MATRICULATION AND SECONDARY EDUCATION CERTIFICATE
EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2023 SECOND SESSION

L-Università ta' Malta

SUBJECT: **Computing**
PAPER NUMBER: I
DATE: 30th August 2023
TIME: 9:00 a.m. to 12:05 p.m.

Directions to Candidates

· Answer **ALL** questions.
· Good English and orderly presentation are important.
· All answers are to be written on the booklet provided.
· The use of flowchart templates is permitted but calculators may **not** be used.

1. The following snippet of Java code takes an array of integers and calculates its total, largest number and average. The average is a double to allow decimal point precision.

```java
1   public void doSomething(int[] numbers) {
2     int total = 0;
3     for (int i=0; i <= numbers.length; i++) {
4       total = total + numbers[i];
5       int max = 0;
6       if (numbers[i] > max) {
7         max = numbers[i];
8       }
9     }
10    double average = total / numbers.length;
11    System.out.println("Total: " + total);
12    System.out.println("Max:" + max);
13    System.out.println("Average:" + average);
14  }
```

   a. Identify and explain the **THREE** mistakes in this code. (3)
   b. Which mistake will prevent the program from compiling? Why? (1)
   c. After you fix the mistake in part (b), the program will compile and run but it will throw an exception. Which exception will be thrown? (1)

(Total: 5 marks)

2. Consider a CPU with a 32-bit data bus and an address bus that is 64 bits wide.
   a. Describe and explain the resulting effect on the CPU performance. (3)
   b. Mention **TWO** other factors that can also impact the performance of a CPU. (2)

(Total: 5 marks)

Please turn the page.

3. A software engineer wants to ensure that the formal language used in a project is accurately translated by the language translator.
   a. How can the syntax of this formal language be defined? (1)
   b. Distinguish between the syntax and semantics of a language. (2)
   c. Using concise Java code snippets, demonstrate and explain **ONE** example of a syntax error and **ONE** example of a semantic error. (2)

   (Total: 5 marks)

4.
   a. Explain what is meant by registers in a Central Processing Unit (CPU). (1)
   b. Explain the purpose of cache memory in a CPU and explain how this purpose is achieved. (2)
   c. Distinguish between Level 1 and Level 2 cache. (2)

   (Total: 5 marks)

5. Consider a system consisting of two processes – `ImageTakerProcess` and `AnalyserProcess`. `ImageTakerProcess` takes a picture with a security camera and sends it to `AnalyserProcess`, which carries out highly complex and intense processing to determine if any suspicious activity is occurring.
   a. Using examples from this scenario, distinguish between the "Wait" state and the "Suspend" state in process management. (4)
   b. The system is modified to consist of two instances of each process so that twice the amount of images can be analysed. Each `ImageTakerProcess` must reserve the camera before using it and then release it once a picture is taken. Explain how this can lead to a deadlock. (1)

   (Total: 5 marks)

6. Interrupts are a crucial component of modern operating systems (OS). They allow for efficient handling of external events and device inputs.
   a. Describe **TWO** methods which an OS can use to handle interrupts. (2)
   b. State which of the two methods is more efficient and explain how it improves the efficiency of interrupt handling. (2)
   c. Explain the purpose of the interrupt enable/disable register. (1)

   (Total: 5 marks)

7. A software engineer is working on the memory management system of a new OS. Using knowledge of contiguous memory partitioning and logical versus physical address spaces, answer the following:
   a. How is memory allocated in a contiguous memory partitioning system to ensure efficient memory usage? (2)
   b. As this OS is developed, it is noticed that there is a high level of fragmentation. What could be the reason for this? (1)
   c. It is important for the OS to manage both logical and physical addresses. Give **TWO** reasons why this management is important. (2)

   (Total: 5 marks)

