JAVA PROGRAMMING

Chap 4 : Packages and Interfaces

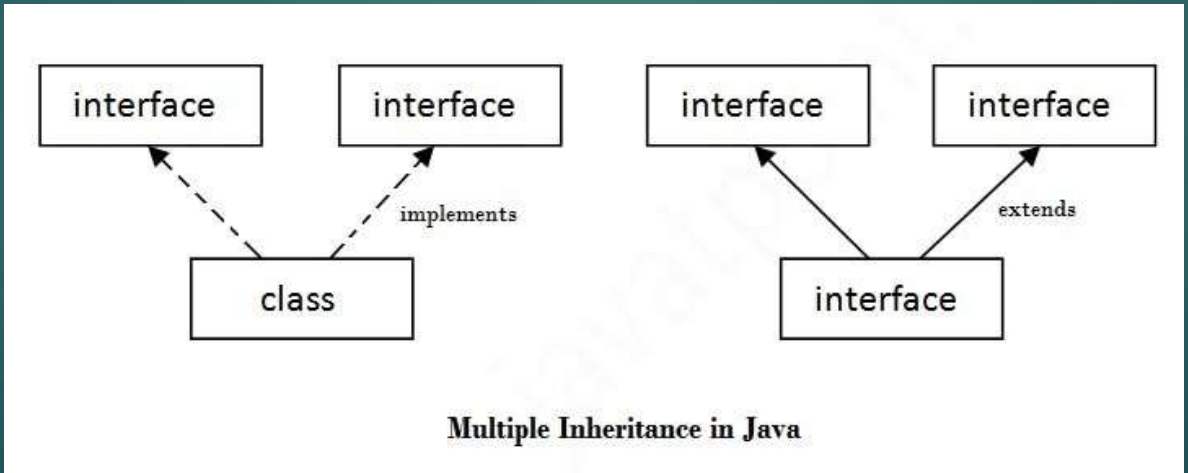
Interfaces

- Multiple Inheritance is not allowed in Java.
- Instead Interface is used to implement multiple inheritance.
- An **interface** in Java is a blueprint of a class. It has static constants and abstract methods.
- There can be only abstract methods in the Java interface, having no method body.
- It is used to achieve abstraction and multiple inheritance in Java.
- Java Interface also represents the IS-A relationship (i.e. Inheritance)
- **Syntax for inheritance**
- An interface is declared by using the interface keyword.
- It provides total abstraction; means all the methods in an interface are declared with the empty body, and all the fields are public, static and final by default.
- A class that implements an interface must implement all the methods declared in the interface.

Syntax : **interface** <interface_name>

```
{
    // declare constant fields
   // declare methods that are abstract by default.
}
```

- a class extends another class, an interface extends another interface, but a class implements an interface.
- Interface do not have constructor.
- If a class implements an interface and does not provide method bodies for all functions specified in the interface, then the class must be declared abstract and method definitions may be provided in the subclass.
- Any class can extend only 1 class but can implement infinite number of interface.



Multiple Inheritance in Java

Abstract Class vs Interface

Abstract Class	Interface
It is a class that contains one or more abstract methods, which are to be defined by sub class	It contains only method declarations and no definitions
Abstract class definition begins with keyword “abstract” followed by class definition	Interface definition begins with keyword “interface” followed by interface definition
Abstract classes can have general methods defined along with some methods with only declarations	Interfaces have all methods with only declarations that are defined in subclasses i.e. classes that implements the interface
Variables in abstract classes need not be public, static and final	All Variables in an interface is by default public, static and final
Abstract classes doesn’t support multiple inheritance	Interfaces supports multiple inheritance
An abstract class can contain private and protected members	An interface can only have public members
Abstract classes are fast	Interfaces are slow as it requires extra indirection to find corresponding methods in the actual class

Interface Example

```
import java.util.*;
interface Base {
    public void read(float x);
    public void calculate();
    public void display();
}
class Sphere implements Base {
  protected float r,vol;
  public void read(float x)
 {
   r=x;
 }
 public void calculate()
    {
        vol=3.14f*r*r*r*4/3;
    }
  public void display()
 {
     System.out.println("Volume of Sphere =
"+vol);
 }}
```

```
class Hemisphere implements Base {
  protected float r,vol;
  public void read(float x)
 {
   r=x;
 }
 public void calculate()
    {
        vol=3.14f*r*r*r*2/3;
    }
  public void display()
 {
     System.out.println("Volume of
Hemisphere = "+vol);
 }}
```

```
class Main
{
  public static void main(String args[])
  {
    float rad;
    Scanner sc=new Scanner(System.in);
    System.out.println("Enter Radius : ");
    rad=sc.nextFloat();
    Sphere s=new Sphere();
    s.read(rad);
    s.calculate();
    s.display();
    Hemisphere h=new Hemisphere();
    h.read(rad);
    h.calculate();
    h.display();
}}
```

```
Enter Radius :
10
Volume of Sphere = 4186.6665
Volume of Hemisphere = 2093.3333
```

Packages

- Package is a way to organize code i.e. similar function or related classes must be in a package.
- Thus, one package will have all the classes of similar functionality while another package for another type of classes.
- A **java package** is a group of similar types of classes, interfaces and sub-packages.
- Package in java can be categorized in two form, built-in package and user-defined package.
- There are many built-in packages such as java, lang, awt, javax, swing, net, io, util, sql etc.
- Advantage of Java Package
  - Java package is used to categorize the classes and interfaces so that they can be easily maintained.
  - Java package provides access protection.
  - Java package removes naming collision.
  - Making searching/locating and usage of classes, interfaces, enumerations and annotations easier
- All we need to do is put related classes into packages. After that, we can simply write an import class from existing packages and use it in our program.
- We can reuse existing classes from the packages as many time as we need it in our program.

Creating a Package

Step-1 : To create a package we use the keyword "package" followed by the name of the package

Step-2 : Create a class and write members of the class

Step-3 : Store the program file in a folder with the same name as that of the package and store the file as the name of the class that has main() method. Eg : if the package name is "world", then the folder in which the program is stored should also be "world". If the name of the class having the main() method is "Hello", then the program should be stored as "Hello.java"

Step-4 : Compile the program as usual using javac. This has to be done in the folder of the package. In case of above eg, in the folder "world" we compile the file as javac Hello.java

Step-5 : Traverse out of the package folder and execute the program with syntax –

java package_name.class_name.

In the above eg, java world.Hello

Creating a Package

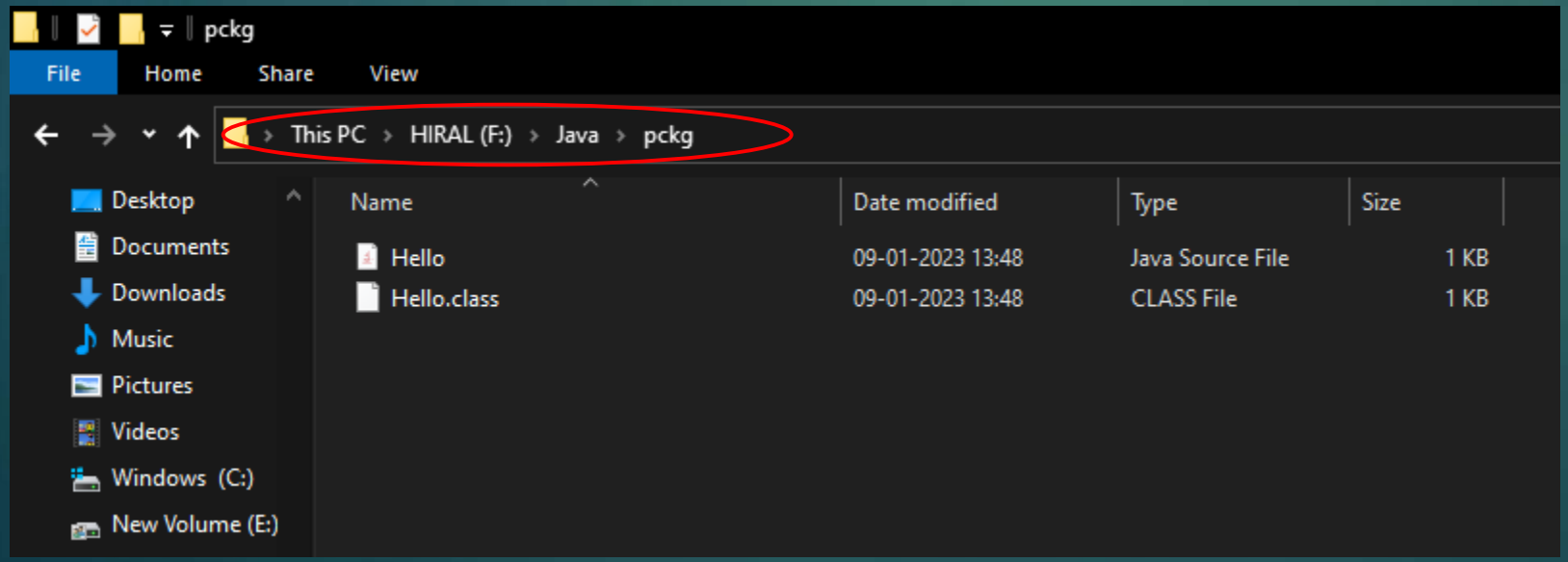
```
package pckg;
class Hello
{
    public static void main(String args[])
    {
        System.out.println("Hello World !!!");
    }
}
```

```
F:\Java\pckg>javac Hello.java

F:\Java\pckg>cd..

F:\Java>java pckg.Hello
Hello World !!!

F:\Java>
```



