Stress, Strain and the Young Modulus

Question paper

Level	International A Level
Subject	Physics
Exam Board	Edexcel
Topic	Stress, strain and the young modulus
Sub Topic	
Booklet	Queston paper

Time Allowed: **92 minutes**

Score: **/76**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 A force is applied to a length of wire.

Which of the following statements is **not** correct for small deformations of the wire?

- ☒ **A** As the force applied increases, the extension increases.
- ☒ **B** The force applied is directly proportional to the extension.
- ☒ **C** The force applied is directly proportional to the original length.
- ☒ **D** The stress is directly proportional to the strain.

(Total for Question 1 = 1 mark)

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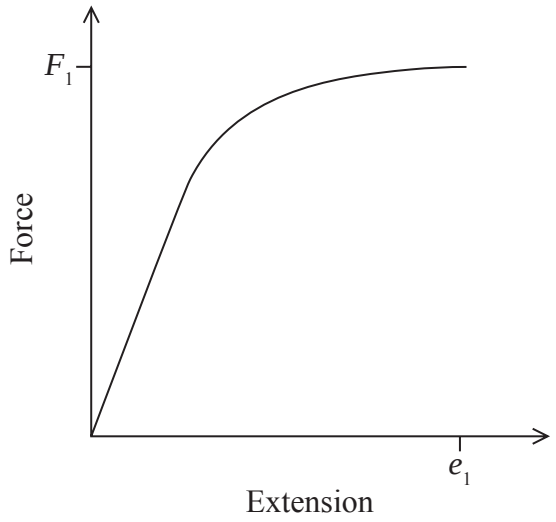
2 Aluminium can be used to produce thin sheets of food wrapping because it is

- ☒ **A** brittle.
- ☒ **B** ductile.
- ☒ **C** hard.
- ☒ **D** malleable.

(Total for Question 2 = 1 mark)

Use the graph below to answer question 3.

The force-extension graph for a wire is shown.
When a force F_1 is applied across the ends of the wire, an extension e_1 is produced.



3 It can be deduced from the graph that, up to force F_1, the material is

☒ **A** brittle.

☒ **B** elastic.

☒ **C** malleable.

☒ **D** tough.

(Total for Question 3 = 1 mark)

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4 Select the row of the table that correctly matches the property of a material to the type of deformation it can experience.

	Property	Elastic deformation	Plastic deformation
☒ **A**	brittle	no	yes
☒ **B**	brittle	yes	little or no
☒ **C**	malleable	no	yes
☒ **D**	malleable	yes	little or no

(Total for Question 4 = 1 mark)

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5 A force of 15 N is applied to a wire of cross-sectional area 3.0×10^{-6} m^2. The wire extends by 1% of the original length.

The Young modulus of the wire, in N m^{-2}, can be found from

☒ **A** $\dfrac{15}{1 \times 3.0 \times 10^{-6}}$

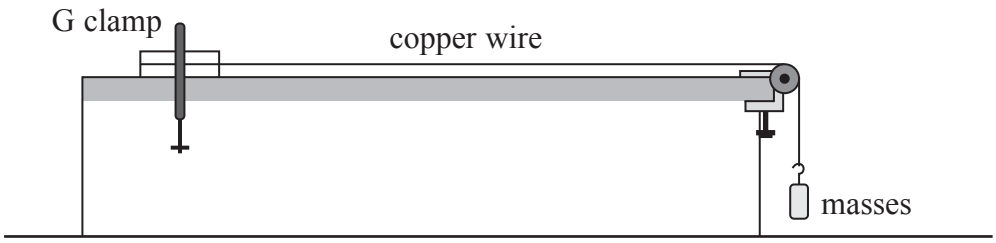
☒ **B** $\dfrac{15}{(0.01)(3.0 \times 10^{-6})}$

☒ **C** $\dfrac{(1)(3.0 \times 10^{-6})}{15}$

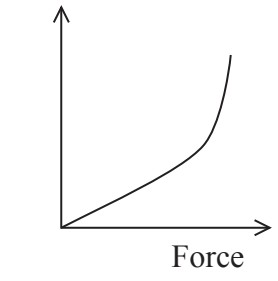
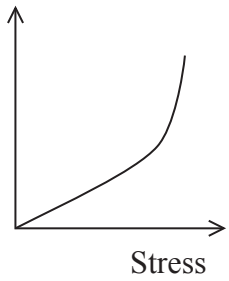
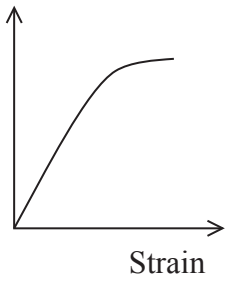
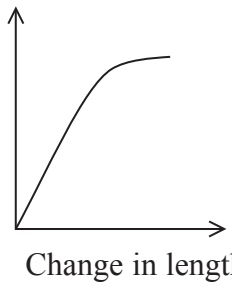
☒ **D** $\dfrac{(15)(0.01)}{(3.0 \times 10^{-6})}$

(Total for Question 5 = 1 mark)

6 Some masses are added to a piece of copper wire as shown. Measurements are taken of the length of the wire as the force on the wire is increased.



