

HWA CHONG INSTITUTION
C2 PRELIMINARY EXAMINATION 2024

COMPUTING
Higher 2
Solutions with Marker's Comments

10 Sept 2024

Paper 1 (9569 / 01)

1400 -- 1700 hrs

1. Validation and verification are used in data entry.
- (a)
 - (i) State the purpose of verification. [1]
 - (ii) State **one** method of verification. [1]
 - (b) The use of check digits is one validation technique.
 - (i) State the purpose of validation. [1]
 - (ii) State **one** method of validation other than check digits. [1]
 - (iii) Name **two** types of error that check digits usually detect. [2]
- ASCII code and Unicode are two of the methods of encoding characters.
- (c) The ASCII code in denary for the character '1' is 49.
 - (i) Using 7 bits, express the ASCII code for the character '4' in binary. [1]
 - (ii) Express the character '4' as a hexadecimal number. [1]
 - (iii) Convert the hexadecimal number 4B1 to a binary number stored as two bytes. [2]
 - (d)
 - (i) State the values that are common to both ASCII and Unicode. [1]
 - (ii) Why is Unicode preferred over ASCII in modern computing? [1]

[Solution]

- (a)
 - (i) Verification checks that data entered is the same as the original source.
 - (ii) One method is double entry, another is proof reading.
- (b)
 - (i) Validation checks that data entered is reasonable or sensible.
 - (ii) Any one method:
 - Range check
 - check that data entered is within a predefined range of values.
 - Format check

- check that data entered is in the correct format. Eg. date is in the format dd/mm/yyyy.
 - Length check - check that data entered has correct length. Eg. length of password.
 - Presence check - check that a field is not left blank. Eg. username field cannot be empty.
 - (iii) Errors that check digits usually detect:
 - Single digit errors. Eg. 1 is wrongly input as 2.
 - Transposition errors. Eg. 12 is wrongly input as 21.
 - (c)
 - (i) 011 0100
 - (ii) 34_{16}
 - (iii) 0000 0100 1011 0001
 - (d)
 - (i) 0 – 127
 - (ii) **Extended Character Set** -- Unicode includes a wide range of characters from various languages, symbols, and scripts, while ASCII is limited to 128 characters, which is insufficient for international text representation.
2. (a) Describe **one** real-life application of multi-factor authentication, [1]
- (b) Describe what happens when you type a URL into your web browser and press Enter. Include the role of DNS and web server in your explanation. [4]
- (c) An IT company's employee Mr. K was fired from his role due to poor performance. However, due to an oversight, his access credentials were not revoked immediately. This allowed him to access the company's systems multiple times between January and March 2023.
- During these unauthorized accesses, Mr. K deployed scripts he had found online to delete 180 virtual servers used for software testing. The total damage caused by this act was estimated to be around \$678,000. For his actions, Mr. K was sentenced to two years and eight months in prison. Identify **two** breaches of the code of ethics committed by Mr. K as a computer professional. [2]

[Solution]

- (a) Combining single factors:
 Something you know: password, security question
 Something you have: third-party app/OTP, staff card
 Something you are: facial recognition, eye, fingerprint

- (b) When you type a URL into your web browser and press Enter, the browser first checks its cache to see if it has a recently stored IP address for the domain. If not, it sends a DNS query to a DNS server (usually provided by your ISP). The DNS server then **checks its own cache**. If the IP address is not found, the server **queries other DNS servers in a hierarchical manner**, starting with the root DNS server, then the top-level domain (TLD) servers, and finally the authoritative DNS servers for the domain.

Once the IP address is found, it is returned to the browser, which then uses it to establish a connection to the web server hosting the website. **The browser sends an HTTP request to the web server, which responds with the requested web page, and the browser displays it to the user.**

- (c) Unauthorized Access: Mr. K accessed the company's systems without authorization after his termination, which is a direct violation of ethical standards that emphasize respecting the boundaries of authorized access.

Misuse of Computing Resources: By deploying scripts found online to delete 180 virtual servers, Mr. K misused computing resources in a destructive manner, causing significant financial damages to the company.

