



# Cambridge International AS & A Level

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**COMPUTER SCIENCE**

**9618/32**

Paper 3 Advanced Theory

**May/June 2023**

MARK SCHEME

Maximum Mark: 75

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**Published**

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the May/June 2023 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

**Generic Marking Principles**

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

**GENERIC MARKING PRINCIPLE 1:**

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

**GENERIC MARKING PRINCIPLE 2:**

Marks awarded are always **whole marks** (not half marks, or other fractions).

**GENERIC MARKING PRINCIPLE 3:**

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

**GENERIC MARKING PRINCIPLE 4:**

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

**GENERIC MARKING PRINCIPLE 5:**

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

**GENERIC MARKING PRINCIPLE 6:**

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

**Mechanics of Marking:**

Every mark given should have a corresponding tick on the script. The number of ticks on each (part) question should match the number of marks awarded for that (part) question. If giving Benefit of Doubt, **the BOD must be accompanied by a tick.**

If a candidate has not given a response or the response is in no way related to the question, such as 'don't know', NR (the Hash key) should be awarded rather than zero.

**Every part question must be annotated to show that it has been read even if awarding NR. Please ensure that all part questions that are marked as NR are also annotated with the SEEN icon. This is a requirement of RM3.**

There are **two** blank pages at the start of each script and a page of syntax diagrams on page 4 (question 3) that must be annotated with the SEEN icon. ☹

**NEW: Words or phrases that are underlined, must be present in the candidate's answer. Words or phrases that are emboldened indicate that the idea represented by the bold text must be included.**

Even though the comments box is visible at the bottom of the screen, please do not put comments or question marks on the scripts. When scripts are returned to centres all the annotations including comments, are visible.

If work has been crossed out and something written in its place, the replacement work is marked even if the crossed-out work is correct. If the crossed-out work has not been replaced, mark the crossed-out answer. Please also annotate the unmarked work as SEEN, especially if the replacement answer is on a separate sheet.

For single mark answers, mark the first answer on the line, unless there is a note to the contrary on the mark scheme.

If a candidate writes something that is not enough (NE) for a mark, but is not actually incorrect, continue reading, even if the mark scheme says, for example, mark first two answers.

| Question | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Marks    |   |   |   |   |   |   |   |          |   |          |   |   |   |  |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|---|---|---|---|---|---|---|----------|---|----------|---|---|---|--|--|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1(a)     | <p><b>One</b> mark per mark point</p> <ul style="list-style-type: none"><li>• correct mantissa</li><li>• correct exponent <b>with</b> associated working</li></ul> <p>Answer</p> <table><tr><th colspan="10">Mantissa</th><th colspan="6">Exponent</th></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td></tr></table> <p>Working</p> <p>exponent = 6 (movement of 6 bicimal places seen to find what exponent should be)</p> <p>calculation of denary 6 to binary (000)110</p> | Mantissa |   |   |   |   |   |   |   |          |   | Exponent |   |   |   |  |  | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 2 |
| Mantissa |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |          |   |   |   |   |   |   |   | Exponent |   |          |   |   |   |  |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 0        | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 0        | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0        | 0 | 0        | 1 | 1 | 0 |  |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 1(b)     | <p><b>One</b> mark per mark point (<b>Max 3</b>)</p> <p>MP1 the mantissa of the number would need to be 0.101011111001 / 13 bits / digits</p> <p>MP2 ... it can only store 10 bits / digits</p> <p>MP3 The <b>3</b> least significant digits would be truncated</p> <p>MP4 ...causing a loss of precision</p>                                                                                                                                                                                                                                                                                          | 3        |   |   |   |   |   |   |   |          |   |          |   |   |   |  |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