The work done in stretching the wire is given by the area under which graph?

☒ **A**	☒ **B**	☒ **C**	☒ **D**
Change in length  Force	Strain  Stress	Stress  Strain	Force  Change in length

(Total for Question 6 = 1 mark)

7 A material that is able to undergo plastic deformation under compression is said to be

☒ **A** brittle.

☒ **B** ductile.

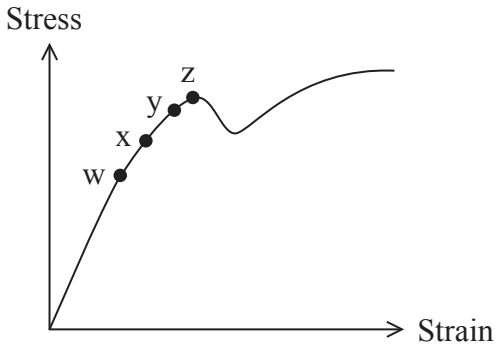
☒ **C** hard.

☒ **D** malleable.

(Total for Question 7 = 1 mark)

8 A thin wire of uniform cross-sectional area is stretched by an increasing force.

The corresponding stress-strain graph is shown.



Points w, x, y and z are shown on the graph.

Select the row of the table that correctly identifies the yield point, the limit of proportionality and the elastic limit.

	Yield point	Limit of proportionality	Elastic limit
☒ **A**	y	w	x
☒ **B**	z	w	y
☒ **C**	y	x	w
☒ **D**	z	x	y

(Total for Question 8 = 1 mark)

9 (a) A force is applied across the ends of a sample of wire. For small forces the deformation of the wire is elastic and for large forces the deformation is plastic.

Explain what is meant by the terms

(3)

elastic deformation .....

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.....

plastic deformation .....

.....

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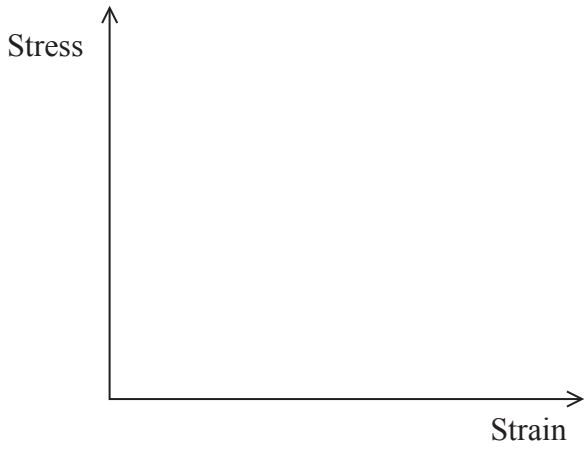
(b) Copper is a ductile material. This makes copper suitable for the production of wires.

(i) On the axes below, sketch the stress-strain graph for copper.

(2)



(ii) With reference to your graph, state why copper is a suitable material for the production of wires.

(1)

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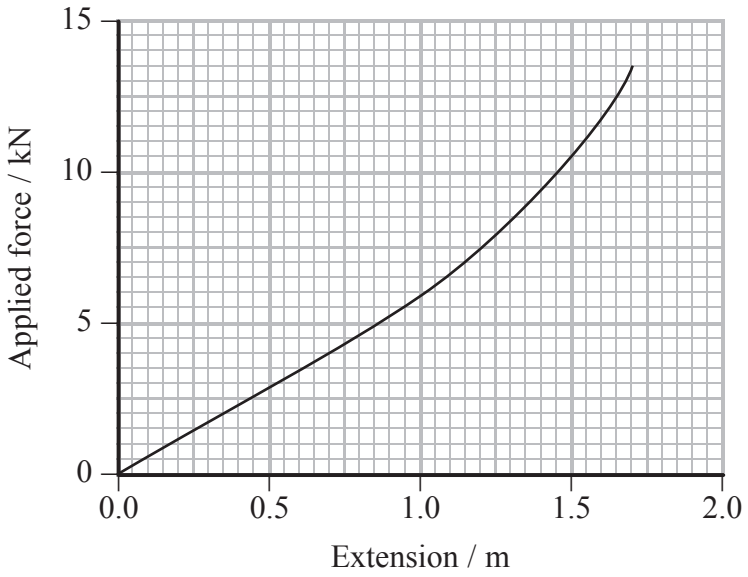
(Total for Question 9 = 6 marks)

10 (a) The force-extension graph obtained when stretching a nylon rope is shown below.



