General Certificate of Education
June 2007
Advanced Subsidiary Examination

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

Monday 21 May 2007 1.30 pm to 2.45 pm

For this paper you must have:
- 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 **all** questions.
- Answer **both** Section 1 (Questions 1 to 25) **and** Section 2 (Questions 26 to 50) using the answer sheet provided.
- 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 based on material provided in a separate Data Booklet.
  Section 2 contains 25 objective test questions testing mathematical reasoning and its application.
- There is 1 mark for each question. You will not lose marks for wrong answers.
- 2 mm graph paper is available from the Invigilator.

SECTION 1

Answer **Questions 1** to **25**.

Read the passage entitled **The formula for speed** which is printed in the separate data booklet and answer **Questions 1** to **25** by choosing the answer represented by the letter **A**, **B**, **C** or **D** that you think best.

1 In a 6-cylinder car engine running at 10 000 revolutions per minute, how many explosions will occur every second?

A 500
B 800
C 1000
D 5000

2 A covalent bond (paragraph 3) is one where

A atoms are shared.
B electrons are shared.
C protons are shared.
D molecules are shared.

3 The balance of fuel and air reaching the engine is critical to the success and efficiency of the engine. Which of the following are true statements (paragraph 3)?

1 Too much air and the engine will overheat.
2 Too much air and the engine will not burn all the fuel.
3 Too little air and the engine will overheat.
4 Too little air and the engine will not burn all the fuel.

Answer

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

4 If in a race the car engine receives too little oxygen (paragraph 3) the car will lag behind because it

A does not utilise all its fuel.
B produces the wrong exhaust gases.
C has lower engine temperatures.
D has increased engine wear.

5 How much carbon would you expect to find in 114 g of octane?

Relative atomic mass of carbon	12
Relative atomic mass of hydrogen	1

A 8 g
B 12 g
C 18 g
D 96 g

6 What are the positions of the inlet and exhaust ports (**Figure 1**) when a spark ignites the mixture of fuel and oxygen?

A both open
B inlet open, exhaust closed
C inlet closed, exhaust open
D both closed

7 Petrol used in racing cars contains additives. Which of the following properties do all additives have (**Box 1**)?

1 All contain oxygen.
2 All make combustion more efficient.
3 All contain carbon and hydrogen.
4 All are alcohols.

Answer

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

8 Additives are added to fuels to improve performance (paragraph 6 and **Box 1**). Which of the following is an additive?

A 2-methyl heptane
B ethanol
C cyclohexane
D methyl benzene

9 Each of the following statements is correct **except**

A carbon atoms can form 4 bonds.
B oxygen atoms can form 2 bonds.
C hydrogen atoms can form 3 bonds.
D carbon atoms can form double bonds.

Turn over ▶

10 Which of the following compounds contains the highest percentage of oxygen by mass?

Relative atomic mass of hydrogen	1
Relative atomic mass of carbon	12
Relative atomic mass of oxygen	16

A CH_3OH
B C_2H_5OH
C CH_3OCH_3
D $(CH_3)_3COCH_3$

11 To be a good lubricant an oil must

1 vaporise readily.
2 maintain the necessary viscosity under all conditions.
3 adsorb closely to metal surfaces.
4 maintain the same viscosity under all conditions.

Answer

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

12 Which of the following is most likely to make the best lubricant?

A C_2H_6
B C_8H_{18}
C $C_{20}H_{42}$
D $C_{36}H_{74}$

13 In the context of paragraph 10, what is meant by ‘traction’?

A pulling force of the engine
B friction force between wheels and road
C the movement of the vehicle
D forward thrust of the engine

14 Different tyres are needed for F1 cars (paragraph 10) to provide optimum driving performance for a variety of

1 fuel mixtures.
2 weather conditions.
3 track surfaces.

Answer

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

15 Vulcanisation involves which of the following processes (paragraph 11)?

1 a cross-linking reaction
2 a reaction with sulfur
3 the production of a harder material

Answer

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

16 Which of the following are reasons for the use of dry nitrogen to inflate racing car tyres?

1 Nitrogen expands less than oxygen.
2 Water in air makes expansion unpredictable.
3 Nitrogen is lighter than air.
4 Nitrogen is unreactive to rubber.

Answer

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

17 Which gas in the air reacts most readily with hot rubber?

A nitrogen
B water vapour
C carbon dioxide
D oxygen

Turn over ▶

18 Mass-produced cars are usually made of steel rather than fibre-reinforced composites (paragraph 14) because the newer materials are too

A light.
B strong.
C expensive.
D flammable.

