# Computer Science

## *Timezone 1*

*To protect the integrity of the assessments, increasing use is being made of examination variants. By using variants of the same examination, students in one part of the world will not always be responding to the same examination content as students in other parts of the world. A rigorous process is applied to ensure that the content across all variants is comparable in terms of difficulty and syllabus coverage. In addition, measures are taken during the standardisation and grade awarding processes to ensure that the final grade awarded to students is comparable.*

# Contents

# Grade boundaries

## Higher level overall

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-13 | 14-28 | 29-39 | 40-49 | 50-59 | 60-69 | 70-100 |

## Standard level overall

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-11 | 12-23 | 24-36 | 37-47 | 48-57 | 58-68 | 69-100 |

## HL/SL solution

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-4 | 5-9 | 10-14 | 15-18 | 19-22 | 23-26 | 27-34 |

## Higher level paper one

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-11 | 12-23 | 24-35 | 36-45 | 46-54 | 55-64 | 65-100 |

## Standard level paper one

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-5 | 6-11 | 12-20 | 21-29 | 30-37 | 38-46 | 47-70 |

## Higher level paper two

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-10 | 11-20 | 21-24 | 25-31 | 32-37 | 38-44 | 45-65 |

## Standard level paper two

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-7 | 8-15 | 16-20 | 21-22 | 23-25 | 26-27 | 28-45 |

## Higher level paper three

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-5 | 6-11 | 12-14 | 15-17 | 18-19 | 20-22 | 23-30 |

# HL/SL solution

## The range and suitability of the work submitted

There was again a wide variety in the quality of projects submitted. Most students showed a good understanding of the assessment criteria, but many chose to address them in a superficial manner. Few students put in the effort to produce high quality work.

Like last year, many solutions consisted of a front-end coded in either Java, Python or HTML, which connected to a variety of back-end databases. A few of the samples showed evidence that these had been developed from a standard outline solution provided to the students by the teacher. This kind of uniform approach is (obviously) not valid. Similarly, a "fill in the boxes" approach to the documentation will not allow much differentiation between projects in a school's sample, as all students will make the same misguided mistakes. On the other hand, many inspiring and sometimes surprising products were seen that had been developed with the client's need in mind.

Overall, there appear to be more issues with superficial projects, for example:

- prototypes of a potential solution instead of an actual solution.
- underdeveloped databases, that hardly do more than save and display data.
- classroom exercises in coding (basic add/edit/delete/save).
- non-integrated solutions (often websites) where the client must edit the back-end database directly.
- trivial use of complex tools and techniques, like recursion to run a loop.
- trivial login with sign-up that gives access to a single workspace (in other words, anybody can enter and access all data and functionality).

Projects that aimed to address a real-life need for a real client tend to achieve better than the ones with unfocused Criteria for Success.

## Student performance against each criterion

### Criterion A

This was generally done well with lots of evidence of client interaction. Unfortunately, many consultations were less meaningful as students decided on a product before the interview, instead of first finding out from the client what the actual problem is. The rationale for the solution was rarely described explicitly and the rationale for the software often remained generic and did not relate to the intended product. Criteria for Success (CfS) need to be sufficient in number to fully describe a functional solution to the scenario. They need to be specific and testable. Inadequate CfS constitute a lack of focus and will have an impact on achievement in criteria A, B, D and E.

### Criterion B

Moderators continue to comment on a continuing decline in effort to document the design. Many students submitted a few, incomplete design components that showed limited (or no) algorithmic thinking. Most Record of Task documents did not reflect the need to address a real problem with a real solution and lacked a proper implementation stage during which the client uses the final product for its intended purpose over a period of time.

### Criterion C

Most projects showed moderate to high Complexity at Standard Level, but Ingenuity was often impacted by a poor design. Reasonably good attempts were made to describe some tools and techniques, but only a few students achieved at the highest band by explaining and justifying. Stronger projects tended to provide detail by annotating code excerpts, while weaker projects provided a narrative without actual explanations.

### Criterion D

Most videos did not show full Functionality of the product as a solution. The general shortcomings included using limited test data, talking about functionality without actually showing it, not showing persistence of data changes by restarting the program, and showing only some inadequate / incomplete Criteria for Success.

Extensibility is measured against the amount of documentation of the solution. To achieve in the highest descriptor students should provide better documentation in B and C, and add ample comments in the code in order to make Extensibility easy. Note that a trivial product cannot achieve marks for Extensibility.

### Criterion E

Generally, students attached in an appendix the evidence of client feedback after testing, but few students did use this feedback in their own evaluation of the Criteria for Success. Merely quoting the client's feedback does not fulfil this criterion - the students must evaluate the solution themselves. Recommendations for improvement should address issues with the created solution that typically show up during testing. Unfulfilled Criteria for Success are typically considered trivial improvements, as are generic suggestions for 'more data' or 'more functionality'.

## Recommendations and guidance for the teaching of future students

Some students embarked on overly ambitious projects like a fully functional library system or a time-tabling system for their school. These project ideas are beyond the scope of the Computer Science IA and should be discouraged.

Teachers should encourage the students to follow the Systems Development Life Cycle and document the various stages as they work through them.

There is a clear correlation between strong Criteria for Success and successful projects. It is therefore recommended that teachers spend time on guiding students to produce sufficient, specific and measurable Criteria for Success.

Students should be guided to create a proper Design Overview which documents their algorithmic thinking in flowcharts and/or pseudocode, and which explains the data structures to be used in their solution. Screenshots of the actual product have no place in design and will be discounted.

Please limit the screencast videos to 7 minutes. Do not allow students to speed-up their videos as sped-up videos tend to become unintelligible. These videos should only show evidence for the full functionality of the solution. Code design or extensibility should not be included in the screencast.

