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Computer science

Higher level

Paper 2

4 May 2026

Zone A morning | **Zone B** morning | **Zone C** morning

1 hour 20 minutes

Instructions to students

- Do not open this examination paper until instructed to do so.
- Answer all of the questions from one of the options.
- The maximum mark for this examination paper is **[65 marks]**.

Option	Questions
Option A — Databases	1 – 4
Option B — Modelling and simulation	5 – 8
Option C — Web science	9 – 13
Option D — Object-oriented programming	14 – 19

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Option A — Databases

1. A software company employs programmers and managers.

- Each programmer works on a single project.
- Each project has multiple programmers.
- Each manager oversees multiple projects.
- Each project has one manager.

(a) Construct an entity-relationship diagram (ERD) that shows the relationships between programmer, manager and project. [2]

When a programmer changes source code, the changes are automatically written to a database and timestamped.

(b) Outline **one** benefit of using a database to track changes to source code. [2]

(c) Outline the role of timestamps in maintaining data consistency. [2]

Multiple programmers can work on the same source code concurrently (at the same time).

(d) Explain **one** way in which concurrency can be managed in the database when two programmers update the same line of code at the same time. [5]

(e) When data corruption occurs, databases need to be restored to a consistent state.

(i) Outline what is meant by a consistent database state. [2]

(ii) Describe **one** recovery method that can be used to restore a database. [3]

(Option A continues on the following page)

(Option A continued)

2. A software company has a manager who oversees several projects. Each project is developed for a specific client.

A record of a project is placed in a PROJECT table:

PROJECT (ManagerID, ClientID, ProjectID, ProjectName, StartDate, EndDate, Priority)

- (a) Suggest a primary key for the PROJECT table. [2]

The Priority field stores only two pieces of data: High or Low.

- (b) Outline an appropriate data type for the Priority field. [2]

The PROJECT table is shown in **Figure 1**, the MANAGER table is shown in **Figure 2**, and the CLIENT table is shown in **Figure 3**.

Figure 1: The PROJECT table

ManagerID	ClientID	ProjectID	ProjectName	StartDate	EndDate	Priority
M123	C001	1	AI bot	2024-01-01	2025-12-31	High
M456	C002	2	Website	2024-02-01	2025-08-31	Low
M123	C003	3	Data analysis	2024-03-01	2025-11-30	Low
M789	C004	4	Cybersecurity	2024-04-01	2025-09-30	High

Figure 2: The MANAGER table

ManagerID	ManagerName	PhoneNumber	EmploymentDate
M123	Sehee Choi	0107930361	2023-04-12
M456	Errol Blake	0105940577	2022-01-29
M789	Faye Yang	0109839399	2023-12-18

(Option A continues on the following page)

(Option A, question 2 continued)

Figure 3: The CLIENT table

ClientID	ClientName	ContactNumber	Industry
C001	Tech Innovators	0123456789	Technology
C002	Web Solutions	0987654321	Web development
C003	Data Insights	0234567890	Data analysis
C004	Secure Corp	0345678901	Cybersecurity

- (c) Construct a query to find ClientName and ContactNumber for projects managed by Sehee Choi that are High priority.

[5]

The database table (**Figure 4**) includes the professional development details of programmers.

Figure 4: The database table showing the professional development details of programmers

ID	Programmer	Level	Qualification	Company	CourseDate	Complete	Cost
1	Jana Jain	Senior	Oracle-certified, Java	CyberSafe	2024-01-29	Yes	2000
2	Kev McClure	Senior	Azure AI engineer	UniCode	2024-02-05	Yes	3000
3	Colin Sinclair	Junior	Certified data scientist	DataCamp	2024-03-11	No	2500
4	Dave Lees	Junior	CISSP certification	CyberSafe	2024-04-21	Yes	2200
1	Jana Jain	Senior	Azure AI engineer	UniCode	2024-05-28	No	3200
2	Kev McClure	Senior	Oracle-certified, Java	DataCamp	2024-06-01	No	2000

- (d) Construct the database in 3rd normal form (3NF) for the entities shown in **Figure 4**.