3. (a) Explain the need for communication protocols in a network. [1]
- (b) State the **five** layers of the TCP/IP model and give a reason why layering is necessary. [2]
- (c) Describe how packet switching handles network congestion. State **two** items that are stored in the packet header. [3]
- (d) Describe the roles of switches and routers in a computer network. [2]

[Solution]

- (a) Protocols enable devices to communicate effectively based on **a set of rules that both senders and receivers agree to**, for example, data format, type, size, error detection and correction.
- (b) Application, Transport, Network, Data Link, Physical.
Reason for layering:
- Simplifies the network model
 - Enables programmers to specialize in a particular layer of the model
 - Provides design modularity
 - Allows for standardized interfaces to be produced by networking vendors

- (c) Each data is **divided into packets and travel independently** to the destination, so they can avoid the congested network.
Items stored in the packet header: source/destination address, packet/sequential number, protocol information.
- (d) Switch uses **MAC addresses** to forward data frames between devices **within the same network**. Router uses **IP addresses** to send data packets between devices **in different networks**.
4. (a) Describe how the sender creates a digital signature and how the recipient verifies the authenticity of a digital signature. [5]
- (b) Describe how a firewall protects computer networks and **one** limitation of a firewall. [2]

[Solution]

- (a) The sender uses a hash function to **generate a hash value** from the message. The sender then **encrypts this hash value with their private key** to create the digital signature.

To verify the authenticity of a digital signature, the recipient **uses the sender's public key to decrypt the signature**. This decryption produces a hash value. The recipient also generates a hash value from the received message **using the same hash function** used by the sender. If both hash values **match**, the digital signature is verified, confirming that the message has not been altered and is indeed from the purported sender.

- (b) Firewall monitors and controls all incoming and outgoing network traffic based on a set of security rules to prevent unauthorized access from entering a private network.

Limitations:

- Hackers can bypass firewall by inserting malicious attacks inside legitimate programs, for example, emails
- Firewall cannot protect against internal attacks, for example, virus in one computer in the network
- The setting of firewall may block some legitimate programs

5. (a) State the ideal pivot for the quicksort algorithm and explain why it improves the efficiency of the algorithm. [2]

- (b) The following function implements the bubble sort in Python.

```
def bubble(array):  
    n = len(array)  
    for i in range(n-1):  
        for j in range(n-i-1):  
            if array[j] > array[j+1]:  
                array[j+1], array[j] = array[j], array[j+1]
```

Amend the function to improve its efficiency. Give **one** set of test data that could be used to demonstrate the improvement of efficiency in your amended function.

[4]

- (c) The contents of an array are shown:

47	82	16	54	91	37
----	----	----	----	----	----

Show how the array can be sorted in ascending order using insertion sort and merge sort. [5]

- (d) A given data set is largely sorted. Explain why a programmer might choose to use an insertion sort rather than merge sort in this situation. [2]

[Solution]

- (a) Ideal pivot is the median of the data set, since it will produce more balanced partitions.

- (b)

```
def bubble(array):  
    n = len(array)  
    swapped = True  
    while swapped:  
        swapped = False  
        n -= 1  
        for j in range(n):  
            if array[j] > array[j+1]:  
                array[j+1], array[j] = array[j], array[j+1]  
                swapped = True
```

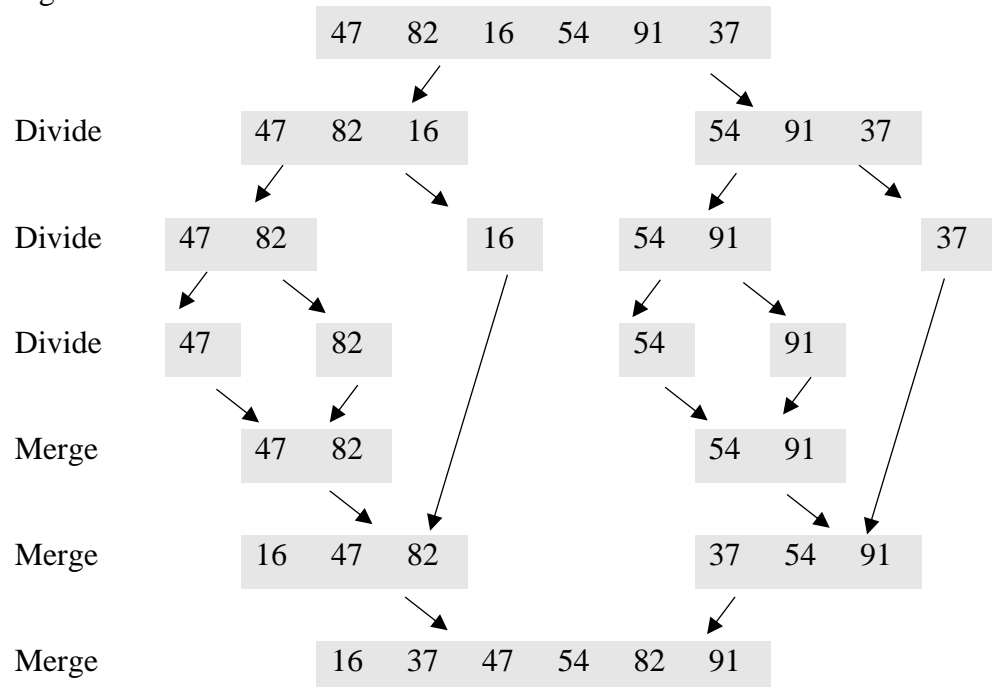
```
def bubble(array):
    n = len(array)
    last_check = n - 1    # initialize flag
    while last_check > 0:
        last_swap = 0
        for j in range(last_check):
            if array[j] > array[j+1]:
                array[j+1], array[j] = array[j], array[j+1]
                last_swap = j    # move flag
        last_check = last_swap
```