Students should be guided to write a proper evaluation against the Criteria for Success, which incorporates and refers to meaningful client feedback (to be added in an appendix). Recommendations for improvement should go beyond unfulfilled CfS (which are considered trivial). They should avoid the word ‘more’ (more content, more images, more levels, etc.) and instead focus on realistic improvements

to the existing product (like solving problems that only became apparent after the client started using the product).

In comparison to the May 2023 session, fewer projects followed the guidelines for submission by not including all the appropriate documents. Some students submitted links to products, videos or even documentation. This is not acceptable and linked components will be ignored by the moderator. Both the product and the video need to be uploaded as part of the submission. Only one 7-minute video should be included and only to show evidence of the functionality of the solution (no code, no extensibility, no recommendations for improvement). Moderators are not required to watch or listen to any other (potentially lengthy) video or audio files.

## Further comments

Please double-check submissions after uploading the sample to IBIS. Schools will no longer be consulted if components are missing or corrupted.

# Higher level paper one

## General comments

Students attempted most of the questions on this paper achieving a wide range of marks.

## The areas of the programme and examination which appeared difficult for the students.

Students who provided comprehensive responses that addressed all aspects of the questions, using the appropriate key terminology and level of detail relevant to the available marks, generally earned higher scores. Students who gave responses appropriate to the number of points asked in the question generally achieved better marks than those who did not.

There were very few attempts at Q13(e) and Q16(c) indicating that the students were not well prepared for questions based on pseudocode.

## The areas of the programme and examination in which students appeared well prepared

Students did well in constructing trace tables and answering questions related to data representations.

Direct questions on concepts and principles such as questions on usability, peripherals etc in Section A were better attempted than questions that required application of a scenario.

## The strengths and weaknesses of the students in the treatment of individual questions

### Question 1

1(a) Students who gave a more specific answer identifying the benefit of using SaaS, scored better than the ones who gave one word answer such as 'cheap' and 'easy'.

1(b) Most students lost mark here due to the lack of specificity. Simply saying that it is 'not secured' or 'expensive' does not help gain a mark.

### Question 2

Very few students were able to score full two marks here. Answers like 'Acceptance testing is done to make sure user is happy' did not get a mark. Answers that simply referred to the system being 'tested' or 'accepted by users' were not sufficient, as this was given in the question.

### Question 3

Most students scored a mark on this question for the definition of the term using the right key terminology. Answers that only gave 'examples' of peripherals did not gain a mark.

### Question 4

Several correct and varied responses were seen here.

### Question 5

Many correct answers were given here. The most common ones were 'Braille Keyboard', 'Voice Recognition', and 'Screen Readers'.

### Question 6

Some students found the purpose of MDR challenging and were able to score only one mark here. MDR only holds/stores the data/instruction. It is not responsible for sending or processing them.

### Question 7

7(a) A vast majority of the students achieved a mark here.

7(b) A vast majority of the students achieved a mark here.

### Question 8

Applications of stack had to be computer related and not generic like 'pile of dishes'. Responses like 'Undo' without the mention of an application where 'Undo' is used were not credited.

### Question 9

Most of the students were able to achieve at least two marks out of four here. Very few students were able to describe the technique using specific key terminology.

### Question 10

Quite a few students repeated the 'temperature sensor" in their answers. There was also a lot of guess work on this. Others who were able to score full two marks here identified the name of sensor correctly along with an appropriate description.

### Question 11

There were very small number of completely correct answers to this question with many students achieving at least one or two marks for the mention of 'sensors detecting temperature' or 'the use of microprocessor to compare detected temperature with set values.' Several students incorrectly mentioned "sensors detect changes in temperature" and lost marks.

### Question 12

12(a)(i) Students who correctly specified 'Fast data transmission speed' gained better marks than those who used one word vocabulary like 'Fast' to identify the feature of Fibre Optic.

12(a)(ii) Most of the students scored at least one mark here. Students need to understand that statements such as 'it does not use wires/ cables' which repeats the information given in the question are not enough.

12(b) Many students found this question challenging. Responses included vague references to encryption, often confusing with other security methods. Students who identified the use of 'key' to scramble data and went on to explain it further achieved higher marks. Students should be aware that encrypted text can still be accessed or read when intercepted, but that it cannot be understood.

12(c) Attempted well by most of the students.

12(d) Very few students were able to score marks on this question. There was only 'one' social impact asked and many students went on to explain the advantages and disadvantages of 'working from home' with no reference to 'social impact'.

## Question 13

13(a) Most students were able to score a mark by drawing the truth table for the NOR gate. Students who gave vague descriptions like 'opposite of OR' gained no marks here.

13(b) This was a question that needed to be read carefully. There were many students that gave a truth table instead of the logic diagram and gained no marks.

13(c) Very few students were able to provide the two values of D corresponding to the two rules. Many students ignored the descriptions and wrote 'less than 3 metres' etc.

13(d) Attempted well by most of the students.

13(e) A number of varied answers were seen here with very few students attempting this question. Some students missed the loop while others did not initialise the flag or added input statements in the wrong places.

## Question 14

14(a) Majority of the students were able to identify the two causes of data loss correctly and gained full marks here.

14(b) A few students explained the consequence to the customer instead of the hotel and lost marks.

14(c) There were a small number of completely correct answers to this question with many getting at least one mark. Responses that only mentioned 'backups' without further clarity did not get any mark.

14(d) Many students gained some credit, usually for reference to incompatibility.

14(e) This was a question that needed careful reading. Most of the students confused this question and compared the primary storage with secondary storage instead of comparing their usage within tablets versus desktop.

14(f)(i) Most students achieved a mark here.

14(f)(ii) Many correct responses here with majority of students achieving all three marks.

