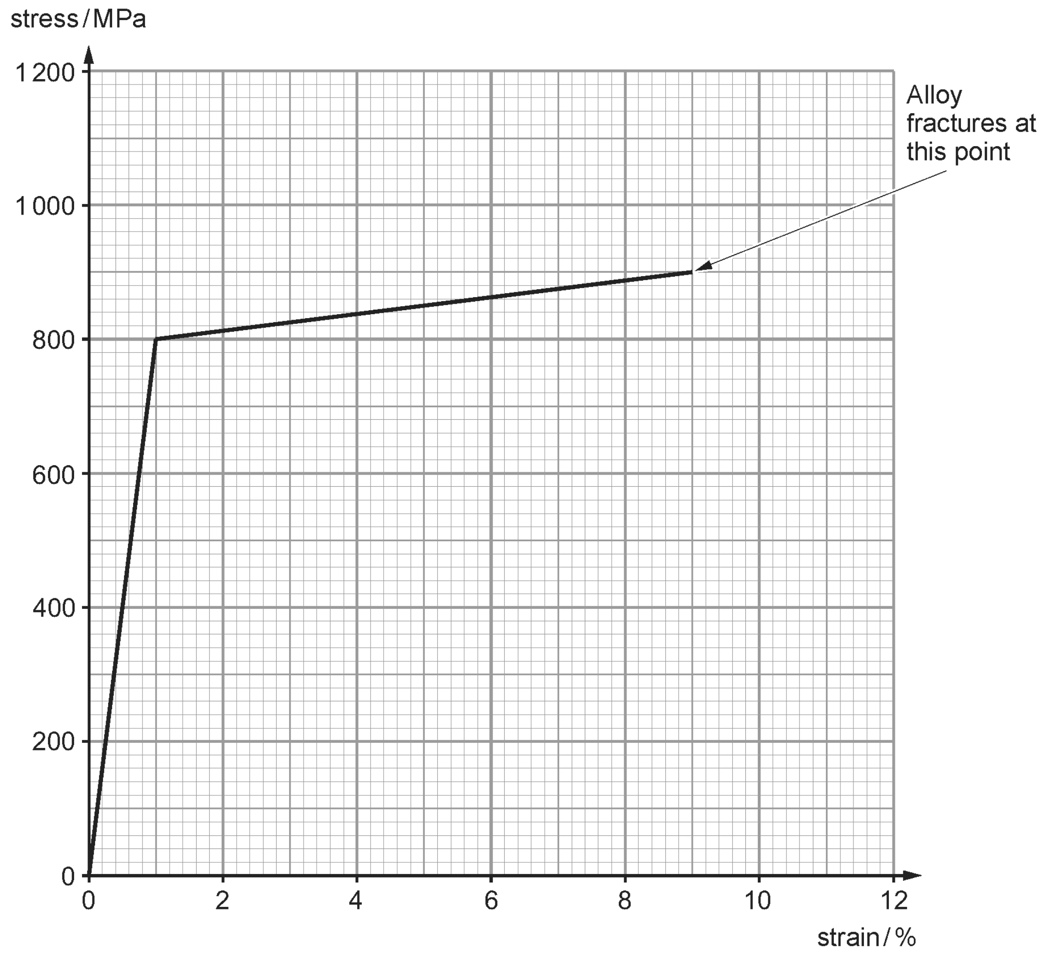

(iii) Draw, on the same axes, a simplified stress against strain graph for **alloy B** using data from the table opposite. [3]

(iv) When these alloys are placed under a constant stress over a long period of time all three undergo *creep* leading to *necking* and eventually fracture.

I. Explain the terms in italics. [2]

Creep: ....

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Necking: ....

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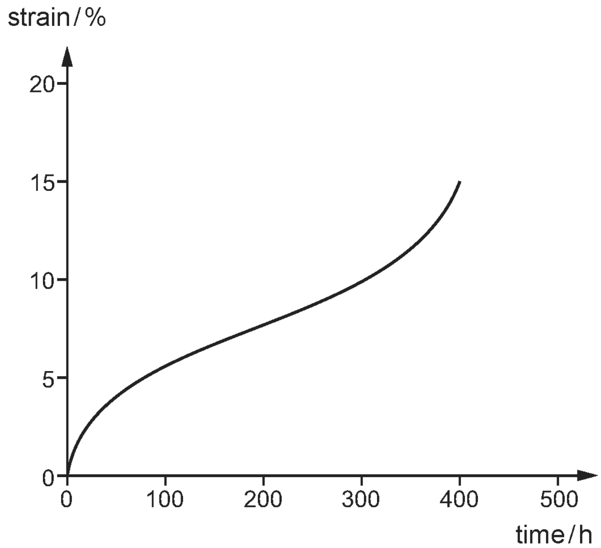
II. A creep curve for **alloy C** is shown. The alloy was subjected to a constant stress of 100 MPa. Using information in the table on page 28, sketch on the same graph (below) a creep curve which could represent alloy C when it is subjected to a constant stress of 120 MPa. [2]



(v) During production the strength of the alloy is controlled by a process called cold working (or work hardening). Describe this process and explain how it increases the strength of the alloy under production. [3]

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