Solutions to Quiz 1 (October 24, 2016)

Problem 1 (Specifications) (18 points).
Consider this partial specification:

```
/**
   * Shift the values in inputs, wrapping around the ends of the array.
   * For example, [2, 4, 6, 8, 10] shifted by 2 to the right is [8, 10, 2, 4, 6].
   * @param inputs array to shift, ...
   * @param delta amount to shift by, ...
   * @return inputs shifted by ...
   */

public static int[] shiftArray(int[] inputs, int delta)
```

Here are two versions of this specification that fill in the missing pieces:

Specification A:

@param inputs array to shift, must be non-empty
@param delta amount to shift by, must be a positive integer
@return inputs shifted by delta units to the right

Specification B:

@param inputs array to shift, must be non-empty
@param delta amount to shift by
@return inputs shifted by delta units, to the right if positive, to the left if negative

For each question, answer by filling in the blanks. You may leave blanks empty if desired, and you may use the same answers more than once.

(a) Complete a specification that is weaker than A:
@param inputs array to shift, ____________________________
@param delta amount to shift by, ___________________________
@return inputs shifted by _________________________________
______________________________

Solution.  Strengthen A's precondition (e.g. delta = 5) or weaken the postcondition (e.g. shifted by at most delta units to the right).

(b) Complete a specification that is stronger than A and weaker than B:
@param inputs array to shift, ____________________________
@param delta amount to shift by, ___________________________
@return inputs shifted by _________________________________
______________________________


Solution. Precondition between A and B (e.g. \( \delta \) non-negative).

(c) Complete a specification that is stronger than \( A \) but neither stronger nor weaker than \( B \):

@param inputs array to shift, 
@param \( \delta \) amount to shift by, 
@return inputs shifted by 

Solution. Weaken the precondition and choose a different postcondition (e.g. any \( \delta \), but shift by \( \text{Math.abs}(\delta) \) to the right).

Problem 2 (Testing) (28 points).

Given this specification:

```java
/**
 * If text contains bound, split into two substrings a and b, where:
 * - a ends with bound, b starts with bound, and
 * - if \( a = a._\text{begin} + \text{bound} \), and \( b = \text{bound} + b._\text{end} \), then
 * \( \text{text} = a._\text{begin} + \text{bound} + b._\text{end} \).
 * Otherwise, don’t split.
 *
 * For example: \( \text{splitWithBound}("1a2", 'a') \) is \{ "1a", "a2" \}
 * \( \text{splitWithBound}("123", 'a') \) is \{ "123" \}
 *
 * @param text text to split
 * @param bound character to split on
 * @return a set containing some a and b as defined above, if any,
 * or just text if none
 */
 public static Set<String> splitWithBound(String text, char bound)
```

(a) For each test case below, write YES or NO in the first box to say whether the test is a valid test for `splitWithBound`. If the test is not valid, explain why or provide a corrected test.

1. "zaz" × ‘a’ → { "az", "za" }
   Valid? Reason if invalid:

2. "az" × ‘a’ → { "a", "az" }
   Valid? Reason if invalid:

3. "zaaz" × ‘a’ → { "za", "aaz" }
   Valid? Reason if invalid:

4. "aa" × ‘a’ → { "a" }
   Valid? Reason if invalid:

5. "a" × ‘a’ → { "a" }
   Valid? Reason if invalid:

6. "
   Valid? Reason if invalid:
Solution. 1, 2, and 5 are valid.

For 3, output \{ "zaa", "az" \} is also possible. For 4, the output would be \{ "a", "aa" \}. For 6, the output would be \{ "" \}. ■

(b) Start implementing a systematic testing strategy for this function by writing one good partitioning of the input space on input text alone. Your partitions for this question should not mention bound. In addition, the subdomains in your partitioning must not overlap.

Solution. E.g. text.length() = 0, = 1, > 1. ■

(e) Now, write one good partitioning of the input space on location(s) where bound appears in text. In addition, the subdomains in your partitioning must not overlap.

