Collections & Maps

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Schedule for Next Few Weeks

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- 11/16: Collections & Maps
  - HW8/Optional Final Project(s) begin (due 12/7)
- 11/21: No Class -- Open Office Hours (in Meyerson Hall B3)
- 11/23: No Class -- Thanksgiving Break!
- 11/28: Regular Expressions
- 11/30: Connecting to Databases
- 12/5: TBD
- 12/7: No Class -- Open Office Hours (in Meyerson Hall B3)
  - Final Exam posted (due 12/19)
- 12/12: No Class -- Open Office Hours (in Meyerson Hall B3)

Collections & Maps

Collections

- A Collection is a structured group of objects

Ref: https://docs.oracle.com/javase/8/docs/api/java/util/Collection.html

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- Java includes a *Collections Framework* which is a unified architecture for representing and manipulating different kinds of collections
  - Collections are defined in java.util
  - The *Collections Framework* is designed around a set of standard interfaces
  - There are a number of predefined implementations (i.e. classes)

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- An ArrayList is one type (or implementation) of Collection
  - To be more precise, ArrayList is an implementation of List, which is a *subinterface* of Collection

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  - To be more precise, ArrayList is an implementation of List, which is a *subinterface* of Collection
- For reference, an Array is NOT a type (or implementation) of any of the Collection interfaces

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Types of Collections & “Collection-Like” Things (Maps)

- Java supplies several types of Collections
  - Here are some:
    - Set: Cannot contain duplicate elements, order is not important
    - SortedSet: Like a Set, but order is important
    - List: May contain duplicate elements, order is important

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  - Here are some:
    - Set: Cannot contain duplicate elements, order is not important
    - SortedSet: Like a Set, but order is important
    - List: May contain duplicate elements, order is important
- Java also supplies some “collection-like” things (i.e. Maps)
  - Here are some:
    - Map: A “dictionary” that associates keys with values, where order is not important
    - SortedMap: Like a Map, where order is important

Ref: https://docs.oracle.com/javase/8/docs/api/java/util/Collection.html
https://docs.oracle.com/javase/8/docs/api/java/util/Map.html

