UC Berkeley – Computer Science
CS61B: Data Structures

Midterm #1, Spring 2016

This test has 9 questions worth a total of 40 points. The exam is closed book, except that you are allowed to use a one page written cheat sheet. No calculators or other electronic devices are permitted. Give your answers and show your work in the space provided. Write the statement out below, and sign once you're done with the exam. **Write the statement out below in the blank provided and sign. You may do this before the exam begins.**

"I have neither given nor received any assistance in the taking of this exam."

_____
_____

Signature: __Alice Sheng_____

	Points		Points
0	0.5	5	5.5
1	3.5	6	8
2	2.5	7	0
3	5.5	8	6
4	2.5	9	6

Total	40

Name: Alice Sheng
SID: 18675309
Three-letter Login ID: hug
Login of Person to Left: dad
Login of Person to Right: mom

Exam Room: __779 Soda_____

Tips:

- There may be partial credit for incomplete answers. Write as much of the solution as you can, but bear in mind that we may deduct points if your answers are much more complicated than necessary.
- There are a lot of problems on this exam. Work through the ones with which you are comfortable first. Do not get overly captivated by interesting design issues or complex corner cases you're not sure about.
- Not all information provided in a problem may be useful.
- Unless otherwise stated, all given code on this exam should compile. All code has been compiled and executed before printing, but in the unlikely event that we do happen to catch any bugs in the exam, we'll announce a fix. Unless we specifically give you the option, the correct answer is not 'does not compile.'
- The last two problems are the "hard" ones.

Optional. Mark along the line to show your feelings on the spectrum between ☹ and ☺.

Before exam: [☹_____☺].
After exam: [☹_____☺].

0. So it begins (0.5 points). Write your name and ID on the front page. Circle the exam room. Write the IDs of your neighbors. Write the given statement. Sign when you're done with the exam. Write your login in the corner of every page. Enjoy your free half point ☺.

1. **IntList Essentials (3.5 Points).**

a) Recall the definition of the IntList class:

```
public class IntList {
   public int val;
   public IntList tail;
   public IntList(int val, IntList tail) {
       this.val = val;
       this.tail = tail;
   }
}
```

What will be printed by the code below? Write your answer in the three blanks provided.

```
public static void next1(IntList list) {
    list = list.tail;
}

public static IntList next2(IntList list) {
    list = list.tail;
    return list;
}

public static void next3(IntList list) {
    IntList temp = list;
    temp = temp.tail;
}

public static void main(String[] args) {
    IntList L = new IntList(1, null);
    L = new IntList(2, L);
    L = new IntList(3, L);

    next1(L);
    System.out.println(L.val); _____3_______
    next2(L);
    System.out.println(L.val); _____3_______
    next3(L);
    System.out.println(L.val); _____3_______
}
```

b) Fill in the `strangeInsertFront()` method below such that both print statements at the bottom of this page print out "0 1 2 3 4". You may have only one statement per line (do not add semi-colons, use ours).

```
public class IntList {
    public int val;
    public IntList tail;
    public IntList(int val, IntList tail) {
        this.val = val;
        this.tail = tail;
    }

     public void print() {
         System.out.print(val + " ");
         if (tail != null) {
             tail.print();
         }
     }

     public IntList strangeInsertFront(int x) {
        this.tail = new IntList(this.val, this.tail);
        this.val = x;
        return this;
     }
}

public class P2 {
    public static void main(String[] args) {
      IntList L = new IntList(4, null);
      L = L.strangeInsertFront(3);
      L = L.strangeInsertFront(2);
      L = L.strangeInsertFront(1);

      IntList L2 = L;
      L = L.strangeInsertFront(0);

      L.print();  // should print 0 1 2 3 4
      L2.print(); // should also print 0 1 2 3 4
    }
}
```

