This 90-minute exam has 6 questions (numbered 0..5) worth a total of 100 points. Spend a few minutes looking at all questions before beginning so that you can see what is expected. Budget your time wisely. Use the back of the pages, if you need more space.

**Question 0 (2 points).** Write your netid and your name, legibly, at the top of each page (Hint: do it now).

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**Question 1 (10 points).** Answer the following questions briefly

(a) What is a loop invariant?

(b) Fill in the assignment so that the following assertion is true.

```java
// {y is sum of 1..k–1}

y = ;

// {y is sum of 1..k+1}
```

(c) Write a boolean expression that evaluates to true when variable b is an instance of class Employee, false otherwise.
Question 2 (20 points). Write a complete class MyCount that contains a static function howMany that returns how many Integers in its parameter Vector v are 0. Assume that v is not null. Class MyCount should contain only one thing: the static function. Put a suitable javadoc specification on the function.

The elements of Vector v can be any type of object. Function howMany should count how many of v’s elements are of class Integer and contain the integer 0 and return that number as an int. Examples: Below, we use ? for the value of an Object that is not of class Integer. For an object that is of class Integer, we use the integer that it wraps.

If v contains (?, 0, ?, 1, ?, 0, ?), the result is 2.
If v is empty, which we can write as (), the result is 0.
If v is (6, 0, −1, 1, 4), the result is 1.

The following methods in class Vector might be useful (not all of them are):

<table>
<thead>
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<th>Return</th>
<th>Method</th>
<th>Purpose</th>
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<tbody>
<tr>
<td>Object</td>
<td>v.get(int k)</td>
<td>v[k]</td>
</tr>
<tr>
<td>void</td>
<td>v.set(int k, Object ob)</td>
<td>replace v[k] by ob</td>
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<tr>
<td>int</td>
<td>v.size()</td>
<td>the number of elements in v’s list</td>
</tr>
<tr>
<td>int</td>
<td>v.indexOf(Object ob)</td>
<td>i, where v[i] is ob; -1 if ob not in v</td>
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This method in class Integer might be useful:

| int      | ob.intValue() | the value in this Integer, ob, as an int |
Question 3 (21 points). (a) What is the apparent type of a variable? What is the real type of a variable?

(b) Below are definitions of four classes.

```java
public class Movie {
    private String title; // title of the movie
    private int length; // length in minutes

    /** Constructor: document with title t and length len */
    public Movie(String t, int len) {
        title= t;
        length= len;
    }

    /** = title of this Movie */
    public String getTitle() {
        return title;
    }

    /** = length of this document, in minutes */
    public int getLength() {
        return length;
    }

    /** = the popularity --shorter means more popular */
    public int popularity() {
        return 240 - length;
    }
}

public class Documentary extends Movie {
    private String topic; //
    /** Constructor: instance with title t, length n, and topic p */
    public Documentary(String t, int n, String p) {
        super(t, n);
        topic= p;
    }

    /** = "Documentary" */
    public String DocumentaryType() {
        return "Documentary";
    }

    /** = popularity of this instance */
    public int popularity() {
        return 200 - getLength();
    }
}

public class Short extends Documentary {
    /** Constructor: instance with title t, length n, and topic p */
    public Short(String t, int n, String p) {
        super(t, n, p);
    }

    /** = "Short Doc" */
    public String DocumentaryType() {
        return "Short Doc";
    }
}

public class Trailer extends Movie {
    /** Constructor: a trailer of movie t.
     * Trailers are 1 minute long */
    public Trailer(String t) {
        super(t, 1);
    }
}
```

For each pairs of statements below, write the value of d after execution. If the statements lead to an error, write “BAD” and briefly explain the error. (The question continues on the next page.)

(1) Documentary e = new Short("War", 5, "Iraq");
    boolean d = "Short Doc".equals(e.DocumentaryType());

(2) Movie c = new Documentary(null, 3, "Carter Peace Center");
    int d = c.popularity();

(3) Short b = (Short)(new Documentary("", 2, "WMD"));
    int d = b.DocumentaryType().length();

(4) Movie a = (Movie)(new Trailer("Harry Potter"));
    int d = a.popularity();

(5) Movie f = new Short("War", 1, "Vietnam");
    char d = f.DocumentaryType().charAt(1);
Question 4 (24 points). (a) Write an instance method equals(Object obj) for class Documentary in Question 3. Here is the class definition, with only method equals for you to fill in.

```java
public class Documentary extends Movie {
    /** = "obj is a non-null Documentary with the same values in its fields as this Documentary" */
    public boolean equals(Object obj) {
        // Your implementation here
    }
}
```

(b) Assuming that d1 contains (the name of) a Documentary object, draw the frame for method call d1.equals(null).
Question 5 (23 points). Write a method shortTitle() in class Movie in Question 3. The method returns the title but with all vowels ‘a’, ‘e’, ‘i’, ‘o’, and ‘u’ removed except those that begin a word (i.e. are the first character of the title or are preceded by a blank).

Examples:
If the title is “Harry Potter”, the output is “Hrry Ptttr”.
If the title is “On the Outer Bank”, the output is “On th Otr Bnk”.
If title is “One Ocloooock”, the output is “On Oclck”.

You must write a loop. A loop invariant is given below, and you must use it to develop the loop. Your grades will be determined by how well you deal with the four loopy questions. Note: for a String s, s.length() yields the length of s and s.charAt(int k) yields the character at position k.

```java
public class Movie {
    String title; // title of the Movie
    /** = the title but with vowels removed (except those that begin a word).
     * Precondition: title != null */
    public String shortTitle() {

        //Invariant: s contains title[0..k-1] but with vowels removed
        // (except those that begin a word)

        while ( ) {

            //Postcondition: s contains title[0..] but with vowels removed
            // (except those that begin a word)
        }
    }
}
```