1. Give em the ‘Ol Switcheroo

For each function call in the main method, write out the x and y values of both foobar and baz after executing that line. (Spring ’15, MT1)

```java
public class Foo {
    public int x, y;

    public Foo (int x, int y) {
        this.x = x;
        this.y = y;
    }
}

public static void switcheroo (Foo a, Foo b) {
    Foo temp = a;
    a = b;
    b = temp;
}

public static void fliperoo (Foo a, Foo b) {
    Foo temp = new Foo(a.x, a.y);
    a.x = b.x;
    a.y = b.y;
    b.x = temp.x;
    b.y = temp.y;
}

public static void swaperoo (Foo a, Foo b) {
    Foo temp = a;
    a.x = b.x;
    a.y = b.y;
    b.x = temp.x;
    b.y = temp.y;
}

public static void main (String[] args) {
    Foo foobar = new Foo(10, 20);
    Foo baz = new Foo(30, 40);
    switcheroo(foobar, baz);   foobar.x: ___ foobar.y: ___ baz.x: ___ baz.y: ___
    fliperoo(foobar, baz);     foobar.x: ___ foobar.y: ___ baz.x: ___ baz.y: ___
    swaperoo(foobar, baz);     foobar.x: ___ foobar.y: ___ baz.x: ___ baz.y: ___
}
```
Solution:

line 34: foobar.x: 10 foobar.y: 20 baz.x: 30 baz.y: 40
line 35: foobar.x: 30 foobar.y: 40 baz.x: 10 baz.y: 20
line 36: foobar.x: 10 foobar.y: 20 baz.x: 10 baz.y: 20

Here is a video walkthrough of the solutions for this problem.

Explanation:

**switcheroo:** Note that switcheroo assigns a local variable temp to a, but never mutates objects, e.g. by reassigning a.x. This means that all switcheroo does is move around its local pointers to temp, a, and b; nothing in foobar or baz is actually changed.

**fliperoo:** Here, a points to foobar and b points to baz. temp refers to an object with the same initial x and y values as a, which are 10 and 20 respectively. Lines 15 and 16 change foobar to have \{x: 30, y: 40\}. Then, lines 17 and 18 allow baz to take on the same x and y values as temp, which are \{x: 10, y: 20\}.

**swaperoo:** In swaperoo, instead of creating a new object, we simply point temp to the same object as a. In lines 22 and 23, we override foobar’s x and y values to become the same as baz’s: \{x: 10, y: 20\}. In line 24 and 25, we assign baz’s x and y values to be equal to temp’s. But remember, temp is pointing to the same object as a, which points to foobar, and which we just modified to have \{x: 10, y: 20\}. Thus, baz does not change.
2 Flatten

Write a method `flatten` that takes in a 2-D array `x` and returns a 1-D array that contains all of the arrays in `x` concatenated together.

For example, `flatten([{1, 2, 3}, {}, {7, 8}])` should return `{1, 2, 3, 7, 8}`.

(Summer 2016 MT1)

```java
public static int[] flatten(int[][] x) {
    int totalLength = 0;
    for (int i = 0; i < x.length; i++) { // Sum the total length of all arrays.
        totalLength += x[i].length;
    }
    int[] a = new int[totalLength];
    int aIndex = 0;
    for (int i = 0; i < x.length; i++) { // Place each element in the 1-D array.
        for (int j = 0; j < x[i].length; j++) {
            a[aIndex] = x[i][j];
            aIndex++;
        }
    }
    return a;
}
```
Solution:

```java
public static int[] flatten(int[][] x) {
    int totalLength = 0;
    for (int[] arr: x) {
        totalLength += arr.length;
    }
    int[] a = new int[totalLength];
    int aIndex = 0;
    for (int[] arr: x) {
        for (int value: arr) {
            a[aIndex] = value;
            aIndex++;
        }
    }
    return a;
}
```

Alternate Solutions:

```java
public static int[] flatten(int[][] x) {
    int totalLength = 0;
    for (int[] arr: x) {
        totalLength += arr.length;
    }
    int[] a = new int[totalLength];
    int aIndex = 0;
    for (int[] arr: x) {
        System.arraycopy(arr, 0, a, aIndex, arr.length);
        aIndex += arr.length;
    }
    return a;
}
```

```java
public static int[] flatten(int[][] x) {
    int totalLength = 0;
    for (int i = 0; i < x.length; i++) {
        totalLength += x[i].length;
    }
    int[] a = new int[totalLength];
    int aIndex = 0;
    for (int i = 0; i < x.length; i++) {
        for (int j = 0; j < x[i].length; j++) {
            a[aIndex] = x[i][j];
            aIndex++;
        }
    }
    return a;
}
```
Here is a video walkthrough of the solutions for this problem.