Creating a Sub-Package

- To create a sub-package we use the same process that we used to create the package.
- The folder of the sub package name has to be stored inside the folder with the package name.

```
package pckg.india;
class Hello
{
    public static void main(String args[])
    {
        System.out.println("Hello Indians !!!");
    }
}
```

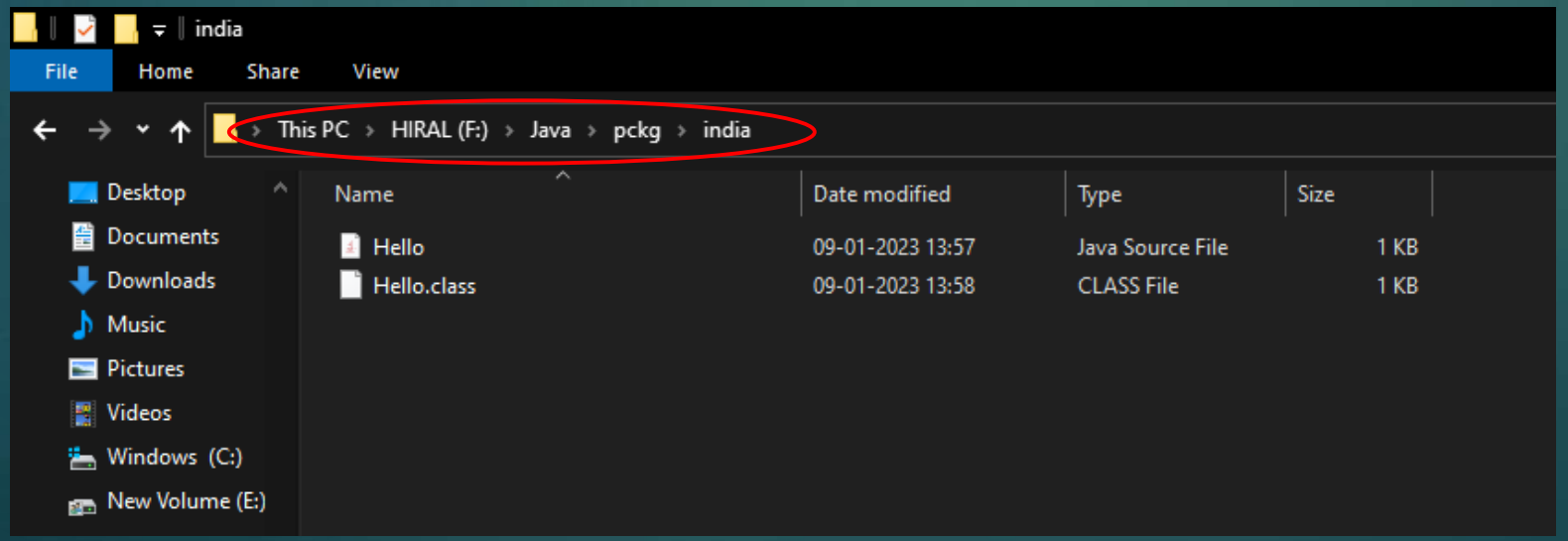
```
F:\Java\pckg\india>javac Hello.java

F:\Java\pckg\india>cd..

F:\Java\pckg>cd..

F:\Java>java pckg.india.Hello
Hello Indians !!!

F:\Java>
```



Importing a Package

- We have imported many built in packages like java.io, java.util,etc. as of now.
- To import self made packages we follow the following steps –
- Create the package as described in previous slides.
- This package is to be imported by another program outside the folder with package name
- That is we write two programs, one the package and another that imports the package. The package i to be stored in the folder with same name.

Importing a Package

The Package (Hello1.java)

```
package pckg.india;
public class Hello1
{
    public void display()
        {
        System.out.println("Hello Indians !!!");
        }
}
```

Importing Package (packimp.java)

```
import pckg.india.*;
class packimp
{
    public static void main(String args[])
    {
        Hello1 h=new Hello1();
        h.display();
    }
}
```

```
F:\Java>cd pckg

F:\Java\pckg>cd india

F:\Java\pckg\india>javac Hello1.java

F:\Java\pckg\india>cd..

F:\Java\pckg>cd..

F:\Java>javac packimp.java

F:\Java>java packimp
Hello Indians !!!
```

Exploring Important Java Packages

- Java.lang
- Java.io
- Java.util

Wrapper Classes

Primitive Type	Wrapper class
boolean	Boolean
char	Character
byte	Byte
short	Short
int	Integer
long	Long
float	Float
double	Double

Programming Practice Questions

- Design an interface Shape with methods calculateArea() and displayArea(). Implement this interface in two classes, Circle and Rectangle. The Circle class should have a constructor that takes the radius, and the Rectangle class should have a constructor that takes width and height. Write a program that creates instances of Circle and Rectangle, and calculates and prints their areas.
- Create an interface SortStrategy with a method void sort(int[] array). Implement this interface in classes, BubbleSort, QuickSort and MergeSort. Each class should provide its own implementation of the sorting algorithm. Write a program that uses different sorting strategies to sort an array of integers.
- Design an interface named TemperatureConverter with a method convertToCelsius() to convert temperatures to Celsius. Implement this converter in classes FahrenheitToCelsiusConverter and KelvinToCelsiusConverter to convert the temperature in different units to Celsius.
- Define an interface Shape with methods getArea and getPerimeter. Define another interface Volume with a method getVolume to calculate Volume of the shape. Implement classes Cube and Sphere that implements both Shape and Volume interfaces, allowing them to calculate their area, perimeter and Volume.

Programming Practice Questions

- Create a basic Java application with three packages: employee, department and company. In employee package, create a class Employee with fields name, id, and department, and methods to get and print these fields. In department package, create a class Department with fields departmentName and location, and methods to get and print these fields. Write a main method in a class located in company Package that creates instances of Employee and Department, sets their fields, and prints their details.
- Create a package hierarchy for a university system with the following structure: university, university.students, and university.courses. In university package, create a base class UniversityMember with common fields like name and id, and methods for displaying member information. In university.students, create classes Student and TeachingAdjunct that extends UniversityMember. Class Student includes additional fields for major and gpa and overrides method to display student details. Class TeachingAdjunct includes fields for no. of hours worked and stipend per hour and method to calculate total stipend alongwith displaying TeachingAdjunct Details by overriding method of base class. In university.courses, create a class Course with fields for courseName and courseCode, and methods to print course details. Write a class in university.main that demonstrates creating instances of Student and Course, and shows how they interact within the university system.