| Question   | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Marks      |            |      |   |      |   |      |   |          |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------|------|---|------|---|------|---|----------|
| 2(a)       | <p><b>One</b> mark per mark point (<b>Max 3</b>)</p> <p>MP1    <b>records</b> are stored in a particular <b>order</b></p> <p>MP2    the order is determined based on the value in a key field</p> <p>MP3    <b>records</b> are accessed one after the other</p> <p>MP4    <b>records</b> can be found by searching from the beginning of the file, record by record,</p> <p>MP5    ... until the required <b>record</b> is found <u>or</u> key field value is exceeded.</p> | <b>3</b>   |            |      |   |      |   |      |   |          |
| 2(b)       | <p><b>One</b> mark for each correct hash value (<b>Max 2</b>)</p> <table><tr><th>Record key</th><th>Hash value</th></tr><tr><td>3003</td><td>3</td></tr><tr><td>1029</td><td>4</td></tr><tr><td>7630</td><td>0</td></tr></table>                                                                                                                                                                                                                                            | Record key | Hash value | 3003 | 3 | 1029 | 4 | 7630 | 0 | <b>2</b> |
| Record key | Hash value                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |            |            |      |   |      |   |      |   |          |
| 3003       | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |            |      |   |      |   |      |   |          |
| 1029       | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |            |      |   |      |   |      |   |          |
| 7630       | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |            |      |   |      |   |      |   |          |

| Question | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Marks |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 3(a)     | <p><b>One mark per correct valid/invalid and reason combination (Max 2)</b></p> <p>9SW – Invalid<br/>Reason - This begins with a digit and a variable must begin with a letter</p> <p>UWY – Valid<br/>Reason – This begins with a letter and is followed by two other letters.</p>                                                                                                                                                                                                                                                                                                                                                         | 2     |
| 3(b)     | <p><b>One mark per mark point (Max 3)</b></p> <ul style="list-style-type: none"> <li>• <code>&lt;word&gt; ::= &lt;letter&gt; </code></li> <li>• <code>...&lt;word&gt;&lt;letter&gt;</code></li> <li>• <code>&lt;variable&gt; ::= &lt;word&gt; &lt;word&gt;&lt;digit&gt;</code></li> </ul> <p>Example answers</p> <p><code>&lt;word&gt; ::= &lt;letter&gt; &lt;word&gt;&lt;letter&gt;</code><br/> <code>&lt;word&gt; ::= &lt;letter&gt;&lt;word&gt; &lt;letter&gt;</code></p> <p><code>&lt;variable&gt; ::= &lt;word&gt; &lt;word&gt;&lt;digit&gt;</code><br/> <code>&lt;variable&gt; ::= &lt;word&gt;&lt;digit&gt; &lt;word&gt;</code></p> | 3     |
| 3(c)(i)  | <p>Answer must be two letters followed by one, two or three digits using the letters and digits on the syntax diagram.</p> <p>Example answer<br/>AC768</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1     |
| 3(c)(ii) | <p><b>One mark per mark point (Max 3)</b></p> <ul style="list-style-type: none"> <li>• always has only two letters</li> <li>• one, two or three digits possible</li> <li>• correct arrows, boxes and name of syntax diagram</li> </ul> <p>Example answer</p> <p>Vehicle registration</p> <pre> graph LR     Entry(( )) --&gt; L1[letter]     L1 --&gt; L2[letter]     L2 --&gt; D1[digit]     D1 --&gt; D2[digit]     D2 --&gt; D3[digit]     D3 --&gt; Exit(( ))     D3 --&gt; D1   </pre>                                                                                                                                                | 3     |