**Explanation:** All these solutions do essentially the same thing. In Java, an array’s length must be known before we can instantiate it—as such, we have to loop over all inner arrays to get the `totalLength` of our flattened array. Then, we iterate over the elements of x, filling a as we go. `aIndex` keeps track of where we are in the a array.
3 \hspace{1em} \textbf{IntList to Array}

For this problem we will implement a version of \texttt{arraycopy} that copies elements from an \texttt{IntList} into an array of \texttt{int}s. As a reminder, here is the \texttt{arraycopy} method:

\begin{verbatim}
System.arraycopy(Object src, int sourcePos, Object dest, int destPos, int len)
\end{verbatim}

\texttt{System.arraycopy} copies \texttt{len} elements from array \texttt{src} (starting at index \texttt{source}) to array \texttt{destArr} (starting from index \texttt{dest}).

To simplify things, let’s restrict ourselves to using only \texttt{int[]}, and assume that \texttt{srcList} and \texttt{destArr} are not null. Additionally, assume that \texttt{sourcePos}, \texttt{destPos}, and \texttt{len} will not cause an \texttt{IndexOutOfBoundsException} to be thrown.

For example, let \texttt{IntList L} be \texttt{(1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5)} and \texttt{int[]} \texttt{arr} be an empty array of length 3. Calling \texttt{arrayCopyFromIntList(L, 1, \texttt{arr}, 0, 3)} will result in \texttt{arr=\{2, 3, 4\}}.

\begin{verbatim}
/** Works just like System.arraycopy, except srcList is of type IntList. */
public static void arrayCopyFromIntList(IntList srcList, int sourcePos,
                                        int[] destArr, int destPos, int len) {

    for (int i = sourcePos; i < sourcePos; i += 1) {
        srcList = srcList.tail;
    }

    for (int i = destPos; i < destPos + len; i += 1) {
        destArr[i] = srcList.head;
        srcList = srcList.tail;
    }
}
\end{verbatim}

\textbf{Solution:}

\begin{verbatim}
/** Works just like System.arraycopy, except srcList is of type IntList. */
public static void arrayCopyFromIntList(IntList srcList, int sourcePos,
                                        int[] destArr, int destPos, int len) {

    for (int i = 0; i < sourcePos; i += 1) {
        srcList = srcList.tail;
    }

    for (int i = destPos; i < destPos + len; i += 1) {
        destArr[i] = srcList.head;
        srcList = srcList.tail;
    }
}
\end{verbatim}
Here is a video walkthrough of the solutions for this problem. **Explanation:**

`arrayCopyFromIntList` should copy over `len` items from our source `IntList` to our destination array, starting at `sourcePos` in the source `IntList` and `destPos` in the destination array.

In the first loop, we move along the `srcList` to get the correct starting position. In the second loop, we copy over `len` items from the `srcList`, starting at `destPos` in the array.
4  Static Books

Suppose we have the following `Book` and `Library` classes.

```java
class Book {
    public String title;
    public Library library;
    public static Book last = null;

    public Book(String name) {
        title = name;
        last = this;
        library = null;
    }

    public String getTitle() {
        return title;
    }
}

class Library {
    public Book[] books;
    public int index;
    public static int totalBooks = 0;

    public Library(int size) {
        books = new Book[size];
        index = 0;
    }

    public void addBook(Book book) {
        books[index] = book;
        index++;
        totalBooks++;
        book.library = this;
    }

    public static String lastBookTitle() {
        return last.title;
    }

    public String getTitle() {
        return title;
    }
}
```

(a) For each modification below, determine whether the code of the `Library` and `Book` classes will compile or error if we only made that modification, i.e. treat each modification independently.

1. Change the `totalBooks` variable to `non static`
2. Change the `lastBookTitle` method to `non static`
3. Change the `addBook` method to `static`
4. Change the `last` variable to `non static`
5. Change the `library` variable to `static`

**Solution:**

Here is a video walkthrough of the solutions for this part and the next.