Use the graph to determine the work done in extending the rope by 1.5 m.

(3)

Work done = ...

(b) Kinetic towing of cars is a method that can be used when it is difficult for a towing car to achieve sufficient grip, such as in snow or sand.

A nylon strap is connected, with a lot of slack, between the two cars. The towing car drives forward and the strap must become stretched before it is able to pull the trapped car free.

*(i) Explain why, even if the towing car had then stopped, the trapped car would still begin to move.

(2)

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(ii) The nylon strap used for kinetic towing typically has a breaking strain of 25%. Steel cables, often used for towing cars along roads, typically have a breaking strain of 0.02%.

It can be assumed that the nylon strap and the steel cable both obey Hooke's law. Show that, for the same pulling force and just before breaking, a nylon strap can store over 1000 times more energy than a steel cable of identical initial length and cross sectional area.

(3)

(iii) Suggest why steel cables are **not** suitable for kinetic towing of cars.

(1)

(Total for Question 10 = 9 marks)

11 A contact lens is a thin plastic lens placed directly onto the eye to correct vision. Contact lenses are commonly made from a silicone hydrogel material.

The Young modulus of the material used in a contact lens can determine how well the lens fits the eye and how well the lens functions at correcting vision.

(a) State the meaning of the term Young modulus.

(1)

.....

.....

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(b) Suggest how the fit of a lens and its function are affected when it is made from a material with a high Young modulus.

(2)

Fit .....

.....

.....

Function .....

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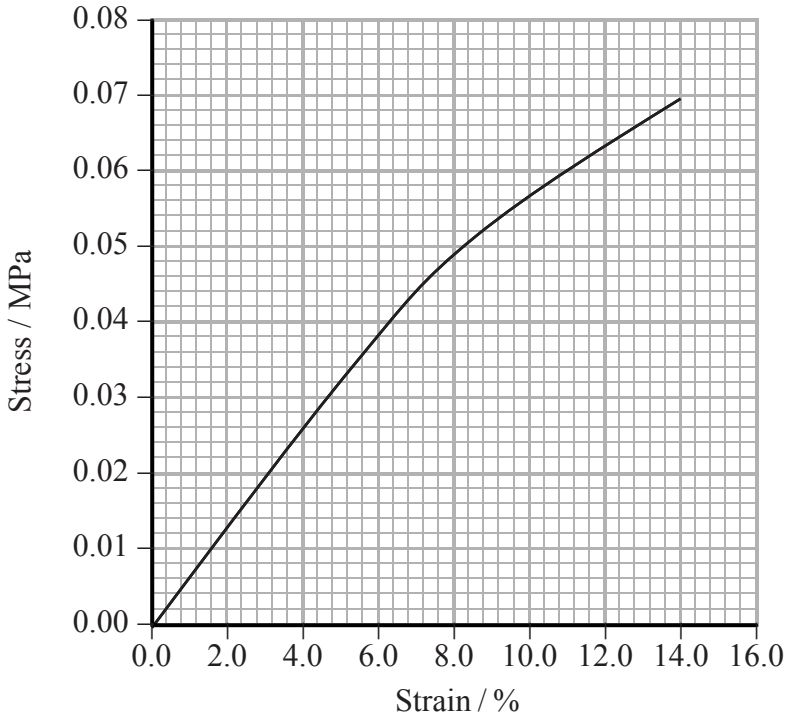
(c) To investigate the properties of a contact lens, a lens manufacturer placed a rectangular sample of a silicone hydrogel material in a tensile testing machine and a tensile force was exerted on the sample.

The resulting stress-strain graph for the sample is shown.



(i) Show that the Young modulus of the silicone hydrogel is about 0.6 MPa.

(2)

(ii) When a force of 0.101 N is applied across the sample, a strain of 8% is produced.

Determine the thickness of the sample.

width of sample = 5.5×10^{-3} m

(4)

Thickness of the sample = ...