You should use the following notation:

TABLE (Key, Field1, Field2,...)

[5]

(Option A continues on the following page)

(Option A continued)

3. A company is developing a database to track employees working remotely. This database is planned using conceptual schema and a data dictionary.

- (a) Outline the role of conceptual schema. [2]
- (b) Outline the purpose of a data dictionary. [2]
- (c) Describe the role of a data definition language in implementing a data model. [3]

Remote working requires increased levels of data security.

- (d) List **three** tasks that a database administrator carries out to ensure data security. [3]

The company is planning to allow external regulators to view the database.

- (e) Explain the benefits of allowing external regulators to view the database. [5]

(Option A continues on the following page)

(Option A continued)

4. A company has implemented a multidimensional database model, which is beneficial for data mining.

- (a) List **three** benefits of using a multidimensional database model for data mining. [3]

The extract, transform, load (ETL) process was used to extract data from a database, transform it and load it into a data warehouse.

- (b) Define the term *data warehouse*. [1]

- (c) Explain the need for data transforming in the ETL process. [5]

Common programming errors are input into a decision tree to predict possible programming errors.

- (d) Describe how predictive modelling using decision trees can help predict programming errors. [4]

The company wants to ensure copyrighted code is not used in its projects. Deviation detection is applied to a historical dataset of code to establish baseline patterns.

- (e) Describe how deviation detection could be used to identify copyrighted code. [2]

The company uses cluster analysis and classification to gain insights into coding practices and identify areas for improvement.

- (f) Compare cluster analysis and classification techniques in this scenario. [5]

End of Option A

Option B — Modelling and simulation

5. The spreadsheet extract in **Figure 5** shows the scores for five students at City Walk School for two semesters (Sem 1 and Sem 2).

Figure 5: Spreadsheet extract showing five students' scores for two semesters

	A	B	C	D	E
1	Student name	Sem 1	Sem 2	Final %	Student grade
2	Elaine Anaya Khan	20	30	50.0	
3	Angel Chanchikova	32	54	87.5	
4	Isabella	26	45	72.5	
5	Sarah Naveneethan	32	38	67.5	
6	Scott Abou Khalil	16	24	40.0	

- Sem 1 scores (column B) are out of 40.
- Sem 2 scores (column C) are out of 60.
- Final (column D) combines the scores for both semesters, weighted 25 % for semester 1 (Sem 1) and 75 % for semester 2 (Sem 2).

- (a) (i) State Elaine Anaya Khan's percentage for semester 1. [1]
- (ii) Construct the formula to calculate the percentage for cell D2. [2]

City Walk School reports students' grades from lowest to highest (E to A), inclusively:

- A score between 35 and 46, inclusive, returns an E grade.
- A score between 47 and 59, inclusive, returns a D grade.
- A score between 60 and 69, inclusive, returns a C grade.
- A score between 69 and 84, inclusive, returns a B grade.
- A score of 85 or more returns an A grade.

(Option B continues on the following page)

(Option B, question 5 continued)

The data for these scores are stored in columns H and I (see **Figure 6**).

Figure 6

	A	...	D	E	...	H	I
1	Student name		Final	Student grade		School score	Grade
2	Elaine Anaya Khan		50.0			35	E
3	Angel Chanchikova		87.5			47	D
4	Isabella		72.5			60	C
5	Sarah Naveneethan		67.5			70	B
6	Scott Abou Khalil		40.0			85	A

- (b) Construct a formula to automatically add Elaine Anaya Khan's grade (shown in column I) to cell E2.

[3]

The formula `=FIND(A2, " ")` has been added to cell F2 and replicated down the rest of the column (see **Figure 7**).

Figure 7

	A	...	F
1	Student name		FIND
2	Elaine Anaya Khan		7
3	Angel Chanchikova		6
4	Isabella		#VALUE!
5	Sarah Naveneethan		6
6	Scott Abou Khalil		6

Row 4 produces an error.

- (c) Outline why cell F4 produced an error.

