CIS 110 — Introduction to Computer Programming
20 December 2013 — Final Exam

Answer Key

0.) THE EASY ONE: (1 point total) Check coversheet for name, recitation #, PennKey, and signature.

1.) MISCELLANEOUS (8 points total)

1.1) (2 points) What is the common pattern of class definitions that we used in class?

(a) Methods and field variables are both public

(b) **Methods are public, and field variables are private**

(c) Methods are private, and field variables are public

(d) Methods and field variables are both private

1.2) (2 points) Suppose that `p` and `q` are both nodes in a linked list of strings. What happens when the expression `p.data == q.data` is evaluated?

(a) **The expression is true if `p.data` and `q.data` refer to the same object instance**

(b) The expression is true if `p.data` and `q.data` refer to objects with the same field values

(c) The expression is false

(d) Compiler error

(e) Run-time error

1.3) (2 points) Suppose that `p` and `q` are both nodes in a linked list of strings. What happens when the expression `p.data.equals(q.data)` is evaluated?

(a) The expression is true if `p.data` and `q.data` refer to the same object instance

(b) **The expression is true if `p.data` and `q.data` refer to objects with the same field values**

(c) The expression is false

(d) Compiler error

(e) Run-time error

1.4) (2 points) Which ordering is correct from fastest to slowest computational complexity?

(a) SinglyLinkedList.insert(0, x) $\leq$ SinglyLinkedList.insert(x) $\leq$ BinarySearchTree.insert(x)

(b) **BinarySearchTree.contains(x) $\leq$ SinglyLinkedList.contains(x) $\leq$ contains(array, x)**

(c) selection sort $\leq$ merge sort $\leq$ insertion sort

(d) remove(array, x) $\leq$ SinglyLinkedList.remove(x) $\leq$ BinarySearchTree.remove(x)

(e) None of the above are correct

2.) OBJECT ORIENTED PROGRAMMING (12 points total)

```
public interface Animal {
    public String getName();
    public String speak();
}

public interface Talker {
    public String speak(String s);
}
```

```
public class Dog implements Animal {
    private String name = null;
    public Dog(String name) { ... }
    ...
}

public class CartoonCharacter
             implements Animal, Talker {
    public CartoonCharacter(String name) { ... }
    ...
}
```

2.1) (4 points) Are the following code fragments valid? (Yes or No)

(a) `CartoonCharacter c = new CartoonCharacter("Mickey Mouse"); Animal a = c; a.speak();`
Yes

(b) `Dog d = new Dog("Pluto"); CartoonCharacter c = (Animal) d; c.speak("Hello");`
No

2.2) (3 points) List the signatures of **all** methods that can be called on an instance of the `CartoonCharacter` class (excluding constructors).
getName(), speak(), speak(String s)

2.3) (2 points) Provide the body for the Dog constructor, based on the class definition above.

```
public Dog(String name) {
  // your code here
  this.name = name;
}
```

2.4) (3 points) Briefly (**thirty words or less**) describe the purpose of an interface in Java (e.g., `Animal`).
Answer must mention something about formalizing an API, or requiring that classes implement methods in the interface.

3.) DEBUGGING (11 points total)

3.1) (6 points) Each of the following Java statements could cause one or more of the run-time errors listed below under certain circumstances. For each statement, write the letter(s) corresponding to the error(s) it could trigger. If a statement could trigger more than one error, your answer should list multiple letters.

(a) `java.lang.NullPointerException`

(b) `java.lang.ArrayIndexOutOfBoundsException`

(c) `java.lang.IllegalArgumentException`

(d) `java.util.InputMismatchException`

(e) `java.lang.RuntimeException`

A, C	`linkedlist.get(10);`
A, B	`vertices[i] = v;`
A, B, D	`arr[i] = StdIn.readInt();`
A	`if (node.next != null) tmp = node.next.next;`
A	`if (node != null) tmp = node.next.next;`
A, B	`if (vertices.length > i) vertices[i] = v;`

3.2) (1 point) When compiling your program, you receive the compiler error, "**missing return statement**." Which of the following could be the source of this error. Circle **all** that apply.

