CIS 120 Midterm II November 16, 2012

Name (printed): ____________________________
Pennkey (login id): ____________________________

My signature below certifies that I have complied with the University of Pennsylvania's Code of Academic Integrity in completing this examination.

Signature: ____________________________ Date: ____________________

1	/22
2	/20
3	/16
4	/20
5	/22
Total	/100

- Do not begin the exam until you are told to do so.
- You have 50 minutes to complete the exam.
- There are 100 total points.
- There are 9 pages in this exam.
- Make sure your name and Pennkey (a.k.a. username) is on the top of this page.
- Be sure to allow enough time for all the problems—skim the entire exam first to get a sense of what there is to do.

1. **Java vs. OCaml** (22 points)

a. In OCaml, the proper way to check whether two `string` values `s` and `t` are structurally equal is:

- `s == t`
- `s = t`
- `s.equals(t)`
- `s := t`

b. In Java, the proper way to check whether non-**`null`** `String` objects `s` and `t` are structurally equal is:

- `s == t`
- `s = t`
- `s.equals(t)`
- `String.equals(s,t)`

c. Every Java type is a(n) __________________ of class `Object`.

- supertype
- subtype
- instance
- extension

d. In Java, object values are stored in the __________________ of the Abstract Stack Machine.

- stack
- workspace
- heap
- class table

e. If you were to port the OCaml GUI project (HW06) to Java, it would be natural to make `Gctx` (graphics contexts) a class that is a subtype of `Widget`.

- true
- false

f. In simple inheritance, the subclass adds new fields or methods without overriding any of the parent class's members.

- true
- false

g. Invariants (like the ones used in queue programming HW05 or in the resizable array example from lecture) are properties of a datastructure or relationships among values that hold both before and after a method/function runs.

- true
- false

h. Encapsulation of state to preserve invariants can be enforced in OCaml using:

- first-class option types
- local `let` declarations or module interfaces
- recursion and lists
- mutable record fields

i. Encapsulation of state to preserve invariants can be enforced in Java using:

- private fields and interfaces
- static methods and `null`
- loops and arrays
- mutable fields

j. In Java, a static method dispatch `C.m()` implicitly pushes the `this` reference onto the stack.

- true
- false

k. Which OCaml construct is closest to a Java object?

- a record of closures
- a record of mutable option fields
- an anonymous function
- a module with just one type

l. Which Java construct is closest to an OCaml anonymous function?

- an interface with just one method called `apply`
- an object with just one method called `apply`
- a class with just one method called `apply`
- a static method called `apply`

2. **Abstract Stack Machine** (20 points)

Consider the following OCaml program that uses the queue types seen in Lecture and HW05:

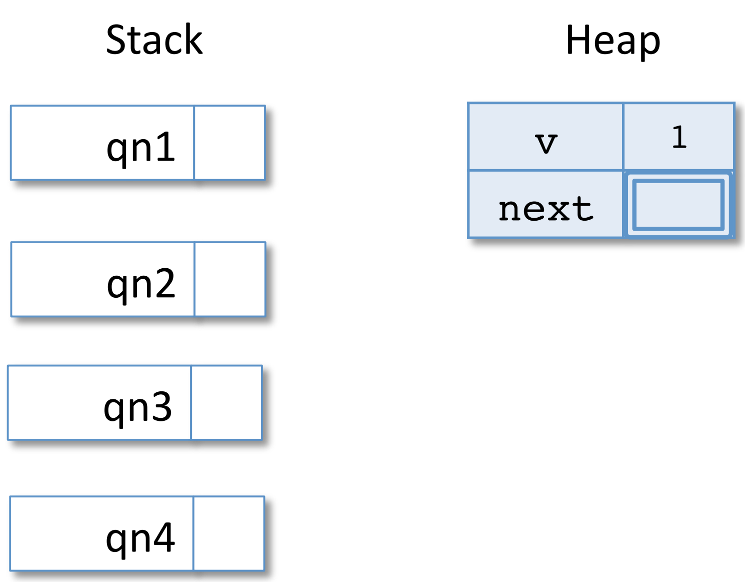
```
(* Mutable queues, as defined in class. *)
type 'a queuenode = { v: 'a;
                      mutable next: 'a queuenode option}

type 'a queue = { mutable head : 'a queuenode option;
                  mutable tail : 'a queuenode option }

let qn1 : int queuenode = {v = 1; next = None;}
let qn2 : int queuenode = {v = 2; next = None;}
let qn3 : int queuenode = qn1
;; qn2.next <- Some qn2
;; qn3.next <- Some qn2
let qn4 : int queuenode = {v = 4; next = qn1.next}
(* HERE *)
```

Complete the diagram below of the state of the stack and heap parts of the ASM when the program reaches the point marked (* HERE *) in the program above. Note:

- you might need to allocate new heap objects,
- you may need to add "`Some` bubbles" in the appropriate places,
- if you are simulating the execution of the program, you might have to *erase* pointers at times (or, if using ink, mark the erased pointers *clearly* with an X)
- should show only the final state!
- the Appendix of the exam contains an example of the stack and heap diagram for a similar OCaml program.



3. Subtyping, Interfaces, and Inheritance (16 points)

Consider the following Java interface and class definitions:

```
interface X {
   int getX();
}

interface Y extends X {
   int getY();
}

class C implements X {
   public int getX() {
      return 1;
   }
   public int getY() {
      return getX() + getX();
   }
}

class D extends C implements X, Y {
   public int getX() {
      return 2;
   }
}

class E extends C {
   public int getY() {
      return 3;
   }
}
```

For each code snippet below, write the integer value that will be printed out, or write "ill typed" if the compiler would flag a type error (*i.e.* Eclipse would underline something in red).

