ADVANCED OOP: CONTAINERS

OVERVIEW

OVERVIEW

- **What is a container?**
  - Something that can store multiple items of same type
    - A public library contains a large number of books
  - Some containers provide some organization to the items
    - The card catalog tells us where to look for each book

- **Java container classes store objects from another class**
  - They can store any type of data
  - They have methods for storing and accessing data
  - They have different representations that greatly effect storage and access speed

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OVERVIEW

- **Java provides a number of container classes that can store an unlimited number of objects of one data type**
  - Some container classes also provide methods for very rapid data storage and retrieval

- **In this section, we will look into four Java container classes in detail**
  - ArrayList – stores data in a variable length array
  - LinkedList – stores data in a sequence of data nodes
  - HashMap – stores (key, value) pairs in a hash table
  - HashSet – stores data in a hash table without duplicates

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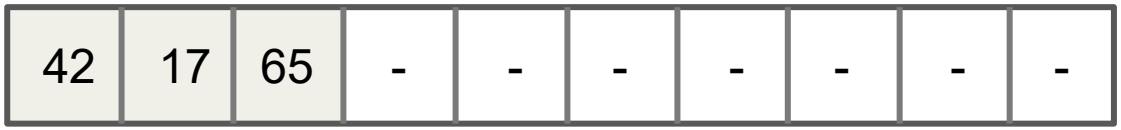
OVERVIEW

- **ArrayList – Stores data in a variable length array where only a portion of the array currently contains data**



  - As we add data it goes into “unused” section
  - When the “unused” section is full the size of the array automatically grows so we can store more data
  - Data access is as fast and easy like an Array

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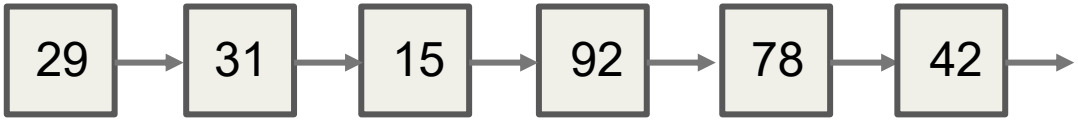
OVERVIEW

- **LinkedList – Stores data in a sequence of data storage nodes that are linked together**



  - As we add data the linked list add nodes to increase the size of this container so we can store the data
  - Data access is much slower than an Array or ArrayList
  - Adding or removing data from linked list can also be slow

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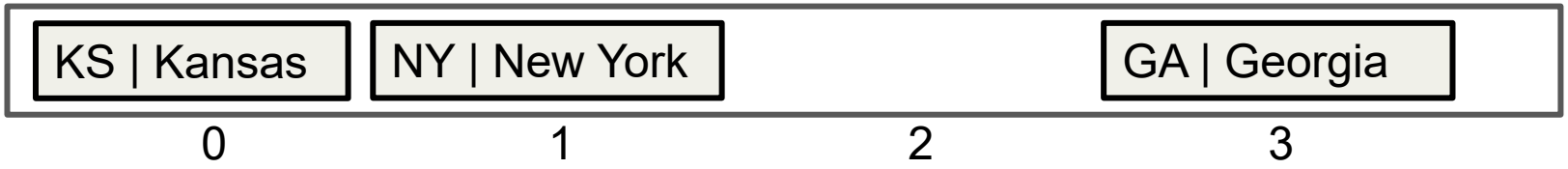
OVERVIEW

- **HashMap – Stores key/value pairs in a hash table and uses the key to quickly access the corresponding value**



  - A hash function is used to convert the key into the array location for the key/value pair
  - In this example, hash(NY) = 1, so we store (NY, New York) in location 1 of the hash table
  - Data access is even faster than an Array because we can jump immediately to desired value