## Question 15

15(a)(i) Many correct answers were given here, 'Efficient use of memory' being the most common one. Students who went on to explain it further scored a second mark.

15(a)(ii) A large number of students mentioned the drawback of dynamic data structure by making a comparison to the static data structure. This was not a part of the question and should have been answered accordingly. Here too there were many vague answers such as 'less time consuming' or 'It is slower'.

15(b) Very few students were able to attempt this question successfully by making specific reference to the use of pointers and their manipulation. There is also a need for care in the use of the terminology here. Students who went on to describe a linear search without any reference to the pointers did not gain marks.

15(c) Many correct responses were seen here. Those who lost marks here described the structure of a 'binary tree' instead of the 'node'.

15(d)(i) A few students were able to score all three marks here while others identified at least the root node correctly.

15(d)(ii) Most of the students were able to identify the leaf nodes despite incorrectly answering part (i).

### Question 16

16(a) Few correct responses were seen here. A few students changed the 'while' loop into an 'if statement' and did not gain a mark for using the OR operator.

16(b) A range of performance was seen here with some scoring full marks too. The most common mistakes were joining the strings incorrectly for the column J and the improper use of substring to extract characters.

16(c) A small number of good solutions were seen. Most students made little or no viable attempt. Those who did attempt, scored at least one mark with the input statement while a few of them scored marks in the higher range. The use of the string manipulation functions was misunderstood by most students, the use of flags or loops were rarely correct. There were a handful of those who did not know the use of input statement either.

## Recommendations and guidance for the teaching of future students

- At this level, student responses are expected to include more than simply general knowledge. There should be some demonstration of technical knowledge and appropriate use of the subject specific terminology. Many students would benefit from a better understanding of the different command words used in the questions. A question that asks for 'compare and contrast' must mention both similarities and differences.
- Some students need to be careful with the use of terminology. For example, 'variables' was used frequently instead of 'input'.
- Questions should also be read carefully and answered appropriately. For example, if a question asks for a 'consequence to the hotel', no marks will be awarded for generic responses that are not a consequence for the hotel. A question that asks for 'benefit of using a dynamic data structure', should not be answered by making a comparison to another data structure.
- Students need to make sure they understand what is being asked and should not assume that because a question shares key phrases with those from a past paper that the required answer is the same. An example in this paper is Question 6 which asks for two applications of a stack. Many students gave a description of how a stack operates.
- There is a greater emphasis on the application of knowledge in this syllabus. Some questions will be set in a particular context and answers will be expected to refer to that context in order to demonstrate a student's application of the theory.
- Students should be encouraged to develop their programming skills using the standard pseudocode as defined in the syllabus and supporting documents. This encourages them to demonstrate their understanding of the structure of algorithms in a manner that is transferrable to multiple programming languages and encourages computational thinking. Student must not make flowcharts when a question asks for pseudocode.
- Students should be encouraged to attempt all questions, even the more advanced ones. The questions that ask for pseudocode algorithms are accessible to most students, at least in part.

# Standard level paper one

## General comments

Students achieved a wide range of marks with more than 90% attempting all the questions given in the paper. A notable observation is that the students were comfortable attempting the questions based on theory concepts than attempting the programming section.

## The areas of the programme and examination which appeared difficult for the students

Students who understood the question, the associated command term and used appropriate terminology or gave sufficient depth / key points in their responses, generally achieved higher marks. Students faced difficulty in those questions requiring algorithms to be written in pseudocode, with the students not fully following the rules and concepts of programming. Also, they found it difficult to come up with appropriate points for some unfamiliar contexts. It is observed that mostly the students have lost marks due to vagueness in their responses and not using the correct key terms.

## The areas of the programme and examination in which students appeared well prepared

Students appeared to be well prepared in the areas covering some of the theoretical aspects of computer science requiring shorter, more specific responses, such as those in Section A as well as some of the Section B sub-parts. It is found that the maximum marks are obtained not depending on the topic but on the type of question asked. Straight forward knowledge-based questions fetched better responses compared to application questions.

## The strengths and weaknesses of the students in the treatment of individual questions

### Question 1

1(a) Students who were able to give a brief answer stating the benefit of SaaS scored a mark.

1(b) Students who were able to give a brief answer stating the drawback of SaaS scored a mark.

### Question 2

Students whose responses described that pilot running as implementation to a subset of users and it is rolled out to the complete set of users with appropriate reason achieved the highest marks. Some students have interpreted pilot running as pilot testing incorrectly.

### Question 3

Most students have correctly described user acceptance testing as a mechanism before release to ensure that the user requirements are met or that the product can be improved removing bugs or making required modifications for the user. However, some have provided incomplete answers without expanding the purpose.

## Question 4

Most students were able to score full marks by providing diverse examples of user documentation. However, very few students had repeated the documentation in online and offline modes, or they had given the methods of obtaining user requirements, not fully understanding the question.

## Question 5

Students who stated as well as described briefly the user training methods scored full marks. Some students did not provide the description of the user training method but outlined the advantages or disadvantages.

## Question 6

Majority of the students were able to define the term using correct key words and score a mark.

## Question 7

Many students were able to correctly write two usability issues. However, there were some responses which listed accessibility problems as usability issues. Students are recommended to fully understand the difference between usability and accessibility.

## Question 8

Most of the students achieved full marks for correctly writing two accessibility methods. Some responses contained the latest methods or devices available commercially which also scored full marks.

## Question 9

9(a) Students had difficulty in expressing the purpose of MDR using correct keywords. Responses which stated that MDR "fetches" or "transfers" data did not score full mark.

9(b) Majority of the students scored full marks by correctly outlining the role of ALU in performing arithmetic and logical operations.

## Question 10

10(a) This question had the most correct answer. Students were able to convert the given denary number to binary.