2. **SList Debugging and Testing (2.5 Points).** Consider the SList implementation below.

```
public class SList {
      public class IntNode {
            public int item;
            public IntNode next;
            public IntNode(int i, IntNode n) {
                  item = i;
                  next = n;
            }
      }
      private static IntNode sentinel; // static sentinel is the flaw
      public SList() {
            sentinel = new IntNode(982734, null);
      }
      public void insertFront(int x) {
            sentinel.next = new IntNode(x, sentinel.next);
      }
      public int getFront() {
            if (sentinel.next == null) {
                  return -1;
            }
            return sentinel.next.item;
      }
}
```

Write a JUnit test that fails on the code above, but would pass on a correct implementation. You may use any JUnit methods like `assertEquals`, `assertNotEquals`, `assertTrue`, `assertFalse`, etc.

```
    @Test
    public void test() {
        SList s1 = new SList();
        SList s2 = new SList();
        s1.insertFront(1);
        s2.insertFront(2);
        assertNotEquals(s1.getFront(), s2.getFront());
        assertEquals(1, s1.getFront()); /* also fails */
}
```

3. **ArrayHorse.com (5.5 Points)**.

a) Consider the code below. Assume N is odd and positive.

```
public static int[][] genCoolGrid(int N) {
    int[][] grid = new int[N][N];// Everything defaults to 0 in int arrays
    for (int i = 0; i <= N / 2; i += 1) {
        for (int j = (N / 2) - i; j <= (N / 2) + i; j += 1) {
            grid[i][j] = 8;
            grid[N - 1 - i][j] = 8;
        }
    } return grid; /* sorry, low on space, bad style, but works! */
}
```

Show the return value of `genCoolGrid(5)` in the boxes below. Note: top left is `grid[0][0]`.

`grid[0][0]`	0	0	**8**	0	0	`grid[0][4]`
	0	**8**	**8**	**8**	0	
	8	**8**	**8**	**8**	**8**	
	0	**8**	**8**	**8**	0	
`grid[4][0]`	0	0	**8**	0	0	`grid[4][4]`

Solutions that left the 0's blank were given almost-full points.

b) Suppose we define an interface for functions on integers of a single variable called `IUF`. An example implementation of this interface that squares integers is shown to the right.

```
public interface IUF {
    int apply(int x);
}
```

```
public class Squarer implements IUF {
    public int apply(int x) { return x * x; }
}
```

Write a method `mapColumn` that destructively applies the given function to a single column of a 2D array. For example, if we pass in a Squarer object as f and 0 as c, we'd get back a copy of the grid with column 0 squared.

```
public static int[][] mapColumn(IUF f, int[][] m, int c) {
    for(int i = 0; i < m.length; i += 1) {
        m[i][c] = f.apply(m[i][c]);
    }
    return m;
}
```

c) Write code such that veryCoolGrid is set equal to 5x5 coolGrid, but with the middle column squared.

You need to instantiate a new Squarer, which is a IUF. If you used "coolGrid", that was accepted.

```
int[][] veryCoolGrid = mapColumn(new Squarer(), genCoolGrid(5), 2);
```

4. **All Natural (2.5 points).** Add a new method `allNatural` to the SList class. After execution, the SList should contain only numbers that are greater than or equal to zero, and in the same order that they were in before the operation began. For example, if the list were [5, -7, 2, 6, -3, 0] the list would be [5, 2, 6, 0] afterwards. As in class, the sentinel node's value is a dummy value and is not considered part of the list. We have filled in part of the method for you; each line should be filled in with exactly one statement or variable name (you may not add any semi-colons). **To give you some flexibility, you may fill in EITHER solution below. Do not fill out both.** You should not use new.

```
public class SList {
      public static class IntNode {
         public int item;
         public IntNode next;
         public IntNode(int item, IntNode next) {
             this.item = item;
             this.next = next;
         }
      }
      IntNode sentinel;
      public SList() {
        sentinel = new IntNode(99999, null);
      }
      public void insertFront(int item) {
          IntNode n = new IntNode(item, sentinel.next);
          sentinel.next = n;
      }
```

```
public void allNatural() {
   IntNode a = sentinel;
   IntNode b = sentinel.next;
   while (b != null) {
       if (b.item >= 0) {
           a.next = b;
           a = b;
       }
       b = b.next;
   }
   a.next = null;
}   ...
```