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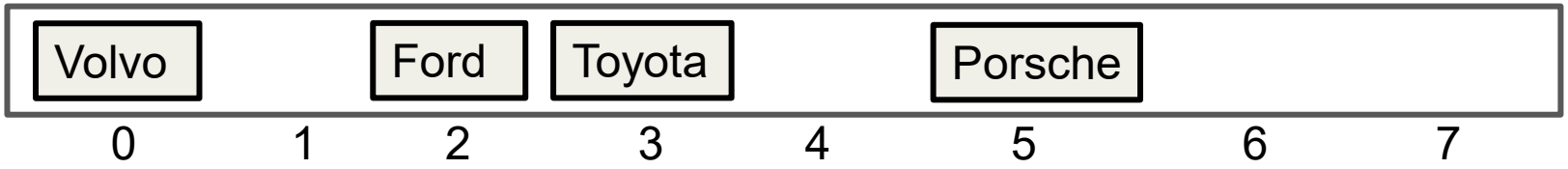
OVERVIEW

- **HashSet – Stores data values in a hash table and also provides mathematical Set operations**



  - A hash function is used to convert the data value into the array location for the data value
  - In this example, hash("Porsche") = 5, so we store "Porsche" at location 5 of the hash table
  - Duplicate data values are not stored in a HashSet
  - Set operations are very fast compared to using an Array

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OVERVIEW

- **Lesson objectives:**
  - Learn how ArrayList can be defined and used
  - Learn how LinkedList can be defined and used
  - Learn how HashMap can be defined and used
  - Learn how HashSet can be defined and used
  - Study sample programs using these container classes

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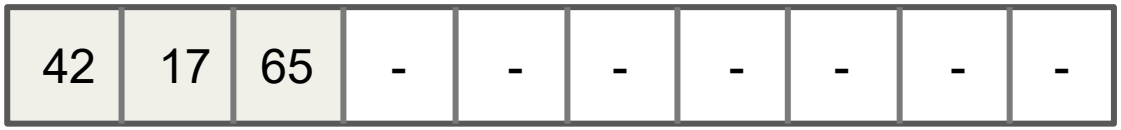
ADVANCED OOP: CONTAINERS

PART 1

ARRAY LIST

ARRAY LIST

- **The ArrayList class is a resizable Array that is defined in the java.util package**



  - A built-in array is fixed size
  - When the array becomes full, you have to manually create another array and copy the data
  - An ArrayList is not fixed size
  - When the ArrayList becomes full, the container will automatically resize itself to be 50% larger

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ARRAY LIST

- **How to declare an ArrayList**

```
import java.util.ArrayList;
public class Main
{
   public static void main(String[] args)
   {
      ArrayList<String> cars = new ArrayList<String>();
      ...
   }
}
```


Bring in the ArrayList class

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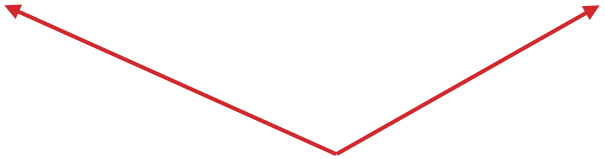
ARRAY LIST

- **How to declare an ArrayList**

```
import java.util.ArrayList;
public class Main
{
   public static void main(String[] args)
   {
      ArrayList<String> cars = new ArrayList<String>();
      ...
   }
}
```



Declare an ArrayList
to store Strings

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ARRAY LIST

- **How to declare an ArrayList**

```
import java.util.ArrayList;
public class Main
{
   public static void main(String[] args)
   {
      ArrayList<String> cars = new ArrayList<String>();
      ...
   }
}
```

We do not need to give a size for the ArrayList

ARRAY LIST

- **How to store data in an ArrayList**

```
ArrayList<String> cars = new ArrayList<String>();
cars.add("Volvo");
cars.add("BMW");
cars.add("Ford");
cars.add("Mazda");
```

