General Certificate of Education
June 2005
Advanced Subsidiary Examination

GENERAL STUDIES (SPECIFICATION A) GSA2
Unit 2 Science, Mathematics and Technology

Monday 23 May 2005 Afternoon Session

In addition to this paper you will require:
- an objective test answer sheet;
- a data booklet for Questions 1 to 25 (enclosed);
- a black ball-point pen.

You may use a calculator.

Time allowed: 1 hour 15 minutes

Instructions
- Use a black ball-point pen.
- Answer **both** Section 1 (Questions 1 to 25) **and** Section 2 (Questions 26 to 50) using the answer sheet provided.
- Answer **all** questions.
- For each question there are several alternative responses. When you have selected the response which you think is the best answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book, **not** on your answer sheet.

Information
- The maximum mark for this paper is 50.
- This paper consists of **two** Sections.
  Section 1 contains 25 objective test questions (Questions 1 to 25) based on material provided in a separate data booklet.
  Section 2 contains 25 objective test questions (Questions 26 to 50) testing mathematical reasoning and its application.
- Each question carries 1 mark. No deductions will be made for wrong answers.
- 2 mm graph paper is available from the Invigilator.

Advice
- Do not spend too long on any question. If you have time at the end, go back and answer any question you missed out.

SECTION 1

Answer Questions 1 to 25

Each of the 25 questions carries 1 mark.

Read the passage entitled **BODY PARTS FROM THE POLYMER LAB** which is printed in the separate data booklet.

Questions 1 to 21

Each of Questions **1** to **21** consists of a question or an incomplete statement followed by four suggested answers or completions. You are to select the most appropriate answer (**A** to **D**) in each case.

1 This passage is about polymers. In science the word ‘polymer’ is used to mean a molecule

A with many physical forms.
B consisting of many atoms.
C with many repeated units.
D which is made synthetically.

2 Each of the following is considered to be an implant (paragraph 1) **except**

A a gauze used to repair a hernia.
B a kidney donated by a close relative.
C steel pins inserted into badly fractured bone.
D electrodes inserted into the ear to improve hearing.

3 The development of synthetic polymers (paragraphs 1 and 2) has been studied seriously by chemists for about

A 20 years.
B 40 years.
C 50 years.
D 70 years.

4 According to paragraphs 1 and 2, implants have become more successful as the scientists improved their

1 ability to make polymers with required properties.
2 knowledge of psychological factors affecting transplants.
3 understanding of the physiological environment.

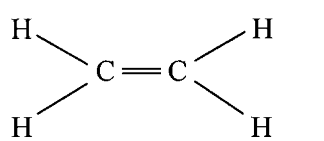
Answer

A if **1** alone is correct.
B if **3** alone is correct.
C if **1** and **3** only are correct.
D if all are correct.

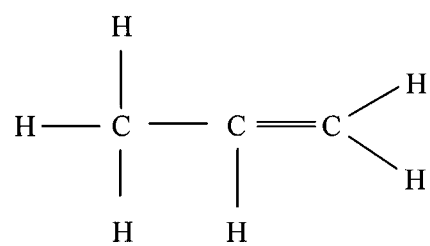
5 In modern scientific nomenclature, polyethylene (paragraph 5) is known as polyethene.

Which of the following is the correct structure of an ethene molecule (from which polyethene is made)?

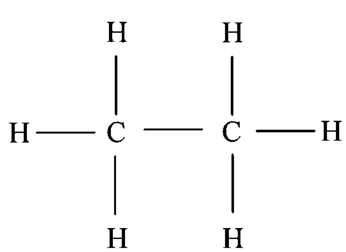
A



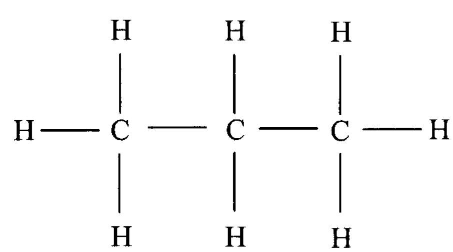
B



C



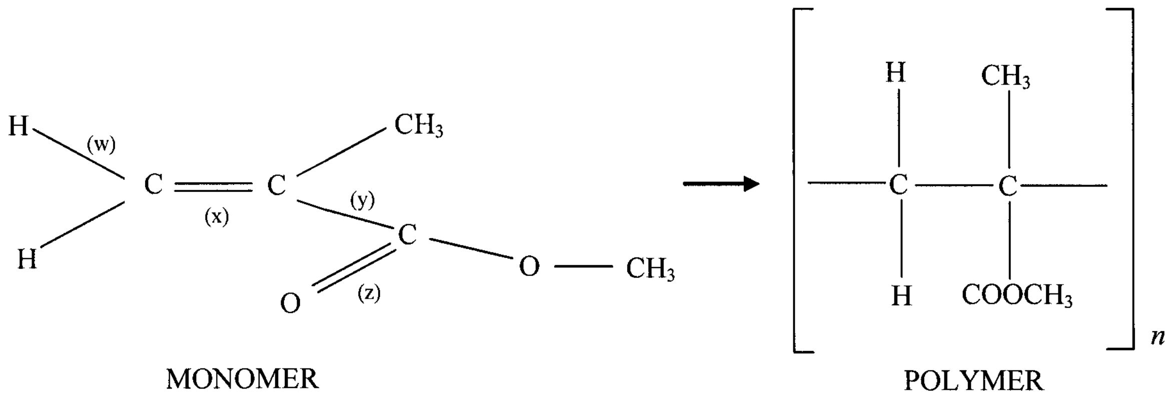
D



6 Each of the following statements is given as a reason for using PMMA for a replacement lens in the eye **except**

A it changes shape easily.
B it is transparent.
C it is tolerated by the body.
D it is very long lasting.

