Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
January 2009
Advanced Subsidiary Examination

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

Friday 16 January 2009 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 black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show the working of your calculations.

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			
4			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

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SC05

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

1 Materials used in construction and in manufacturing products can be grouped into five main types: *metals*, *ceramics*, *polymers*, *glasses* and *composites*. Some of the properties of three of these types are shown.

Draw a line from each properties box to the **one** type of material the properties describe. Then link the type of material chosen to **one** correct example.

Properties	**Type of material**	**Example**
Often strong for their mass Often flexible Soft and easily scratched Transparent or translucent	Metal	Pottery
Strong in tension and compression Often hard, stiff and tough Ductile	Composite	Aluminium
Strong in compression Weak in tension Very hard Brittle Heat resistant	Ceramic	Perspex
	Glass	Bone
	Polymer	

(6 marks)

6

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2 (a) Most metals in everyday use are used as alloys.
Why are pure metals seldom used in construction?

....

....
(1 mark)

2 (b) Steel is a widely used alloy. In its basic form it is iron mixed with carbon. The table shows how the properties of steel change as the percentage of carbon changes.

Type of steel	**Percentage of carbon (%)**	**Properties**
Low carbon	0.1 – 0.25	Easily cold worked
Medium carbon	0.25 – 0.5	Wear resistant
High carbon	0.5 – 1.5	Strong and wear resistant
Cast iron	2.5 – 4.0	Easy to mould into complicated shapes but brittle

Which type of steel would be most suitable for making

railway lines ....

engine blocks..

paper clips?..
(3 marks)

2 (c) The addition of small amounts of other metals to make steel alloys can change the properties of the steel further.

Metal added	**Properties given to the steel**
Cobalt	High magnetic permeability
Molybdenum	Maintains high strength at high temperature
Nickel and chromium	Resists corrosion
Tungsten	High melting temperature, tough
Vanadium	Strong and hard

Which of the metals in the first column of the table might be found in steel alloys used to make

chisels ....

surgical instruments ....

magnets?..
(3 marks)

Question 2 continues on the next page

Turn over ▸

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2 (d) Some types of steel are used specifically for making large structures.
They are called high-strength-low-alloy or HSLA steels.
HSLA steels are much stronger and tougher than carbon steels, which means that structures can be built that contain less steel.
These structures are lighter than they otherwise would be.

2 (d) (i) Suggest why this is an important feature for

large trucks ....

....

the design of bridges. ....

....

(2 marks)

2 (d) (ii) HSLA steels are highly ductile. What does the term *ductile* mean?

....

....

(1 mark)

The picture below shows the Angel of the North sculpture.
The sculpture is made from a type of HSLA steel.
The sculpture is exposed to the atmosphere in its bare condition.

Areas outside the box will not be scanned for marking

2 (d) (iii) The Angel of the North sculpture does not need to be painted. Suggest a reason why.

....

....

(1 mark)

2 (e) Stainless steel is much more resistant to corrosion than other steels.
Stainless steel contains at least 4% of the metal chromium.
As well as its resistance to corrosion, stainless steel has advantages such as strength and aesthetic appeal.
Suggest a reason why stainless steel is not used more widely.

....

....

(1 mark)

Question 2 continues on the next page

Turn over ▸

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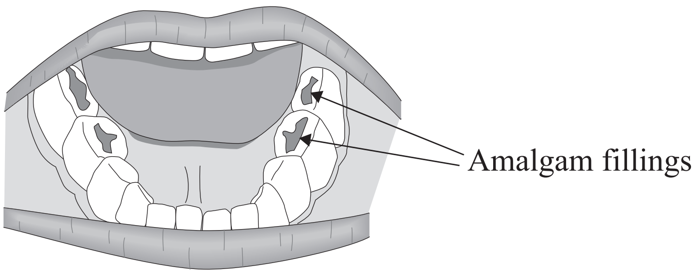
2 (f) One type of filling used in dentistry is made of an alloy containing mercury. This alloy is called amalgam.



2 (f) (i) Amalgam is hard and strong. Why is this an advantage?

....

....
(1 mark)

2 (f) (ii) Like all metals, amalgam conducts heat well. Why is this a disadvantage?

....

....
(1 mark)

2 (f) (iii) Teeth fillings must have a similar thermal expansivity to that of natural teeth. Suggest a reason why this is useful.

....

