

## CS2040S: Data Structures and Algorithms

### Discussion Group Problems for Week 3

*For: January 23–January 27*

#### Problem 1. Java Review

At this point, most of you should be comfortable enough to work with Java. Let's take some time to review a few concepts in Java so that we can limit our Java-related issues and, hence, focus on the algorithms when solving future Problem Sets.

- (a) What is the difference between a class and an object? Illustrate with an example.
- (b) Why does the `main` method come with a `static` modifier?
- (c) Give an example class (or classes) that uses the modifier `private` incorrectly (i.e., the program will not compile as it is, but would compile if `private` was changed to `public`).
- (d) The following question is about Interfaces.
  - (d)(i) Why do we use interfaces?
  - (d)(ii) Give an example of using an interface.
  - (d)(iii) Can a method return an interface?
- (e) Refer to `IntegerExamination.java`, which can be found in the same folder as this PDF. Without running the code, predict the output of the `main` method. Can you explain the outputs?
- (f) Can a variable in a parameter list for a method have the same name as a member (or static) variable in the class? If yes, how is the conflict of names resolved?

#### Problem 2. Asymptotic Analysis

This is a good time for a quick review of asymptotic big-O notation. For each of the expressions below, what is the best (i.e. tightest) asymptotic upper bound (in terms of  $n$ )?

- (a)  $f_1(n) = 7.2 + 34n^3 + 3254n$        **$O(n^3)$**
- (b)  $f_2(n) = n^2 \log n + 25n \log^2 n$        **$O(n^2 \log n)$**
- (c)  $f_3(n) = 2^{4 \log n} + 5n^5$        **$O(n^5)$**
- (d)  $f_4(n) = 2^{2n^2 + 4n + 7}$        **$O(2^{2n^2 + 4n})$**

**Problem 3. More Asymptotic Analysis!**

Let  $f$  and  $g$  be functions of  $n$  where  $f(n) = O(n)$  and  $g(n) = O(\log n)$ . Find the best asymptotic bound (if possible) of the following functions.

(a)  $h_1(n) = f(n) + g(n)$       $O(n)$

(b)  $h_2(n) = f(n) \times g(n)$       $O(n \log(n))$

(c)  $h_3(n) = \max(f(n), g(n))$       $O(n)$

(d)  $h_4(n) = f(g(n))$       $O(\log(n))$

(e)  $h_5(n) = f(n)^{g(n)}$       $O(n^{\log n})$  ← constant term matters

**Problem 4. Application of Binary Search**

Given a sorted array of  $n - 1$  unique integers in the range  $[1, n]$ , how would you find the missing element? Discuss possible naive solutions and possibly faster solutions.

**Problem 5. Another Application of Binary Search**

You have  $n$  piles of homework and the  $i^{th}$  pile has  $piles[i]$  pieces of homework. Unfortunately, you realised you have  $h$  hours left before all your homework is due. In a moment of panic, you try to figure out the rate  $k$  (that is, the “pieces of homework”-per-hour) at which you need to do your homework at in order to finish everything on time.

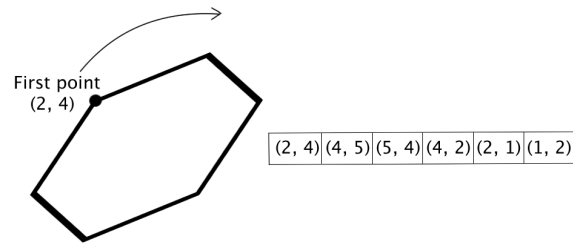
Here’s how you plan to go about it: At every hour, you choose a pile of homework and start clearing pieces of homework from that pile. If the pile has less than  $k$  pieces of homework remaining, you decide to just finish that pile itself, and not start on the next pile yet during the same hour. We all need to take breaks after all, *right?*

To maintain your sanity, you want to minimise the number of pieces of homework you do per hour, i.e.  $k$ , while still finishing all piles of homework in time. You can assume that there exists a  $k$  that allows you to complete all piles of homework within  $h$  hours given the above constraints. Discuss how you can find the minimum integer  $k$  such that you can finish all your homework within  $h$  hours.

**Problem 6. Yet Another Application of Binary Search**

(Optional) Given an array of  $n$   $x$  and  $y$ -coordinates of an  $n$ -sided convex polygon in clockwise order, find a bounding box around the polygon. Discuss possible naive solutions and possibly faster solutions. A convex polygon is a polygon where all interior angles are less than 180 degrees.

An example of such an array is shown below:



(a) What is the difference between a class and an object? Illustrate with an example.

A class defines an object's properties and behaviours as well as implementing them. On the other hand, An object is an instance of said class which you input said values into their properties.

(b) Why does the main method come with a static modifier?

During runtime, the Java Virtual Machine (JVM) does not create any object to call the main method, hence static method allows them to be called using class name without the need to create a default constructor.

(c) Give an example class (or classes) that uses the modifier private incorrectly (i.e., the program will not compile as it is, but would compile if private was changed to public).

`private class xxx {...}` cannot be called outside of other classes file, only works for nested class

d) The following question is about Interfaces.

(d)(i) Why do we use interfaces?

Used to achieve abstraction in which it stores the implementation needed for other classes to use and follow said interface, ensuring consistency. It also helps to uniquely define 2 classes that are depend on a parent class but able to define method and signature separately

(d)(ii) Give an example of using an interface.

```
public interface Shape {  
    public void sumOfSides();  
    public void area();  
}
```

Classes such as Circle, Square are part of Shape but you are able to define the implementation separately.

(d)(iii) Can a method return an interface?

Yes

(e) Refer to IntegerExamination.java, which can be found in the same folder as this PDF. Without running the code, predict the output of the main method. Can you explain the outputs?

8 8 8

(f) Can a variable in a parameter list for a method have the same name as a member (or static)

**Problem 2. Asymptotic Analysis** This is a good time for a quick review of asymptotic big-O notation. For each of the expressions below, what is the best (i.e. tightest) asymptotic upper bound (in terms of  $n$ )?

- (a)  $O(n^3)$
- (b)  $O(n^3)$
- (c)  $O(n^5)$
- (d)

**Problem 3. More Asymptotic Analysis!** Let  $f$  and  $g$  be functions of  $n$  where  $f(n) = O(n)$  and  $g(n) = O(\log n)$ . Find the best asymptotic bound (if possible) of the following functions.

- (a)  $h_1(n) = f(n) + g(n) = O(n)$
- (b)  $h_2(n) = f(n) \times g(n) = O(n \log(n))$
- (c)  $h_3(n) = \max(f(n), g(n)) = O(n)$
- (d)  $h_4(n) = f(g(n)) = O(n \log(n))$
- (e)  $h_5(n) = f(n)g(n) =$

**Problem 4. Application of Binary Search**

Given a sorted array of  $n-1$  unique integers in the range  $[1, n]$ , how would you find the missing element? Discuss possible naive solutions and possibly faster solutions.

```
let start = 0, end = n-1, and arr be arr[1,n]
while start < end do
  let mid = start + (end - start)/2
  if(arr[start] > arr[mid]) then
    end = mid
```

**Problem 5:**

```
minimalHw(piles, n) {
  let start = 0
  let end = sum of piles[0] to piles[n]
  while (start < end) {
    let mid = start + (end - start)/2
    if(canfinish(arr[mid]) < k)
      end = mid;
    else start = mid + 1;
  }
  return start;
}
```