Name: ______________________
Pennkey: ____________________

CIS 120 Midterm II
March 30, 2012

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<td>/15</td>
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<td>/100</td>
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- 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 13 pages in this exam.
- Make sure your name and Pennkey (a.k.a. username) is on the top of this page.
1. **OO terminology** (20 points)

*Fill in the blank with the correct term from the list at the bottom of the page. Each term will be used at most once and not all terms will be used.*

a. A _______________ method may not refer to the this reference.

b. Object-oriented programs use _______________ to preserve the invariants of data structures.

c. The static type of a variable is always a _______________ of the dynamic class of the object value that it refers to.

d. In a method call `o.m()`, the ASM uses the _______________ of the object `o` to determine which version of `m` to copy from the class table to the workspace.

e. Any Java type is a _______________ of type `Object`.

f. The **new** expression creates an object value through class _______________.

g. When an object value is created, the class runs code defined in a _______________. This code often initializes the fields of the object.

h. Object values are stored in the _______________ by the Abstract Stack Machine.

i. A class may _______________ multiple interfaces if it includes definitions for all of the methods declared in each of the interfaces.

j. The interface `Queue<E>` uses _______________. The variable `E` is a type parameter, and may appear elsewhere in the definition of the interface.

**Terms:**
class
class table
constructor
dynamic class
encapsulation
extension
extend
generics
heap
implement
inherit
instantiation
object
stack
class table
supertype
static
class table
static type
workspace
subtype
2. Queues in OCaml (20 points)

Recall the OCaml queue type from lecture and HW05.

```ocaml
type 'a qnode = { v: 'a;
  mutable next: 'a qnode option}

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

The next few questions concern the four stack/heap configurations shown below and labeled (A), (B), (C) and (D). There are no responses required on this page, so if you would like to carefully remove this page from the exam booklet you may.

(A) Stack

(B) Stack

(C) Stack

(D) Stack
a. For each of the code segments below, which configuration displays the final state of the stack and heap after it has been executed on the workspace? Circle the correct letter.

i.  
\[
\text{let } qn1 = \{ v = 1; \text{next} = \text{None} \} \\
\text{let } qn2 = \{ v = 2; \text{next} = \text{Some qn1} \} \\
\text{let } qn3 = \{ v = 3; \text{next} = \text{Some qn2} \} \\
\text{let } q = \{ \text{head} = \text{Some qn3}; \text{tail} = \text{Some qn1} \} \\
\]  
(A) (B) (C) (D)  

ii.  
\[
\text{let } qn1 = \{ v = 1; \text{next} = \text{None} \} \\
\text{let } qn3 = \{ v = 2; \text{next} = \text{Some qn1} \} \\
\text{let } qn2 = \{ v = 3; \text{next} = \text{Some qn2} \} \\
\text{let } q = \{ \text{head} = \text{Some qn1}; \text{tail} = \text{Some qn3} \} \\
\]  
(A) (B) (C) (D)  

iii.  
\[
\text{let } qn1 = \{ v = 1; \text{next} = \text{None} \} \\
\text{let } qn2 = \{ v = 2; \text{next} = \text{Some qn1} \} \\
\text{let } qn3 = \{ v = 3; \text{next} = \text{Some qn2} \} \\
\text{let } q = \{ \text{head} = \text{Some qn1}; \text{tail} = \text{Some qn1} \} \\
\]  
(A) (B) (C) (D)  

b. 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

Which of the queues q depicted in configurations (A), (B), (C) and (D) satisfy the queue invariant? Circle either SATISFIES or DOES NOT SATISFY below. For the ones that do not satisfy the invariant, describe the part of the invariant that they violate.

i. (A) SATISFIES, or DOES NOT SATISFY, because ...

ii. (B) SATISFIES, or DOES NOT SATISFY, because ...

iii. (C) SATISFIES, or DOES NOT SATISFY, because ...

iv. (D) SATISFIES, or DOES NOT SATISFY, because ...
c. Consider the definition of the `contains` function, which determines whether a particular value is contained within a queue.

```ocaml
let contains (elt:'a) (q:'a queue) : bool =
  let rec loop (q: 'a qnode option) (vv: 'a) : bool =
    begin match q with
    | None -> false
    | Some a -> a.v = vv || loop a.next vv
    end
  in
  begin match q.head with
  | None -> false
  | Some n -> loop (Some n) elt
  end
```

Suppose the expression `contains 1 q` was placed on the workspace with the stack and heap as depicted in each of (A), (B), (C) and (D). Circle whether the expression evaluates to `true`, `false`, or goes into an infinite loop.

i. With configuration (A), `contains 1 q` evaluates to

```
true false infinite loop
```

ii. With configuration (B), `contains 1 q` evaluates to

```
true false infinite loop
```

iii. With configuration (C), `contains 1 q` evaluates to

```
true false infinite loop
```

iv. With configuration (D), `contains 1 q` evaluates to

```
true false infinite loop
```
3. Subtyping, Interfaces, and Static types (16 points)

The following question involves the interface Area and classes Circle and Rectangle presented in lecture. For reference, these definitions are included in the Appendix—the last two pages of the exam.

Consider the static methods defined in the class below:

```java
class C {
    public static Area asArea (Area s) {
        return s;
    }

    public static void main(String[] args) {
        Rectangle r = new Rectangle (1,2,1,1);
        Circle c = new Circle (1,1,3);
        Area s1 = r;
        Area s2 = c;