JAVA PROGRAMMING

Chap 5 : String Handling

- A string is a sequence of characters surrounded by double quotations.
- In a java programming language, a string is the object of a built-in class String.
- In the background, the string values are organized as an array of a character data type.
- **The string created using a character array** can not be extended.
- **It does not allow to append more characters after its definition, but it can be modified.**
- The Java String is immutable by default which means it cannot be changed.
- Whenever we change any string, a new instance is created.
- For mutable strings, you can use StringBuffer and StringBuilder classes.
- Syntax :

```
char[] name = {'J', 'a', 'v', 'a', ' ', 'T', 'u', 't', 'o', 'r', 'i', 'a', 'l', 's'};
// name[14] = '@'; //ArrayIndexOutOfBoundsException when trying to add more characters to the string
System.out.println(name);
name[4] = '-';    // modifying the string
System.out.println(name);
```

```
Java Tutorials
Java-Tutorials
```

- The String class defined in the package java.lang package.
- The String class implements Serializable, Comparable, and CharSequence interfaces.
- **Java String** class provides a lot of methods to perform operations on strings such as compare(), concat(), equals(), split(), length(), replace(), compareTo(), intern(), substring() etc.
- The string created using the String class can be extended.
- It allows us to add more characters after its definition, and also it can be modified.
- Syntax :

```
String name = "Java Tutorials";
System.out.println(name);
name = "Java Programming";
System.out.println(name);
```

```
Java Tutorials
Java Programming
```

Creating String object in Java

- In java, we can use the following two ways to create a string object.
  - Using string literal
  - Using String constructor
- Syntax :

```
String title = "Java Tutorials"; // Using literals
String name = new String("Java Programming");       // Using constructor
System.out.println(title);
System.out.println(name);
char ch[]={'S','t','r','i','n','g','s'};
 String s=new String(ch);          //converting char array to string using constructor
System.out.println(s);
```

```
Java Tutorials
Java Programming
Strings
```

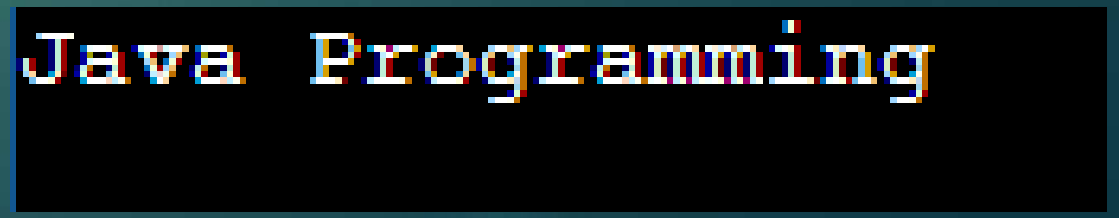
Why are String objects immutable?

- A String is an unavoidable type of variable while writing any application program.
- String references are used to store various attributes like username, password, etc.
- In Java, String objects are immutable. Immutable simply means unmodifiable or unchangeable.
- Once String object is created its data or state can't be changed but a new String object is created.
- Let's try to understand the concept of immutability by the example given below:

```
String s="Java";
s.concat(" Programming");    //concat() method appends the string at the end
System.out.println(s);       //will print Java because strings are immutable objects
```

- Now it can be understood that Java is not changed but a new object is created with Java Programming and s reference variable still refers to “Java" and not to “Java Programming". That is why String is known as immutable.
- But if we explicitly assign it to the reference variable, it will refer to “Java Programming" object. Please notice that still “Java” object is not modified, only that the reference variable refers to the new object.

```
String s="Java";
s=s.concat(" Programming");
System.out.println(s);
```



String Handling Methods

Method	Description	Return Value
charAt(int)	Finds the character at given index	char
length()	Finds the length of given string	int
compareTo(String)	Compares two strings	int
compareToIgnoreCase(String)	Compares two strings, ignoring case	int
concat(String)	Concatenates the object string with argument string.	String
contains(String)	Checks whether a string contains sub-string	boolean
contentEquals(String)	Checks whether two strings are same	boolean
equals(String)	Checks whether two strings are same	boolean
equalsIgnoreCase(String)	Checks whether two strings are same, ignoring case	boolean
startsWith(String)	Checks whether a string starts with the specified string	boolean
endsWith(String)	Checks whether a string ends with the specified string	boolean
getBytes()	Converts string value to bytes	byte[]

String Handling Methods

hashCode()	Finds the hash code of a string	int
indexOf(String)	Finds the first index of argument string in object string	int
lastIndexOf(String)	Finds the last index of argument string in object string	int
isEmpty()	Checks whether a string is empty or not	boolean
replace(String, String)	Replaces the first string with second string	String
replaceAll(String, String)	Replaces the first string with second string at all occurrences.	String
substring(int, int)	Extracts a sub-string from specified start and end index values	String
toLowerCase()	Converts a string to lower case letters	String
toUpperCase()	Converts a string to upper case letters	String
trim()	Removes whitespace from both ends	String
toString(int)	Converts the value to a String object	String
split(String)	splits the string matching argument string	String[]
intern()	returns string from the pool	String
join(String, String, ...)	Joins all strings, first string as delimiter.	String

String Handling Methods

```
public class Main {
public static void main(String[] args) {
String title = "Java Tutorials";
String Name = "www.javaprogramming.com";
System.out.println("Length of title: " + title.length());
System.out.println("Char at index 3: " + title.charAt(3));
System.out.println("Index of 'T': " + title.indexOf('T'));
System.out.println("Last index of 'a': " +
title.lastIndexOf('a'));
System.out.println("Empty: " + title.isEmpty());
System.out.println("Ends with '.com': " +
Name.endsWith(".com"));
System.out.println("Equals: " + Name.equals(title));
System.out.println("Sub-string: " + Name.substring(9, 14));
System.out.println("Upper case: " + Name.toUpperCase());
System.out.println("Upper case: " + title.toLowerCase());
String s="  Java  ";
System.out.println("Before Trimming :"+s);
System.out.println("After trimming :"+s.trim());
System.out.println("Replacing a by z in " + title + " we get "
+ title.replace("a","z"));
}
}
```

```
Length of title: 14
Char at index 3: a
Index of 'T': 5
Last index of 'a': 11
Empty: false
Ends with '.com': true
Equals: false
Sub-string: rogra
Upper case: WWW.JAVAPROGRAMMING.COM
Upper case: java tutorials
Before Trimming :  Java
After trimming :Java
Replacing a by z in Java Tutorials we get Jzvz Tutorizls
```

String Compare

- We can compare String in Java on the basis of content and reference.
- It is used in authentication (by equals() method), sorting (by compareTo() method), reference matching (by == operator) etc.
- There are three ways to compare String in Java:
  - By Using equals() Method
  - By Using == Operator
  - By compareTo() Method
- The String class **equals() method** compares the original **content** of the string. It compares values of string for equality. String class provides the following two methods:
  - public boolean equals(Object another) compares this string to the specified object.
  - public boolean equalsIgnoreCase(String another) compares this string to another string, ignoring case.

```
Eg 1: String s1="Java";
      String s2="Java";
      String s3=new String("Java");
      String s4="Python";
      System.out.println(s1.equals(s2));      // o/p will be true
      System.out.println(s1.equals(s3));      // o/p will be true
      System.out.println(s1.equals(s4));      // o/p will be false
```

```
Eg 2: String s1="Java";
      String s2="JAVA";
 System.out.println(s1.equals(s2));  //false
System.out.println(s1.equalsIgnoreCase(s2));
//true
```

String Compare

- The **== operator** compares **references** not values.

Eg 1: String s1="Java";
String s2="Java";
String s3=new String("Java");
System.out.println(s1==s2); // o/p will be true (because both refer to same instance)
System.out.println(s1==s3); // o/p will be false(because s3 refers to another instance created)

- The String class **compareTo() method** compares values lexicographically and returns an integer value that describes if first string is less than, equal to or greater than second string.
- Suppose s1 and s2 are two String objects. If:
  - s1 == s2 : The method returns 0.
  - s1 > s2 : The method returns a positive value.
  - s1 < s2 : The method returns a negative value.