The array ArrayList
now contains four cars
in locations 0,1,2,3

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ARRAY LIST

- **How to access and print data in an ArrayList**

```
ArrayList<String> cars = new ArrayList<String>();
cars.add("Volvo");
cars.add("BMW");
cars.add("Ford");
cars.add("Mazda");
for (int i = 0; i < cars.size(); i++)
   System.out.println(cars.get(i));
```

The size method tells us how many values are stored in the ArrayList

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ARRAY LIST

- **How to access and print data in an ArrayList**

```
ArrayList<String> cars = new ArrayList<String>();
cars.add("Volvo");
cars.add("BMW");
cars.add("Ford");
cars.add("Mazda");
for (int i = 0; i < cars.size(); i++)
   System.out.println(cars.get(i));
```

The get method lets us access locations 0,1,2,3

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ARRAY LIST

- **How to access and print data in an ArrayList**

```
ArrayList<String> cars = new ArrayList<String>();
cars.add("Volvo");
cars.add("BMW");
cars.add("Ford");
cars.add("Mazda");
System.out.println(cars);
```

This will print [Volvo, BMW, Ford, Mazda]

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ARRAY LIST

- **How to remove one data value from an ArrayList**

```
ArrayList<String> cars = new ArrayList<String>();
cars.add("Volvo");
cars.add("BMW");
cars.add("Ford");
cars.add("Mazda");
cars.remove(1);
System.out.println(cars);
```

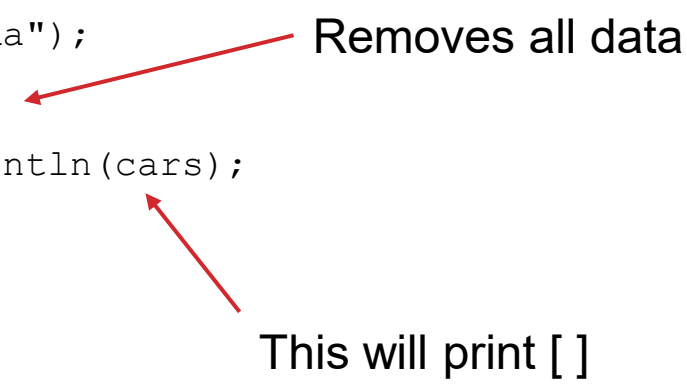
This will remove data from location 1

This will print [Volvo, Ford, Mazda]

ARRAY LIST

- **How to remove all data from an ArrayList**

```
import java.util.Collections;
...
ArrayList<String> cars = new ArrayList<String>();
cars.add("Volvo");
cars.add("BMW");
cars.add("Ford");
cars.add("Mazda");
cars.clear();
System.out.println(cars);
```



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ARRAY LIST

- **How to sort data in an ArrayList**

```
import java.util.Collections;
...
ArrayList<String> cars = new ArrayList<String>();
cars.add("Volvo");
cars.add("BMW");
cars.add("Ford");
cars.add("Mazda");
Collections.sort(cars);
System.out.println(cars);
```

Bring in the Collections class

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ARRAY LIST

- **How to sort data in an ArrayList**

```
import java.util.Collections;
...
ArrayList<String> cars = new ArrayList<String>();
cars.add("Volvo");
cars.add("BMW");
cars.add("Ford");
cars.add("Mazda");
Collections.sort(cars);
System.out.println(cars);
```

Sort the data in alphabetical order

This will print [BMW, Ford, Mazda, Volvo]

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ARRAY LIST

- **See the full list of methods in the ArrayList class here:**

https://docs.oracle.com/javase/10/docs/api/java/util/ArrayList.html

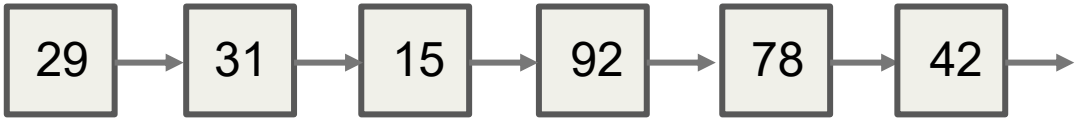
ADVANCED OOP: CONTAINERS

PART 2

LINKED LIST

LINKED LIST

- **The LinkedList class uses a node based representation to store variable amount of data**



