Surname		Other Names	
Centre Number			Candidate Number				
Candidate Signature									

For Examiner's Use

General Certificate of Education
January 2007
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Friday 19 January 2007 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 19 and 20 are perforated. Detach these pages and use the information to answer Question 6.

Information
- The maximum mark for this paper is 80.
- The marks for 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			
4			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

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

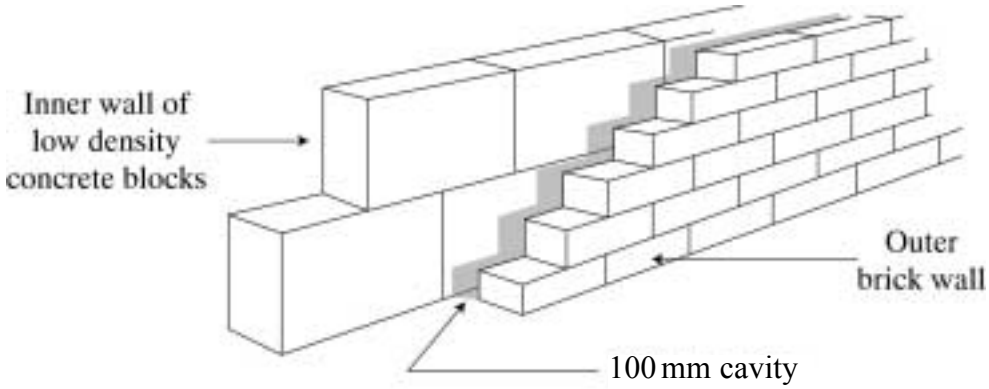
1 Many different materials are used in the construction industry. The table below gives some information about building materials.

Use the information from the table and the diagram to answer the questions that follow.

Material	**Strength in compression ($MN\,m^{-2}$)**	**Strength in tension and bending ($MN\,m^{-2}$)**	**Density ($kg\,m^{-3}$)**	**Thermal conductivity ($W\,m^{-1}\,K^{-1}$)**
Bricks (for load-bearing walls)	60	Depends on joints	1800	1.0
Low density concrete blocks (for inner walls)	6	Depends on joints	600	0.4
Plain concrete	30	Cracks unless reinforced	2400	1.5
Hardwood (oak)	20	25	700	0.2
Mild steel	200	2500	7000	60

1 MN = one million newton

The diagram below shows part of a cavity wall of a house.



(a) Give and explain **two** reasons why it is better to build the inner wall from concrete blocks rather than from bricks.

Reason 1 .....

Explanation .....

.....

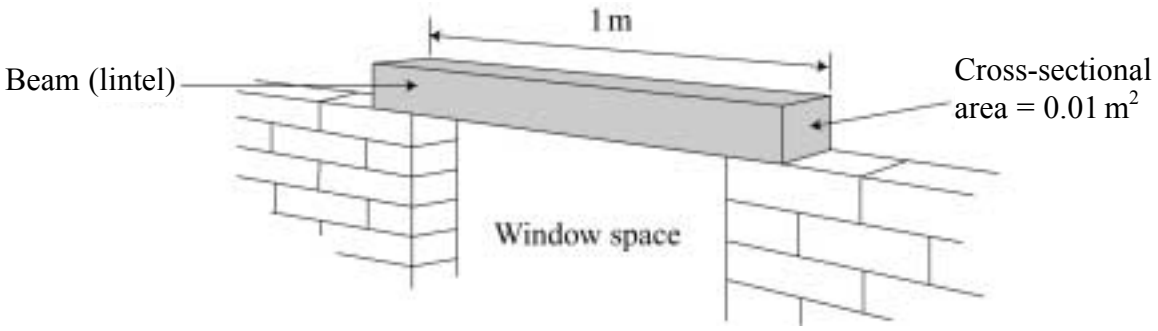
Reason 2 .....

Explanation .....

.....

(4 marks)

(b) The diagram below shows a beam that is to be used as a lintel for a window in the wall.