Hierarchy of Collections

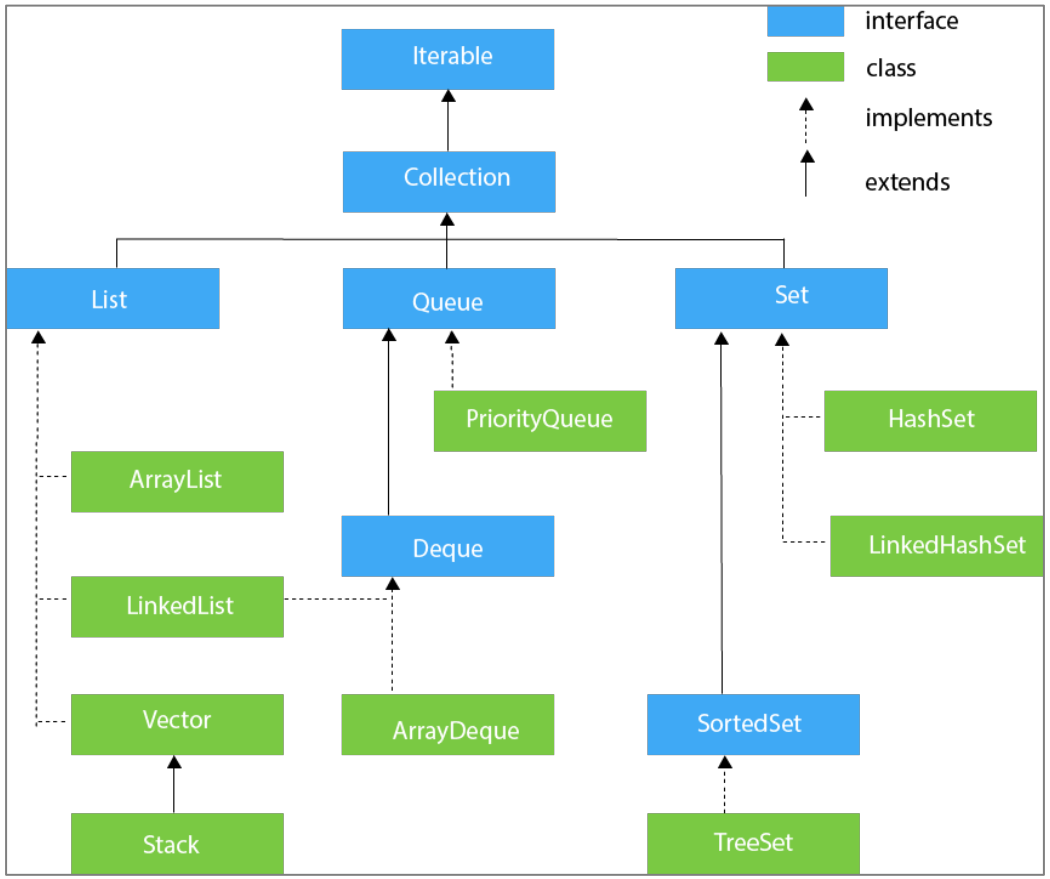

Image: https://www.javatpoint.com/collections-in-java

Hierarchy of “Collection-Like” Things (Maps)

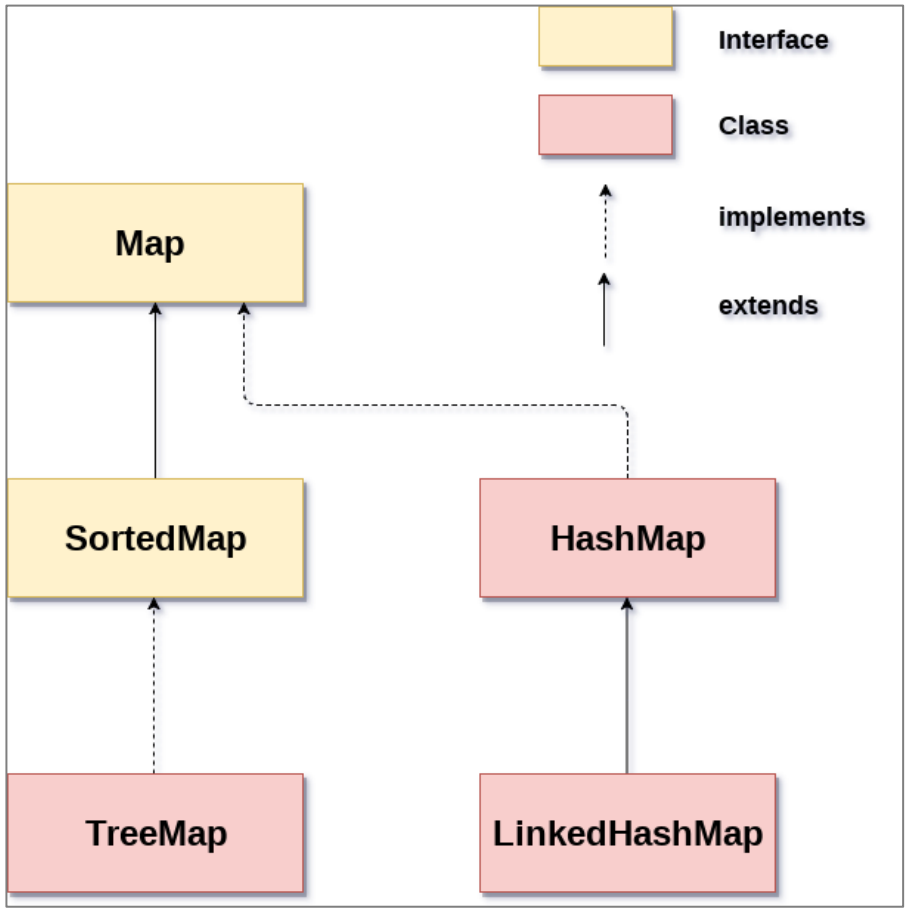

Image: https://www.javatpoint.com/java-map

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- All *subinterfaces* include the methods in the Collection interface
- Here are some, but not all of the methods:

```
boolean add(E o)
boolean contains(Object o)
boolean remove(Object o)
boolean isEmpty()
int size()
Object[] toArray()
Iterator<E> iterator()
```

Implementations

Each interface has at least one implementation. Here are some:

- List – ArrayList, LinkedList
- Deque (Double-ended queue) – ArrayDeque, ConcurrentLinkedDeque, LinkedList
- Set – HashSet, LinkedHashSet, TreeSet
- Map – HashMap, TreeMap

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- Some additional specialized methods of the List interface:

```
void add(int index, E element)
E get(int index)
void set(int index, E element)
ListIterator<E> listIterator()
```

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```
void addFirst(E o)
void addLast(E o)
E getFirst()
E getLast()
E removeFirst()
E removeLast()
```

Set Interface

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- Models the mathematical set
- Does not allow duplicates
- No additional methods other than those in the Collection interface (*add*, *remove*, *size*, etc.)

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Important methods:

```
V put(K key, V value)
V get(Object key)
```

General Rules for Selecting an Implementation

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- Map – Choose TreeMap if you want to access the collection in key order. Otherwise, choose HashMap.

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- Use an *iterator* instead of a for loop to modify the collection while traversing

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```
//get iterator object from treeset (ordered set)
Iterator<String> it = treeSet.iterator();

//modify (remove) the values using the iterator while traversing the
treeset
while(it.hasNext()) {
    if(it.next().equals(“red”)) {
        it.remove();
    }
}
```

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- A *ConcurrentModificationException* may be thrown when a collection is modified while traversing, by any means other than through its *iterator*

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for(String s : treeSet) {
    if(s.equals(“red”)) {
        //throws Exception
        treeSet.remove(“red”);
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        it.remove();
    }
}
```

Exercises with Collections

CollectionsClass

CollectionsClass.java

```
 1 import java.util.ArrayList;
13
14 /**
15  * Class with various methods for using different kinds of Collections.
16  */
17 public class CollectionsClass {
18
```

Remove from a List

```
19      /**
20       * Takes an ArrayList of integers and two integer values min and max
21       * as parameters and removes all elements with values in the range min through
22       * max (inclusive).
23       *
24       * For example, if an ArrayList named 'list' stores
25       * [7, 9, 4, 2, 7, 7, 5, 3, 5, 1, 7, 8, 6, 7], the call of
26       * removeRange(list, 5, 7) should change the list to [9, 4, 2, 3, 1, 8].
27       *
28       * Uses Iterator.
29       *
30       * @param list of values
31       * @param min of range
32       * @param max of range
33       */
34      public static void removeRange(ArrayList<Integer> list, int min, int max) {
35
36          //Create iterator and use it to remove items in place
37          //Avoid ConcurrentModificationException
38          Iterator<Integer> iterator = list.iterator();
39          while (iterator.hasNext()) {
40              Integer next = iterator.next();
41              if (next >= min && next <= max) {
42                  iterator.remove();
43              }
44          }
45      }
```

Remove from a List

```
310
311     public static void main(String[] args) {
312
313         //removeRange
314         //create array of Integers
315         Integer[] removeRangeArray = {7, 9, 4, 2, 7, 7, 5, 3, 5, 1, 7, 8, 6, 7};
316         ArrayList<Integer> list = new ArrayList<Integer>();
317
318         //add all items from Integer array to arraylist
319         list.addAll(Arrays.asList(removeRangeArray));
320         CollectionsClass.removeRange(list, 5, 7);
321
322         //expected output [9, 4, 2, 3, 1, 8]
323         System.out.println("removeRange: " + list);
324         System.out.println();
325
```

Add to a List

```
47      /**
48       * Takes an ArrayList of strings as a parameter and modifies the list
49       * by placing a "*" in between each element, and at the start
50       * and end of the list.
51       *
52       * For example, if a list named 'list' contains
53       * ["the", "quick", "brown", "fox"],
54       * the call of addStars(list) should modify it to store
55       * ["*", "the", "*", "quick", "*", "brown", "*", "fox", "*"].
56       *
57       * @param list of values to add stars
58       */
59      public static void addStars(ArrayList<String> list) {
60
61          //copy all values in arraylist to array
62          //Note: toArray takes an empty array into which the values are to be stored
63          String[] array = list.toArray(new String[list.size()]);
64
65          //empty original arraylist
66          list.removeAll(Arrays.asList(array));
67
68          //add stars and values back into the original arraylist
69          list.add("*");
70          for (String s : array) {
71              list.add(s);
72              list.add("*");
73          }
74      }
75
```

Add to a List

