Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

# A-level
# COMPUTER SCIENCE

## Paper 2

Tuesday 18 June 2024 Afternoon Time allowed: 2 hours 30 minutes

**Materials**
For this paper you must have:
- a calculator.

**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.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.

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

**Advice**
- In some questions you are required to indicate your answer by completely shading a lozenge alongside the appropriate answer as shown. ⬬
- If you want to change your answer you must cross out your original answer as shown. ⊠
- If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. ⊗

| For Examiner's Use | |
|---|---|
| Question | Mark |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |
| 11 | |
| **TOTAL** | |

Answer **all** questions.

*Do not write outside the box*

**0 1** Anti-virus software and user training are measures that can be used to reduce the threat posed by viruses.

Describe **four other** measures that can be used to reduce the threat posed by viruses.

**[4 marks]**

**4**

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**Turn over for the next question**

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**ANSWER IN THE SPACES PROVIDED**

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**0 2 . 1** A digital camera takes photographs that are 4000 pixels wide by 3000 pixels tall and can contain up to 16 777 216 different colours.

Calculate the size of one image in megabytes.

**[2 marks]**

Answer _____ megabytes

**0 2 . 2** How many images, taken using the camera referred to in Question **02.1**, could be stored on a 256 gigabyte memory card?

You should assume that all of the storage space on the memory card is available to store image data.

Round your answer down to the nearest whole number.

**[1 mark]**

Answer _____

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When a digital camera takes a photograph, an array of photosensors produces analogue voltages representing the amount of light falling on each photosensor. An analogue-to-digital converter then converts these analogue voltages into digital values. These digital values are used to create the pixel data for the bitmap image.

**0 2 . 3** Explain why the voltages produced by the photosensors are considered to be analogue **and** why the pixel data is considered to be digital.

**[2 marks]**

**Question 2 continues on the next page**

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An image is 20 pixels wide by 30 pixels tall. The colour of each pixel is represented using one byte.

Here is a row of data from the original image. The colour of each of the 20 pixels is shown as a decimal value, with commas used to separate the data for the different pixels:

24, 24, 24, 253, 254, 255, 76, 76, 76, 80, 82, 0, 0, 9, 223, 223, 224, 220, 76, 76

The image is to be compressed using Run Length Encoding (RLE). The RLE method used will:

- represent the length of a run using one byte
- represent a colour using one byte.

In decimal, the RLE for the colour of the first four pixels would be:

3, 24, 1, 253

**0 2 . 4** Calculate how much memory the row of pixels will take up before **and** after it has been encoded using RLE.

**[1 mark]**

Memory before RLE (bytes) _____

Memory after RLE (bytes) _____

**0 2 . 5** Comment on the effectiveness of the use of RLE to encode the row of pixels in Question **02.4 and** explain why this is the case.

**[1 mark]**

**7**

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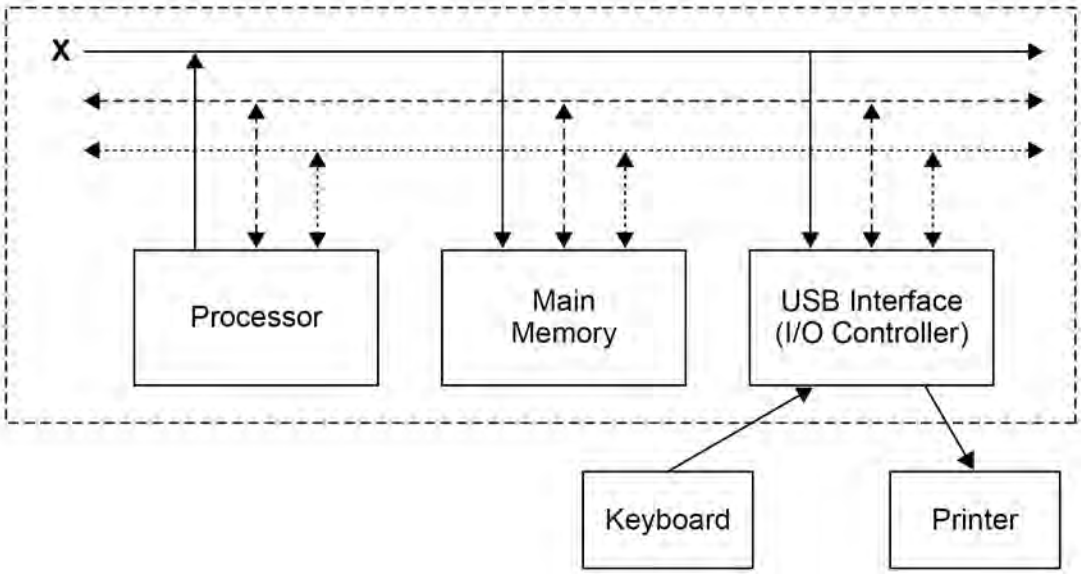
**0 3** **Figure 1** shows the organisation of part of a simple computer system.