Eg : String s1="Java";
String s2="Java";
String s3="Jp";
System.out.println(s1.compareTo(s2)); //0
System.out.println(s1.compareTo(s3)); //-15 (because s1<s3 and "a" is 15 times lower than "p")
System.out.println(s3.compareTo(s1)); //15 (because s3 > s1 and "p" is 15 times greater than "a")

String Concatenation

- In Java, String concatenation forms a new String that is the combination of multiple strings. There are two ways to concatenate strings in Java:
  - By + (String concatenation) operator
  - By concat() method

Eg 1:

```
String s="Java"+" Programming";
String s1=50+30+" JP "+40+40;
System.out.println(s);    // Java Programming
System.out.println(s1);  //80 JP 4040  Note: After a string literal, all the + will be treated as string concatenation operator.
String s2=" by Oracle";
String s3=s.concat(s2);
System.out.println(s3);    // Java Programming by Oracle
```

StringBuffer Class

- Java StringBuffer class is used to create mutable (modifiable) String objects.
- A String that can be modified or changed is known as mutable String. StringBuffer and StringBuilder classes are used for creating mutable strings.
- The StringBuffer class in Java is the same as String class except it is mutable i.e. it can be changed.
- Important Constructors of StringBuffer Class
  - StringBuffer() : It creates an empty String buffer with the initial capacity of 16. If the number of the character increases from its current capacity, it increases the capacity by (oldcapacity*2)+2.
  - StringBuffer(String str) : It creates a String buffer with the specified string.
  - StringBuffer(int capacity) : It creates an empty String buffer with the specified capacity as length.

- Important methods of StringBuffer class

Method	Description
append(String s)	It is used to append the specified string with this string. The append() method is overloaded like append(char), append(boolean), append(int), append(float), append(double) etc.
insert(int offset, String s)	It is used to insert the specified string with this string at the specified position. The insert() method is overloaded like insert(int, char), insert(int, boolean), insert(int, int), insert(int, float), insert(int, double) etc.
replace(int startIndex, int endIndex, String str)	It is used to replace the string from specified startIndex and endIndex.
delete(int startIndex, int endIndex)	It is used to delete the string from specified startIndex and endIndex.
reverse()	is used to reverse the string.
capacity()	It is used to return the current capacity.
ensureCapacity(int minimumCapacity)	It is used to ensure the capacity at least equal to the given minimum.
charAt(int index)	It is used to return the character at the specified position.
length()	It is used to return the length of the string i.e. total number of characters.
substring(int beginIndex)	It is used to return the substring from the specified beginIndex.
substring(int beginIndex, int endIndex)	It is used to return the substring from the specified beginIndex and endIndex.

StringBuffer Class Example

```
public class Main {
public static void main(String[] args) {
StringBuffer sb=new StringBuffer("Java");
System.out.println(sb.append(" Tutorials"));        //original string Java is changed to Java Tutorials
System.out.println(sb.insert(5, "Programming "));  // inserts the given String in original string at the given position
System.out.println(sb.replace(0,4, "HTML"));       // replaces the given String from the specified beginIndex and
endIndex.
System.out.println(sb.delete(17,26));              //deletes the String from the specified beginIndex to endIndex.
System.out.println(sb.reverse());                  // reverses the String
}
}
```

```
Java Tutorials
Java Programming Tutorials
HTML Programming Tutorials
HTML Programming
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```

- WAP to convert a string into an array of characters and display each character with its index

```
import java.util.*;
public class Main{
public static void main(String[] args) {
String str;
int i,n;
Scanner sc=new Scanner(System.in);
System.out.println("Enter the string");
str=sc.nextLine();
n=str.length();
char c[]=new char[n];
c=str.toCharArray();
for(i=0;i<=n-1;i++)
{
System.out.println(i+"\t"+c[i]);
}
}
}
```

```
Enter the string
Hello world !!!
0       H
1       e
2       l
3       l
4       o
5
6       w
7       o
8       r
9       l
10      d
11
12      !
13      !
14      !
```

- WAP to count number of vowels, consonants, digits and blank spaces in a string

```
import java.util.*;
public class Main{
public static void main(String[] args) {
String str;
int i,n,v=0,co=0,d=0,bs=0;
Scanner sc=new Scanner(System.in);
System.out.println("Enter the string");
str=sc.nextLine();
n=str.length();
char c[]=new char[n];
c=str.toCharArray();
for(i=0;i<=n-1;i++)
{
if(c[i]=='a' || c[i]=='e' || c[i]=='i' || c[i]=='o' || c[i]=='u' || c[i]=='A' ||
c[i]=='E' || c[i]=='I' || c[i]=='O' || c[i]=='U')
v++;
else if(c[i]==' ' )
bs++;
else if(c[i]>='0' && c[i]<='9')
d++;
else if((c[i]>='a' && c[i]<='z') || (c[i]>='A' && c[i]<='Z')
co++;
}
System.out.println("No. of vowels : " + v + "\nNo. of Consonants : " +
co + "\nNo. of digits : " + d + "\nNo of blank spaces : " + bs);
}}
```