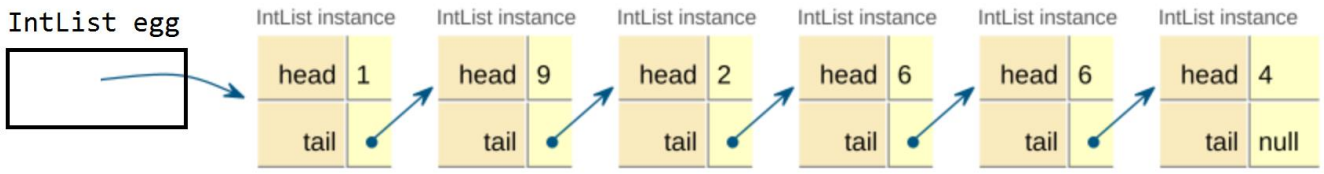
```
public void allNatural() {
    IntNode p = sentinel;

    while(p!=null && p.next !=null){
        if (p.next.item < 0) {
            p.next = p.next.next;
        }
        p = p.next; // **see note**
    }
}  ...
```

NOTE: else { p = p.next } is even better because it handles consecutive negatives correctly.

Circle which of your two solutions you'd like graded. We will ONLY grade one of your solutions. Regrades will not be accepted for mis-circled responses.

LEFT RIGHT

5. **Egg$^{\text{Egg}_{\text{egg}_{\text{egg}}}}$ (5.5 points).** You start with only one variable, `egg`, whose contents are fully described in the following box-and-pointer diagram:

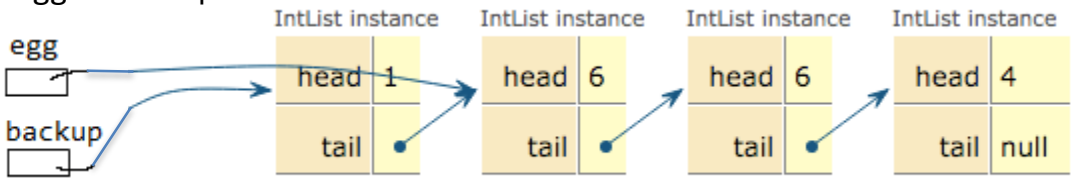


a) Draw a box-and-pointer diagram if we run the following statements in the order shown:

```
Statement A: for (int i = 0; i < 2; i += 1) {egg.tail = egg.tail.tail;}

Statement B: egg.tail = new IntList(egg.tail.head - 1, egg.tail);

Statement C: IntList backup = egg;

Statement D: egg = egg.tail.tail;

Statement E: backup.tail = egg;
```

Descriptions of the above statements for explanation purposes:
A: Deletes two nodes from the tail.
B: Spawns a copy of the tail, with a value of 1 less than head. In part B, we'll need to use this to make an IntList with a head value of 3
C: Makes a backup pointer
D: Moves egg forward twice.
E: Connects backup and egg

To make grading easier, redraw your answer below in the box-and-pointer diagram provided. You may not need all of the boxes provided. Work outside these lines will not graded. Make sure to point the variables `egg` and `backup` at the appropriate box. Do not include boxes that cannot be reached from either `egg` or `backup`.



b) Rearrange the 5 statements so that after execution is completed, there exists an `IntList` with exactly four elements: `1->2->3->4` (not necessarily pointed to by <egg>). Write your response in the blanks below, one letter per blank. Use each letter once.

	C	D	A	B	E
	First operation	Second	Third	Fourth	Final

Two alternative, correct answers: CD**E**AB, CDA**E**B

6. **Array Processing (8 Points).** You are a programmer for the people's glorious state of Oceania. Your citizens have started trying to avoid censorship by rotating their text messages. For example, suppose a citizen wants to use the banned word "light", for example: "nice light today". Instead, the citizen might say "ght today nice li". It is your job to write code to remove banned words. Throughout this problem you may assume that `message` and `banned` are of length greater than zero, and that `banned.length` < `message.length`. You may also assume that `k` is a valid number[1]. Hint: for positive integers, `a % b` returns the remainder of dividing `a` by `b`, e.g. `7 % 3` is `1`.

