*Answer THREE questions, including question 1 or question 2 (or both).*

1. a. The following piece of C++ code is an initial design for a class.

```
class String_store
{
private:
  char ** store;
  int number;
public:
  String_store(int = 1);
  ~String_store();
  void add(char *, int);
  void remove(int);
};
```

Something of type `String_store` should be capable of storing a specified and arbitrary number of strings of arbitrary length. The number of strings stored is specified by passing a parameter to the constructor, which also initializes all stored strings to be empty:

```
String_store::String_store(int new_number)
: number(new_number)
{
  store = new char * [new_number];
  for (int i = 0; i < new_number; i++)
    {
      store[i] = new char [1];
      *(store[i]) = '\0';
    }
}
```

The member function `add` should add a string to the store in a specified position. For example, `add("Hello",2);` should make string number $2$ in the store equal to

"Hello". The member function `remove` should empty a specified position. Implement the destructor and the member functions `add` and `remove` for this class. You may use the functions `strlen` which returns the length of a string, and `strcpy` which copies a string. Your answer should include a full description of the design process and your C++ code should be appropriately commented.

[20 marks]

b. Comment on the differences between pointers and references.

[3 marks]

c. Explain what is meant by the term "constant member function".

[3 marks]

d. Explain the difference between public, protected and private members of a class. When would protected members be used?

[7 marks]

[Total 33 marks]

2. a. Explain what is meant by the term “recursive function”, and why such functions are useful in C++ programming. Discuss the trade-offs involved in deciding whether to use a recursive or a non-recursive function in a particular situation. What conditions must be satisfied when constructing a recursive function to insure correct operation.

[10 marks]

b. Briefly discuss the difference between passing a parameter to a function by value, and passing a parameter to a function by reference.

[3 marks]

c. Design a recursive function called `substring` that takes two strings as parameters and returns 1 if the second is a substring of the first and 0 otherwise. For example,

```
substring("they said hello","id ");
```

should return 1 and,

```
substring("they said hello","small");
```

should return 0. You may assume that the function `strlen`, which returns the length of a string, is available but you may not assume the availability of any other functions. Your answer should include a full description of the design process including pseudo-code, and a properly commented C++ implementation. (Hint: try to match string 2 against the beginning of string 1. If it matches return 1, otherwise get rid of the first letter of string 1 and do a recursive call.)

[15 marks]

d. Explain how you would modify your function `substring` to produce a new function `substring2` such that if the second string is a substring of the first the new function returns the position at which the match occurs. For example,

```
substring2("they said hello","id ");
```

should return 8.

[5 marks]

[Total 33 marks]

3. Discuss the software development process. Your answer should cover the process in its entirety, from specification through to documentation of a final product.

[Total 33 marks]

4. a. Describe each of the following features of C++ and explain how they are used, including examples of C++ code where necessary: pointers, references, copy constructors, scope, virtual functions.

[25 marks]

b. Explain what is meant by the term "memory leakage". How can memory leakage be avoided? What precautions should be taken when using `new` and `delete`?

[8 marks]

[Total 33 marks]

5. a. Why is it the case that there are often many different standard algorithms for solving the same problem? For example, quicksort, mergesort, treesort *etc*.

[3 marks]

b. Provide a detailed explanation, including pseudo-code descriptions, of the operation of the "linear search" and "binary search" algorithms. Your answer should include a comparison of the two algorithms.

[20 marks]

c. Explain how a binary search tree can be constructed to store a collection of words, and how a specific word can be searched for in the resulting tree.

[10 marks]

[Total 33 marks]

END OF PAPER