| Surname | | Other Names | |
|---|---|---|---|
| Centre Number | | | Candidate Number | | | | |
| Candidate Signature | | | | | | | | |

For Examiner's Use

General Certificate of Education
January 2008
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

**APPLIED SCIENCE** **SC05**
**Unit 5 Choosing and Using Materials**

Friday 18 January 2008 1.30 pm to 3.00 pm

**For this paper you must have:**
- a pencil and a ruler
- a calculator.

Time allowed: 1 hour 30 minutes

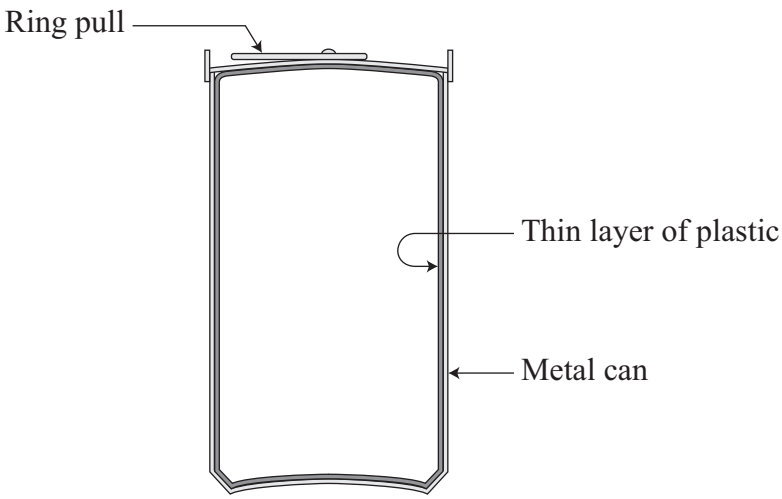
**Instructions**
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Answer the questions in the spaces provided.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show the working of your calculations.
- Pages 17 and 18 are perforated. Detach this sheet to help you to answer Question 8.

**Information**
- The maximum mark for this paper is 80.
- The marks for the questions are shown in brackets.
- You are expected to use a calculator where appropriate.

| For Examiner's Use | | | |
|---|---|---|---|
| Question | Mark | Question | Mark |
| 1 | | 5 | |
| 2 | | 6 | |
| 3 | | 7 | |
| 4 | | 8 | |
| Total (Column 1) → | | | |
| Total (Column 2) → | | | |
| TOTAL | | | |
| Examiner's Initials | | | |

Answer **all** questions in the spaces provided.

**1** The diagram shows a drinks can.




Cans may be made from aluminium or steel.

(a) Suggest **one** reason why the inside of the can is coated with a thin layer of plastic.

.....

.....

*(1 mark)*

(b) Suggest **two** factors, other than physical or chemical factors, that the manufacturer might take into account when choosing between aluminium or steel for the can.

1 .....

.....

2 .....

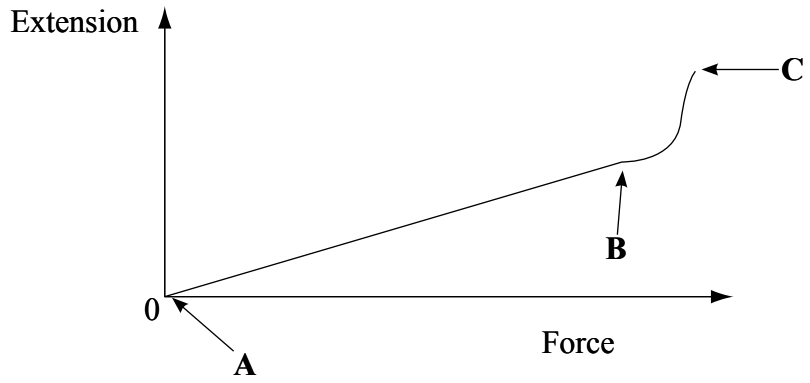
.....

*(2 marks)*

3

**2** A lift manufacturer is deciding which type of steel cable to use.

The graph below shows how the extension of the steel cable varies with the force applied.




(a) Describe in detail the relationship between force and extension

(i) from point **A** to point **B**,

.....