Test case for any largely sorted array

(c) Insertion Sort:

47
 47, 82
 16, 47, 82
 16, 47, 54, 82
 16, 47, 54, 82, 91
 16, 37, 47, 54, 82, 91

Merge Sort:



- (d) Since the data set is largely sorted, each pass of insertion sort will require few movements, making the time complexity close to $O(N)$. But merge sort requires at least $O(N \log N)$ regardless of the initial order of the data. Hence insertion sort is better for this situation.

6. A library management system is being developed to manage the catalogue of items available for borrowing. The library has books and DVDs in its collection.

For all library items, the data that will be stored include:

- Item ID
- Title
- Creator
- Launch Date
- Borrowed Status
- Due Date

For books, the additional data stored include:

- ISBN
- Number of Pages
- Genre

For DVDs, the additional data stored include:

- Duration (minutes)
- Age Rating

When an item is borrowed:

- Borrowed status is set to TRUE
- Due date is set to the borrowing date plus the borrowing period (e.g. 21 days).

When an item is returned:

- Borrowed status is set to FALSE
- Due date is cleared
- A fine is calculated based on the number of overdue days multiplied by the standard daily fine rate.

Object-oriented programming will be used to model library items.

- (a) Draw a class diagram that shows the following for the situation described above.

- The superclass
- Any subclasses
- Inheritance
- Properties
- Appropriate methods

[7]

- (b) State the purpose of a superclass. Give an example of a superclass from the library management example. [2]

Encapsulation and polymorphism are fundamental principles of object-oriented programming.

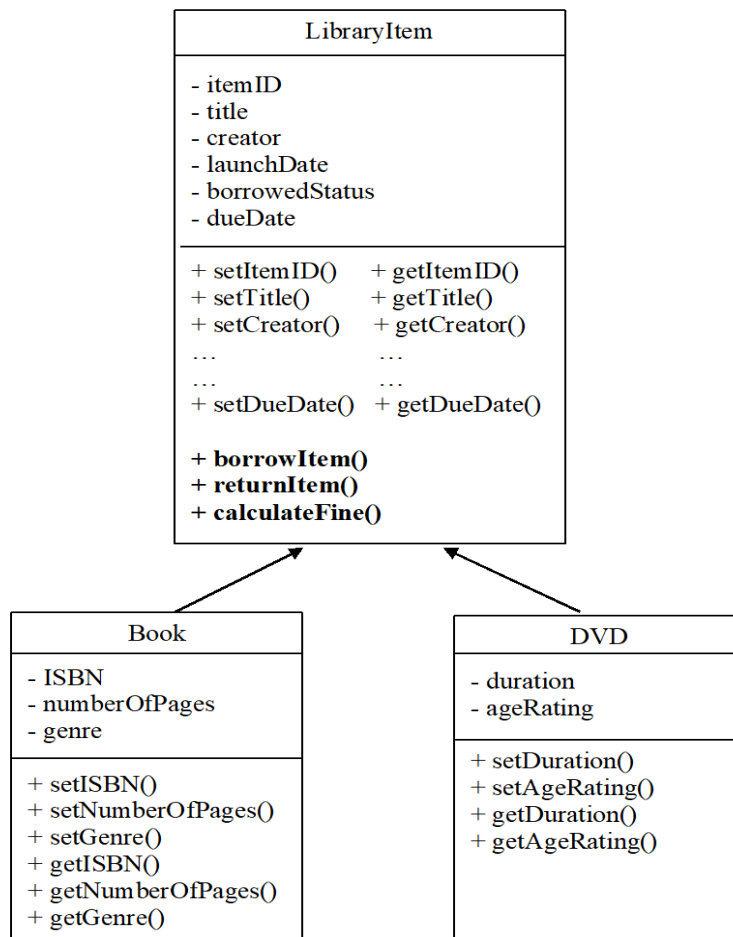
- (c) State the purpose of encapsulation. [1]
- (d) Explain how data hiding is achieved in a class through encapsulation. Support your answer with examples from the library management system. [3]
- (e) Define the term polymorphism. [1]

The library wants to introduce an additional charge for DVDs that varies for each DVD for each day they are overdue, in addition to the standard daily fine.

