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# Computer science

## Higher level

### Paper 2

Monday 2 November 2020 (morning)

1 hour 20 minutes

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#### Instructions to candidates

- 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 – 12
Option D — Object-oriented programming	13 – 17

**Option A — Databases**

1. The *Driving Licensing Agency* stores information about individuals who hold a driving license and/or own vehicles.

The following rules apply:

- Each individual may only hold one driving license.
- Each individual may own more than one vehicle.
- Each vehicle may be owned by one individual only.

- (a) Construct the entity-relationship diagram (ERD) that shows the relationship between the individual, their driving license, and their vehicle(s). [2]

When an individual applies for a driving license, they have to complete a license application form. The following is an extract from that form:

**Figure 1: Extract from driving license application form**

Surname

First name(s)

Mr  Mrs  Miss  Ms

Other title  Male  Female

Day Month Year

Date of birth

- (b) Explain why *Date of birth* has been separated into three fields. [3]

The data in the form shown above is stored in the **Person** table. The license application form also requires an individual's medical information. This is stored in a table called **PersonMedical**.

The following extract is a sample of the medical questions that are asked.

**Figure 2: A sample of the medical questions asked on the license application form**

Have you ever had any of the following conditions? No  Yes

If you have answered "Yes", please tick all the appropriate boxes.

Epilepsy

Fits or blackouts

Repeated attacks of sudden disabling giddiness

Diabetes controlled by insulin

(Option A continues on the following page)

**(Option A, question 1 continued)**

- (c) Explain **two** reasons why medical information should not be stored in the **Person** table. [6]
- (d) Outline **two** issues caused by storing redundant data. [4]
- (e) Outline **two** situations where data stored by the *Driving Licensing Agency* may need to be open to interrogation by other parties. [4]

2. *Billetmania* is an online company that sells tickets for theatre performances and music concerts. After a customer has chosen their seats, they can pay for the tickets through a secure online payment system. Once the transaction has been completed, the customer receives an email receipt.

- (a) Define the term *database transaction*. [1]

An information system and a database are used for *Billetmania's* day-to-day operations.

- (b) Outline how the *Billetmania* information system would utilize a database. [2]
- (c) Explain the importance of transaction durability to *Billetmania* when clients book tickets. [3]
- (d) Explain how the *Billetmania* database management system ensures that a seat is not booked by two people simultaneously. [4]

**(Option A continues on the following page)**

**(Option A continued)**

3. *WineForAll* is a retailer that sells wine in its stores. Each store sells wine from a number of vineyards.

The following extract from the **Wine** file contains unnormalized data.

<b>NameOfWine</b>	<b>Vineyard</b>	<b>Description</b>	<b>UnitPrice</b>	<b>Region</b>	<b>StoreID</b>	<b>StockQty</b>
Chardonnay	Stormy Bay	2015, Dry, 13 %	\$19.99	Gisborne	1	45
Sauvignon Blanc	Stormy Bay	2017, Dry, 12 %	\$29.99	Gisborne	2	20
Sauvignon Blanc	Stormy Bay	2017, Dry, 12 %	\$29.99	Gisborne	1	45
Pelorus	Stormy Bay	2016, Brut, 14 %	\$34.99	Gisborne	1	10
Pinot Noir	Pecan Block	2016, Fruity, 14 %	\$29.99	Gisborne	3	32
Sauvignon Blanc	Pecan Block	2017, Dry,13 %	\$29.99	Gisborne	4	25
Shiraz	James Tree	2013, Fruity, 13.5 %	\$25.99	Hawkes Bay	3	15
Shiraz	James Tree	2013, Fruity, 13.5 %	\$25.99	Hawkes Bay	2	40
Merlot	James Tree	2014, Fruity, 14 %	\$29.99	Hawkes Bay	1	25
Sauvignon Blanc	John Glad	2016, Dry, 12.5 %	\$19.99	Gladstone	4	30
Chardonnay	John Glad	2017, Dry, 13.5 %	\$15.99	Gladstone	2	28