(a) A `private` method that should be `public`.

(b) A `void` method contains more than one `return` statement.

(c) **A non-`void` method does not contain a `return` statement.**

(d) **There is a way to reach the end a non-`void` method without reaching a `return` statement.**

(e) **The compiler thinks there is a way to reach the end of a non-`void` method without reaching a `return` statement.**

3.3) (1 point) When testing Guitar Hero, you receive a **java.lang.ArrayIndexOutOfBoundsException**. From the stack trace, you see that the error occurs at the following statement in `GuitarHero.java`:

```
strings[note].pluck();
```

Recall that `strings` is an array of `GuitarString` objects. Which of the following debugging strategies are most likely to help you pinpoint the error? Circle all that apply.

(a) **Print out note immediately before this statement.**

(b) Print out **strings** immediately before this statement.

(c) Print out **strings[note]** immediately before this statement.

(d) **Print out strings.length immediately before this statement.**

3.4) (3 points) After you find and correct the array error from Question 3.3, you receive a **java.lang.NullPointerException**, which you trace to the same statement. You discover it is occurring because **strings[0]** is **null**. In thirty words or less, explain the most likely cause of this.
The `strings` array was created but the individual `GuitarString` objects were not created.

4.) VIRTUAL BLING (23 points total)

This holiday season, you have decided to give virtual strands of beads to all your virtual Facebook friends. Each **Bead** has a color and a diameter. The **StrandOfBeads** class implements a virtual strand of beads as a doubly linked list of **Bead**s with a sentinel node at either end.

(Recall that with sentinel nodes, the first and last nodes in the list don't represent beads. Also, recall that in a doubly linked list, each node points to both the next node and the previous node.)

```
public interface Bead {
  public String getColor();
  public double getDiameter();
}

public class StrandOfBeads {
  private class Node {
    Bead bead;
    Node next;
    Node prev;

    Node(Bead b, Node n, Node p) {  bead = b;   next = n;   prev = p; }
  }

  private Node first;  // the sentinel node at the beginning of the strand
  private Node last;   // the sentinel node at the end of the strand

  // create an empty strand of beads
  public StrandOfBeads() {
    last = new Node(null, null, null);      // sentinel node for the tail
    first = new Node(null, last, null);     // sentinel node for the head
    last.prev = first;
  }

  // return true if the strand has no beads on it, false otherwise
  public boolean isEmpty() { /* IMPLEMENT THIS METHOD */ }

  // add a bead to the beginning/end of the strand
  // if the argument is null, do nothing
  public void addFirst(Bead b) { ... }
  public void addLast(Bead b)  { /* IMPLEMENT THIS METHOD */ }

  // remove and return the first/last bead from the strand
  // if the strand is empty return null
  public Bead removeFirst() { ... }
  public Bead removeLast()  { /* IMPLEMENT THIS METHOD */ }
} // end StrandOfBeads class
```

4.1) (3 points) Implement **isEmpty()** here:

```
public boolean isEmpty() {
    return first.next == last; // an empty list has only the two sentinel nodes
}
```

4.2) (6 points) Implement **addLast()** here:

```
public void addLast(Bead b) {
    if (b == null) return;
    Node n = new Node(b, last, last.prev); // create new node to insert at end
    last.prev.next = n;                    // stick it just before the end sentinel
    last.prev = n;                         // update the end sentinel's prev pointer
}
```

4.3) (6 points) Implement **removeLast()** here:

```
public Bead removeLast() {
    if (isEmpty()) return null;

    Bead b = last.prev.bead;    // get the last bead

    last.prev.prev.next = last; // drop the last bead's node from the list
    last.prev = last.prev.prev;

    return b;
}
```

4.4) (8 points) For your many Penn friends, you want to make sure you give strands that don't include the Princeton colors `"black"` and `"orange"`. However, the manufacturer made a mistake and all the strands contain at least some black and orange beads.

