Quiz 2 (December 4, 2017)

Your name:__________________________________________________

Your Kerberos username:________________________________________

You have 50 minutes to complete this quiz. It contains 10 pages (including this page) for a total of 100 points.

The quiz is closed-book and closed-notes, but you are allowed one two-sided page of notes.

Please check your copy to make sure that it is complete before you start. Turn in all pages, together, when you finish. Before you begin, write your Kerberos username on the top of every page.

Please write neatly. **No credit will be given if we cannot read what you write.**

For questions which require you to choose your answer(s) from a list, do so clearly and unambiguously by circling the letter(s) or entire answer(s). Do not use check marks, underlines, or other annotations – they will not be graded.

Good luck!

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This quiz uses the same abstract data type as Quiz 1: a **shopping list** is an **ordered** list of **unique** items together with a **positive integer** quantity for each listed item (we will not consider units for quantities, *e.g.* 1 oz. vs. 1 lb. vs. 1 box, just a number).

For example, someone who plans to buy a gallon of milk, a small bunch of bananas, and a box of Klondike bars, might have this shopping list:

- 1% milk (1)
- Banana (3)
- Klondike bars (1)

Shopping lists are ordered, so the following is a **different** shopping list. It has the same items and quantities, but in a different order:

- Banana (3)
- Klondike bars (1)
- 1% milk (1)

This is **not** a shopping list:

- Banana (1)
- Banana (1)
- Banana (1)
- Klondike bars (1)
- 1% milk (1)

And neither is this:

- 1% milk (0)

An unlisted item has zero quantity, so the quantity of **Oranges** on every list on this page is 0.
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Problem 1 (Recursive data types) (15 points).

The problems of this exam refer to the code for ShoppingList on page 9, which you may detach.

(a) Write the data type definition for ShoppingList.

(b) Here is a new operation proposed for the ShoppingList type.

\[ \text{atMost: ShoppingList list \times String anItem \times int count} \rightarrow \text{ShoppingList} \]

\text{requires} \text{ true}
\text{effects} \text{ returns a shopping list identical to list, except that anItem's quantity on the returned list is the smaller of count and its quantity on list, i.e.}
\text{returnedList.howMany(anItem) == min(count, list.howMany(anItem))}

Change just the \text{precondition} of this specification, as little as possible, so that the postcondition can always be satisfied:

Circle whether your new \text{specification} is STRONGER or WEAKER than the original \text{specification}, and explain why in one sentence:

\text{spec is STRONGER / WEAKER because:}
Problem 2 (Recursive data types) (23 points).
Using your revised spec for atMost, fill in the blanks below to implement the new operation as an instance method of ShoppingList. Assume the other code in those classes remains unchanged.

```java
public interface ShoppingList {
    ...
    /** assume specification comment is here, don’t write it */
}

class Empty implements ShoppingList {
    ...
    @Override public /* assume method signature is here, don’t write it */ {
        ...
    }
}

class AnotherItem implements ShoppingList {
    ...
    @Override public /* assume method signature is here, don’t write it */ {
        if (anItem.equals(this.item)) {
            ...
        } else {
            ...
        }
    }
}
```
Problem 3 (Thread safety) (25 points).
This problem refers to the code for `goShopping()` on page 10, which you may detach.
For each of these comments about the thread safety of the code below, circle AGREE or DISAGREE and explain why in one sentence.

(a) The `i` variable is threadsafe because it is confined.

AGREE / DISAGREE because:

(b) The `itemLocations` map is threadsafe because `goShopping` doesn’t call any of its mutators.

AGREE / DISAGREE because:

(c) The `shoppers` list is threadsafe because it uses threadsafe data types.

AGREE / DISAGREE because:

(d) The code shown has a race condition.

AGREE / DISAGREE because:

(e) Declaring `goShopping()` with `public synchronized` would make `goShopping()` threadsafe.

AGREE / DISAGREE because:
Problem 4 (Map-filter-reduce) (22 points).

Let’s define map and filter operations for ShoppingList that examine and operate on the items (but not their quantities). For example, map could be used to replace Milk with 1% Milk, and filter could be used to filter to only the vegetarian items on the shopping list.

(a) Write mathematical type signatures (not Java method declarations) for the map and filter operations of ShoppingList. One argument of each operation should be a function, and all types should be specific to the shopping list problem, not generic type variables like \(<E>\) or \(<T>\).

\[
\text{map: } \quad \times \quad \rightarrow \\
\text{filter: } \quad \times \quad \rightarrow
\]

(b) Assuming that map and filter are now implemented as instance methods of ShoppingList, write Java code to convert the list input:

• small apples (5)
• green apples (3)
• leafy lettuce (1)
• yucky meat (3)
• yummy meat (7)

into the list output:

• apples (8)
• lettuce (1)
• meat (7)

Use the fewest Java expressions you can.

ShoppingList input = ...; // abstract value shown above

ShoppingList output =
Problem 5 (Grammars) (15 points).

(a) Complete this partial grammar so that it can recognize shopping lists. It should match as many valid shopping lists as possible, and exclude as many invalid lists as possible. For example, the grammar should match:

- Milk (1)
- Banana (30)
- Klondike bars (1)

but not match:

- Milk (0)

Here is the partial grammar, with root nonterminal list. Complete the grammar by adding new rules; don’t change existing rules.

```
list ::= (’• ’ item ’ ’ quantity ’
’n’)*;
item ::= [A-Za-z]*;
```

(b) Read the grammar carefully, and then write Java code below to construct a ShoppingList that this grammar cannot match. (If you can’t think of one, say that, but also write Java code that constructs some ShoppingList.)

```java
ShoppingList list =
```
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You may detach this page. Write your username at the top, and hand in all pages when you leave.

```java
/** Immutable shopping list. */
public interface ShoppingList {

  /** @return an empty shopping list */
  public static ShoppingList empty() {
    return new Empty();
  }

  /** @return this list with 1 instance of item added */
  public ShoppingList another(String item);

  /** @return the items on this list */
  public Set<String> items();

  /** @return the quantity of item on this list, >= 0 */
  public int howMany(String item);

  // ...
}

class Empty implements ShoppingList {
  public Empty() {
  }

  // ...
}

class AnotherItem implements ShoppingList {
  private final String item;
  private final ShoppingList list;

  public AnotherItem(String item, ShoppingList list) {
    this.item = item;
    this.list = list;
  }

  // ...
}
```
1 /* Aisle is a threadsafe mutable data type representing an aisle in a store */
2 public class Aisle { ... }

3 /* ShoppingCart is a threadsafe mutable data type representing a shopping cart */
4 public class ShoppingCart { ... }

5 public class Store {

6   private final Map<String,Aisle> itemLocations;
7   ... // other fields and operations

8 /*
9   * Requires that this store has sufficient quantity of every item on list.
10   * Modifies the cart and this store to move the quantity of each item on list
11   * from the store to the cart.
12   */
13   public void goShopping(final ShoppingList list, final ShoppingCart cart) {
14       final List<Thread> shoppers = new ArrayList<>();
15       for (final String item: list.items()) {
16           Thread shopper = new Thread() -> {
17               Aisle aisle = itemLocations.get(item);
18               for (int i = 0; i < list.howMany(item); ++i) {
19                 if (aisle.howMany(item) > 0) {
20                     cart.add(item);
21                     aisle.remove(item);
22                 }
23               }
24           }
25       }
26       shopper.start();
27       shoppers.add(shopper);
28       }
29       for (Thread shopper : shoppers) { shopper.join(); }
30   }
31 }