19 Which of the following are true statements about the effect of bonding cotton fibres with THPC (paragraph 15)?

1 The cotton becomes flame retardant.
2 The material maintains its ability to be flame retardant even after laundering.
3 The cotton now becomes capable of withstanding severe impact.
4 If the fabric is exposed to fire it chars and this charred layer helps to insulate against further heat damage.

Answer

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

20 Which of the following statements about lightweight fibre-reinforced composites are true?

They are used for

1 racing car bodies.
2 racing car tyres.
3 drivers' helmets.
4 drivers' overalls.

Answer

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

21 Which of the following are facts rather than opinions?

1 F1 racing should be banned because the cars are fuelled by hydrocarbons which harm the environment.
2 F1 cars are safer than they used to be because they are now made with fibre-reinforced composites.

Answer

A if neither are facts.
B if **1** alone is a fact.
C if **2** alone is a fact.
D if both are facts.

22 In addition to improving standards in F1 racing, chemists have also been involved in

1 developing new running tracks.
2 producing better tennis racquets.
3 designing materials for sports shoes.

Answer

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

Turn over for the next question

Assertion / Reason questions

For each of **Questions 23** 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.

	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**
23	The energy contained in hydrocarbons is released during combustion	because	additives contain oxygen.
24	X-rays show up bits of metal in oil	because	X-rays readily pass through oil but not metal.
25	Cotton fibres have THPC bonded onto them in the making of flame retardant materials	because	this enables the materials to retain the flame retardant properties after washing.

SECTION 2

Answer **Questions 26** to **50**.

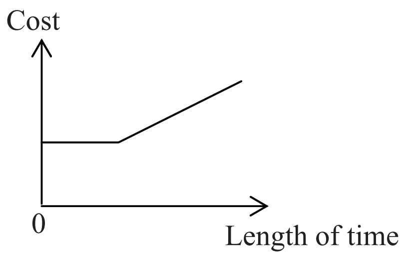
Answer **Questions 26** to **50** by choosing the answer represented by the letter **A**, **B**, **C** or **D** that you think best. Graph paper is available from the Invigilator.

Questions 26 to 28

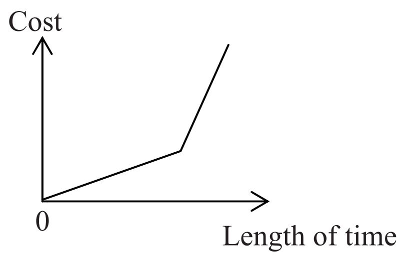
A mobile phone company charges 30p per minute for the first 10 minutes of calls every day and 5p per minute for any further time.

26 Which graph best indicates how the total cost for all calls on one day varies depending on the total length of time a phone is used?

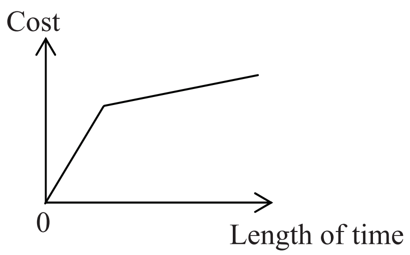
A



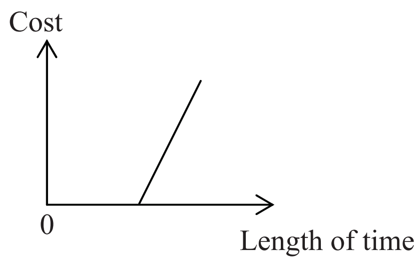
B



C



D



27 Which of the following equations gives the total cost, P pence, of using the phone for m minutes in one day when m is greater than 10?

A $P = 5m$
B $P = 30 + 5(m - 10)$
C $P = 300 + 5m$
D $P = 300 + 5(m - 10)$

28 Over two days a customer uses a phone to make calls for a total of 45 minutes.
The total cost of these calls must have been

A £4.75
B £7.25
C either £4.75 or £7.25
D between £4.75 and £7.25 (inclusive)

Turn over ▸

Questions 29 and 30

There is a lucky dip at a charity fair. The lucky dip contains a selection of bags of sweets, key rings, pens, watches, staplers and empty boxes.

Each individual object in the lucky dip has an equal chance of being picked.

The probabilities of picking the different objects in the lucky dip at the start of the fair are:

Sweets	**Keyrings**	**Pens**	**Watches**	**Staplers**	**Empty boxes**
$\frac{23}{60}$	$\frac{1}{4}$	$\frac{1}{12}$	$\frac{1}{30}$	$\frac{1}{12}$	?

