# **Section 6:** Midterm Review

Slides by Alex Mariakakis

{  

$$z = x + y;$$
  
{  
 $y = z - 3;$   
 $\{x > y\}$ 

{  

$$z = x + y;$$
  
{ $x > z - 3$ }  
 $y = z - 3;$   
{ $x > y$ }

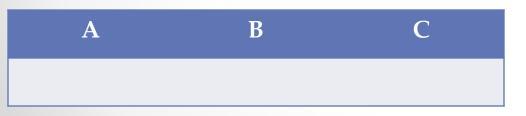
$$\{x > x + y - 3 => y < 3\}$$
  
z = x + y;  
$$\{x > z - 3\}$$
  
y = z - 3;  
$$\{x > y\}$$

```
{a + b + a - b = 42 => a = 21}
p = a + b;
{p + a - b = 42}
q = a - b;
{p + q = 42}
```

Suppose we have a BankAccount class with instance variable balance. Consider the following specifications:

- A. @effects decreases balance by amount
- B. @requires amount >= 0 and amount <= balance @effects decreases balance by amount
- C. @throws InsufficientFundsException if balance < amount @effects decreases balance by amount

```
I. void withdraw(int amount) {
    balance -= amount;
}
```

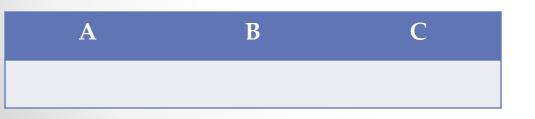


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- C. @throws InsufficientFundsException if balance < amount @effects decreases balance by amount

#### Which specifications does this implementation meet?

```
I. void withdraw(int amount) {
    balance -= amount;
}
```



Another way to ask the question:

If the client does not know the implementation, will the method do what he/she expects it to do based on the specification?

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#### Which specifications does this implementation meet?

```
I. void withdraw(int amount) {
    balance -= amount;
}
```

Α	В	С
О		

a. The method does exactly what the spec says

Suppose we have a BankAccount class with instance variable balance. Consider the following specifications:

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I. void withdraw(int amount) {
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Α	В	С
Ο	О	

- a. The method does exactly what the spec says
- b. If the client follows the @requires precondition, the code will execute as expected

Suppose we have a BankAccount class with instance variable balance. Consider the following specifications:

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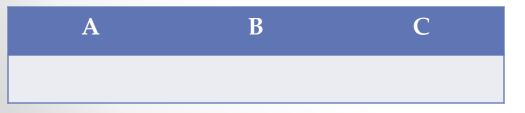
Α	В	С
0	0	X

- a. The method does exactly what the spec says
- b. If the client follows the @requires precondition, the code will execute as expected
- c. The method does not throw an exception

Suppose we have a BankAccount class with instance variable balance. Consider the following specifications:

- A. @effects decreases balance by amount
- B. @requires amount >= 0 and amount <= balance @effects decreases balance by amount
- C. @throws InsufficientFundsException if balance < amount @effects decreases balance by amount

```
II. void withdraw(int amount) {
    if (balance >= amount) balance -= amount;
}
```



Suppose we have a BankAccount class with instance variable balance. Consider the following specifications:

- A. @effects decreases balance by amount
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- C. @throws InsufficientFundsException if balance < amount @effects decreases balance by amount

Which specifications does this implementation meet?

```
II. void withdraw(int amount) {
    if (balance >= amount) balance -= amount;
}
```

Α	В	С
Х		

a. The balance will not always decrease

Suppose we have a BankAccount class with instance variable balance. Consider the following specifications:

- A. @effects decreases balance by amount
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```
II. void withdraw(int amount) {
    if (balance >= amount) balance -= amount;
}
```

Α	В	С
Х	0	

- a. The balance will not always decrease
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```
II. void withdraw(int amount) {
    if (balance >= amount) balance -= amount;
}
```

Α	В	С
X	Ο	Х

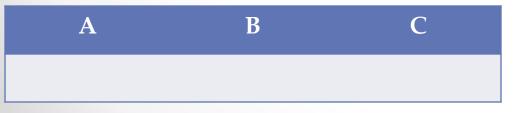
- a. The balance will not always decrease
- b. If the client follows the @requires precondition, the code will execute as expected
- c. The method does not throw an exception