[2]

(Option B continues on page 11)

Blank page

(Option B, question 5 continued)

The function `=ISNUMBER(value)` returns `TRUE` if the value is a number and `FALSE` if the value is not a number.

For example, the value in F2 should be 7 because 7 is an integer. The value in F4 should be `FALSE` because `#VALUE!` is not an integer.

(d) Construct a formula for cell F4 as described.

[3]

To fix the error in row 4, Isabella's last name has been added. Two additional columns have been inserted: Last name and First name (see **Figure 8**).

Figure 8

	A	B	C	D
1	Student name	Last name	First name	Sem 1
2	Elaine Anaya Khan	Khan	Elaine	20
3	Angel Chanchikova	Chanchikova	Angel	32
4	Isabella Hodroge	Hodroge	Isabella	26
5	Sarah Naveneethan	Naveneethan	Sarah	32
6	Scott Abou Khalil	Khalil	Scott	16

The first name in cell C2 has been extracted from the full name in cell A2 using the `MID` function and `FIND` function:

`=MID(A2,1,FIND(" ",A2)-1)`

In column B, last names have been extracted from the student names in column A. Any middle name has been ignored.

(e) Explain how a last name could be extracted while ignoring a middle name.

[4]

(Option B continues on the following page)

(Option B continued)

6. Schools in the region are required to upload student names and their scores for each subject to the portal of the Ministry of Education (a governmental organization that oversees standards for examination scores).

City Walk School's grade boundaries* are lower than the Ministry of Education's grade boundaries, as shown in **Figure 9**.

Figure 9: Grade boundaries for City Walk School and the Ministry of Education

	H	I	J	K
1	School score	Grade	Ministry score	Grade
2	35–46	E	40–51	E
3	47–59	D	52–65	D
4	60–69	C	66–75	C
5	70–84	B	76–90	B
6	85–100	A	91–100	A

Consider the formula:

$$KS = \left(\frac{SSS - MinSS}{MaxSS - MinSS} \right) \times (91 - 40) + 40$$

where:

- SSS is the student's school score.
- *MinSS* is 35, the minimum score in the school's data range.
- *MaxSS* is 85, the minimum score for an A grade in the school's data range.
- 40 is the minimum score in the Ministry of Education's data range.
- 91 is the minimum score for an A grade in the Ministry of Education's data range.

This formula is used to scale data from one range (e.g. school score: 35–85) to a different range (Ministry score: 40–91).

- (a) Calculate *KS* to one decimal place, where *SSS* = 60.

You must show your working.

[2]

* grade boundaries: the range of marks required to achieve a specific grade

(Option B continues on the following page)

(Option B, question 6 continued)

The spreadsheet extract shown in **Figure 9** has been imported into a program.

- An array, STUDENTS, stores student's last names.
- An array, SCORES, stores student's school scores rounded to the nearest integer.
- An array, MINISTRY, consists of five integers of 0.

```
STUDENTS = [Khan, Chanchikova, Hodroge, Naveneethan, Khalil]
SCORES = [50, 88, 73, 68, 40]
MINISTRY = [0, 0, 0, 0, 0]
```

A pseudocode algorithm should take each value in the SCORES array and apply the formula to calculate the Ministry score. The result of this calculation should be rounded to the nearest integer and stored in the MINISTRY array.

- (b) Construct an algorithm in pseudocode as described. [3]

When schools upload student names and scores, the portal only allows integers between 40 and 100 to be entered. The Ministry of Education runs several automated checks on the data.

- (c) Describe **one** other automated check the Ministry of Education might use to ensure the data is accurate. [3]

For a student to achieve a grade A, they must score between 91 and 100.

A pseudocode algorithm should count the number of grade A students and store the result as a percentage of the total number of students.

- (d) Construct an algorithm in pseudocode as described. [4]

(Option B continues on the following page)

(Option B continued)

7. The Ministry of Education is developing a real-time simulation model to monitor and analyse the impact of student attendance on academic performance across all schools in the region.

- (a) Outline what is meant by real-time simulation. [2]

Student attendance rate is a variable used in the simulation.