  - Each node contains one data element
  - Each node is “connected” by a reference (shown as arrows) to the next node to the right in the linked list

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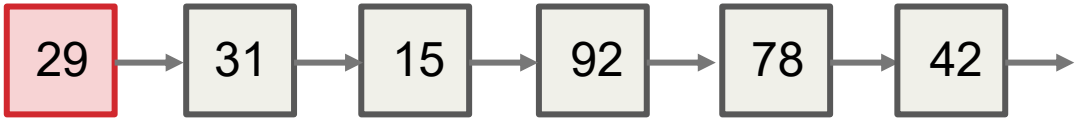
LINKED LIST

- **The LinkedList class uses a node based representation to store variable amount of data**



  - Each node contains one data element
  - Each node is "connected" by a reference (shown as arrows) to the next node to the right in the linked list
  - The node on far left is the "head" of the list

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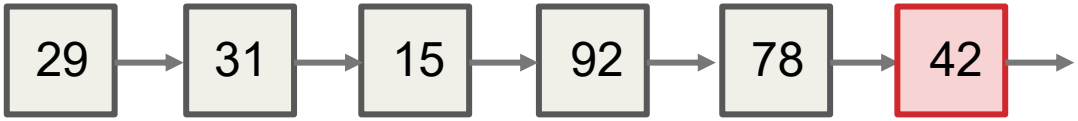
LINKED LIST

- **The LinkedList class uses a node based representation to store variable amount of data**



  - Each node contains one data element
  - Each node is "connected" by a reference (shown as arrows) to the next node to the right in the linked list
  - The node on far left is the "head" of the list
  - The node on far right is the "tail" of the list

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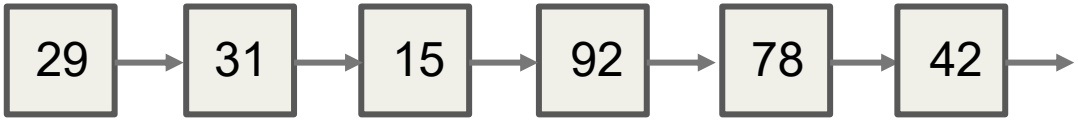
LINKED LIST

- **How do we use a LinkedList to store data?**



  - To access data, we must start at head and “walk the list” from node to node to desired node
  - To add data, we create a new node and connect it at the desired location (often before head or after tail)
  - To remove data, we must find the desired node, delete it, and connect the node before to node after

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LINKED LIST

- **Cons of a LinkedList?**
  - It does not support random access like an Array or ArrayList so data access can be much slower
  - It is slow and complicated to insert/delete new data in the middle of the LinkedList

- **Pros of a LinkedList?**
  - It can grow/shrink to meet exact storage needs
  - Fast and easy to insert/delete data at head or tail
  - We can insert data anywhere without having to move data
  - It has all of the methods in the ArrayList class

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LINKED LIST

- **How to declare a LinkedList**

```
import java.util.LinkedList;
public class Main
{
   public static void main(String[] args)
   {
      LinkedList<String> cars = new LinkedList<String>();
      ...
   }
}
```

Bring in the LinkedList class

Declare a LinkedList
to store Strings

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LINKED LIST

- **How to add and remove data in a LinkedList**

```
LinkedList<String> cars = new LinkedList<String>();
cars.add("Volvo");
cars.add("BMW");
cars.add("Ford");
cars.add("Mazda");
cars.remove(1);
System.out.println(cars);
```

This will add four data values

This will remove data from location 1

This will print [Volvo, Ford, Mazda]