**(Option A continues on the following page)**

**(Option A, question 3 continued)**

- (a) Define the term *record*. [1]
  - (b) Identify the steps to create a query to find the vineyards and names of fruity wines where the quantity in stock is between 25 and 35 bottles. [3]
  - (c) (i) Identify the steps to create a non-persistent derived field called `TotalPrice`, which would hold the total value of wine stored for each record. [2]  
(ii) Outline why the inclusion of a derived field will not affect the normalization of a database. [2]
  - (d) Construct the 3rd Normal Form (3NF) of the unnormalized **Wine** file. [6]
  - (e) Outline why a single-field primary key is not always an appropriate solution for normalized databases. [2]
4. The Criminal Information Support System (CISS) project is being developed to provide the Puerto Rico Police (PRP) with countrywide access to a centralized data warehouse. The data warehouse will be created from the databases of several police departments.
- (a) Identify **two** differences between a data warehouse and a database. [2]
  - (b) Outline **two** advantages that the PRP will gain from using a data warehouse. [4]
  - (c) Describe how data in the CISS data warehouse could be updated in real time from the police department databases. [4]
- Data mining techniques are being used with the new PRP data warehouse to assist the detection of patterns in crime data. Pattern detection approaches include cluster analysis and classifications.
- (d) Compare cluster analysis and classifications as pattern detection techniques. [5]
  - (e) Explain how link analysis could be used to detect patterns in crime data. [5]

**End of Option A**

### Option B — Modelling and simulation

5. *EnviroBuild* is a construction company that recently purchased land. It has permission to build either small houses **or** large houses but not both types of house. The maximum number of small houses that can be built is 10. The maximum number of large houses that can be built is five.

The cost of building the houses is calculated using a model with the following three variables:

House\_Type: The type of house (small or large).

House\_Num: The number of houses to be built.

Profit: The total sales revenue minus the land costs, labour costs and material costs.

- (a) Identify the data types for the `House_Type`, `House_Num` and `Profit` variables. [3]

The decision whether to build small houses or large houses is a purely financial one and is based on the following information:

- A single payment of \$500 000 for the land, regardless of whether 10 small houses or five large houses are to be built.
- The revenue from each house sale will be \$220 000 for a small house and \$400 000 for a large house.
- The labour costs will be \$2500 per day, regardless of the type of house built.
- It will take 17 days to build each small house and 23 days to build each large house. Houses are built sequentially so that they can be sold as soon as they are completed.
- The material costs will be \$100 000 for each small house and \$190 000 for each large house.

- (b) Construct a spreadsheet model that shows the total profit for the chosen type of house. The user must input the `House_Type` and `House_Num` to calculate the total profit. [6]

- (c) Outline **two** validation tests that should be included in the test plan for this spreadsheet model. [4]

To finance this project, *EnviroBuild* took out a bank loan of \$400 000 and will be required to pay interest on this loan. The project starts on 1 January 2021.

The following steps are used to calculate the total profit:

- Read the `Profit` variable and the `No_of_Days` variable from the spreadsheet model in (b).
- Calculate the number of months that the project will take.
  - There are no partial months.
  - For example, if a project finished on 1 July 2021, the loan interest rates will include July: the project will last for 7 months.
- The rate of interest on the bank loan of \$400 000 is 1 % per month.
- The land tax is \$500 per month.

- (d) Construct the pseudocode that will calculate the profit after these additional costs have been considered. You can introduce any new variables, if necessary. [5]

(Option B continues on the following page)

**(Option B continued)**

6. Global warming is a term used to describe the increase in mean global temperatures.

There have been numerous computer simulations developed to predict the effects of global warming. One simulation is NASA’s Virtual Earth System Laboratory (VESL), which allows users to see how climate change affects glacier size, global sea level and changes to the coastline.