7 PMMA is a polymer made by adding together units of transformed monomer MMA (shown below).



Which of the labelled bonds shown above has been broken in this process?

A (w)
B (x)
C (y)
D (z)

8 Opthalmic work using implants has been particularly successful because

1 eyesight is regarded as important and given priority.
2 transparent polymers are easy to make.
3 the occular environment does not place any great mechanical stress on any device.
4 there are many opthalmic surgeons.

Answer

A if **1** and **2** only are correct.
B if **1** and **4** only are correct.
C if **2** and **3** only are correct.
D if **2** and **4** only are correct.

9 All joints have articulating surfaces – so that one part can move easily over the other.

In a normal healthy person, which of the following would make up an articulating surface?

A bone
B cartilage
C ligament
D tendon

10 In a natural body joint the surfaces in contact do not wear out (paragraph 5) because

A they are extremely hard.
B they are very well lubricated.
C the surface replaces itself.
D there is little friction.

11 The femoral head of an artificial hip joint is made from the metal zirconium which is heated to produce the compound zirconia.

Which element is most likely to have combined with zirconium during this process?

A carbon
B hydrogen
C nitrogen
D oxygen

12 Which of the following describes the composition of the contact surfaces of the metallic cup and the femoral head of an artificial hip joint?

A The cup is made of UHMWPE and the head of ceramic coated zirconium.
B The cup is made of ceramic coated zirconium and the head of UHMWPE.
C Both the cup and head are made of UHMWPE.
D Both the cup and head are made of ceramic coated zirconium.

13 In paragraph 6 the bone cement is referred to as a 'viscous' liquid.

Other examples of liquids which are viscous at room temperature include

1 engine oil.
2 alcohol.
3 golden syrup.

Answer

A if **1** alone is correct.
B if **2** alone is correct.
C if **1** and **3** only are correct.
D if all are correct.

14 Which component is used to make PMMA cement visible to X-rays?
(paragraph 6 and Figure 2)

A PMMA powder particles
B benzoyl peroxide
C barium sulfate
D tertiary amine catalyst

15 From the data in Figure 2, if 100 g of the liquid component of a PMMA bone cement were prepared, what would be the minimum quantity of tertiary amine catalyst used?

A 0.001 g
B 0.005 g
C 0.01 g
D 0.5 g

16 Which event led to the realisation that PMMA was inert in the physiological environment?

A observation of the thread used for stitching a wound
B repairing of blood vessels using Dacron
C seeing pieces of aircraft windscreen in the eye
D replacement of diseased hip joint with an artificial joint

17 Degradable polymers are used for each of the following **except**

A surgical stitches.
B tooth filling.
C release of drugs.
D scaffolding for tissue growth.

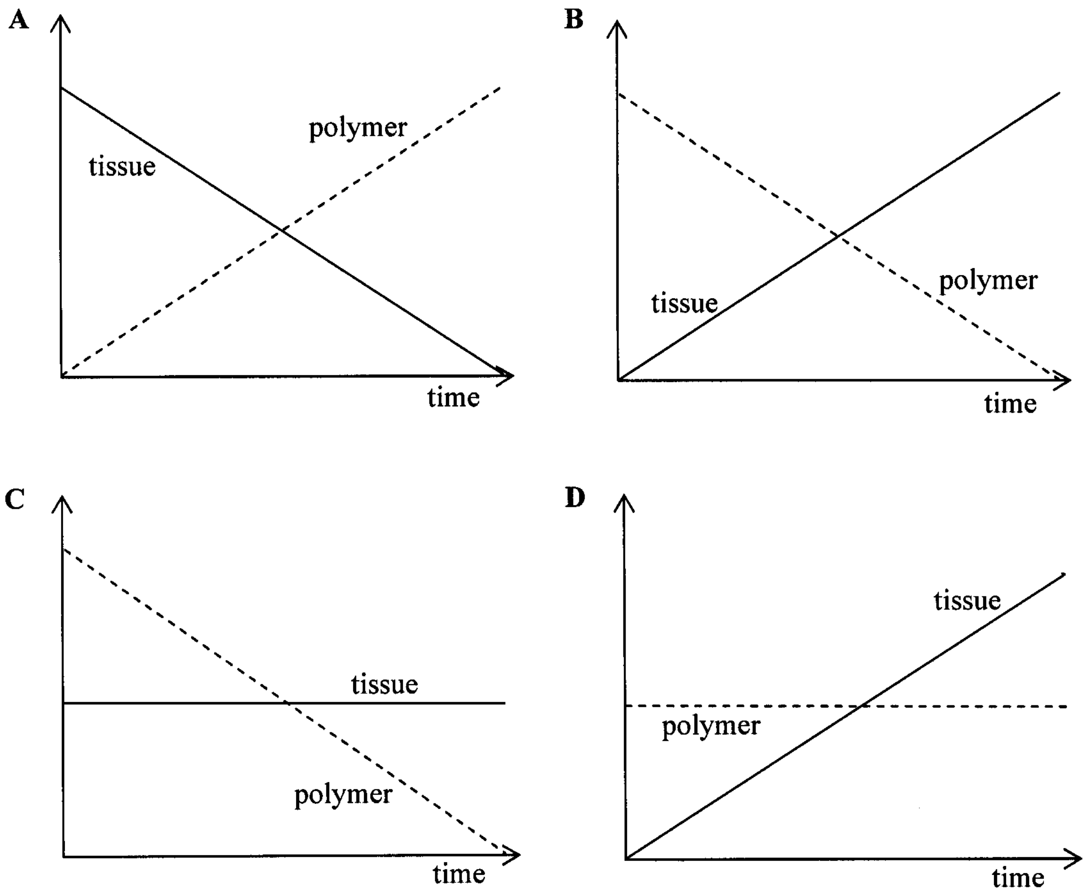
18 The use of degradable polymers in the controlled delivery of a drug could have advantages for