.....

*(2 marks)*

(ii) from point **B** to point **C**.

.....

.....

*(1 mark)*

(b) On the graph,

(i) label with a letter **E**, **one** point at which the wire is undergoing elastic deformation, *(1 mark)*

(ii) label with a letter **P**, **one** point at which the wire is undergoing plastic deformation. *(1 mark)*

(c) Add a line to the graph to show what would happen to the extension if the force were reduced to zero at point **C**. *(1 mark)*

**Question 2 continues on the next page**

(d) The lift cable must be able to support the load without stretching too much or breaking.
The lift manufacturer's research department tested one of the cables.
Their results are shown below.

| **Stress ($N\,m^{-2}$)** | $2 \times 10^8$ | $4 \times 10^8$ | $6 \times 10^8$ | $8 \times 10^8$ | $10 \times 10^8$ |
|---|---|---|---|---|---|
| **Strain** | $1 \times 10^{-3}$ | $2 \times 10^{-3}$ | $3 \times 10^{-3}$ | $4 \times 10^{-3}$ | $5 \times 10^{-3}$ |

(i) Write down the definition of *stress*.

.....

*(1 mark)*

(ii) Write down the definition of *strain*.

.....

*(1 mark)*

(iii) Explain why there are no units for strain written in the table.

.....

.....

*(1 mark)*

(iv) Plot a graph of the results on the grid provided on **page 5**.

*(4 marks)*

(v) Calculate the Young modulus for the cable.

.....

.....

*(2 marks)*

(vi) The cable has a cross-sectional area of $1 \times 10^{-2}\,m^2$.
What is the stress in the cable when the load is 10 000 N?

.....

.....

