A-level
COMPUTER SCIENCE

Paper 2

TBC am/pm 2 hours 30 minutes

Materials
- There are no additional materials required for this paper.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the bottom of this page.
- Answer **all** questions.
- Do all rough work in this book. Cross through any work that you do not want to be marked.
- You may use a calculator.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.

Advice
- In some questions you may be required to indicate your answer by shading a lozenge. If you wish to change your answer make sure that the incorrect answer is clearly crossed through with an x.

Please write clearly, in block capitals, to allow character computer recognition.

Centre number ☐☐☐☐☐ Candidate number ☐☐☐☐

Surname

Forename(s)

Candidate signature _____

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

0 1 **Figure 1** shows how some of the components of a computer system can be connected together.

Figure 1

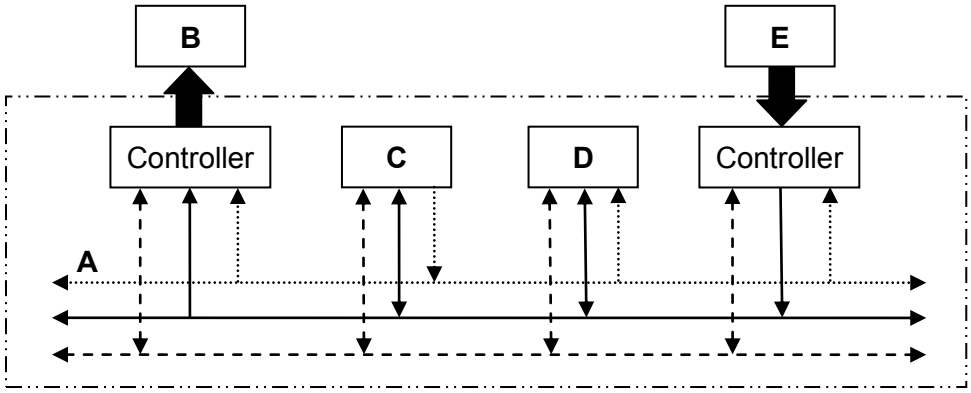


Table 1 lists the names of six components in the column headings and the five letters (**A**-**E**) from **Figure 1** in the row headings.

For each row in **Table 1**, shade **one** lozenge, in the appropriate column, to indicate which component in **Figure 1** has been labelled with the row letter.

As an example, the first row has been completed for you, to indicate that component **A** in **Figure 1** is the Address bus.

[4 marks]

Table 1

	Processor	Address bus	Data bus	Main memory	Keyboard	Visual display unit
A	⬭	⬬	⬭	⬭	⬭	⬭
B	⬭	⬭	⬭	⬭	⬭	⬭
C	⬭	⬭	⬭	⬭	⬭	⬭
D	⬭	⬭	⬭	⬭	⬭	⬭
E	⬭	⬭	⬭	⬭	⬭	⬭

4

0 2 The internal buses in a computer use parallel communication while most peripherals communicate with a computer using serial communication.

0 2 . 1 Explain the differences between the ways in which parallel and serial communication is carried out.

[2 marks]

Most peripherals, such as printers and keyboards, communicate with a computer using a serial connection.

0 2 . 2 Apart from the widespread availability of USB (Universal Serial Bus) ports, explain why peripherals usually use a serial communication method such as USB instead of parallel communication.

[1 mark]

In communications systems, a distinction is made between the bit rate and the baud rate.

0 2 . 3 Define the term baud rate.

[1 mark]

0 2 . 4 Explain how it is possible for the bit rate to be higher than the baud rate.

[1 mark]

5

0 3 A burglar alarm system is to be implemented that has the following sensors:

- a door sensor **D** that outputs TRUE when the door is open and FALSE when the door is shut
- a pressure mat sensor **M** that outputs TRUE while a weight is detected on it and FALSE when no weight is detected on it.