Write a static function **pennify** that accepts a **StrandOfBeads** and returns a new **StrandOfBeads**. It should discard all beads whose color is `"black"` or `"orange"`, and move all other beads from the old strand to the new strand, while maintaining their order.

- Your method may modify the input **StrandOfBeads**.
- If the original strand is **null**, your method should return **null**.
- Assume that all the methods in **StrandOfBeads** are implemented correctly.
- Assume that your **pennify** function is not contained in the **StrandOfBeads** class, but do not write its surrounding class (only write the function).
- You are not required to write comments, but may use them to help clarify your code.

```
public static StrandOfBeads pennify(StrandOfBeads strand) {
  if (strand == null) return null;

  StrandOfBeads newStrand = new StrandOfBeads();

  while (!strand.isEmpty()) {
    Bead b = strand.removeFirst();
    String color = b.getColor();
    if (!color.equals("orange") && !color.equals("black"))
      newStrand.addLast(b);
  }

  return newStrand;
}
```

5.) TOY (12 points total) The following TOY program reads one value from standard input, performs a series of computations, and writes three values to standard output. The program and assembly language comments are correct as given.

```
01: FFFF   (1111 1111 1111 1111,     -1)
10: 7A01   R[A] <- 0001
11: 7B03   R[B] <- 0003
12: 8C01   R[C] <- mem[01]
13: 8DFF   read R[D]
14: 5EDB   R[E] <- R[D] << R[B]
15: 2EED   R[E] <- R[E] - R[D]
16: 9EFF   write R[E]
17: 4FEC   R[F] <- R[E] ^ R[C]
18: 1FFA   R[F] <- R[F] + R[A]
19: 9FFF   write R[F]
1A: 1FFE   R[F] <- R[F] + R[E]
1B: 9FFF   write R[F]
1C: 0000   halt
```

For the questions below, you may write all values the program prints as 4-digit hexadecimal numbers (e.g., 00A3), **or** as decimal (e.g., -623). However, you must not mix the two formats.

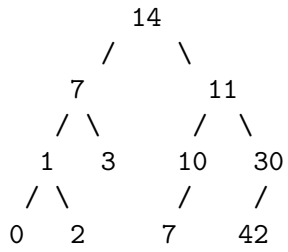
5.1) (3 points) What three values does this program write if it reads the value 0?
0, 0, and 0 *or* 0000, 0000, and 0000

5.2) (3 points) What three values does this program write if it reads the value 1?
7, and -7, and 0 *or* 0007, FFF9, and 000

5.3) (3 points) What three values does this program write if it reads the value 2?
14, -14, and 0 *or* 000E, FFF2, and 0000

5.4) (3 points) In **twenty words or less**, what three values does this program compute? Do not tell us *how* it computes these values, only what they are intuitively. If you prefer, you may give your answer as formulas in terms of a value x that the program reads in.
$7x$, $-7x$, and 0

6.) TREES (18 points total)



6.1) (6 points) Circle all the true statements about the tree above:

(a) **The tree is a binary tree.**

(b) The tree is a binary search tree.

(c) The tree is complete.

(d) The tree is full.

(e) The tree has a height of 4.

(f) **The node "30" is at depth 2.**

6.2) (2 points) Draw a box around the root node and circle the leaf nodes in the diagram above.

6.3) (4 points) Label the following tree traversals as pre-order, in-order, post-order, or invalid. (Invalid signifies that one or more sequences are improper traversals of the tree.)

preorder	14 7 1 0 2 3 11 10 7 30 42
invalid	0 1 2 3 7 7 10 11 14 30 42
inorder	0 1 2 7 3 14 7 10 11 42 30
postorder	0 2 1 3 7 7 10 42 30 11 14

6.4) (2 points) Suppose that T is a binary tree with 13 nodes. What is the minimum possible height of T?

(a) 0

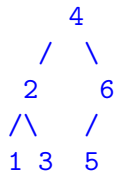
(b) **3**

(c) 4

(d) 5

6.5) (4 points) Draw the binary search tree generated by the following operations:

insert: 4, 2, 1, 6, 5, 3 (in that order)



remove: 4