**Figure 1**




**0 3 . 1** State the name of the bus labelled **X** in **Figure 1**.

**[1 mark]**

**0 3 . 2** The data bus inside the computer uses synchronous parallel data transmission.

Describe what synchronous transmission is.

**[1 mark]**

**Question 3 continues on the next page**

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**0 3 . 3** Peripherals, such as a keyboard or printer, are connected to the computer using a USB (Universal Serial Bus) connection. USB uses synchronous serial data transmission.

Explain why serial transmission has been chosen to communicate with peripherals connected to the computer **and** why parallel transmission is used by the data bus inside the computer.

**[3 marks]**

**0 3 . 4** The USB interface inside the computer is an example of an I/O controller.

Describe the role of an I/O controller.

**[2 marks]**

Do not write outside the box

**0 3 . 5** The computer's address bus uses 36 wires/lines and each main memory location can hold a 16-bit data value.

In gibibytes, express the maximum amount of main memory that could be installed in the computer, assuming that the CPU could access all of the memory using the address bus.

You should show your working.

**[2 marks]**

Answer _____ gibibytes

**0 3 . 6** State an example of how the control bus is used when the processor stores data into main memory.

**[1 mark]**

10

**Turn over for the next question**

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**0 4 . 1** Shade the lozenges next to **all** of the **true** statements about representing numbers using fixed and floating point representations.

**[2 marks]**

**A** A processor can usually carry out calculations on fixed point numbers more quickly than calculations on floating point numbers. ⬭

**B** Fixed point numbers represent data using a mantissa and an exponent. ⬭

**C** In a given number of bits, a fixed point system can represent positive numbers that are closer to zero than a floating point system can. ⬭

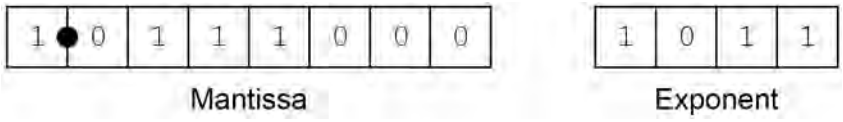
**D** In a given number of bits, a fixed point system can represent some numbers more precisely than a floating point system. ⬭

**E** In a given number of bits, a floating point system can represent a bigger range of numbers than a fixed point system. ⬭

Questions **04.2**, **04.3** and **04.4** use a **normalised** floating point representation with an **8-bit mantissa** and a **4-bit exponent**, both stored using **two's complement**.

**0 4 . 2** **Figure 2** shows a floating point representation of a number:

**Figure 2**




Calculate the decimal equivalent of the number in **Figure 2**.

You should show your working.

**[2 marks]**

Answer _____

*Do not write outside the box*

Questions **04.2**, **04.3** and **04.4** use a **normalised** floating point representation with an **8-bit mantissa** and a **4-bit exponent**, both stored using **two's complement**.

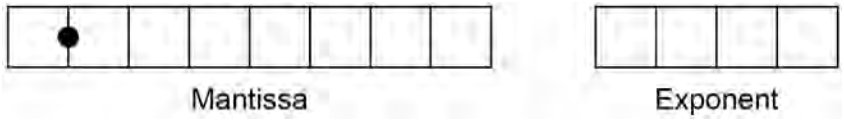
**0 4 . 3** The decimal number 12.765625 (which can also be expressed as $12\frac{49}{64}$) cannot be represented exactly in this floating point system.

