This test is open-book, open-notes, but you may not use any computing device other than your
brain and may not communicate with anyone. You have 50 minutes to complete the test.

The phrase “design a program” means follow the steps of the design recipe. Unless specifically
asked for, you do not need to provide intermediate products like templates or stubs, though they
may be useful to help you construct correct solutions.

You may use any of the data definitions given to you within this exam and do not need to repeat
their definitions.

Unless specifically instructed otherwise, you may use any Java language features we have seen in
class.

You do not need to write visibility modifiers such as public and private.

When writing tests, you may use a shorthand for writing check-expects by drawing an arrow be-
tween two expressions to mean you expect the first to evaluate to same result as the second. For ex-
ample, you may write "$foo$.length() → 3" instead of t.checkExpect("foo".length(), 3). You do not have to place tests inside a test class.
Problem 1 (15 points). The designers of Java have decided that Java 38, which will be released in 2026, is going to remove boolean values from the language. Here is a potential substitute:

```java
interface Bool {
    Bool or(Bool b);     // is this or b true?
    Bool and(Bool b);    // is this and b true?
    Bool not();          // negate this
    Bool same(Bool b);   // is this and b the same?
}
```

Design two classes, True and False, that implement the Bool interface. (You may not use Boolean or boolean values, or any other built-in data types for that matter.)
[Space for problem 1.]
Problem 2 (15 points). Here is a data representation for (a small subset of) JSON documents:

```java
interface Json {
}

class JStr implements Json {
    String s;
    JStr(String s) { this.s = s; }
}

class JInt implements Json {
    Integer i;
    JInt(Integer i) { this.i = i; }
}

interface LoJson extends Json {

class JMt implements LoJson {}

class JCons implements LoJson {
    Json first;
    LoJson rest;
    JCons(Json first, LoJson rest) {
        this.first = first;
        this.rest = rest;
    }
}

Design a method Boolean hasString(Predicate<String> p) that determines if this document has a string within it that satisfies the predicate.
[Space for problem 2.]
Problem 3 (15 points). In mathematics, in addition to the concept of a pair (sometimes called an ordered pair), like (3, 8), there is also a concept of an unordered pair: \{3, 8\}. Like a standard pair, an unordered pair consists of two parts. However, in an unordered pair there’s no designated left or right part. Hence the unordered pair \{3, 8\} is the same as \{8, 3\}.

Design a class representation for unordered pairs and implement the equals and hashCode methods to correspond with the notion of equality described above. Make sure to obey the law of hashCode and be able to distinguish at least some objects with hashCode. (Note: you can make unordered pairs out of any kind of elements, but the type of those elements must be the same.)
[Space for problem 3.]
Problem 4 (15 points). Here is a parameterized definition for lists of elements of type T, with the visitor pattern implemented:

interface Listof<T> {
    <R> R accept(ListVisitor<T,R> v);
}

interface ListVisitor<T,R> {
    R visitEmpty(Empty<T> e);
    R visitCons(Cons<T> c);
}

class Empty<T> implements Listof<T> {
    <R> R accept(ListVisitor<T,R> v) { return v.visitEmpty(this); }
}

class Cons<T> implements Listof<T> {
    T first;
    Listof<T> rest;
    Cons(T first, Listof<T> rest) {
        this.first = first;
        this.rest = rest;
    }
    <R> R accept(ListVisitor<T,R> v) { return v.visitCons(this); }
}

Here is the start of a visitor that is given a Comparator<T> and T when constructed, and produces the largest element (according to the comparator) among all the elements in the list and the given T:

class Max<T> implements ListVisitor<T,T> {
    Comparator<T> c;
    T max;
    Max(Comparator<T> c, T max) {
        this.c = c;
        this.max = max;
    }
}

Here are some examples; finish the implementation of Max:

Comparator<Integer> lt = (i, j) -> i - j;
Listof<Integer> li = new Cons<>(1, new Cons<>(2, new Cons<>(3, new Empty<>()));
li.accept(new Max<>(lt, 2)) --> 3
li.accept(new Max<>(lt, 4)) --> 4