The VESL runs simulations in real time and is an abstraction of reality.

- (a) (i) Outline what is meant by a real-time simulation in the context of a glacier size simulation. [2]
- (ii) Outline what is meant by the statement “the VESL simulation is an abstraction of reality”. [2]

A recent study reported that previous simulations of predicted global sea levels for 2100 were highly inaccurate.

- (b) Outline **two** reasons why predictions of global sea levels from simulations may not be accurate. [4]
- (c) NASA has decided to make its simulation software available for other scientists as well as members of the public.
- Evaluate the social and ethical implications of this decision. [6]

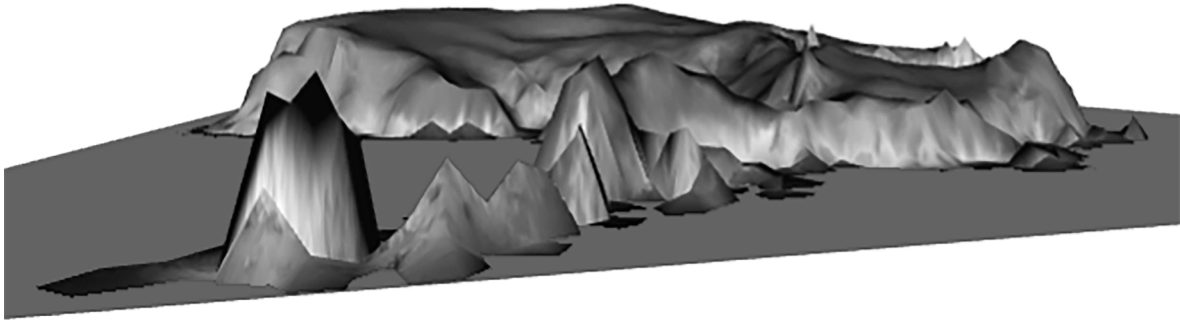
**(Option B continues on the following page)**



**(Option B continued)**

- 7. Simulation software can be used to produce a 3D visualization of rising sea levels that change as the user alters the percentage of ice that has melted.

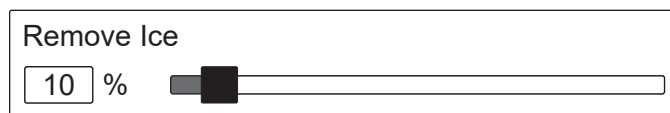
**Figure 3: 3D visualization of rising sea levels**



- (a) (i) Define the term *visualization*. [1]
- (ii) Identify how a 2D visualization could be used in this scenario. [1]
- (b) Explain the benefits of using visualization when simulating rising sea levels. [5]

Once the 3D visualization has been rendered, when the user drags a slider bar to simulate the amount of ice that has melted, the visualization is re-rendered without any delay.

**Figure 4: Slider bar to simulate different percentages of sea ice**



- (c) Describe how this 3D visualization is rendered. [6]

**(Option B continues on the following page)**

**(Option B continued)**

8. Genetic algorithms are used to influence the behaviour of non-playing characters (NPCs) in role-playing games (RPGs). NPCs are computer-controlled characters that the player interacts with but does not control.

- (a) Outline **two** advantages of developing NPCs using genetic algorithms. [4]

A series of generic NPCs are being developed for use in any multi-player RPG. The environmental and social interactions of these NPCs are being developed using supervised learning and will continue to develop as the game is played.

- (b) Explain how supervised learning of a genetic algorithm could be used to support the way NPCs learn. [6]

Once NPCs have completed their supervised training, they are placed in a dynamic game environment. Each NPC learns to adapt its behaviour to its environment.

At this stage of the training, NPCs will not be verbally communicating with other characters in their environment.

- (c) Describe the way an NPC in a game could adapt its behaviour when moving and interacting with its environment. [6]

The last stage of NPC development is verbal communication with player characters and other NPCs. To assist with this process, it was decided to explore research related to chatbots.