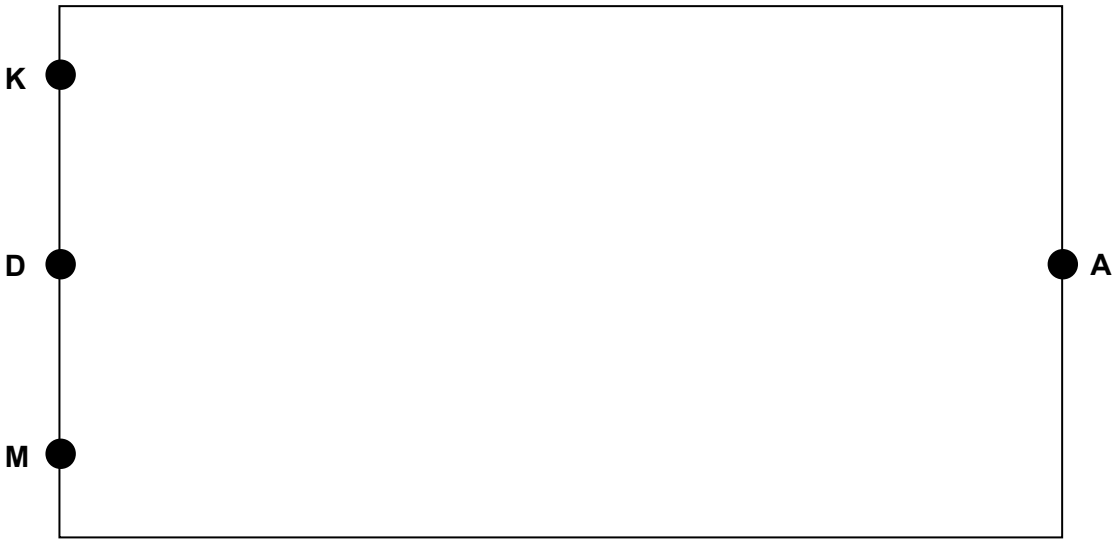
The alarm also has a key **K** that turns the alarm on and off. **K** outputs a TRUE signal when the alarm is switched on and FALSE when the alarm is off.

The alarm output **A** sounds a bell. It should be TRUE if:

- the alarm is on AND
- either of the sensors **D** or **M** are set to the value TRUE.

0 3 . 1 In the space below, draw a logic circuit that will behave as described above for the inputs **D**, **M** and **K** and the output **A**.

[2 marks]



0 3 . 2 Write a Boolean expression to represent the logic of this alarm system.

[2 marks]

A = _____

0 3 . 3 In this alarm system, the alarm bell will sound only while the door is open or a weight is placed on the pressure mat. If someone who has stepped on to the mat moves off it, or an open door is closed, the alarm bell will stop ringing.

A D-type flip-flop could be incorporated into the logic circuit so that the alarm bell would continue to sound after a person closed the door or moved off the pressure mat.

Explain how this could be achieved. In your answer refer to:

- why a D-type flip-flop would be suitable for this task
- where the D-type flip-flop would need to be inserted into the circuit
- what additional input the D-type flip-flop would need.

[3 marks]

7

Turn over for the next question

0 4 The phrase “Internet of Things” is used to describe the connection of many everyday devices such as home heating controls, utility meters, cars and environmental sensors to the Internet. It is believed that tens of billions of devices will be connected to the Internet of Things by the end of the decade.

One anticipated use of the Internet of Things is to monitor the food that consumers have inside their fridges. This data could be gathered automatically from consumers’ devices by retailers who sell food. Retailers could use the data to analyse consumer consumption habits or automatically prepare deliveries for customers.

In the context of an Internet connected fridge, discuss the technologies that will be required to make the Internet of Things work.

