



University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER I EXAMINATION – 2016/2017

COMP 20010

Data Structures & Algorithms I

Prof. S. Dobson

Prof. P. Cunningham

Dr. Aonghus Lawlor

Time allowed: 2 hours

Instructions for candidates

This paper contains two sections: A and B.

You should answer **one** question from Section A **and** one from Section B.

The paper is marked out of 100.

Instructions for Invigilators

Non programmable calculators allowed

Question A1

(40 marks)

1. (a) Explain the use of the `dynamic_cast` keyword in C++. (2 marks)
- (b) What is the output of the following 4 lines:

```
i. cout << 11/3 << endl;

ii. cout << setprecision(6) << static_cast<float>(11/3) << endl;

iii. cout << setprecision(6)
      << static_cast<float>(11)/static_cast<float>(3) << endl;

iv. cout << std::ceil(static_cast<float>(11)/3) << endl;
```

(3 marks)

- (c) Provide the syntax of class declaration in C++ and give an example, showing a public constructor, accessor functions and private variables. (3 marks)
2. (a) Briefly explain the difference between pass-by-value and pass-by-reference in C++. Give an example function illustrating each kind of argument passing. (4 marks)
- (b) What is the output of each of the following lines of code, assuming the following definition:

```
int arr[5] = { 1, 12, 0, 12, 10 };

i. cout << arr[3] << endl;

ii. cout << (*arr + 3) << endl;

iii. cout << *(arr + 3) << endl;

iv. cout << *(arr + sizeof(arr) / sizeof(arr[0]) - 1) << endl;
```

(4 marks)

3. (a) Rewrite this for loop as a while loop:

```
1 for (int k=10; k >= 0; k = k - 4) {
2     cout << k << endl;
3 }
```

(4 marks)

- (b) What is the output of the following code? While the code is valid C++ it contains a logical error. Identify the error and suggest a solution.

```
1 int n = 12;
2 while(n >= 0) {
3     cout << n << endl;
4     n/=2;
5 }
```

(4 marks)

4. (a) Provide the syntax for a template function definition in C++. *(4 marks)*
- (b) Write a template function definition which computes the max of two variables. *(4 marks)*
5. Briefly define the C++ class access modifiers in terms of scope of class members: public, protected, private. You should also say which is the default access level if none is specified explicitly? *(8 marks)*
-

Question A2

(40 marks)

1. Why is the `main()` function important for a C++ program? Explain the various elements of the following basic C++ program:

```
1  #include <iostream>
2
3  using namespace std;
4
5  int main(int argc, char **argv) {
6      cout << "goodbye!" << endl;
7      return 0;
8  }
```

(8 marks)

2. What is the output of the following code:

```
1  #include <iostream>
2  #include <vector>
3  #include <algorithm>
4
5  void my_str_reverse(string str) {
6      std::reverse(str.begin(), str.end());
7  }
8
9  int main() {
10     std::vector<std::string> strs{"Adam", "Paul", "Joe", "Mary"};
11     for(unsigned int i = 0; i < strs.size(); ++i) {
12         my_str_reverse(strs[i]);
13         cout << i << " " << strs[i] << endl;
14     }
15     return 0;
16 }
```

(8 marks)

3. Outline a C++ class which represents complex numbers. A complex number is number $a + bi$ where a is the real part and b is imaginary part. Make any necessary member variables private and define an overloaded multiplication operator:

`Complex& Complex::operator*=(const Complex& other)`

using the fact that:

$$(a + bi) \times (c + d)i = (a \times c - b \times d) + (a \times d + b \times c)i$$

(8 marks)

4. (a) Explain why a function might be declared as `virtual` in a C++ superclass. (2 marks)
- (b) What is the $O(n)$ running time of the following code snippets?

```
i. sum = 0;
   for(int i = 0; i < n; ++i ) {
       for(int j = 0; j < n * n; ++j ) {
           ++sum;
       }
   }
```

1
2
3
4
5
6

(3 marks)

```
ii. sum = 0;
    for(int i = 0; i < n; ++i ) {
        for(int j = 0; j < i; ++j ) {
            ++sum;
        }
    }
```

1
2
3
4
5
6

(3 marks)

5. Briefly define the following terms that are commonly used while designing classes

- (a) abstraction
- (b) encapsulation
- (c) modularity
- (d) inheritance
- (e) polymorphism

(8 marks)

Question B1

(60 marks)

1. (a) Order the following functions by asymptotic growth rate as n tends to infinity:

- i. $n \log n + 4$
- ii. 2^{n+4}
- iii. n^5
- iv. $n^3 + 5n + 5$
- v. 2^8
- vi. $4n + 5 \log n + 4n^2$
- vii. $8n + 10$
- viii. $3n!$

(6 marks)

- (b) Provide a brief definition of recursion. Comment on the difference between linear recursion and binary recursion. *(6 marks)*

2. Define the following Data Structures and give a brief description for each one, including the operations commonly associated with each Abstract Data Type (ADT).

- (a) Queue
- (b) Deque

(12 marks)

3. When comparing algorithms, the typical approach adopted is to evaluate each algorithm's performance in terms of "Big-Oh" and then to compare performances based on a "hierarchy of functions". What do we mean by "hierarchy of functions" and how is it used to compare algorithms? *(12 marks)*

4. One way of carrying out the analysis of an algorithm is to estimate the running time of the algorithm. To do this, we identify a set of primitive operations to which we assign a fixed and equivalent running time. List the seven primitive operations that we used in the course. *(12 marks)*

5. Work out the running time of the following pseudo code algorithms. Which of the following Algorithm1 or Algorithm2 has better running time? Explain your answer. *(12 marks)*

Algorithm 1

```
1 Algorithm1( $A, n$ )
2 Input: an integer array  $A$  of size  $n$ 
3  $X \leftarrow$  an integer array of size  $n$ 
4 for  $j \leftarrow 0, n - 1$  do
5      $a \leftarrow 0$ 
6     for  $k \leftarrow 1, j$  do
7          $a \leftarrow a + A[k]$ 
8     end for
9      $X[j] \leftarrow a/(j + 1)$ 
10 end for
11 return  $X$ 
```

Algorithm 2

```
1 Algorithm2( $A, n$ )
2 Input: an integer array  $A$  of size  $n$ 
3  $X \leftarrow$  an integer array of size  $n$ 
4  $s \leftarrow 0$ 
5 for  $i \leftarrow 0, n - 1$  do
6      $s \leftarrow s + A[i]$ 
7      $X[j] \leftarrow s/(i + 1)$ 
8 end for
9 return  $X$ 
```

Question B2

(60 marks)

1. What kind of recursion does the following Algorithm3 use? Work out the running time and provide the pseudo code of a non-recursive version of the algorithm. (12 marks)

Algorithm 3

```
1 Foo( $k$ )
2 Input: non-negative integer  $n$ 
3 if  $k \leq 1$  then
4   return  $k$ 
5 else
6   return  $\text{Foo}(k - 1) + \text{Foo}(k - 2)$ 
7 end if
```

2. Work out the running time of the following pseudo code Algorithm4. Explain what the algorithm computes. (12 marks)

Algorithm 4

```
1 Foo( $n$ )
2 Input: integer  $n$ 
3 if  $n \leq 1$  then
4   return 0
5 else
6   return  $1 + \text{Foo}(n/2)$ 
7 end if
```

3. Provide a justification to show the following function is $O(n^4)$:

$$(n + 4)^4 + (n + 28)^3 + 6n \log n + 6(n/2) + 2$$

(12 marks)

4. Define the following Data Structures and give a brief description for each one, including the operations commonly associated with each Abstract Data Type (ADT).

(a) Stack

(b) Priority Queue

(12 marks)

5. Write the pseudo code for an algorithm which prints the n th node from the end of singly linked list. The only available List operations are `begin()`, `end()`, `insert(p, e)`, `erase(p)`. (12 marks)

oOo