29 What is the probability that the first person picks an empty box?

A $\frac{7}{60}$

B $\frac{1}{6}$

C $\frac{5}{6}$

D $\frac{53}{60}$

30 What is the probability that the first person picks either a pen or a watch?

A $\frac{1}{360}$

B $\frac{1}{60}$

C $\frac{1}{21}$

D $\frac{7}{60}$

31 If $x = 3$ and then $x = 5$ is substituted into the expression $x^2 - 8x - 2$, what is the difference between the two results?

A 0
B 12
C 34
D 52

32 In a market 9 peaches cost €2.
If there are €1.40 to £1 then one peach costs approximately

A 4p
B 8p
C 16p
D 25p

33 A sequence is defined by $u_n = 2^n - n$. What is the difference between the fifth term, u_5, and the sixth term, u_6?

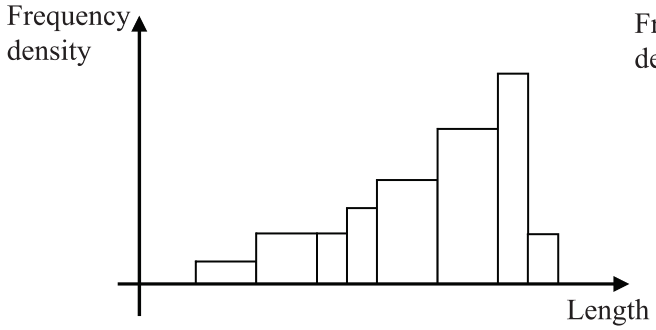
A 27
B 31
C 32
D 58

Turn over for the next question

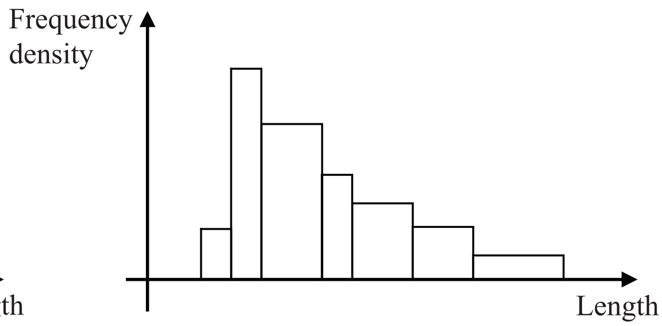
Questions 34 and 35

Histograms are shown for each of four different samples of data on the length of fish.

