1 Merge sort is a divide and conquer algorithm that arranges elements of an array into predefined order with a methodological approach that uses recursion.

(a) What are the main characteristics of an algorithm with an approach that uses recursion? **[2]**

(b) Describe the algorithm of merge sort. **[3]**

The pseudocode of a recursively defined merge sort that takes in the unsorted array `A` and its start and end index positions `p` and `r` respectively as parameters.

```
mergeSort(ARRAY A, INTEGER p, INTEGER r)
IF (p < r) THEN
    DECLARE mid : INTEGER
    mid ← (p + r)//2      // (p+r) integer division by 2
    //splits A[p..r] into A[p..mid] and A[mid..r]
    mergeSort(A, p, mid)
    mergeSort(A, mid+1, r)
    merge(A, p, mid, r)
  ENDIF
END mergeSort
```

(c) It is given that `ar = [27,11,-2,16,14,5,13]`, and has position index starting from `0`. Draw a diagram to show how the values in `ar` are sorted into **descending** order at every recursive process when `mergeSort(ar, 0, 6)` is called in the main program. **[3]**

(d) (i) With the arguments passed into each recursive call clearly stated, write down in **chronological order** the sequence of recursive calls made to `mergeSort` and `merge` when `[49,29,41,59]` is to be sorted using `mergeSort`. **[2]**

(ii) State the number of times `mergeSort` is called. **[1]**

(e) Explain why the use of stack is necessary in order for merge sort to execute properly? **[2]**

(f) State the worst case time complexity for merge sort. **[1]**

(g) Explain why the time complexities for best, average and worst cases in merge sort are the same. **[2]**

2 Zadala is a business to consumer e-commerce platform that charges no delivery fee for any orders over $500. Orders that are $500 and lower but more than $250 will be charged $20 for delivery if the distance is within 10km, and $30 if the distance is more than 10km. For all cases other than the ones mentioned, a flat fee of $50 will be charged. Zadala promotes its loyalty programme by giving $15 off to its VIP members.

(a) Create a decision table to determine the delivery fee and discount reflected by the e-commerce platform. **[4]**

(b) Simplify your decision table in **(a)** by removing any redundancies. **[2]**

3 The pseudocode of function `Q3` that returns an integer, and takes in an array of integers `ar` and an integer `key` as input parameters is given below:

```
1  FUNCTION Q3(ar : ARRAY, key : INTEGER) RETURNS INTEGER
2    DECLARE index : INTEGER
3    index ← 1
4    REPEAT
5      IF key = ar[index]
6        THEN
7          RETURN index
8      ENDIF
9      index ← index + 1
10   UNTIL index-1 > LEN(ar) OR key < ar[index-1] // LEN() returns ar size
11   RETURN 0
12 ENDFUNCTION
```

(a) Describe the purpose of `Q3`. **[3]**

(b) Perform dry-run on `Q3([3,12,32,54],54)` in the format of the trace table shown below:

key	index	ar[index]	Remarks
...	...	...	...

[2]

An error is detected in the pseudocode above.

(c) (i) Identify the error by stating the line number and the type of error. **[2]**

(ii) **Without** changing the order and the types of constructs used, explain how the error in **(c)(i)** can be rectified. **[1]**

(iii) State the number of times the `REPEAT UNTIL` loop iterates when `Q3([3,12,32,54],56)` is called in the main program with errors corrected. **[1]**

(d) Re-write the pseudocode from lines `4` to `10` using a `WHILE` loop instead. **[3]**

(e) Give **two** suggestions that improve code readability. **[2]**

4 A command-line calculator is capable of reading and evaluating fully-parenthesised infix expression with positive-integer-only operands a, b, c, d, and e.

(a) A binary expression tree T is used to represent an infix form of an algebraic expression that is given to be (a-b)+c*(d+e).

    (i) Explain what a binary expression tree is, and describe how it can be used to represent an algebraic expression. **[3]**

    (ii) Draw binary expression tree T. **[2]**

The diagram below shows the implementation of T using **three** arrays LeftPointer, RightPointer, Item, and **one** integer Root. The table below shows an incomplete representation of T.