Suppose we have a BankAccount class with instance variable balance. Consider the following specifications:

- A. @effects decreases balance by amount
- B. @requires amount >= 0 and amount <= balance @effects decreases balance by amount
- C. @throws InsufficientFundsException if balance < amount @effects decreases balance by amount

```
Which specifications does this implementation meet?
```

```
III.void withdraw(int amount) {
    if (amount < 0) throw new IllegalArgumentException();
    balance -= amount;
}</pre>
```



Suppose we have a BankAccount class with instance variable balance. Consider the following specifications:

- A. @effects decreases balance by amount
- B. @requires amount >= 0 and amount <= balance @effects decreases balance by amount
- C. @throws InsufficientFundsException if balance < amount @effects decreases balance by amount

```
Which specifications does this implementation meet?
```

```
III.void withdraw(int amount) {
    if (amount < 0) throw new IllegalArgumentException();
    balance -= amount;
  }</pre>
```

Α	В	С
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III.void withdraw(int amount) {
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Α	В	С
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- a. The balance will not always decrease
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Which specifications does this implementation meet?
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III.void withdraw(int amount) {
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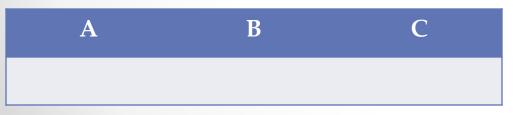
Α	В	С
Х	Ο	Х

- a. The balance will not always decrease
- b. If the client follows the @requires precondition, the code will execute as expected
- c. The method throws the wrong kind of exception and for the wrong reason

Suppose we have a BankAccount class with instance variable balance. Consider the following specifications:

- A. @effects decreases balance by amount
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- C. @throws InsufficientFundsException if balance < amount @effects decreases balance by amount

```
IV. void withdraw(int amount) throws InsufficientFundsException {
    if (balance < amount) throw new InsufficientFundsException();
    balance -= amount;
}</pre>
```



Suppose we have a BankAccount class with instance variable balance. Consider the following specifications:

- A. @effects decreases balance by amount
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- C. @throws InsufficientFundsException if balance < amount @effects decreases balance by amount

#### Which specifications does this implementation meet?

```
IV. void withdraw(int amount) throws InsufficientFundsException {
    if (balance < amount) throw new InsufficientFundsException();
    balance -= amount;</pre>
```

```
A B C
X
```

a. The balance will not always decrease

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IV. void withdraw(int amount) throws InsufficientFundsException {
    if (balance < amount) throw new InsufficientFundsException();
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```
ABCXO
```

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IV. void withdraw(int amount) throws InsufficientFundsException {
    if (balance < amount) throw new InsufficientFundsException();
    balance -= amount;</pre>
```

```
ABCXOO
```

- a. The balance will not always decrease
- b. If the client follows the @requires precondition, the code will execute as expected
- c. The method does exactly what the spec says

```
/**
```

```
* An IntPoly is an immutable, integer-valued polynomial
* with integer coefficients. A typical IntPoly value
* is a_0 + a_1*x + a_2*x^2 + ... + a_n*x_n. An IntPoly
* with degree n has coefficent a_n != 0, except that the
* zero polynomial is represented as a polynomial of
* degree 0 and a_0 = 0 in that case.
*/
```

```
public class IntPoly {
    int a[];
    // AF(this) = a has n+1 entries, and for each entry,
    // a[i] = coefficient a_i of the polynomial.
}
```

#### public class IntPoly {

/\*\*

\* Return a new IntPoly that is the sum of this and other

- \* @requires
- \* @modifies
- \* @effects
- \* @return
- \* @throws

\*/

public IntPoly add(IntPoly other);

}

public class IntPoly {

/\*\*

\* Return a new IntPoly that is the sum of this and other

\* @requires other != null

- \* @modifies **none**
- \* @effects none

\* @return a new IntPoly that is the sum of this and the other

\* @throws none

\*/

}

public IntPoly add(IntPoly other);

public class IntPoly {

/\*\*

\* Return a new IntPoly that is the sum of this and other

\* @requires other != null

\* @modifies none
 \* @effects none
 Note: if you have an instance variable in @modifies,
 it usually appears in @effects as well