- (d) Explain the benefits of giving NPCs the functionality of chatbots. [4]

**End of Option B**

Blank page

**Option C — Web science**

9. Pugh University has a website that allows computer science students to enter their name and customize the web pages.

Consider the section of HTML and CSS code shown below.

File name: index.html

```
<!DOCTYPE html>
<html>
<body>
<script>
  function setVar(){
    var subject=document.getElementById("kippers").value;
    document.getElementById("subj").innerHTML = subject;
  }
</script>
<h2>My First Page</h2>
<p>Welcome to the <span id="subj"></span> Faculty</p>

<input type="text" id="kippers"/>
<button onclick="setVar();" />clickme</button>
</body>
</html>
```

- (a) (i) State the output of the `index.html` file in the web browser. [2]
- (ii) Describe the processing that takes place when the user inputs “Pugh” into the text box and then uses the `clickme` button. [3]

When a student enrolls, they must enter their name on a web page. Before being added to the database, the system should check that the name typed is not blank and that it has not already been added to the database.

- (b) Explain why these **two** validation checks occur on different computer systems. [4]

Consider the following URL:

<https://www.follettibstore.com>

- (c) Explain how website certificates are used to authenticate a user’s browser through secure protocol communications like HTTPS. [3]

The common gateway interface (CGI) offers a standard protocol for web servers.

- (d) Describe the working of the common gateway interface (CGI). [4]

Pugh University uses cloud computing services, such as Google Docs or Office 365.

- (e) Describe how cloud computing is different to a client–server architecture. [4]

**(Option C continues on the following page)**

**Turn over**

**(Option C continued)**

**10.** The internet and World Wide Web are often considered to be the same, or the terms are used in the wrong context.

- (a) Distinguish between the internet and the World Wide Web. [2]

Many organizations produce computer-based solutions that implement open standards.

- (b) Outline **two** advantages of using open standards. [4]

A search engine is software that allows a user to search for information. The most commonly used search algorithms are the PageRank and HITS algorithms.

- (c) Outline why a search engine using the HITS algorithm might produce different page ranking from one using the PageRank algorithm. [2]

Web crawlers browse the World Wide Web.

- (d) Explain how data stored in a meta-tag is used by a web crawler. [3]

**11.** The World Wide Web can be divided into three categories: the surface web, the dark web and the deep web.

- (a) Distinguish between the surface web and the deep web. [2]

The dark web is only accessible by using specialist software, such as TOR and I2P. Many users of the dark web use it to protect their anonymity.

- (b) Explain how a user’s anonymity can be maintained while accessing the dark web. [3]

Many users of the dark web use peer-2-peer (P2P) networks for activities like torrent streaming. This opens up ports on the computer to upload and download data.

- (c) Explain why users have concerns about opening up ports to upload and download data. [3]

- (d) The founders of the World Wide Web intended it to be a decentralized and democratic environment.

To what extent have the aspirations of the founders of the World Wide Web been met? [6]

**(Option C continues on the following page)**

**(Option C continued)**

**12.** The World Wide Web can be represented as a web graph.

- (a) Describe how a web graph can be used to represent the connectivity of the World Wide Web. [4]

The World Wide Web has expanded significantly over the last 10 years. In June 2018, there were an estimated 1600 million websites and 4100 million users. This is approximately twice the figures of January 2014.

- (b) Explain why a user can still navigate from one web page to another web page in the same amount of time as previously, even though the number of web pages is significantly larger. [4]

The World Wide Web can be divided into the text web and the semantic web.

- (c) Outline **two** reasons why there needs to be a balance between expressivity and usability on the semantic web. [4]

The development of technologies that underpin the World Wide Web has led to the growth of ambient intelligence and collective intelligence.