....
(1 mark)

15

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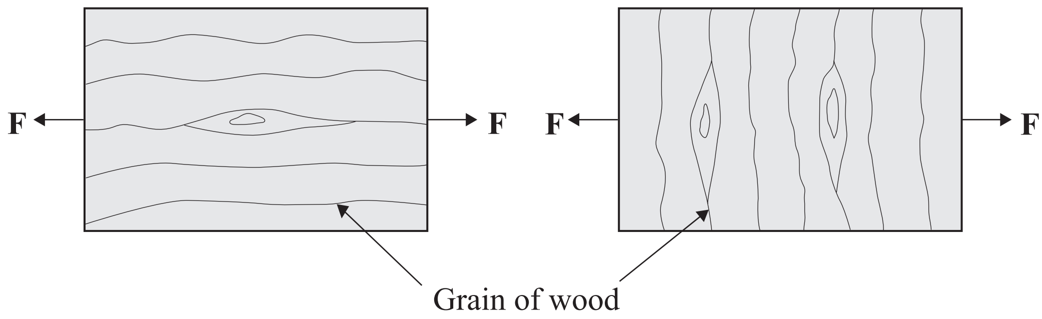
3 This question is about composite materials.

3 (a) Wood is a natural composite. The diagrams show pieces of wood subjected to tensile forces **F**.

Diagram A **Diagram B**



Which diagram shows the situation where the wood is more likely to split?
Explain your answer.

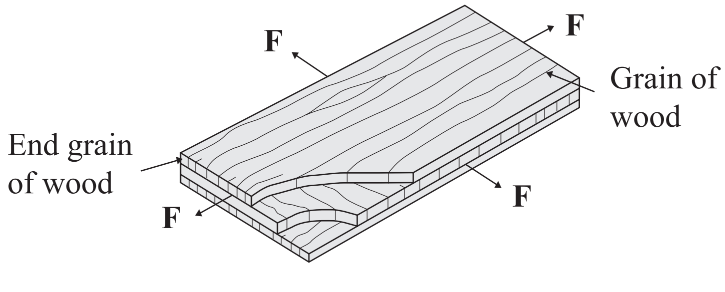
Diagram ....

Explanation ....

....

(1 mark)

3 (b) Plywood is a laminated composite. It is made by gluing thin sheets of wood together.



Plywood is equally strong in both directions. Explain why.

....

....

(1 mark)

3 (c) Chipboard is a fibre composite. It consists of wood chips glued together.
The packing of the wood chips is random. Explain why chipboard is equally strong in all directions.

....

....

Question 3 continues on next page *(1 mark)*

Turn over ▸

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3 (d) Glass reinforced plastic (GRP) is also a fibre composite.
Suggest **two** reasons, other than cost, why many small boats are now made from GRP instead of wood.

Reason 1 ....

....

Reason 2 ....

....

(2 marks)

3 (e) The data in the table shows how the tensile strength of GRP changes with the percentage of glass fibre in the mixture.

Percentage of glass fibre (%)	**Tensile strength (MPa)**
10	122
30	144
50	176
70	220
80	245

3 (e) (i) Plot the data on the grid on **page 9**.
Plot percentage of glass fibre on the *x*-axis and tensile strength on the *y*-axis.
Label the axes, add appropriate units and draw a line of best fit. *(4 marks)*

3 (e) (ii) Describe the trend shown in the graph.

....

....

(1 mark)

3 (e) (iii) Use the graph to determine the tensile strength of the plastic used to make the composite mixture.

Tensile strength = ... MPa. *(1 mark)*

Question 3 continues on page 10

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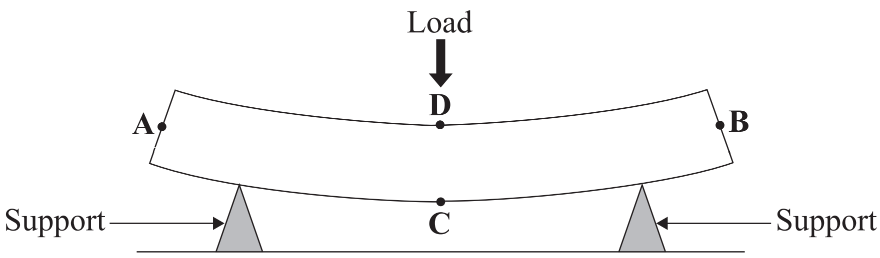
3 (f) Concrete is a composite.
The diagram shows a concrete beam on two supports.



3 (f) (i) Which of the points (**A**, **B**, **C** or **D**) shows a part of the beam which is in compression?