\* @return a new IntPoly that is the sum of this and the other

\* @throws none

\*/

public IntPoly add(IntPoly other);

public class IntPoly {

/\*\*

\* Return a new IntPoly that is the sum of this and other

\* @requires other != null

- \* @modifies none
- \* @effects none

\* @return a new IntPoly that is the sum of this and the other

\* @throws none
 \*/
 Note: this is not the only answer, you could specify an exception in @throws or specify the output in @return

public IntPoly add(IntPoly other);

```
public class IntPoly {
    int a[];
    // AF(this) = a has n+1 entries, and for each entry,
    // a[i] = coefficient a_i of the polynomial.
    // Return the coefficients of this IntPoly
    public int[] getCoeffs() {
        return a;
    }
}
```

One of your colleagues is worried that this creates a potential representation exposure problem. Another colleague says there's no problem since an IntPoly is immutable. Is there a problem? Give a brief justification for your answer.

```
public class IntPoly {
    int a[];
    // AF(this) = a has n+1 entries, and for each entry,
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    public int[] getCoeffs() {
        return a;
    }
}
```

One of your colleagues is worried that this creates a potential representation exposure problem. Another colleague says there's no problem since an IntPoly is immutable. Is there a problem? Give a brief justification for your answer.

Yes, there is a problem. IntPoly seems immutable because there are no setters, but the return value is a reference to the same coefficient array stored in the IntPoly and the client code could alter those coefficients.

```
public class IntPoly {
    int a[];
    // AF(this) = a has n+1 entries, and for each entry,
    // a[i] = coefficient a_i of the polynomial.

// Return the coefficients of this IntPoly
public int[] getCoeffs() {
    return a;
```

If there is a representation exposure problem, give a new or repaired implementation of getCoeffs() that fixes the problem but still returns the coefficients of the IntPoly to the client. If it saves time you can give a precise description of the changes needed instead of writing the detailed Java code.

}

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public class IntPoly {
    int a[];
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If there is a representation exposure problem, give a new or repaired implementation of getCoeffs() that fixes the problem but still returns the coefficients of the IntPoly to the client. If it saves time you can give a precise description of the changes needed instead of writing the detailed Java code.

#### Create a new array the same length as a, copy the contents of a to it, and return the new array.

}

We would like to add a method to this class that evaluates the IntPoly at a particular value x. In other words, given a value x, the method valueAt (x) should return  $a_0 + a_1x + a_2x^2 + ... + a_nx^n$ , where  $a_0$  through an are the coefficients of this IntPoly.

For this problem, develop an implementation of this method and prove that your implementation is correct.

```
/** Return the value of this IntPoly at point x */
public int valueAt(int x) {
          int val = a[0];
          int xk = 1;
          int k = 0;
          int n = a.length-1; // degree of this, n \ge 0
             }
          while (k != n) 
                     {<u>___}}
xk = xk * x;</u>
                        ____}
                      val = val + a[k+1]*xk;
                      k = k + 1;
          return val;
```

}

```
/** Return the value of this IntPoly at point x */
public int valueAt(int x) {
          int val = a[0];
          int xk = 1;
          int k = 0;
          int n = a.length-1; // degree of this, n \ge 0
          {inv: xk = x^k && val = a[0] + a[1]*x + ... + a[k]*x^k}
          while (k != n) {
                    xk = xk * x:
                     {____}
                     val = val + a[k+1]*xk;
                     k = k + 1;
          return val;
```

}

```
/** Return the value of this IntPoly at point x */
public int valueAt(int x) {
          int val = a[0];
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          int n = a.length-1; // degree of this, n \ge 0
          {inv: xk = x^k && val = a[0] + a[1]*x + ... + a[k]*x^k}
          while (k != n) {
                    {inv && k != n}
                    xk = xk * x;
                     {____}
                     val = val + a[k+1]*xk;
                     k = k + 1;
          return val:
```

}

```
/** Return the value of this IntPoly at point x */
public int valueAt(int x) {
          int val = a[0];
          int xk = 1;
          int k = 0;
          int n = a.length-1; // degree of this, n >=0
          \{inv: xk = x^k \& val = a[0] + a[1]^*x + ... + a[k]^*x^k\}
          while (k != n) {
                     {inv && k != n}
                     xk = xk * x:
                     xk = x^{k+1} \& val = a[0] + a[1]^{*}x + ... + a[k]^{*}x^{k}
                     val = val + a[k+1]*xk;
                       }
                     k = k + 1;
          return val:
}
```