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LINKED LIST

- **The LinkedList class has very fast methods for adding and removing at the head or tail of the linked list**
  - addFirst() - Adds an item before head of the list.
  - addLast() - Adds an item after tail of the list
  - removeFirst() - Remove item from the head of the list.
  - removeLast() - Remove item from the tail of the list
  - getFirst() - Get the item at the head of the list
  - getLast() - Get the item at the tail of the list

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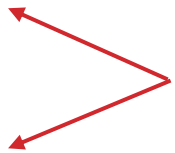
LINKED LIST

- **How to add at beginning and end of a LinkedList**

```
LinkedList<String> cars = new LinkedList<String>();
cars.addFirst("Volvo");
cars.addLast("BMW");
cars.addFirst("Ford");
cars.addLast("Mazda");
System.out.println(cars);
```

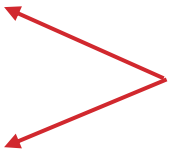


This adds to the beginning of linked list

LINKED LIST

- **How to add at beginning and end of a LinkedList**

```
LinkedList<String> cars = new LinkedList<String>();
cars.addFirst("Volvo");
cars.addLast("BMW");
cars.addFirst("Ford");
cars.addLast("Mazda");
System.out.println(cars);
```



This adds to the end of linked list

LINKED LIST

- **How to add at beginning and end of a LinkedList**

```
LinkedList<String> cars = new LinkedList<String>();
cars.addFirst("Volvo");
cars.addLast("BMW");
cars.addFirst("Ford");
cars.addLast("Mazda");
System.out.println(cars);
```

This will print [Ford, Volvo, BMW, Mazda]

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LINKED LIST

- **See the full list of methods in the LinkedList class here:**

https://docs.oracle.com/javase/10/docs/api/java/util/LinkedList.html

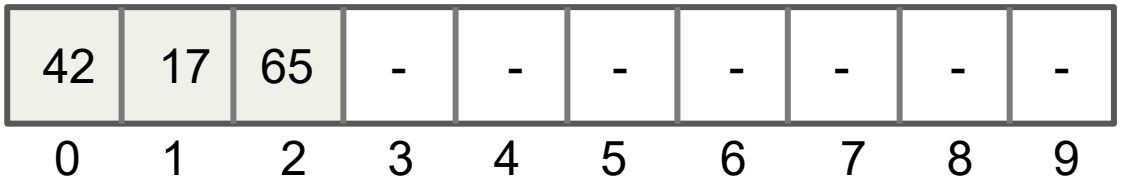
ADVANCED OOP: CONTAINERS

PART 3

HASH MAP

HASH MAP

- **The data elements in an Array or ArrayList can be accessed with an integer index number**



  - Once we know the index, we can access the data value
  - In this case, Data[0] = 42, Data[1] = 17, Data[2] = 65
  - Unfortunately, with an Array there is no way to know in advance where a given data value will be stored
  - If we want to find the 17 we have to loop over all possible index numbers and check the Array at that location

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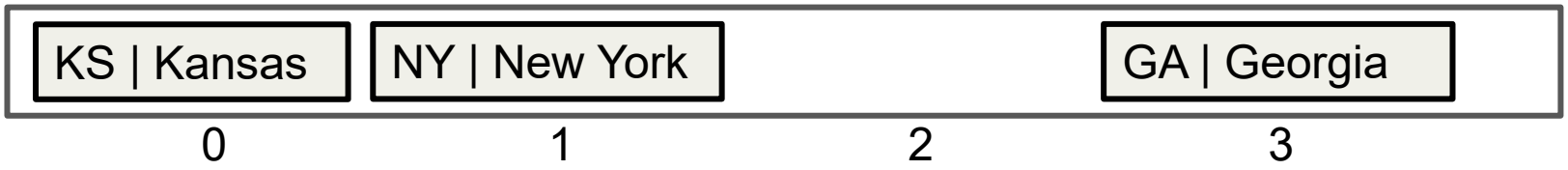
HASH MAP

- **The data elements in a HashMap are stored in key/value pairs and can be directly accessed using the key**