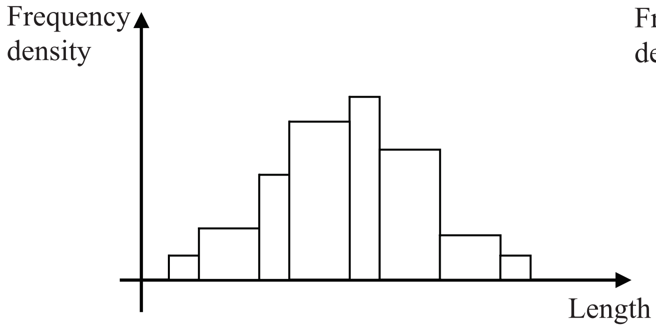
A



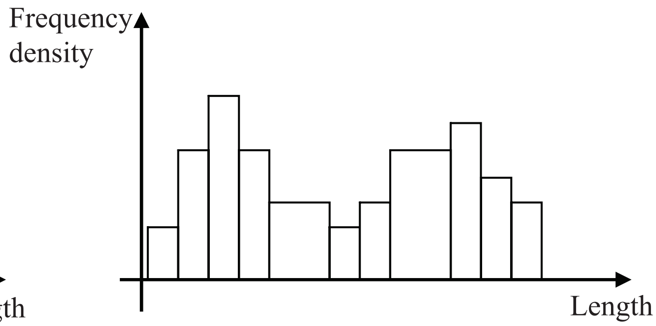
B



C

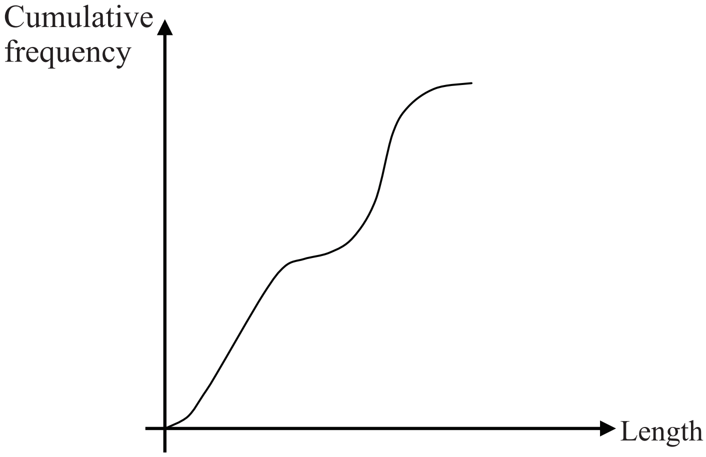


D



34 For which set of data would the mean give the best indication of the length of a typical fish?

35 For which set of data would the cumulative frequency diagram be approximately as shown below?



36 Which one of the following expressions is **not** equivalent to $4x^2 - 8x - 32$?

A $4(x - 2)(x + 4)$
B $(x - 4)(4x + 8)$
C $(x + 2)(4x - 16)$
D $(2x + 4)(2x - 8)$

37 If $xy = 2$ and $xy^2 = 8$, what is the value of x?

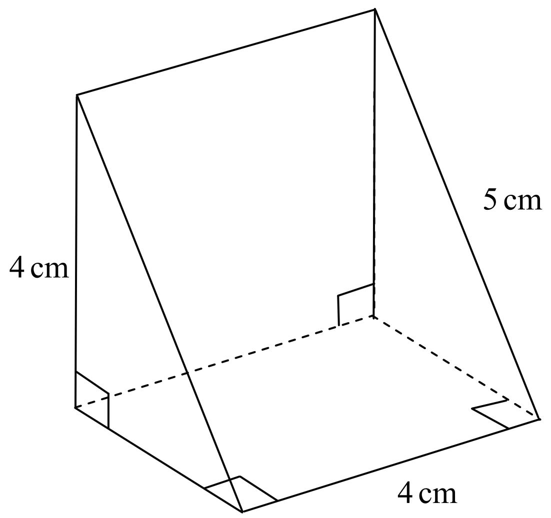
A $\frac{1}{2}$

B 1

C 2

D 4

38 A triangular prism has dimensions as shown. The triangular faces are right-angled.



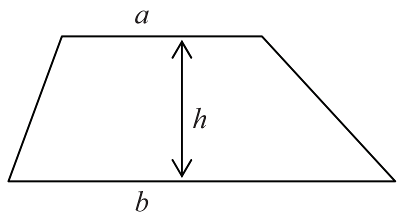
The volume of the prism is

A $24\,cm^3$
B $40\,cm^3$
C $48\,cm^3$
D $80\,cm^3$

Questions 39 to 41

The formula for the area of a trapezium is

$$A = \frac{1}{2}(a + b)h$$



where a and b are the lengths of the parallel sides, and h is the distance between them.

39 Which of the following expresses h in terms of A, a and b?

A $h = 2A - (a + b)$

B $h = \dfrac{\frac{1}{2}A}{a + b}$

C $h = \dfrac{\frac{1}{2}A - a}{b}$

D $h = \dfrac{2A}{a + b}$

40 What is the value of A when $a = \frac{1}{6}$, $b = \frac{1}{12}$ and $h = \frac{1}{10}$?

A $\frac{1}{180}$

B $\frac{1}{80}$

C $\frac{1}{40}$

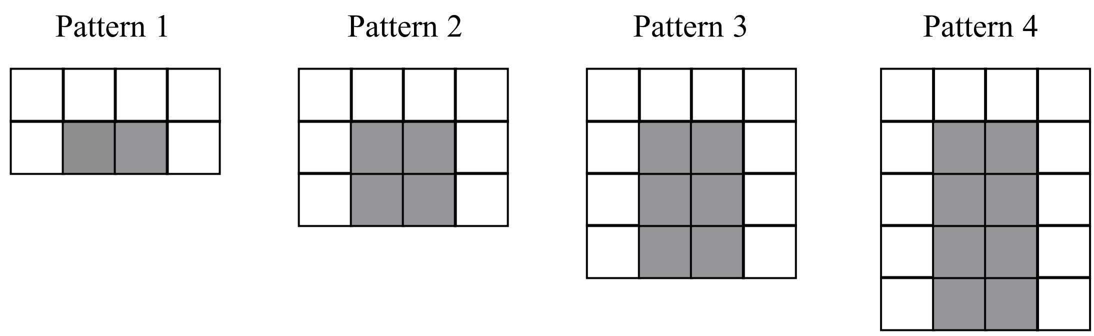
D $\frac{1}{20}$

41 A trapezium has an area of $100\,\text{cm}^2$.

If the trapezium is enlarged so the lengths of a, b and h are all three times as large as they were originally, what would be the area of the larger trapezium?