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/** Return the value of this IntPoly at point x */
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          \{inv: xk = x^k \& val = a[0] + a[1]^*x + ... + a[k]^*x^k\}
          while (k != n) {
                     {inv && k != n}
                     xk = xk * x:
                     {xk = x^{(k+1)} \& val = a[0] + a[1]^{*}x + ... + a[k]^{*}x^{k}}
                     val = val + a[k+1]*xk;
                     \{xk = x^{(k+1)} \& val = a[0] + a[1]^*x + ... + a[k+1]^*x^{(k+1)}\}
                     k = k + 1;
          return val:
}
```

```
/** Return the value of this IntPoly at point x */
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          int k = 0;
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          while (k != n) {
                     {inv && k != n}
                     xk = xk * x:
                     {xk = x^{(k+1)} \& val = a[0] + a[1]^{*}x + ... + a[k]^{*}x^{k}}
                     val = val + a[k+1]*xk;
                     \{xk = x^{(k+1)} \& val = a[0] + a[1]^*x + ... + a[k+1]^*x^{(k+1)}\}
                     k = k + 1:
                     {inv}
          return val:
}
```

```
/** Return the value of this IntPoly at point x */
public int valueAt(int x) {
          int val = a[0];
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          while (k != n) {
                     {inv && k != n}
                     xk = xk * x:
                     {xk = x^{(k+1)} \& val = a[0] + a[1]^{*}x + ... + a[k]^{*}x^{k}}
                     val = val + a[k+1]*xk;
                     \{xk = x^{(k+1)} \& val = a[0] + a[1]^*x + ... + a[k+1]^*x^{(k+1)}\}
                     k = k + 1:
                     {inv}
          }
          \{inv \&\& k = n => val = a[0] + a[1]*x + ... + a[n]*x^n\}
          return val:
```

}

Suppose we are defining a class to represent items stocked by an online grocery store. Here is the start of the class definition, including the class name and instance variables:

```
public class StockItem {
   String name;
   String size;
   String description;
   int quantity;
```

```
/* Construct a new StockItem */
public StockItem(...);
```

}

A summer intern was asked to implement an equals function for this class that treats two StockItem objects as equal if their name and size fields match. Here's the result:

```
/** return true if the name and size fields match */
public boolean equals(StockItem other) {
    return name.equals(other.name) && size.equals(other.size);
}
```

This equals method seems to work sometimes but not always. Give an example showing a situation when it fails.

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This equals method seems to work sometimes but not always. Give an example showing a situation when it fails.

```
Object s1 = new StockItem("thing", 1, "stuff", 1);
Object s2 = new StockItem("thing", 1, "stuff", 1);
System.out.println(s1.equals(s2));
```

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```
Object s1 = new StockItem("thing", 1, "stuff", 1);
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System.out.println(s1.equals(s2));
```

#### The equals method was overloaded, rather than overwritten

Show how you would fix the equals method so it works properly (StockItems are equal if their names and sizes are equal)

/\*\* return true if the name and size fields match \*/

Show how you would fix the equals method so it works properly (StockItems are equal if their names and sizes are equal)

```
/** return true if the name and size fields match */
@Override
public boolean equals(Object o) {
    if (!(o instanceof StockItem))
        return false;
    StockItem other = (StockItem) o;
    return name.equals(other.name) && size.equals(other.size);
}
```

Which of the following implementations of hashCode() are legal:

```
public int hashCode() {
        return name.hashCode();
}
public int hashCode() {
        return name.hashCode()*17 + size.hashCode();
}
public int hashCode() {
        return name.hashCode()*17 + quantity;
}
public int hashCode() {
        return quantity;
}
```

legal illegal

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```
public int hashCode() {
        return name.hashCode();
}
public int hashCode() {
        return name.hashCode()*17 + size.hashCode();
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public int hashCode() {
        return name.hashCode()*17 + quantity;
}
public int hashCode() {
        return quantity;
}
```

legal illegal  $\mathbf{O}$ 

Which of the following implementations of hashCode() are legal:

```
public int hashCode() {
         return name.hashCode();
                                                                  \mathbf{O}
}
public int hashCode() {
         return name.hashCode()*17 + size.hashCode();
                                                                  \bigcirc
}
public int hashCode() {
         return name.hashCode()*17 + quantity;
}
public int hashCode() {
         return quantity;
}
```

illegal

legal

Which of the following implementations of hashCode() are legal:

```
legal
                                                                            illegal
public int hashCode() {
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                                                                    \mathbf{O}
}
public int hashCode() {
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                                                                    \bigcirc
}
public int hashCode() {
                                                                               \bigcirc
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         return quantity;
}
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```
legal
                                                                              illegal
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                                                                      \mathbf{O}
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                                                                      \bigcirc
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                                                                                 \bigcirc
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}
public int hashCode() {
                                                                                 \bigcirc
         return quantity;
}
```

Which of the following implementations of hashCode() are legal:

```
legal
                                                                              illegal
public int hashCode() {
         return name.hashCode();
                                                                      \mathbf{O}
}
public int hashCode() {
         return name.hashCode()*17 + size.hashCode();
                                                                      \bigcirc
}
public int hashCode() {
                                                                                 \bigcirc
         return name.hashCode()*17 + quantity;
}
public int hashCode() {
                                 The equals method does not
                                                                                 \bigcirc
                                 care about quantity
         return quantity;
}
```

Which implementation do you prefer?

```
public int hashCode() {
    return name.hashCode();
}
public int hashCode() {
    return name.hashCode()*17 + size.hashCode();
}
```

Which implementation do you prefer?

```
public int hashCode() {
    return name.hashCode();
}
public int hashCode() {
    return name.hashCode()*17 + size.hashCode();
}
```

(ii) will likely do the best job since it takes into account both the size and name fields. (i) is also legal but it gives the same hashCode for StockItems that have different sizes as long as they have the same name, so it doesn't differentiate between different StockItems as well as (ii).

Suppose we are specifying a method and we have a choice between either requiring a precondition (e.g., @requires: n > 0) or specifying that the method throws an exception under some circumstances (e.g., @throwsIllegalArgumentException if n <= 0).

Assuming that neither version will be significantly more expensive to implement than the other and that we do not expect the precondition to be violated or the exception to be thrown in normal use, is there any reason to prefer one of these to the other, and, if so, which one?

Suppose we are specifying a method and we have a choice between either requiring a precondition (e.g., @requires: n > 0) or specifying that the method throws an exception under some circumstances (e.g., @throwsIllegalArgumentException if  $n \le 0$ ).

Assuming that neither version will be significantly more expensive to implement than the other and that we do not expect the precondition to be violated or the exception to be thrown in normal use, is there any reason to prefer one of these to the other, and, if so, which one?

It would be better to specify the exception. That reduces the domain of inputs for which the behavior of the method is unspecified. It also will cause the method to fail fast for incorrect input, which should make the software more robust – or at least less likely to continue execution with erroneous data.

Note: You could just as easily argue the other way. It may be better to specify the precondition because once the exception is in the specification, it has to stay there because the client may expect it.

Suppose we are trying to choose between two possible specifications for a method. One of the specifications S is stronger than the other specification W, but both include the behavior needed by clients. In practice, should we always pick the stronger specification S, always pick the weaker one W, or is it possible that either one might be the suitable choice? Give a brief justification of your answer, including a brief list of the main criteria to be used in making the decision.

Suppose we are trying to choose between two possible specifications for a method. One of the specifications S is stronger than the other specification W, but both include the behavior needed by clients. In practice, should we always pick the stronger specification S, always pick the weaker one W, or is it possible that either one might be the suitable choice? Give a brief justification of your answer, including a brief list of the main criteria to be used in making the decision.

Neither is necessarily better. What is important is picking a specification that is simple, promotes modularity and reuse, and can be implemented efficiently.

(Many answers focused narrowly on which would be easier to implement. While that is important – we don't want a specification that is impossible to build – it isn't the main thing that determines whether a system design is good or bad.)

# **Midterm** Topics

- Reasoning about Code
- Specification vs. Implementation
- Abstract Data Types
- Abstract Functions
- Representation Invariants
- Testing
- Identity & Equality
- Exceptions vs. Assertions