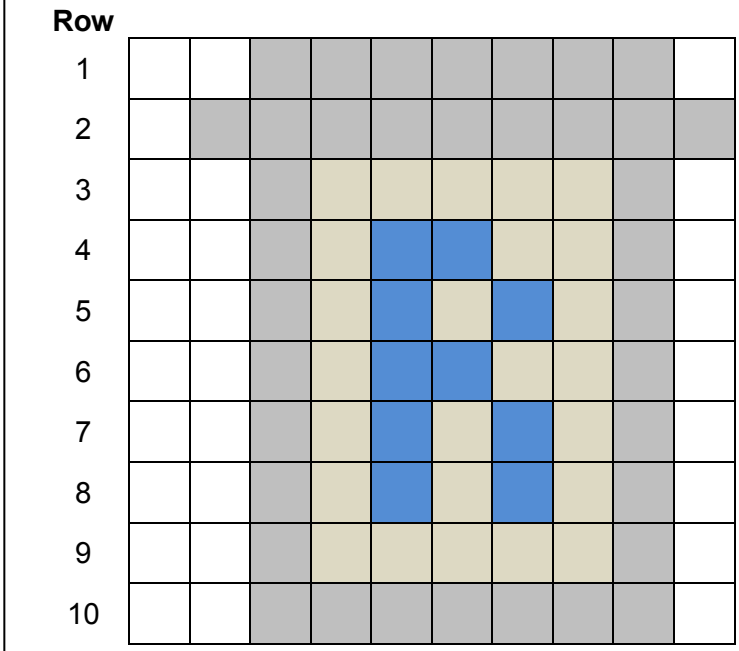
You may wish to consider how the data might be captured, how networking technologies are changing to provide the necessary infrastructure, and how the data gathered by retailers could be stored and processed, from a hardware and software viewpoint.

[12 marks]

12

0 5 The icon in **Figure 2** is represented in a computer's memory as a bitmap image.

Figure 2



Four different colours have been used in the icon.

Row 1 of the icon is represented in the computer's memory as the bit pattern:

1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

0 5 . 1 What are the bit patterns that have been used to represent a grey pixel and a white pixel?

[1 mark]

Grey pixel: _____ White pixel: _____

0 5 . 2 State **one** possible 20-bit representation for **Row 4** of the icon in **Figure 2**.

[1 mark]

0 5 . 3 Calculate the number of bytes required to represent all the pixel data in the icon as a bitmap.

Show your working.

[2 marks]

Answer: _____

0 5 . 4 When the bitmap is saved as a file, the file size is bigger than the answer to **0 5 . 3** . This is because metadata is saved in the file with the pixel data

State **one** item of metadata that would be stored in a bitmap file.

[1 mark]

Run-length encoding (RLE) is an example of a compression method that could be used to reduce the amount of memory required to store the icon in **Figure 2**.

0 5 . 5 Describe the principle used by RLE to compress a file and explain why RLE is an appropriate compression method for compressing images such as icons.

[3 marks]

8

0 6 **Figure 3** shows the structure of an example machine code instruction, taken from the instruction set of a particular processor.

Figure 3

Opcode							Operand(s)							
Basic Machine Operation						Addressing Mode								
0	1	1	0	1	0	1	0	0	1	0	1	0	1	1

0 6 . 1 How many different basic machine operations could be supported by the instruction set of the processor used in the example in **Figure 3**?

[1 mark]

Figure 4 shows an assembly language program together with the contents of a section of the main memory of the computer that the program will be executed on.

The assembly language instruction set that has been used to write the program is listed in **Table 2**.The lines of the assembly language program have been numbered to help you answer question parts **0 6 . 2** to **0 6 . 4**.

Figure 4

Line	Command
1	`MOV R2, #100`
2	`LDR R3, 101`
3	`ADD R2, R2, R3`
4	`LSL R3, R2, #1`
5	`HALT`

Memory Address (in decimal)	Main Memory Contents (in decimal)
100	23
101	10
102	62
103	18

0 6 . 2 What value will be stored in register `R2` immediately after the command in line 1 has been executed?

[1 mark]

---

0 6 . 3 What value will be stored in register `R2` immediately after the program has executed the commands from line 1 through to line 3?

[1 mark]

---

0 6 . 4 What value will be stored in register `R3` after the complete program has finished executing?