(i) Calculate the volume of the beam.

.....

.....

Volume =.....m^3

(1 mark)

(ii) What would be the mass of the beam if it were made of oak?
Show your working.

.....

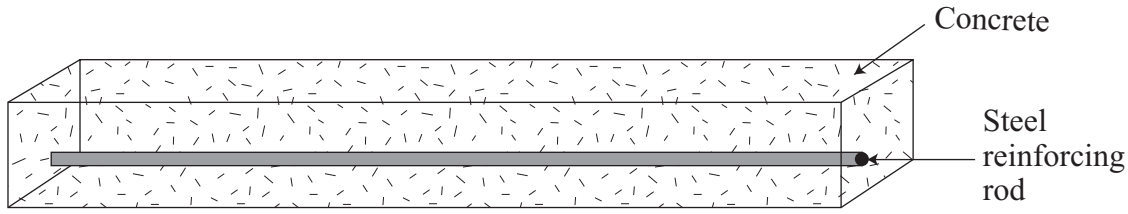
.....

Mass = ...kg

(2 marks)

Question 1 continues on the next page

(c) The builder decides not to use oak for the lintel. He decides to use a reinforced concrete beam, like the one shown below.



(i) When the lintel is in position, as shown in the diagram on **page 3**, part of the lintel will be in compression and part of the lintel will be in tension.

Draw on the diagram above an arrow labelled **C** pointing to a part of the beam that will be in compression, and draw an arrow labelled **T** pointing to a part of the beam that will be in tension. *(2 marks)*

(ii) Why does the concrete beam need to be reinforced with steel?

.....

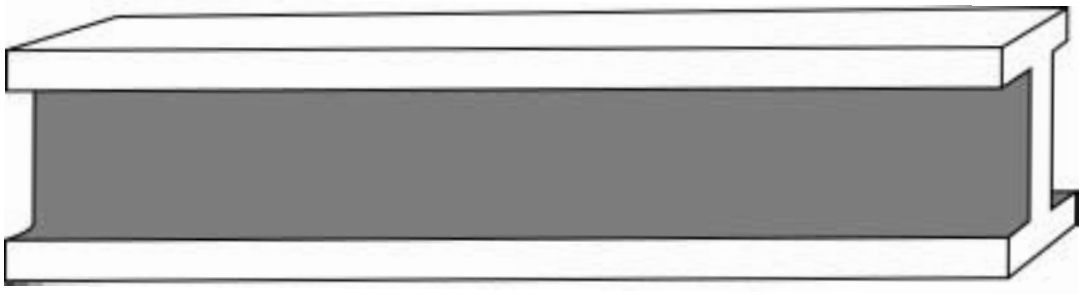
(1 mark)

(iii) Why is the steel reinforcing rod placed in the lower part of the concrete beam rather than in the upper part?

.....

(1 mark)

(iv) An alternative to using either a hardwood oak beam or a reinforced concrete beam is to use a steel beam like the one shown below.



Why does the steel beam have an I-section, rather than a rectangular section like the others?

.....

(1 mark)

(d) A load-bearing pillar needs to support a maximum compression force of 100 000 newtons.

Complete the table below to show

(i) the minimum cross-sectional area that the pillar must have if it were to be made from hardwood (oak)
Assume that the strength in compression of oak is 20 MN m^{-2}. *(1 mark)*

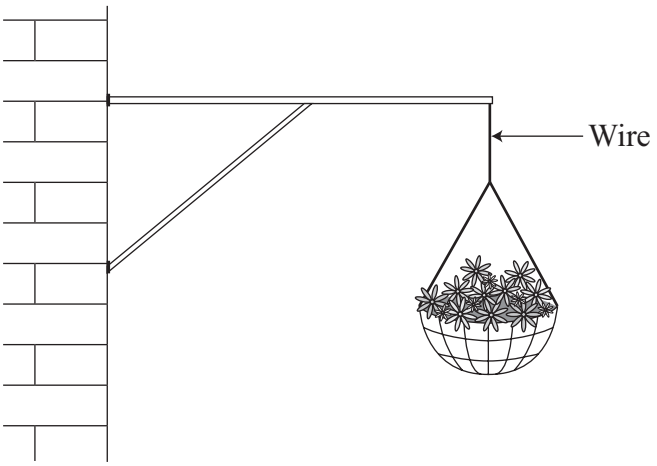
(ii) the advantages and disadvantages of using each of the three types of material for the pillar.