```
Enter the string
Hello how r u 123
No. of vowels : 4
No. of Consonants : 6
No. of digits : 3
No of blank spaces : 4
```

Programming Practice Questions

- WAP in Java to perform the following String Operations.

1. Create a string instance using String and String Buffer class each.
2. Check the length and capacity of String and String Buffer objects
3. Reverse the contents of a string and convert the resultant string in Upper Case.
4. Append the second string to above resultant string.
5. Extract a substring from resultant string.

- WAP in Java to implement run-length encoding.
- Write a Java method to extract all digits from a given string and return them as a new string.

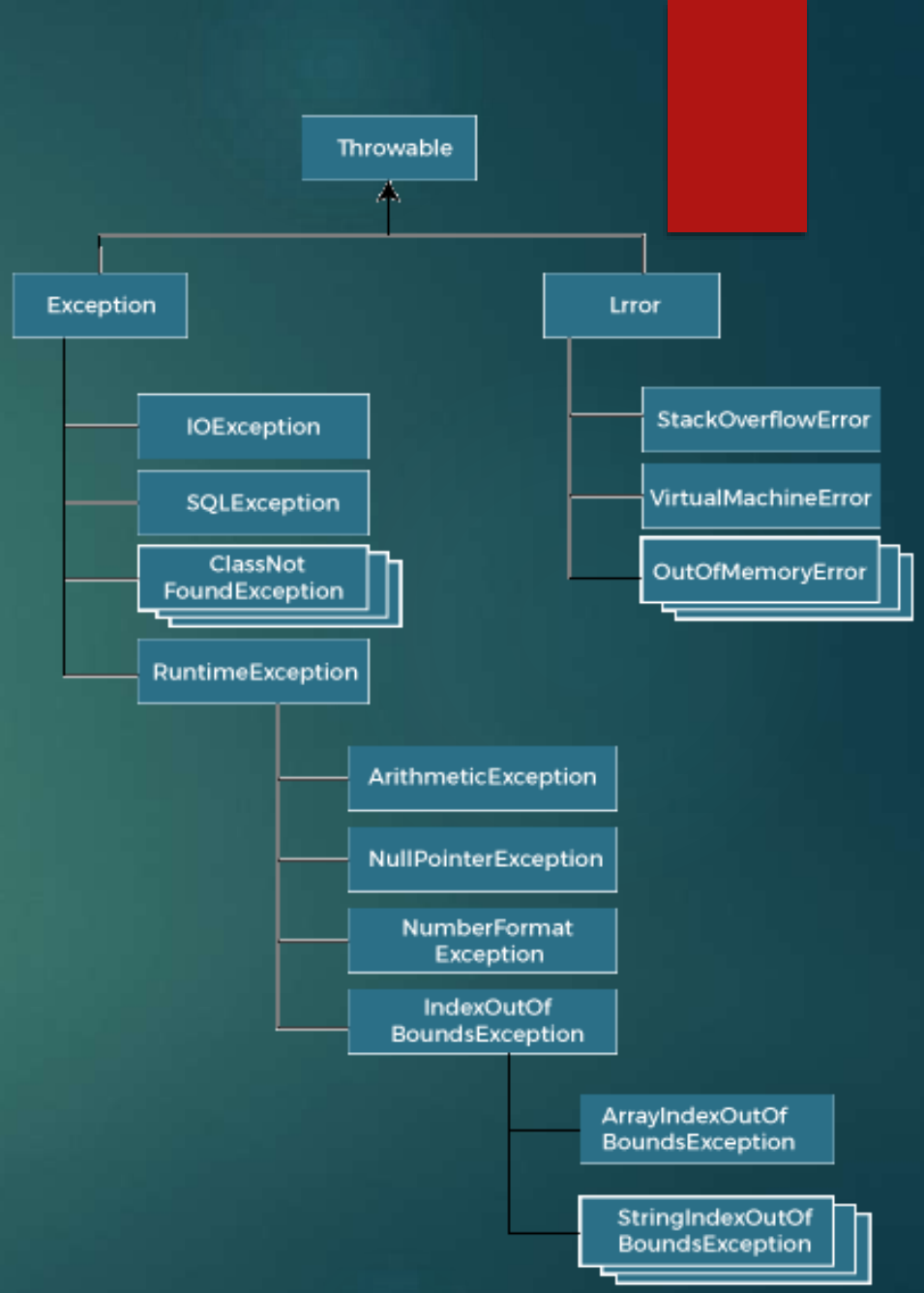
JAVA PROGRAMMING

Chap 6 : Exception Handling

- Exception handling refers to handling of abnormal or unexpected events.
- Some of these exceptions are known to the compiler while some other occur during runtime and are unknown to the compiler.
- The Exception Handling in Java is one of the powerful mechanism to handle the runtime errors such as ClassNotFoundException, IOException, SQLException, RemoteException, etc. so that the normal flow of the application can be maintained.
- Exceptions can be caught and handled by the program.
- When an exception occurs within a method, it creates an object.
- This object is called the exception object.
- It contains information about the exception, such as the name and description of the exception and the state of the program when the exception occurred.
- Major reasons why an exception Occurs
  - Invalid user input
  - Device failure
  - Loss of network connection
  - Physical limitations (out of disk memory)
  - Code errors
  - Opening an unavailable file

- **Errors** represent irrecoverable conditions such as Java virtual machine (JVM) running out of memory, memory leaks, stack overflow errors, library incompatibility, infinite recursion, etc.
- Errors are usually beyond the control of the programmer, and we should not try to handle errors.
- When executing Java code, different errors can occur: coding errors made by the programmer, errors due to wrong input, or other unforeseeable things.
- When an error occurs, Java will normally stop and generate an error message. The technical term for this is: Java will throw an exception (throw an error).
- "Exception" is a class and has subclasses according to the exceptions possible in Java.
- Eg: If a integer is expected while taking input and instead if a character is entered, then while parsing, error will occur. This error is called NumberFormatException. It is one of the subclass of the base class Exception.
- **Exceptions are classified as :**
- **Built-in Exceptions**
  - Checked Exception
  - Unchecked Exception
- **User-Defined Exceptions**

- The java.lang.Throwable class is the root class of Java Exception hierarchy inherited by two subclasses: Exception and Error.
- All exception and error types are subclasses of class **Throwable**, which is the base class of the hierarchy.
- One branch is headed by **Exception**. This class is used for exceptional conditions that user programs should catch. NullPointerException is an example of such an exception.
- Another branch, **Error** is used by the Java run-time system(JVM) to indicate errors having to do with the run-time environment itself(JRE). StackOverflowError is an example of such an error.



Built-in Exceptions

- Built-in exceptions are the exceptions that are available in Java libraries. These exceptions are suitable to explain certain error situations.
- **Checked Exception :** The classes that directly inherit the Throwable class except RuntimeException and Error are known as checked exceptions. For example, IOException, SQLException, etc. Checked exceptions are checked at compile-time.
- Checked exceptions are called compile-time exceptions because these exceptions are checked at compile-time by the compiler.
- Checked Exceptions make the programmers to handle the exception that may be thrown.
- There are two ways to deal with an exception :
  - Indicate that the method throws an exception
  - Method must catch the exception and take appropriate action using the try catch block
- **Unchecked Exception :** The classes that inherit the RuntimeException are known as unchecked exceptions. For example, ArithmeticException, NullPointerException, ArrayIndexOutOfBoundsException, etc.
- The unchecked exceptions are just opposite to the checked exceptions. The compiler will not check these exceptions at compile time, but they are checked at runtime.
- In simple words, if a program throws an unchecked exception, and even if we didn't handle or declare it, the program would not give a compilation error.
- Hence the programmers may not even know that such an exception would be thrown

Built-in Exceptions

- There are given some scenarios where unchecked exceptions may occur. They are as follows:
- If we divide any number by zero, there occurs an ArithmeticException.

```
int a=50/0;//ArithmeticException
```

- If we have a null value in any variable, performing any operation on the variable throws a NullPointerException.

```
String s=null;
System.out.println(s.length());//NullPointerException
```

- If the formatting of any variable or number is mismatched, it may result into NumberFormatException. Suppose we have a string variable that has characters; converting this variable into digit will cause NumberFormatException.

```
String s="abc";
int i=Integer.parseInt(s);//NumberFormatException
```

- When an array exceeds to it's size, the ArrayIndexOutOfBoundsException occurs

```
int a[]=new int[5];
a[10]=50; //ArrayIndexOutOfBoundsException
```

User defined Exceptions

- Sometimes, the built-in exceptions in Java are not able to describe a certain situation. In such cases, users can also create exceptions, which are called ‘user-defined Exceptions’.
- The advantages of Exception Handling in Java are as follows:
  - Provision to Complete Program Execution
  - Easy Identification of Program Code and Error-Handling Code
  - Propagation of Errors
  - Meaningful Error Reporting
  - Identifying Error Types

Java's Unchecked Exceptions

Exception	Meaning
ArithmeticException	Arithmetic error, such as divide-by-zero.
ArrayIndexOutOfBoundsException	Array index is out-of-bounds.
ArrayStoreException	Assignment to an array element of an incompatible type.
ClassCastException	Invalid cast.
EnumConstantNotPresentException	An attempt is made to use an undefined enumeration value.
IllegalArgumentException	Illegal argument used to invoke a method.
IllegalMonitorStateException	Illegal monitor operation, such as waiting on an unlocked thread.
IllegalStateException	Environment or application is in incorrect state.
IllegalThreadStateException	Requested operation not compatible with current thread state.
IndexOutOfBoundsException	Some type of index is out-of-bounds.
NegativeArraySizeException	Array created with a negative size.
NullPointerException	Invalid use of a null reference.
NumberFormatException	Invalid conversion of a string to a numeric format.
SecurityException	Attempt to violate security.
StringIndexOutOfBounds	Attempt to index outside the bounds of a string.
TypeNotPresentException	Type not found.
UnsupportedOperationException	An unsupported operation was encountered.

Table 10-1 Java's Unchecked **RuntimeException** Subclasses Defined in **java.lang**

Java's Checked Exceptions

Exception	Meaning
ClassNotFoundException	Class not found.
CloneNotSupportedException	Attempt to clone an object that does not implement the **Cloneable** interface.
IllegalAccessException	Access to a class is denied.
InstantiationException	Attempt to create an object of an abstract class or interface.
InterruptedException	One thread has been interrupted by another thread.
NoSuchFieldException	A requested field does not exist.
NoSuchMethodException	A requested method does not exist.
ReflectiveOperationException	Superclass of reflection-related exceptions.

Table 10-2 Java's Checked Exceptions Defined in **java.lang**

WAP to perform division of two numbers accepted from the user to demonstrate ArithmeticException and NumberFormatException.