[1 mark]

Table 2

`LDR Rd, <memory ref>`	Load the value stored in the memory location specified by `<memory ref>` into register `d`.
`STR Rd, <memory ref>`	Store the value that is in register `d` into the memory location specified by `<memory ref>`.
`ADD Rd, Rn, <operand2>`	Add the value specified in `<operand2>` to the value in register `n` and store the result in register `d`.
`SUB Rd, Rn, <operand2>`	Subtract the value specified by `<operand2>` from the value in register `n` and store the result in register `d`.
`MOV Rd, <operand2>`	Copy the value specified by `<operand2>` into register `d`.
`CMP Rn, <operand2>`	Compare the value stored in register `n` with the value specified by `<operand2>`.
`B <label>`	Always branch to the instruction at position `<label>` in the program.
`B<condition> <label>`	Conditionally branch to the instruction at position `<label>` in the program if the last comparison met the criteria specified by the `<condition>`. Possible values for `<condition>` and their meaning are: • EQ: Equal to. • NE: Not equal to. • GT: Greater than. • LT: Less than.
`AND Rd, Rn, <operand2>`	Perform a bitwise logical AND operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`ORR Rd, Rn, <operand2>`	Perform a bitwise logical OR operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`EOR Rd, Rn, <operand2>`	Perform a bitwise logical exclusive or (XOR) operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`MVN Rd, <operand2>`	Perform a bitwise logical NOT operation on the value specified by `<operand2>` and store the result in register `d`.
`LSL Rd, Rn, <operand2>`	Logically shift left the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`LSR Rd, Rn, <operand2>`	Logically shift right the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`HALT`	Stops the execution of the program.

Interpretation of `<operand2>`

`<operand2>` can be interpreted in two different ways, depending upon whether the first symbol is a `#` or an `R`:

- `#` - use the decimal value specified after the `#`, eg `#25` means use the decimal value 25.
- `Rm` - use the value stored in register `m`, eg `R6` means use the value stored in register 6.

The available general purpose registers that the programmer can use are numbered 0 to 12.

Question 6 continues on the next page

Programs written in a high-level language can be compiled or interpreted.

Companies that develop computer programs to sell usually compile the final version of a program before distributing it to customers.

0 6 . 5 Explain why the final version of a computer program is usually translated using a compiler.

[2 marks]

The JavaScript programming language can be used to write programs that are executed in a web browser on any Internet user's computer.

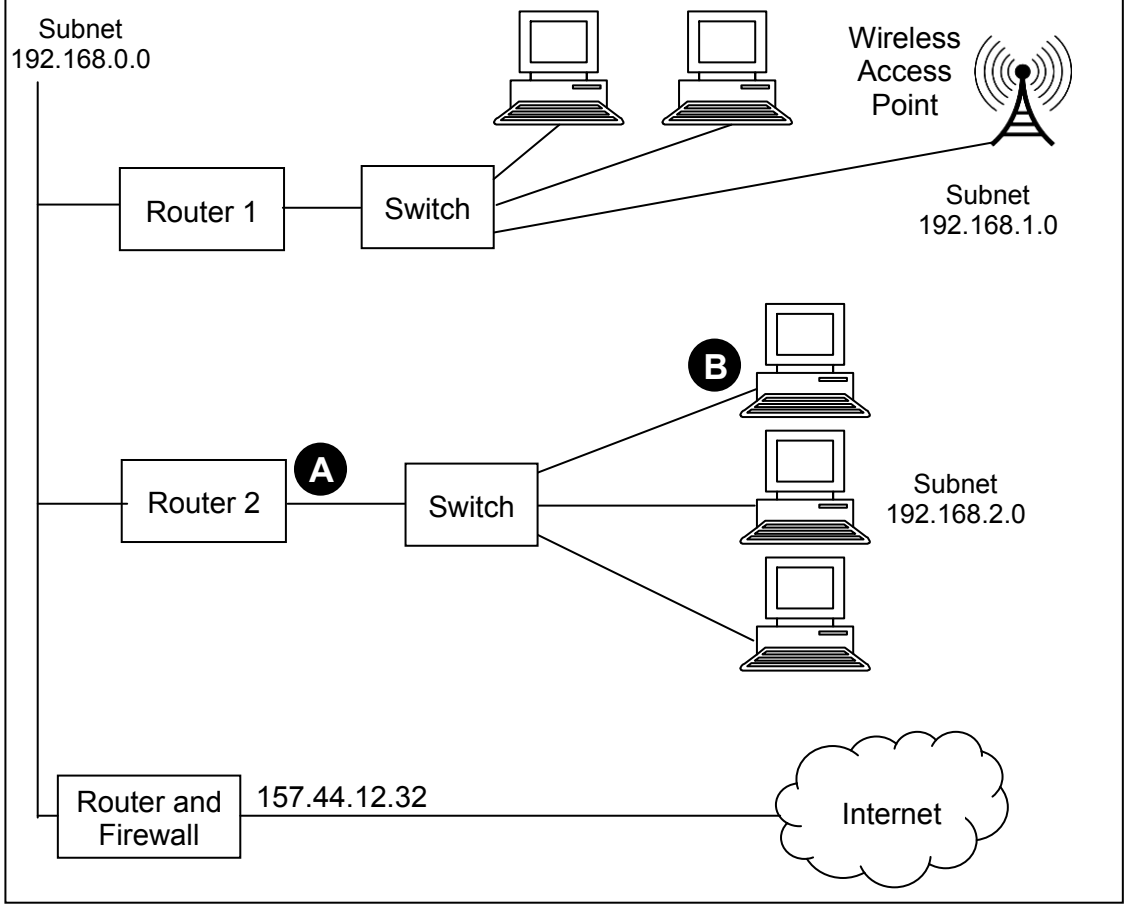
0 6 . 6 Explain why programs written in the JavaScript language, to be executed in a web browser, are interpreted rather than compiled.