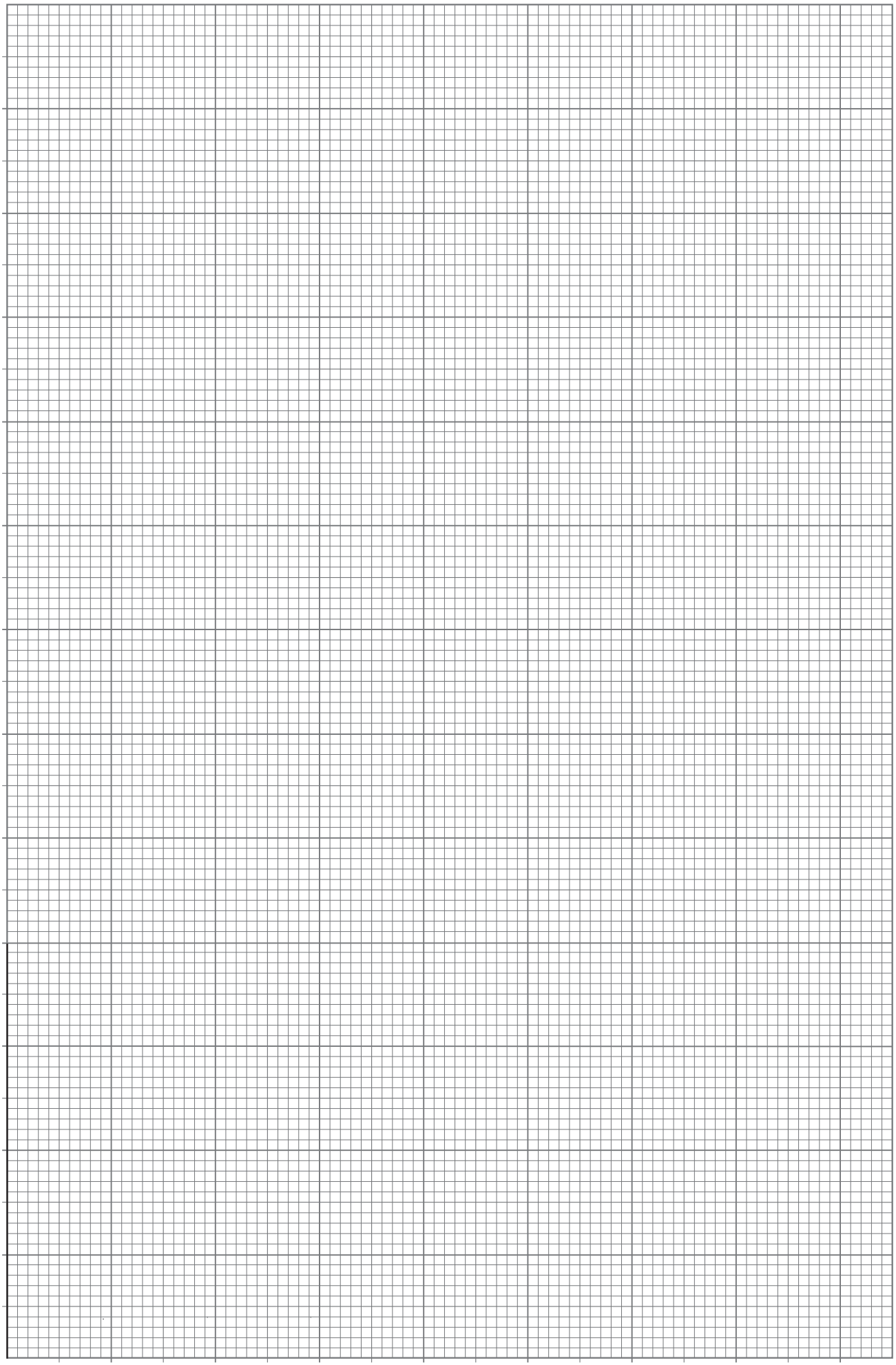
*(2 marks)*

(vii) Other than the properties mentioned above, write down **one** further physical property of the cable that the lift manufacturer should consider when choosing the cable.

.....

*(1 mark)*

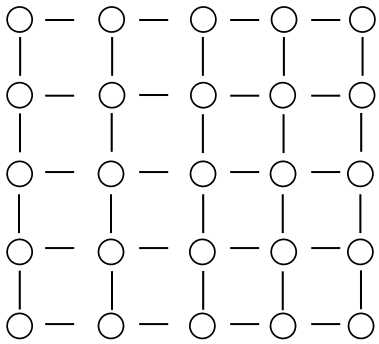
*LEAVE MARGIN BLANK*



18

**3** The diagram represents the internal structure of copper, in two dimensions.

○ = copper atom
— = bond



(a) What type of internal structure is this?
Tick the box beside the correct answer.

Amorphous ☐ Crystalline ☐ Monomeric ☐ Polymeric ☐

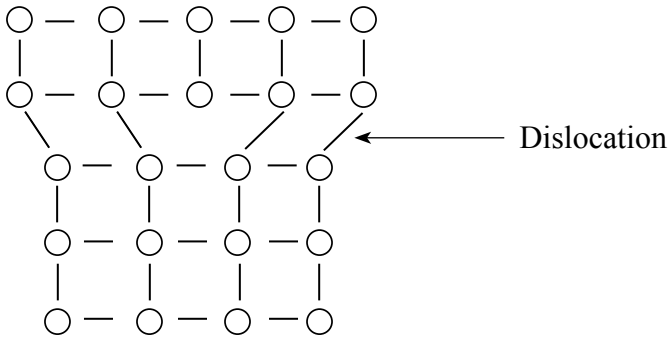
*(1 mark)*

(b) Write down the name of the type of bonding between the copper atoms.

.....

*(1 mark)*

(c) The diagram below also shows copper but this time with a dislocation.




(i) State what has caused the dislocation.

.....

*(1 mark)*

(ii) Dislocations like these will weaken the copper.
Explain why.

.....

.....

*(2 marks)*

(d) Pure copper is very malleable.

(i) What is the meaning of the word *malleable*?

.....

*(1 mark)*

(ii) Write down the name of **one** process by which copper can be treated to increase its hardness.