8. A GPS navigation system generates voice prompts to guide a driver to arrive at a particular destination. A voice prompt has two parts to it. In the first part, the driver is told where his next action will take place and takes the form of "In {distance} metres". Distance can be one of 50, 100, 200 or 400. The second part of the prompt is an instruction telling the driver to either turn left, turn right or keep going. An example prompt is "In 100 metres turn left". Using an appropriate formal notation, specify the syntax of the language for the GPS prompts described above. (5)

(Total: 5 marks)

9. SciTech company is using Object-Oriented Programming (OOP) for scientific computing. They develop tools using numeric algorithms and mathematical models to solve complex scientific and engineering problems. However, they are encountering issues with performance and efficiency. They have asked for recommendations on a different programming paradigm that could address these issues.
   a. Name and describe the programming paradigm suitable for the scenario above. (2)
   b. State **THREE** reasons for your recommendation. (3)

(Total: 5 marks)

10. Sandra is trying to implement a data structure which stores positive numbers and allows users to retrieve them on a last-in-first-out (LIFO) basis. She is using an `int` array of size 10 to store numbers and is writing methods to add and take numbers from the data structure.
    a. What is this data structure being created called? (1)
    b. Is it a static or dynamic data structure? Explain. (1)
    c. Assume that as numbers are added to the data structure, the array is populated from index 0 onwards. For example, if the numbers 3,9 and 2 are added in sequence, the resulting array would be [3,9,2,0,0,0,0,0,0,0]. Explain how the operation to add numbers to the data structure is implemented. Include any checks that need to be carried out and explain how this should be done. There is no need to produce any code. (3)

(Total: 5 marks)

11. Digital logic plays a crucial role in the design and implementation of digital systems, enabling the manipulation and processing of binary data with high accuracy and speed.
    a. Draw the logic diagram for a 2-input XOR gate using only AND, OR and NOT gates. (2)
    b. Construct a logic gate circuit using only NAND gates that performs the following Boolean function:

    $$F=(A + B)C + DE$$

    (3)

(Total: 5 marks)

Please turn the page.

12. Simplify the following Boolean expression using the laws of Boolean algebra:

$$F = (A + B)\overline{A}C + A\overline{C} + \overline{B}C$$

Show each step of the simplification and provide the final simplified expression.

(5)

(Total: 5 marks)

13. Assembly languages are low-level programming languages that provide a human-readable representation of machine code instructions. They allow programmers to directly manipulate the hardware and control the behaviour of a computer system through concise and efficient instructions.
    a. Define what an instruction set is. (1)
    b. Describe the format of an instruction, highlighting the roles of opcode and operand. (2)
    c. Explain how the opcode and operand work together to specify the operation to be performed. (1)
    d. Distinguish between an instruction and a pseudo-directive in assembly language programming. (1)

(Total: 5 marks)

14. Consider the following assembly language program.

```
init:       MOV AX, 12    ; Move 12 into register AX
            MOV BX, 5     ; Move 5 into register BX
start:      CMP AX, BX    ; Compare AX with BX
            JG label      ; Jump to label if AX > BX
            JMP exit      ; Jump to exit
label:      ADD AX, BX    ; Add value of AX to BX and store in AX
            MOV CX, AX    ; Move the value of AX into CX
            SUB CX, BX    ; Subtract the value of BX from CX and store in CX
            SUB AX, CX    ; Subtract the value of CX from AX and store in AX
            MOV BX, CX    ; Move the value of CX into BX
exit:       HLT           ; Halt
```

    a. Perform a dry run of the program and determine the final values of AX and BX. Show your working. (3)
    b. Explain the difference between immediate addressing and indirect addressing modes in assembly language. (2)

(Total: 5 marks)

15. A company wants to set up a computer network to connect multiple departments within their office building. The network should provide high-speed connectivity, security, and efficient data transmission.
    a. Define the term LAN and explain its purpose in the context of the company's network setup. (1)
    b. Discuss **THREE** common network topologies that the company can consider for their LAN setup. Provide advantages and disadvantages for each topology. (3)
    c. Explain the concept of a firewall and its role in network security. (1)