- (f) Suggest a modification to the class diagram to accommodate the new charging scheme for DVDs. [2]

[Solution]

- (a)



- (b)
 - provides a common structure and behavior that can be shared by subclasses.
 - promotes code reuse and maintainability.
 - Example: 'LibraryItem' is the superclass for 'Book' and 'DVD'.
- (c)
 - restricts direct access to object data and methods
 - ensures data is accessed and modified through public interfaces
 - promotes data integrity and security.
- (d)
 - makes the class properties private
 - provides public getter and setter methods to control access and modification.

Example:

 - In the 'LibraryItem' class, properties like 'borrowedStatus', 'dueDate' can be private. The class can provide public methods to borrow and return items, ensuring that these properties are modified only in appropriate ways.
- (e)
 - Polymorphism refers to an object's ability to take different forms.
 - It enables the same operation to behave differently on different classes.
- (f)

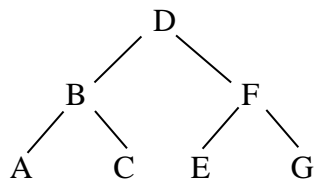
Modify the DVD class to:

 - include 'additonalCharge' property for the extra overdue charge.
 - override the 'calculateFine()' method to include this additional charge.

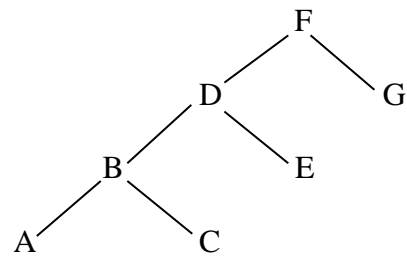
7. A binary search tree (BST) holding the first 10 prime numbers is implemented using object-oriented programming. Each node comprises three attributes: a `left` pointer, the `data` and a `right` pointer. `None` indicates there are no further nodes in a particular direction.

- (a) Draw the BST given its preorder traversal: 11, 7, 3, 2, 5, 19, 13, 17, 29, 23. [3]
- (b) Write a recursive function in **pseudocode** that takes the `root` node of a BST as a parameter and returns the number of nodes in the tree. [3]
- (c) Write a recursive function in **pseudocode** that returns a list of the prime numbers in the BST in in-order sequence. [3]

A binary search tree may be *balanced* (with the left and right subtrees of about the same size) or *unbalanced* (with left and right subtrees of significantly different sizes).



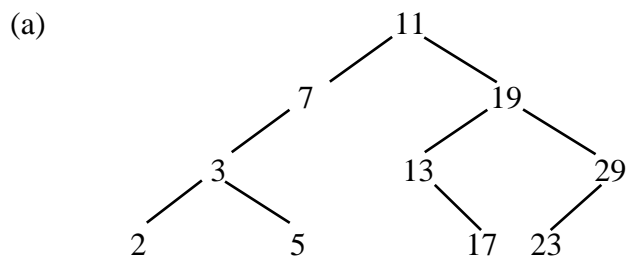
Balanced tree



Unbalanced tree

- (d) What is the main advantage that a balanced BST has over an unbalanced BST? [1]
- (e) Outline how you would transform an unbalanced BST into a balanced BST. [4]

[Solution]



(b) **FUNCTION** CountNodes(root)
 IF root = None
 RETURN 0
 ELSE
 RETURN 1 + CountNodes(root.left) + CountNodes(root.right)
 ENDIF
ENDFUNCTION

(c) **FUNCTION** InOrder(root)
 IF root = None
 RETURN []
 ELSE
 leftList = InOrder(root.left)
 rightList = InOrder(root.right)
 RETURN leftList + [root.data] + rightList
 ENDIF
ENDFUNCTION
OR

```

FUNCTION InOrder(root, primeList)
    IF root <> None
        InOrder(root.left, primeList)
        primeList.append(root.data)
        InOrder(root.right, primeList)
    ENDIF
ENDFUNCTION

```

(d) Balanced BSTs offer efficient performance for operations like search, insertion, and deletion, with a time complexity of $O(\log n)$, while unbalanced BSTs exhibit a time complexity of $O(n)$.

- (e)
- Traverse the unbalanced BST in **inorder** and store each element into an array
 - Select the **middle** element of the array and make it **root** node
 - Arrange all elements preceding the middle element as the **left subtree**, and those succeeding it as the **right subtree**
 - Repeat this process **recursively** for each subtree, selecting the middle element as the root and arranging smaller subtrees to its left and right, until each subtree is either null or consists of a single leaf node.