- `X x1 = new C();`
  `System.out.println(x1.getX());` ______________________
- `X x2 = new D();`
  `System.out.println(x2.getY());` ______________________
- `X x3 = new E();`
  `System.out.println(x3.getX());` ______________________
- `Y y1 = new C();`
  `System.out.println(y1.getY());` ______________________
- `C c1 = new D();`
  `System.out.println(c1.getX());` ______________________
- `C c2 = new C();`
  `System.out.println(c2.getY());` ______________________
- `D d1 = new D();`
  `System.out.println(d1.getY());` ______________________
- `D d2 = new E();`
  `System.out.println(d2.getY());` ______________________

4. Java Programming (20 points total)

The following Java class `ATree` implements a tree datastructure in which each node has an integer value `v` and an arbitrary (but finite) number of children stored in an array.

```
class ATree {
   int v;
   ATree[] children;

   public ATree(int v, ATree[] c) {
      this.v = v;
      this.children = c;
   }
}
```

Consider the problem of writing a method called `sum` such that `a.sum()` returns the result of adding up *all* of the values in the tree `a`.

Step 1: The first step of the program design process is to *understand the problem.* There is nothing for you to write here, but we need to pay careful attention to the use of **`null`** in this datatype.

- If `a.children == null` then `a` is a leaf node of the tree.
- If `a` is not **`null`**, then `a.sum()` should *never* throw a `NullPointerException`.

Step 2: The second step is to *define the interface* of the method. For this problem the interface is particularly simple, so we do not ask you do it:

```
public int sum() { ... }
```

Step 3: The next step is to *write test cases*. We have provided the two test cases shown below. Make sure that you understand them!

```
@Test
public void testLeaf() {
   ATree a = new ATree(1, null); // leaf
   assertTrue(a.sum() == 1);
}

@Test
public void testChild1() {
   ATree a1 = new ATree(1, null); // leaf
   ATree a2 = new ATree(2, null); // leaf
   ATree[] children = { a1, a2 };
   ATree a = new ATree(4, children); // non−empty tree
   assertTrue(a.sum() == 7); // (1 + 2) + 4 == 7
}
```

a. (6 points) Now consider the following similar test code:

```
@Test
public void testChild2() {
   ATree a1 = new ATree(1, null);
   ATree a2 = ____________________; // Fill in here!
   ATree[] children = { a1, a2 };
   ATree a = new ATree(2, children);
   assertTrue(a.sum() == 3); // note expected value is 3
}
```

Give *two different* Java expressions (that evaluate to *distinct* values) that can be placed in the blank above to create a well-typed program such that the test succeeds.

Answer 1: ____

Answer 2: ____

b. (14 points) Complete the implementation of the `sum` method. For your convenience, we repeat the other code for `ATree` here:

```
class ATree {
   int v;
   ATree[] children;

   public ATree(int v, ATree[] c) {
      this.v = v;
      this.children = c;
   }

   /* Sums the values of all the v's in the tree */
   public int sum() {









}
```

5. Array Programming (22 points)

Implement in Java a static method called `canBalance`, that, given a non-**`null`** and non-empty array, returns **`true`** if there is a place to split the array so that the sum of the numbers on the left side is equal to the sum of the numbers on the right side (and **`false`** otherwise).

For example (using a shorthand notation for integer arrays):

`canBalance({1, 1, 1, 2, 1})`	⇒	**`true`**	*because* (1+1+1) == (2+1)
`canBalance({2, 1, 1, 2, 1})`	⇒	**`false`**	
`canBalance({10, 10})`	⇒	**`true`**	*because* 10 == 10
`canBalance({5})`	⇒	**`false`**	
`canBalance({10, 0, 1, -1, 10})`	⇒	**`true`**	*because* 10 == (0 + 1 + -1 + 10)
`canBalance({1, 1, 1, 3})`	⇒	**`true`**	*because* (1+1+1) == 3

To get you started, we have given you the skeleton of the algorithm:

```
public static boolean canBalance(int[] nums) {

   if (nums.length < ___________) {
      return false;
   }

   int leftSum = 0;

   int rightSum = 0;

   for (int i = _____________; i < _____________; i++) {

      leftSum = leftSum + ________________; // accumulate left sum

      rightSum = ________________;

      for (int j = _____________; j < ______________; j++) {

         rightSum = rightSum + ________________;; // accumulate right sum
      }

      if (__________________________________________) {

        return _______________;
      }
   }
   return _______________;
}
```

Appendix

This appendix shows an example of the Stack and Heap components of the OCaml Abstract Stack Machine. Your diagram for Problem 1 should use similar "graphical notation" for `Some v` and `None` values.

```
(* The types of mutable queues. *)
type 'a queuenode = { v : 'a;
                      mutable next : 'a queuenode option}

type 'a queue = { mutable head : 'a queuenode option;
                  mutable tail : 'a queuenode option }

let qn1 : int queuenode = {v = 1; next = None;}
let qn2 : int queuenode = {v = 2; next = Some qn1;}
let q : int queue = {head = Some qn2; tail = Some qn1;}
(* HERE *)
```

The OCaml program above yields the ASM Stack and Heap depicted below when the program execution reaches the point marked *(* HERE *)*.