- (b) Identify **three** other variables that would be required to model this simulation effectively. [3]

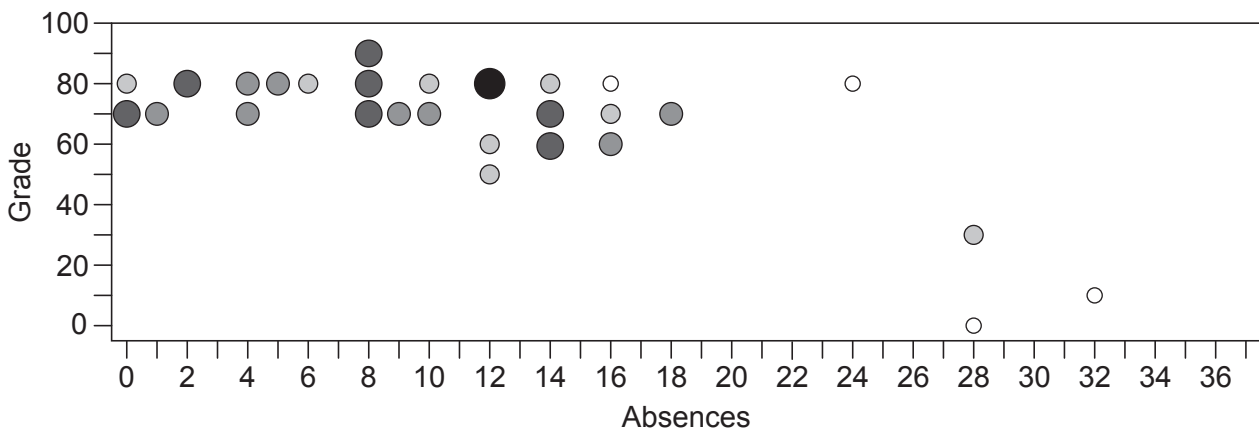
- (c) Outline **two** categories of hardware needed for this simulation. [4]

The Ministry of Education decided to use City Walk School as a test case to assess the simulation model's accuracy in predicting student scores based on attendance.

- (d) Discuss **one** factor that could be used to judge the effectiveness of this test case for assessing the accuracy of the simulation model. [5]

After completing the test case, the Ministry of Education applied the simulation to all schools in the region. A heat map visualization was used to show the relationship between absences and grades (see **Figure 10**).

Figure 10: Heat map visualization showing the relationship between absences and grades in schools in the region



- (e) Outline **two** factors that would affect the memory needs of a 2D visualization such as the heat map shown in **Figure 10**. [4]

(Option B continues on the following page)

(Option B continued)

8. The Ministry of Education is using a genetic algorithm to determine the most suitable locations for new schools.

An initial population of random site locations is added to a population pool, and the algorithm runs iteratively until a stopping condition is reached.

- (a) Outline **two** steps, **other than** the ones already stated, that must be taken for the genetic algorithm to find the most suitable locations for new schools. [4]

The Ministry of Education is implementing a chatbot on its website to provide guidance for schools.

- (b) (i) Outline **one** advantage of using a chatbot. [2]

- (ii) Outline **one** disadvantage of using a chatbot. [2]

The Ministry of Education plans to use a neural network for natural language processing to analyse large volumes of handwritten student essays.

- (c) Identify **two** key structures of natural language. [2]

- (d) Evaluate the effectiveness of natural language processing for analysing student essays. [4]

The Ministry of Education is developing an educational tool designed to enhance students' language skills by incorporating cognitive research on how humans learn languages.

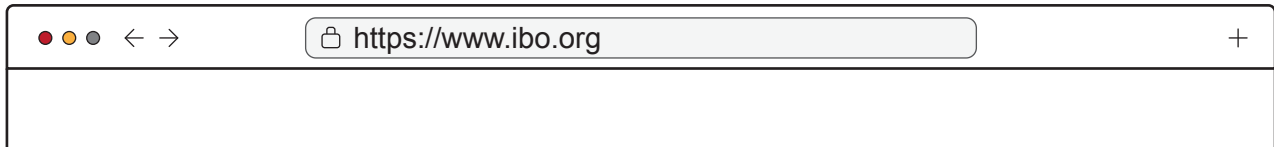
- (e) Explain **two** principles of language learning that should be applied in this educational tool. [6]

End of Option B

Option C — Web science

9. Callum opens a web browser and enters the universal resource locator (URL) of the International Baccalaureate Organization (see **Figure 11**).