10(b) Majority of the students were able to express the given binary number in hexadecimal format. However, some students did not apply the correct method and tried converting to denary incorrectly.

## Question 11

Some students did not identify the primary memory types correctly. Their responses included comparisons between hard disk drive, solid state drive, cache etc.

## Question 12

This question had a good number of correct responses. Students could write the names of the layers exactly. Very few students did not use the correct term – they wrote "transportation" instead of "transport".

## Question 13

13(a)(i) Students who were able to give a brief answer stating two characteristics of fibre optic cables achieved maximum marks. Some vague responses (cables are faster / secure) or one-word responses did not score full. The transmission part is missed in these responses.

13(a)(ii) Students who were able to give a brief answer stating two characteristics of wireless transmission achieved maximum marks. Some vague responses (just outlining that the wireless transmission is without wires), or one-word responses did not score full.

13(b) Though the students had an idea of encryption, they did not score allotted maximum marks as they did not use the appropriate keywords. Responses did not include "Key" for encryption and decryption. Students wrote "data cannot be accessed/read by hackers" where they should have written "data cannot be understood by hackers even though they could access/read".

13(c) Students who elaborated all the steps in packet switching, right from data split into packets till packets assembled at the destination, achieved the maximum score. It is recommended that the students use the complete technical terms "Destination IP address", "Source IP address" instead of just writing "address".

13(d) Many students had difficulty in correctly expressing the social implications. It was observed that the responses included economical, technical implications and some ethical too instead of social implications.

## Question 14

14(a) Many students have correctly defined the NOR operator in words. Some of them have written the equivalent truth table for which they achieved full mark. However, a few of them have just written "OR and NOT combination" which did not fetch any mark.

14(b) Many students have misread the question and constructed a truth table instead of producing a logical diagram. Students are recommended to use the correct number of inputs for each gate and also label the inputs and output.

14(c) While about 50% of the students could correctly state the rules, the other 50% did not fully specify the conditions for input D.

14(d) This question had most of the students who attempted getting full marks. A very few students did not show the working properly breaking down the conditions in a stepwise manner.

14(e) Students who constructed algorithms using a loop to take the inputs and also devised a way to stop the loop using correct condition achieved full marks. Students need to use correct output statements and consider the steps that need to be present inside and outside the loop carefully. They are reminded to use pseudocode conventions provided.

## Question 15

15(a) Many students had difficulty in getting the full marks. The students did not write the associated description for the operation or method (Note that the description should include the parameters / return value). Some wrote the purpose or application of the method. It is recommended that the students go through the additional document "Pseudocode in Examinations" which is part of the IB resources.

15(b) Some good algorithms were seen for this question. Few students had mixed up the operations associated with a collection and an array. They had used collection methods for array / index for collection.

15(c) Some students were confident in producing a bubble sort or a selection sort algorithm for this question. Majority of the students made mistakes in defining the loop limits, comparison of adjacent elements / finding the smallest element and exchanging the required elements. Some had combined the code for bubble sort and selection sort.

15(d) Students who wrote at least one similarity and listed the differences achieved the highest marks. It is not sufficient to say "Both are sorting algorithms" for similarity, students should cite correct technical points for similarities (Both use nested loops, have same time complexities) and differences.

## Recommendations and guidance for the teaching of future students

- Students should be encouraged to develop their programming skills using the standard pseudocode as defined in the syllabus and supporting documents. This will help them demonstrate their understanding of algorithms in multiple programming languages and will improve their computational thinking. Students need to get sufficient practice to construct standard and complex algorithms, using arrays and collections, which can then be extended to solving unfamiliar and comprehensive problems.
- While writing answers for theory questions, students should be encouraged to carefully read and understand the question to ensure that their response is written according to the context provided in the question with valid technical points (without any vagueness or ambiguity). Students should make sure that the number of points written match the number of marks allotted for a question. This will help them achieve high marks.
- Students should be thorough with the syllabus content provided in the syllabus guide. This will help them provide the required responses for some specific topics like the correct types of primary memory, accessibility methods, methods of providing user documentation etc.
- Students should look at the command word in the question and make sure that their response is appropriate for that command word.
- Students should be encouraged to make use of past papers and published mark schemes to be aware of the answering requirements set by the IB.

# Higher level paper two and standard level paper two

## Overall comments

As the four options are very different in nature, each one has been commented on individually.

The Standard Level (SL) forms a complete subset of the Higher Level paper (HL), so this content has been merged. The SL question numbers have been added after, for example:

### Question 9 / Question 7.

The percentages of students taking each option in the exam were:

| | SL | HL |
|---|---|---|
| Option A | 31% | 30% |
| Option B | 9% | 6% |
| Option C | 18% | 14% |
| Option D | 42% | 50% |
| TOTAL | 100% | 100% |

In many cases, students from a few schools completed different options. In very rare cases, some students attempted to answer questions from more than one option.

## Option A

## General comments

Excellent responses to every question and several outstanding performances were received overall. The paper achieved a good spread of marks, with students generally making a good attempt at the majority of the questions. This demonstrates that most schools provide good coverage of the syllabus.

## The areas of the programme and examination which appeared difficult for the students

Most students were not expecting an explanation of how databases could be designed ethically as an extension of the general principle of Data Protection.

Normalization was also challenging, with most students showing only a partial understanding of the concept and the importance of explicitly identifying primary and foreign keys as part of the process.

## The areas of the programme and examination in which students appeared well prepared

The questions on data types and validation were straightforward for the majority of the students. The students were also very comfortable identifying the roles of a Database Administrator.

## The strengths and weaknesses of the students in the treatment of individual questions

### Question 1

1(a)(i) This was well-answered by a large majority of students.

1(a)(ii) This was also well-answered. A common error was stating programming-related data types.