| Question      | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Marks    |             |               |                                                |         |                                                                   |              |                                                |         |                                                    |  |                                                                       |   |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------------|---------------|------------------------------------------------|---------|-------------------------------------------------------------------|--------------|------------------------------------------------|---------|----------------------------------------------------|--|-----------------------------------------------------------------------|---|
| 4             | <p><b>One</b> mark for each correct line connecting an OOP term to its description <b>(Max 4)</b>.</p> <table><thead><tr><th>OOP term</th><th>Description</th></tr></thead><tbody><tr><td>Encapsulation</td><td>methods used to return the value of a property</td></tr><tr><td>Getters</td><td>the process of putting data and methods together as a single unit</td></tr><tr><td>Polymorphism</td><td>methods used to update the value of a property</td></tr><tr><td>Setters</td><td>allows methods to be redefined for derived classes</td></tr><tr><td></td><td>enables the defining of a new class that inherits from a parent class</td></tr></tbody></table> | OOP term | Description | Encapsulation | methods used to return the value of a property | Getters | the process of putting data and methods together as a single unit | Polymorphism | methods used to update the value of a property | Setters | allows methods to be redefined for derived classes |  | enables the defining of a new class that inherits from a parent class | 4 |
| OOP term      | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |          |             |               |                                                |         |                                                                   |              |                                                |         |                                                    |  |                                                                       |   |
| Encapsulation | methods used to return the value of a property                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |             |               |                                                |         |                                                                   |              |                                                |         |                                                    |  |                                                                       |   |
| Getters       | the process of putting data and methods together as a single unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |          |             |               |                                                |         |                                                                   |              |                                                |         |                                                    |  |                                                                       |   |
| Polymorphism  | methods used to update the value of a property                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |             |               |                                                |         |                                                                   |              |                                                |         |                                                    |  |                                                                       |   |
| Setters       | allows methods to be redefined for derived classes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |          |             |               |                                                |         |                                                                   |              |                                                |         |                                                    |  |                                                                       |   |
|               | enables the defining of a new class that inherits from a parent class                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |          |             |               |                                                |         |                                                                   |              |                                                |         |                                                    |  |                                                                       |   |

| Question | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Marks |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 5(a)     | <p><b>One mark per mark point (Max 2)</b></p> <p>MP1 to produce a <b>virtually unbreakable</b> encryption system / send <b>virtually un-hackable</b> secure messages ...</p> <p>MP2 ...using the laws / principles of quantum mechanics / properties of photons</p> <p>MP3 detects <b>eavesdropping</b> ...</p> <p>MP4 ...because the properties of photons change</p> <p>MP5 to protect security of data transmitted over <b>fibre optic cables</b></p> <p>MP6 to <b>enable</b> the use of longer keys.</p>                                                                                                                                                                                      | 2     |
| 5(b)     | <p><b>One mark per mark point (Max 3)</b></p> <p>MP1 Symmetric cryptography uses a single key to encrypt and decrypt messages, Asymmetric cryptography uses two.</p> <p>MP2 The symmetric key is shared, whereas with asymmetric, only the public key is shared (and the private key isn't).</p> <p>MP3 ... the risk of compromise is higher with symmetric encryption and asymmetric encryption is more secure.</p> <p>MP4 Symmetric cryptography is a simple process that can be carried out quickly, but asymmetric is much more complex, so slower.</p> <p>MP5 The length of the keys in symmetric encryption are (usually) shorter than those for asymmetric (128/256 bits v 2048 bits).</p> | 3     |

| Question | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Marks |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 6(a)     | <p><b>One mark for TYPE TAppointments and ENDTYPE correct</b><br/> <b>One mark for every two correct declarations (Max 3)</b></p> <p>Example answer</p> <pre> TYPE TAppointments     DECLARE Name : STRING     DECLARE DateOfBirth : DATE     DECLARE Telephone : STRING     DECLARE LastAppointment : DATE     DECLARE NextAppointment : DATE     DECLARE TreatmentsComplete : BOOLEAN ENDTYPE </pre>                                                                                                   | 4     |
| 6(b)     | <p><b>One mark for each correctly completed line (Max 5)</b></p> <pre> DECLARE DentalRecord : ARRAY[1:250] OF TAppointments DECLARE DentalFile : STRING DECLARE Count : INTEGER DentalFile ← "DentalFile.dat" OUTPUT "The file ", DentalFile, " contains these records:" OPENFILE DentalFile FOR RANDOM Count ← 1 REPEAT     SEEK DentalFile, Count     GETRECORD DentalFile, DentalRecord[Count]     OUTPUT DentalRecord[Count]     Count ← Count + 1 UNTIL EOF(DentalFile) CLOSEFILE DentalFile </pre> | 5     |