1 people living in remote areas with limited access to a doctor.
2 elderly patients with failing memory.
3 patients with a limited ability to deal with everyday situations.
4 very young patients.

Answer

A if **1** alone is correct.
B if **2** and **3** only are correct.
C if **1** and **4** only are correct.
D if all are correct.

19 Which diagram best illustrates the proportion of tissue to polymer in tissue engineering?



20 Which of the following occurs during the growth of new tissues on a polymer scaffold of synthetic material (paragraphs 10 and 11)?

A The polymers remain in place throughout to support the complete growth of the new tissues.
B The polymers slowly degrade as they are replaced by new tissues.
C The polymers degrade quickly as soon as the new tissues start to grow.
D The scaffold of synthetic polymers remains permanently in place.

21 A researcher carrying out work in tissue engineering (paragraphs 12 and 13) needs to take which of the following into account?

1 the problem of growing more than one cell type together
2 the chemical characteristics of the scaffold material
3 the surface and pore size of the scaffold material
4 the properties of the synthetic polymer as it degrades

Answer

A if **1**, **2** and **3** only are correct.
B if **1** and **3** only are correct.
C if **2**, **3** and **4** only are correct.
D if all are correct.

Questions 22 to 25

For each of Questions **22** to **25** you are given an assertion followed by a reason. Consider the assertion and decide whether, on its own, it is a true statement. If it is, consider the reason and decide if it is a true statement. If, and only if, you decide that *both* the assertion and the reason are true, consider whether the reason is a valid or true explanation of the assertion. Choose your answer (**A** to **D**) as follows and indicate your choice on the answer sheet.

Directions summarised			
	Assertion	**Reason**	**Argument**
A	True	True	Reason is **a correct** explanation of assertion
B	True	True	Reason is **not a correct** explanation of assertion
C	True	False	Not applicable
D	False	-	Not applicable

	ASSERTION		**REASON**
22	PMMA (paragraph 4) was one of the first successful implant materials	because	there is no reaction between the PMMA and the eye.
23	'Wear and tear' in natural surfaces is not a problem compared to artificial ones	because	artificial surfaces can be constantly regenerated.
24	It is advantageous for some implants to be biodegradable	because	the breakdown products of polymers derived from lactic acid are non-toxic.
25	Biodegradable polymers are used as scaffolding for tissue	because	they are easy to remove when the tissue is complete.

SECTION 2

Answer Questions 26 to 50

Each of the 25 questions carries 1 mark.

For each of Questions **26** to **50** choose the answer you consider the best of the alternatives offered in **A**, **B**, **C** and **D**.
You are reminded that graph paper is available on request from the Invigilator.

26 A firm pays travel expenses to its employees who use their own cars on company business.
For mileage up to and including 25 miles the rate is 44p per mile.
For mileage over 25 miles the rate is £11, plus 32p per mile in excess of 25 miles.

These expenses can be written as formulae as follows

$T = 0.44M$ for $M \leq 25$,
$T = 11 + 0.32(M - 25)$ for $M > 25$,

where M is the mileage and T is the travel expenses.

The expenses for 60 miles are

A £15.40
B £22.20
C £26.40
D £30.20

27 Simplify $\dfrac{n^2 \times n^3}{n^6}$.

A n^{-1}

B n^0

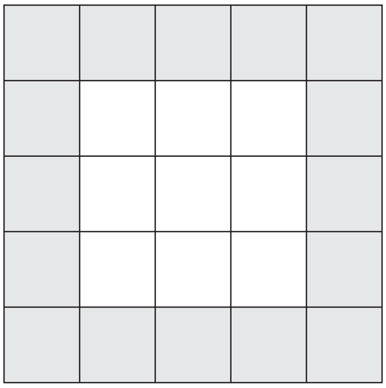
C $n^{\frac{5}{6}}$

D n

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

Question 28 and 29



Grey tiles are used to form a border one tile wide around a square of white tiles. All tiles are the same size.

The diagram shows a 3×3 square of white tiles surrounded by a border of grey tiles.

28 How many grey tiles will be needed to surround an $n \times n$ grid of white tiles?

A $(n + 1)^2 - n^2$

B $(n + 2)^2 - n^2$

C $(n + 1)^2 + 4$

D $(n + 2)^2 + 4$

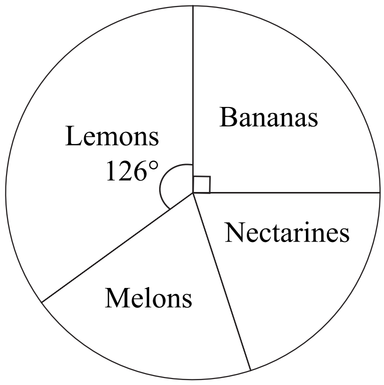
29 For a 4×4 square of white tiles what is the ratio
number of white tiles : number of grey tiles?