*(iii) The thickness of a lens is not uniform. An actual lens is placed in the tensile testing machine.

Explain why the extension produced is greater where the thickness of the lens is smaller.

(3)

(Total for Question 11 = 12 marks)

12 Brass is an alloy made from copper and zinc. The ultimate tensile strength and hardness of brass increase as the zinc content increases.

(a) (i) State what is meant by the term strength.

(1)

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(ii) State what is meant by the term hardness.

(1)

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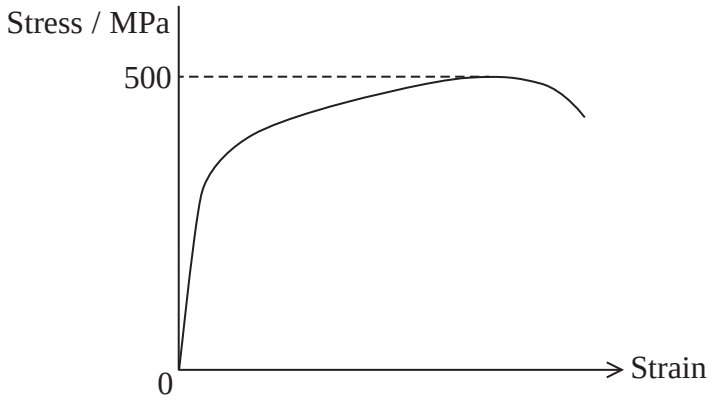
(b) The stress-strain graph for a sample of brass is shown.



The typical stress when turning a key in a lock is about 10 MPa.

Use information from the graph to suggest why brass is a suitable material for use in keys.

(4)

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(Total for Question 12 = 6 marks)

13 (a) Show that a unit for the Young modulus is N m^{-2}.

(2)

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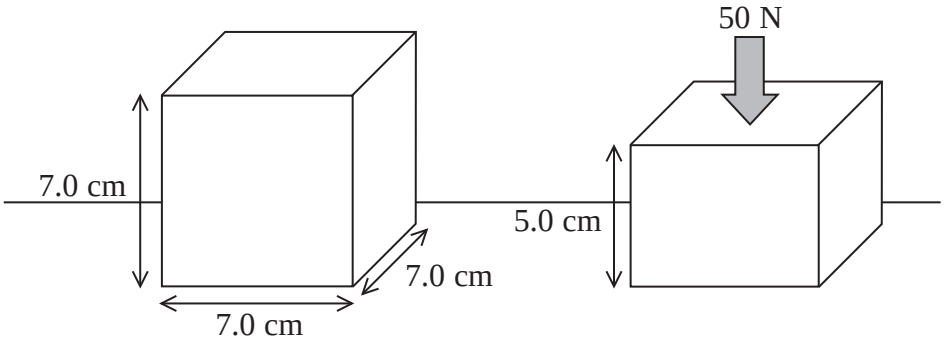
(b) A foam cube of side 7.0 cm is compressed.

The cube is compressed with a force of 50 N and the vertical sides are reduced to 5.0 cm in length.



(i) Calculate the Young modulus of the foam. Assume that the other dimensions of the foam do not change.

(3)

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Young modulus = ...

(ii) The assumption in (i) is incorrect.

Explain how this would affect the calculated value of the Young modulus. **(2)**

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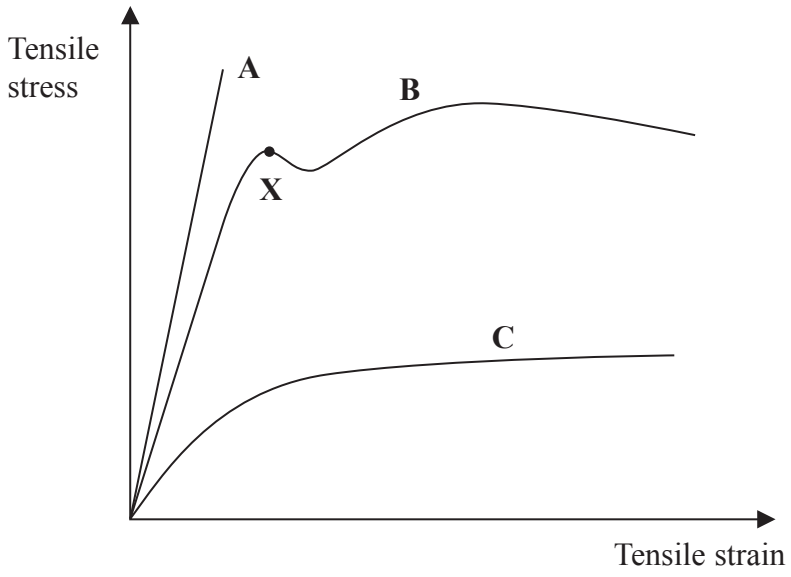
(Total for Question 13 = 7 marks)

14 The graph shows the stress-strain curves for three materials A, B, and C up to the point of fracture.



(a) (i) Identify which of the materials A, B or C is

(4)

a brittle material .....

a ductile material .....

the strongest material .....

the least stiff material .....