Write the closest possible normalised representation of this number in the boxes below.

You should show your working.

**[3 marks]**

Answer




**0 4 . 4** What is the smallest number of bits that would need to be **added to** the mantissa so that the decimal number 12.765625 could be represented exactly?

**[1 mark]**

**Question 4 continues on the next page**

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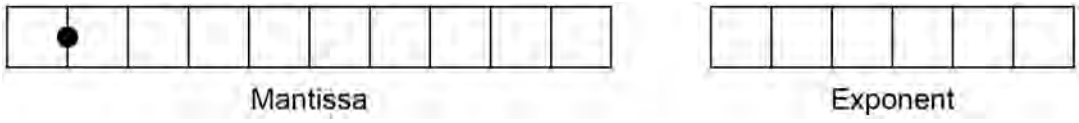
**0 4 . 5** A different system uses a **normalised** floating point representation with a **10-bit mantissa** and a **6-bit exponent**, both stored using **two's complement**.




In **decimal**, what is the most negative number that this system could represent?

You should show your working.

**[2 marks]**

Most negative number _____

10

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**0 5 . 1** A company uses a file server that stores files on magnetic hard disk drives. These files can be accessed by other computers through a network.

Describe:

- how the data for a file would be stored on a magnetic hard disk **and** read from it by the file server
- how the individual layers of the TCP/IP stack in the file server would be used to transmit the file onto the network.

In your response, you do **not** need to describe how the file would be transmitted across the network or how the TCP/IP stack would be used in the computer that has requested the file. You only need to write about how the data would be put onto the network by the file server.

**[12 marks]**

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Do not write outside the box

**0 5 . 2** The company needs to purchase a second file server.

It is considering whether to purchase a file server with magnetic hard disk drives installed or a file server with solid-state disks (SSDs) instead. Each of the file servers has the same total storage capacity.

State **one advantage** and **one disadvantage** of purchasing the file server that uses SSDs.

**[2 marks]**

Advantage _____

_____

_____

Disadvantage _____

_____

_____

14

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**Turn over for the next question**

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**ANSWER IN THE SPACES PROVIDED**

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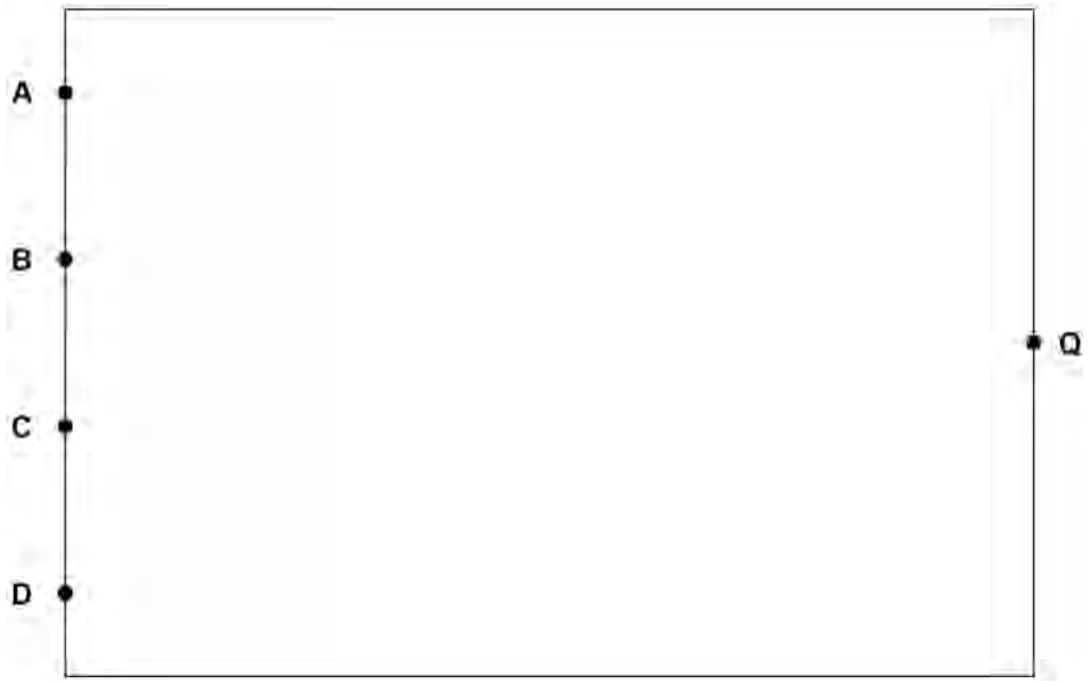
**0 6 . 1** Draw a logic circuit for the Boolean expression:

$$Q = \overline{\overline{A} \cdot B + \overline{B + C \cdot D}}$$

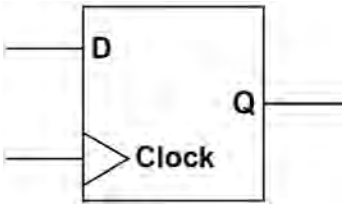
Do **not** simplify the expression.

**[4 marks]**




**0 6 . 2** A flip-flop is a component that can be incorporated into a logic circuit. **Figure 3** shows a diagram of an edge-triggered D-type flip-flop.

**Figure 3**




Explain how the output **Q** will be affected when a pulse is received on the **Clock** input.

**[1 mark]**

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**0 6 . 3** Using the rules of Boolean algebra, simplify the following Boolean expression.

$$\overline{A} \cdot \left( B \cdot C \cdot D + B \cdot C \cdot \overline{D} + B \right) + \overline{\overline{A} + B}$$

You **must** show your working.

**[4 marks]**

Working

Answer

9

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**0 7** A student has a Local Area Network (LAN) in her house. She uses one of the computers on the LAN as a web server to host a website for a club that she is a member of.

**Figure 4** shows the Uniform Resource Locator (URL) of a page on the website.

**Figure 4**

`http://www.loveapug.org.uk/pictures/cutepugs.html`

**0 7 . 1** State the protocol and domain name used in the URL in **Figure 4**.

**[1 mark]**

Protocol _____

Domain name _____

**0 7 . 2** Describe how domain names are organised.

**[2 marks]**

**0 7 . 3** Explain the service provided by Internet registries **and** why they are needed.

**[2 marks]**

**Question 7 continues on the next page**

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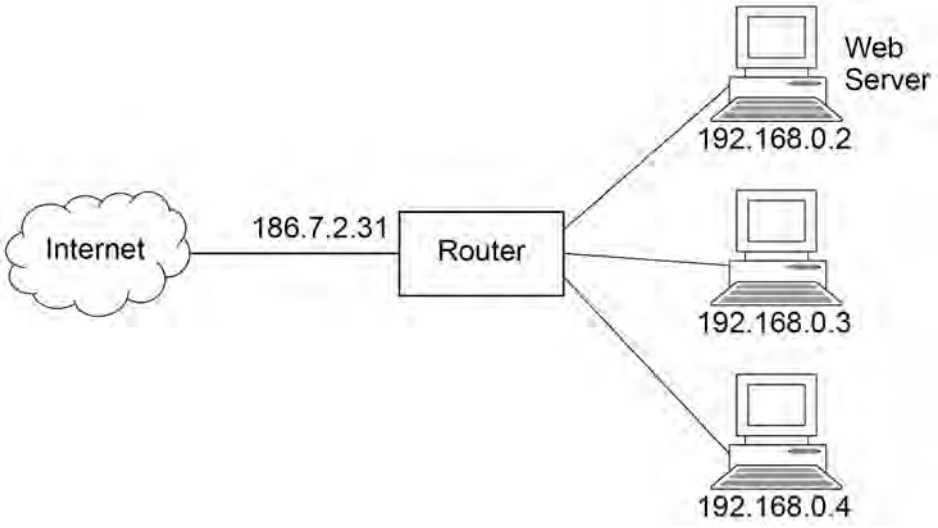
**Figure 5** shows a diagram of the LAN in the student's house. The LAN connects three computers, including the web server, to the Internet via a router.