    (Total: 5 marks)

16. Data communication refers to the process of transmitting and receiving data between two or more devices or systems. It involves the encoding, transmission, and decoding of data to enable information exchange, facilitating seamless communication and collaboration in various fields such as networking, telecommunications, and Internet-based services.
    a. Differentiate between analogue and digital data communication. Include diagrams to illustrate the key differences between these two types of communication. (3)
    b. Explain the purpose of the Presentation Layer in the OSI seven-layer protocol and provide an example of its functionality in data communication. (2)

    (Total: 5 marks)

17. An online shopping system allows customers to browse and purchase products from an e-commerce website. Customers can search for products, add items to their cart, proceed to checkout, and make payments. The system also allows registered customers to manage their profiles and view their order history.
    a. Explain the purpose of a Use Case Diagram (UCD) in the System Analysis and Design stage of the software development lifecycle. (1)
    b. Draw a UCD for the above online shopping system with an explanation of the components, highlighting their roles and interactions. (4)

    (Total: 5 marks)

18. A team is developing a mobile banking application for a financial institution. The application allows customers to perform various banking transactions, including account balance inquiries, fund transfers, bill payments, and transaction history. The application needs to be thoroughly tested to ensure its functionality, security, and usability before its release.
    a. Given the above mobile banking application, identify and explain the appropriate software testing techniques to be used. (3)
    b. Explain the main characteristics of black-box testing and white-box testing. (2)

    (Total: 5 marks)

Please turn the page.

19. Consider a database schema for an e-commerce system with tables: Customers, Orders, and Products. The Customers table contains columns for customer ID, name, and email. The Orders table contains columns for order ID, customer ID, order date, and total amount. The Products table contains columns for product ID, name, price, and quantity.
    a. Explain database normalisation and its importance in database design. (2)
    b. Describe the relationships between the tables in the given schema using appropriate terminology. (2)
    c. Discuss the benefits of using a relational database management system for storing and managing data in an e-commerce system. (1)

(Total: 5 marks)

20. The university database system manages data related to students, courses, and instructors, representing distinct entities within the system.

    The following relationships exist:

    - A student can enrol in multiple courses.
    - A course can have multiple students enrolled in it.
    - Each course is taught by a single instructor.
    - An instructor can teach multiple courses.
    - An instructor can be the advisor for multiple students.
    - Each student can have only one advisor.

    a. Draw an entity-relationship (E-R) diagram using the Crow's Foot notation representing the entities, relationships, and cardinalities described above. Include appropriate labels and primary keys. (3)
    b. Explain the purpose of cardinality constraints in an E-R diagram and describe the cardinality constraints present in the relationships defined above. (2)

(Total: 5 marks)

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EXAMINATIONS BOARD

L-Università
ta' Malta

ADVANCED MATRICULATION LEVEL
2023 SECOND SESSION

SUBJECT:	**Computing**
PAPER NUMBER:	II
DATE:	31st August 2023
TIME:	9:00 a.m. to 12:05 p.m.

Directions to Candidates

· Answer **any FIVE** questions.
· Good English and orderly presentation are important.
· All answers are to be written on the booklet provided.
· The use of flowchart templates is permitted but calculators may **not** be used.