Figure 11: Web browser showing the URL of the International Baccalaureate Organization



- (a) State **two** characteristics of a URL. [2]
- (b) Outline **two** functions of a web browser. [2]
- (c) Hypertext transfer protocol secure (HTTPS) is an example of a protocol. Explain why protocols are important. [3]
- (d) Identify **two** characteristics of extensible mark-up language (XML). [2]

A website contains a page that lists the students in a class. The page uses two files to develop the list as shown.

Class.xml

```
<?xml-stylesheet type="text/xsl" href="class_style.xsl"?>
<class>
  <student>
    <firstname>John</firstname>
    <surname>Doe</surname>
    <classname>Mathematics</classname>
  </student>
  <student>
    <firstname>Jane</firstname>
    <surname>Smith</surname>
    <classname>Physics</classname>
  </student>
  <student>
    ...
  </class>
```

(Option C continues on the following page)

(Option C, question 9 continued)

Class_style.xsl

```
<?xml version="1.0" encoding="UTF-8"?>
<xsl:stylesheet version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/
Transform">
<xsl:template match="/">
  <html>
    <body>
      <h1>Class Members</h1>
      <table>
        <tr>
          <th>First Name</th>
          <th>Surname</th>
          <th>Class</th>
        </tr>
        <xsl:for-each select="class/student">
          <tr>
            <td><xsl:value-of select="firstname"/></td>
            <td><xsl:value-of select="surname"/></td>
            <td><xsl:value-of select="classname"/></td>
          </tr>
        </xsl:for-each>
      </table>
    </body>
  </html>
</xsl:template>
</xsl:stylesheet>
```

(e) With reference to Class.xml and Class_style.xsl, describe how a page connects to the underlying data source. [2]

(f) Identify **three** characteristics of transmission control protocol (TCP). [3]

10. It is estimated that the deep web is 500 times larger than the surface web.

(a) Outline **one** difference between the deep web and the surface web. [2]

(b) Define the term *web crawler*. [1]

(c) Outline the web crawling process. [3]

(d) Describe **two** advantages of parallel web crawling. [4]

Developers attempt to have their site rank higher in the search engine result.

(e) Evaluate **two** white hat techniques that may be used in search engine optimization. [5]

(Option C continues on the following page)

(Option C continued)

11. (a) Distinguish between ubiquitous computing and mobile computing. [4]

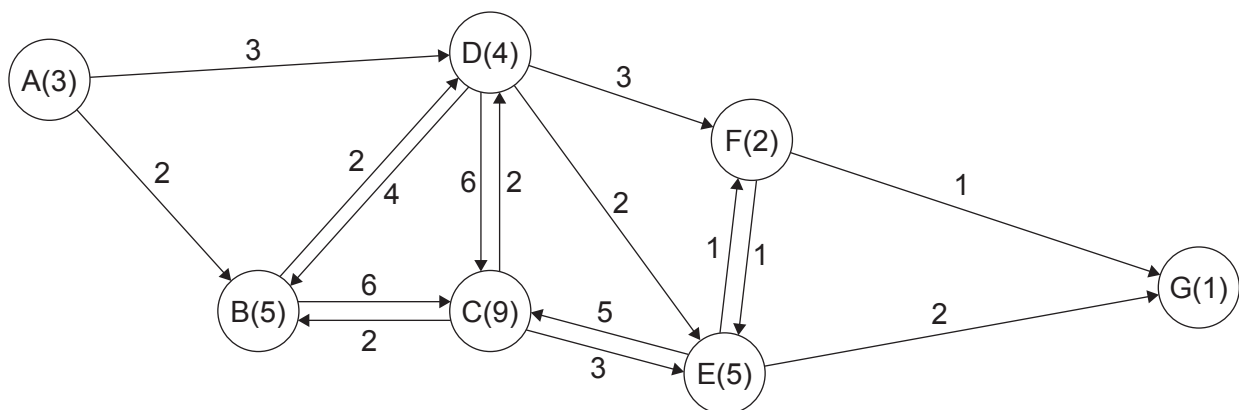
Violet is a photographer who has profiles on multiple social media platforms.