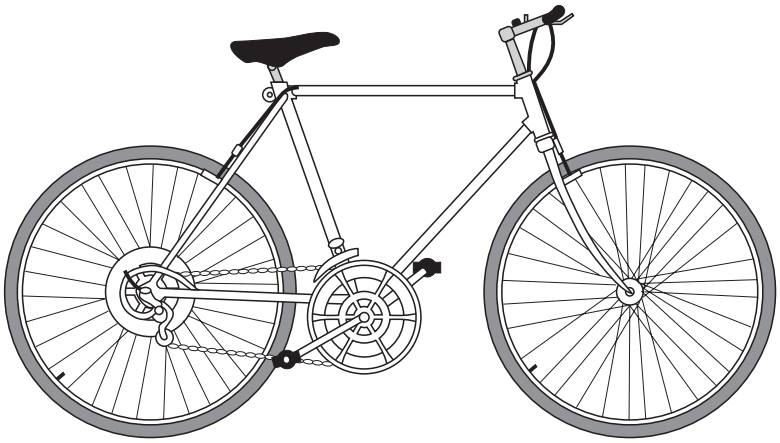
.....

*(1 mark)*

7

**Turn over for the next question**

**4** A bicycle is shown below.



(a) The frame may be made out of solid metal rods or hollow tubing.
Suggest **two** reasons why it is better to build the frame out of hollow tubing.

1 .....

2 .....

*(2 marks)*

(b) Three materials that are commonly used to make bicycle frames are shown in the table.

| **Material** | **Young modulus ($10^9$ N m$^{-2}$)** | **Yield strength ($10^6$ N m$^{-2}$)** | **Density (kg m$^{-3}$)** |
|---|---|---|---|
| Aluminium alloy | 70 | 140 to 500 | 2700 |
| Steel alloy | 210 | 450 to 1000 | 7900 |
| Titanium alloy | 115 | 800 to 1000 | 4500 |

(i) What is the meaning of the word *alloy*?

.....

*(1 mark)*

(ii) Using only data from the table on **page 8**, state and explain **one** advantage of using each of the alloys compared with the other two.

Advantage of aluminium alloy

.....

Explanation .....

.....

Advantage of steel alloy

.....

Explanation .....

.....

Advantage of titanium alloy

.....

Explanation .....

.....

*(6 marks)*

(iii) Suggest **one** factor, other than a physical factor, that the manufacturer should take into account when choosing the material for the frame.

.....

*(1 mark)*

(iv) You are given a 10 cm length of a tube made of titanium alloy.
Describe how you would measure the density of this titanium alloy.

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.....

.....

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.....

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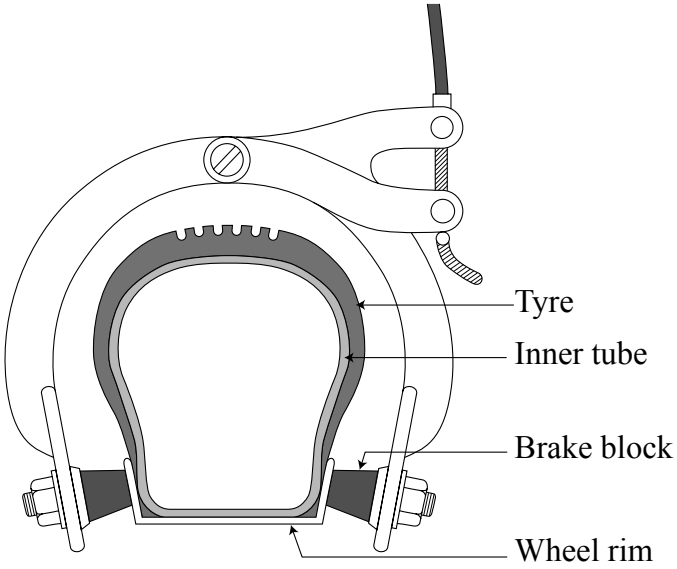
*(5 marks)*