1. Digital logic is the fundamental building block of digital circuits and computer systems, involving the manipulation and processing of binary data using logic gates and Boolean algebra. It encompasses the design and analysis of logic circuits, enabling the creation of complex digital systems that form the basis of modern technology.

    a. Perform the following arithmetic operations and determine if an overflow or underflow occurs:
        i.   Add the binary numbers 01100101 and 10101010.   (2)
        ii. Subtract the binary number 10011001 from 01010101.   (2)
    b. Explain the purpose of the carry output in the full adder circuit and how it is used for adding larger numbers.   (2)
    c. Convert the decimal value -23 into its 2's complement representation.   (2)
    d. Given the following truth table, identify the logic gate represented by it.   (1)

A	B	Y
0	1	1
1	1	0

    e. Simplify the following Boolean expression using Boolean algebra theorems and logic gates. Show **each** step of simplification and provide the final simplified expression. (3)

$$F = (A + B)(\overline{A} + C) + B\overline{C}$$

    f. Design a logic circuit using AND and OR gates to implement the simplified Boolean expression obtained in the previous question. Draw the circuit diagram and provide the corresponding truth table for the circuit.   (3)

Question continues on next page.

g. Consider the following truth table representing a combinational logic circuit with three inputs (A, B, C) and two outputs (X, Y):

A	B	C	X	Y
0	0	0	1	0
0	0	1	0	1
0	1	0	1	1
0	1	1	0	0
1	0	0	0	1
1	0	1	1	0
1	1	0	0	0
1	1	1	1	1

    i. Create a Karnaugh map for **each** output, X and Y, based on the given truth table. (3)

    ii. Simplify the boolean expressions for outputs X and Y separately using the Karnaugh maps. (2)

(Total: 20 marks)

2. Networking and communication play a crucial role in connecting devices and facilitating the exchange of information, enabling collaboration and information sharing across different locations and systems.

a. Define and explain the concepts of bit rate and data sampling in the context of data communication. How do these factors affect the quality of data communication when modulating data? (3)

b. Discuss the importance of modulation in transmitting data. How does modulation increase data speed transmission? (2)

c. Describe the difference in wave properties of modulation in terms of amplitude, frequency, phase, and pulse. Provide examples to illustrate the differences and their impact on data communication. (4)

d. Differentiate between time division multiplexing (TDM) and frequency division multiplexing (FDM). Discuss the advantages and disadvantages of each technique. (4)

e. Highlight the importance of protocols in ensuring interoperability and seamless connectivity across diverse network environments. (1)

f. Define encryption and its role in ensuring secure data communication. (2)

g. Distinguish between Public Key Encryption and Private Key Encryption. (2)

h. Explain the concept of digital signatures and their role in verifying the authenticity and integrity of digital documents or messages. (2)

(Total: 20 marks)

3. Amy is working for a financial institution that provides online banking services. The current system has become outdated and lacks several essential features. The organisation's requirements for the new system include:

- *Enhanced Security*: The new system should implement robust security measures to protect customer data and prevent unauthorised access.

- *Mobile Compatibility*: The system needs to be accessible and user-friendly on various mobile devices to cater to the increasing number of customers using smartphones and tablets.

- *Improved Performance*: The new system should offer faster transaction processing and response times to provide a seamless user experience.

- *Multi-language Support*: The system should be capable of supporting multiple languages to cater to customers from diverse backgrounds.

- *Integration with Third-Party Systems*: The system needs to integrate with external payment gateways and financial institutions to facilitate seamless fund transfers and transactions.

- *Scalability*: The new system should be scalable to accommodate the growing customer base and handle increased transaction volumes.

Based on the given scenario and requirements:
a. Create a report-like review that follows the stages of the Waterfall methodology for developing the new system. Clearly state any assumption(s) made during the review. (10)
b. Explain how the design process would address the requirements for enhanced security, mobile compatibility, and multi-language support. Additionally, describe the key deliverables that would result from the System Design stage. (5)
c. Discuss the potential risks and challenges associated with using the Waterfall methodology for developing the new system. Identify at least **THREE** risks and provide strategies or recommendations for mitigating or addressing these risks within the Waterfall framework. (5)

(Total: 20 marks)

Please turn the page.

4. Kevin is responsible for designing a database for a university to manage student information. One of the tables in the database is called "Students" and has the following attributes: StudentID, Name, Age, Gender, Major and Average Mark. The table contains several records with information about different students.