(a) Fill in the `matches` method below, which returns true if the message starting at `k` matches the banned word, treating the message as circular. For example, if message is `['d', 'd', 'o', 'g', 'b', 'a']` and banned is `['b', 'a', 'd']`, this method will return true for `k = 4`, and false for all other `k`. **You may not need all lines. If you don't use a line, leave it blank.**

```
private static boolean matches(char[] message, char[] banned, int k) {
      ____________________________________________________
      for (int i = __0__; i < ___banned.length___; i += 1) {
            int messageIndex = ___(k + i) % message.length____;
            if (message[messageIndex] != banned[i]) {
                  ______return false____________________;
            }
      }
      _____return true_____________________________;
}
```

(b) Complete the helper function `matchStart`, which returns the start index of a banned word in a message. For example, if message is ['d', 'd', 'o', 'g', 'b', 'a'] and banned is ['b', 'a', 'd'], this method should return 4, because the match begins at position 4. If there is no match, return -1. **You can do this part even if you skipped part a!** You may use the method from part a, even if you didn't actually get it right. You may assume that banned words occur only once (if at all).

```
public static int matchStart(char[] message, char[] banned) {
    for (int k = 0; k < message.length; k += 1) {
        if (matches(message, banned, k)) {
            return k;
        }
    }
    return -1;
}
```

[1] By valid we mean `0 ≤ k ≤ message.length - 1`

Finally write the filter method, which returns the original message but with the banned word removed. Assume that a banned word, if it appears at all, appears only once. **You can do this part even if you skipped parts a and b**. You may use your methods from part a or part b in this problem.

Some examples:

- `message` = ['d', 'd', 'o', 'g', 'b', 'a'], `banned` = ['b', 'a', 'd'], return ['d', 'o', 'g']
- `message` = ['d', 'd', 'o', 'g', 'b', 'a'], `banned` = ['o', 'g'], return ['d', 'd', 'b', 'a']
- `message` = ['b', 'a', 'b', 'a', 'd', 'd', 'd', 'o', 'g'], `banned` = ['b', 'a', 'd'], return ['b', 'a', 'd', 'd', 'o', 'g'] [2]

We gave the solution below almost full credit. In some cases, it will properly filter out the banned, but "rotate" the array (see second example)

```
public static char[] filter(char[] message, char[] banned) {
    int match = matchStart(message, banned);
    if (match < 0) {
           return message;
    }
    int numToCopy = message.length - banned.length;
    char[] result = new char[numToCopy];
    int messageIndex = (match + banned.length) % message.length;

    for (int i = 0; i < numToCopy; i += 1) {
           result[i] = message[(messageIndex + i) % message.length];
           ____________________________________________;
    }
    return result;
}
```

The full solution for the `for` loop is as follows. It requires you to use insight from problem 9 (where we introduce `Math.max`)

```
for (int i = 0; i < numToCopy; i += 1) {
   int d = Math.max(messageIndex - banned.length, 0);
   result[(d + i) % numToCopy] = message[(messageIndex + i) % message.length];
}
```

7. Pip Digs Pep (0 Points). What Bay Area experimental music collective released a 1997 jingle for Pepsi, associating the ubiquitous beverage with "Old outdated software getting thrown into the trash" and a "Medicated ointment being spread on painful rash"? Negativland

[2] By using this trick, citizens can defeat our censorship tool! No doubt our citizens will discover this trick. To fix this, we will simply apply the filter function multiple times.

