Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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6	
7	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
June 2010

Applied Science SC05

Unit 5 Choosing and Using Materials

Thursday 27 May 2010 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. Do not write outside the box around each page or on blank pages.
- 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 marks for questions are shown in brackets.
- The maximum mark for this paper is 80.
- You are expected to use a calculator where appropriate.

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

1 Materials scientists need to consider the properties of the materials they work with.

The properties of a material depend on its chemical structure.

Draw **one** line from each property to the correct explanation.

Property	**Explanation**
Magnesium oxide has a very high melting point because	its structure has free-moving electrons
	its structure has weak intermolecular forces between polymer molecules
Iron conducts electricity because	its structure has free-moving ions
Polythene is flexible because	its structure has positive and negative ions held together by strong ionic bonds
	its structure has atoms held together by very weak covalent bonds
Carbon dioxide has a low melting point because	its structure has small molecules held together by weak intermolecular forces

(4 marks)

4

2 The table shows some information about the breaking stress and Young modulus for four different materials, **A**, **B**, **C** and **D**.

	Breaking stress	**Young modulus**
A	High	Low
B	High	High
C	Low	Low
D	Low	High

Tick the box to show which material **A**, **B**, **C** or **D** best fits each of the following.

	A	**B**	**C**	**D**
A material suitable for a girder in a building	☐	☐	☐	☐
A weak material that is hard to bend	☐	☐	☐	☐
A material that is not stiff and breaks at low stress	☐	☐	☐	☐

(3 marks)

3

Turn over for the next question

3 A kitchen designer can use a variety of materials for making cupboards and worktops, and for covering the walls and floor of a new kitchen.

His choice will depend on the cost, appearance and properties of the material. Some suitable materials are shown in the table.

Name of material	Type of material	Properties of material
Stainless steel	Metal	High density, flexible, waterproof, does not corrode, conducts heat
Marble	Compound	High density, brittle, waterproof, does not corrode, heat resistant
MDF (medium density fibreboard)	Composite	Low density, porous, damaged by water and chemicals, damaged by heat, flammable
Fired clay (pottery)		

3 (a) Fired clay can be used to make tiles for kitchen walls.
Complete the table for fired clay, stating the type of material and giving **two** of its properties. *(3 marks)*

3 (b) MDF is a *composite* material.

3 (b) (i) What is meant by a composite material?

.....

.....

(1 mark)

3 (b) (ii) What is the benefit of using a composite material?

.....

.....

(1 mark)

3 (c) Which of the four materials shown in the table on **page 4** could be used for each of the following purposes?
Give **one** reason for each choice.
You may select a material more than once.

3 (c) (i) A surface for food preparation.

Material .....

Reason.....

.....

(1 mark)

3 (c) (ii) A fume hood above a cooker.

Material .....

Reason.....

.....

(1 mark)

3 (c) (iii) The sides of a cupboard.

Material .....

Reason .....

.....

(1 mark)

Question 3 continues on the next page

3 (d) Stainless steel is made from several different elements mixed together.
All stainless steels contain iron.
The table shows the percentage composition of the elements other than iron in one type of stainless steel.

Element	Percentage composition by mass (%)
Nickel	10.1
Chromium	15.6
Manganese	1.3
Carbon	0.2
Tungsten	0.1

3 (d) (i) What type of material is stainless steel?

.....

(1 mark)

3 (d) (ii) Iron is the only other element in the stainless steel.
Calculate the percentage by mass of iron in the stainless steel.

.....

(1 mark)

3 (d) (iii) Use your answer from part d(ii) to calculate the mass of iron in a 2.5 kg sheet of the stainless steel.

.....

.....

(2 marks)

3 (d) (iv) A rectangular stainless steel sheet has a uniform thickness.
Use the information below to calculate the thickness (in centimetres) of the 2.5 kg sheet.

density of the stainless steel = 7.7 g cm^{-3}
length of the sheet = 100 cm
width of the sheet = 20 cm

.....

.....

.....

.....

.....

Answer ..... cm
(3 marks)

3 (d) (v) Pure iron is much cheaper than stainless steel.
Give **one** reason why pure iron is not usually used for kitchen surfaces.

.....

.....
(1 mark)

3 (e) Marble is a naturally occurring form of calcium carbonate.
The chemical formula for calcium carbonate is $CaCO_3$.
What is the type of chemical bonding in marble?

.....
(1 mark)

17

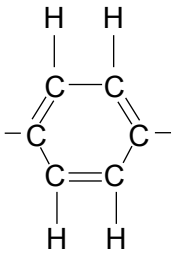
Turn over for the next question

Read this article about Kevlar and use the information and your own knowledge to answer Question 4.