Material	**Minimum cross-sectional area (m^2)**	**Advantage**	**Disadvantage**
Plain concrete	0.0033	....	....
Hardwood (oak)	.....	....	....
Mild steel	0.0005	....	....

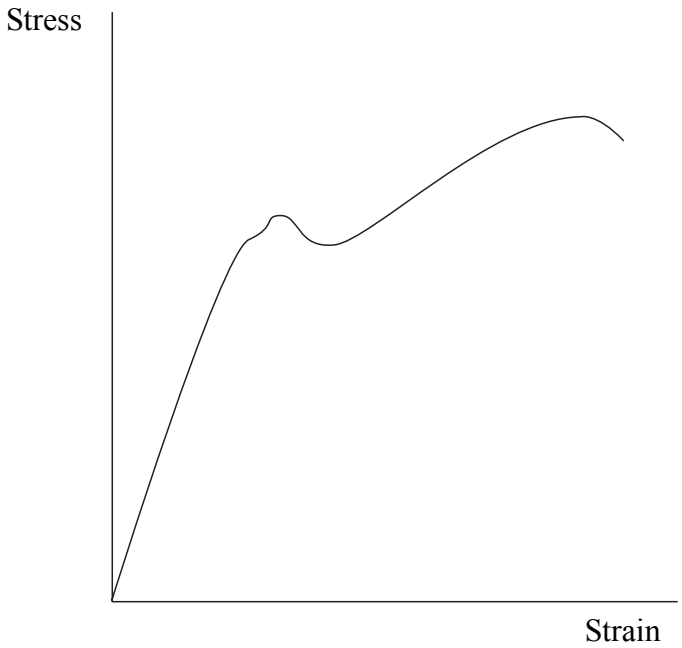
(6 marks)

19

2 A manufacturer of hanging baskets needs to select a suitable steel wire to supply with the basket.



The wire manufacturer has supplied some information about the stress–strain characteristics for the proposed wire.
The graph below gives some information about the wire.



(a) Give a definition of

(i) stress .....

.....

(1 mark)

(ii) strain .....

.....

(1 mark)

(b) How can the values of stress and strain be used to calculate the Young modulus of the wire?

.....

(1 mark)

(c) Label the following points on the graph on **page 6**.

(i) An arrow labelled **E** to show the region where the wire is behaving elastically. *(1 mark)*

(ii) An arrow labelled **P** to show the region where the wire is showing plastic behaviour. *(1 mark)*