Point .... *(1 mark)*

3 (f) (ii) The concrete beam is reinforced with a steel rod. On the diagram draw a line to show the best position for the steel rod. *(1 mark)*

13

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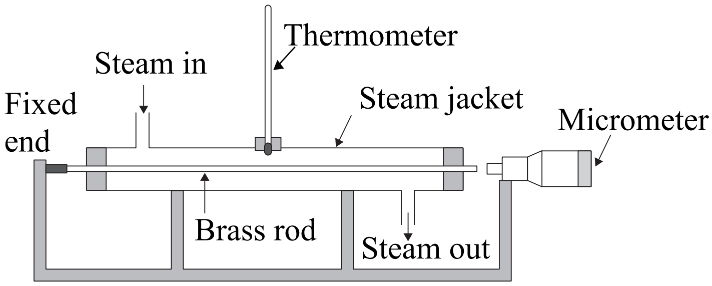
4 Substances expand when they are heated. The expansion of different substances can be compared by looking at their coefficients of linear expansion.
The coefficient of linear expansion of a substance is the fraction of its original length by which a rod of the substance expands per degree rise in temperature.

The diagram shows apparatus which can be used to determine the coefficient of linear expansion of brass.



Method:

- The length of the brass rod is measured using a metre rule.
- The rod is then placed in the steam jacket between a fixed end and a micrometer.
- The rod is pushed tightly against the fixed end and the micrometer is turned until it touches the rod. The micrometer reading and the thermometer reading are recorded.
- The micrometer is then unscrewed several turns, and steam is passed through the jacket.
- Once steam has been emerging from the jacket for several minutes, the micrometer is again turned so it touches the rod and its new reading taken.
- As a precaution, the micrometer is unscrewed again and the steam flow continued for a further few minutes. The micrometer reading and the thermometer reading are taken again.

4 (a) Why is the final micrometer reading repeated?

....

....
(1 mark)

4 (b) Between readings, the micrometer is unscrewed a few turns. Why is this necessary?

....

....
(1 mark)

Question 4 continues on the next page

Areas outside the box will not be scanned for marking

4 (c) A set of results for this experiment is given below.

Initial temperature of brass rod	= 16.4 °C
Final temperature of brass rod	= 99.3 °C
Original length of brass rod	= 50.2 cm
Initial micrometer reading	= 4.15 mm
Final micrometer reading	= 3.36 mm

4 (c) (i) Calculate the rise in temperature of the brass rod.

....

(1 mark)

4 (c) (ii) Calculate the expansion of the brass rod.

....

(1 mark)

4 (c) (iii) The coefficient of linear expansion can be calculated using the formula

$$\text{coefficient} = \frac{\text{expansion}}{\text{original length} \times \text{rise in temperature}}$$

Calculate the coefficient of linear expansion for brass.

....

....

....

....

Answer =.................$°C^{-1}$

(2 marks)

4 (d) The expansion of the brass rod is measured to the nearest 0.01 mm using the micrometer.
However, the original length of the rod is measured with a metre rule to the nearest 1 mm. Why is this acceptable?

....

....

(1 mark)

Areas outside the box will not be scanned for marking

4 (e) (i) The coefficient of linear expansion for steel is 0.000012 $°C^{-1}$. By how much will a 1 m length of steel expand if its temperature increases by 1°C?

....

....

(1 mark)

4 (e) (ii) By how much will a 1000 m length of steel expand if its temperature increases by 1 °C?

....

....

(1 mark)

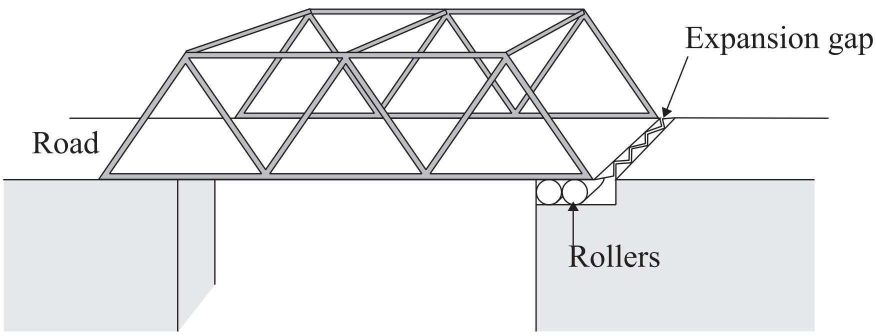
4 (e) (iii) A steel bridge is 1000 m long. Its length is measured when the temperature is 5 °C and again when the temperature is 25 °C. By how much will the bridge expand between these temperatures?