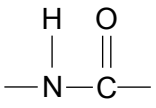
Kevlar

Kevlar is a low density, synthetic polymer with a very high tensile strength. In equal weights it is five times as strong as steel. Kevlar can withstand temperatures of up to 300°C and shows no loss of strength or signs of becoming brittle at temperatures as low as −196°C. It is resistant to water and acids and it undergoes plastic deformation when subjected to a sudden force.

Kevlar is a polymer containing aromatic and amide molecular groups. The structure of each of these groups is shown below.



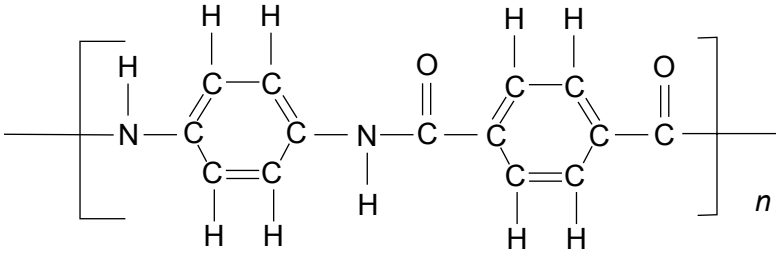
Aromatic group



Amide group

Many other polymers with a high tensile strength contain one or both of these molecular groups. Nylon, for example, contains the amide group.

The structure of Kevlar is shown below.



When Kevlar is spun into fibres, the polymer chains lie parallel to each other along the fibre's axis. This crystalline structure makes Kevlar strong and rigid. Also, there are forces of attraction (known as hydrogen bonds) between the N—H groups in one chain and the C═O groups in an adjacent parallel chain. These hydrogen bonds also help to make Kevlar strong.

Kevlar has a wide range of uses.

- Kevlar fibres are used to strengthen car tyres.
- Bulletproof vests contain Kevlar.
- Some canoes contain Kevlar because it provides high impact resistance without adding much weight.
- Windsurfing sails contain Kevlar so that they can withstand the force of 60 mph winds without ripping.

4 (a) Give the meaning of the following terms used in the article.

Synthetic .....

.....

High tensile strength .....

.....

Brittle .....

.....

Polymer .....

.....

Crystalline .....

.....

(5 marks)

4 (b) Which atoms in an amide group are **not** in an aromatic group?

.....

.....

(1 mark)

4 (c) What type of bond joins the carbon atoms to the oxygen atoms in Kevlar?

.....

.....

(2 marks)

4 (d) Give **two** reasons why Kevlar is a strong material.

Reason 1 .....

.....

Reason 2 .....

.....

(2 marks)

Question 4 continues on the next page

4 (e) Kevlar has a much higher tensile strength than steel.
Give **one** other advantage of Kevlar over steel.

.....

.....

(1 mark)

4 (f) A Kevlar fibre extends by 1.7 cm when a stress of $2 \times 10^9\,\text{N m}^{-2}$ is applied to a 1.10 m length.

4 (f) (i) Define *stress.*

.....

.....

(1 mark)

4 (f) (ii) Calculate the strain in the fibre.

.....

.....

.....

.....

(2 marks)

4 (f) (iii) Calculate the Young modulus for Kevlar. Include the correct unit in your answer.

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(3 marks)

17

Turn to page 12 for the next question

Turn over for the next question

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5 A technician is employed by a manufacturer of metal window frames. She thinks that there is a relationship between the thermal conductivity of metals and their specific heat capacity.

To investigate this she measures the *specific heat capacity* and *thermal conductivity* of five different metals. Her results are shown in the table.

Metal	Specific heat capacity ($J\,kg^{-1}K^{-1}$)	Thermal conductivity ($W\,m^{-1}K^{-1}$)
1	900	80
2	700	180
3	100	200
4	250	170
5	500	130