A $300\,\text{cm}^2$
B $900\,\text{cm}^2$
C $1350\,\text{cm}^2$
D $2700\,\text{cm}^2$

42 Grey and white tiles are used to make patterns. For example, Pattern 3 has 6 grey tiles and 10 white tiles.



The number of white tiles in Pattern n will be

A $n + 2$
B $2n$
C $2n + 4$
D $4n - 2$

Questions 43 and 44

Some statistics for the weight loss over 6 weeks for two groups of 10 people following two different diets are given below.

	Weight loss for those on diet X	Weight loss for those on diet Y
Mean	1.8 kg	2.1 kg
Inter-quartile range	0.9 kg	0.4 kg

43 Which of the following statements can most reasonably be deduced from the table above?

A Those on diet X were originally generally lighter than those on diet Y.
B The person who lost the most weight was on diet X.
C The effect of diet Y is more consistent than the effect of diet X.
D All 20 people lost at least some weight during the 6 weeks.

44 Which of the following statements can be deduced from the table above?

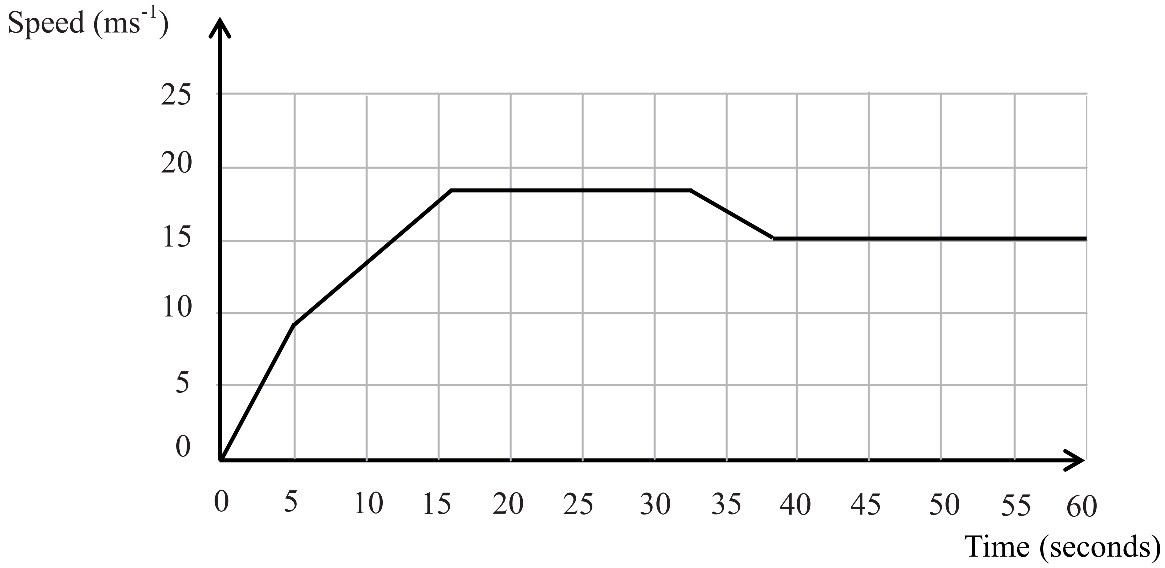
1 The people on diet X generally ate more than those on diet Y.
2 The people on diet X were not as good at keeping to their diet as those on diet Y.

Answer

A if neither can be deduced.
B if **1** but not **2** can be deduced.
C if **2** but not **1** can be deduced.
D if both can be deduced.

Turn over ▶

45 The speed-time graph shows a simplified version of the first part of a car journey.



The distance travelled during the first 15 seconds is approximately

A 18 m
B 160 m
C 185 m
D 900 m

46 Three friends are comparing the fuel consumption of their cars.
Emma says, "My car will travel 13 km on 1 litre of petrol".
Sam says, "My car does 540 km on a full tank of 45 litres".
Tim says, "Mine uses just 8 litres to do 100 km".

List the friends' cars in order of fuel consumption, with the most economical first.