1(b) Many students were able to identify an appropriate validation check for the gradient attribute, but giving an outline of the stated validation check in the context was challenging. Some responses included verification checks instead.

1(c) The majority of the students were able to correctly represent the entities in the scenario described. However, representing the relationship between the entities was a challenge. A few students identified one-to-many relationships but incorrectly indicated the prime and the dependent entities on the diagram. A few other students struggled with the use of appropriate symbols, with some incorrectly using the diamond symbol to represent entities.

1(d) Many students demonstrated the understanding that a composite key involves two or more fields but the idea of uniqueness for a primary key needed to be included in their responses: most of them incorrectly stated that Plant_ID and Site_ID together form a valid composite key for the relation. It is obvious these students need to learn how prime attributes are shown in relations since the primary key has been clearly indicated in the table.

1(e) This was the most challenging question for the students. Only a handful of students used the COUNT aggregate function. Most of them were able to identify the tables required for the query but they failed to describe/write an appropriate JOIN condition. Majority of the responses did not include the filtering condition on the Species field; they went on to incorrectly use the Plant_ID corresponding to the given species, and consequently lost the WHERE CLAUSE mark.

1(f) The majority of students responded appropriately to the question. Many of them wrote copiously about data consistency without being particular about the steps that must be taken to ensure it.

### Question 2

2(a) Most students were able to outline the required steps in a logical manner. Others wrote a lot about the properties of transactions without relating the properties to the scenario with specifics.

2(b) A large majority of students explained row-locking adequately, but they could not proffer any other method to enable them to get all the marks. Only a handful of students referred to Optimistic Concurrency Control or Multi-version concurrency control.

2(c) This was generally well-answered. Though the question only required students to identify the roles of a DBA, some produced lengthy responses, wasting time.

2(d) The majority of the students answered the question well. A few of them lost marks because they mixed up authentication and authorisation: they would indicate the use of logins and then give the outline of authorization rather than authentication.

2(e) The majority of students found marks hard to come by in this question because they concentrated on the ethical use of the database instead of how to ensure that the database has been designed ethically.

### Question 3

3(a) The majority of the students identified the removal of duplicate data as a reason for normalisation; the more able students went further to gain the other mark.

3(b) This was well-answered by a large majority of students.

3(c) The majority of students could identify the required relations, but they lost a lot of marks as they did not identify the primary and foreign keys for the relations. A few students wasted too much time putting the data into different tables.

3(d) Many students identified the removal of transitive dependency as the reason for normalizing databases from 2NF to 3NF; however, they were largely unable to elaborate on the benefits of eliminating the dependency or offer any other reason.

### Question 4

4(a) This was the best-answered question, with most students providing excellent reasons for using a data warehouse. A few students, however, demonstrated a complete lack of understanding of the concept by referring to data warehouses as extensions of transactional databases that allowed larger amounts of data to be stored.

4(b) A good number of students showed an understanding of the transformation process and identified some activities carried out, but the reason for the transformation was missing in most cases. A number of students also failed to relate their responses to the scenario.

4(c) This question was not particularly well-answered. The more able students gave very good reasons for the use of timestamping. A large majority of the students could only identify knowledge of the time of data loading into the data warehouse as a use for timestamping.

4(d) This was not well-answered, as most of the students concentrated on the structural differences between decision trees and neural networks instead of the differences between their algorithms.

4(e) Most students demonstrated a good understanding of data deviation but struggled to apply it appropriately to the scenario. Successful students supported their explanation with examples based on the scenario.

4(f) Many students demonstrated an understanding of cluster analysis and forecasting individually as data mining techniques, but most struggled to adequately compare them based on their uses.

## Recommendations and guidance for the teaching of future students

Students should be taught to answer questions with the command terms in mind to avoid unnecessarily losing marks.

Prioritising practical activities related to database design using different scenarios can help ensure a better understanding of data modelling concepts.

Identifying primary and foreign keys in normalisation is crucial in establishing relational database relationships. Too many students lost marks due to this. This must be emphasised during teaching.

Teachers can use the Internal Assessment as a practical way of helping students learn complex data access techniques like JOINS and aggregate functions. It was easy for students who wrote SQL queries in question 1(e) to get all the marks.

Students should be taught how to respond to questions within the context of the given scenario.

Students should be taught other concurrency control methods beyond row/record locking.

## Option B

### General comments

As every year, there was a wide range of achievements but very few excellent students. Across the cohort, there were some good responses that were straightforward and based on conceptual understanding. However, many students showed superficial knowledge and understanding. Specifically, the extended response and pseudocode construction questions were not well answered. Overall, too many students were ill-prepared to answer an exam paper about simulations and modelling, giving narrative answers where code is expected and giving a generic response where specificity is needed.

### The areas of the programme and examination which appeared difficult for the students

Constructing algorithms remains difficult for many students who do this option. Extended response questions were often addressed superficially with limited writing, and therefore could not achieve full credit. Some students used generic statements lacking specific details relevant to the questions.

### The areas of the programme and examination in which students appeared well prepared

Most students responded well to the questions related to models vs simulations, hardware implications of 3D rendering, and supervised versus unsupervised learning, showing a fair theoretical understanding of these concepts. Questions that required extended responses were typically well done by those students who wrote extensive responses.

### The strengths and weaknesses of the students in the treatment of individual questions

#### Question 5 / Question 4

(a) This question was generally answered well. A wide range of possible variables was seen but also some vague responses (typically, "size") that could not be credited.

(b) The term "rules" (for a simulation) was widely interpreted, and only a few students provided concrete rules for implementation in this simulation.

(c) Like the previous question, most students did not realize the basic intent of the question. Most responses that vaguely addressed reliability were given some benefit of the doubt.