```
import java.io.*;
class Main{
  public static void main(String args[])throws IOException{
   int a,b,res;
BufferedReader sc=new BufferedReader (new InputStreamReader (System.in));
   System.out.println("Enter 2 nos.");
   a=Integer.parseInt(sc.readLine());
   b=Integer.parseInt(sc.re adLine());
   res=a/b;
   System.out.println("The Result is : "+res);
  }
}
```

ArithmeticException →

```
Enter 2 nos.
4
0
Exception in thread "main" java.lang.ArithmeticException: / by zero
        at Main.main(Main.java:9)
```

NumberFormatException →

```
Enter 2 nos.
5
d
Exception in thread "main" java.lang.NumberFormatException: For input string: "d"
        at java.base/java.lang.NumberFormatException.forInputString(NumberFormatException.java:65)
        at java.base/java.lang.Integer.parseInt(Integer.java:652)
        at java.base/java.lang.Integer.parseInt(Integer.java:770)
        at Main.main(Main.java:11)
```

Java Exception Keywords

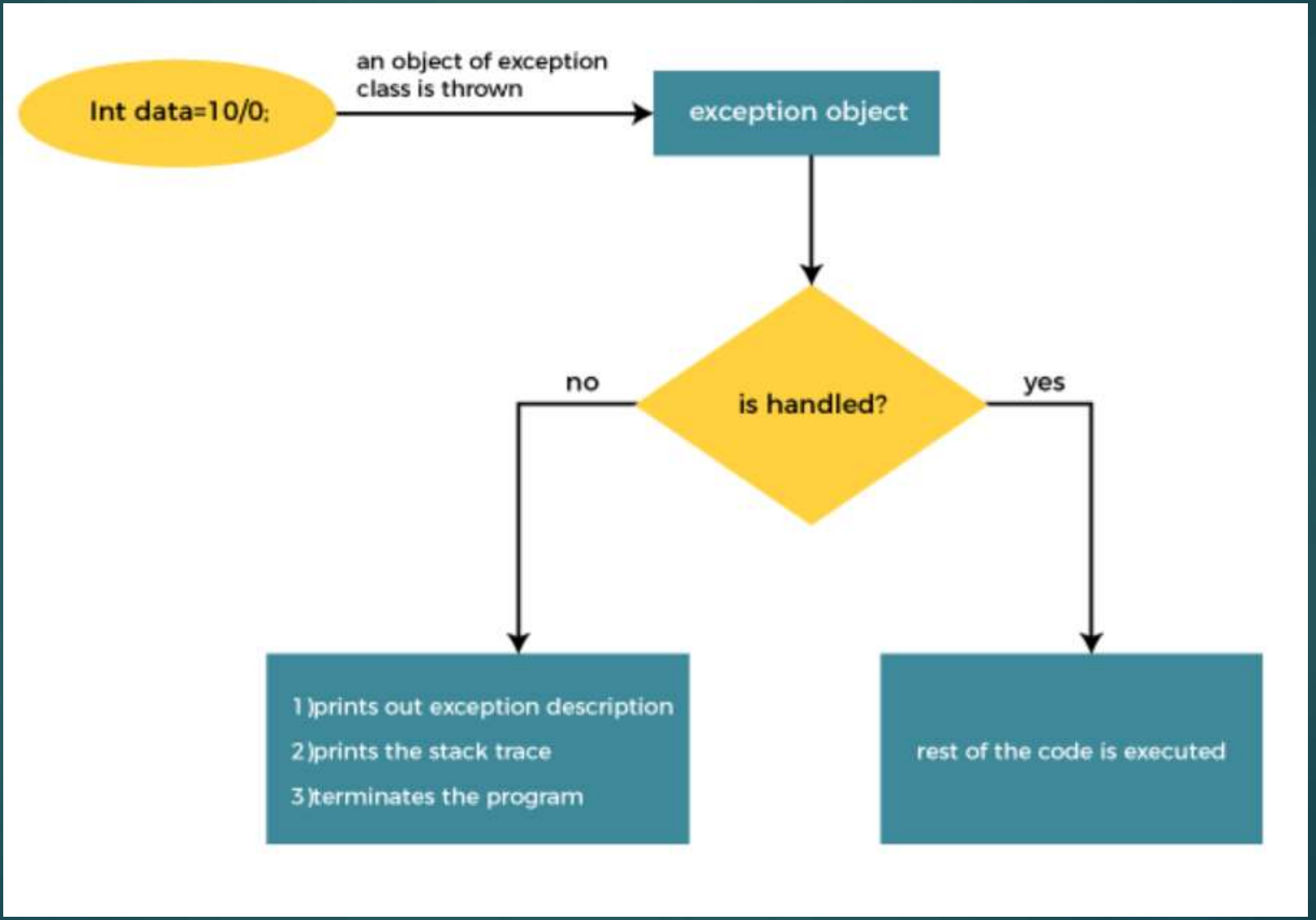
- Java provides five keywords that are used to handle the exception. The following table describes each.

Keyword	Description
try	The "try" keyword is used to specify a block where we should place an exception code. It means we can't use try block alone. The try block must be followed by either catch or finally.
catch	The "catch" block is used to handle the exception. It must be preceded by try block which means we can't use catch block alone. It can be followed by finally block later.
finally	The "finally" block is used to execute the necessary code of the program. It is executed whether an exception is handled or not.
throw	The "throw" keyword is used to throw an exception.
throws	The "throws" keyword is used to declare exceptions. It specifies that there may occur an exception in the method. It doesn't throw an exception. It is always used with method signature.

try-catch-finally

- **Try Block :**
- The statements that are prone to generate errors or exception are placed in try block.
- If an exception occurs then the catch block will be executed and then the finally block will be executed.
- Else if no exception occurs, then the control will directly go to the finally block i.e. the catch block will not be executed.
- The java code that you think can generate an exception is placed in the try catch block to handle the error.
- If an exception occurs but a matching catch block is not found then it reaches to the finally block.
- In any case, when the exception occurs in a particular statement of try block, the remaining statements of the try block after this statement are not executed i.e. no statements of the try block are executed after the exception generating statement.
- **Catch Block :**
- The exception thrown by the try block are caught by the catch block.
- The type of the exception occurred must match with the exception mentioned in the brackets of the catch block.
- **Finally Block :**
- A finally block is always executed irrespective of whether the exception occurred or not
- It is an optional block. It is not necessary to have a finally block i.e. you may just have try catch blocks.

Internal Working of Java try-catch block



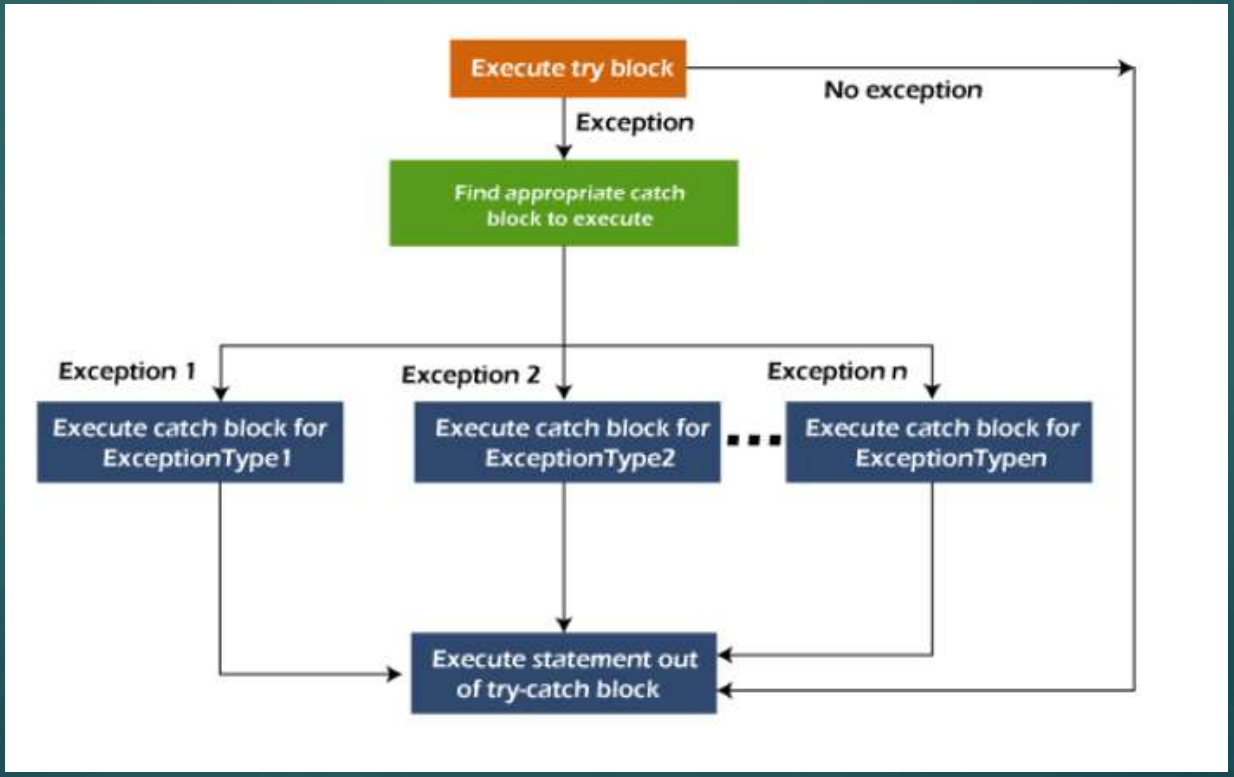
WAP to perform division of two numbers accepted from the user to demonstrate ArithmeticException using try catch block.