(iii) An arrow labelled **Y** to indicate the yield point. *(1 mark)*

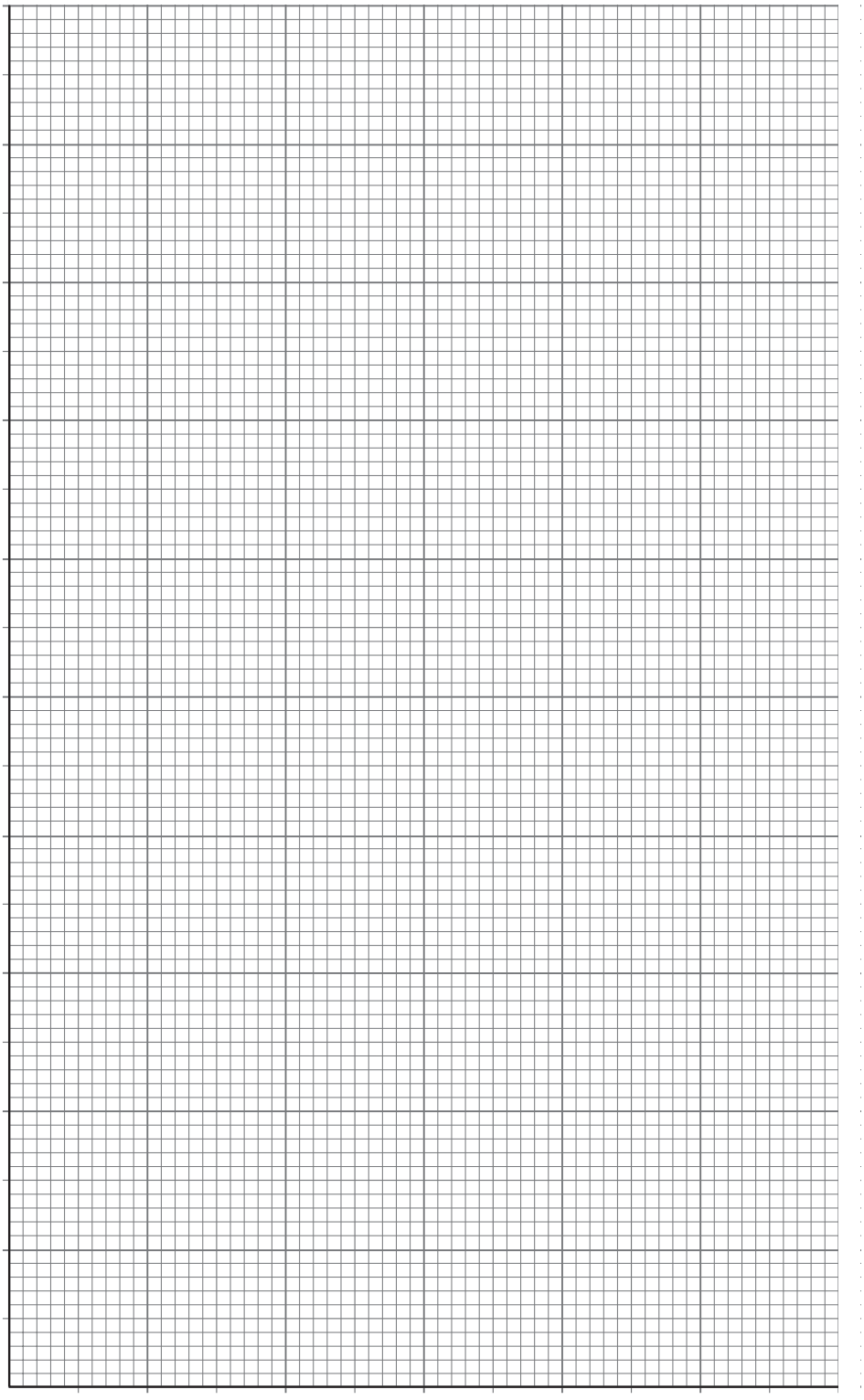
Question 2 continues on the next page

(d) The table below shows the values of stress and strain for a sample of the wire.

Stress/MN m^{-2}	10	15	20	25	30	35	40
Strain × 10^{-4}	5.0	7.5	10.0	12.5	15.0	18.0	25.0

(i) Plot the data from the table above onto the grid below, and then draw a line of best fit. *(4 marks)*

Stress



Strain

(ii) Label the elastic limit on your graph on **page 8**. *(1 mark)*

(iii) Use your graph to answer this question.
The manufacturer does not want the strain to exceed 10×10^{-4}.
What is the minimum cross-sectional area of the wire if it needs to support a load of 50 N?

.....

.....

.....

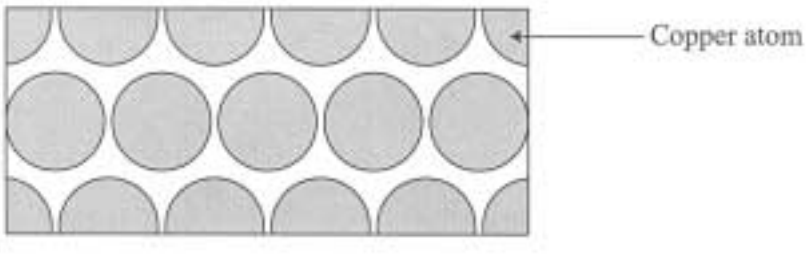
.....