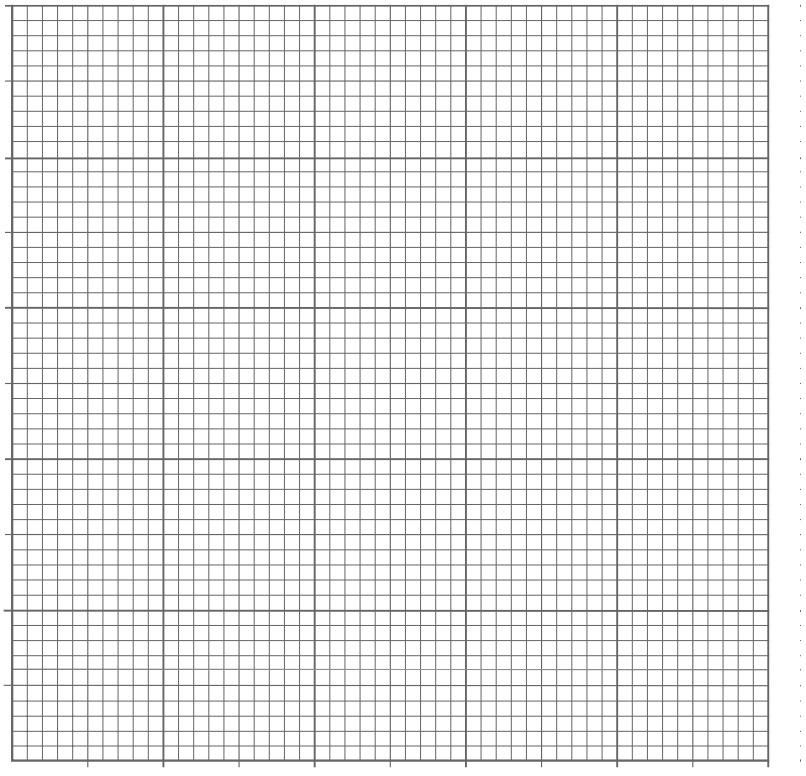
5 (a) What is meant by thermal conductivity?

.....

.....

(1 mark)

5 (b) Plot the data in the table above on the grid provided.
Plot specific heat capacity on the *x*-axis and thermal conductivity on the *y*-axis.
Label the axes, add appropriate units and draw a line of best fit.



(4 marks)

5 (c) (i) Use your graph to estimate the thermal conductivity of a metal with a specific heat capacity of $300\,J\,kg^{-1}\,K^{-1}$.

.....

(1 mark)

5 (c) (ii) State the relationship between thermal conductivity and specific heat capacity shown by your graph.

.....

.....

(1 mark)

5 (c) (iii) Which metal, **1**, **2**, **3**, **4** or **5,** does not fit this pattern?

Put a tick in the correct box.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐

(1 mark)

5 (d) Should the manufacturer make the window frames using a metal with a low thermal conductivity or a metal with a high thermal conductivity?
Explain your answer.

.....

.....

.....

.....

(2 marks)

5 (e) A problem with metal window frames is that during cold weather moisture can condense on the inside of the frame.
Plastic window frames do not have this problem.
Suggest a reason why.

.....

.....

(1 mark)

11

6 (a) What is meant by plastic deformation in a metal?

.....

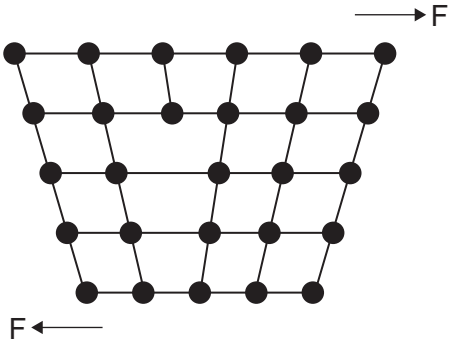
.....

(1 mark)

6 (b) The diagram represents some of the atoms in the crystal structure of a metal.

The structure contains a defect.

The arrows show forces, F, sufficient to cause plastic deformation of the structure.



6 (b) (i) State the type of defect in the crystal structure.

.....

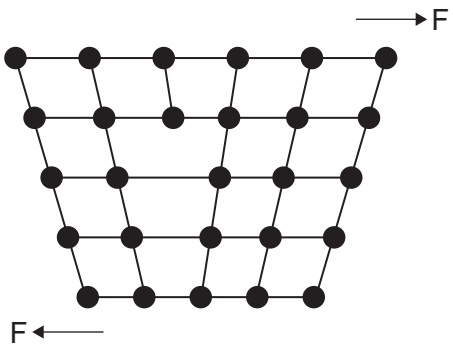
(1 mark)

6 (b) (ii) Which property of metals depends on this defect in the crystal structure?

.....

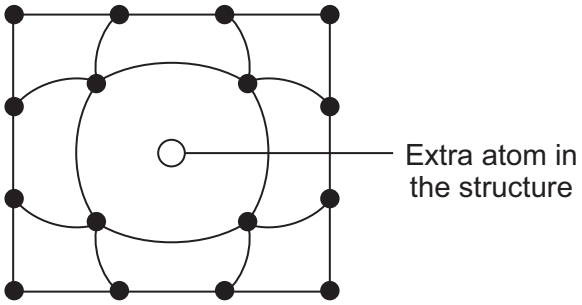
(1 mark)

6 (b) (iii) In the space next to the diagram below, draw an arrangement of the atoms which is produced when plastic deformation has occurred.



(2 marks)

6 (c) The diagram shows another type of defect in the crystal structure of a metal.