(ii) The three materials are copper, glass and steel.

Identify which graph refers to each material.

(2)

A .....

B .....

C .....

(b) Explain why steel is a suitable material for making paper clips.

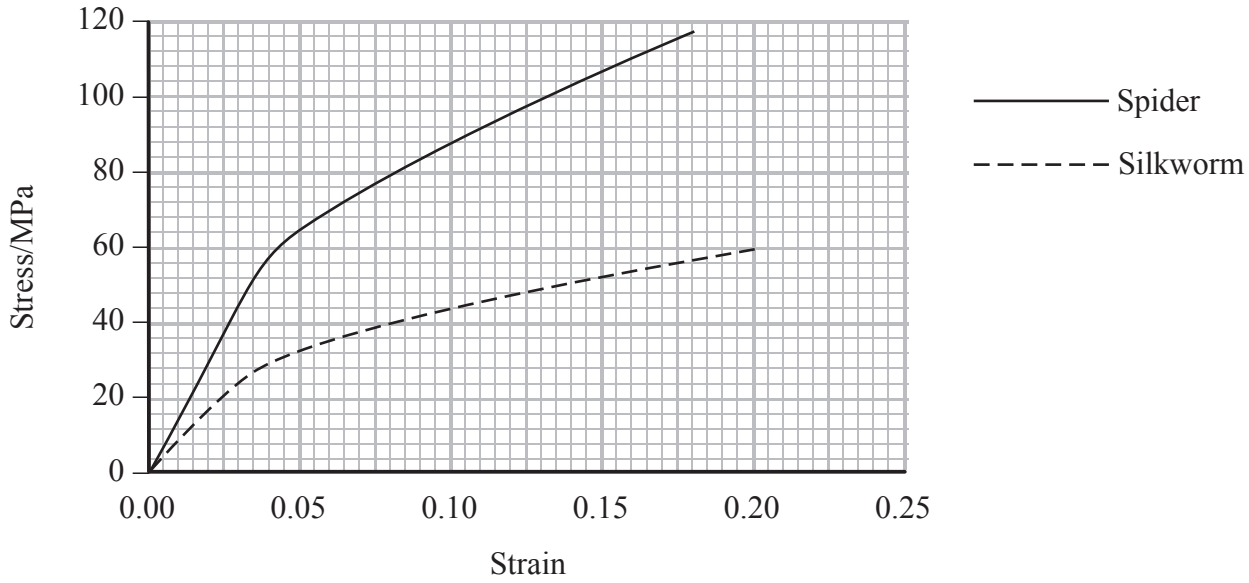
(3)

(c) State the name for the point marked **X** on graph B and explain its significance.

(2)

(Total for Question 14 = 11 marks)

15 Silk is a natural protein fibre produced by spiders and silkworms. It is a material of high tensile strength. The graph gives the stress-strain curves, up to the point of fracture, for silk produced by spiders and by silkworms.



(a) (i) State what is meant by high tensile strength.

(1)

*(ii) Spiders use silk to build webs to catch insects. Use the graph to explain how the properties of spider silk make it more suitable than silkworm silk for building webs to catch insects.

(4)

(b) (i) Use the graph to determine the Young modulus of spider silk for small stresses.

(2)

Young modulus = ...

(ii) An insect flies into a spider's web and becomes attached to a single thread. This creates a tension in the thread of 580 μN. The thread extends by approximately 3% of the original length.

Calculate the radius of a single thread of spider silk.

(4)

Radius = ...

(Total for Question 15 = 11 marks)

16 (a) A manufacturer of spring balances needs to select a spring that produces an extension of 0.80 cm for each 100 g mass added.

Show that the manufacturer will need to select a spring with a spring constant of about 120 N m^{-1}.

(3)

(b) The manufacturer states that the maximum mass that can be hung on the spring balance is 1.2 kg.

Explain why it is necessary to state the maximum mass.

(3)

(Total for Question 16 = 6 marks)