1 A 1D array, Value, stores a list of scores as follows:

Index	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Score	1	7	13	22	33	44	50	52	64	69	75	77	80	95	99

A student proposed to use the following algorithm to search through the list of scores.

```
01 Lower ⟵ LowestIndex
02 Upper ⟵ HighestIndex
03 REPEAT
04     Middle ⟵ Lower + Upper
05      IF SearchItem < Value [Middle]
06          THEN
07                Lower ⟵ Middle + 1
08          ELSE
09                Upper ⟵ Middle - 1
10     ENDIF
11 UNTIL Value[Middle] = SearchItem or Lower > Upper
12 OUTPUT ''Score found at position'' Middle
```

(a) There are errors in the algorithm causing an incorrect result. Describe the errors and explain the change required to correct these errors. [3]

(b) State the name(s) of the type of errors made. [1]

2 A programmer is going to write an application, using an object-oriented programming language, which will store details of the workers available for hire from an employment agency. The company hires out cleaners and nannies. The conditions of the hire state that cleaners can only clean rooms and nannies can only help taking care of children. Properties identified include:

- Registration number of the worker

- Maximum number of rooms to clean

- Maximum number of children to take care

- Nationality

- Age

  (a) Draw a class diagram, with base class `WORKER`, showing:

     (i) appropriate sub-class(es)

    (ii) inheritance

   (iii) the properties required

   (iv) appropriate methods. including one pair of 'get' and 'set' methods for one of the properties. [8]

  (b) The company decide that they wish to also hire out janitors who not only cleans, but also, do minor plumbing and electrical repairs. They decide to offer the janitors with 5 or 10 plumbing or electrical work. Explain how this affects the classes, properties and methods given in (a). [5]

  (c) Explain, using this example, why encapsulation is an example of good programming practice. [3]

  (d) Explain the meaning of the term polymorphism. [2]

3 An event organiser organises a computing competition for the general public every year since 2018.

In the competition, a competitor is to compete in 3 categories: Artificial Intelligence and Machine Learning (AI/ML), Cloud Computing (CC) and Data Science (DS). The event for each category lasts for a day.

In order to participate in a competition, competitors are to register on a web portal with the following information: name, gender, age, NRIC and contact number.

An ID number to identify each competitor is to be generated automatically upon successful registration for the competition. Note that the same competitor registering for the competition in different years will have a different ID number. The ID number is unique across all the competitions.

For each of the Artificial Intelligence and Machine Learning, Cloud Computing and Data Science categories, competitors will submit their code online and be awarded a score upon 100. A competitor is disqualified for an event if the competitor fails to submit their solution by the end of the day. A disqualified entry is indicated by a -1 value.

If a competitor is not disqualified for any of the events, the overall score for each competitor is computed by the following formula

$$2 \times (\text{AI/ML Score}) + \text{CC Score} + 3 \times (\text{DS Score}).$$

Else, the overall score is -1.

A `Result` table is used to consolidate the competitor's performance in the competition. The `Result` table should contain the following information:

ID Number, AI/ML score, CC score, DS score, Overall score and Rank. You may include other attributes that is necessary. Ranking starts with 1 for the competitor that has the highest overall score. A disqualified competitor has a rank of -1.

Example of result records to be generated:

ID Number	AI/ML	CC	DS	Overall Score	Rank
1001	23	64	55	275	30
0811	25	-1	75	-1	-1

(a) Design a entity-relationship (ER) diagram to model the entities and relationships for a relational database in 3NF. Your solution must be able to implement the use case described above. [3]

(b) Describe the relations to be implemented with the primary and foreign keys clearly indicated. [3]

(c) Assuming that the database has been populated with data. Write the SQL statement/s to generate a list of ID numbers for all the competitors participating in the competition in the year 2021. [2]

(d) Explain using structured english or pseudo code how the data captured can be used to check if a particular competitor with a ID number of 1234 is disqualified for the DS event. Write the necessary SQL statement/s that is needed. [2]

(e) Explain using structured english or pseudo code how the Rank column in the `Result` table described above can be updated after the overall score is computed. Write the SQL statement/s that is needed to retrieve the required data. [4]

4 Quicksort is an algorithm can be used to arrange data items in a data set into ascending or descending order.

   (a) **(i)** State the ideal pivot for quicksort algorithm to execute most efficiently.   [1]

       (ii) State the difficulty in locating this ideal pivot.   [1]

     (iii) For quicksort algorithm, explain the advantage of random selection of pivot in a data set over selection of first or last data items in the same data set as the pivot.   [2]

     (iv) Write the pseudo code for the quicksort algorithm to sort data items into a descending order.   [4]

  (b) Name another algorithm, besides quicksort, that can be used to arrange data items into ascending or descending order.   [1]

  (c) With the pivot identified in **(a)(i)**, describe the difference between the quicksort and algorithm you named in **(b)** by tracing their use over the following array:

<div align="center">

[7, 3, 12, 9, 3, 1]

</div>

     (i) Provide the quicksort trace by using an appropriate diagram.   [3]

     (ii) Provide the trace of the algorithm you identified in **(b)**.   [3]

     (iii) Describe the difference between the two sorting algorithms. You should use the traces performed in (i) and (ii) to do so. You should also comment on the computational complexity of these algorithms.   [2]

    A given data set is largely sorted.

  (d) Between quicksort and the algorithm you gave in part **(b)**, which one would you choose in this situation? Explain your choice.   [2]

5 The recursive function f takes an integer parameter and returns an integer value.

```
01 FUNCTION f(INTEGER a) RETURNS INTEGER
02     IF a = 0 THEN
03         RETURN 0
04     ELSE
05         RETURN (a MOD 8 + 10 * f(a DIV 8))
06     ENDIF
07 ENDFUNCTION
```

(a) State what is meant by **recursion**. [1]

(b) State the line number(s) that indicate function f is recursive. [1]

(c) Copy and then complete the trace table for the instruction:

OUTPUT f(2534)

Function call	a	Return

[4]

(d) State the purpose of function f. [1]

(e) Draw a flowchart depicting an iterative version of the specified function. [3]

(f) State one advantage and one disadvantage of writing a recursive solution to a problem compared to an iterative one. [2]