The social media platform that Violet uses is a community of independent and personal sites connected by open standards such as ActivityPub. It is described as a distributed social network.

- (b) Describe how open standards support interoperability. [2]
- (c) Explain how distributed social networks support decentralization of the web. [6]
- (d) Discuss the challenges faced by distributed social networks with reference to intellectual property. [4]

12. The subgraph in **Figure 12** represents a portion of the web with weighted nodes and edges. The weight in each node represents the activity level within that node.

Figure 12: Subgraph representing a portion of the web



- (a) Outline why **Figure 12** is best described as a weighted and directed graph. [2]
- (b) Explain why some nodes in **Figure 12** are described as weakly connected and some as strongly connected. [4]
- (c) Explain which **three** nodes in **Figure 12** would rank highest using the PageRank algorithm. [4]

(Option C continues on the following page)

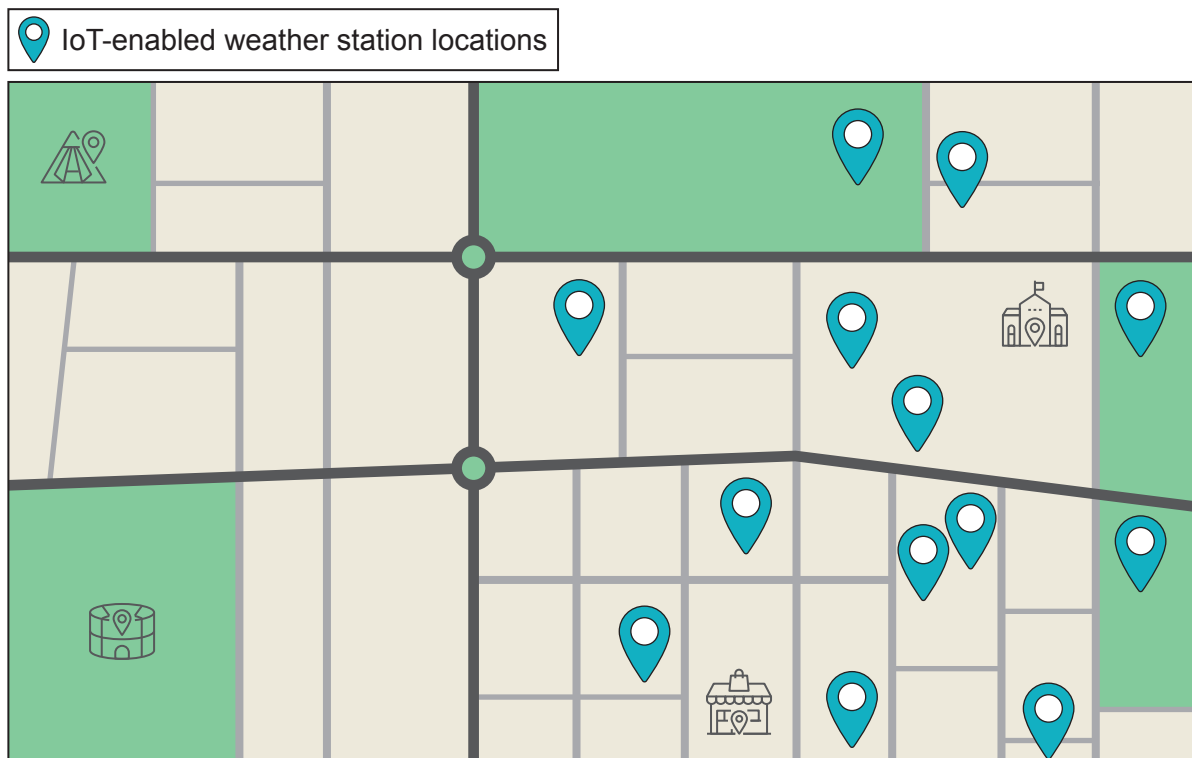
(Option C continued)

13. An Internet of Things (IoT)-enabled weather station uses a network of devices and sensors to collect, analyse and transmit weather data in real time.