Solution. E.g. bound appears at beginning only; beginning and middle; beginning and end; beginning, middle, and end; middle only; middle and end; end only; not at all. ■

(d) Suppose we instead make this function an instance method of an immutable class Splitter. An instance of Splitter uses a fixed bound:

```java
public class Splitter {
    // Make a Splitter that uses the given bound
    public Splitter(char bound) { ... }

    // Split with bound, as above
    public Set<String> splitWithBound(String text) { ... }
}
```

Which of the following are true? (choose all that apply)

A. Unit tests of Splitter(char) should not call splitWithBound(String)
B. Unit tests of splitWithBound(String) should not call Splitter(char)
C. This immutable class doesn’t make sense, because splitWithBound can be called with different values of text
D. The splitWithBound operation of Splitter is an observer according to our classification
E. none of the above

Solution. D. ■

Problem 3 (Debugging) (12 points).
You’ve written the following program:

```java
public class Sentences {
    public static void main(String[] args) {
        String s = "no sentence. Sentence. also no sentence";
        System.out.println(findSentence(s.toCharArray()));
    }
}
```
public static char[] findSentence(char[] chars) {
    int start = 0;
    boolean scanning = false;
    for (int i = 0; i < chars.length; i++) {
        if (Character.isUpperCase(chars[i]) && !scanning) {
            start = i;
            scanning = true;
        }
        if (chars[i] == '.' && scanning) {
            return ArrayUtils.copySubarray(chars, start, i);
        }
    }
    return new char[0];
}

You run it, and the output is:
Sentence. also no sen

But you expected the output to be just:
Sentence

It’s broken!

Just then, your boss shows up at your desk: We can’t afford all these CPU cycles you’re burning! Run your program one more time, then just fix it already!

(a) Choose your own adventure!

<table>
<thead>
<tr>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run again with input:</td>
<td>Run again with input:</td>
<td>Run again with input:</td>
</tr>
</tbody>
</table>

Raise your hand and quietly inform the responding TA that you would like to explore Option 1, 2, or 3. The TA will highlight your chosen option and the corresponding output on the next page.

You may not change your choice or ask again.

21.Abc

1.Abc

Abc

Abc. Only the output highlighted by the TA is produced by your chosen input.

You may ignore all the other possibilities.

Abc.1

Abc.12
Abc.123

Exception in thread "main" java.lang.ArrayIndexOutOfBoundsException
   at Sentences.findSentence(Sentences.java:15)
   at Sentences.main(Sentences.java:5)

Exception in thread "main" java.lang.IndexOutOfBoundsException
   at ArrayUtils.copySubarray(ArrayUtils.java:18)
   at Sentences.findSentence(Sentences.java:20)
   at Sentences.main(Sentences.java:5)

Exception in thread "main" java.lang.IllegalArgumentException
   at ArrayUtils.copySubarray(ArrayUtils.java:18)
   at Sentences.findSentence(Sentences.java:20)
   at Sentences.main(Sentences.java:5)

Solution. The outputs are:

Option 1: IndexOutOfBoundsException from copySubarray (ArrayUtils.java:18)
Option 2: Abc
Option 3: Abc.12

(b) Given all the information you have, what is the bug? Write your single best hypothesis clearly and succinctly, giving evidence to support it.

Solution. ArrayUtils.copySubarray requires a start index and a length, but is called with a start index and an end index.

(c) Propose a fix. If you can, identify a line or lines of code, and say how they should be changed.