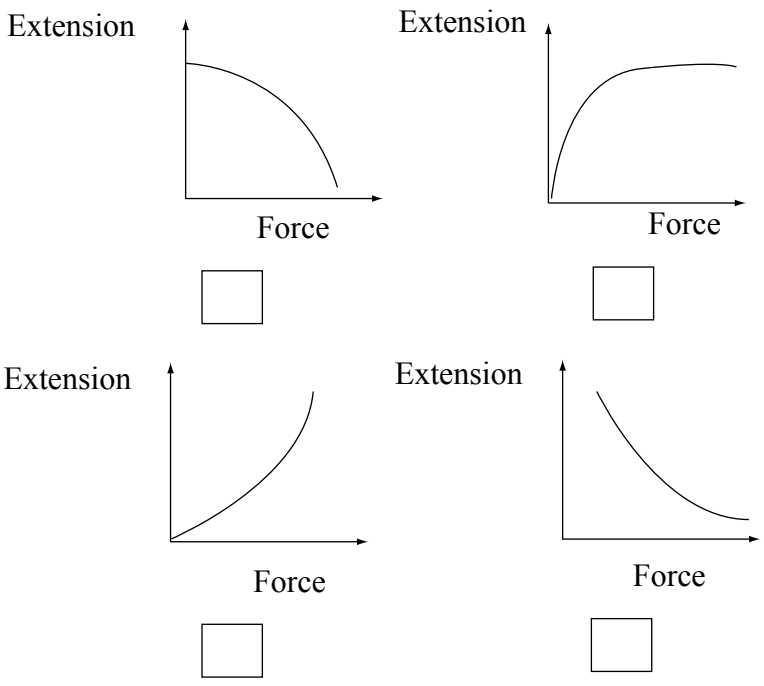
**Question 4 continues on the next page**

(c) The diagram shows part of the braking system of the bicycle.




The tyre and the inner tube are made from rubber. The wheel rim is made from steel.

(i) Which graph below shows the correct relationship between force and extension for rubber?
Tick the box below the correct answer.




*(1 mark)*

(ii) Write down **one** property of rubber that makes it suitable to use for bicycle tyres.

.....

*(1 mark)*

(iii) The steel wheel rim heats up when the brake blocks press against it. It is important that both the thermal expansivity and the thermal conductivity of the steel are not too great.

Write down the definition of *thermal expansivity*.

.....

.....

*(1 mark)*

(iv) Suggest **one** reason why it is important that the thermal expansivity is not too great.

.....

.....

*(1 mark)*

(v) Write down the definition of *thermal conductivity*.

.....

.....

*(1 mark)*

(vi) Suggest **one** reason why it is important that the thermal conductivity is not too great.

.....

.....

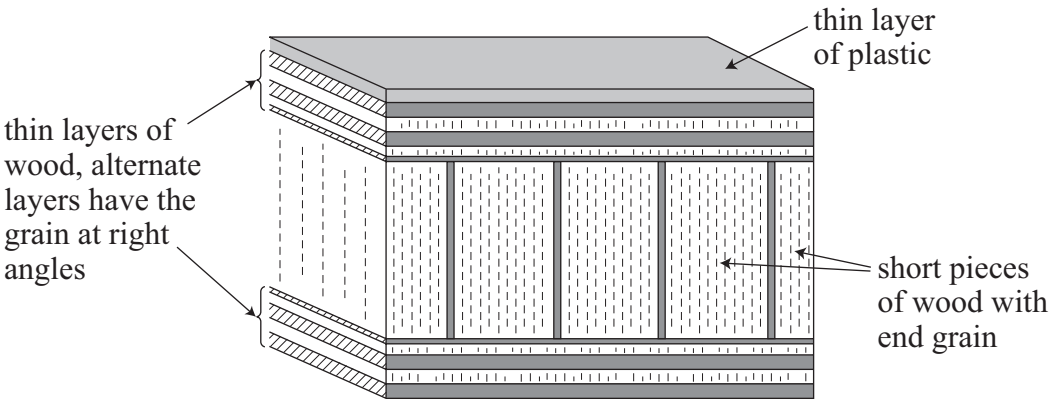
*(1 mark)*

21

**Turn over for the next question**

**5** A householder wants to fit a shelf.
A choice has to be made between using a solid wooden shelf or a shelf made from a composite material such as plywood or blockboard.

The diagram shows a section through a composite shelf made from blockboard.




(a) What is the meaning of the term *composite material*?

.....

.....

