Name: _____

Pennkey: _____

CIS 120 Midterm II

November 18, 2011

1	/20
2	/20
3	/20
4	/20
5	/20
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.

1. Abstract Stack Machine (20 points)

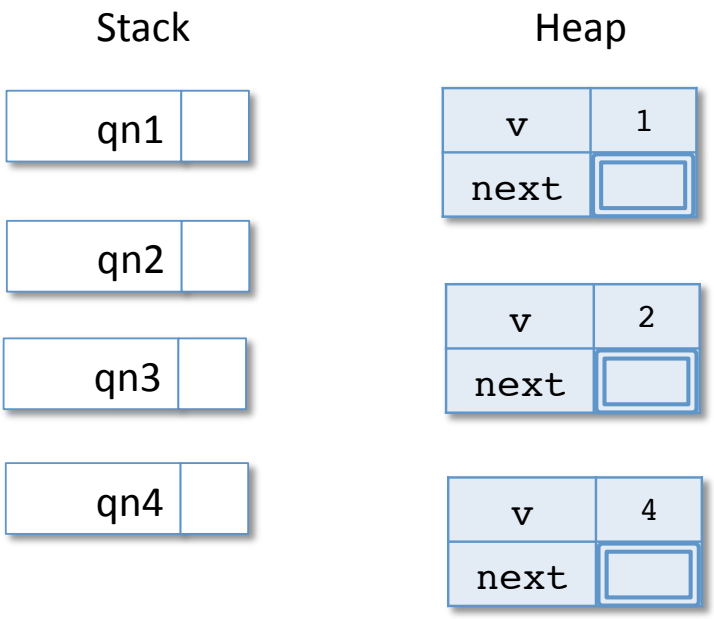
Consider the following OCaml program that uses the queue types seen in Lecture and HW05:

```
(* 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 = Some qn1;}
let qn3 : int queuenode = qn2
let qn4 : int queuenode = {v = 4; next = Some qn3;}
;; qn1.next <- qn3.next
;; qn3.next <- Some qn4
(* 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 that you may need to add "`Some` bubbles" in the appropriate places, and that 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)—you 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.



2. Mutable State, Queues, and Iteration (20 points total)

This problem uses the `'a queue` and `'a queuenode` datatypes from Problem 1. Recall that the *queue invariant* for an `'a queue` value `q` is:

- `q.head` and `q.tail` are either both `None`, or
- `q.head` and `q.tail` both point to `Some` nodes, and
  - `q.tail` is reachable by following `next` pointers from `q.head`
  - `q.tail`'s `next` pointer is `None`

a. (10 points) Complete the definition of the function `insert_after`, given below. Its inputs are `q`, an `'a queue`, `qn` an `'a queuenode` value *that is assumed to be a node in* `q`, and a value `x`. The function should modify `q` *in place* to insert a new node with value component `x` after the node `qn`. Note that this function is *not* recursive. Make sure that it preserves the queue invariant.

```
(* Modify q by inserting a node with value x after the node qn:

   q satisfies the queue invariant
   qn is a node in q
   x is the value to insert

   After the insertion, q must still satisfy the queue invariant.
*)
let insert_after (q:'a queue) (qn:'a queuenode) (x:'a) : unit =
```

b. (10 points) Complete the definition of the function `insert_after_first`, which, given a queue `q` and values `x` and `a`, inserts a node with value `x` after the *first occurrence* of a node with value `a` that is reachable from `q.head`. If `q` does not contain `a`, then `x` is not inserted.

For example: if `(to_list q)` $\Longrightarrow$ `[1;2;3;2;4]`, where `1` is the head and `4` is the tail, running

```
;; insert_after_first q 17 2
```

should yield: `(to_list q)` $\Longrightarrow$ `[1;2;17;3;2;4]`.

Your solution should use the function `insert_after` defined above. Write the `loop` function in *tail recursive* form.