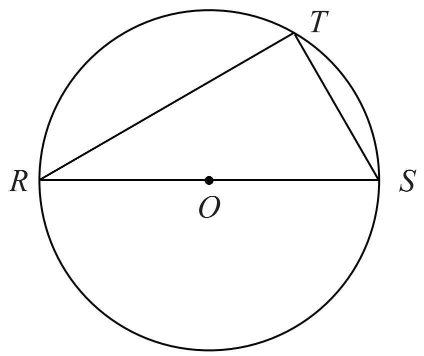
A Sam's, Tim's, Emma's
B Sam's, Emma's, Tim's
C Tim's, Emma's, Sam's
D Emma's, Tim's, Sam's

47 A digital camera can take pictures at different resolutions.
A 'standard' image measures 1024 by 768 pixels.

The total number of pixels in a 'standard' image, written in standard form to 2 significant figures, is

A 1.8×10^3
B 7.9×10^5
C 7.7×10^6
D 7.9×10^6

48 *RS* is a diameter of a circle, centre *O*. *ST* = 9 cm and *RT* = 12 cm.



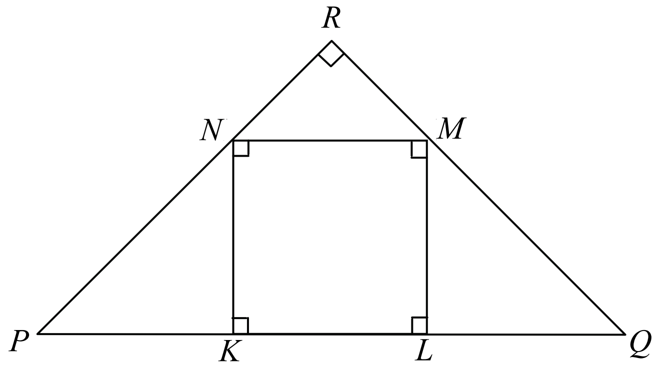
The size of the angle *TRS* is

A 36.9°
B 41.4°
C 48.6°
D 53.1°

49 The price of a car is increased by 17%.
As part of a promotion a discount of 8% is given on this new price.
If the price before the increase was £8500, how much extra does the car cost during the promotion?

A £649.40
B £765
C £1329.40
D £2125

50 The diagram shows part of a patchwork quilt. Square *KLMN* fits exactly inside the isosceles right-angled triangle *PQR*.



The square is yellow and the triangular pieces are blue. The ratio of yellow to blue showing on this part of the quilt is

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

END OF QUESTIONS

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General Certificate of Education
June 2007
Advanced Subsidiary Examination

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

Data Booklet

Data Booklet for use with **Section 1 Questions 1** to **25**

PASSAGE FOR QUESTIONS 1 TO 25

Consider the following passage, **Figure 1** and **Box 1**.

The formula for speed

(1) Although Formula One (F1) racing is one of the world's most glamorous sports, few people stop to consider the impact that chemists have had on motor racing, arguably more than on any other sport. Chemists have been involved not only in making cars go faster for longer, but also making them safer. It is only by chemical and engineering perfection that man and machine are able to set new performance records. Chemists have made a huge impact on F1 racing, from the bodywork to additives in fuel.

Explosive reactions

(2) The engine is the heart of the car. It converts chemical energy into kinetic energy through an organised sequence of chemical explosions. With the engine running at 10 000 revolutions per minute there will be 5000 explosions per minute in each cylinder. Which means, for a 10-cylinder engine, over 800 explosions per second! But these are not brute-force explosions. Despite lasting for milliseconds they must be smooth and not just a detonation. There is nothing brutal about the racing engine: it is a most sophisticated reaction vessel working at extremes of pressure and temperature. The level of refinement is a result of chemists and engineers working in partnership with a total commitment to perfection.

Covalent bonds into energy

(3) Chemists need to focus upon the reactions of the petrol/air mixture which produce the explosions. The aim is to convert the chemical energy in the various covalent bonds of the hydrocarbon/oxygen mixture into kinetic energy. Petrol is a complex mixture of hydrocarbons obtained from distillation of petroleum, the main component being octane (C_8H_{18}). Traditionally, a carburettor would vaporise the liquid petrol and mix the resulting vapour with an exact amount of air. This task is now performed by computer-controlled fuel injection systems. The reaction that subsequently occurs in the cylinder is shown below in Equation 1, but the exact stoichiometric* ratio varies due to the demands upon the engine. Hence the fuel injection system must be finely tuned: too much air and the engine will burn out before the first lap; too little air and the car will be lagging behind, churning out unburnt hydrocarbons from its exhaust. The role of the engine is to convert the chemical energy in the covalent bonds of the octane (and other hydrocarbons) by means of efficient oxidation.