8. The Singapore Bird Group (SBG) conducts numerous bird censuses annually to count and record the number and species of birds in Singapore over a defined period. Volunteers will report the number and species of birds at the locations they are situated.

The following table shows the data sheet that contains the collected information:

Census Date	Census Duration	Volunteer Name	Volunteer Contact	Bird Name	Location	Bird No
20230301	0800 to 1000	John	98765432	Javan Myna	Botanic Garden	20
20230301	0800 to 1000	John	98765432	Spotted Dove	Botanic Garden	5
20230301	0800 to 1000	Keith	91234567	Javan Myna	Admiralty Park	15
20230301	0800 to 1000	Keith	91234567	House Crow	Admiralty Park	5
20230601	1600 to 1800	John	98765432	Javan Myna	Kranji Marsh	25
20230601	1600 to 1800	John	98765432	House Crow	Kranji Marsh	15
20230601	1600 to 1800	Keith	91234567	Javan Myna	Lower Pierce Res	5
20230601	1600 to 1800	Keith	91234567	Spotted Dove	Lower Pierce Res	4

- (a) Describe, with example, **one** possible issue with the way the collected information is stored. [2]
- (b) Normalisation is a process used when designing database tables. The above table is already in first normal form (1NF). State **two** other requirements of the table being in third normal form (3NF). [2]

SBG decides to develop a system and model it using a relational database. A database designer identified the following entities based on the data sheet given.

- (c) Copy and complete the entity-relationship (E-R) diagram for the database.



[3]

A table description can be expressed as:

TableName(Attribute1, Attribute3, ...)

The primary key is indicated by underlining one or more attributes. Foreign keys are indicated by using a dashed underline.

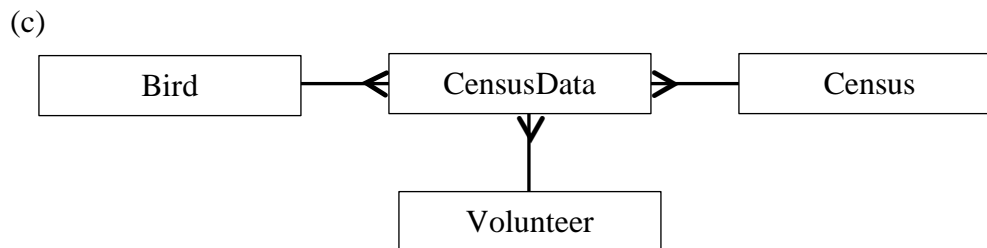
- (d) Using the information given, write table descriptions for each of the tables listed below.
- (i) Census [2]
 - (ii) Bird [1]
 - (iii) Volunteer [1]
 - (iv) CensusData [3]

Based on the table descriptions in **part (d)**,

- (e) write an SQL query to output the bird name, location, bird number and volunteer name for census conducted on '20230301'. [5]
- (f) write an SQL query to output location and the total number of birds for each location for the census conducted on '20230601'. [4]

[Solution]

- (a) Data redundancy - the same data is being stored more than once. Example volunteer name is stored in multiple records.
- (b) Two other requirements for the table to be in 3NF
- **The table must be in 2NF** -- All non-key attributes must be fully functionally dependent on the primary key. If the table has a composite key as the primary key, then each non-key attribute must be fully dependent on the entire composite primary key, and not the subset of the primary key.
 - **The table must have no transitive dependencies** -- Every non-key attribute must be directly dependent on the primary key, and not on any other non-key attributes.



(d)

```
Bird(BirdID, BirdName)
Census(CensusID, CensusDate, CensusDuration)
  Volunteer (VolunteerID, VolunteerName, VolunteerContact)
CensusData(CensusID, BirdID, VolunteerID, Location, BirdNo)
```

(e)

```
SELECT Bird.BirdName, CensusData.Location,
CensusData.BirdNo, Volunteer.VolunteerName
FROM CensusData
INNER JOIN Bird ON CensusData.BirdID = Bird.BirdID
INNER JOIN Census on CensusData.CensusID = Census.CensusID

INNER JOIN Volunteer on CensusData.VolunteerID =
Volunteer.VolunteerID
WHERE Census.CensusDate = '20230301'
```

(f)

```
SELECT CensusData.Location, SUM(CensusData.BirdNo) as
Total_Birds
FROM CensusData
INNER JOIN Census on CensusData.CensusID = Census.CensusID

GROUP BY CensusData.Location
HAVING Census.CensusDate = '20230601'
```