Cross-sectional area = ...
(3 marks)

14

Turn over for the next question

3 Metallurgists need to know the internal structure of materials in order to understand their strengths and weaknesses.
The diagram shows the arrangement of atoms in a sample of pure copper.

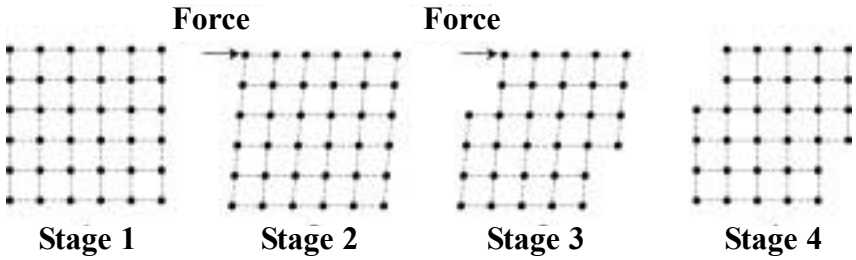


(a) What type of bonding holds these atoms together?

.....

(1 mark)

(b) If a shearing force is applied, these atoms can slip. This is shown in the diagram below.



In the table below, use the numbers **1** to **4** to identify the correct labels for each stage.

Label	Stage number
Stress applied and yielding occurring	
Stress applied and elastic strain produced	
Stress removed leaving permanent deformation	
No stress applied	

(2 marks)

(c) This slip of the copper atoms can be reduced by adding tin atoms to make an alloy.

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

.....

(1 mark)

(ii) In the space below, draw a diagram to show the arrangement of atoms in an alloy of copper and tin. Label the different kinds of atom.

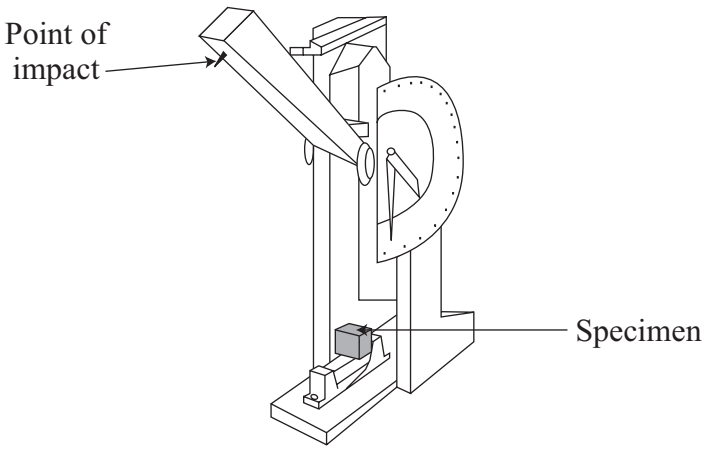
(1 mark)

(iii) Alloying can make copper harder.
In what other way could copper be treated to make it harder?

.....

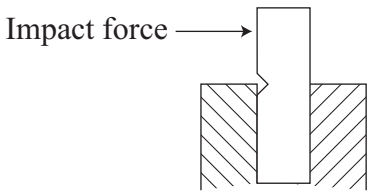
(1 mark)

(d) The diagram below shows a piece of equipment for testing the strength of materials.



The specimen is tightly clamped in position. A heavy mass is fixed to the end of the arm (labelled 'Point of impact'). The arm is released and swings down to hit the specimen.

The specimen has a notch cut into it.



Question 3 continues on the next page

The equipment shown in the diagram on **page 11** can be used to test brittleness.

(i) Explain the meaning of the term *brittleness*.

.....

(1 mark)

(ii) The notch is placed in the material in order to provide a stress concentration zone.