(d) This question was answered well, though most students did not provide a weighed conclusion.

#### Question 6 / Question 5

(a) This question was mostly answered well, though some students quizzically addressed the memory capabilities of the prospective buyer.

(b) Few students answered this one-mark question correctly. Many copied the term "ray tracing" from the next question.

(c) This question was answered reasonably well, showing that many students have learned the basics of ray tracing.

(d) Most students were able to identify at least one suitable ethical issue, but many had difficulty developing their responses into full explanations.

### Question 7 / Question 6

(a) This question required writing spreadsheet formulas, but a good number of students provided narrative responses.

Parts (i) and (ii) were typically answered well, even though half of the students needed to be more precise.

Parts (iii) and (iv) were less well received, with many incorrect formulas given.

(b) This question required writing spreadsheet formulas with references. Many good attempts were made, but only a few students achieved full marks.

(c) Most responses were superficial or vague. Hardly any student indicated that this simulation cannot be used to make predictions. Considerations of extraneous events were given the benefit of the doubt.

(d) Few students provided the correct formulas. Instead, many narrative responses were seen.

(e) Very few correct answers were provided. Too many students showed that they needed to be practising writing code. The ones who attempted the question typically achieved one mark for writing a proper loop.

### Question 8

(a) This question was answered well.

(b) Some students were able to provide specifics of the processes involved. However, most responses were generic statements about speech recognition and Natural Language Processing.

(c) The majority of students did not realize that this question was about syntax versus semantics. Many narrative responses achieved a mark here or there.

(d) Very few students had studied recent developments (over the past 8 years) in machine text translators. Most responses made generic references to older developments and achieved no credit.

(e) This question was generally well done and supervised versus unsupervised learning appears to be well-understood. The students who wrote more extensive responses tended to achieve better.

## Recommendations and guidance for the teaching of future students

Students should be exposed to programming concepts and pseudocode. They need to develop their confidence in understanding and writing algorithms. Students are also advised not only to learn the required topics by heart but also to focus more on conceptual understanding. This will allow them to apply such concepts to any given scenario appropriately.

# Option C

## General comments

Overall, students demonstrated a mixed level of understanding across all the assessed topics of option C. While some areas were well understood, others posed significant challenges. There was a noticeable variation in performance, with certain questions consistently answered well and others revealing gaps in knowledge and conceptual understanding.

## The areas of the programme and examination which appeared difficult for the students

Students struggled with questions requiring a deeper conceptual understanding and application of knowledge. Specifically, many found it difficult to explain why a web page is static, often providing insufficient explanations tied to HTML rather than addressing the core characteristics of static pages. Questions on the importance of client-side scripting languages, the benefits of breadth-first search in search engines, and the use of lossy compression in mobile computing were also challenging. Additionally, students had difficulty justifying the impact of black hat SEO techniques.

## The areas of the programme and examination in which students appeared well prepared

Students were well-prepared for several foundational topics. Most could accurately identify the components of a full URL and differentiate between a protocol and a standard. They also demonstrated a good understanding of DNS functionality, with many correctly describing the steps in accessing a new site. Responses to questions about the features of the PageRank algorithm and the advantages of using keywords in searches were generally strong, reflecting a solid grasp of these concepts. Furthermore, students effectively answered questions about distinguishing between a web graph and a web sub-graph, showing their ability to understand and differentiate between these concepts.

## The strengths and weaknesses of the students in the treatment of individual questions

### Question 9 / Question 7

(a) Most students found this question easy to answer but failed to identify all the required components. A majority of the students could only name two to three components.

(b) The majority of students sketched it correctly; however, a few did not meet two of the three requirements.

(c)While most students provided adequate reasoning, a few couldn't answer correctly due to their limited understanding of why the given page was static.

(d) This question was answered correctly by the majority of the students, showing a good understanding of client-side scripting as a key function of web browsers.

(e) The majority of students answered this correctly, distinguishing between the protocol and standard.

(f) The majority of students described four valid steps and scored full marks.

(g) This question challenged the majority of the students. They could identify valid reasons but couldn't develop them further in the context of the question to score full marks.

## Question 10 / Question 8

(a) The majority of the students could reference metatags and how they help web crawlers search more efficiently than phrases. However, many generic responses resulted in low scores.

(b) This question was tricky to respond to; most students answered it incorrectly as B-H-E.

(c) The majority of the students couldn't answer this question correctly, indicating a lack of understanding of breadth-first search benefits in search engine operations.

(d) Most students found it hard to answer and could only identify that PageRank uses the PageRank of incoming and outgoing links and couldn't go beyond this.

(e) Most students only mentioned access to inaccurate information impacting grades, without addressing other aspects, resulting in very low scores.

## Question 11 / Question 9

(a) The students were expected to identify and develop the reason for 2 marks, but the majority gave vague responses like "it was developed due to a larger geographical area" or "for easy exchange of data" without proper reasoning or development.

(b) This question clearly showed a need for more understanding of the command term. Many students identified two advantages, including centralized control and security, instead of identifying one advantage and further developing it.

(c) Scores were given to compare similarities, and the majority of the students were able to provide a justifiable answer. However, a few students listed points in isolation and provided vague answers like "data is less safe in the cloud" or "it can be accessed remotely" without proper justification.

(d) Students were expected to balance their discussion between open standards and interoperability. The majority of students could provide well-developed responses, maintaining a balance between the two.

## Question 12

12(a) The majority of students answered this question correctly.

12(b) (i) The correct answer was B & I, and most students answered it correctly.

12(b) (ii) The correct answer was E,D,C,G, & H and the majority of students answered it correctly.

12(b) (iii) The correct answer was F&A, and most students answered it correctly.

12(c) Most students only mentioned that a node's PageRank score is based on the volume of incoming and outgoing links without further elaboration, resulting in low score for this question.