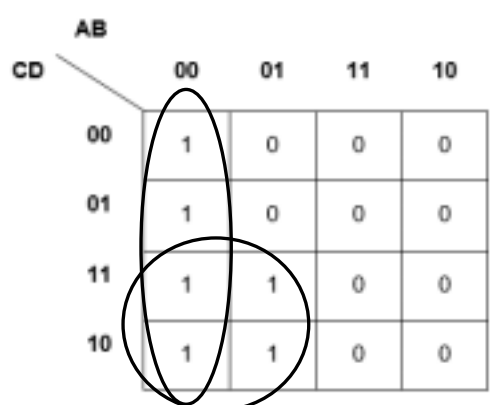
| Question | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Marks |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 7(a)     | <p><b>One mark per mark point (Max 2)</b></p> <p>MP1 Packet switching is most commonly used on data networks such as the internet to send large data files that don't need to be live streamed</p> <p>MP2 Packet switching is used when it is necessary to be able to overcome failed/faulty lines by rerouting.</p> <p>MP3 Packet switching is used when it is necessary for the communication to be more secure.</p> <p>MP4 Packet switching is used for high volume data transmission.</p> <p>MP5 Packet switching is used when it isn't necessary to use all the bandwidth.</p> <p>MP6 Specific examples e.g. email, text messages, documents, VOIP etc. (up to <b>two</b> marks).</p> | 2     |

| Question | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Marks    |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 7(b)     | <p><b>One</b> mark per mark point (<b>Max 4</b>)</p> <p>MP1 Circuit switching uses a dedicated channel to make communication, whereas packet switching forms data into packets to transmit over a digital network.</p> <p>MP2 The dedicated path for circuit switching must be established before the transfer of data can commence, which is not the case with packet switching (as it doesn't require a dedicated path).</p> <p>MP3 Data in packet switching is split into packets, in circuit switching the message remains intact.</p> <p>MP4 All of the transmission in circuit switching follows the same path whereas different packets in packet switching can take different routes.</p> <p>MP5 The message is received in the same order in which it is sent with circuit switching, but with packet switching, the packets can be received out of order (for assembly at the destination).</p> <p>MP6 Circuit switching is implemented at the physical layer while packet switching is implemented at the network layer.</p> <p>MP7 Circuit switching uses the whole bandwidth of the channel used, packet switching can share bandwidth.</p> <p>MP8 Circuit switching communication ends with an error but packet switching allows packets to be re-sent.</p> <p>MP9 Circuit switching is a simpler process than packet switching.</p> | <b>4</b> |

| Question | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Marks    |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 8(a)     | <p><b>One</b> mark per mark point (<b>Max 2</b>)</p> <p>MP1 Pipelining allows several <b>instructions</b> to be processed simultaneously / concurrently.</p> <p>MP2 ... therefore, increasing the CPU <b>instruction</b> throughput / the number of <b>instructions</b> completed per unit of time.</p> <p>MP3 Each <b>instruction</b> stage / subtask is completed during one clock cycle</p> <p>MP4 No two <b>instructions</b> can execute their same stage of instruction / subtask at the same clock cycle.</p> <p>MP5 ... e.g., while one <b>instruction</b> is being decoded, the next <b>instruction</b> can be fetched, etc.</p> | <b>2</b> |