Explain, using the term *force* and by referring to the arrangement of atoms in the material, why the sample is most likely to fracture at the notch.

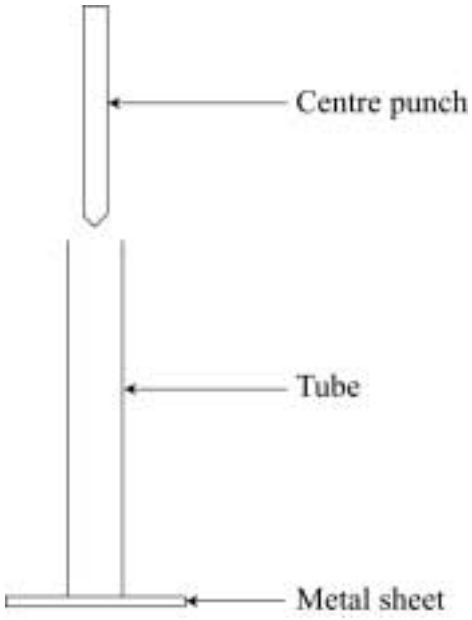
.....

.....

.....

(2 marks)

(e) A simple way to test resistance to denting is to use a centre punch. The centre punch falls down a tube onto a sheet of the metal being tested.



Describe how you would use this equipment to compare the resistance to denting of two samples of metal.

Make clear

- what measurements you would need to take
- the instruments that you would use to make these measurements
- how you would ensure that it is a fair test
- how the results would enable you to judge which sample had the higher resistance to denting.

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(7 marks)

16

4 Sports equipment manufacturers need to have a good understanding of the properties of materials when designing their sports equipment.
The frames of tennis racquets may be made from many different materials.

The list below shows some of the most common materials used.

- Aluminium
- Carbon fibre composite
- Fibreglass
- Titanium alloy
- Wood

(a) Give **two** physical properties that you think would be important to consider when selecting a material for the construction of the frame of a tennis racquet.

Property 1 .....

.....

Property 2 .....

.....

(2 marks)

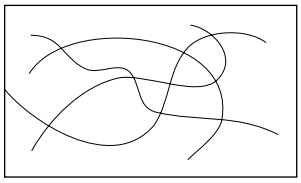
(b) Write down **one** factor, other than a physical property, that should also be taken into account.

.....

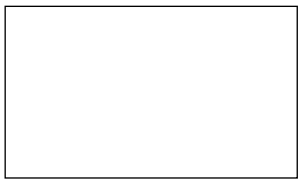
(1 mark)

(c) The strings of a tennis racquet can be made from nylon that has been cold drawn. The diagram on the left below shows the nylon polymer molecules before cold drawing.

(i) Draw a diagram in the right-hand box to show the arrangement of the nylon polymer molecules after cold drawing.



Before cold drawing



After cold drawing

(1 mark)

(ii) How does cold drawing make the nylon more suitable for use as tennis racquet strings?

.....

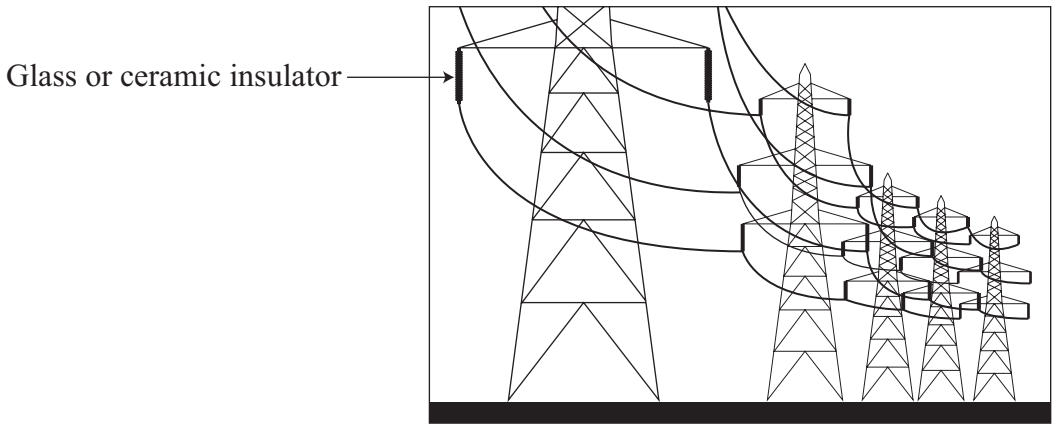
.....