```
199
200         //addStars
201         //create array of Strings
202         String[] addStar = {"the", "quick", "brown", "fox"};
203
204         //add all items from String array to arraylist
205         ArrayList<String> sList = new ArrayList<String>();
206         sList.addAll(Arrays.asList(addStar));
207
208         CollectionsClass.addStars(sList);
209
210         //expected output ["*", "the", "*", "quick", "*", "brown", "*", "fox", "*"]
211         System.out.println("addStars: " + sList);
212         System.out.println();
213
```

Count Words

```
63      /**
64       * The classic word-count algorithm: given an array of strings,
65       * return a Map<String, Integer> with a key for each different string,
66       * with the value the number of times that string appears in the array.
67       *
68       * wordCount(["a", "b", "a", "c", "b"])  {"a": 2, "b": 2, "c": 1}
69       * wordCount(["c", "b", "a"])  {"a": 1, "b": 1, "c": 1}
70       * wordCount(["c", "c", "c", "c"]) {"c": 4}
71       *
72       * Uses HashMap
73       *
74       * @param strings to count
75       * @return map of word counts, where key is word and value is count
76       */
77      public static Map<String, Integer> wordCount(String[] strings) {
78
79          //create a hashmap (has no order)
80          Map<String, Integer> map = new HashMap<String, Integer>();
81
```

Count Words

```
82          //iterate over given array
83          for (String s : strings) {
84
85              //if map does not contain string as a key
86              if (!map.containsKey(s)) {
87
88                  //add key with default value 1
89                  map.put(s, 1);
90              } else {
91
92                  //replace the old count with incremented count
93                  map.replace(s, map.get(s) + 1);
94              }
95          }
96
97          return map;
98      }
```

Count Words

```
339         //wordCount
340         String[] s = {"a", "b", "a", "c", "b"};
341         Map<String, Integer> ret = CollectionsClass.wordCount(s);
342
343         //expected: {a=2, b=2, c=1}
344         System.out.println("wordCount: " + ret);
345         System.out.println();
```

Count Unique Words

```
110     /**
111      * Takes an array of Strings as a parameter and returns a count of the
112      * number of unique words in the array.
113      *
114      * DOES consider capitalization and/or punctuation; for example,
115      * "Hello", "hello", and "hello!!" are considered different words.
116      *
117      * Uses HashSet.
118      *
119      * @param words to count
120      * @return count of unique words
121      */
122     public static int countUniqueWords(String[] words) {
123
124         //create hashset (has no order)
125         Set<String> hashSetWords = new HashSet<String>(Arrays.asList(words));
126
127         return hashSetWords.size();
128     }
```

Count Unique Words

```
347         //countUniqueWords
348         String[] countUniqueWordsArray = {"hello", "izzy", "and", "Elise", "Hello"};
349
350         //expected: 5
351         System.out.println("countUniqueWords: "
352                 + CollectionsClass.countUniqueWords(countUniqueWordsArray));
353         System.out.println();
354
```

Count Unique Words (Case Insensitive)

```
129
130     /**
131      * Takes an array of Strings as a parameter and returns a count
132      * of the number of unique words in the array.
133      *
134      * DOES NOT consider capitalization; for example,
135      * "Hello" and "hello" should NOT BE considered different words for this problem.
136      *
137      * Uses TreeSet.
138      *
139      * @param words to count
140      * @return count of unique words
141      */
142     public static int countUniqueWordsCaseInsensitive(String[] words) {
143
144         //create treeset (like hashset, but ordered)
145         //Note: String.CASE_INSENSITIVE_ORDER makes internal comparison use equalsIgnoreCase
146         Set<String> treeSetWords = new TreeSet<String>(String.CASE_INSENSITIVE_ORDER);
147         treeSetWords.addAll(Arrays.asList(words));
148
149         return treeSetWords.size();
150     }
```

Count Unique Words (Case Insensitive)

```
354         //countUniqueWordsCaseInsensitive
355         //expected: 4
356         System.out.println("countUniqueWordsCaseInsensitive: "
357                 + CollectionsClass.countUniqueWordsCaseInsensitive(countUniqueWordsArray));
358         System.out.println();
359
```

Remove Duplicates