| Question         | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Marks        |     |              |     |     |     |     |     |     |     |    |    |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |
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| 8(b)             | <p><b>One</b> mark per mark point (<b>Max 4</b>)</p> <ul style="list-style-type: none"><li>• First stage of first instruction in first clock cycle</li><li>• First instruction successfully completed over five clock cycles</li><li>• Remaining instructions completed over ten clock cycles ...</li><li>• ... with no extra instruction sections added on any row.</li></ul> <p>Example answer 1</p> <table><tr><td colspan="2"></td><th colspan="12">Clock cycles</th></tr><tr><td colspan="2"></td><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th></tr><tr><td rowspan="5">Processor stages</td><td>IF</td><td>1.1</td><td>2.1</td><td>3.1</td><td>4.1</td><td>5.1</td><td>6.1</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>ID</td><td></td><td>1.2</td><td>2.2</td><td>3.2</td><td>4.2</td><td>5.2</td><td>6.2</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>OF</td><td></td><td></td><td>1.3</td><td>2.3</td><td>3.3</td><td>4.3</td><td>5.3</td><td>6.3</td><td></td><td></td><td></td><td></td></tr><tr><td>IE</td><td></td><td></td><td></td><td>1.4</td><td>2.4</td><td>3.4</td><td>4.4</td><td>5.4</td><td>6.4</td><td></td><td></td><td></td></tr><tr><td>WB</td><td></td><td></td><td></td><td></td><td>1.5</td><td>2.5</td><td>3.5</td><td>4.5</td><td>5.5</td><td>6.5</td><td></td><td></td></tr></table> <p>Example answer 2</p> <table><tr><td colspan="2"></td><th colspan="12">Clock cycles</th></tr><tr><td colspan="2"></td><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th></tr><tr><td rowspan="5">Processor stages</td><td>IF</td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>ID</td><td></td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>OF</td><td></td><td></td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td><td></td><td></td><td></td><td></td></tr><tr><td>IE</td><td></td><td></td><td></td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td><td></td><td></td><td></td></tr><tr><td>WB</td><td></td><td></td><td></td><td></td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td><td></td><td></td></tr></table> |              |     | Clock cycles |     |     |     |     |     |     |     |    |    |  |  |  |  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Processor stages | IF | 1.1 | 2.1 | 3.1 | 4.1 | 5.1 | 6.1 |  |  |  |  |  |  | ID |  | 1.2 | 2.2 | 3.2 | 4.2 | 5.2 | 6.2 |  |  |  |  |  | OF |  |  | 1.3 | 2.3 | 3.3 | 4.3 | 5.3 | 6.3 |  |  |  |  | IE |  |  |  | 1.4 | 2.4 | 3.4 | 4.4 | 5.4 | 6.4 |  |  |  | WB |  |  |  |  | 1.5 | 2.5 | 3.5 | 4.5 | 5.5 | 6.5 |  |  |  |  | Clock cycles |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Processor stages | IF | A | B | C | D | E | F |  |  |  |  |  |  | ID |  | A | B | C | D | E | F |  |  |  |  |  | OF |  |  | A | B | C | D | E | F |  |  |  |  | IE |  |  |  | A | B | C | D | E | F |  |  |  | WB |  |  |  |  | A | B | C | D | E | F |  |  | 4 |
|                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Clock cycles |     |              |     |     |     |     |     |     |     |    |    |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |
|                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1            | 2   | 3            | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11 | 12 |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |
| Processor stages | IF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1.1          | 2.1 | 3.1          | 4.1 | 5.1 | 6.1 |     |     |     |     |    |    |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |
|                  | ID                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |              | 1.2 | 2.2          | 3.2 | 4.2 | 5.2 | 6.2 |     |     |     |    |    |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |
|                  | OF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |              |     | 1.3          | 2.3 | 3.3 | 4.3 | 5.3 | 6.3 |     |     |    |    |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |
|                  | IE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |              |     |              | 1.4 | 2.4 | 3.4 | 4.4 | 5.4 | 6.4 |     |    |    |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |
|                  | WB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |              |     |              |     | 1.5 | 2.5 | 3.5 | 4.5 | 5.5 | 6.5 |    |    |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |
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| Processor stages | IF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | A            | B   | C            | D   | E   | F   |     |     |     |     |    |    |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |
|                  | ID                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |              | A   | B            | C   | D   | E   | F   |     |     |     |    |    |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |
|                  | OF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |              |     | A            | B   | C   | D   | E   | F   |     |     |    |    |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |
|                  | IE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |              |     |              | A   | B   | C   | D   | E   | F   |     |    |    |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |
|                  | WB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |              |     |              |     | A   | B   | C   | D   | E   | F   |    |    |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |     |     |     |     |     |     |  |  |  |  |  |  |    |  |     |     |     |     |     |     |  |  |  |  |  |    |  |  |     |     |     |     |     |     |  |  |  |  |    |  |  |  |     |     |     |     |     |     |  |  |  |    |  |  |  |  |     |     |     |     |     |     |  |  |  |  |              |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |                  |    |   |   |   |   |   |   |  |  |  |  |  |  |    |  |   |   |   |   |   |   |  |  |  |  |  |    |  |  |   |   |   |   |   |   |  |  |  |  |    |  |  |  |   |   |   |   |   |   |  |  |  |    |  |  |  |  |   |   |   |   |   |   |  |  |   |