1. Compile
   `totalBooks` is only used inside of a nonstatic function, so changing it to nonstatic would not cause compilation errors (although note that it no longer counts the total number of books correctly).

2. Compile
   Both static and nonstatic methods can access static variables, so changing `lastBookTitle` to be static would still allow it to access `last.title`.

3. Error
   Static methods cannot access instance variables, so changing `addBook` to be static would cause it to be unable to find the `books` or `index` variables.
4. Error
Again, static methods cannot access instance variables, so changing last
to be static would cause lastBookTitle to fail.

5. Compile
Constructors are allowed to modify static variables; similarly, instances
of a class can access that class’s static variables. Thus, changing library
to be static would not affect the Book constructor or book.library in
addBook.
(b) Using the Book and Library classes from before, write the output of the main method below. If a line errors, put the precise reason it errors and continue execution.

```
public class Main {
    public static void main(String[] args) {
        System.out.println(Library.totalBooks); 0
        System.out.println(Book.lastBookTitle()); Error, NullPointerException
        System.out.println(Book.getTitle()); Error, does not compile

        Book goneGirl = new Book("Gone Girl");
        Book fightClub = new Book("Fight Club");

        System.out.println(goneGirl.title); Gone Girl
        System.out.println(Book.lastBookTitle()); Fight Club

        Library libraryA = new Library(1);
        Library libraryB = new Library(2);
        libraryA.addBook(goneGirl);

        System.out.println(libraryA.index); 2
        System.out.println(libraryA.totalBooks); 2
        libraryA.totalBooks = 0;
        libraryB.addBook(fightClub);
        libraryB.addBook(goneGirl);

        System.out.println(libraryB.index); 2
        System.out.println(Library.totalBooks); Error, doesn't compile
        System.out.println(goneGirl.library.books[0].title); Error, does not compile
    }
}
```

Solution:

```
public class Main {
    public static void main(String[] args) {
        System.out.println(Library.totalBooks); 0
        System.out.println(Book.lastBookTitle()); Error, NullPointerException
        System.out.println(Book.getTitle()); Error, does not compile

        Book goneGirl = new Book("Gone Girl");
        Book fightClub = new Book("Fight Club");

        System.out.println(goneGirl.title); Gone Girl
        System.out.println(Book.lastBookTitle()); Fight Club
```
System.out.println(fightClub.lastBookTitle());       Fight Club
System.out.println(goneGirl.last.title);             Fight Club

Library libraryA = new Library(1);
Library libraryB = new Library(2);
libraryA.addBook(goneGirl);

System.out.println(libraryA.index);                  1
System.out.println(libraryA.totalBooks);              1

libraryA.totalBooks = 0;
libraryB.addBook(fightClub);
libraryB.addBook(goneGirl);

System.out.println(libraryB.index);                  2
System.out.println/Library.totalBooks);              2
System.out.println(goneGirl.library.books[0].title);  Fight Club

Explanation:
Line 3: The static variable totalBooks is initialized to 0.
Line 4: We haven’t created any books yet, so the Book constructor has never been called, and last is null. When we attempt to call lastBookTitle, we access the title property of a null object, which results in a NullPointerException.
Line 5: You cannot call a nonstatic method using the class name; only instances of the class can call their instance methods.
Line 10: The string "Gone Girl" was passed into the constructor of the goneGirl object, so its title is Gone Girl (printing removes quotes).
Line 11: Whenever a new book is created, the static variable last points to it. Thus, last points to the most recently created book, fightClub.
Line 12: Instances of a class can access static variables.
goneGirl.last is the same as Book.last, which is fightClub.
Line 19: index gets incremented each time we call addBook, so after adding goneGirl to libraryA, its index is 1.
Line 20: totalBooks gets incremented each time we call addBook, so after adding goneGirl to libraryA, its totalBooks is 1. (Remember, instances can access a class’s static variables).
Line 26: index gets incremented each time we call addBook, and it is an instance variable, so each library has its own copy of index. After adding goneGirl and fightClub to libraryB, its index is 2.
Line 27: totalBooks is a static variable, so on line 22, totalBooks gets reset to 0 for the entire class. Then, it gets incremented twice in addBook for a total of 2.
Line 28: In addBook, we set book.library equal to the library to which that book was most recently added to. goneGirl was most recently added
to libraryB, so its library is libraryB. Each library has its own books array which tracks books from oldest to newest addition. The first book added to libraryB was fightClub.