*(1 mark)*

(b) Suggest **two** reasons why the composite shelf might be better than the solid wooden shelf.

1 .....

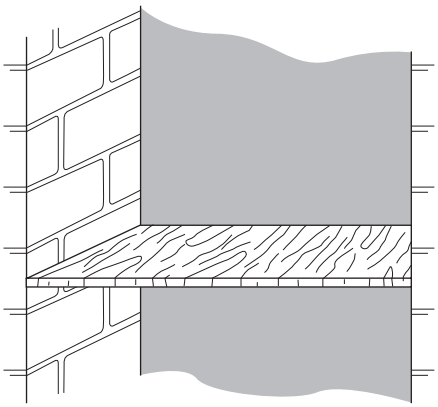
.....

2 .....

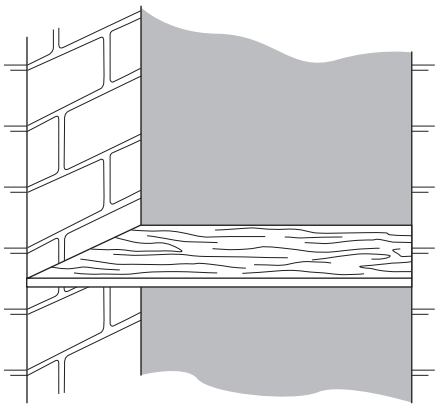
.....

*(2 marks)*

(c) The householder decides to use solid wood. Two different ways of using the wood are shown below.



**Method 1**



**Method 2**

Explain why **Method 2** will result in a stronger shelf than **Method 1**.

.....

.....

.....

*(1 mark)*

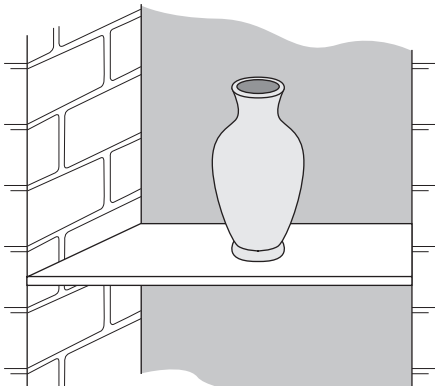
(d) When a load is placed on the shelf, some parts will be in compression and some parts will be in tension.
On the diagram below,

(i) draw an arrow labelled **C** to a part of the shelf that will be in compression,

*(1 mark)*

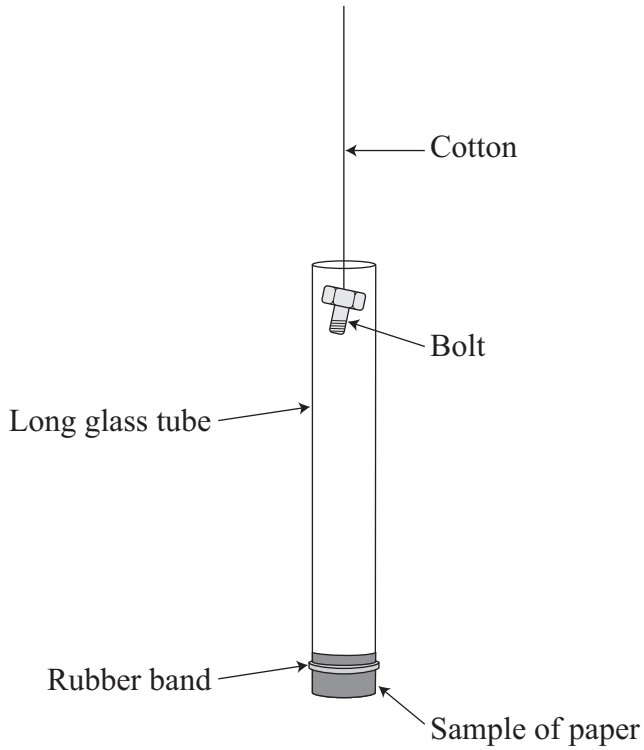
(ii) draw an arrow labelled **T** to a part of the shelf that will be in tension.

*(1 mark)*



6

**6** A shopkeeper wants to test several different makes of paper bag to find out which is the strongest.
She decides to test them using the equipment shown below.