```
151
152     /**
153      * Takes as a parameter an ArrayList of integers, and modifies it
154      * by removing any duplicates.
155      *
156      * Note that the elements of the list are not in any particular order, so the
157      * duplicates might not occur consecutively. This method retains the original
158      * relative order of the elements.
159      *
160      * For a given list [4, 0, 2, 9, 4, 7, 2, 0, 0, 9, 6, 6],
161      * the call of removeDuplicates(list) should modify it to store [4, 0, 2, 9, 7, 6].
162      *
163      * Use LinkedHashSet.
164      *
165      * @param list of ints to remove duplicates from
166      */
167     public static void removeDuplicates(ArrayList<Integer> list) {
168
169         //create LinkedHashSet (like hashset, but maintains insertion order)
170         Set<Integer> linkedHashSet = new LinkedHashSet<Integer>(list);
171
172         list.removeAll(list);
173         list.addAll(linkedHashSet);
174     }
175
```

Remove Duplicates

```
355
356         //removeDuplicates
357         Integer[] removeDuplicatesArray = {4, 0, 2, 9, 4, 7, 2, 0, 0, 9, 6, 6};
358         ArrayList<Integer> list2 = new ArrayList<Integer>();
359         list2.addAll(Arrays.asList(removeDuplicatesArray));
360         CollectionsClass.removeDuplicates(list2);
361
362         //expected: {4, 0, 2, 9, 7, 6}
363         System.out.println("removeDuplicates: " + list2);
364         System.out.println();
365
```

Set Toppings

```java
149
150     /**
151      * Takes a map of food keys and topping values, and modifies and returns the map as follows:
152      * If the key "ice cream" is present, set its value to "cherry".
153      * In all cases, set the key "bread" to have the value of "butter".
154      *
155      * setToppings({"ice cream": "peanuts"}) {"bread": "butter", "ice cream": "cherry"}
156      * setToppings({}) {"bread": "butter"}
157      * setToppings({"pancake": "syrup"}) {"bread": "butter", "pancake": "syrup"}
158      *
159      * @param map of food items and toppings
160      * @return updated map of food items and toppings
161      */
162     public static Map<String, String> setToppings(Map<String, String> map) {
163
164         //add key (bread) and value (butter) if it's not in map
165         if (!map.containsKey("bread")) {
166             map.put("bread", "butter");
167         }
168
169         //if key is 'ice cream', set value to 'cherry'
170         if (map.containsKey("ice cream")) {
171             map.replace("ice cream", "cherry");
172         }
173
174         return map;
175     }
176
```

Set Toppings

```
370         //setToppings
371         //create hashmap with food items
372         Map<String, String> food = new HashMap<String, String>();
373         food.put("ice cream", "peanuts");
374
375         Map<String, String> m = CollectionsClass.setToppings(food);
376         //expected: {bread=butter, ice cream=cherry}
377         System.out.println("setToppings: " + m);
378         System.out.println();
379
```

Friend List

```
216
217     /**
218      * Takes a Map<String, String> as a parameter and
219      * reads friend relationships and stores them into a compound
220      * collection that is returned.
221      *
222      * Creates a new map where each key is a person's name from the original Map,
223      * and the value associated with that key is a set of all friends of that person.
224      *
225      * Friendships are bi-directional:
226      * If Marty is friends with Danielle, then Danielle is friends with Marty
227      *
228      * The Map parameter contains one friend relationship per key/value pair,
229      * consisting of two names.  For example, if the map parameter friendMap
230      * looks like this: {Marty: Cynthia, Danielle: Marty}
231      *
232      * Then the call of friendList(friendMap) should return a map with the following
233      * contents: {Cynthia:[Marty], Danielle:[Marty], Marty:[Cynthia, Danielle]}
234      *
235      * Uses a TreeMap of TreeSets.
236      *
237      * @param friendMap of friendships
238      * @return map where each key is a person's name and the value is the set of all friends
239      */
240     public static TreeMap<String, TreeSet<String>> friendList(Map<String, String> friendMap) {
241
242         //create a treemap of treesets (like hashsets, but ordered)
243         TreeMap<String, TreeSet<String>> treeMap = new TreeMap<String, TreeSet<String>>();
244
```

Friend List