[2 marks]

8

0 7 **Figure 5** shows the physical topology of a local area network (LAN) and its connection to the Internet. The LAN uses the IPv4 protocol.

Figure 5



0 7 . 1 State suitable IP addresses for:

[2 marks]

The 'Router 2' port labelled **A**: _____

The computer network interface card labelled **B** : _____

0 7 . 2 State **one** advantage of the star topology over the bus topology, and explain how this is achieved.

[2 marks]

_____

_____

_____

_____

Question 7 continues on the next page

Laptop computers connect to the network using WiFi. They use carrier sense multiple access with collision avoidance (CSMA/CA) to determine when to transmit data.

0 7 . 3 Describe how the CSMA/CA method is used.

[6 marks]

Each packet of data transmitted around the LAN includes a checksum, which is used for error detection.

0 7 . 4 Describe how the checksum is used for error detection.

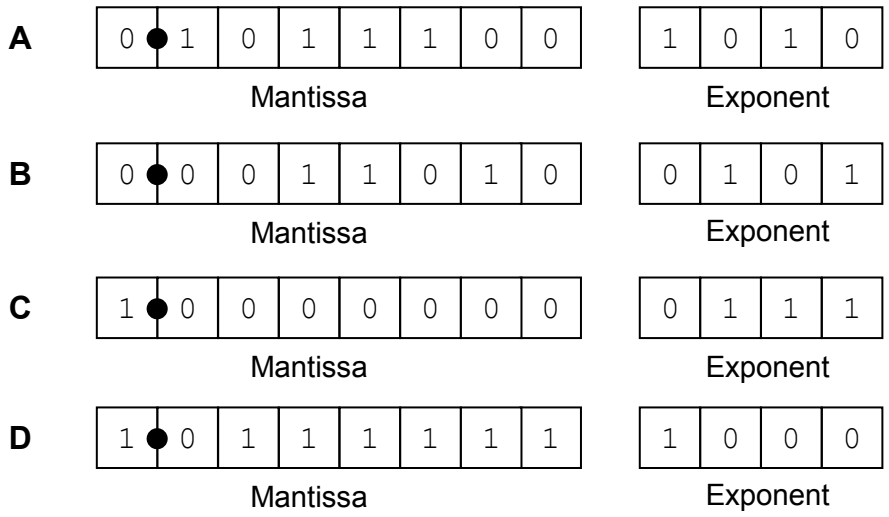
[3 marks]

13

0 8 A particular computer uses a **normalised** floating point representation with an 8-bit mantissa and a 4-bit exponent, both stored using **two's complement**.

Four bit patterns that are stored in this computer's memory are listed in **Figure 6** and are labelled **A**, **B**, **C**, **D**. Three of the bit patterns are valid floating point numbers and one is not.

Figure 6



0 8 . 1 Complete **Table 3**. In the Correct letter (**A**-**D**) column shade the appropriate lozenge **A**, **B**, **C** or **D** to indicate which bit pattern in **Figure 6** is an example of the type of value described in the Value description column.