Describe how the shopkeeper could use this equipment to test the strength of the paper, and produce useful results, to find out which paper is the strongest.

.....

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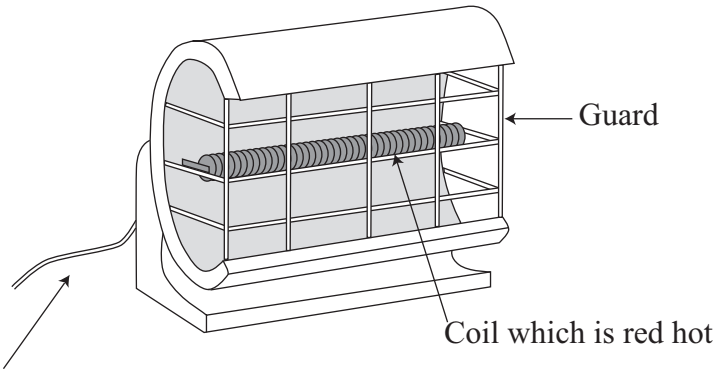
*(6 marks)*

6

**Turn over for the next question**

**7** The diagram shows an electric fire.




The manufacturer has four types of wire from which the coil could be made.

| Wire type | Melting point (°C) | Electrical conductivity | Thermal conductivity | Thermal expansivity | Ultimate tensile strength |
|---|---|---|---|---|---|
| **A** | 1083 | very low | very high | medium | medium |
| **B** | 98 | medium | very high | high | very low |
| **C** | 1512 | high | medium | low | high |
| **D** | 1550 | very high | low | low | high |

(a) Which type of wire, **A**, **B**, **C** or **D**, do you think the manufacturer should choose?

Wire type .....

Give and explain **two** reasons for your choice.

Reason 1 .....

.....

Explanation .....

.....

Reason 2 .....

.....

Explanation .....

.....

*(5 marks)*

(b) In what units is electrical conductivity measured?
Circle the correct answer.

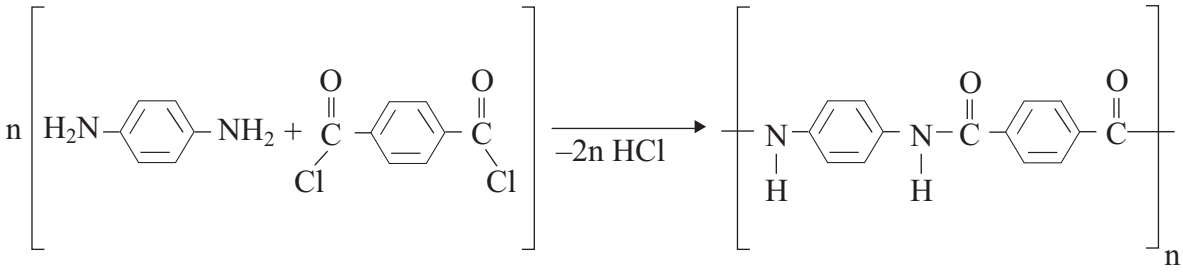
$\Omega m$ $\Omega m^{-1}$ $m\Omega^{-1}$ $\Omega^{-1}m^{-1}$ *(1 mark)*

**Use the information on this sheet to answer Question 8.**

## Full Liquid Jacket?

For centuries, metal armour has been used to protect soldiers from injury. The main problem is that it is heavy and inflexible. In 1965 the Dupont company invented Kevlar. This is a very light but strong fibre. The fibre has a very high strength-to-weight ratio (five times greater than that of steel) and is both heat and cut resistant. The fibres are resistant to water and acids, but decompose when exposed to alkalis or chlorine.

Kevlar is a polymer that is synthesised from two types of monomer. The diagram below shows this.




The polymer is spun into fibres and drawn so that the polymer chains lie parallel to each other.

Kevlar consists of long molecular chains with many interchain bonds that make it very strong. However it does have some weaknesses. Although it has great tensile strength, sometimes in excess of 4 GPa, like all fibres it tends to buckle in compression. Also, unless specially treated, its ability to stop bullets and knife penetration is much reduced when wet.