```
import java.io.*;
class Main{
  public static void main(String args[]) throws IOException{
   int a,b,res;
   BufferedReader sc=new BufferedReader (new InputStreamReader (System.in));
   System.out.println("Enter 2 nos.");
   a=Integer.parseInt(sc.readLine());
   b=Integer.parseInt(sc.readLine());
   try {
   res=a/b;
   System.out.println("The Result is : "+res);
   }
   catch (ArithmeticException ae)
   {System.out.println("Exception has occurred as divisor entered is zero");
   }
   System.out.println("Remaining code");
  }
}
```

```
Enter 2 nos.
5
0
Exception has occurred as divisor entered is zero
Remaining code
```

Multiple catch blocks

- A try block can be followed by one or more catch blocks. Each catch block must contain a different exception handler. So, if you have to perform different tasks at the occurrence of different exceptions, use java multi-catch block.
- **Points to remember**
- At a time only one exception occurs and at a time only one catch block is executed.
- All catch blocks must be ordered from most specific to most general, i.e. catch for ArithmeticException must come before catch for Exception.



WAP to perform division of two numbers accepted from the user to demonstrate ArithmeticException and NumberFormatException using try catch block.

```
import java.io.*;
class Main{
  public static void main(String args[]) throws IOException{
   int a=0,b=0,res;
   BufferedReader sc=new BufferedReader (new
InputStreamReader (System.in));
   try {
   System.out.println("Enter 2 nos.");
   a=Integer.parseInt(sc.readLine());
   b=Integer.parseInt(sc.readLine());
   res=a/b;
   System.out.println("The Result is : "+res);
   String s=null;
   System.out.println(s.length());
   }
   catch (ArithmeticException ae) {
   System.out.println("Exception has occurred as divisor entered
is zero");
   }
   catch (NumberFormatException ne) {
   System.out.println("Invalid Input. Enter Integer Number.");
   }
    catch(Exception e) {
    System.out.println(e);
    }
    System.out.println("Remaining Code Continues");
  }}
```

```
Enter 2 nos.
5
0
Exception has occurred as divisor entered is zero
Remaining Code Continues
```

```
Enter 2 nos.
5
d
Invalid Input. Enter Integer Number.
Remaining Code Continues
```

```
Enter 2 nos.
5
2
The Result is : 2
java.lang.NullPointerException
Remaining Code Continues
```

Nested try blocks

- Sometimes a situation may arise where a part of a block may cause one error and the entire block itself may cause another error. In such cases, exception handlers have to be nested.
- In Java, using a try block inside another try block is permitted. It is called as nested try block.
- Every statement that we enter a statement in try block, context of that exception is pushed onto the stack.
- For example, the inner try block can be used to handle ArrayIndexOutOfBoundsException while the outer try block can handle the ArithemeticException (division by zero).

```
....
//main try block
try
{
    statement 1;
    statement 2;
//try catch block within another try block
    try
    {
        statement 3;
        statement 4;
//try catch block within nested try block
        try
        {
            statement 5;
            statement 6;
    }
catch(Exception e2)
        {
//exception message of 2nd nested try block
        }
    }
    catch(Exception e1)
    {
//exception message of 1st nested try block
    }
}
catch(Exception e3)
{
//exception message  of parent (outer) try block
}
....
```

WAP to perform division of two numbers accepted from the user to demonstrate ArithmeticException and NumberFormatException using nested try catch block.

```
import java.io.*;
class Main{
  public static void main(String args[]) throws IOException{
   int a=0,b=0,res;
   BufferedReader sc=new BufferedReader (new
InputStreamReader (System.in));
   try {
   System.out.println("Enter 2 nos.");
   a=Integer.parseInt(sc.readLine());
   b=Integer.parseInt(sc.readLine());
       try {
       res=a/b;
       System.out.println("The Result is : "+res);
        }
       catch (ArithmeticException ae) {
       System.out.println("Exception has occurred as divisor
       entered is zero");
        }
   }
   catch (NumberFormatException ne) {
   System.out.println("Invalid Input. Enter Integer Number.");
   }
    System.out.println("Remaining Code Continues");
  }
}
```

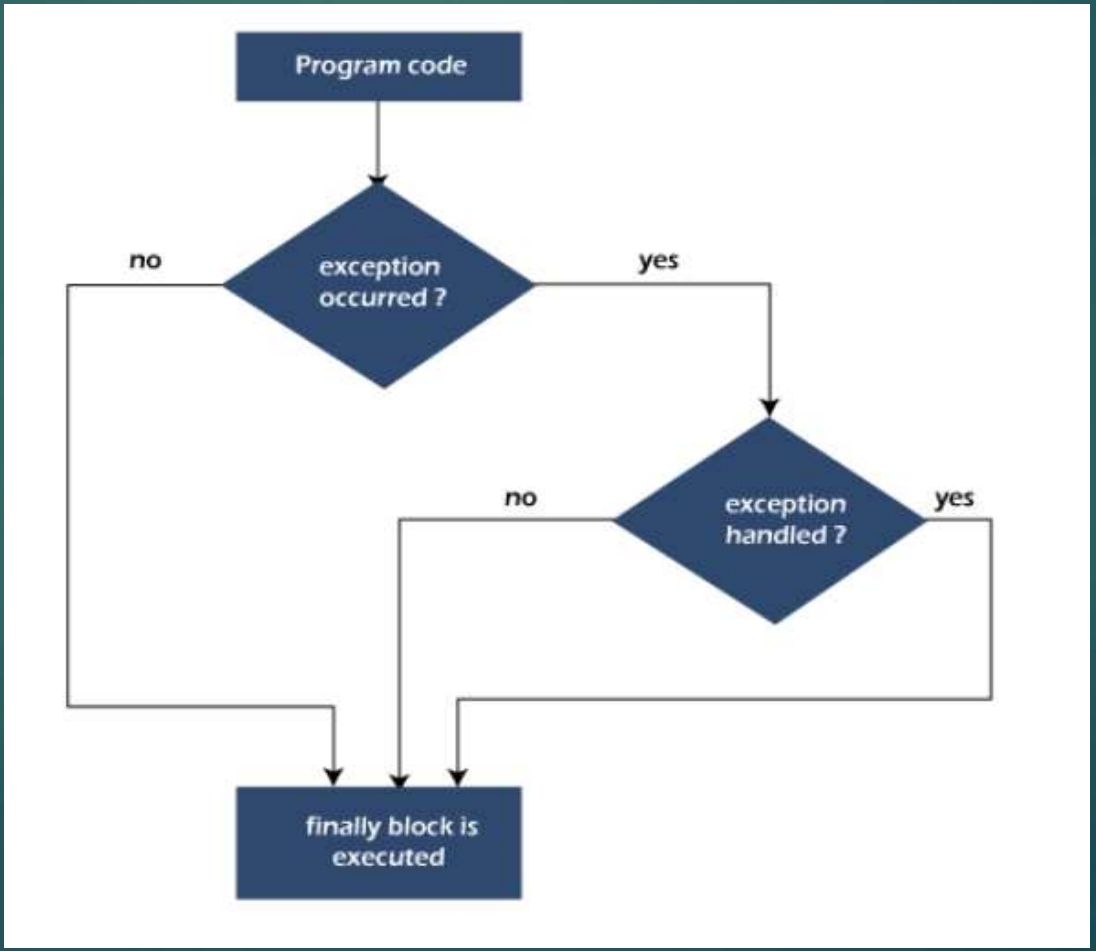
```
Enter 2 nos.
5
0
Exception has occurred as divisor entered is zero
Remaining Code Continues
```