Do **not** use the same letter more than once.

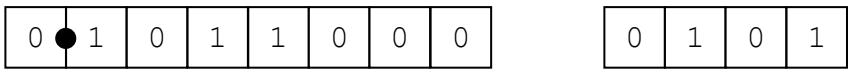
[3 marks]

Table 3

Value description	Correct letter (A-D)
A positive normalised value	A ⬭ B ⬭ C ⬭ D ⬭
The most negative value that can be represented	A ⬭ B ⬭ C ⬭ D ⬭
A value that is not valid in the representation because it is not normalised	A ⬭ B ⬭ C ⬭ D ⬭

Question 8 continues on the next page

0 8 . 2 The following is a floating point representation of a number:



Mantissa Exponent

Calculate the decimal equivalent of the number. Show how you have arrived at your answer.

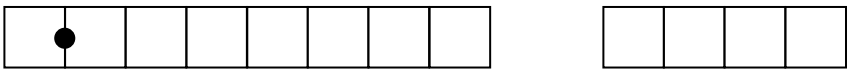
[2 marks]

Answer:

0 8 . 3 Write the normalised floating point representation of the negative decimal value -6.75 in the boxes below. Show how you have arrived at your answer.

[3 marks]

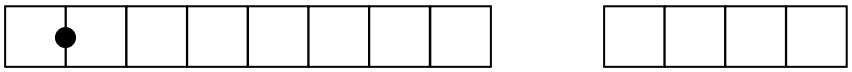
Answer:



Mantissa Exponent

An alternative two's complement format representation is proposed. In the alternative representation 6 bits will be used to store the mantissa and 6 bits will be used to store the exponent.

Existing Representation (8-bit mantissa, 4-bit exponent):



Mantissa Exponent

Proposed Alternative Representation (6-bit mantissa, 6-bit exponent):

Mantissa Exponent

0 8 . 4 Explain the effects of using the proposed alternative representation instead of the existing representation.

[2 marks]

10

Turn over for the next question

0 9 A school stores information about its sports day in a relational database.

The details of the track events are stored using the three relations in **Figure 7**.

Figure 7

Athlete (AthleteNumber, Forename, Surname, Class, Gender, DateOfBirth)

Race (RaceNumber, Gender, Distance, Type, StartTime)

RaceEntryAndResult (RaceNumber, AthleteNumber, TimeSet)

Each athlete who takes part in a race is given a unique AthleteNumber. Athletes can run in more than one race. If they do, they keep the same AthleteNumber for the entire day.

Many races are run throughout the day. An example race would be the boys 80m hurdles, the third race of the day, which starts at 13:30. The entry in the Race table for this race is shown in **Table 4**:

Table 4

RaceNumber	Gender	Distance	Type	StartTime
3	Boys	80	Hurdles	13:30

When an athlete is entered into a race, a record of the entry is created in the RaceEntryAndResult table. Initially, the TimeSet is recorded as 00:00.00 (meaning 0 minutes, 0 seconds, 0 hundredths of a second) to indicate that the race has not yet been run. After the race has been run, if the athlete successfully completes it, then their TimeSet value is updated to record the time that they achieved in minutes, seconds and hundredths of a second. The TimeSet value remains at 00:00.00 for athletes who fail to complete the race.

The primary keys in the Athlete and Race relations have been identified in **Figure 7** by underlining them. The correct primary key for the RaceEntryAndResult relation has not been identified.

0 9 . 1 In **Figure 8** below, underline the appropriate attribute name(s) to identify the correct primary key for this relation.

[1 mark]

Figure 8

RaceEntryAndResult(RaceNumber, AthleteNumber, TimeSet)

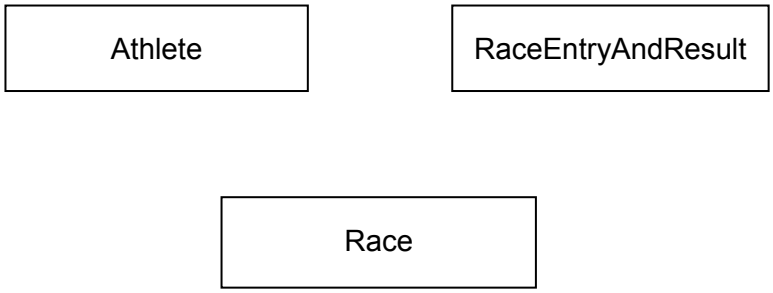
0 9 . 2 Relations in a database should usually be fully normalised.