**Shear Thickening Fluids (STFs)**

The viscosity of a fluid is a measure of how easily it flows. Most fluids have a more or less constant viscosity when they are stirred. With shear thickening fluids, the apparent viscosity increases with the rate of shear, making it more resistant to flow.

A typical STF is made by suspending hard particles (nanoparticles of silica) in a non-evaporating fluid such as polyethylene glycol. The STF flows like a liquid under low-energy conditions, but under a high-energy impact it stiffens and behaves like a solid. This temporary stiffening occurs within a millisecond of the impact and is caused by the nanoparticles locking the liquid particles together.

An STF can be soaked into the Kevlar fibres. When the liquid stiffens after a blow, the energy of the impact is distributed over a much larger surface area. Bulletproof jackets made of Kevlar soaked with STF provide improved protection and more flexibility than traditional armour.

**There are no questions printed on this page**

**Use the information on page 17 to answer the questions that follow.**

**8** (a) Kevlar is described as having a very high strength-to-weight ratio.

(i) Explain the meaning of the term *strength-to-weight ratio*.

.....

.....

*(1 mark)*

(ii) Why is it an advantage to have a high strength-to-weight ratio?

.....

.....

*(1 mark)*

(iii) Give **one** advantage of Kevlar compared with steel, other than the high strength-to-weight ratio.

.....

.....

*(1 mark)*

(b) Use the diagram on **page 17** to answer these questions.

(i) What type of bond joins the carbon atoms to the oxygen atoms?

.....

.....

*(2 marks)*

(ii) Explain how the two monomers join together to form the polymer.

.....

.....

.....

*(3 marks)*

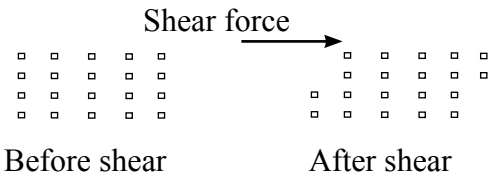
(iii) What type of bonding will occur between the parallel polymer chains? Circle the correct answer.

**Covalent** **Ionic** **Metallic** **Weak**

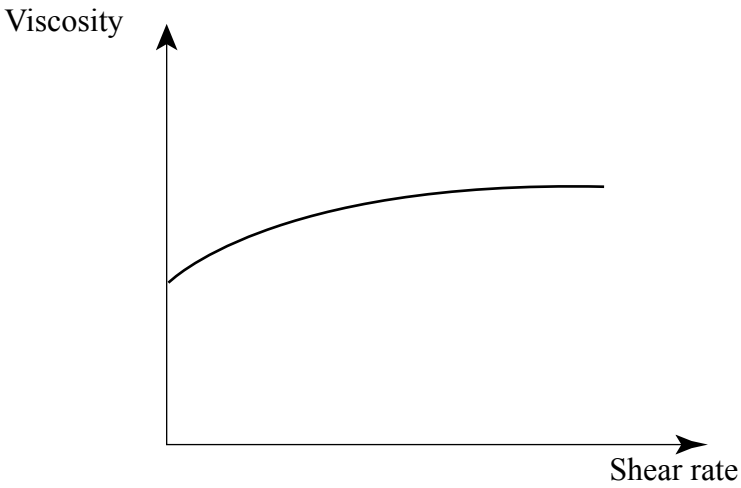
*(1 mark)*

**Question 8 continues on page 20**

(c) A shearing force is one in which the layers of atoms are made to slide across each other.




The rate at which shearing occurs in a fluid can affect its viscosity.
The graph below shows how the viscosity of a normal fluid varies with shear rate.




Draw a line on the graph to show how a shear thickening fluid (STF) would behave.

*(1 mark)*

(d) Using the idea of pressure, explain how an STF can help reduce injury from bullet or knife wounds.

.....

.....

.....

.....

*(2 marks)*

(e) Other than increased protection from bullet and knife wounds, suggest **one** reason why a Kevlar/STF jacket is an improvement on steel armour.

.....

.....

*(1 mark)*

13

**END OF QUESTIONS**