| Question | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Marks |    |    |    |    |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |   |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----|----|----|----|----|---|---|---|---|----|---|---|---|---|----|---|---|---|---|----|---|---|---|---|---|
| 9(a)     | <p><b>One</b> mark for every two correct products (<b>Max 3</b>)</p> <p>(Z =) <math>\bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}\bar{C}D + \bar{A}\bar{B}C\bar{D} + \bar{A}\bar{B}CD + \bar{A}BC\bar{D} + \bar{A}BCD</math></p>                                                                                                                                                                                                                         | 3     |    |    |    |    |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |   |
| 9(b)     | <p><b>Two</b> marks if no errors present<br/><b>One</b> mark if one error present</p> <div><div>AB</div><div>CD</div><table><tr><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr><tr><td>00</td><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>01</td><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>11</td><td>1</td><td>1</td><td>0</td><td>0</td></tr><tr><td>10</td><td>1</td><td>1</td><td>0</td><td>0</td></tr></table></div> |       | 00 | 01 | 11 | 10 | 00 | 1 | 0 | 0 | 0 | 01 | 1 | 0 | 0 | 0 | 11 | 1 | 1 | 0 | 0 | 10 | 1 | 1 | 0 | 0 | 2 |
|          | 00                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 01    | 11 | 10 |    |    |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |   |
| 00       | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 0     | 0  | 0  |    |    |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |   |
| 01       | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 0     | 0  | 0  |    |    |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |   |
| 11       | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1     | 0  | 0  |    |    |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |   |
| 10       | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1     | 0  | 0  |    |    |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |    |   |   |   |   |   |

| Question | Answer                                                                                                                                                                                                                                                          | Marks    |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 9(c)     | <p><b>One</b> mark for each correct loop (<b>Max 2</b>)</p>                                                                                                                    | <b>2</b> |
| 9(d)     | <p><b>One</b> mark for each mark point (<b>Max 2</b>)</p> <ul style="list-style-type: none"> <li>Any correct Boolean term</li> <li>Boolean terms and operator correct and no other terms present</li> </ul> <p><math>(Z =) \bar{A}\bar{B} + \bar{A}C</math></p> | <b>2</b> |
| 9(e)     | <p><b>One</b> mark for simplest form (<b>Max 1</b>)</p> <p><math>(Z =) \bar{A}(\bar{B} + C)</math></p>                                                                                                                                                          | <b>1</b> |

| Question | Answer                                                                                                                                          | Marks    |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 10(a)    | <p><b>One</b> mark from:</p> <p>Supervised (learning)</p> <p>Unsupervised (learning)</p> <p>Reinforcement (learning)</p> <p>Deep (learning)</p> | <b>1</b> |

