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

| For Examiner's Use | |
|---|---|
| Examiner's Initials | |
| Question | Mark |
| 1 | |
| 2 | |
| 3 | |
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| 5 | |
| 6 | |
| 7 | |
| TOTAL | |

AQA

General Certificate of Education
Advanced Subsidiary Examination
January 2012

# Applied Science SC05

## Unit 5 Choosing and Using Materials

**Thursday 12 January 2012 1.30 pm to 3.00 pm**

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

*Do not write outside the box*

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

**1 (a)** Different materials have different properties.
Materials scientists use these properties to decide which material to use for a particular purpose.
Draw one line to join each property to the material it describes and one line from each material to its correct use.

| **Property** | **Material** | **Use** |
|---|---|---|
| ductile | metals | fibreglass canoes |
| heat resistant | polymers | carrier bags |
| lightweight | ceramics | lining of furnaces |
| combination of different properties | composites | pipes |

*(3 marks)*

Do not write outside the box

**1 (b)** The table shows information about some properties of three materials, **A**, **B** and **C**.

| | Melting point (ºC) | Electrical conductivity | Thermal conductivity |
|---|---|---|---|
| **A** | 1358 | Very high | High |
| **B** | 801 | Only conducts when melted | Low |
| **C** | 265 | Very low | Very low |

The materials in the table have different structures.
Tick **one** box in each row below to show which material **A, B** or **C**, best fits each of the following structures.

| | **A** | **B** | **C** |
|---|---|---|---|
| Molecular | ☐ | ☐ | ☐ |
| Ionic | ☐ | ☐ | ☐ |
| Metallic | ☐ | ☐ | ☐ |

*(3 marks)*

6

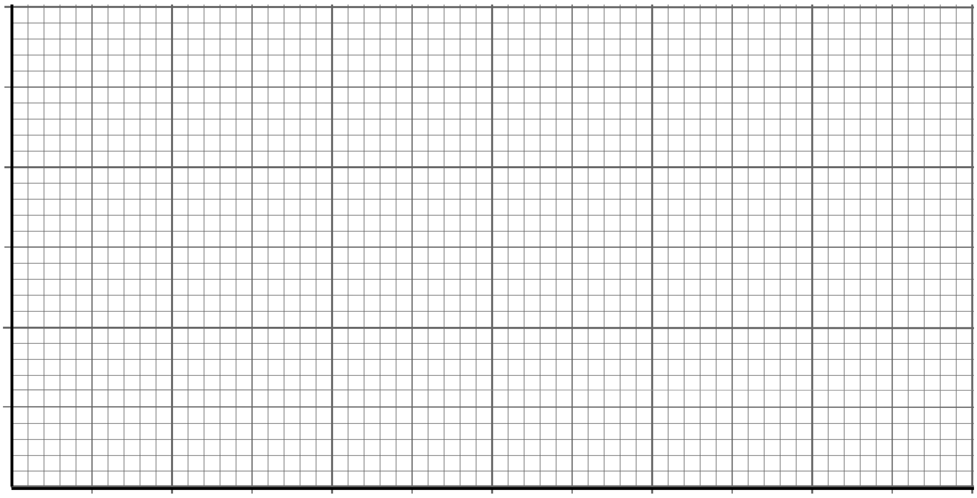
**Turn over for the next question**

**2** A materials scientist determined the breaking forces of wires made from the same material but with different cross-sectional areas.

The table shows her results.

| **Cross-sectional area ($mm^2$)** | 1·0 | 1·6 | 3·4 | 5·0 | 7·6 | 9·8 |
|---|---|---|---|---|---|---|
| **Breaking force (N)** | 0·5 | 0·8 | 1·7 | 2·5 | 3·8 | 4·9 |

**2 (a)** Plot the data in the table on the grid provided.
Plot cross-sectional area on the *x*-axis and breaking force on the *y*-axis.
Label the axes, add appropriate units and draw a line of best fit.