8. Interfaces (6 points). You may assume that you have a correct implementation of `ArrayDeque` and `LinkedListDeque` throughout this problem, and that it implements the `Deque` interface.

a) Consider the Deque interface from Project 1c. Add a default method reverse that reverses the Deque.

```
public interface Deque<Item> {
        void addFirst(Item x);              void addLast(Item x);
        boolean isEmpty();                  int size();
        void printDeque();                  Item get(int index);
        Item removeFirst();                 Item removeLast();
    default void reverse() {
        There were many, MANY solutions. See below for sample solutions.
    }
}
```

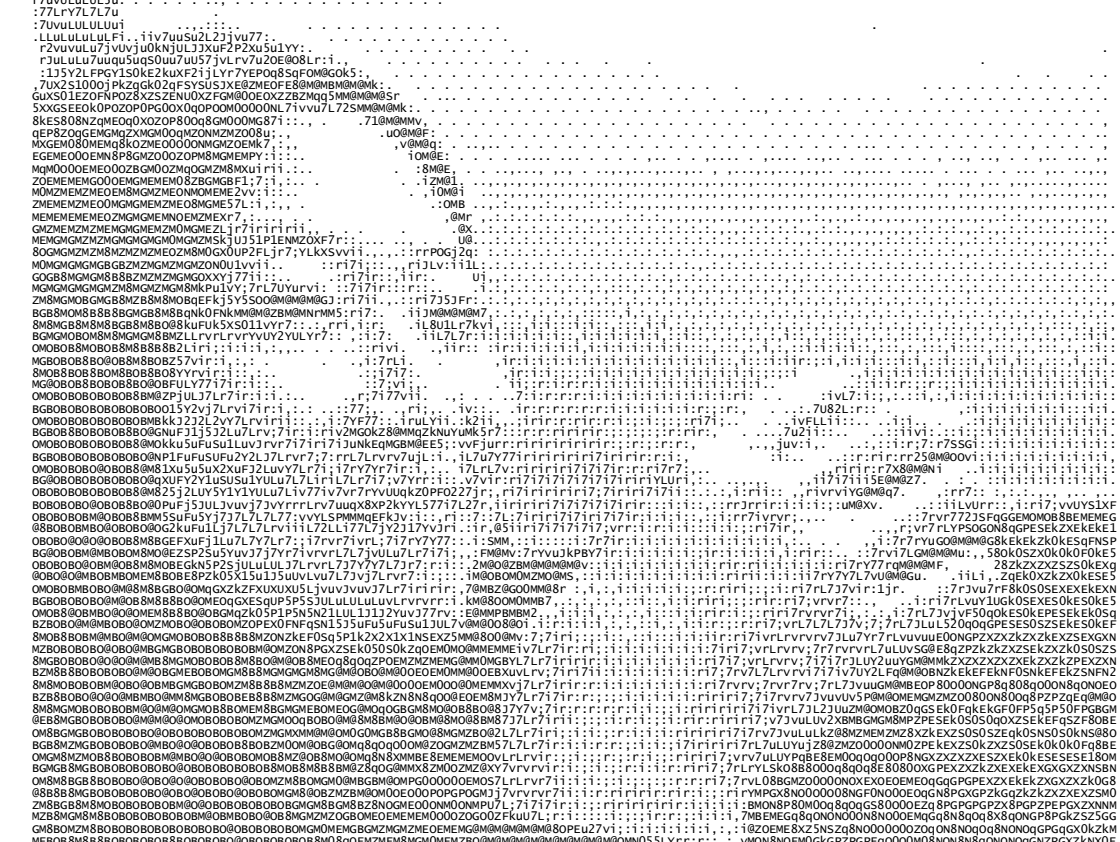
```
default void reverseRecursive() {
    // Note: if(size() != 0) is wrong if reversing two at a time
    if (size() > 1) {
        Item tempFirst = removeFirst();
        reverseRecursive();
        addLast(tempFirst);
    }
}
```

```
default void reverseUsingArray() {
    int size = size();
    Item[] tmp = (Item[]) new Object[size];
    for (int i = 0; i < size; i += 1) {
        tmp[i] = removeLast();
    }
    for (int i = 0; i < size; i += 1) {
        addLast(tmp[i]);
    }
}
```

```
default void reverseUsingList(){
    Deque<Item> helper = new LinkedListDeque<Item>();
    // Can also use:         ArrayDeque<Item>();
    while (!isEmpty()) {
        helper.addLast(removeFirst());
    }
    while (!helper.isEmpty()) {
        addFirst(helper.removeFirst());
    }
}
```

```
// "In place" solutions need two for loops: one to add, one to remove
// Appending to the end. Note the for loop is different
default void reverseLast2() {
    int size = size();
    for (int i = size - 1; i >= 0; i-= 1)
        addLast(get(i));
    for (int i = 0; i < size; i += 1)
        removeFirst();
}

// Appending to the beginning
default void reverseFirst() {
    int size = size();
    for (int i = 0; i < size; i += 1)
        addFirst(get(i*2));
    for (int i = 0; i < size; i += 1)
        removeLast();
}
```