This represents ambient intelligence.

Figure 13 shows the distribution of IoT-enabled weather stations in a town, with the 13 tear drop markers representing the devices.

Figure 13: Map showing the distribution of IoT-enabled weather stations in a town



- (a) Describe **one** difference between ambient intelligence and collective intelligence. [2]
- (b) Discuss **one** benefit **and one** limitation of IoT-enabled weather stations providing accurate weather data. [6]

The IoT-enabled weather stations in people's homes typically use meta-tags to describe and categorize data. This metadata is not considered an ontology.

- (c) Outline why this metadata is not considered an ontology. [2]

End of Option C

Option D — Object-oriented programming

14. A video game is being developed. It allows a player to build a fleet of different spaceships (such as trade ships, scout ships and cruisers) with two types of engines—standard drive and hyperdrive. These ships are used to explore the game’s galaxy and discover and trade with other civilizations.

A partial outline of the class `Ship` is shown.

```
public class Ship
{
    private String type;           // "trade", "scout" or "cruiser"
    private int level;             // current level of the ship
    private int speed;             // speed of the ship
    private boolean hyperdrive;    // whether or not the ship has
                                   // a hyperdrive
    private int size;              // relative size of the ship

    public Ship(String t, int l, int s, boolean h, int size)
    {
        this.type = t;
        this.level = l;
        this.speed = s;
        this.hyperdrive = h;
        this.size = size;
    }

    public int getSize()
    {
        return this.size;
    }

    // other accessor and mutator methods are implemented but not shown
}
```

Figure 14 gives examples of data stored in `Ship` objects.

Figure 14

<pre>type: "scout" level: 4 speed: 50 hyperdrive: true size: 1</pre>	<pre>type: "trade" level: 3 speed: 12 hyperdrive: false size: 5</pre>	<pre>type: "cruiser" level: 1 speed: 20 hyperdrive: true size: 20</pre>
--	---	---

(Option D continues on the following page)

(Option D, question 14 continued)

- (a) Distinguish between a class and an object in terms of memory use during runtime. [2]
- (b) State **one** accessor method, **other than** `getSize()`, to be included in the class `Ship`. [1]
- (c) Outline **one** purpose of a mutator method. [2]
- (d) Construct the code for the mutator method `setType()`. [3]

Based on this `Ship` class, the programmer defines a sub-class `PowerShip`. The sub-class `PowerShip` has an additional `boolean` attribute, `stealth`, which has a starting value of `false`.

- (e) Construct the code for the sub-class `PowerShip` without duplicating all the attributes and methods from the class `Ship`. The code must include the new variable, the constructor for this class, and accessor and mutator methods for the new variable. [4]

A new engine, the Xdrive, is introduced in addition to the standard drive and hyperdrive.

- (f) Outline **one** change that needs to be made to the variable `hyperdrive` to include this new engine. [2]

- 15.**
- (a) Identify **two** features of object-oriented programming (OOP). [2]
 - (b) Identify the OOP feature that is indicated by the modifier `private` as used in `private String type;` [1]
 - (c) Describe **one** advantage of an OOP feature you identified in part (a) **or** part (b). [2]
 - (d) Describe **one** disadvantage of an OOP feature you identified in part (a) **or** part (b). [2]

(Option D continues on the following page)

(Option D continued)

- 16.** In the video game, ships need to be refilled with fuel. Ships waiting to refuel are added to an array, `refuel`, that is instantiated as follows:

```
Ship[] refuel = new Ship[100];
```

The `refuel` array can store any combination of `Ship` objects, but the total fuel required by all ships must not exceed 80 units (the daily limit). Different types of ships need different amounts of fuel depending on their size:

- A scout ship has `size` 1 and needs 1 unit of fuel.
- A trade ship has `size` 5 and needs 5 units of fuel.
- A cruiser has `size` 20 and needs 20 units of fuel.