| Question   | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Marks                    |                  |                          |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|------------------|--------------------------|---------------|-------------------|-------|-------|---|----|----|-------|---|---|---|----|-------|---|---|---|----|-------|---|---|---|----|-------|---|---|----|----|---|---|-----------|---|----|---|---|----------------|---|----|---|-----|----------------|---|----|---|-----|--------------------|---|----|--|--|--|--|--|------------|-------------------------------------------------------------------------|---|
| 10(b)      | <p><b>One</b> mark for each correct calculation as follows (<b>Max 2</b>):</p> <ul style="list-style-type: none"><li>Node B (from Begin) (Line 3 in table)</li><li>Node C (from Begin) (Line 4 in table)</li><li>Node D (from Begin) (Line 5 in table)</li></ul> <p><b>One</b> mark for each correct calculation as follows (<b>Max 2</b>):</p> <ul style="list-style-type: none"><li>Node G (from C) (Line 6 in table)</li><li>Node F and Node End (from G) (Lines 7 and 8 in table)</li><li>Node End (from F) (Line 9 in table)</li></ul> <p><b>One</b> mark for correct path (<b>Max 1</b>):</p> <ul style="list-style-type: none"><li>Begin <math>\Rightarrow</math> C <math>\Rightarrow</math> G <math>\Rightarrow</math> F <math>\Rightarrow</math> End</li></ul> <table><tr><th>Start node</th><th>Destination node</th><th>Cost from start node (g)</th><th>Heuristic (h)</th><th>Total (f = g + h)</th></tr><tr><td>Begin</td><td>Begin</td><td>0</td><td>12</td><td>12</td></tr><tr><td>Begin</td><td>A</td><td>5</td><td>8</td><td>13</td></tr><tr><td>Begin</td><td>B</td><td>6</td><td>7</td><td>13</td></tr><tr><td>Begin</td><td>C</td><td>5</td><td>7</td><td>12</td></tr><tr><td>Begin</td><td>D</td><td>4</td><td>11</td><td>15</td></tr><tr><td>C</td><td>G</td><td>5 + 2 = 7</td><td>5</td><td>12</td></tr><tr><td>G</td><td>F</td><td>5 + 2 + 4 = 11</td><td>1</td><td>12</td></tr><tr><td>G</td><td>End</td><td>5 + 2 + 7 = 14</td><td>0</td><td>14</td></tr><tr><td>F</td><td>End</td><td>5 + 2 + 4 + 1 = 12</td><td>0</td><td>12</td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr></table> <table><tr><td>Final Path</td><td>Begin <math>\Rightarrow</math> C <math>\Rightarrow</math> G <math>\Rightarrow</math> F <math>\Rightarrow</math> End</td></tr></table> | Start node               | Destination node | Cost from start node (g) | Heuristic (h) | Total (f = g + h) | Begin | Begin | 0 | 12 | 12 | Begin | A | 5 | 8 | 13 | Begin | B | 6 | 7 | 13 | Begin | C | 5 | 7 | 12 | Begin | D | 4 | 11 | 15 | C | G | 5 + 2 = 7 | 5 | 12 | G | F | 5 + 2 + 4 = 11 | 1 | 12 | G | End | 5 + 2 + 7 = 14 | 0 | 14 | F | End | 5 + 2 + 4 + 1 = 12 | 0 | 12 |  |  |  |  |  | Final Path | Begin $\Rightarrow$ C $\Rightarrow$ G $\Rightarrow$ F $\Rightarrow$ End | 5 |
| Start node | Destination node                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Cost from start node (g) | Heuristic (h)    | Total (f = g + h)        |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |
| Begin      | Begin                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0                        | 12               | 12                       |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |
| Begin      | A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 5                        | 8                | 13                       |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |
| Begin      | B                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 6                        | 7                | 13                       |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |
| Begin      | C                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 5                        | 7                | 12                       |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |
| Begin      | D                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 4                        | 11               | 15                       |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |
| C          | G                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 5 + 2 = 7                | 5                | 12                       |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |
| G          | F                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 5 + 2 + 4 = 11           | 1                | 12                       |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |
| G          | End                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 5 + 2 + 7 = 14           | 0                | 14                       |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |
| F          | End                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 5 + 2 + 4 + 1 = 12       | 0                | 12                       |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |
|            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                          |                  |                          |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |
| Final Path | Begin $\Rightarrow$ C $\Rightarrow$ G $\Rightarrow$ F $\Rightarrow$ End                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                          |                  |                          |               |                   |       |       |   |    |    |       |   |   |   |    |       |   |   |   |    |       |   |   |   |    |       |   |   |    |    |   |   |           |   |    |   |   |                |   |    |   |     |                |   |    |   |     |                    |   |    |  |  |  |  |  |            |                                                                         |   |