TABLE: STUDENTS					
StudentID	**Name**	**Age**	**Gender**	**Major**	**Average Mark**
1	Jeanpaul	19	Male	Computer Engineering	65
2	Christina	20	Female	Computer Science	75
3	Benjamin	20	Male	Finance	77
4	Alex	18	Male	Law	82
5	Kurt	19	Male	Computer Science	92
6	Karin	20	Female	Law	100
7	Leanne	18	Female	Education	92
8	Roxanne	19	Female	Arts	85
9	Neil	19	Male	Computer Engineering	72
10	Gustav	20	Male	Computer Science	88

a. Explain the purpose and importance of a database in the context of the university scenario. (1)
b. Identify the primary key in the "Students" table and explain its significance. Discuss why it is necessary to have a primary key. (2)
c. Define and explain the concept of a foreign key in the context of relational databases. (2)
d. Give the output of the following SQL statements:
   i. SELECT Name,AverageMark FROM Students WHERE Major = 'Computer Science' ORDER BY AverageMark DESC; (2)
   ii. SELECT COUNT(*),Major FROM Students GROUP BY Major. (2)
e. Discuss the concept of normalisation in database design. Explain the goals of normalisation and the advantages it offers in terms of data integrity and efficiency. (3)
f. Analyse the "Students" table and identify any potential normalisation issues. Explain how the table violates the principles of normalisation and suggest the appropriate normalisation form that can address these issues. (4)
g. Based on the normalisation principles, propose a revised design for the "Students" table that adheres to a specific normalisation form. Describe the changes made to the table structure, attributes, and relationships to achieve the desired level of normalisation. (4)

(Total: 20 marks)

5. Jacob is a software consultant in the 1980s. A group of accountants are seeing the rise of automated processes being taken over by the computer. They want to take advantage of this trend and decide to come up with an automated solution to process payroll but do not completely understand how all of this can work.

    a. Explain what an Operating System (OS) is and its role in the computer system. (2)
    b. Which would be the best OS for this scenario? Justify your choice based on the company's needs. (2)
    c. Describe the application of Job Control Languages (JCL) and how they are used to control batch jobs in an OS. (2)
    d. Accountants deal with very sensitive data and are worried about how that data will be protected. Differentiate between confidentiality, integrity and availability when it comes to data protection. (3)
    e. The accountants are still worried that some hacker will gain unauthorised access to their systems over the Internet. What type of software security application should Jacob use to help prevent this? Explain how it works. (2)
    f. Jacob points out that sometimes security and privacy threats originate from inside the organisation. He recalls a case where a bank employee was caught accessing his colleagues' files and spying on the accounts of clients that he did not work with directly. Name and explain **THREE** of the facilities offered by OS to protect files against unauthorised access. (3)
    g. Financial records tend to be very voluminous, leading to the creation and management of very large files. Consider the following diagram which represents files (black and grey cells) and empty space (white cells) on a storage device.
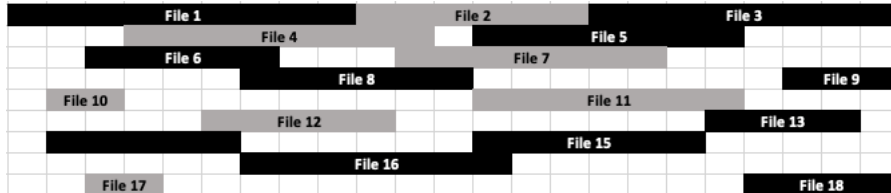
      i. Explain the concept of blocks in the context of file management by the OS. (1)
      ii. What allocation method is being used in the diagram? (1)
      iii. State **ONE** advantage and **ONE** disadvantage of this allocation method. (2)
      iv. Fast data retrieval will be essential in payroll processing. Explain and justify an alternative allocation strategy that Jacob should use. (2)

(Total: 20 marks)

Please turn the page.