  - A "hash function" is used to convert keys into locations
  - hash("KS") = 0, so (KS, Kansas) is stored in location 0
  - hash("NY") = 1, so (NY, New York) is stored in location 1
  - hash("GA") = 3, so (GA, Georgia) is stored in location 3
  - Once we know hash(key), we can jump immediately to desired key/value pair in the HashMap

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HASH MAP

- **The keys for HashMap must be Java objects**
  - We can not use primitive types like int, double, char
  - Instead, we must use corresponding “wrapper classes” Integer, Double, Character

- **Java will allow you to use any combination of data types for the value and the key**
  - String value, Integer key
  - Double value, String key
  - Integer value, Student key

HASH MAP

- **Declaring a HashMap:**

```
import java.util.HashMap;
public class Main
{
   public static void main(String[] args)
   {
      HashMap<String, String> capitals = new HashMap<String, String>();
      ...
   }
}
```

Bring in the HashMap class

Declare a HashMap to store String keys and String values

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HASH MAP

- **Adding items to a HashMap:**

```
public static void main(String[] args)
{
    HashMap<String, String> capitals = new HashMap<String, String>();
    capitals.put("England", "London");
    capitals.put("Germany", "Berlin");
    capitals.put("Norway", "Oslo");
    capitals.put("USA", "Washington DC");
    ...
```

This will store (key, value) pairs in the HashMap

HASH MAP

- **Printing items in a HashMap:**

```
public static void main(String[] args)
{
    HashMap<String, String> capitals = new HashMap<String, String>();
    capitals.put("England", "London");
    capitals.put("Germany", "Berlin");
    capitals.put("Norway", "Oslo");
    capitals.put("USA", "Washington DC");
    System.out.println(capitals);
    ...
```

This will print all of the (key, value) pairs {USA=Washington DC, Norway=Oslo, England=London, Germany=Berlin}

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HASH MAP

- **Accessing items in a HashMap:**

```
public static void main(String[] args)
{
    HashMap<String, String> capitals = new HashMap<String, String>();
    capitals.put("England", "London");
    capitals.put("Germany", "Berlin");
    capitals.put("Norway", "Oslo");
    capitals.put("USA", "Washington DC");
    System.out.println(capitals.get("England"));
    ...
```

This will get the value associated with the key “England” and print “London”

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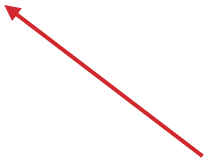
HASH MAP

- **Removing items from a HashMap:**

```
public static void main(String[] args)
{
    HashMap<String, String> capitals = new HashMap<String, String>();
    capitals.put("England", "London");
    capitals.put("Germany", "Berlin");
    capitals.put("Norway", "Oslo");
    capitals.put("USA", "Washington DC");
    capitals.remove("USA");
    ...
```



This will remove the (key, value) pair that has “USA” as the key

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HASH MAP

- **Looping over items in a HashMap:**

```
public static void main(String[] args)
{
    HashMap<String, String> capitals = new HashMap<String, String>();
    ...
    for (String i : capitals.keySet())
    {
        System.out.println(i);
    }
}
```

This will return a Set with all HashMap keys that we can iterate over and print

HASH MAP

- **Looping over items in a HashMap:**

```
public static void main(String[] args)
{
    HashMap<String, String> capitals = new HashMap<String, String>();
    ...
    for (String i : capitals.values())
    {
        System.out.println(i);
    }
}
```

This will return a Collection with all HashMap values that we can iterate over and print

HASH MAP

- **Looping over items in a HashMap:**

```
public static void main(String[] args)
{
    HashMap<String, String> capitals = new HashMap<String, String>();
    ...
    for (String i : capitals.keySet())
    {
        System.out.println("key: " + i + " value: " + capitals.get(i));
    }
}
```

We can iterate over all keys to access and print all (key, value) pairs in the HashMap