**Figure 5**




The router's public IP address is 186.7.2.31. The non-routable IP addresses of each of the computers on the LAN is shown in **Figure 5**.

The router uses Network Address Translation (NAT) because the computers on the LAN, including the web server, have non-routable IP addresses.

The router also incorporates a switch and a DHCP server.

**0 7 . 4** Explain how a computer located outside the LAN can access the web server, despite the fact that the web server is identified by a non-routable IP address.

**[3 marks]**

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**0 7 . 5** Explain why it might be undesirable to allow the network settings of the web server to be configured by a DHCP server.

**[1 mark]**

**0 7 . 6** The student uses the computer with IP address 192.168.0.4 to download a file from an FTP server on the Internet using the File Transfer Protocol (FTP).

Describe how NAT will be used in this process, to handle both the outgoing request and the returned data.

**[4 marks]**

**Question 7 continues on the next page**

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**0 7 . 7** The replacement of IPv4 with IPv6 would mean that NAT is no longer necessary.

Explain why this is the case.

**[1 mark]**

**0 7 . 8** The web server and the web browser on a client computer use the Websocket protocol when they communicate with each other.

Shade **one** lozenge to indicate which of these statements about the Websocket protocol is true.

**[1 mark]**

**A** All messages sent using the protocol encode data using XML. ⬭

**B** All messages sent using the protocol have a digital signature. ⬭

**C** Messages sent using the protocol can only originate from the web server. ⬭

**D** The protocol establishes a full-duplex communication channel. ⬭

**E** The protocol operates at the network layer of the TCP/IP stack. ⬭

**15**

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**0 8** A shop that sells items through a website uses a relational database to store information about the products that it sells and the sales that it has made.

**Figure 6** shows the structure of the relations in the database.

**Figure 6**

Product(ProductID, Description, QuantityInStock, SupplierID)

Sale(SaleID, CustomerID, SaleDate)

SaleLine(SaleID, ProductID, QuantitySold)

Customer(CustomerID, Forename, Surname, EmailAddress)

Supplier(SupplierID, SupplierName, SupplierEmail)

- The Product relation stores information about the products that the shop sells and who supplies them. Each type of product is identified by a unique number and has a brief description. For example, ProductID 1 has the Description 'A4 Ring Binder – Purple'. The QuantityInStock indicates how many of the product the shop currently has in stock.
- The Sale and SaleLine relations are used to record the details of the sale of products to a customer. Each sale is identified by a unique SaleID, which is a number.
- The Customer relation stores the details of customers who have registered on the website so that they can purchase products. Each customer is identified by a unique CustomerID, which is a number.
- The Supplier relation records the details of companies who supply the products to the shop. Each supplier is identified by a unique SupplierID, which is a number.

**0 8 . 1** Shade **one** lozenge to indicate which of the listed assumptions has been made when the database was designed.

**[1 mark]**

**A** A customer cannot be added to the database until a sale has been made to them. ⬭

**B** Each product is only supplied by one supplier. ⬭

**C** Each supplier only supplies one product. ⬭

**D** Only one sale can be made to a customer on a particular date. ⬭

**E** Two different products cannot be purchased as part of the same sale. ⬭

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When a sale is made to a customer, three changes need to be made to the data in the database:

- a new record is created in the Sale table
- a new record is created in the SaleLine table for each different product that is part of the sale
- the records in the Product table are updated to reduce the QuantityInStock by the purchased quantity for each type of product that has been sold.

A sale is made on the 29/09/2024 to the Customer with CustomerID 48. The sale is for 3 of the products with ProductID 1. The sale is to be given the SaleID 4072.

**0 8 . 2** Write an SQL query that will create the new record for sale 4072 in the Sale table.

**[2 marks]**

**0 8 . 3** Write an SQL query that will update the QuantityInStock of the product with ProductID 1 when this sale is made. The value 3 should be subtracted from the current quantity in stock.