6 (c) (i) Give **one** reason why this defect hardens and strengthens the metal.

.....

.....

(1 mark)

6 (c) (ii) Which process, that creates this defect, is often used to harden metals?

.....

(1 mark)

6 (d) Two other processes used to treat metals are quenching and annealing.

6 (d) (i) Give **one** similarity between quenching and annealing.

.....

.....

(1 mark)

6 (d) (ii) Explain the differences between quenching and annealing.

.....

.....

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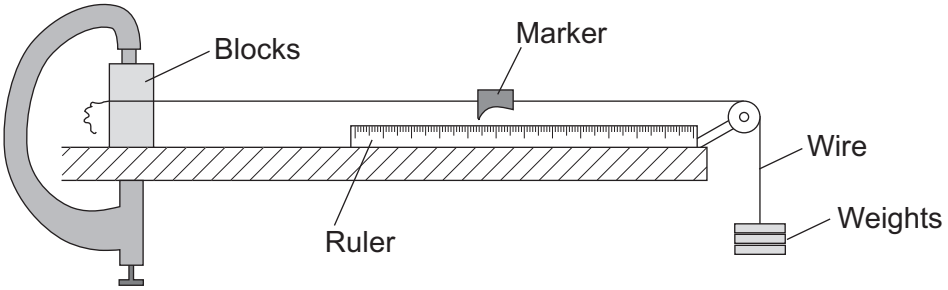
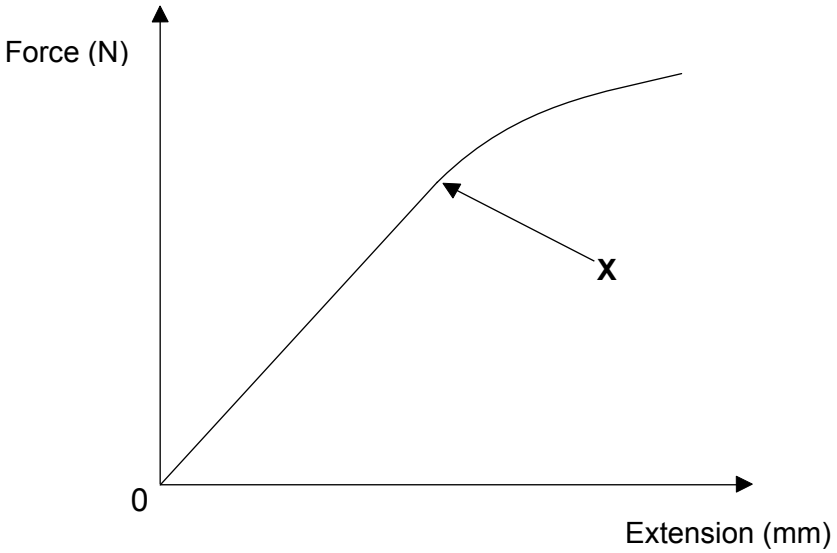
(2 marks)

10

7 A student carries out an experiment to investigate the extension of a copper wire when different forces are applied to it.



The graph shows his results.



7 (a) What is the name given to point **X** on the graph?

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(1 mark)

7 (b) Mark the following points on the graph.

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

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

7 (c) What property of the wire could be determined by calculating the gradient of the graph?

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(1 mark)

7 (d) Explain how the graph would be different if the student had used a thicker copper wire.

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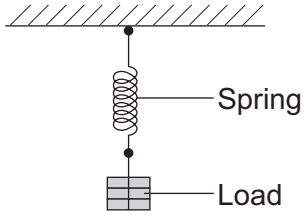
(3 marks)

7 (e) Another student attaches different loads to the end of a spring.



She measures the length of the spring for different loads.
The table shows her data.

Load (N)	0	1	2	3	4	5	6
Length of spring (mm)	30	70	110	150	190	250	320

7 (e) (i) Name the type of force acting on the stretched spring.

.....

(1 mark)

7 (e) (ii) Work out the load that would produce a length of 130 mm.

Load = ……..N

(1 mark)

7 (e) (iii) Estimate the maximum load up to which the spring obeys Hooke's law.

Maximum load = ……N

(1 mark)

Question 7 continues on the next page

Turn over ▶

7 (f) A third student is measuring the electrical conductance of copper wires.
Electrical conductance is calculated using the formula

$$\text{conductance} = \frac{\text{current}}{\text{potential difference}}$$

The student thinks that a wire with a bigger cross-sectional area will have a higher conductance. He has three equal lengths of copper wire each with a different cross-sectional area.
Explain how the student could carry out an investigation to test his idea in the laboratory.
You should include the measurements that need to be made, and the instruments you would use to make these measurements.

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(8 marks)

18

END OF QUESTIONS

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