*(4 marks)*

**2 (b)** Use your graph to estimate the breaking force for a wire with a cross-sectional area of 5·6 $mm^2$.

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*(1 mark)*

**2 (c)** State the relationship between breaking force and cross-sectional area shown by your graph.

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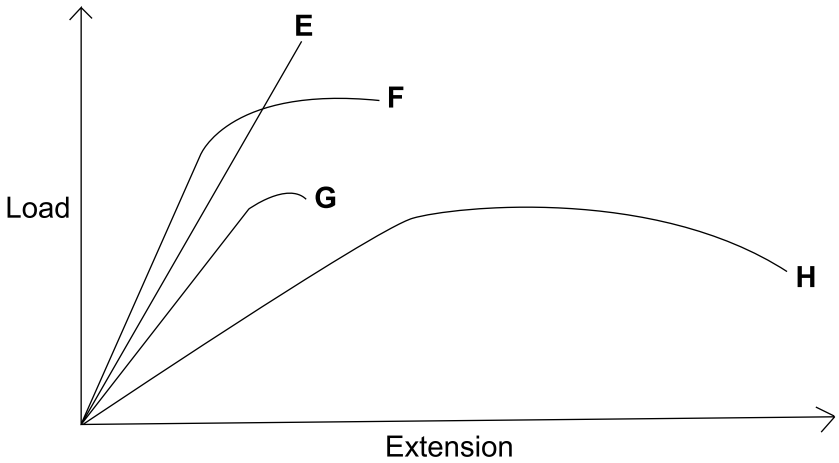
*(2 marks)*

**2 (d)** The results of a tensile strength test on four materials, **E**, **F**, **G** and **H**, are shown in the diagram. The materials were subjected to increasing loads, until they broke.




Use the graph to answer the questions below.

**2 (d) (i)** Which material, **E**, **F**, **G** or **H** is the most ductile? Explain your answer.

Material ........................................

Explanation ........................................................................................................................

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*(2 marks)*

**2 (d) (ii)** Which material **E**, **F**, **G** or **H** has the greatest stiffness? Explain your answer.

Material ........................................

Explanation ........................................................................................................................

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*(2 marks)*

**2 (d) (iii)** Which material **E**, **F**, **G** or **H** has the greatest strength? Explain your answer.

Material ........................................

Explanation ........................................................................................................................

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*(2 marks)*

13

**Turn over ▸**

**3** Pure metals such as iron and copper are quite soft and malleable.
Cast iron contains about 4% carbon. Cast iron is hard and brittle.
Steel contains about 1% carbon. Steel is strong.

**3 (a)** Give the definition of the following terms.

*Malleable*...........................................................................................................................

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*Brittle*...............................................................................................................................

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*(2 marks)*

**3 (b)** What is the name given to materials such as cast iron and steel?

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*(1 mark)*

**3 (c)** Explain why cast iron is less malleable than pure iron.

You may use diagrams to help your answer.

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*(3 marks)*

Do not write outside the box

**3 (d) (i)** Metals can be made harder by the process of quenching.
Describe how *quenching* is carried out.

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*(2 marks)*

**3 (d) (ii)** Apart from hardness, state **two** other properties that are changed when a metal is quenched.

Property 1 ..............................................................................................................................

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Property 2 ..............................................................................................................................

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*(2 marks)*

**10**

**Turn over for the next question**

Do not write outside the box

**4** At outdoor events, drinks are usually served in containers made of polymers rather than glass.

**4 (a)** What is meant by the term *polymer*?

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*(1 mark)*

**4 (b)** Glass is an amorphous solid.
What is meant by *amorphous*?

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*(1 mark)*

**4 (c)** Complete the gaps in the paragraph below by selecting words from the following list.

**compressive density energy force mass stiff tensile tough**

A container made from a polymer has several advantages over a glass container.

Polymers have a low ……………………, and so the ……………………. of the container is kept low. Polymers are also ……………………. and so can absorb large amounts of ……………………. before breaking. Glass is only strong under …………………. forces, but polymers are also strong under ……………………. forces. *(3 marks)*

**4 (d)** A greenhouse manufacturer uses toughened glass, rather than conventional glass, in its greenhouses.

**4 (d) (i)** Give **two** reasons why a customer may prefer to have toughened glass in a greenhouse.

Reason 1 ..............................................................................................................

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Reason 2 ..............................................................................................................

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*(2 marks)*

Do not write outside the box

**4 (d) (ii)** Describe a procedure that could be used to toughen glass.

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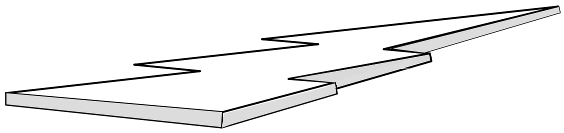
*(2 marks)*

**4 (e)** A forensic scientist is asked to find the density of a piece of glass that has been found at a crime scene. The piece of glass has an irregular shape.



Describe the procedure he would use. Include the apparatus he would use and the measurements he would take.

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*(6 marks)*

15

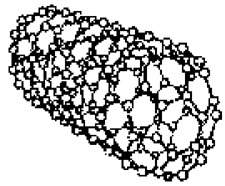
**Turn over ▶**

**5** Read the following article about nanotubes and use the information and your own knowledge to answer the questions that follow the article.