- (d) Identify **two** features of ambient intelligence. [2]

- (e) Evaluate the role of collective intelligence in the advancement of human knowledge. [6]

**End of Option C**

### Option D — Object-oriented programming

13. A company provides car parking services in large cities and needs a computer system to keep track of the number of vehicles using its parking areas.

When a vehicle arrives, its registration plate is recorded on the system and it is allocated a number that identifies where it should park. When the vehicle leaves, that space is made available for other vehicles to use.

Vehicles are identified by their unique registration plate, which is an alphanumeric code of eight characters (eg X1234567). This is clearly displayed on the vehicle.

A programmer created the classes `ParkingArea` and `Vehicle` to model the above situation.

```
public class ParkingArea {
    private Vehicle vehicles[];
    private String name;

    ParkingArea(String name, int capacity) {
        this.name = name;
        if (capacity > 300) capacity = 300;
        this.vehicles = new Vehicle[capacity];
    }

    String getName() {
        return name;
    }

    public int getCapacity() {
        return vehicles.length;
    }

    public int findVehicle(String reg) {
        //find where the vehicle is located in the array and
        //return the index not yet written
    }
}
```

(Option D continues on the following page)

**(Option D, question 13 continued)**

```
public class Vehicle {
    private String registration;
    private byte colour;
    private boolean broken;

    public final static byte BLACK=1;
    public final static byte WHITE=2;
    public final static byte BLUE=3;
    public final static byte RED=4;
    public final static byte GREEN=5;
    private final static double ADMIN_FEE = 3;

    public Vehicle() {}

    public Vehicle(String registration) {
        this.registration = registration;
    }
    public Vehicle(String registration, byte colour) {
        this.registration = registration;
        this.colour=colour;
    }
    public void setBroken(boolean broken) {
        this.broken=broken;
    }
    public void setColour(byte colour) {
        this.colour=colour;
    }
    public boolean getBroken() {
        return broken;
    }
    public String getRegistration() {
        return registration;
    }
    public double pay(int hours) {
        // code to return admin fee - only if applicable
    }
}
```

- (a) Outline **one** effect of using the modifier `static` when declaring a variable. [2]
- (b) Describe the relationship between the classes `Vehicle` and `ParkingArea`. [3]
- (c) Outline why it is necessary to use the keyword `this` in the `setBroken` method of the `Vehicle` class. [2]
- (d) (i) Construct code to create an instance of the `Vehicle` class that has a registration of X1234567. [2]  
(ii) Construct code that sets the colour of the object created in part (i) as black. [2]

**(Option D continues on the following page)**



**(Option D continued)**

14. (a) Construct the method `addVehicle(Vehicle v)` that will add a vehicle to the first empty position of the array `vehicles[]` and return the position (ie the index of the array) at which it has added the car. If it is not possible to fit the vehicle into the array then it should return `-1`. [6]
- (b) Outline **two** differences between inheritance and aggregation. [4]

Two further classes, `Car` and `Motorbike`, are created.

```
public class Car extends Vehicle{
    public static double hourlyFee=3.5;
    public double pay(int hours) {
        //code to calculate and return the complete price
    }
}

public class Motorbike extends Vehicle{
    public static double hourlyFee=2.5;
    public double pay(int hours) {
        //code to calculate and return the complete price
    }
}
```

- (c) Construct a UML diagram that shows the relationships between the `ParkingArea`, `Vehicle`, `Motorbike` and `Car` classes. There is no need to include the attributes or methods of each class. [4]

The method `pay` in the `Vehicle` class returns the administration fee (which is only part of the total price), while the method `pay` of the `Car` class calculates the total price for a car staying in the parking area.

- (d) (i) Construct the method `pay` in the `Vehicle` class that returns the admin fee stored in the variable `AdminFee` if the vehicle has stayed for five hours or less; otherwise, it returns 0. [2]
- (ii) Construct the method `pay` in the `Car` class, where it uses the `vehicle` method `pay` but adds the charge for the amount of time spent in the parking area. [2]

The array `vehicles[]` in the `ParkingArea` class is used to store instances of the `Car` or `Motorbike` class.