6. An aviation enthusiast has decided to launch a website which displays information about aircraft but knows very little about web design. He has been advised to make use of a formal language to define the properties for each aircraft on the website. Aircraft descriptions written in this language can then be automatically translated into an HTML website using a language translator. An aircraft has the following properties:

   - ID: 3 or 4 characters long and consisting of a mix of letters and/or numbers (e.g. F16 or A320)
   - Type: Can be either commercial or military
   - Top speed: A number between 2 and 4 digits
   - Date of manufacture: A date in the format MM/YYYY (e.g. 03/1987). Only valid month numbers are allowed.
   - Image: A filename of the image which consists of 5 characters, must start with a letter, can contain letters and numbers, and must end with the characters ".jpg".

   Properties are separated by a semi-colon and you can assume only upper case letters will be used. The following is a sample entry:

   ```
   A320;COMMERCIAL;582;02/1981;A320.jpg
   ```

   a. Produce a Backus-Naur Form (BNF) specification which adheres to the rules specified above. (15)
   b. Explain what a syntax error is and exemplify this with an aircraft description that contains a syntax error. (2)
   c. Explain what a semantic error is and produce an example aircraft description with a semantic error. (3)

   (Total: 20 marks)

7. A programmer is working on a project that requires implementing a search algorithm to find a specific item in a list of data. The programmer has been asked to consider both sequential and binary search algorithms, and to evaluate the performance of each algorithm under different conditions.

   a. Explain the difference between a sequential search and a binary search. Mention **ONE** advantage and disadvantage of binary search when compared to sequential search. (4)
   b. Using Java, write code to search for an item in a list of data using sequential search. (3)
   c. State the conditions necessary for the use of a binary search algorithm. (2)
   d. Using Java, write code to search for an item in a list of integers which meets the conditions discussed in part (c) using binary search. (4)
   e. Explain how the performance of a binary search algorithm varies according to the number of data items. (2)
   f. Name and briefly explain how the sorting algorithm implemented in the following Java code works.

```
            public static void sort(int[] arr) {
                int n = arr.length;

                for (int i = 1; i < n; i++) {
                    int key = arr[i];
                    int j = i - 1;

                    while (j >= 0 && arr[j] > key) {
                        arr[j + 1] = arr[j];
                        j--;
                    }

                    arr[j + 1] = key;
                }
            }
```

(5)

(Total: 20 marks)

8. A property agent has been working with a paper-based system for several years and now services around 500 clients and 1000 properties. To modernise their applications, a software program that helps them keep track of their properties is being developed. It will be used by estate agents to create and update property listings. It is worth noting that agents can only update properties after they have been created. Customers will also be able to search for properties online. Following an initial discussion, the following Java code was produced.

```
public abstract class Property {
    public int id;
    private String address;
    private double areaInSquareMetres;
    private double priceInEuros;
}

public class CommercialProperty extends Property {
    private String licenseType;
}

public abstract class ResidentialProperty extends Property {
    private int numBedrooms;
    private int numBathrooms;
}

public class TerracedHouse extends ResidentialProperty {
    private public boolean hasGarage;
}

public class Apartment extends ResidentialProperty {
    private int floor;
    private boolean hasElevator;
}
```

Question continues on next page.

a. Produce a Use-Case diagram for the system being developed.   (5)

b. Produce a class diagram of the above code.   (5)

c. The client is worried that when they turn on the new system mistakes will be made that would not have been made in the paper-based system. Name, describe, justify and state how **ONE** changeover technique would be implemented to reduce the client's worries.   (4)

d. Consider a scenario where another class called `PropertyManager` attempts to create a new instance of a `CommercialProperty` and populates all its properties. Why is this currently not possible? Identify which class(es) need to be changed in order to solve this problem and carry out these changes by rewriting these classes. There is no need to show the code of the `PropertyManager` class.   (6)

(Total: 20 marks)