## Question 13

13(a) The majority of students answered this question correctly, although a few only identified the reason without further description.

13(b) Most students answered this question correctly.

13(c) While most students identified reasons why folksonomies support web democratization, only a few fully met the command term 'discuss' by providing a detailed analysis.

## Recommendations and guidance for the teaching of future students

Overall, students performed well in both application-based questions and content-related questions. However, many students lost marks due to insufficient detail in their answers.

While students understand concepts, they often struggle to apply them in context. Discussing concepts with real-life examples can mitigate this issue, helping students see their practical applications.

Students should be encouraged to use appropriate key terms in their responses to score higher, as many responses lacked the necessary technical vocabulary.

Students need to better understand the command terms used in questions. This will enable them to comprehend the questions thoroughly and provide accurate answers.

# Option D

## General comments

Students demonstrated a fair to moderate overall understanding of fundamental OOP concepts across both levels. While students generally grasped basic principles, they encountered challenges applying these concepts to more complex scenarios, such as constructing algorithms or modifying classes. This gap between theory and practise was particularly evident in questions that required deeper understanding of specific topics like recursion, tree manipulation, or the application of OOP principles. Additionally, the range of performance within each level suggests that some students excelled while others struggled, highlighting the need for differentiated instruction to address individual learning needs. It's important providing more hands-on exercises, real-world examples, which can enhance students' ability to effectively apply OOP concepts in practical scenarios. The length of the paper appears to be fine, since the vast majority of the students attempted all the questions.

## The areas of the programme and examination which appeared difficult for the students

While students demonstrated a fair understanding of basic OOP concepts, they struggled with applying this knowledge in practical scenarios. This was evident in questions that required constructing code for specific tasks. Questions involving recursive algorithms, particularly those applied to binary search trees, proved to be challenging for many students. Students also struggled with questions that involved identifying and evaluating complex relationships between classes, including dependencies and inheritance. Several questions required students to define specific terms; many students could identify the concepts but struggled to provide clear and comprehensive definitions, indicating a need for more emphasis on precise terminology.

## The areas of the programme and examination in which students appeared well prepared

Students generally demonstrated proficiency in fundamental OOP concepts, such as identifying OOP features in class declarations and constructing accessor methods. They also showed a reasonable understanding of class relationships and were able to discuss the ethical considerations involved in program development. Additionally, many students were able to successfully compare linked lists and binary search trees in the context of searching efficiency, demonstrating a good grasp of these data

structures. Some students demonstrated a good grasp of algorithmic logic and construction. However, it remains an area where further instruction and practise is needed.

## The strengths and weaknesses of the students in the treatment of individual questions

### Question 14 / Question 10

(a) Reasonable level of understanding of the general nature of an object among HL and SL students. Some students excelled while others struggled with the concept. This range of marks would indicate that some students may require further instruction to solidify their grasp of this fundamental OOP concept.

(b) A considerable number of students performed well on this question demonstrating a fair level of understanding and confidence with the concept of mutators, some struggled with the application of the concept.

(c) The majority of students at both levels were comfortable with the concept of accessor methods and demonstrated a good level of mastery in constructing them. However, there was some variation in performance, indicating that some students may need further practise and guidance on this topic.

(d) Many students demonstrated some understanding of the purpose of default constructors, but it's a concept that many still struggle with.

(e) A significant number of students attempted this question and demonstrated a moderate level of understanding outlining the necessary adjustments to be made on the class for the new given condition. Class exercises would be beneficial for students for applying concepts and knowledge in complex scenarios.

(f) Reasonably well answered at HL, showing students' ability to identify class relationships in OOP in a given context. For SL there was a fair understanding of class relationships. It's important to reinforce this basic OOP concept so students do not struggle with more complex or nuanced scenarios.

(g) Students at both levels had a good level of understanding, which indicates that most students grasped the fundamental concepts of class inheritance and constructor modification.

### Question 15 / Question 11

(a) Many students were able to identify the OOP feature correctly at both levels.

(b) Both levels demonstrated a moderate level of understanding of the benefits of inheritance. Many students were able to identify benefits but struggled to elaborate on them.

(c) Students at both levels showed a decent understanding of OOP features and were generally familiar to them, though a few struggled to identify the two additional ones required by the question.

(d) Students at both levels demonstrated a fair to moderate understanding of modularity in the context of software development. While many could identify the advantages of modularity, their ability to articulate a clear and comprehensive description was sometimes limited.

### Question 16 / Question 12

(a) Students at both levels provided evidence of basic understanding and struggled to provide a comprehensive definition. Weaker students only provided examples and could not offer a proper definition.

(b) Students at both levels demonstrated a range of performance in constructing an algorithm to process a given array and returning another one meeting specific conditions, with HL students showing a better grasp of the algorithm's logic and implementation than SL ones, for whom the task seemed more challenging. This question showed some students excelling while others struggled significantly.

(c) It was not exceptional, but SL and HL generally performed well. Most students were able to outline the basic steps for the required method. Many omitted the use of the given method in the previous question.

### Question 17 / Question 13

(a) Most students at both levels attempted the question but struggled to correctly identify the requested relationship type. More practical examples and exercises could help students apply their knowledge of class relationships to real-world scenarios.

(b) This question was challenging, and many students struggled to assess the inappropriateness of the given suggestion in the scenario correctly.

(c) Students at both levels showed a fair understanding of the ethical obligations of programmers involved in database development. While not exceptional, many students grasped the basic principles.

### Question 18

18(a) This question was challenging for many students, who struggled to construct the method correctly. It required a good understanding of linked list manipulation and object reference concepts.

18(b) Most students attempted this question, demonstrating a moderate level of understanding by grasping the basic concept of accessing class methods. However, many struggled with updating the requested class variable and implementing the method with optimal efficiency.