- (e) Outline why `Vehicle` is a valid type for this array. [2]

**(Option D continues on the following page)**

**(Option D continued)**

15. The management of the company will launch a new scheme to give every 50th car driver and every 60th motorcyclist a free coffee voucher. The code for printing this voucher has already been created and is activated by calling the static method `Vouchers.printCoffeeVoucher()`.

A `getKind()` method has already been added to the `Vehicle` class, which returns a `char` value indicating whether it is a car (c) or a motorbike (m).

(a) Describe, **without writing code**, any changes required to the `addVehicle` method and the `ParkingArea` class to make the new voucher scheme work. [5]

One test performed on the finished code was defined as follows:

Test data	Vouchers printed
29 cars	0
130 motorbikes	2

(b) Identify **three** other tests you might perform on the completed code to prove that it functions correctly. [3]

The `removeVehicle` method of the `ParkingArea` class searches in the array for a `Vehicle` object with a specified registration plate, then removes it by setting that array index to `null`.

The method returns a reference to the `Vehicle` object that has been removed from the array, or `null` if no matching registration plate was found.

(c) Construct the `removeVehicle` method. [6]

**(Option D continues on the following page)**

**(Option D continued)**

- 16. A single parking space that holds one car can be used to hold two motorbikes. The programmer has decided to use a two-dimensional array to create a map of the parking area.

```
Vehicle parkingSpaces[][] = new Vehicle[2][200];
```

	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	<i>etc</i>	[198]	[199]
[0]	c	m	c	m	c	c	m	c	c	m		c	c			c	
[1]		m								m	m						m

**Note:** m and c have been used to show where motorbikes and cars are parked.

- (a) (i) Identify **one** advantage of using a two-dimensional array for this purpose. [1]
- (ii) Identify **one** disadvantage of using a two-dimensional array for this purpose. [1]

Police have requested a way of searching the parking area for vehicles with a specified registration plate, and a binary tree has been suggested.

- (b) Outline why searching for the registration plate in a binary tree would be faster than looking for it in the two-dimensional array. [3]
- (c) Identify the steps that would be involved in taking the data from this two-dimensional array and creating a binary search tree. [5]

**(Option D continues on the following page)**

(Option D continued)

- 17. A new parking service has been introduced: staff will park the car for the driver and then return it later when the driver wants to leave. This service will use a narrow parking area surrounded on three sides by walls, where any cars behind the required car must be reversed out. For example, car X00000011 was the first vehicle to be parked, so to remove it from the parking area, the other five cars, starting with X00000123, will need to be removed. The cars are then returned starting with car X00000010.

Figure 5: Cars parked in the parking area



The class Stack, which contains the Vehicle objects, has the following methods:

Method signature	Returns
isEmpty()	Returns true if the stack is empty, otherwise false.
push(Vehicle v)	Adds a vehicle to the stack.
pop()	Removes and returns a Vehicle object.

The method staffRemoveCar will remove a vehicle with a specified registration plate from the parking area (you can assume the vehicle is in the parking area):

```
public static void staffRemoveCar(Stack stack, String reg){
    Stack temp = new Stack();
    //add code here
}
```

- (a) Construct the staffRemoveCar method. [6]

A stack can be implemented using an array or a singly linked list.

- (b) Compare the use of these two data structures for creating a stack. [4]

End of Option D

#### References:

4. Text adapted from: Rivera-Vázquez, J. C., Ortiz-Fournier, L. V. and Ramaswamy, M. (2011). Designing data warehouses to support criminal investigation. *Issues in Information Systems*, 12(1), pp. 445–54.
6. © International Baccalaureate Organization 2020.

**Figure 3** Courtesy NASA/JPL-Caltech.

**Figure 4** Courtesy NASA/JPL-Caltech.