A 1 : 4
B 1 : 1
C 4 : 5
D 4 : 9

30 A fruit merchant sells bananas, lemons, melons and nectarines.

The pie chart shows the proportion of each fruit sold on a particular Saturday.

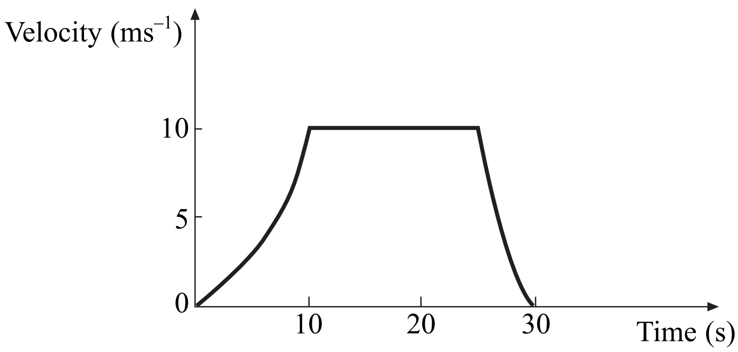
The merchant sold an equal number of melons and nectarines.



If the merchant sold 189 lemons, how many fruits were sold altogether?

A 240
B 360
C 540
D 600

31 The velocity-time graph for a sprinter is shown.



The approximate distance run is

A 175 m.
B 225 m.
C 300 m.
D 325 m.

Questions 32 and 33

In an experiment, a pupil tossed three coins together 50 times and recorded the number of heads obtained each time. The results are shown in the table.