Designated fun zone. Draw something. Leave a scent on the paper. It is up to you.



b) Suppose we add another default method to the Deque interface:

```
A:    default void append(Deque<Item> d) { /* code not shown */ }
```

Suppose that we also add the following four methods to `ArrayDeque` (not `BadArrayDeque`):

```
B:    public void append(ArrayDeque<Item> ad) { /* code not shown */ }

      @Override
C:    public void append(Deque<Item> d) {  /* code not shown */ }

D:    public void prepend(Deque<Item> d) { /* code not shown */ }

E:    public void prepend(ArrayDeque<Item> ad) /* code not shown */ }
```

Consider the code below. For each call to append or prepend, tell us what happens by circling exactly one of the provided answers. If you circle a letter (A, B, C, D, or E), you are saying that the method with that label is called. If you circle compile-error you are saying this line will not compile. If you circle runtime-error, you are saying the code will compile, but will crash when this line is reached. Some possibilities may not occur (e.g. there may actually be no compiler errors).

When you're done, you should have circled exactly 8 items.

```
public class DMS {
    public static void main(String[] args) {
        Deque<Integer> d = new ArrayDeque<Integer>();
        d.addLast(10);
        d.addLast(20);
        ArrayDeque<Integer> ad = new ArrayDeque<Integer>();
        ad.addLast(30);
        ad.addLast(40);

        d.prepend(d);    Compile-Error  Runtime-Error  A    B    C    D    E
        d.prepend(ad);   Compile-Error  Runtime-Error  A    B    C    D    E
        ad.prepend(d);   Compile-Error  Runtime-Error  A    B    C    D    E
        ad.prepend(ad);  Compile-Error  Runtime-Error  A    B    C    D    E

        ad.append(d);    Compile-Error  Runtime-Error  A    B    C    D    E
        ad.append(ad);   Compile-Error  Runtime-Error  A    B    C    D    E
        d.append(d);     Compile-Error  Runtime-Error  A    B    C    D    E
        d.append(ad);    Compile-Error  Runtime-Error  A    B    C    D    E
    }
}

/* Did you circle 8 things, one per line? If not, go circle 8 things. */
```

9. **Dynamic Method Selection and Inheritance (6 points)**. Modify the code below so that the max method works properly. Assume all numbers inserted into a `DMSList` are positive. You may not change anything in the given code. You may only fill in blanks. You may not need all blanks.

```
public class DMSList {
    private IntNode sentinel;
    public DMSList() {
        sentinel = new IntNode(-1000, new LastIntNode());
    }
    public class IntNode {
        public int item;     /* Equivalent of first */
        public IntNode next; /* Equivalent of rest */
        public IntNode(int i, IntNode h) {
            item = i;
            next = h;
        }
        public int max() {
            return Math.max(item, next.max());
        }
    }
    public class LastIntNode extends IntNode {
        public LastIntNode() {
            super(0, null);
        }
        @Override
        public int max() {
            return 0;
        }
    }
    public void insertFront(int x) {
        sentinel.next = new IntNode(x, sentinel.next);
    }
    public int max() {
        return sentinel.next.max();
    }
    public static void main(String[] args) {
        DMSList dmsl = new DMSList ();
        dmsl.insertFront(5);
        dmsl.insertFront(10);
        dmsl.insertFront(20);
        System.out.println(dmsl.max());/* should print 20 */
    }
}  /* end of class */  /* end of test, boo */
```