HASH MAP

- **Summary of common HashMap methods:**
  - put(key, value) – adds (key, value) to the HashMap
  - get(key) – returns value for this key from HashMap
  - remove(key) – removes (key, value) from HashMap
  - clear() – removes all (key, value) pairs from HashMap
  - size() – returns the number of (key, value) pairs
  - isEmpty() – returns true if size == 0
  - keySet() – returns a Set containing all keys
  - values() – returns a Collection containing all values

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CODE DEMO

CountWords2.java

CountWords3.java

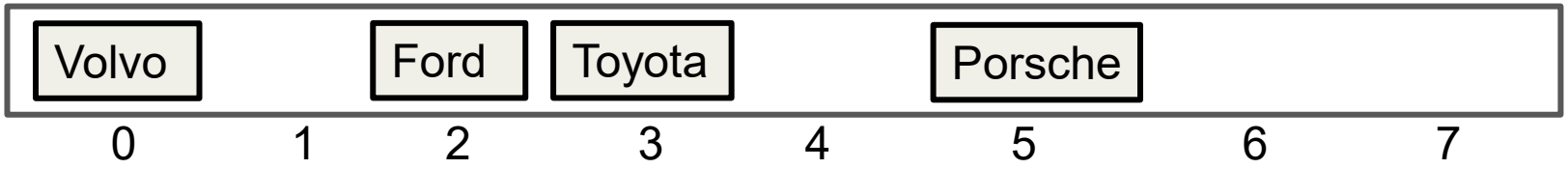
ADVANCED OOP: CONTAINERS

PART 4

HASH SET

HASH SET

- **A HashSet stores data values in a hash table and also provides all mathematical Set operations**



  - Like a HashMap, a “hash function” is used to determine the location for the data value in the hash table
  - hash(“Porsche”) = 5, so “Porsche” is stored in location 5
  - Duplicate data values are not stored in a HashSet
  - Operations are very fast compared to a regular Set

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HASH SET

- **Declaring a HashSet:**

```
import java.util.HashSet;
public class Main
{
   public static void main(String[] args)
   {
      HashSet<String> cars = new HashSet<String>();
      ...
   }
}
```

Bring in the HashSet class

Declare a HashSet to store String values

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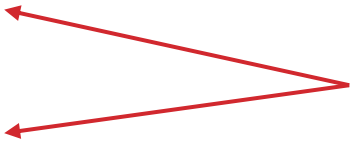
HASH SET

- **Adding items to a HashSet:**

```
public static void main(String[] args)
{
    HashSet<String> cars = new HashSet<String>();
    cars.add("Volvo");
    cars.add("BMW");
    cars.add("Ford");
    cars.add("BMW");
    cars.add("Mazda");
    System.out.println(cars);
```



This will store car names in the HashSet and ignore duplicate values

HASH SET

- **Printing items in a HashSet:**

```
public static void main(String[] args)
{
    HashSet<String> cars = new HashSet<String>();
    cars.add("Volvo");
    cars.add("BMW");
    cars.add("Ford");
    cars.add("BMW");
    cars.add("Mazda");
    System.out.println(cars);
```

This will print all the car names in the HashSet
[Volvo, Mazda, Ford, BMW]

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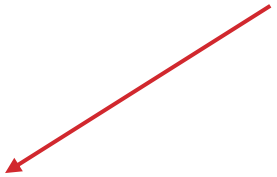
HASH SET

- **Checking if an item is in a HashSet:**

```
public static void main(String[] args)
{
    HashSet<String> cars = new HashSet<String>();
    cars.add("Volvo");
    cars.add("BMW");
    cars.add("Ford");
    cars.add("BMW");
    cars.add("Mazda");
    if (cars.contains("BMW")
        System.out.println("Found BMW");
```



This will return true if "BMW" is in the HashSet The hash table makes this operation very fast