Number of heads	0	1	2	3
Frequency	8	20	17	5

32 The experimental probability of obtaining at least two heads is

A $\frac{1}{10}$

B $\frac{17}{50}$

C $\frac{1}{2}$

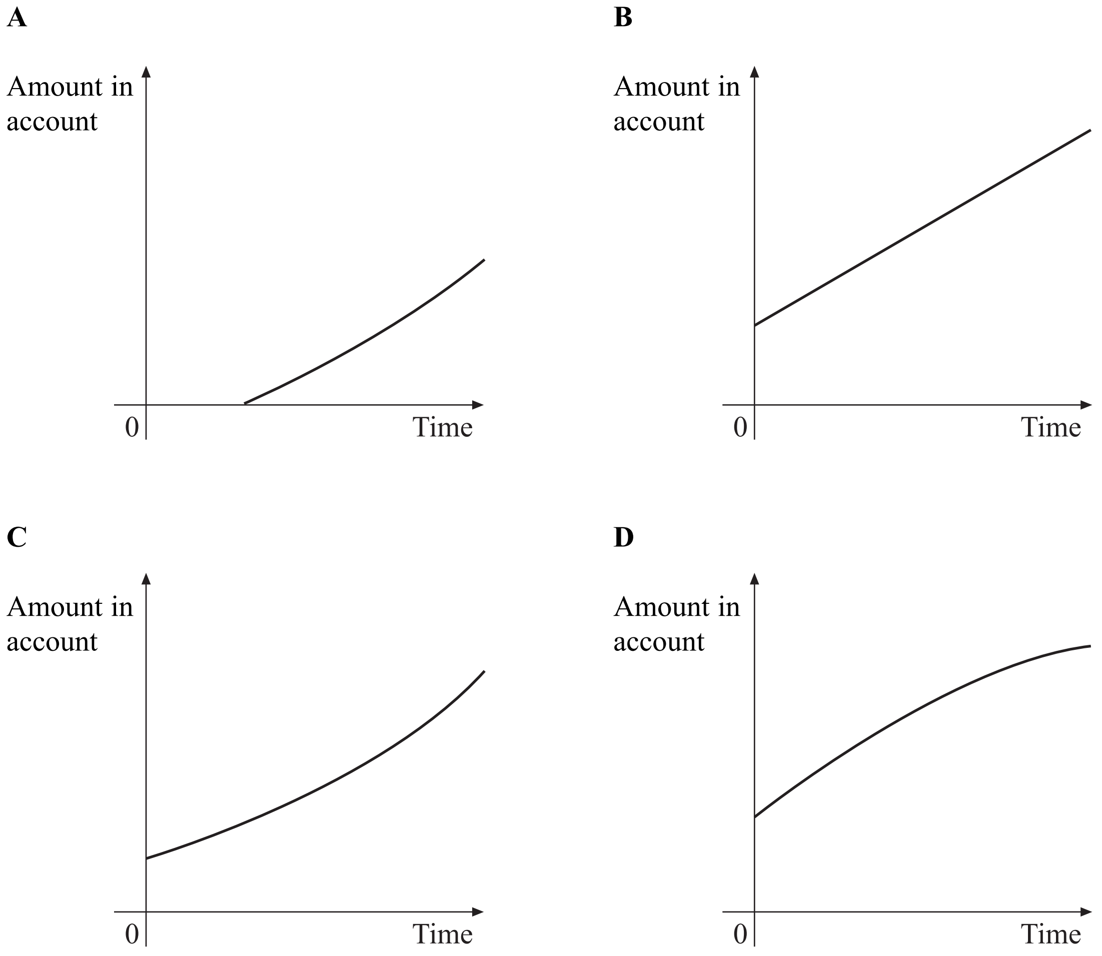
D $\frac{22}{50}$

33 The mean number of heads obtained in this experiment is

A 1
B 1.38
C 1.5
D 8.33

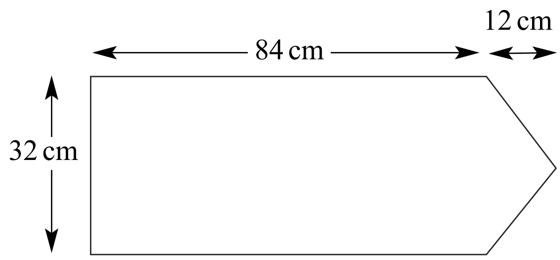
34 A sum of money is invested in a building society account with a fixed rate of interest. The interest is added on regularly to the amount in the account.

Which of these graphs is most consistent with this information?



TURN OVER FOR THE NEXT QUESTION

Questions 35 and 36



The outline of a symmetrical road sign is shown above.

35 What is the perimeter of the road sign?

A 156 cm
B 224 cm
C 240 cm
D 264 cm

36 What is the area of the road sign, to the nearest 100 cm^2?

A 2700 cm^2
B 2800 cm^2
C 2900 cm^2
D 3000 cm^2

37 Which of the following is equivalent to $3x^2y\,(x^2 + 2y^3)$?

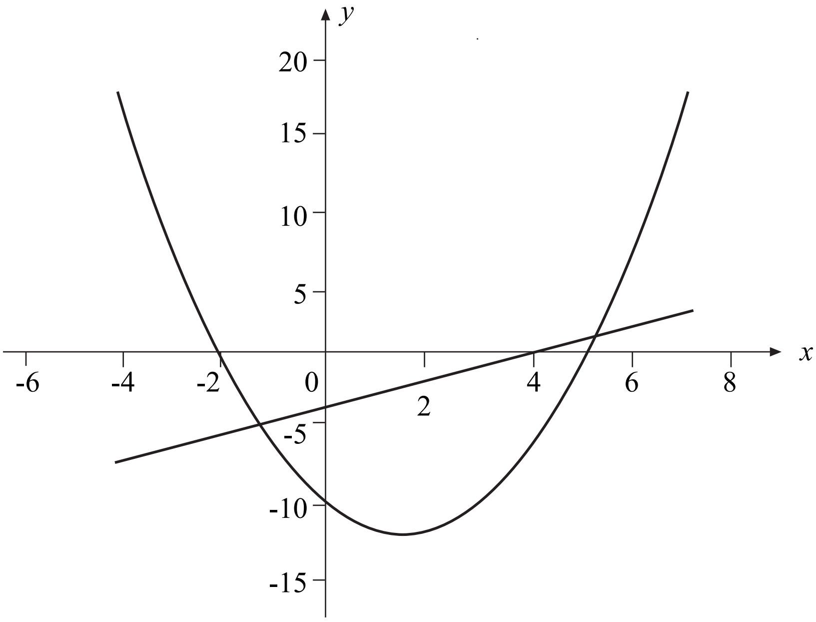
A $3x^4y + 5x^2y^3$
B $3x^4y + 5x^2y^4$
C $3x^4y + 6x^2y^3$
D $3x^4y + 6x^2y^4$

38 Seven children play in a netball team. One year later, the team still has the same seven members. What has happened to the median and inter-quartile range of the ages of the children in the team during the year?

A The median and the inter-quartile range have both increased.
B The median and the inter-quartile range are both the same.
C The median has increased and the inter-quartile range has stayed the same.
D The median has stayed the same and the inter-quartile range has increased.

Questions 39 to 41

The diagram shows the quadratic graph
$y = x^2 - 3x - 10$ and the straight line graph
$y = x - 4$



39 The solutions of the quadratic equation
$x^2 - 3x - 10 = 0$ are

A $x = -4$ and $x = -10$
B $x = -2$ and $x = 5$
C $x = -2$ and $x = 4$
D $x = -1.2$ and $x = 5.2$

40 The equation of the line of symmetry of the quadratic graph is

A $y = x - 4$
B $y = 0$
C $x = 0$
D $x = 1.5$

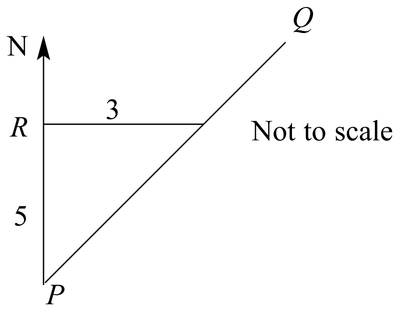
41 The number of solutions of the simultaneous equations $y = x^2 - 3x - 10$ and $y = x + 8$ is

A 0
B 1
C 2
D 3

Turn over

Questions 42 to 44

A boat sails in a straight line from P towards Q.
R is a point 5 km north of P.
When the boat is 5 km north of P it is 3 km east of R.