**[3 marks]**

**Question 8 continues on the next page**

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**0 8 . 4** The database system can be accessed by many users simultaneously.

Describe how timestamp ordering can be used to manage concurrent access to a database.

**[3 marks]**

**0 8 . 5** The database described in **Figure 6** is fully normalised.

Describe **two** problems that can occur with databases that are **not** fully normalised.

**[2 marks]**

Problem 1

Problem 2

**11**

**Turn over for the next question**

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**0 9** Algorithms and artificial intelligence are being increasingly used to assist with the diagnosis of medical conditions. For example, algorithms based on artificial intelligence can diagnose some medical conditions from X-ray images.

Discuss some of the moral, ethical and legal issues that might arise as a result of using computer systems to assist with diagnosing medical conditions.

In your answer you will be assessed on your ability to follow a line of reasoning to produce a coherent, relevant and structured response.

**[6 marks]**

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6

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**This table is included so that you can answer Question 10.1 on page 35.**

**Table 1 – Standard AQA assembly language instruction set**

| | |
|---|---|
| `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>` | Branch to the instruction at position `<label>` if the last comparison met the criterion specified by `<condition>`. Possible values for `<condition>` and their meanings are:<br>`EQ`: equal to `NE`: not equal to<br>`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 XOR (exclusive or) 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. |

**Labels**: A label is placed in the code by writing an identifier followed by a colon (:). To refer to a label, the identifier of the label is placed after the branch instruction.

**Interpretation of `<operand2>`**

`<operand2>` can be interpreted in two different ways, depending on whether the first character 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 0–12

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**1 0** **Figure 7** shows an assembly language program which has been written using the AQA assembly language instruction set. The instruction set is explained in **Table 1** on page 33.

**Figure 7**

```
  LDR R1, 130
  MOV R2, #0
  MOV R4, #0
repeat:
  ADD R2, R2, #1
  AND R3, R1, #1
  CMP R3, #0
  BEQ skip
  ADD R4, R4, #1
skip:
  LSR R1, R1, #1
  CMP R2, #7
  BNE repeat
  LDR R1, 130
  AND R4, R4, #1
  CMP R4, #0
  BNE else
  ORR R1, R1, #128
  B end
else:
  AND R1, R1, #127
end:
  STR R1, 130
  HALT
```

The program performs a task on a value stored in memory location 130. The value in this memory location is a 7-bit ASCII code.

For example, if memory location 130 was used to store the ASCII character ‘S’ then it would contain the value 83, which in binary is:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 |

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**1 0 . 1** Complete the trace table below to show the results of executing the program in **Figure 7** when the initial value in memory location `130` is 83

Each register can hold an 8-bit value.

You may find it easier to understand the operation of the program if you write the contents of memory location `130` and register `R1` out in both binary and decimal.

You may not need to use all the rows in the table.

**[6 marks]**

| **Memory Location 130** | **R1** | **R2** | **R3** | **R4** |
|---|---|---|---|---|
| 83 (01010011) | | | | |
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**1 0 . 2** The value in memory location `130` before the program is executed is the program's input and the value stored in memory location `130` when the program finishes executing is its output.

By considering your trace table for Question **10.1** and the assembly language code in **Figure 7**, describe the purpose of the program.

**[2 marks]**

**1 0 . 3** Describe **two** advantages of writing programs in assembly language over writing programs using a high-level language.

**[2 marks]**

Advantage 1

Advantage 2

**1 0 . 4** Some high-level languages are described as being imperative.

Explain what imperative means in this context.

**[1 mark]**

**11**

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**1 1 . 1** A functional programming function `f` has the function type:

$$f: \mathbb{N} \rightarrow \mathbb{R}$$

Describe the co-domain of the function `f`.

**[1 mark]**

**1 1 . 2** Describe **two** features of functional programming languages that make it easier to write code that can be distributed to run across multiple servers.

**[2 marks]**

Feature 1

Feature 2

**3**

**END OF QUESTIONS**

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**ANSWER IN THE SPACES PROVIDED**

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