HASH SET

- **Removing an item from a HashSet:**

```
public static void main(String[] args)
{
    HashSet<String> cars = new HashSet<String>();
    cars.add("Volvo");
    cars.add("BMW");
    cars.add("Ford");
    cars.add("BMW");
    cars.add("Mazda");
    cars.remove("Ford");
    System.out.println(cars);
```

This will remove “Ford” from the HashSet and print [Volvo, Mazda, BMW]

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HASH SET

- **Looping over items in a HashSet:**

```
public static void main(String[] args)
{
    HashSet<String> cars = new HashSet<String>();
    cars.add("Volvo");
    cars.add("BMW");
    cars.add("Ford");
    cars.add("BMW");
    cars.add("Mazda");
    for (String i : cars)
        System.out.println(i);
```

This will iterate over the Set of cars and print each value on a separate line

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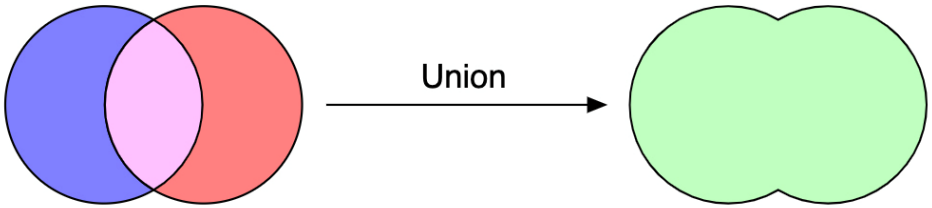
HASH SET

- **Set union combines all elements in in two sets**




```
HashSet<Integer> A = new HashSet<Integer>();
HashSet<Integer> B = new HashSet<Integer>();
A.add(1); A.add(2); A.add(3);
B.add(2); B.add(4); B.add(6);
A.addAll(B);
System.out.println(A);
```

This will calculate the Set union and print [1, 2, 3, 4, 6]

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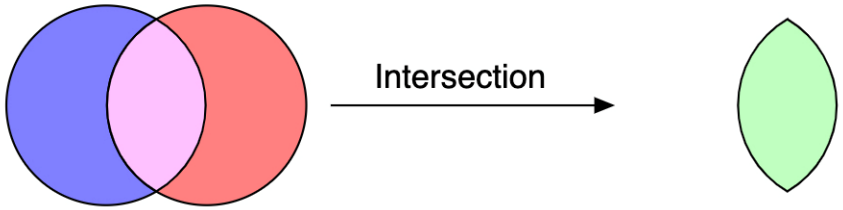
HASH SET

- **Set intersection finds common elements in two sets**




```
HashSet<Integer> A = new HashSet<Integer>();
HashSet<Integer> B = new HashSet<Integer>();
A.add(1); A.add(2); A.add(3);
B.add(2); B.add(4); B.add(6);
A.retainAll(B);
System.out.println(A);
```

This will calculate the Set intersection and print [1, 3]

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HASH MAP

- **Summary of common HashSet methods:**
  - add(value) – adds value to the HashSet
  - contains(key) – returns true value is in HashSet
  - remove(key) – removes value from HashSet
  - clear() – removes all values from HashSet
  - size() – returns the number of values in HashSet
  - isEmpty() – returns true if size == 0
  - addAll(Set s) – adds all elements of s to this HashSet
  - removeAll(Set s) – removes all elements of s from HashSet
  - retainAll(Set s) – removes all elements that are not from set s
  - equals(Set s) – returns true if every member of the given set is contained in this set

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SUMMARY

- **The container classes in Java are very powerful because they allow us to store and access large collections of data**
  - They grow and shrink in size to meet the data storage needs of an application
  - They provide very specialized data access methods that can be very fast (hash table) or very slow (linked list)

- **See the Java documentation for more details**
  - https://docs.oracle.com/en/java/javase/16
  - https://docs.oracle.com/javase/tutorial/index.html
  - https://www.w3schools.com/java/default.asp

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