42 The bearing the boat is sailing on is

A 031°
B 037°
C 053°
D 059°

43 At this time a coastguard looks out from P and sees the boat. The coastguard must be able to see at least

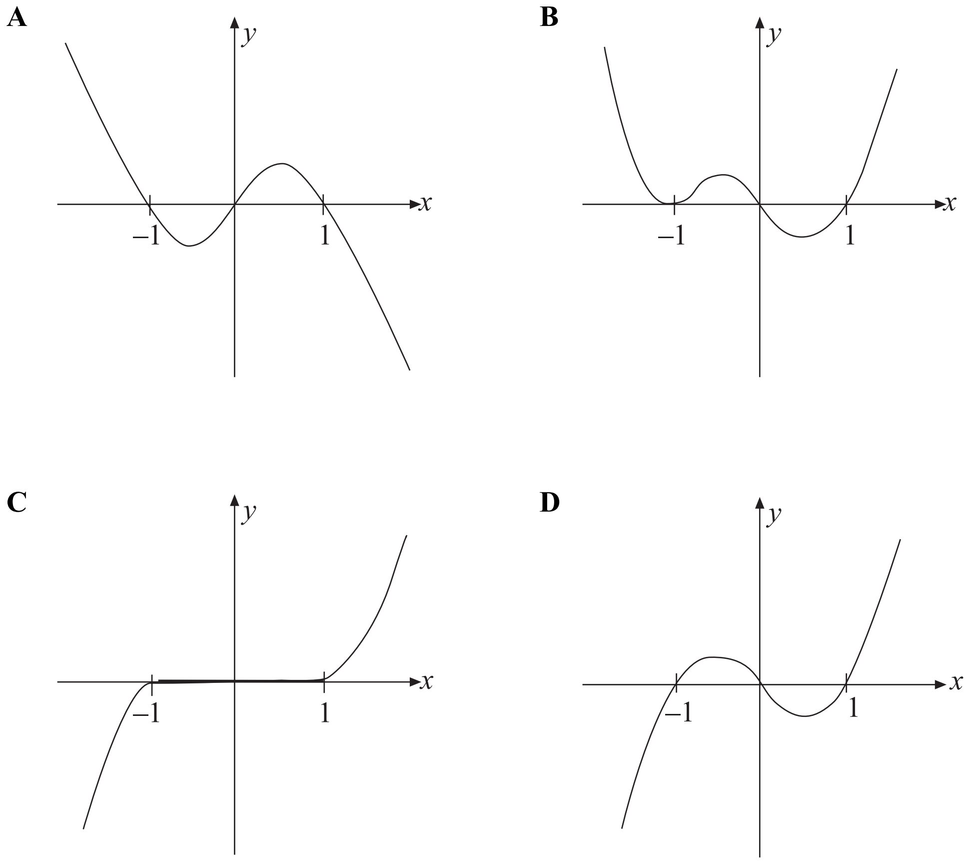
A 5 km
B 5.5 km
C 6 km
D 8 km

44 When the boat left P a second boat set off from R, 5 km north of P. This second boat is sailing due East at the same speed as the first boat.

The boats will not meet because

A they must travel on the same bearings if they are to meet.
B they would need to have different speeds if they are to meet.
C they would both have to start at P if they are to meet.
D the second boat would have to start further north of P if the boats are to meet.

45 Which one of the following (**A**-**D**) is a sketch of the graph of $y = x(x^2 - 1)$?



46 A golfer hit a golf ball over level ground. Its height, h metres, above the ground, t seconds after it was hit, is given by the equation

$$h = 20t - 5t^2$$

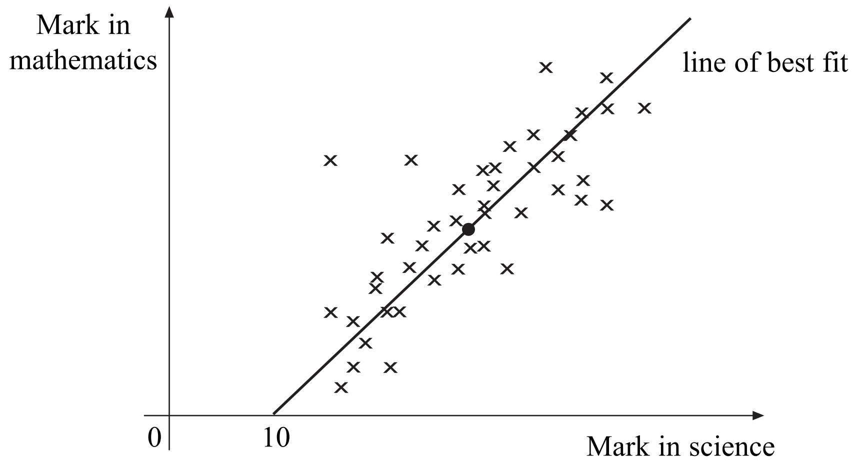
For how long was the golf ball in the air?

A 4 seconds
B 4.5 seconds
C 8 seconds
D 10 seconds

TURN OVER FOR THE NEXT QUESTION

47 Each cross on this scatter diagram shows a student's marks in science and in mathematics.
The diagram has the same scale on each axis.

The line of best fit goes through the point whose co-ordinates are the mean mark in science and the mean mark in mathematics. This point is marked by ●.



Which of the following can you deduce from the scatter diagram?

1 Marks in mathematics and science are increasing.
2 There is a positive correlation between the marks in science and the marks in mathematics for these students.
3 These students' marks in mathematics are generally higher than their marks in science.
4 The mean mark in science is approximately 10 marks higher than the mean mark in mathematics.