(1 mark)

5

Turn over for the next question

5 The diagram shows cables suspended from pylons. The cables are attached to the pylons using glass or ceramic insulators.



(a) Glass is sometimes called an amorphous ceramic.

(i) What does the word *amorphous* tell you about its internal structure?

.....

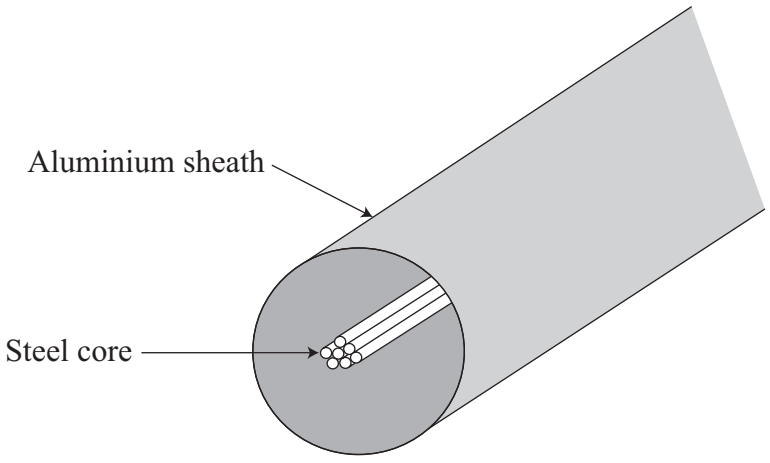
(1 mark)

(ii) Name **one** type of ceramic material, other than glass.

.....

(1 mark)

(b) The cables are made from an inner core of steel, which is then clad with aluminium.



The table below shows some properties of the two metals.

Material	Density ($kg\,m^{-3}$)	Tensile strength ($MN\,m^{-2}$)	Electrical conductivity (S)	Cost per kg (£)
Aluminium	2700	100	3700	2.00
Steel	7800	2500	1000	0.20

(i) To measure the electrical conductivity of a sample of aluminium, an engineer measures its electrical resistance.

What **two** other measurements of the sample must the engineer take in order to calculate the electrical conductivity?

Tick the box beside the correct answer.

Cross-sectional area and density ☐

Cross-sectional area and the Young modulus ☐

Length and cross-sectional area ☐

Length and density ☐

(1 mark)

(ii) Use data from the table above to explain why

the cable is **not** made entirely from steel,

.....

.....

.....

the cable is **not** made entirely from aluminium.

.....

.....

.....

(4 marks)

Question 5 continues on the next page

(iii) When choosing a material for the overhead cables, the thermal expansivity also needs to be taken into account.

What is the meaning of the term *thermal expansivity*?

.....

Why is it important in this situation?

.....

(2 marks)

9

Use the information printed on this sheet to answer Question 6.

Many manufacturers use composite materials for their goods. They need to understand how the internal structure of these materials affects their properties. One type of composite material consists of a plastic matrix in which fibres are embedded.

Read the article below and then use it to answer the questions that follow.

Fibre-reinforced plastics
Fibre-reinforced plastics are composite materials consisting of a plastic matrix with fibres embedded to give added strength. Some are high performance composites, such as carbon fibre-reinforced plastics, CFRP. Continuous-aligned fibres give them high stiffness and strength but they are expensive, both for raw materials and manufacture. Others are materials such as sheet moulding compounds or glass mat thermoplastics that contain non-aligned short fibres and fillers. These are cheaper and easier to fabricate, but are not as strong.