$$2C_8H_{18}(g) + 25O_2(g) \longrightarrow 16CO_2(g) + 18H_2O(g) \qquad \text{Equation 1}$$

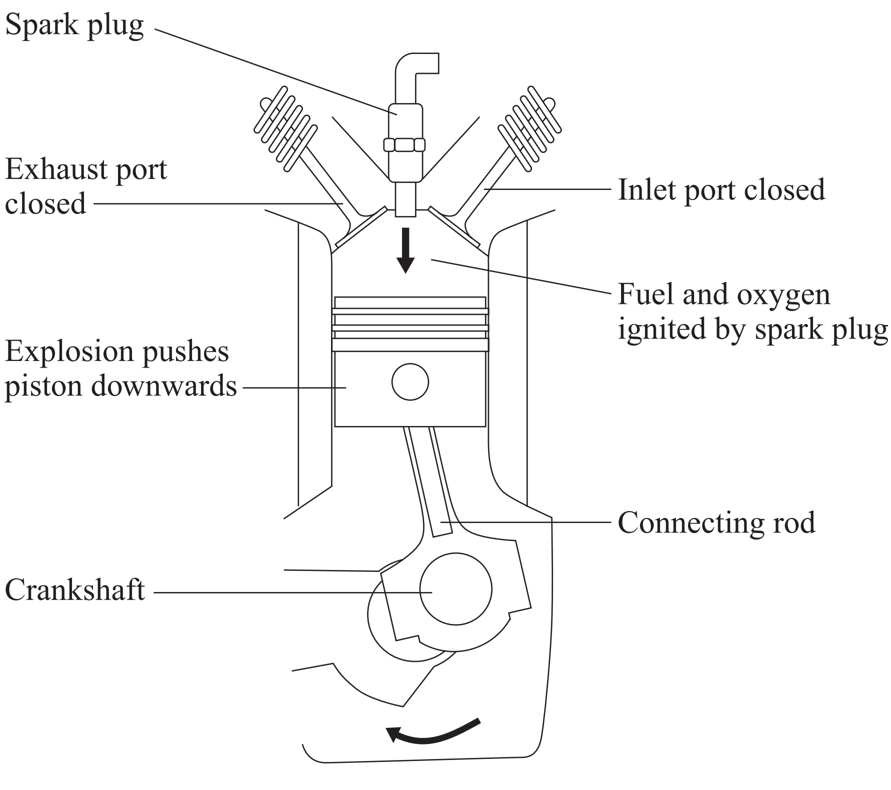
* Stoichiometric – describes chemical reactions in which the reactants combine in simple whole-number ratios.

(4) The most important feature of the reaction in Equation 1 is the heat released. The energy is produced in milliseconds and causes a huge temperature rise which, in turn, results in a dramatic pressure increase. All this takes place in the cylinders (see **Figure 1**) and delivers a massive force upon the pistons. As the pistons are forced down inside the cylinders, they push connecting rods to turn the crankshaft. Thus the sequence goes:

chemical energy – heat energy – kinetic energy

(5) As the piston moves down the cylinder, the volume increases and the gases cool. They are discharged to the atmosphere as exhaust gases – cooler than in the explosions but still very hot.

Figure 1: Illustration of a car cylinder



Fuel chemistry

(6) Equation 1 is a simplification of the engine's combustion reaction. In fact, many hydrocarbons are involved because petrol is not a single compound but a mixture of hydrocarbons: alkanes, alkenes, aromatics and isomers of each group. For racing cars it is common practice to put in additives to improve combustion characteristics and so increase performance. Some of the additives used are shown in **Box 1** overleaf. As illustrated by the examples, all of them contain oxygen in one form or another and this enables combustion to take place in a more efficient manner.

(7) Research in fuel chemistry relies upon analytical techniques such as gas chromatography-mass spectrometry (GC-MS). In addition to this research, GC-MS is used at the trackside to check the fuel going into the cars to see that it is within the legal specification.

Lubrication

(8) With all the metal parts rubbing against each other at high speed – speeds can reach hundreds of miles per hour in bearings and cylinders – efficient lubrication is essential. The most widely used lubricants are hydrocarbon oils obtained, like petrol, from petroleum distillation, but the molecules used as lubricants are long-chain hydrocarbons. The lubricants must adsorb onto the metal surface to prevent metal-metal contact, and they must maintain the required viscosity at extremes of temperature.