```
245         //iterate over entrySet (key/value pairs) for friendship map
246         for (Entry<String, String> friendShip : friendMap.entrySet()) {
247
248             //get key
249             String friend1 = friendShip.getKey();
250
251             //get value
252             String friend2 = friendShip.getValue();
253
254             //if the tree map doesn't contain friend1
255             if (!treeMap.containsKey(friend1)) {
256                 //put friend1 with empty treeset value
257                 treeMap.put(friend1, new TreeSet<String>());
258             }
259
260             //then get friend1 and add friend2 to treeset
261             treeMap.get(friend1).add(friend2);
262
263             //check if friend2 is in tree map
264             if (!treeMap.containsKey(friend2)) {
265                 //if not, put friend2 with empty treeset value
266                 treeMap.put(friend2, new TreeSet<String>());
267             }
268
269             //then get friend2 and add friend1 to treeset
270             treeMap.get(friend2).add(friend1);
271
272         }
273
274         return treeMap;
275     }
```

Friend List

```
376         //friendList
377         //create hashmap of friendships
378         HashMap<String, String> friends = new HashMap<String, String>();
379         friends.put("Marty", "Cynthia");
380         friends.put("Danielle", "Marty");
381
382         TreeMap<String, TreeSet<String>> friendList = CollectionsClass.friendList(friends);
383
384         //expected: {Cynthia=[Marty], Danielle=[Marty], Marty=[Cynthia, Danielle]}
385         System.out.println("friendList: " + friendList);
386         System.out.println();
387
```

Union Sets

```java
178    /**
179     * Takes as a parameter, a HashSet of TreeSets of integers,
180     * and returns a TreeSet of integers representing the union of all of the sets of
181     * ints.  A union is the combination of everything (without duplicates) in each set.
182     *
183     * For example, calling the method on the following set of sets:
184     * {{1, 3}, {2, 3, 4, 5}, {3, 5, 6, 7}, {42}}
185     * Should cause the following set of integers to be returned:
186     * {1, 2, 3, 4, 5, 6, 7, 42}
187     *
188     * Uses HashSet<TreeSet<Integer>>.
189     *
190     * @param sets to union
191     * @return union of all sets
192     */
193    public static TreeSet<Integer> unionSets(HashSet<TreeSet<Integer>> sets) {
194
195        //create treeset to store union of individual treesets
196        TreeSet<Integer> treeSet = new TreeSet<Integer>();
197
198        //iterate over hashset of treesets
199        for (TreeSet<Integer> ts : sets) {
200            //add each int from treeset
201            treeSet.addAll(ts);
202        }
203
204        return treeSet;
205    }
206
```

Union Sets

```
388         //unionSets
389
390         //create hashset of treesets (like hashsets but ordered)
391         HashSet<TreeSet<Integer>> hashSet = new HashSet<TreeSet<Integer>>();
392
393         //create individual treesets with int values and add to hashset
394         TreeSet<Integer> ts = new TreeSet<Integer>();
395         Integer[] arr1 = {1, 3};
396         ts.addAll(Arrays.asList(arr1));
397         hashSet.add(ts);
398
399         ts = new TreeSet<Integer>();
400         Integer[] arr2 = {5, 4, 3, 2};
401         ts.addAll(Arrays.asList(arr2));
402         hashSet.add(ts);
403
404         ts = new TreeSet<Integer>();
405         Integer[] arr3 = {3, 5, 6, 7};
406         ts.addAll(Arrays.asList(arr3));
407         hashSet.add(ts);
408
409         ts = new TreeSet<Integer>();
410         ts.add(42);
411         hashSet.add(ts);
412
413         TreeSet<Integer> treeSet = CollectionsClass.unionSets(hashSet);
414
415         //expected: {1, 2, 3, 4, 5, 6, 7, 42}
416         System.out.println("unionSets: " + treeSet);
```

Homework 8

Homework 8

Will be assigned by tonight, Wednesday, November 16th at midnight and due Wednesday December 7th at midnight

- For this HW assignment, you may work as a group (no more than 2 students)
- Note: As an alternative to this assigned homework, you may have already defined and been approved for an optional final project of your own design
- In this HW, you will implement a **console-based student management system**
  - The objective of this assignment is to design a system for students to manage their courses. There will be three main user roles in the application: Admin, Student, and Professor.
- This HW deals with the following topics:
  - Object-Oriented Programming Design
  - Inheritance
  - File I/O
  - Collections & Maps