Answer

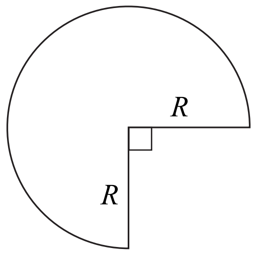
A if **2** alone can be deduced.
B if **2** and **4** only can be deduced.
C if **1**, **2** and **4** only can be deduced.
D if **2**, **3** and **4** only can be deduced.

48 A solution of the equation $(x - 4)(x + 5) = k$ is $x = -4$

The value of k is

A 0
B -8
C 8
D -72

49 A quadrant is cut out of a circle of paper of radius R and discarded.
The cut edges of the remaining shape, labelled R in the diagram, are joined together so that a cone is formed.



The radius of the base of the cone is

A $\frac{1}{2}R$

B $\frac{2}{3}R$

C $\frac{3}{4}R$

D R

50 When $n = 16$ the equation

$$x^2 - n = 0$$

has solutions $x = 4$ and $x = -4$.

If the value of n is increased above 16 then the values of the solutions of the equation will

A both increase.
B both decrease.
C become closer together.
D become further apart.

END OF QUESTIONS

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE

General Certificate of Education
June 2005
Advanced Subsidiary Examination

GENERAL STUDIES (SPECIFICATION A) **GSA2**
Unit 2 Science, Mathematics and Technology

Data Booklet

Monday 23 May 2005 Afternoon Session

Data booklet for use with **Section 1 Questions 1** to **25**.

PASSAGE AND FIGURES FOR QUESTIONS 1 TO 25

Consider the following passage and Figures 1 and 2.

BODY PARTS FROM THE POLYMER LAB

(1) Problems caused by accident, disease, or old age are increasingly being solved by the use of synthetic materials which can replace or supplement natural tissues. Materials used in these ways are called implants because they are implanted into the body. In designing an effective implant, scientists must have a strong understanding both of the physiological environment in which the implant must work and also of the structure-property relationships of the materials themselves. Over the last 40 years considerable improvements have been made in implants as better understanding of chemistry has made it possible for scientists to design synthetic polymers with appropriate properties.

(2) The use of synthetic polymers in the body began to be considered seriously by biomedical scientists about 50 years ago. This was a very rapid response to the development of polymers which at that time had only been studied seriously by chemists for about 20 years. 50 years ago it was not possible to design a polymer with particular properties, and in any case the physiological environment was not as well understood as it is now. Consequently, the first implanted polymers were derived from unlikely sources. For example, a polyester known as Dacron (used at the time in curtain manufacturing) turned out to be a useful material for making into tubes and used as grafts where parts of blood vessels needed replacing.

(3) Not surprisingly, some early attempts to use polymers as implants were not particularly successful. Subsequent research has shown how important it is to look for polymers that match the desired properties as closely as possible.

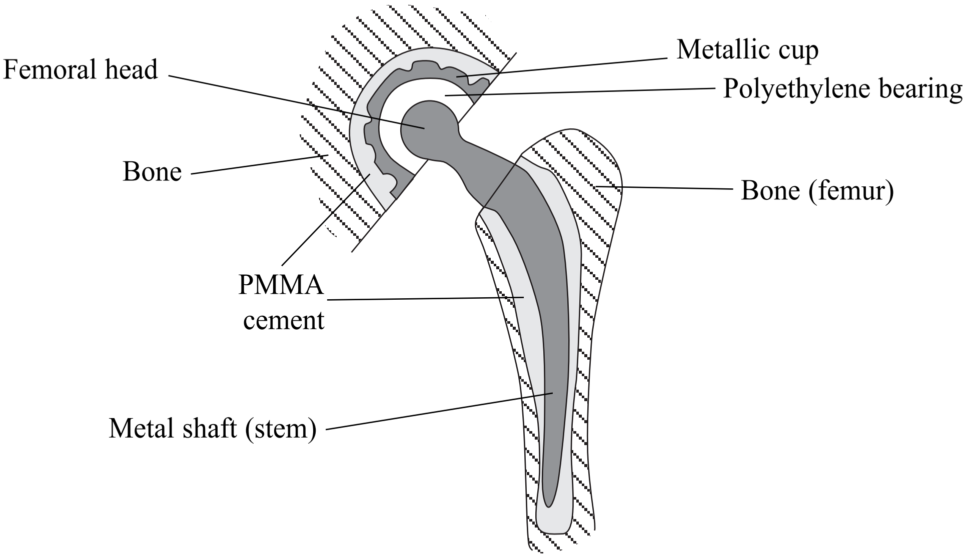
Polymers for the eye: intraocular lenses

(4) One of the early applications of implanted synthetic biomaterials, which continues to be a major success story, is the treatment of eye problems (ophthalmics). During the Second World War ophthalmic surgeon Harold Ridley treated airmen who had shards of cockpit canopy embedded in their eyes following aerial combat. He noticed that the eye was surprisingly tolerant to the canopy material, which was *polymethylmethacrylate* (PMMA). This prompted Ridley to pioneer the use of PMMA as an implant material. Today lenses made of PMMA are used routinely in lens replacement surgery when people's natural lenses have become opaque or damaged due to disease. The PMMA itself is rigid and highly transparent, as well as being physiologically inert, and lenses are able to remain in place indefinitely. One reason for the early success in this field is that the ocular environment is relatively undemanding mechanically and the device is not subject to great stresses.

