

Exercise 5

Behavioral Subtyping and Inheritance

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Task 1

Consider the following Java code:

```
1 interface I {};  
2  
3 class C {};  
4  
5 public class Main {  
6  
7     public static C getC() {  
8         return new C();  
9     }  
10  
11    public static void main(String[] argv) {  
12        C c1 = new C();  
13        C c2 = getC();  
14  
15        I i1 = (I) c1;  
16        I i2 = (I) c2;  
17    }  
18 }
```

Try to compile it. If it compiles, try to execute it. What happens? Why? Do you expect to see the same behavior if `I` were a class, instead of an interface?

Task 2

Consider the following Java classes:

```
class Number {  
    int n;  
  
    /// requires true  
    /// ensures n == p  
    void set(int p) {  
        n = p;  
    }  
}  
  
class UndoNaturalNumber extends Number {  
    int undo;  
  
    /// requires 0 < q  
    /// ensures n == q && undo == old(n)  
    void set(int q) {  
        undo = n;  
        n = q;  
    }  
}
```

```
}  
}
```

Is `UndoNaturalNumber` a behavioral subtype of `Number`, based on the rules from slide 62?

Now consider that we are using specification inheritance. What are the effective pre/post-conditions of the method `UndoNaturalNumber.set` according to the rules from slides 68 and 72?

Task 3

From a previous exam.

Assume the following types in Java:

```
enum Shift {DayShift, NightShift, SpecialShift}  
  
interface PostalWorker {  
    boolean sick();  
  
    ///ensures sick()  
    void catchDisease();  
  
    ///requires when == SpecialShift || when == DayShift  
    ///requires !sick()  
    int work(Shift when);  
}  
  
interface Bartender {  
    boolean sick();  
  
    ///ensures sick()  
    void catchDisease();  
  
    ///requires when == SpecialShift || when == NightShift  
    ///requires !sick()  
    int work(Shift when);  
}
```

The `work()` method can be called to request the corresponding person to work the specified shift. The value returned by `work()` is the average hourly wage that was earned during the working shift including tips.

A) Now we introduce another interface:

```
interface HardWorker extends PostalWorker, Bartender {  
    ///requires true  
    int work(Shift when);  
}
```

Assuming the rules for specification inheritance discussed in the course (slides 68 and 72), what is the effective precondition of the `work()` method of the `HardWorker` interface?

B) Now we add postconditions to all `work()` methods. Everything else remains as before.

```
interface PostalWorker {  
    ...  
    ///ensures result ≥ 15 && result ≤ 25  
    int work(Shift when);  
}  
  
interface Bartender {
```

```

    ...
    ///ensures result ≥ 20 && result ≤ 30
    int work(Shift when);
}

interface HardWorker extends PostalWorker, Bartender {
    ...
    ///ensures result ≥ 25 && result ≤ 50
    int work(Shift when);
}

```

Assuming the rules for specification inheritance discussed in the course (slides 68 and 72), what is the effective postcondition of the `work()` method of the `HardWorker` interface?

C) Consider the following code:

```

///requires worker != null
///requires !worker.sick()
int foo(HardWorker worker) {
    return worker.work(Shift.SpecialShift);
}

```

What is the range of possible return values of the method `foo()`?

D) Change the body of the method `foo()` such that it calls the `work()` method of `worker` in a way that makes it possible for this call to return 50.

Task 4

Suppose that we have a database, for which we would like to add an “automated key generation” feature. This means that each time the user inserts a new tuple, a unique key is automatically generated for the tuple by the system. A way to do this is to write a counter, which increments by 1 the value that it returns each time it is called. The method that generates a new key is called `generate`.

A) Write a Java class `IncCounter` and an accompanying specification for such a counter.

B) Annotate the following Java class with specifications and show that it is not a behavioural subtype of `IncCounter`.

```

class DecCounter {
    int key;
    DecCounter () { key = 0; }
    int generate () { return key--; }
}

```

C) Write an abstract class `GenerateUniqueKey` together with a specification, such that both `IncCounter` and `DecCounter` (with the specifications from tasks **A** and **B**) are behavioural subtypes of `GenerateUniqueKey`, and such that `GenerateUniqueKey.generate` generates unique keys. In the specification, you may use helper methods and fields.

Task 5

From a previous midterm.

Imagine extending the syntax of the Java language to support the following keywords:

- `subtypes`: used to declare that a class is a subtype of another class (without inheritance)
- `inherits`: used to declare that a class inherits from another class (without subtyping)

Now consider the following classes:

```
class A {
    public int foo (int n) { return n - 1; }
}

class B {
    public int foo (int n) { return n + 1; }
    public int bar (int n) { return foo(n) - 1; }
}

class C inherits A subtypes B {
    public int bar (int n) { return foo(n); }
}

class Main {
    public static void main(String[] args) {
        B b = new C();
        System.out.println( b.bar(3) );
    }
}
```

What should happen if we tried to compile the code and execute the method `main` from the class `Main`?

- The code should be rejected by the compiler
- The code should compile but the execution should fail
- The code should compile and print 2
- The code should compile and print 4
- None of the above

Task 6

Consider two classes `Stack` and `Queue`, implementing the standard LIFO/FIFO data structures, both of which have methods with the following signatures:

```
void push(Object o);
Object pop();
bool isEmpty();
int size();
void reverse();
```

- Despite having identical signatures, these two classes cannot be behavioral subtypes of each other. Why is this the case?
- When implementing these two classes, is there any possibility of code reuse? If so, give details.
- Describe at least one way of reusing the code in one class by the other - which programming language features are needed for this to work?