OLLSCOIL NA hÉIREANN MÁ NUAD

THE NATIONAL UNIVERSITY OF IRELAND MAYNOOTH

JANUARY 2010 EXAMINATION

CS210

Algorithms & Data Structures 1

Dr. M. McNeill, Dr. A. Winstanley, Dr. P. Maguire

Time allowed: 2 hours

Answer ***three*** questions

All questions carry equal marks

[25 marks]

1 (a) Provide brief definitions for the following concepts and explain why they are significant for the study of computer science: **[2 marks]**

i. Algorithm
ii. Data Structure

(b) Outline the advantages and disadvantages of storing data in an ordered and unordered array, with reference to insertion, deletion and searching. **[3 marks]**

(c) Describe an algorithm for deleting a String from an ordered array using examples and diagrams as appropriate. **[6 marks]**

Provide a Java implementation of the algorithm, including comments which explain your code.

(d) Outline the differences between linear and binary search. **[6 marks]**

Provide a Java implementation of the binary search algorithm, including comments which explain your code.

(e) Describe in your own words an algorithm for finding prime numbers within a given range, using examples and diagrams as appropriate. Your answer should identify the structure of the algorithm, including variables and loops. **[5 marks]**

(f) Write a Java method which swaps two given elements in an array, including comments which explain your code. **[3 marks]**

[25 marks]

2 (a) Explain the concept of Big O Notation in your own words, using examples and diagrams as appropriate. Your answer should clarify why it is important to know the Big O complexity of a program. **[4 marks]**

(b) A function f(n) describes the number of steps performed by an algorithm, where n is the size of the problem and **[4 marks]**

$$f(n) = 3n + 5n\log n + 18\log n$$

State the Big O complexity of the algorithm and prove that this is the case using the formal definition.

(c) Analyze the following segments of code and for both cases answer the following questions: **[6 marks]**

i. If *n* is 0 how many times does each loop run?
ii. If *n* is 5 how many times does each loop run?
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

Case 1:

```
for(int i = n; i < n+20; i++){
   counter++;
}
for(int j = n; j < 20; j++){
   counter++;
}
```

Case 2:

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

(d) Explain in your own words how the following sorting algorithms work: **[9 marks]**

i. Bubble Sort
ii. Selection Sort
iii. Insertion Sort

Show how each algorithm would sort the following words in alphabetical order, noting each intermediate arrangement:

```
Dog   Cat   Mat   Egg   Jam   Urn   Tea   Fan
```

(e) State the Big O complexities of Bubble Sort and Selection Sort. Explain clearly why Selection Sort improves on the running time of Bubble Sort. **[2 marks]**

[25 marks]

3 (a) Explain the following data structures in detail, using examples and diagrams as appropriate. Your answers should include detailed descriptions of how these data structures could be implemented using an array. **[6 marks]**

i. Stack
ii. Queue
iii. Priority Queue

(b) Show how the data contents of a Stack, Queue and Priority Queue would fluctuate given the following input and output commands. Assume that bigger numbers have higher priority. **[6 marks]**

```
 add (6)
 add (3)
remove ()
 add (2)
 peek ()
 add (9)
remove ()
 add (4)
remove ()
```

(c) Describe an algorithm which uses a stack to check if a given word is a palindrome or not. A palindrome is a word which reads the same forwards as backwards (e.g. *racecar*) **[9 marks]**

Provide a full Java implementation of the algorithm, including both the main class and the Stack class. Include comments which explain your code.

(d) Describe how a Priority Queue could be implemented using a linked list. Identify clearly how each of the Priority Queue methods would interface with the linked list, and how the linked list would be updated, using examples and diagrams as appropriate. **[4 marks]**

[25 marks]

4 (a) Explain in detail the concept of a linked list. Compare and contrast the efficiency of linked lists and arrays, with reference to insertion, deletion, searching and memory use. **[5 marks]**

(b) Using appropriate diagrams show the steps involved in inserting a link at the tail of a single-ended doubly-linked list. **[4 marks]**

(c) Describe the concept of recursion in your own words, clarifying when it is useful in programming. Your answer should identify the principal components of a recursive method. **[3 marks]**

(d) The first two numbers in the Fibonacci sequence are 0 and 1. Each subsequent number in the sequence is the sum of the previous two. Write a recursive Java method which calculates a particular term in the Fibonacci sequence. Include comments which explain your code. **[4 marks]**

Show the sequence of steps your algorithm would go through in computing the fourth Fibonacci number. Is your algorithm efficient for computing larger Fibonacci numbers? Explain your reasoning clearly.

(e) Describe the mergesort algorithm in detail, using examples and diagrams as appropriate. **[6 marks]**

Show step by step how mergesort would sort the following set of numbers:

6 3 9 1 4 7 5 2

(f) State the Big O complexity of the mergesort algorithm. Explain why mergesort is more efficient than other simpler sorting algorithms, with reference to the number of copies and comparisons involved. **[3 marks]**