**Nanotubes**

Nanotubes are cylindrical tubes of atoms. These tubes have diameters of a few nanometres. One nanometre is a billionth of a metre ($10^{-9}$m). Nanotubes are macromolecules that can be made from a number of materials, but the most common one is carbon.

Carbon nanotubes have great stiffness and are one of the strongest materials known. Recently a carbon nanotube was found to have a tensile strength of about 60 GPa. In comparison, high-carbon steel has a tensile strength of about 1·2 GPa. Under tensile stress, the carbon nanotubes undergo plastic deformation. Carbon nanotubes have a very low density for a solid.



a nanotube

Manufacturers are working on using carbon nanotubes in various ways. A few of the applications of carbon nanotubes are listed below:

- to reinforce carbon fibre composites that are used to manufacture very high quality sports equipment e.g. tennis racquets, fishing rods and racing bicycles
- to reinforce polymer composites that can be used to build aircraft and spacecraft
- to deliver drugs directly to diseased cells
- to increase the efficiency of industrial catalysts. The nanotubes have a large surface area and the catalyst molecules can be 'caged' within the nanotube. This means the reacting molecules cannot escape and so more collisions occur between molecules, increasing the rate of reaction.

**5 (a)** Suggest why cylindrical tubes of atoms are called 'nanotubes'.

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*(1 mark)*

**5 (b)** How many times stronger are carbon nanotubes than high-carbon steel?

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*(1 mark)*

Do not write outside the box

**5 (c)** Give the meaning of the following terms used in the article.

*Macromolecule*...............................................................................................................

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*Stiffness* ......................................................................................................................

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*Tensile strength* ............................................................................................................

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*Plastic deformation* .......................................................................................................

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*(4 marks)*

**5 (d)** State **two** advantages of making a bicycle frame using carbon nanotube technology instead of using high-carbon steel.

Advantage 1 ...................................................................................................................

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Advantage 2 ...................................................................................................................

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*(2 marks)*

**5 (e)** Write down **two** reasons why carbon nanotubes make industrial catalysts more efficient.

Reason 1 .......................................................................................................................

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Reason 2 .......................................................................................................................

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*(2 marks)*

**10**

**Turn over for the next question**

*Do not write outside the box*

**6** The construction industry uses many different materials.

**6 (a)** Concrete is a composite material that is strong in compression but weak in tension.

**6 (a) (i)** What is meant by *strong in compression*?

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*(1 mark)*

**6 (a) (ii)** What is meant by *weak in tension*?

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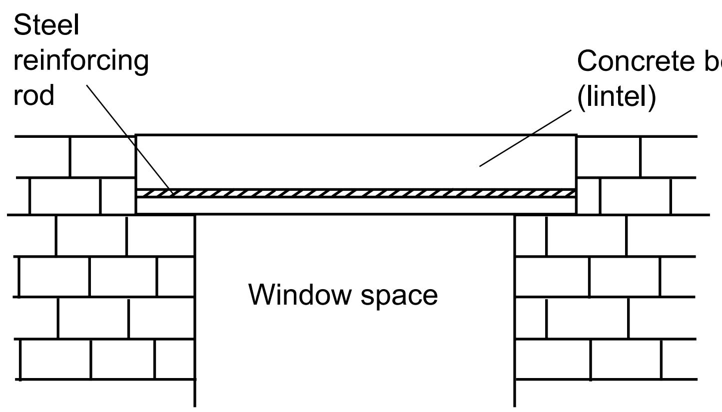
*(1 mark)*

**6 (b)** The diagram shows a concrete beam being used as a lintel for a window in a wall.




**6 (b) (i)** On the diagram draw an arrow labelled **C** to a part of the beam that is in compression.

*(1 mark)*

**6 (b) (ii)** Concrete is often reinforced with steel rods.
Why is the steel reinforcing rod placed in the lower part of the concrete beam instead of the upper part?

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*(1 mark)*

Do not write outside the box

**6 (c)** The windows in new buildings are often made with either a hardwood frame or a PVC frame.

**6 (c) (i)** Apart from cost, give **three** disadvantages of using a traditional material such as hardwood for window frames.

Disadvantage 1 ..........................................................................................................

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Disadvantage 2 ..........................................................................................................

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Disadvantage 3 ..........................................................................................................

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*(3 marks)*

**6 (c) (ii)** The sections of PVC used to make window frames are reinforced with steel.
Why does a PVC frame need to be reinforced with steel?