| Question            | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Marks                                        |           |             |              |        |                                              |                    |         |                                       |               |         |                                             |                     |         |                                        |          |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-----------|-------------|--------------|--------|----------------------------------------------|--------------------|---------|---------------------------------------|---------------|---------|---------------------------------------------|---------------------|---------|----------------------------------------|----------|
| 11(a)(i)            | <p><b>One mark for every two correct identifiers (Max 2)</b></p> <table border="1"> <thead> <tr> <th>Identifier</th><th>Data type</th><th>Description</th></tr> </thead> <tbody> <tr> <td><b>Queue</b></td><td>STRING</td><td>An array to store the contents of the queue.</td></tr> <tr> <td><b>RearPointer</b></td><td>INTEGER</td><td>Points to the last term of the queue.</td></tr> <tr> <td><b>Length</b></td><td>INTEGER</td><td>Indicates the number of items in the queue.</td></tr> <tr> <td><b>FrontPointer</b></td><td>INTEGER</td><td>Points to the first term of the queue.</td></tr> </tbody> </table>                                                                                                                                                              | Identifier                                   | Data type | Description | <b>Queue</b> | STRING | An array to store the contents of the queue. | <b>RearPointer</b> | INTEGER | Points to the last term of the queue. | <b>Length</b> | INTEGER | Indicates the number of items in the queue. | <b>FrontPointer</b> | INTEGER | Points to the first term of the queue. | <b>2</b> |
| Identifier          | Data type                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Description                                  |           |             |              |        |                                              |                    |         |                                       |               |         |                                             |                     |         |                                        |          |
| <b>Queue</b>        | STRING                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | An array to store the contents of the queue. |           |             |              |        |                                              |                    |         |                                       |               |         |                                             |                     |         |                                        |          |
| <b>RearPointer</b>  | INTEGER                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Points to the last term of the queue.        |           |             |              |        |                                              |                    |         |                                       |               |         |                                             |                     |         |                                        |          |
| <b>Length</b>       | INTEGER                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Indicates the number of items in the queue.  |           |             |              |        |                                              |                    |         |                                       |               |         |                                             |                     |         |                                        |          |
| <b>FrontPointer</b> | INTEGER                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Points to the first term of the queue.       |           |             |              |        |                                              |                    |         |                                       |               |         |                                             |                     |         |                                        |          |
| 11(a)(ii)           | <p><b>One mark for each correctly completed line (Max 5)</b></p> <pre> CONSTANT MaxLength = 50 DECLARE FrontPointer : INTEGER DECLARE RearPointer : INTEGER DECLARE Length : INTEGER DECLARE Queue : ARRAY[0:MaxLength - 1] OF STRING // Initialisation of queue PROCEDURE Initialise     FrontPointer ← -1     <b>RearPointer ← -1</b>     <b>Length ← 0</b> ENDPROCEDURE // Adding a new item to the queue PROCEDURE Enqueue(NewItem : STRING)     IF <b>Length &lt; MaxLength</b> THEN // IF <b>Length &lt;= MaxLength - 1</b> THEN         RearPointer ← <b>RearPointer + 1</b>         IF RearPointer &gt; MaxLength - 1 THEN             RearPointer ← 0         ENDIF         <b>Queue[RearPointer] ← NewItem</b>         Length ← Length + 1     ENDIF ENDPROCEDURE </pre> | <b>5</b>                                     |           |             |              |        |                                              |                    |         |                                       |               |         |                                             |                     |         |                                        |          |
| 11(b)               | <p><b>One mark per mark point (Max 3)</b></p> <ul style="list-style-type: none"> <li>• Print jobs are expected to be actioned by the printer in the order they are received</li> <li>• ... because the printer queue is a queue, the first job to be sent to the printer would be the first job printed.</li> <li>• If the printer queue was on a stack, the first job the printer received would not be printed until all the other jobs have been printed.</li> </ul>                                                                                                                                                                                                                                                                                                            | <b>3</b>                                     |           |             |              |        |                                              |                    |         |                                       |               |         |                                             |                     |         |                                        |          |