....

....

(1 mark)

4 (e) (iv) The diagram shows how the bridge is built to allow for changes in temperature.



Explain how this bridge design works.

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(3 marks)

Question 4 continues on the next page

Turn over ▸

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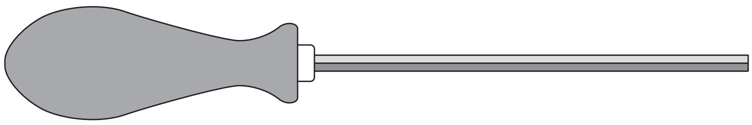
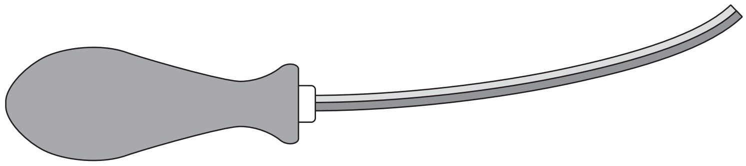
4 (f) The diagram shows a bimetallic strip made of copper and iron.



The coefficients of linear expansion for iron and copper are:

iron	0.000013 °C^{-1}
copper	0.000017 °C^{-1}

When the bimetallic strip is heated it bends as shown below.



Label the copper and iron on the second diagram. *(1 mark)*

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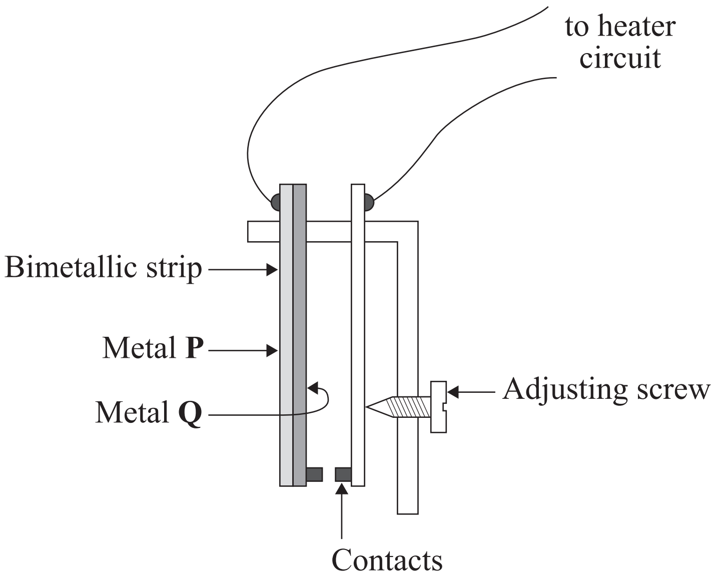
4 (g) The diagram shows a bimetallic strip being used in a thermostat. The thermostat controls the heater in a fish tank.
When the temperature of the water in the tank falls to 25 °C the contacts close to switch on the heater.



4 (g) (i) The coefficients of linear expansion of four metals are:

iron	0.000013 $°C^{-1}$	copper	0.000017 $°C^{-1}$
platinum	0.000009 $°C^{-1}$	aluminium	0.000024 $°C^{-1}$

To make the thermostat as sensitive as possible, which of these metals should be used for **P** and **Q**?

P .... **Q** ....

(2 marks)

4 (g) (ii) How would the thermostat be adjusted if it were required to switch on the heater at a temperature of 22 °C?

....

....

(1 mark)

17

Turn over ▸

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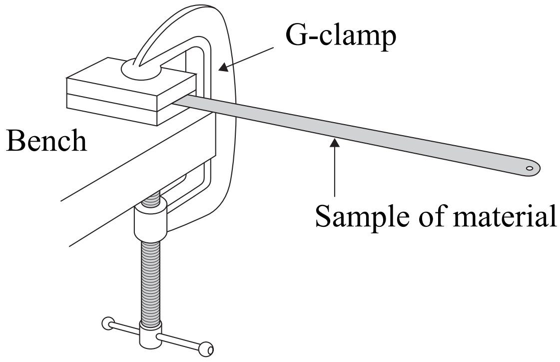
5 A technician is asked to compare the stiffness of three different materials. The equipment available to her is as follows:

samples of materials, G-clamp, needle, stand and clamp, metre rule, mass holder, slotted masses (of varying mass), sticky tape and string.