Polymers in orthopaedics: artificial joints

(5) An environment where the stresses are far greater is in the joints of the body. Surgeons have been implanting artificial hips to restore motion to damaged joints since the early 1960s, and more recently other joints have also been replaced. These joints all have two articulating surfaces, and while a natural surface is constantly regenerated by normal processes this is not the case for synthetic implants, which means that they must be as hard-wearing as possible. In modern practice one of these surfaces is commonly a highly finished metal and the other a polymer. In the early days of hip replacements Teflon was tried as the polymer material, for it has a very low coefficient of friction. However it was found to be far too soft, as the normal movement of an artificial joint caused it to wear away quickly. Modern implants use ultra-high molecular weight polyethylene (UHMWPE) which has far superior mechanical properties and it is very resistant to deformation or wear during use. Wear does still occur, but over many years of use. In the modern artificial hip, the contact surface of the cup section is made from UHMWPE and the bearing ball can be either metallic or ceramic. One appropriate substance for the femoral head is zirconium, for this can be heated to form an outer coating of ceramic zirconia. This gives the component the fracture resistance of metal, with the wear resistance of a ceramic.

Figure 1: Section through an artificial hip joint



(6) The structure of the joint is shown in Figure 1. Notice that the metal stem and the metallic cup are both held in position in the original bone by a cement. Bone cements themselves are another example of the successful use of PMMA in biomedical science, for the cement is made by polymerising a monomer (MMA). The cement must be applied while it is still fluid enough to reach into and fill all the spaces, but must be viscous enough to be handled easily. The MMA is not sufficiently viscous for handling purposes, and so is mixed with a powder of polymerised PMMA. The cement is therefore supplied as two components; a liquid component (including MMA and one part of a catalyst system) and a solid component (PMMA and the second part of the catalyst). Other components are added to stabilise the liquid, and to make the cement visible to X-rays. Figure 2 shows a typical composition. The setting reaction starts when the two components are mixed.

Figure 2: Typical composition of a PMMA bone cement

Powder component	*Amount*
PMMA powder particles (10-150 μm)	>90%
Benzoyl peroxide catalyst	2-3%
Barium sulfate	4-8%

Liquid component	*Amount*
MMA monomer	>85%
Other cross-linking monomers	10-15%
Tertiary amine catalyst	0.005-0.01%

Current trends: degradable polymers

(7) All the examples described so far are materials designed to be as inert as possible in the body environment. However, for some applications it would be an advantage if the implant broke down over a given time period; for example, the thread used to sew up wounds. Early surgical thread had to be removed in a separate operation after the wound had healed. In the early 1970s polyesters derived from lactic acid and glycolic acid were developed for use as surgical thread, which would break down into non-toxic products, spontaneously but slowly.

Turn over ▸

(8) Other uses for degradable polymers quickly emerged, and those made from lactic and glycolic acids are still the most important. One example is the controlled delivery of a drug. In this application the drug is dispersed through a tablet of polymer which is then implanted in a suitable part of the body. The active agent is then released at a rate determined by the rate of breakdown of the polymer. Degradable polymers are also being used as a scaffold on which to grow cells in the laboratory with a view to implanting them into the body to replace or augment damaged tissues. The scaffold acts as a temporary support so that as the cells grow and divide they form into a coherent mass of a predetermined shape. The scaffold slowly degrades and is eliminated, leaving a structure consisting only of cells.

(9) For all these applications, the rate of degradation of the polymer is crucially important. Research into polymers made from lactic acid and glycolic acid has led to the precise control of the breakdown rate, and this has been one of the key issues in the emerging field of tissue engineering.

Tissue engineering

(10) Tissue engineering is the name given to the technology that combines engineering principles to build a polymer scaffold with the techniques of tissue culture to grow cells on the scaffold. This creates new tissue which can be used to restore or replace a non-functional or missing organ. Growing new organs outside the body for subsequent transplantation would clearly have enormous benefits since synthetic devices are never fully integrated into the recipient body. Full exploitation of the potential of this is still many years away, but progress has been made with synthetic polymers being used to control and guide the development of cells or tissues.

(11) Many cells only thrive in the presence of an appropriate surface to which they can attach. Using modern processing techniques, degradable synthetic polymers can be fabricated into porous structures of any desired shape and with pore sizes that encourage cell growth. As the cells multiply, the polymers slowly degrade and are eventually replaced by new tissue mass. Strong adherence to a scaffold usually leads to rapid cell growth, but this is not enough, since it is important that the growing cells maintain their specialist function. The feature of retaining the specialist function of growing cells is one of the most difficult problems to overcome in tissue engineering.

(12) The tissues that are most easily grown by this method consist of a single type of cell, such as the cells making cartilage. Most tissues pose a more complex problem because they consist of more than one cell type. The problem of growing these together, even on a scaffold, is a major challenge.

(13) Any researcher attempting to achieve the potential of tissue engineering needs to take all these factors into account, and also to consider the chemical characteristics of the scaffold material, its surface properties, and its pore size. In addition, it is important to match the properties of the synthetic polymer as it degrades with the requirements of the developing cells.

(14) It is now increasingly possible to use a knowledge of chemistry to design materials to match a required biomedical application and what was once seen as a relatively straightforward task of material substitution is now recognised as a complex and demanding interdisciplinary science. The role of the polymer chemist has been, and will continue to be, of central importance in delivering the polymers and materials required in the future.

Source: adapted from *Body Parts from the Polymer Lab*, CHRIS ANSELL, *Chemistry Review*, January 1999

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