```
let insert_after_first (q: 'a queue) (x:'a) (a:'a) : unit =

  let rec loop (____________________:_____________________________) : unit =

     begin match _____________________ with

       | None -> ____________________

       | Some _________________ ->

            if (_____________________)

            then ___________________________________________________

            else ___________________________________________________

    end
in
  loop _________________
```

3. Object Encodings, Transition to Java (20 points total)

Suppose that we wanted to port the OCaml GUI project to Java. Assume that we have already implemented `Gctx` and `Event` classes, the relevant parts of which are shown below:

```
public class Gctx {
  public Gctx translate(int dx, int dy) { /*...omitted...*/ }
  public void drawString(String s, int x, int y) { /*...omitted...*/ }
  public void textWidth(String s) { /*...omitted...*/ }
  public void textHeight(String s) { /*...omitted...*/ }
  ...
}

public class Event { /*...omitted...*/ }
```

Recall these OCaml type definitions from the `widget` library:

```
type t = {
  repaint: Gctx.t -> unit;
  handle: Gctx.t -> Gctx.event -> unit;
  size: Gctx.t -> int * int
}

type label_controller = {
  set_label: string -> unit
}
```

a. (8 points) A Java **`interface`** called `LabelController` is the translation of the OCaml type `label_controller`. It specifies the signature of the `set_label` method like this:

```
interface LabelController {
  public void setLabel(String s);
}
```

Do the same thing for the `t` type: Define a Java **`interface`** called `Widget` that is the translation of the `t` datatype given above. Because Java does not have tuples, replace the single `size` method with *two* methods, `width` and `height`:

b. (12 points) The OCaml code below (taken verbatim from lecture and the project) creates a `label` widget.

```
let label (s: string) : t * label_controller =
  let r : string ref = ref s in
    {
      repaint = (fun (g: Gctx.t) -> Gctx.draw_string g (0,0) !r);
      handle = (fun _ _ -> ());
      size = (fun (g: Gctx.t) -> Gctx.text_size g !r)
    },
    { set_label = fun (s: string) -> r := s }
```

Translate the above OCaml code into Java by completing the single **`class`** called `Label` that provides the functionality required by *both* the `Widget` and `LabelController` interfaces. Be sure to implement a constructor and all the required methods, which themselves might need to invoke `Gctx` methods. Properly encapsulate the `Label`'s local state.

```
public class Label _____ {
  // put the local state field or fields here




  // constructor
  public Label(_____) {



  }
  // add the methods below









}
```

4. Java Subtyping: Inheritance, Interfaces and Dynamic Classes (20 points)

Hint: Draw the subtype hierarchy. Consider these Java class and interface definitions:

```
interface I { public A method1(); }

interface J extends I { public B method2(); }

interface K { public B method3(B b); }

class A implements I, K {
   public A method1() { return new A(); }
   public B method3(B b) { return b; }
}

class B implements J {
   public A method1() { return new A(); }
   public B method2() { return new C(); }
   public B method3(B b) { return b; }
}

class C extends B implements K {
   public B method4(B b) { return new B(); }
}
```

For each code fragment below, fill in the blank with the name of the *dynamic class* of the value stored in the variable indicated on the line, or write "ill typed" if the code fragment contains a compile-time type error (i.e. Eclipse would put a red line under some part of the program).

```
(a)  K k1 = new C();                                          k1:_____________________

(b)  I i1 = new C();                                          i1:_____________________

(c)  I i2 = new A();                                          i2:_____________________

(d)  K k3;
     if (true) {k3 = new A();} else {k3 = new B();}           k3:_____________________

(e)  K k4;
     if (true) {k4 = new A();} else {k4 = new C();}           k4:_____________________


(f)  J j1 = (new A()).method3(new C());                       j1:_____________________

(g)  B b1 = new C();
     B b2 = b1.method4(new B());                              b2:_____________________

(h)  J j2 = new B();
     J j3 = j2.method2();                                     j3:_____________________

(i)  C c1 = new C();
     Object o1 = c1.method4(new C());                         o1:_____________________

(j)  C c2 = new Object();                                     c2:_____________________
```

5. Array Programming (20 points)

Implement the Java method `growByTwo` that takes in a 2D array of **`int`**s and returns a new array in which each single **`int`** value is replaced with a 2×2 square of copies of that value.

For example, if the input array is:

```
int[][] arr = {{ 0, 1, 2 },
               { 3, 4, 5 }};
```

The output of `growByTwo(arr)` should be:

```
{{ 0, 0, 1, 1, 2, 2 },
 { 0, 0, 1, 1, 2, 2 },
 { 3, 3, 4, 4, 5, 5 },
 { 3, 3, 4, 4, 5, 5 }}
```

You may assume that the input array is rectangular (i.e. every row is the same length) and that both dimensions are of size > 0.

```
public static int[][] growByTwo(int[][] arr) {

   int height = ____________________________;

   int width = ____________________________;

   int[][] newArr = new int[height][width];


   for(int i=_____________; _____________________; _____________________){


      for(int j=_____________; _____________________; _____________________){









      }
   }
   return newArr;
}
```

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 _` and `None`.

```
(* 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 *)*.