Solution. return ArrayUtils.copySubarray(chars, start, i-start);

Problem 4 (ADTs) (28 points).
Consider this abstraction function, rep invariant, and argument for safety from rep exposure for a class Document to represent immutable text documents with section headings, where each heading is a single line, followed by a single line of text:

AF
represents the document heading headings0, then text contents0, then heading headings1, then text contents1, ..., up to length-1; where headingsi is the ith element in headings, and similarly for contents

RI
length = headings.size() = contents.size()
none of the elements in headings or contents contain newlines

Safety from rep exposure
all fields are final
length is primitive
headings and contents are created in constructors, never returned directly to clients, and contain immutable objects
(a) What is the rep of `Document`? Use the most reasonable choices from the standard library, and write valid lines of Java.

Solution.

```java
private final int length;
private final List<String> headings;
private final List<String> contents;
```

(b) Draw a snapshot diagram, including as much information as you can, for the concrete representation of the abstract value:

Solution. Immutable `Document`. Immutable field `length` has value 2. Immutable fields `headings` with `List` value containing the two heading strings, and `contents` with `List` value containing the two content strings.

(c) If all arrays, collections, and strings in the rep (if any) are empty, all primitive values (if any) are their default value, and all other objects (if any) are `null`, what is the abstract value? If none, explain why.

Solution. The empty document, with no headings or text.

(d) Suppose we implement `Document` with a different representation. Here are the rep invariant and safety from rep exposure argument:

**RI**

`length*2 = pieces.size()`

none of the elements in `pieces` contain newlines

**Safety from rep exposure**

all fields are final

`length` is primitive

`pieces` is created in constructors, never returned directly to clients, and contains immutable objects

Write an abstraction function that works with this rep and rep invariant:

**AF**
Solutions to Quiz 1 (October 24, 2016)

Solution. Represents the document: heading pieces\textsubscript{0}, then text pieces\textsubscript{1}, then heading pieces\textsubscript{2}, then text pieces\textsubscript{3}, ..., up to length*2-1; where pieces\textsubscript{i} is the i\textsuperscript{th} element in pieces. ■

(e) Write a recursive datatype definition for Document that uses two concrete variants, one of which must be Empty, to represent the same abstract values as above using a recursive structure:

\[
\text{Document} = \begin{cases} \\
\text{Cons(heading: String, text: String, rest: Document)} & + \\
\text{Empty()} & \end{cases}
\]

Solution. Document = Cons(heading: String, text: String, rest: Document) + Empty() ■

Problem 5 (Multiple Choice) (14 points).

(a) Which of the following statements about equality are true? (choose all that apply)

A. If you override the equals() method for an immutable ADT, you should also override hashCode()
B. You should implement observational equality for all ADTs
C. Returning a constant integer is a valid implementation of hashCode() because the spec of hashCode() specifically allows magic number implementations.
D. Using the abstraction function \(AF\), we can define equality as: \(a\) equals \(b\) if and only if \(AF(a) = AF(b)\)
E. Unless we override it, equals() implements reference equality

Solution. A and D.

B is false, only for immutable ADTs. For C, returning a constant is legal, but not because of a specific exception. ■

(b) Which of the following best describes the benefit of declaring a variable using an interface type, as in this example:

\[
\text{List<String> words = new ArrayList<>();}
\]

(choose one best answer)

A. SFB: the List interface isolates our code from bugs in ArrayList
B. SFB: this requires ArrayList methods to meet specifications in List
C. ETU: readers may not know what an ArrayList is, but they will recognize List
D. RFC: we can change the code to use, e.g., LinkedList instead of ArrayList

Solution. D.

A and B are incorrect. C may be true, but is not as compelling as D. ■

(c) You are implementing a Building ADT. Buildings have a list of rooms, which you represent with:

\[
\text{private final List<Room> rooms;}
\]

Room is immutable. Which of the following implementations for a getRooms() method will avoid rep exposure? (choose all that apply)

\[
\text{public List<Room> getRooms() \{ return ???; }}
\]
A. rooms
B. Collections.unmodifiableList(rooms)
C. new ArrayList<>(this.rooms)
D. Optional.of(this.rooms)
E. this.rooms

Solution. B and C.

B uses an unmodifiable wrapper. C makes a defensive copy.