The matrix
There are two types of matrix polymers.
- *Thermosetting*, in which an irreversible chemical cross-linking reaction causes a liquid to solidify. The presence of double bonds makes the substance unsaturated.
- *Thermoplastics*, which can be shaped by the reversible physical processes of melting and freezing.

Thermosetting matrix
Unsaturated polyester resins are often used, as they will set at room temperature. This allows objects to be made that would be too large to put into an oven to set. They consist of low molecular weight unsaturated polyester dissolved in styrene.

In setting, the styrene polymerises and forms cross-links across unsaturated sites in the polyester. This reaction is strongly exothermic, and so can affect processing rates as excessive heat could damage the final product. Shrinking while setting can also be a problem. A good degree of chemical resistance gives them a wide range of applications.

Thermoplastic matrix
Thermoplastic resins, such as polysulphone, are different from thermosets. They do not undergo irreversible cross-linking reactions, but instead melt and flow on application of heat and pressure.

The main advantages of thermoplastics over thermosets are indefinite shelf-life, good toughness and the fact that processing is concerned with physical transformations only. No chemical reactions are involved and therefore lengthy setting processes are not necessary. This can lead to rapid, low cost manufacture with simplified quality control procedures. However the temperatures needed for processing can be high, meaning that expensive equipment is often needed, particularly where complex shapes are required.

Fibres
Fibres make up the bulk of most composite systems. They should be in positions and orientations so that they are able to contribute efficiently to load-carrying capability.

Glass fibres
When glass is drawn into fine fibres its strength increases markedly over that of bulk glass. Glass fibres account for around 90% of the reinforcement used in structural reinforced plastic applications.

Carbon fibres
Carbon fibres combine low density with high strength and high stiffness, and have a curved stress–strain graph. All fibre types show a marked rise in stiffness with increasing strain.

There are no questions printed on this page

6 (a) Explain the meaning of the following terms used in the article.

(i) *Composite* material

.....

(1 mark)

(ii) *Stiffness*

.....

(1 mark)

(iii) *Strength*

.....

(1 mark)

(b) What is the main difference between a *thermoplastic* and a *thermosetting* plastic?

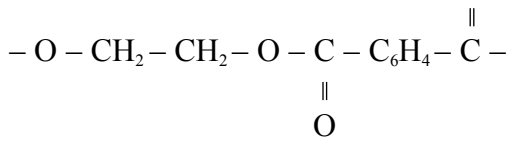
.....

.....

.....

(1 mark)

(c) A section of a polyester molecule is shown below.



(i) What type of bonding in polyester is represented by

C – O

.....

C = O?

.....

(3 marks)

(ii) Explain how this C = O feature of a polyester molecule enables polyesters to be made into thermosetting plastics.

.....

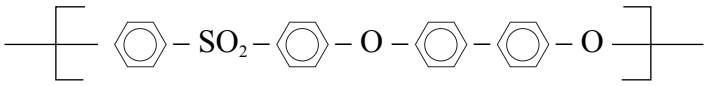
.....

.....

(2 marks)

Question 6 continues on the next page

(iii) The structure of polysulphone is



State why polysulphone can only form a thermoplastic rather than a thermosetting plastic.

.....

.....

(1 mark)

(d) Use information from the article on **page 19** to suggest

(i) **one** advantage of using a thermoplastic rather than a thermosetting plastic

.....

(1 mark)

(ii) **one** advantage of using a thermosetting plastic rather than a thermoplastic.

.....

(1 mark)

(e) What is the purpose of incorporating fibres into the matrix?

.....

(1 mark)

(f) On the axes below sketch a graph to show how the Young modulus would vary with strain for a carbon fibre.

(1 mark)

(g) A manufacturer wishes to mass-produce sterilising trays for the medical profession. The choice is between using polysulphone or carbon fibre-reinforced polyester.

Which would be the better choice? Explain the reason for your answer.

.....

.....

.....

.....

(3 marks)

17

END OF QUESTIONS

There are no questions printed on this page