The diagram shows how she began her experiment.



5 (a) (i) Describe how she could continue the experiment, using the remaining equipment, to compare the stiffness of the three samples of different materials which each have the same length, width and thickness.

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(7 marks)

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5 (a) (ii) How could she ensure that her experiment was reliable?

....

....

....

....

(2 marks)

5 (a) (iii) How would she use her results to decide which material was the stiffest?

....

....

(1 mark)

5 (b) Using measurements of stress and strain, the stiffness of different materials can be compared by calculating the Young modulus.
If a material has a large value of the Young modulus what does this tell you about its stiffness?

....

....

(1 mark)

5 (c) The Young modulus for mild steel is $2.1 \times 10^{11}\,\mathrm{N\,m^{-2}}$.
When the same force is applied to samples of mild steel and copper which have the same dimensions, the copper stretches three times more than the steel.
What is the value of the Young modulus for copper?

....

....

(1 mark)

Question 5 continues on the next page

Turn over ▸

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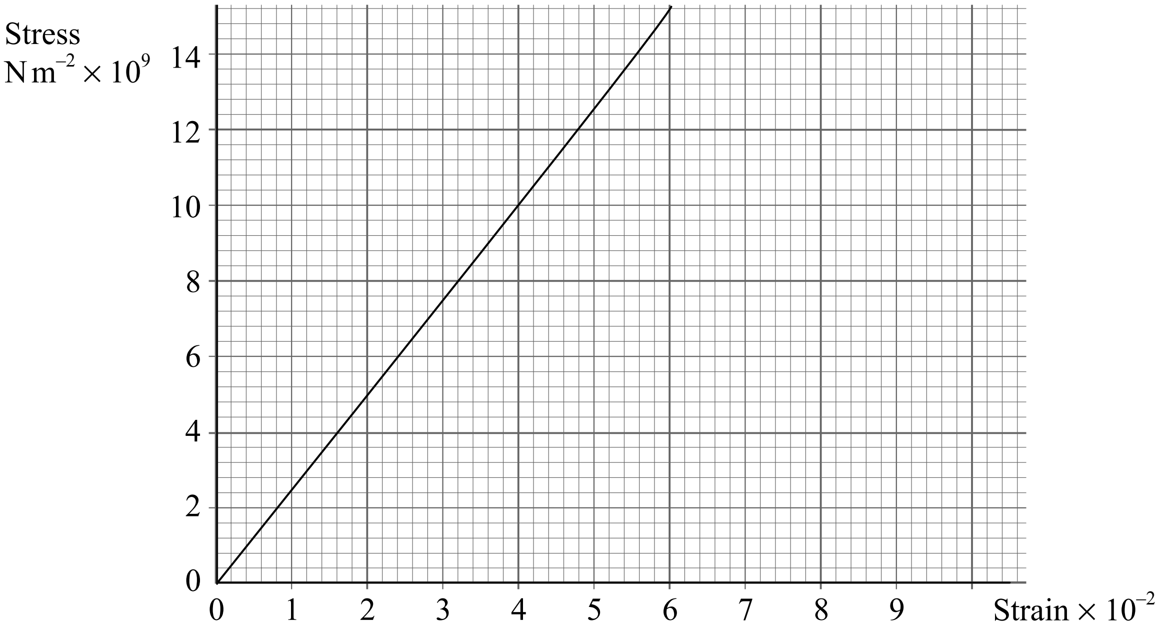
5 (d) The graph shows stress plotted against strain for a sample of a material.



5 (d) (i) Why are there no units for strain?

....

....

(1 mark)

5 (d) (ii) Use the graph to calculate the Young modulus for the material.

....

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(3 marks)

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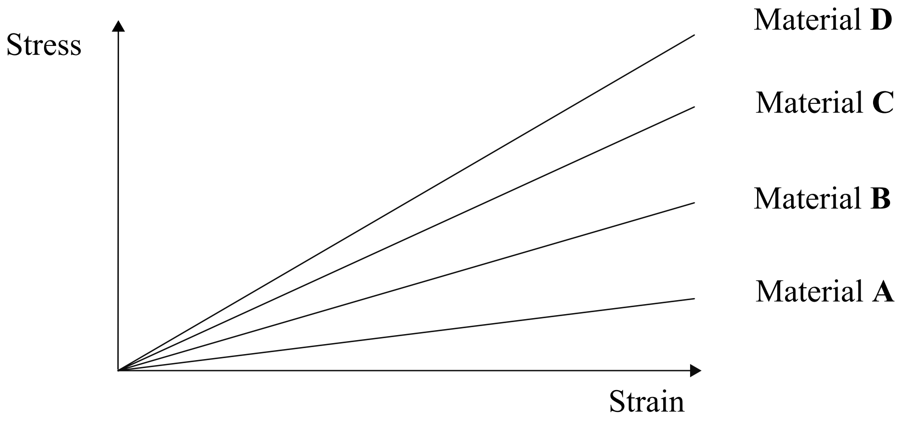
5 (e) The stress against strain graphs for four different materials (**A**, **B**, **C** and **D**) are shown.