- (a) Construct the code for the method `totalFuel()` that returns the sum of the `size` values for all `Ship` objects that are stored in the `refuel` array.

You may assume that the method `totalFuel()` can access the `refuel` array. [6]

The video game needs a method to add a new `Ship` object to the `refuel` array as long as it would not increase the total fuel requirement to more than 80 units of fuel.

- (b) Construct the code for the method `addRefuelShip(Ship aShip)` that will check if there are enough units of fuel left to refuel the object `aShip`. If there is enough fuel, it should add the object `aShip` in the next empty location in the `refuel` array; otherwise, it should output the error message “Maximum refuel limit reached.”

You may assume that the method `addRefuelShip` can access the `refuel` array.

Remember that you can use any previously constructed methods. [5]

- (c) Describe **two** advantages of using libraries of objects, such as `Swing` or `Collections`, when developing a video game program. [4]

- 17.** The video game has a chat area and an option for players to name their account.

- (a) With reference to this video game, outline **two** features of modern programming languages that enable internationalization. [4]

Parents and guardians sometimes worry about the impact of video gaming on their children.

- (b) Discuss the ethical and moral obligations of video game developers. [5]

(Option D continues on the following page)

(Option D continued)

18. In the video game, ships can be destroyed; a player must then build new ships.

A linked list, `newShips`, has been instantiated as follows:

```
LinkedList<Ship> newShips = new LinkedList<Ship>();
```

New ships are selected to be built by the player. They are instantiated as objects of the class `Ship`. These objects are added sequentially to `newShips`.

- (a) Define the term *object reference*. [2]

- (b) Describe the advantages **and** disadvantages of linked lists over static arrays. [4]

In the following question, you must use the Java Examination Tool Subset (JETS) linked list class that has the following methods:

<code>.addFirst(E element)</code>	<code>.addLast(E element)</code>	<code>.add(int index, E element)</code>
<code>.size()</code>	<code>.getFirst()</code>	<code>.getLast()</code>
<code>.get(int index)</code>	<code>.getNext()</code>	<code>.removeFirst()</code>
<code>.removeLast()</code>	<code>.remove(int index)</code>	<code>.isEmpty()</code>

There are three linked lists, named `scouts`, `traders`, and `cruisers`. Each `Ship` object needs to be moved from `newShips` into the correct linked list depending on its type.

- (c) Construct the code for the method `separate()` that will move each `Ship` object from `newShips` to the correct linked list.

You may assume that the method `separate()` can access the four linked lists `newShips`, `scouts`, `traders` and `cruisers`.

[5]

19. (a) Describe the application of recursive algorithms. [3]

A method is required to reverse the content of the linked list `newShips`.

For example, the linked list

```
newShips → [ship1] → [ship2] → [ship3] → [ship4] → null
```

will become

```
newShips → [ship4] → [ship3] → [ship2] → [ship1] → null
```

- (b) Explain the steps of a recursive algorithm that reverses the order of `Ship` objects in the linked list `newShips`.

[6]

End of Option D

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References:

- Figure 10** Etemadpour, R., Zhu, Y., Zhao, Q., Hu, Y., Chen, B., Sharier, M. A., Zheng, S. and Paiva, J. G. S., 2020. Role of absence in academic success: an analysis using visualization tools. *Smart Learning Environments*, [e-journal] 7(2). Available at: <https://slejournal.springeropen.com/articles/10.1186/s40561-019-0112-3> [Accessed 18 June 2025]. Source adapted.
- Figure 13** StudioU, 2022. *Navigation Editable Stroke Line Icons - stock illustration*. [image online] Available at: <http://www.gettyimages.com/detail/1410898169> [Accessed 24 July 2025]. Source adapted.