Array index	LeftPointer	Item	RightPointer
1		'd'	
2		'e'	
3		'+'	
4		'-'	
5		'*'	
6		'a'	
7		'b'	
8		'c'	
9		'+'	

Root: 3

(b) Complete the table above by stating the values in the arrays LeftPointer and RightPointer. **[2]**

The postfix notation of an algebraic expression does not require the use of parenthesis, and it can be obtained by performing a basic postorder traversal on the binary expression tree that represents it.

(c) (i) Write pseudocode for procedure `postorder(root : INTEGER)` that will display the postfix expression obtained from `T`. **[3]**

    (ii) State the value displayed in **(c)(i)**. **[1]**

(d) With the aid of diagrams, show how a stack can be used to evaluate the result of postfix expression `62-351+*+`. **[3]**

The stack data structure `s`, and its stack pointer `stackPtr` used in **(d)** are defined globally as:

```
DECLARE s : ARRAY[1..5] OF CHAR
DECLARE stackPtr : INTEGER
stackPtr ← 0
```

```
PROCEDURE PUSH(item : CHAR)
     .........
END PROCEDURE
```

```
FUNCTION POP() RETURNS CHAR
     .........
END FUNCTION
```

(e) Write in pseudocode the procedure `PUSH(item : CHAR)` and function `POP()`. **[6]**

5 **(a)** Explain the following terms,

    (i) hashing algorithm, **[1]**

    (ii) hash address. **[1]**

(b) Explain why collisions happen in hash tables and how they can be handled. **[3]**

(c) Give a real-life example of the use of hash table in a computer system. **[1]**

6 A college uses a table to store data collected about its teachers and students. Each teacher may teach more than one subject and each subject may be taught by more than one teacher. The college would like to convert the following table into a database.

PersonID	FullName	IsStudent	SubjectID	SubjectName	Department	L1R5
1290	Mindy Tan	1	9569	H2 Computing		15
			9758	H2 Mathematics		
			9749	H2 Physics		
			8808	H1 Project Work		
1350	Lee Xiao Long	1	9749	H2 Phyics		12
			9729	H2 Chemistry		
			9744	H2 Biology		
1477	Haz Awang	1	9569	H2 Computing		10
			9758	H2 Mathematics		
			9760	H2 Further Math		
… …	… …	… …	… …	… …	… …	
2893	Jean Koh	0	9749	H2 Physics	Science	
			8808	H1 Project Work		
3005	Tan Si Jie	0	9744	H2 Biology	Science	
3008	Peter Wong	0	9744	H2 Biology	Science	
3010	Wang Liyang	0	9758	H2 Mathematics	Mathematics	
			9760	H2 Further Math	Mathematics	
2892	Monish Chandra	0	9569	H2 Computing	ICT	
… …	… …	… …	… …	… …	… …	

(a) Explain why the table above is not in first normal form (1NF). **[1]**

(b) A table description can be expressed as:

`TableName (Attribute1, Attribute2, …)`

The primary key is indicated by underlining one or more attributes and foreign keys are indicated by using an asterisk. Write table descriptions for the required tables in the database so they are in third normal form (3NF). **[8]**

(c) Create an entity-relationship (ER) diagram showing the degree of all relations. **[3]**

(d) Explain reasons for reducing data redundancy in a relational database. **[2]**

The college wants to use object-oriented programming to publish the database content on a web page. `Staff` and `Student` classes inherit from `Person` class. And `Person` and `Subject` classes share a HAS-A relationship.

(e) Draw a class diagram that shows the following for the context described above.
- The superclass.
- Any subclasses.
- Inheritance and encapsulation.
- Attributes.
- Appropriate methods **[8]**

(f) State the purpose of a superclass. **[2]**

7 **(a)** Explain how a music file can be sent from the sender's computer to receiver's computer over the Internet using the TCP/IP model. **[5]**

(b) Explain what packet switching, and how data is transmitted in a connection-oriented packet-switched network. **[5]**

8 A checksum is a value calculated by the sender based on the values of the data packet and appended to the data packet. The algorithm to calculate an k-bit checksum involves the following steps:

1. Convert data values to binary data.
2. Segment binary data into k bits.
3. Add the binary values of all the segments keeping the summed result as 8 bits.
4. Add any carry over bits as a result of the addition in **(3)** to its 8-bit summed result.
5. Perform 1's complement on the summed result in **(4)** to obtain its 8-bit checksum.

Show how the 8-bit checksum of $99E22484_{16}$ can be derived using the algorithm above. **[4]**