5 (e) (i) Which material is the stiffest?

Material ....

(1 mark)

5 (e) (ii) Explain your answer.

....

....

(1 mark)

18

Turn over for the next question

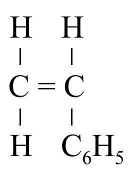
Areas outside the box will not be scanned for marking

Read this article about adhesives and use the information and your own knowledge to answer Question 6.

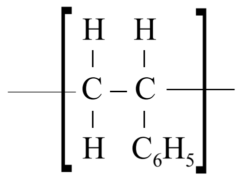
Adhesives

An adhesive is a compound that adheres or bonds two items together. Adhesives may come from either natural or synthetic sources. Adhesives are becoming increasingly important in modern construction and industry.
There are two main kinds of adhesive – **solvent adhesives** and **polymerising adhesives**.

Solvent adhesives have a solid dissolved in a solvent that is volatile (i.e. it evaporates easily). When the solvent evaporates, the solid is left behind. The solid holds the two surfaces together. Two common examples are the rubber adhesive found in bicycle puncture repair kits and the polystyrene cement used in model making. Polystyrene is a polymer formed from the monomer styrene. Their structures are shown below.



Styrene (monomer)
Molecular formula C_8H_8



Polystyrene (polymer)

One problem with solvent adhesives is that the solvent vapour may be toxic. Another problem is that tiny gaps are left where the solvent evaporates. This weakens the join.

Polymerising adhesives do not have a solvent. They consist of a monomer which polymerises when the adhesive sets. The polymer formed holds the two surfaces together. The main problem with this type of adhesive is stopping it from polymerising in its container.

One way is to have a separate 'hardener' which is mixed with the monomer as it is about to be used. The hardener contains a catalyst which starts the polymerisation reaction. The reaction forms a strong thermosetting polymer and the adhesive sets hard. The catalyst itself does not get used in the reaction. Epoxy adhesives work in this way.

Another way is to use a catalyst that is naturally present in the air. Superglue, for example, has a monomer which polymerises when it comes into contact with water. When the adhesive is spread on the surfaces to be joined, it is exposed to water vapour in the air. This starts the polymerisation reaction, which occurs very quickly. Superglue is very good at sticking to skin and doctors sometimes use it to close wounds instead of using stitches.

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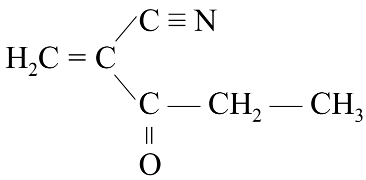
The monomer in superglue is ethyl cyanoacrylate. Its structure is shown below.



Ethyl cyanoacrylate

6 (a) What is meant by a *synthetic* substance?

....

....

(1 mark)

6 (b) Natural rubber is an amorphous polymer. Explain the meaning of the terms *amorphous* and *polymer*.

Amorphous..

....

Polymer ....

....

(2 marks)

6 (c) What type of bonding is present in molecules of styrene?

....

(1 mark)

6 (d) What part of the structure of a styrene molecule allows it to be polymerised?

....

....

(1 mark)

6 (e) What is the molecular formula for ethyl cyanoacrylate (the monomer in superglue)?

....

(1 mark)

Question 6 continues on the next page

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6 (f) Why is it recommended to use solvent adhesives in well ventilated areas?

....

....
(1 mark)

6 (g) Why are polymerising adhesives usually stronger than solvent adhesives?

....

....
(1 mark)

6 (h) Why does polystyrene cement not set while it is in its sealed tube?

....

....
(1 mark)

6 (i) After being opened and used, superglue will often set in its tube even though the tube is tightly capped. Explain why.

....

....
(1 mark)

6 (j) Why do all adhesives set more quickly at higher temperatures?

....

....
(1 mark)

11

END OF QUESTIONS

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