



NUI MAYNOOTH

Ollscoil na hÉireann Má Nuad

**OLLSCOIL NA hÉIREANN MÁ NUAD**

**THE NATIONAL UNIVERSITY OF IRELAND MAYNOOTH**

**JANUARY 2011 EXAMINATION**

**CS210**

**Algorithms & Data Structures 1**

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Time allowed: 2 hours

Answer *three* questions

**All questions** carry equal marks

- 1** (a) Explain what a data structure is in your own words. Why is it important to design appropriate data structures for a given problem? **[25 marks]**  
[3 marks]
- (b) Explain the concept of an object as used in object-oriented programming. Discuss the advantages of object-oriented design, using relevant examples to support your reasoning. [3 marks]
- (c) Explain in detail how the method below works. Show step by step how the values of `lowerbound` and `upperbound` would be updated if this method was used to search for the number 22 in the following array: [5 marks]
- [13   20   36   45   51   54   67   69   72   84   92]
- ```
public int find(int searchKey){
    int lowerBound = 0;
    int upperBound = nElems-1;
    int check;
    while(true){
        check = (lowerBound + upperBound)/2;
        if(myArray[check]==searchKey){
            return check;
        }else if(lowerBound > upperBound){
            return -1;
        }else{
            if(myArray[check] < searchKey){
                lowerBound = check + 1;
            }else{
                upperBound = check - 1;
            }
        }
    }
}
```
- (d) Design and describe an algorithm that takes an array and reverses all of the elements in the array so that the first element is now the last element. Provide a Java implementation of the algorithm and include comments which explain your code. [6 marks]
- (e) Identify all of the errors in the following method for finding the maximum value in an array. Fix the errors and rewrite the code. [5 marks]

```

public double findMax(){
    int biggest = array[biggest];
    for(j=0; j<=array.size; j--){
        if(array[i] > biggest){
            biggest == array[i];
        }
    }
    return j;
}

```

- (f) Compare and contrast the advantages and disadvantages of using ordered and unordered arrays regarding insertion, deletion and searching. In your answer you should refer to the complexity of these algorithms. [3 marks]

- 2 (a) Explain in detail the concept of a linked list, using examples and diagrams to illustrate your explanation. Discuss the advantages and disadvantages of using linked lists to store data in comparison to arrays. [25 marks]  
[5 marks]
- (b) Design and describe an algorithm that reverses a single-ended singly linked list. Show step by step how this algorithm would manipulate the linked list, using an example to illustrate the process. [5 marks]
- (c) Identify all of the errors in the following method for inserting an element at the head of a double-ended doubly linked list. Fix the errors and rewrite the code. [5 marks]

```

public int insertHead(int data) {

    Link newLink = new Link();
    if( isEmpty() ){
        last = first;
    }
    else{
        first.next = newLink;
    }

    newLink.previous = first
    last = newLink;
}

```

(d) Design and describe an algorithm that takes an integer  $n$  as input from the user and outputs the  $n^{\text{th}}$  prime number. For example, if the user inputs 6, then the algorithm will output 13, which is the 6<sup>th</sup> prime number. Use examples and diagrams to explain how your algorithm works. [5 marks]

(e) Describe and design an algorithm that takes the time (in hours and minutes) as input from the user and outputs the angle between the hour and minute hands of a clock displaying that time. For example, if the user inputs 3h 00m then the algorithm would output 90 degrees, which is a quarter of a revolution. Provide a full Java implementation of your algorithm and include comments which explain your code. [5 marks]

**3** (a) Describe the concept of Big O Notation in your own words, using examples and diagrams as appropriate. Explain why it is important to know the complexity of an algorithm. [25 marks]  
[4 marks]

(b) Your colleague claims that an  $O(n^2)$  algorithm sometimes runs faster than an  $O(\log n)$  implementation of the same algorithm. Can this claim be valid? Justify your reasoning. [2 marks]

(c) Analyse the following segment of code and answer the following questions: [4 marks]

- i. If  $n$  is 2 what is the final value of counter?
- ii. If  $n$  is 5 what is the final value of counter?
- iii. In light of this, derive an expression for the number of times each loop will run in terms of  $n$
- iv. State the Big O complexity of the code and explain your reasoning clearly

```
int counter = 0;
for(int i = n; i < n*n; i++){
    for(int j = 10; j < 10*n; j++){
        counter++;
    }
    for(int j = 20; j >= n; j--){
        counter++;
    }
}
```

(d) What is a recursive algorithm? Describe the Towers of Hanoi problem and show how it can be solved using a recursive algorithm, using examples and diagrams as appropriate. [5 marks]

- (e) Write a Java method that uses recursion to compute the greatest common divisor of two integers. The greatest common divisor of a pair of numbers is the biggest numbers that divides evenly into both of them. For example, GCD(77, 22) would yield the output 11. Include comments in your code which explain clearly how the recursion works. [5 marks]
- (f) Describe the mergesort algorithm in detail using examples and diagrams as appropriate. Discuss the efficiency of the algorithm with reference to the number of copies and comparisons involved. [5 marks]

- 4** (a) Describe the following data structures in detail, using examples and diagrams as appropriate. [25 marks]  
[4 marks]
- i. Stack
  - ii. Queue
- (b) Show how the data contents of a Stack and Queue would change given the following input and output commands. [2 marks]

```
remove ( )
add ( 3 )
add ( 6 )
add ( 1 )
remove ( )
add ( 4 )
peek ( )
remove ( )
```

- (c) What is a deque? Show, with the aid of suitable examples, how a deque can be used to simulate a Stack and a Queue. [3 marks]
- (d) Provide a Java implementation of an algorithm which uses a Stack class to reverse every word of an input `String` and include comments which explain your code. For example, "Testing one two three" becomes "three two one Testing". You do not need to provide code for the Stack class itself. [5 marks]
- (e) Describe the following sorting algorithms: [6 marks]
- i. Bubble Sort
  - ii. Selection Sort
  - iii. Insertion Sort

Show how each algorithm would sort the following numbers,

noting each intermediate arrangement:

62    91    16    89    34    41    23

- (f) Design and describe an algorithm that takes in an array of integers and sorts them according to value, but with the even numbers coming first and the odd numbers following after. For example, the numbers from part (e) would be sorted as 16, 34, 62, 23, 41, 89, 91. Provide a full Java implementation of your algorithm and include comments which explain your code. [5 marks]