Define what it means for a database to be fully normalised.

[2 marks]

0 9 . 3 On the incomplete Entity-Relationship diagram below show the degree of the **three** relationships that exist between the entities.

[2 marks]



Athlete number 27 is to be entered into race number 6.

0 9 . 4 Write the SQL commands that are required to make this entry.

[2 marks]

Question 9 continues on the next page

Figure 7 is repeated below.

Figure 7 (repeated)

Athlete(AthleteNumber, Forename, Surname, Class, Gender, DateOfBirth)

Race(RaceNumber, Gender, Distance, Type, StartTime)

RaceEntryAndResult(RaceNumber, AthleteNumber, TimeSet)

Athlete number 27 sets a time of 0:18.76 (0 minutes, 18 seconds, 76 hundredths of a second) for race number 6.

0 9 . 5 Write the SQL commands that are required to update the athlete's entry for this race, to store this time in the TimeSet field.

[3 marks]

The competition organisers want to produce a list of all of the athletes who took part in race number 6 with the athlete who won (set the lowest time) at the top and the other athletes below the winner in the order in which they finished.

Only athletes who finished the race should be included in the list.

The following information should appear for each athlete: AthleteNumber, Forename, Surname and TimeSet.

0 9 . 6 Write an SQL query to produce the list.

[5 marks]

The database system is to be extended for use in an inter-school athletics league. Users at any school in the county will be able to access the system to input the results of races.

It is possible that two users might try to access or update the system at the same time.

0 9 . 7 Explain the conditions under which simultaneous access to a database could cause a problem, and how this could be dealt with.

[3 marks]

18

1 0 Two computers, **A** and **B**, are involved in a secure communication that uses asymmetric encryption. **A** is sending a message to **B**.

Each computer has a public key and a private key.

1 0 . 1 Complete the missing words in the following paragraph.

[2 marks]

A will encrypt the message using _____ key. The message will be decrypted by **B** using _____ key.

The security of the communication could be improved by the addition of a digital signature.

1 0 . 2 State **two** benefits of including a digital signature.

[2 marks]

_____

_____

_____

_____

4

1 1 . 1 **Table 5** lists six Boolean equations. Three of them are correct, the others are not. Shade the lozenges next to the **three** equations are correct.

[3 marks]

Table 5

Equation	Correct? (Shade three)
$A \cdot \overline{A} = 1$	⬭
$A + B = \overline{\overline{A} \cdot \overline{B}}$	⬭
$A + 1 = 1$	⬭
$A \cdot (A + B) = A$	⬭
$A + (A \cdot B) = B$	⬭
$A \cdot 1 = 1$	⬭

1 1 . 2 Use Boolean algebra to simplify the following expression:

$$\overline{\overline{A} + \overline{B}} + B \cdot \overline{A}$$

Show your working.

[3 marks]

Answer:

6

Turn over for the next question

1 2 In a functional programming language, a recursively defined function named `map` and a function named `double` are defined as follows:

```
map f []     = []
map f (x:xs) = f x : map f xs

double x     = 2 * x
```

The function `map` has two parameters, a function `f`, and a list that is either empty (indicated as `[]`), or non-empty, in which case it is expressed as `(x:xs)` in which `x` is the head and `xs` is the tail, which is itself a list.

1 2 . 1 In **Table 6**, write the value(s) that are the head and tail of the list `[ 1, 2, 3, 4 ]`.

[1 mark]

Table 6

Head	
Tail	

The result of making the function call `double 3` is `6`.

1 2 . 2 Calculate the result of making the function call listed in **Table 7**.

[1 mark]

Table 7

Function Call	**Result**
`map double [ 1, 2, 3, 4 ]`	

1 2 . 3 Explain how you arrived at your answer to question **1 2 . 2** and the recursive steps that you followed.

[3 marks]

END OF QUESTIONS

5

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED