CS1102s Data Structures and Algorithms

10/2/2010

Examination Questions Midterm 1

This examination question booklet has 9 pages, including this cover page, and contains 15 questions.

You have 40 minutes to complete the exam. Use a 2B pencil to fill up the provided MCQ form. Leave Section A blank. Fill up Sections B and C.

Java

Question 1: Consider the following Java program:

```java
public class Test {
    public static int i = 0;
    public static int f(int j) {
            i = j + 1;
            return i * i;
    }
    public static void main(String[] args) {
        int k = f(3);
        System.out.println(i);
    }
}
```

What will be the output of the program?

1 [A] 0

1 [B] 4

1 [C] 16

1 [D] Compilation error: assignment to static variable i is not allowed.

1 [E] None of the above

Answer 1:

1 [B] The static variable i is assigned to 4 in the function call, and thus 4 is printed.

Question 2: The type Integer is a subtype of the type Number. Consider the following Java program fragment:

```java
class A {
  public void f(Integer x) {
    System.out.println(x);
  }
}
Number i = 75;
new A().f(i);
```

2 [A] This program leads to a compilation error because the the function call f(i) does not correspond to a function f in class A that accepts arguments of type Number.

2 [B] This program leads to a runtime error because the function call f(i) does not find a function f that accepts arguments of type Number.

2 [C] This program can be compiled with no error, and when executed, prints the number 75.

2 [D] This program leads to a compilation error because the **int** 75 is assigned to the Number variable i.

2 [E] None of the above

Answer 2:

2 [A] The type Number is not a sub-type of Integer, and thus the type of the function f does not include the type of the actual argument of the function call.

Question 3: Consider the following Java program fragment:

```java
switch (x) {...}
```

This fragment may be compiled without error if it is preceded by the declaration

3 [A] java.util.Iterator x

3 [B] Comparable x

3 [C] **boolean** x

3 [D] **int** x

3 [E] none of the below

Answer 3:

3 [D] switch statements require expressions of type int.

Question 4: Assume a class definition of the following form:

class A { ... }

Consider the following program fragment:

```
Object[] arr = new A[100];
arr[100] = new Object();
```

Which statement on this program fragment is true?

4 [A] This program fragment can be compiled with no error, and when executed, adds a new Object to the array arr.

4 [B] This program fragment leads to a compilation error because the variable arr is declared of type Object[], but assigned a value of type A[].

4 [C] This program fragment leads to a compilation error, because a variable that refers to an array of A values is used in an array assignment involving a value of type Object.

4 [D] This program fragment throws an exception, because a variable that refers to an array of A values is used in an array assignment involving a value of type Object.

4 [E] This program fragment throws an exception, because only indices from 0 to 99 are allowed for an array of size 100.

Answer 4:

4 [D] The co-variance of array types allows the program to be well-typed, but the Java runtime check prevents array assignment, leading to an ArrayStoreException. This is therefore one possible answer.

Answer 4:

4 [E] This is another possible answer; before an array assignment is carried out, the array is checked whether its size is sufficient. This is not the case here, so an IndexOutOfBounds exception could be raised.

The Java Language Specification does not make clear, which one of the two runtime checks is carried out first, so both answers are admissible.

4

Program Analysis

Question 5: Which statement on the growth of constant functions is true?

5 [A] $100 = O(0)$

5 [B] $0 = O(100)$

5 [C] $100 = \Theta(0)$

5 [D] $0 = \Theta(100)$

5 [E] all of the above

Answer 5:

5 [B] Review the definition of $O(...)$ and Θ.

Question 6: Consider the following Java program fragment:

```java
for (int i=0; i * i < N; i++)
    for (int j=0; j * j < N; j++)
        System.out.println("Hello!");
```

Which one of the following statements about the runtime $R(N)$ is true?

6 [A] $R(N) = \Theta(\log N)$

6 [B] $R(N) = \Theta(\sqrt{N})$

6 [C] $R(N) = \Theta(N)$

6 [D] $R(N) = \Theta(N^2)$

6 [E] $R(N) = \Theta(2^N)$

Answer 6:

6 [C] Note that the inner loop will be executed $\sqrt{N}\sqrt{N}$ times.

Question 7: Consider the following Java program fragment:

```java
for (int i=1; i < N*N*N; i++)
    for (int j=0; j < N*N*N; j++)
        x = x + 1;
```

Which one of the following statements about the runtime $R(N)$ is true?

7 [A] $R(N) = O(N)$

7 [B] $R(N) = O(N^3)$

7 [C] $R(N) = O(N^6)$

7 [D] $R(N) = O(N^9)$

7 [E] None of the above

Answer 7:

7 [C]

Question 8: Let F be a function such that $F(N) = \Theta(N^3)$. Which one of the following statements is true?

8 [A] $F(N) = o(N^2)$ holds

8 [B] $F(N) = o(N^2)$ does not hold

Answer 8:

8 [B] Note the definition of $o(...)$.

Question 9: Let F be a function such that $F(N) = \Theta(N^3)$. Which one of the following statements is true?

9 [A] $F(N) = o(N^3)$ holds

9 [B] $F(N) = o(N^3)$ does not hold

Answer 9:

9 B Note the definition of $o(...)$.

Question 10: Let F be a function such that $F(N) = \Theta(N^3)$. Which one of the following statements is true?

10 A $F(N) = o(N^4)$ holds

10 B $F(N) = o(N^4)$ does not hold

Answer 10:

10 A Note the definition of $o(...)$.

Lists, Stacks, Queues

Question 11:   Consider the following Java function:

```java
public static int sum(java.util.LinkedList<Integer> mylist) {
    int theSum = 0;
    for (Integer x : mylist)
        theSum += mylist.remove(0);
    return theSum;
}
```

Which one of the following statements is true?

11 [A] This function is guaranteed to return the sum of all elements of the given mylist.

11 [B] This function cannot be compiled, because the iteration variable x is not used within the body of the for-each loop.

11 [C] This function will lead to a runtime error if applied to a non-empty list mylist, because a function argument (the read-only argument mylist) is modified using remove.

11 [D] The behavior of this function is not well-defined, because the collection mylist is modified during iteration.

11 [E] None of the above

Answer 11:

11 [D] Modification of the data structure that underlies an iterator is not allowed.

Answer 11:

11 [E] The specification of the Java API makes it clear that an ConcurrentModificationException is raised. In that sense, the behavior is well-defined.

The question was vague; we consider both alternatives as correct.

Question 12: Consider the following Java program fragment, whose runtime R is a function of the input size N.

```
java.util.ArrayList<Integer> a = new java.util.ArrayList<Integer>();
for (int i = 0; i < N; i++)
    a.add(0,i);
```

Which of the following is correct:

12 $\boxed{\text{A}}$ $R(N) = \Theta(N)$

12 $\boxed{\text{B}}$ $R(N) = \Theta(N^2)$

12 $\boxed{\text{C}}$ $R(N) = \Theta(N^3)$

12 $\boxed{\text{D}}$ $R(N) = \Theta(N^4)$

12 $\boxed{\text{E}}$ $R(N) = \Theta(N \log N)$

Answer 12:

12 $\boxed{\text{B}}$ The operation a.add(0,i) on ArrayList has linear time complexity, wrt to the current size of the data structure. Therefore, overall we have quadratic time complexity.

Question 13: Consider the following Java program fragment, whose runtime R is a function of the input size N.

```
java.util.ArrayList<Integer> a = new java.util.ArrayList<Integer>();
for (int i = 0; i < N; i++)
    a.add(i,i);
for (int j = 0; j < N; j++)
    a.remove(N-j-1);
```

Which one of the following statements about the runtime $R(N)$ is true?

13 $\boxed{\text{A}}$ $R(N) = \Theta(N)$

13 $\boxed{\text{B}}$ $R(N) = \Theta(N^2)$

13 $\boxed{\text{C}}$ $R(N) = \Theta(N^3)$

13 $\boxed{\text{D}}$ $R(N) = \Theta(N^4)$

13 $\boxed{\text{E}}$ $R(N) = \Theta(N \log N)$

Answer 13:

13 A Both loop bodies have constant time complexity because they operate the end of the
ArrayList.

Question 14: Consider the following Java program fragment, whose runtime R is a
function of the input size N.

```
java.util.LinkedList<Integer> k = new java.util.LinkedList<Integer>();
for (int i = 0; i < N; i++)
    for (int j = 0; j < N; j++)
        k.add(k.size()/2,j);
```

Which one of the following statements about the runtime $R(N)$ is true?

14 A $R(N) = \Theta(N)$

14 B $R(N) = \Theta(N^2)$

14 C $R(N) = \Theta(N^3)$

14 D $R(N) = \Theta(N^4)$

14 E $R(N) = \Theta(N \log N)$

Answer 14:

14 D The LinkedList grows to quadratic size during the execution of the program fragment.
Thus the body of the inner loop has quadratic complexity. The inner loop itself is
executed N^2 times.

Question 15: Consider the possibility of implementing a queue using the class java.util.ArrayList. Which one of the following statements is *false*?

15 [A] If the enqueue operation for item x is done using add(0,x) then the dequeue operation for item y can be done using remove(size()−1).

15 [B] If the enqueue operation for item x is done using add(size()−1,x) then the dequeue operation for item y can be done using remove(0).

15 [C] An implementation of queues using java.util.ArrayList can be done such that both enqueue and dequeue require $O(1)$ time.

15 [D] If an item x is entered into the queue before an item y using enqueue, then repeated applications of dequeue will return x before y.

15 [E] One of the above is false.

Answer 15:

15 [E] Regarding alternative C: We can use the ArrayList as an array, and proceed with the technique described in Section 3.7.2, leading to constant time enqueue and dequeue operations.

Answer 15:

15 [C] In class we mentioned that ArrayList is not preferable for implementing arrays; LinkedList is preferrable because no extra book-keeping is required.

Answer 15:

15 [B] The enqueue operation should be done using add(size(), x) and not using add(size()−1,x).

Because of the possible confusion, we allow all three answers.