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*(2 marks)*

**6 (d)** Lead is used in the construction industry as a roofing material.
Suggest **two** properties of lead that make it suitable for this purpose.

Property 1 ..........................................................................................................

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Property 2 ..........................................................................................................

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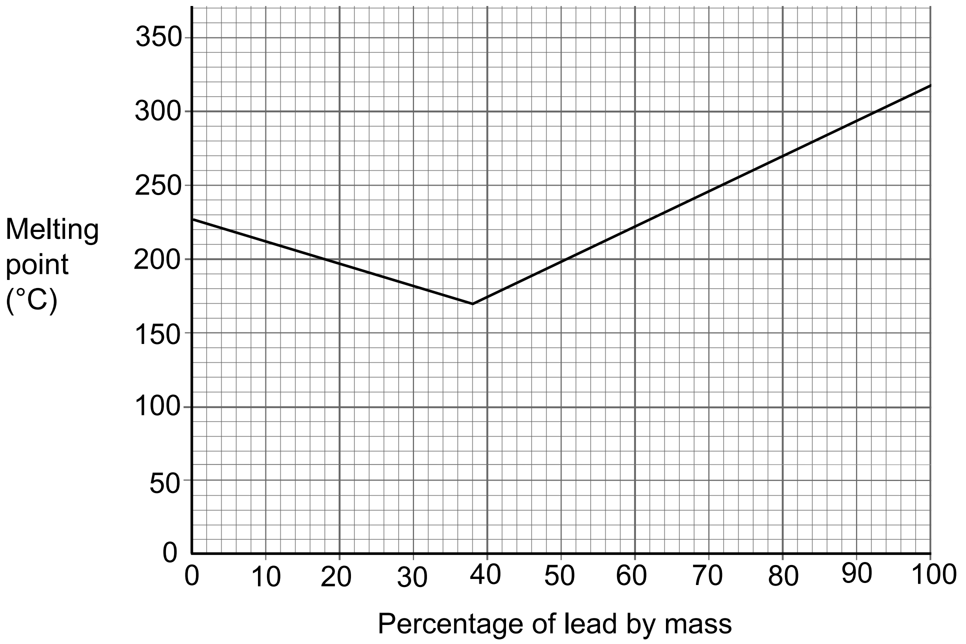
*(2 marks)*

**Question 6 continues on the next page**

Do not write outside the box

**6 (e)** Solder can be made from a mixture of lead and tin. Solder is used in the electronics industry to join metal components in electrical circuits.
The graph shows how the composition of the mixture affects its melting point.




**6 (e) (i)** What is the percentage of tin in solder with the lowest melting point?

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*(1 mark)*

**6 (e) (ii)** Calculate the quantities of each metal needed to make 150 g of solder that has a melting point of 250 °C.

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*(2 marks)*

14

**7 (a)** Define the following quantities.

Stress ..........................................................................................................................

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Strain ..........................................................................................................................

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*(2 marks)*

**7 (b)** In a materials testing laboratory, an experiment is carried out to determine the Young modulus of a metal wire.
The length of the wire is measured.
Then the wire is loaded in steps of 5 N up to 25 N and then unloaded. The extension is measured each time.

The results of the experiment are shown in the table.

| **Load (N)** | **Extension (mm)** | |
|---|---|---|
| | **Loading** | **Unloading** |
| 0 | 0·00 | 0·00 |
| 5 | 0·24 | 0·24 |
| 10 | 0·48 | 0·48 |
| 15 | 0·72 | 0·72 |
| 20 | 0·96 | 0·96 |
| 25 | 1·20 | 1·20 |

**7 (b) (i)** Describe how the original length of the wire can be measured.

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*(1 mark)*

**7 (b) (ii)** Describe how the extension of the wire can be measured.

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*(2 marks)*

**Question 7 continues on the next page**

**Turn over ▶**

Do not write outside the box

Use the results in the table on page 15 to help you answer parts **(b) (iii), (iv)** and **(v)**.

**7 (b) (iii)** In this experiment, is the deformation of the wire plastic or elastic?
Explain your answer.

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*(1 mark)*

**7 (b) (iv)** Does the wire obey Hooke's Law?
Explain your answer.

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*(2 marks)*

**7 (b) (v)** The wire tested is 1·73 m long and has a cross-sectional area of $1{\cdot}82 \times 10^{-7}\,m^2$.
Use the extension value given in the table for a load of 25 N to calculate the Young modulus of the metal.
Give the correct unit in your answer.

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*(4 marks)*

**12**

**END OF QUESTIONS**