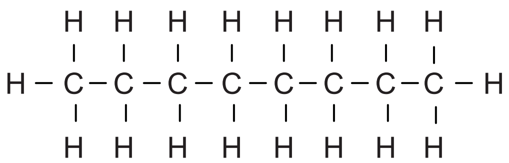
(9) To obtain the best lubricating properties, chemists study the intermolecular attractions between the molecules and the metal surfaces and also between the molecules themselves. Without lubrication the friction would be so intense that the metal parts would melt and weld together. But despite the best efforts of chemists and engineers, sometimes there is a lubrication failure and the engine catastrophically disintegrates. Oil is tested at the trackside to see if small particles of metal are present, which is an indication that wear is taking place and lubrication failure could be imminent. X-rays will show both the presence of metals in oil and are used to determine the elemental composition of any particles in the oil.

Box 1

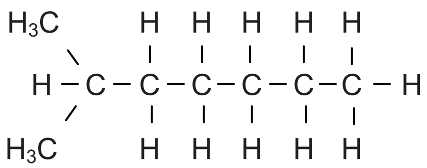
Fuel additives

Petrol is a mixture of hydrocarbons obtained from the distillation of petroleum. Sometimes oxygen-containing molecules are added to improve the fuel's performance. In F1 racing there are strict rules on fuel composition, laid down by the Federation Internationale de l'Automobile (FIA), which is the governing body for F1 racing.

Hydrocarbons, C4 to C9: alkanes, straight chain and branched (e.g. octane and 2-methyl heptane); cycloalkanes (e.g. cyclohexane); alkenes (e.g. pent-2-ene); aromatics (e.g. methyl benzene).



octane C_8H_{18}

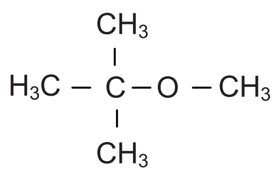


2-methyl heptane C_8H_{18}
(an isomer of octane)

Additives: alcohols (e.g. methanol and ethanol) and ethers

CH_3OH methanol

C_2H_5OH ethanol



an ether

Tyres

(10) It is through the tyres that the power from the rear wheels is applied to the track surface to force the car forward. This can be as much as 1000 horsepower (745 kW). Maximum friction is essential to avoid wheel spin, which wastes much of that vital power. To obtain the best possible traction, tyres of different types are available and the appropriate ones selected for the prevailing conditions.

(11) The major component of tyres is vulcanised rubber. Natural rubber does not have the strength and hardness needed for tyres, but on reaction with sulfur one of the components of rubber, a linear polymer, undergoes a crosslinking reaction to generate a harder material. This process is called vulcanisation. Antioxidants are added to prevent the rubber degrading.

(12) Reinforcement of the tyres is achieved by means of a cord spun from nylon or polyester; steel wire is used for the bead, where the tyre hugs the wheel rim.

(13) During a race the tyres reach temperatures of 80 – 100 °C. To minimise pressure fluctuations as the tyres warm up and cool down they are inflated with dry nitrogen, rather than compressed air. Air contains variable amounts of water, which makes its expansion properties unpredictable. Pure nitrogen also expands less than air when heated and is unreactive towards hot rubber, so making it a better choice of gas for the tyres.

Car body and structure

(14) F1 racing drivers put their cars under great stress and the structural parts of the car must withstand huge forces. In the early days of racing the cars had aluminium bodies but, to provide the high strength and light weight for a modern F1 car, new materials have been developed by polymer chemists. After a lot of research and testing, a range of fibre-reinforced composites was produced which are now superior to metals in both weight and strength.

Driver protection

(15) F1 racing is a dangerous business with an ever-present risk of crash or fire. Thus protecting the driver is a major consideration. The driver's helmet must be lightweight and capable of withstanding severe impact – again fibre-reinforced composites are ideal for this purpose. Clothing must be flame retardant and textile chemists have found ways of treating cotton fabrics. Cotton is a natural polymer of cellulose (with glucose as its monomer). To make it flame retardant, it is treated with tetrakis(hydroxymethyl)phosphonium chloride (THPC). This is made to bond with the cotton fibres so that it is not lost during laundering. In a fire the fabric chars rather than burns, and this charred layer prevents further heat damage.

(16) As the ability to drive faster increases, the need for better safety equipment is increased, so it is up to the chemists to keep up with this race within a race!

Source: from an article by TONY HARGREAVES, *Chemistry Review*, Vol.13, November 2003

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