### Question 19

19(a) A good proportion of students could effectively compare linked lists vs binary trees in the context of searching and outline the reasons for using an ADT over the other in the given context.

19(b) Fair understanding was demonstrated, but many students found outputting the result of a recursive algorithm on a BST a challenging task.

19(c) This question was moderately well answered, with students generally demonstrating an understanding of the basic concept of constructing a binary tree from a sequence.

19(d) The question required constructing a recursive method for binary tree storage and retrieval, which proved moderately challenging for students. Some struggled with the complexities of recursion and tree manipulation.

## Recommendations and guidance for the teaching of future students

Students demonstrated a range of abilities in understanding and applying OOP concepts. While many showed proficiency in basic concepts like object creation and class relationships, there's room for improvement in applying these concepts to practical scenarios, particularly when it comes to complex algorithms and data structures. The inclusion of more hands-on practice is essential to reduce the gap between theory and practice. Future students should focus on strengthening their foundational knowledge of OOP principles, data structures, and algorithms (such as searching and sorting, recursion, etc). Engaging in regular practise with coding exercises, particularly those involving class interactions, algorithm implementation, and data structure manipulation, will solidify understanding and improve

problem-solving skills. In addition to practical application, effective communication of OOP knowledge is essential. Students should practise articulating clear and concise explanations of OOP concepts, utilising proper terminology. Schools are increasingly introducing programming and computational thinking modules lower down the school. This strategy puts these schools at an advantage when offering computer science at IB Diploma programme, as their students will be better prepared for the practical aspects of this course. All schools are encouraged to do the same.

## Further comments relating to all four options

Teachers should ensure students know which option to attempt in the exam. In most schools, students who attempted multiple options didn't perform well. This may suggest the students are answering questions on options they have not addressed in class.

Teachers should ensure students are aware that they only need to answer questions from one option. Where students answered questions from more than one option, they tended to perform less well (self-penalised).

Teachers should teach the theory using examples wherever possible. The exam questions are scenario based, and this requires students to link the theory they have learned to the scenario. This higher level of thinking means that generic or rote-learned answers are likely only to achieve partial marks.

Theory should be taught iteratively and in a range of contexts. The text on pages 12 – 15 inclusive relates to the 'approaches to teaching and learning' and the text on Page 27 at the start of Topic 4 also that applies to each of the options.

# Higher level paper three

## The areas of the programme and examination which appeared difficult for the students

The most challenging question asked students to describe how implementing bundle adjustment improves optimisation in the vSLAM process. Although only worth four marks, few students understood the process despite bundle adjustment being listed in the additional terminology section. Those students who gained the first mark were often awarded two or three more for their expansion.

The 12-mark extended question was also challenging. The terminology of benefits and costs confused some students, who focused on a financial cost rather than a computational or storage cost. Even when students had broad knowledge of computer science related to rescue robots, they tended to merely describe instead of discussing the different technologies.

## The areas of the programme and examination in which students appeared well prepared

Nearly all students gained marks on the four-mark ethics question. This very generic question required little understanding of the complex topic. The question asked for ethical considerations of deploying autonomous rescue robots, and the mark scheme contained 13 possible correct answers.

Students appeared well prepared for the additional terminology list of technical terms. Both 2-mark questions (1a and 1b) were answered reasonably well.

## The strengths and weaknesses of the students in the treatment of individual questions

### Question 1

1(a) The definition of dead reckoning was made easier because part of the answer could be extracted from the case study. Many students expanded on the information or gave a more specific response.

1(b) Technically, this was a harder question than 1(a). Students were able to explain why loop closure is difficult to achieve. Most students gained at least one mark, and many could expand on their first point.

### Question 2

2(a) Bundle adjustment is a complex concept. Many students were unable to describe its implementation in the VSLAM process. Those who understood that multiple views or readings were needed continued to gain additional marks.

2(b) Students found it relatively easy to identify two ethical concerns about deploying rescue robots. Better students were able to give a reasonable expansion for each concern.

### Question 3

Explaining the challenges associated with rescue robots and estimating the pose of survivors is a complex task. Many students could explain that obscured key points were a major difficulty. Surprisingly, few students considered poor lighting, smoke or dust as an obscuring factor. A small percentage of students gained full marks.

### Question 4

The extended response challenge was to discuss the benefits and costs of deploying rescue robots that use the vSLAM process and pose estimation techniques to carry out rescue operations in closed spaces.

Most students focused excessively on ethical points, such as the safety of deploying robots rather than human rescue teams. When technical concepts were mentioned, they were done so without any depth. Few students referenced information beyond the case study, giving the impression that little research had been conducted.

## Recommendations and guidance for the teaching of future students

The case study is released about a year before the examination, allowing schools to approach Paper 3 from a research perspective. This method helps contextualise the computer science aspects of the case study. Treating the topic like an extended essay enhances students' understanding of the various issues and likely boosts engagement.

While the additional terminology list should be covered, the challenges faced should be the primary focus, or the extended response question becomes difficult to answer in depth. This higher-level paper requires evaluation or discussion rather than describing technical information.

Schools should encourage students to pay close attention to the wording of the questions and, in particular, the command terms used. The type of response depends upon the command term, and merely writing down everything a student knows is not an effective strategy.

Students who read journal articles and complete video courses on the case study topic have a broader understanding of the concepts. This additional reading allows students to employ references to real-world examples or research in the extended response question.

Several unofficial online forums have provided questionable information and guidance. Teachers should inform students that they should research broadly and cross-check the information they find.

The quality of students' handwriting has declined, sometimes making understanding the extended responses difficult. While this is understandable, it is still a written exam, and students should practise writing legibly under pressure in class before taking the exam.