        ____ x = C.asArea (r);
        ____ y = C.asArea (s1);
    }
}
```

a. For each variable, fill in its static type and the dynamic class of the object that it refers to in the main method. Note that the type declarations for x and y have been intentionally omitted above.

<table>
<thead>
<tr>
<th>variable</th>
<th>static type</th>
<th>dynamic class</th>
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<tbody>
<tr>
<td>s1</td>
<td></td>
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<tr>
<td>s2</td>
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<tr>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>y</td>
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</tbody>
</table>
b. Which of these assignments would type check if added to the end of the main method? Circle GOOD if the line would not cause a compile-time error, and TYPE ERROR otherwise.

\[ \begin{align*}
  r &= c; \quad \text{GOOD} \quad \text{TYPE ERROR} \\
  r &= s1; \quad \text{GOOD} \quad \text{TYPE ERROR} \\
  s1 &= c; \quad \text{GOOD} \quad \text{TYPE ERROR} \\
  s1 &= s2; \quad \text{GOOD} \quad \text{TYPE ERROR}
\end{align*} \]

c. Which of these variable declarations would type check if added to the end of the main method? Circle one.

\[ \begin{align*}
  \text{Area } a &= \text{new Area();} \quad \text{GOOD} \quad \text{TYPE ERROR} \\
  \text{double } d &= \text{s1.getRadius();} \quad \text{GOOD} \quad \text{TYPE ERROR} \\
  \text{double } d &= \text{C.asArea(c).getRadius();} \quad \text{GOOD} \quad \text{TYPE ERROR} \\
  \text{double } d &= \text{C.asArea(c).getArea();} \quad \text{GOOD} \quad \text{TYPE ERROR}
\end{align*} \]
4. Array programming (16 points)

Implement a static method, called `removeZeros`, that takes as input an array of `int`s and returns a new array that contains all of the nonzero values from the input array.

For example, if the input array is:

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

the output of `removeZeros(arr)` should be

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

If the input to this method is `null`, then the result should also be `null`. 
5. Program Design (28 points total)

Recall the definition of queues in Java. For reference, the interface Queue and the implementation of the classes QNode and QueueImpl appear in the Appendix.

Suppose you would like to add a public method, called cutoff, to the queue interface that cuts the queue off after a given value. In other words, given a value x, this method x the last element that appears in the queue by removing all elements that come after it. The method should return true if it modifies the queue and false otherwise.

a. (0 points) The first step of the program design process is to understand the problem. There is nothing to write here, but there are a few details to pay attention to.

- If there are multiple occurrences of the value, cutoff should truncate the queue after the first occurrence of the element.
- If the value does not appear in the queue, the queue should not be changed.
- You may assume that the queue does not contain nulls, and that the argument to this method is not null.
- Queues are generic and can store any type of objects. Therefore you should use .equals to compare values stored in the queue.

b. (3 points) The second step is to define the interface of the method. Write the method declaration that you should add to the Queue<E> interface.

c. (10 points) The next step is to write test cases. For example, one possible test case creates a new queue containing three elements and then cuts off the queue after the middle element.

```java
@Test
public void testCutOff() {
    QueueImpl<Integer> q = new QueueImpl<Integer>();
    q.enq(1);
    q.enq(2);
    q.enq(3);
    assertTrue(q.cutoff(2)); // the method DOES modify the queue
    assertTrue(q.deq() == 1);
    assertTrue(q.deq() == 2);
    assertTrue(q.is_empty()); // there is no value 3 in the queue
}
```

On the next page, write two more test cases for this method, accompanied by a short explanation of why they are interesting. As above, your test cases should test both the result of the cutoff method and the complete structure of the queue after the method call. You will LOSE points on this problem if you don’t include the explanation.
Test cases for the \texttt{cutoff} method.
d. (15 points) The final step is to implement the method as a new member of the QueueImpl\<E> class.
Reference Appendix

```java
interface Area {
    public double getArea ();
}

class Rectangle implements Area {
    private double x, y; // upper left coordinates
    private double w, h; // width and height
    public Rectangle (double x0, double y0, double w0, double h0) {
        x = x0; y = y0;
        w = w0; h = h0;
    }
    public double getArea () {
        return w * h;
    }
    public double getWidth () {
        return w;
    }
    public double getHeight () {
        return h;
    }
}

class Circle implements Area {
    private double r;
    private double x,y;
    public Circle (double x0, double y0, double r0) {
        r = r0; x = x0; y = y0;
    }
    public double getArea () {
        return 3.14159 * r * r;
    }
    public double getRadius () { return r; }
}

public interface Queue<E> {
    /** Determine if the queue is empty */
    public boolean is_empty ();

    /** Add a value to the end of the queue */
    public void enq (E elt);

    /** Remove the front value and return it (if any) */
    public E deq ();
}
```
public class QNode<E> {

    public final E v; // the value in the qnode is immutable
    public QNode<E> next; // the next pointer can be arbitrarily changed

    public QNode (E v0, QNode<E> next0) {
        v = v0;
        next = next0;
    }
}

public class QueueImpl<E> implements Queue<E> {

    private QNode<E> head;
    private QNode<E> tail;

    /** Constructor */
    public QueueImpl () {
        this.head = null;
        this.tail = null;
        return;
    }

    /** Determine if the queue is empty. */
    public boolean is_empty() {
        return (this.head == null);
    }

    /** Add a new value to the end of the queue */
    public void enq(E x) {
        QNode<E> newnode = new QNode<E>(x, null);
        if (tail == null) {
            head = newnode;
            tail = newnode;
        } else {
            tail.next = newnode;
            tail = newnode;
        }
    }

    /** Remove the front value and return it (if any).
     * @throws a NullPointerException if the queue is empty. */
    public E deq() {
        E x = head.v;
        QNode<E> next = head.next;
        head = next;
        if (next == null) {
            tail = null;
        }
        return x;
    }
}