```
Enter 2 nos.
5
d
Invalid Input. Enter Integer Number.
Remaining Code Continues
```

```
Enter 2 nos.
10
2
The Result is : 5
Remaining Code Continues
```

Internal Working of Java try-catch-finally block

- A finally block is always executed irrespective of whether the exception occurred or not
- It is an optional block. It is not necessary to have a finally block i.e. you may just have try catch blocks.
- finally block in Java can be used to put "cleanup" code such as closing a file, closing connection, etc.
- The important statements to be printed can be placed in the finally block.



WAP to perform division of two numbers accepted from the user to demonstrate ArithmeticException and NumberFormatException using try-catch-finally block.

```
import java.io.*;
class Main{
  public static void main(String args[]) throws IOException{
   int a=0,b=0,res;
   BufferedReader sc=new BufferedReader (new
InputStreamReader (System.in));
   try {
   System.out.println("Enter 2 nos.");
   a=Integer.parseInt(sc.readLine());
   b=Integer.parseInt(sc.readLine());
   try {
   res=a/b;
   System.out.println("The Result is : "+res);
   }
   catch (ArithmeticException ae)
   { System.out.println("Exception has occurred as divisor entered
is zero");
   }
   }
   catch (NumberFormatException ne)
   { System.out.println("Invalid Input. Enter Integer Number.");
   }
   finally {
    System.out.println("Finally block executed");
  }
 }
}
```

```
Enter 2 nos.
5
0
Exception has occurred as divisor entered is zero
Finally block executed
```

```
Enter 2 nos.
5
d
Invalid Input. Enter Integer Number.
Finally block executed
```

```
Enter 2 nos.
10
2
The Result is : 5
Finally block executed
```

“throws” keyword

- The Java throws keyword is used to declare an exception.
- It gives an information to the programmer that there may occur an exception. So, it is better for the programmer to provide the exception handling code so that the normal flow of the program can be maintained.
- Exception Handling is mainly used to handle the checked exceptions.
- Syntax of Java throws

```
return_type method_name() throws exception_class_name{
//method code
}
```

- throws keyword in Java is used in the signature of method to indicate that this method might throw one of the listed type (i.e. checked) exceptions. The caller to these methods has to handle the exception using a try-catch block.
- Important points to remember about throws keyword:
  - throws keyword is required only for checked exception and usage of throws keyword for unchecked exception is meaningless.
  - throws keyword is required only to convince compiler and usage of throws keyword does not prevent abnormal termination of program.
  - By the help of throws keyword we can provide information to the caller of the method about the exception.

WAP to demonstrate throws keyword.

```
import java.util.*;
public class Main {
 public static void main(String[] args) {
     int a;
     System.out.println("Enter age :");
     Scanner sc=new Scanner(System.in);
     a=sc.nextInt();
     checkAge(a);
 }
 static void checkAge(int age) throws ArithmeticException
{
    if (age < 18) {
      throw new ArithmeticException("Access denied - You
must be at least 18 years old.");
    }
    else
    {
      System.out.println("Access granted - You are old
enough!");
    }
 }
}
```

```
Enter age :
20
Access granted - You are old enough!
```

```
Enter age :
15
Exception in thread "main" java.lang.ArithmeticException: Access denied - You must be at least 18 years old.
        at Main.checkAge(Main.java:13)
        at Main.main(Main.java:8)
```

“throw” keyword

- The Java throw keyword is used to throw an exception explicitly.
- We specify the exception object which is to be thrown. The Exception has some message with it that provides the error description. These exceptions may be related to user inputs, server, etc.
- We can throw either checked or unchecked exceptions in Java by throw keyword.
- It is mainly used to throw a custom exception i.e. you can make your own conditions to throw exceptions.
- It will not be a built in exception but it will be your user defined exception.

WAP to accept and display month number. Throw a NumberFormatException if month number exceeds 12 or is less than 0.

```
import java.util.*;
class Main{
  public static void main(String args[]){
   int m;
   Scanner sc=new Scanner(System.in);

   System.out.println("Enter month number");
   m=sc.nextInt();
   try {
   if(m<1 || m>12)
   throw new NumberFormatException();
   System.out.println("The entered month number is :
"+m);
   }
      catch (NumberFormatException ne)
   { System.out.println("Invalid month number.");
   }
 }
}
```

```
Enter month number
25
Invalid month number.
```

```
Enter month number
5
The entered month number is : 5
```

WAP to accept and display month number. Throw an Exception if month number exceeds 12 or is less than 0. Make your own exception class to handle this exception.

```
import java.util.*;
class MonthNumberException extends Exception {
    MonthNumberException()
    {
    System.out.println("Invalid Month Number");
    }
}
class Main{
  public static void main(String args[]){
   int m;
   Scanner sc=new Scanner(System.in);
   System.out.println("Enter month number");
   m=sc.nextInt();
   try {
   if(m<1 || m>12)
   throw new MonthNumberException();
   System.out.println("The entered month number is :
"+m);
   }
      catch (MonthNumberException me)
   {
   }
 }
}
```

```
Enter month number
25
Invalid month number.
```

```
Enter month number
5
The entered month number is : 5
```

Programming Practice Questions

- Write a Java program that simulates a simple banking system. Implement nested try-catch blocks to handle:
  1. ArithmeticException when dividing by zero in calculating interest.
  2. NumberFormatException if the user inputs invalid account details.
- Create a custom exception class InvalidAgeException that extends Exception. Write a Java program that uses this custom exception to validate a user's age. If the user enters an age less than 0 or greater than 100, throw and handle InvalidAgeException.
- Create a Java application that prompts the user to enter a number and performs a calculation with it. Implement exception handling to manage invalid inputs and arithmetic errors, and ensure that any resources (e.g., scanners) used for input are closed in the finally block.
- Develop a program that prompts the user for two integers and performs division. Use multiple catch blocks to handle InputMismatchException (if the user inputs non-numeric values), ArithmeticException (if there is a division by zero), and Exception (for any other unexpected errors).
- Develop a library management system where you can borrow and return books. Define custom exceptions for scenarios such as when a book is already borrowed (BookAlreadyBorrowedException), when a book is not available in the library (BookNotFoundException), and when a user tries to return a book that they haven't borrowed (InvalidReturnOperationException).

JAVA PROGRAMMING

Chap 7 : Generics and Collections

Generics

- Imagine, wouldn't it be nice if we could write a single sort method that could sort the elements in an Integer array, a String array, or an array of any type that supports ordering.
- Java Generic methods and generic classes enable programmers to specify, with a single method declaration, a set of related methods, or with a single class declaration, a set of related types, respectively.
- Generics also provide compile-time type safety that allows programmers to catch invalid types at compile time.
- Using Java Generic concept, we might write a generic method for sorting an array of objects, then invoke the generic method with Integer arrays, Double arrays, String arrays and so on, to sort the array elements.
- The idea is to allow type (Integer, String, … etc., and user-defined types) to be a parameter to methods, classes, and interfaces.
- Using Generics, it is possible to create classes that work with different data types.
- An entity such as class, interface, or method that operates on a parameterized type is a generic entity.
- There are mainly 3 advantages of generics. They are as follows:
  1) **Type-safety:** We can hold only a single type of objects in generics. It doesn't allow to store other objects.
  2) **Type casting is not required**: There is no need to typecast the object.
  3) **Compile-Time Checking:** It is checked at compile time so problem will not occur at runtime. The good programming strategy says it is far better to handle the problem at compile time than runtime.

Types of Java Generics

Generic Methods

- You can write a single generic method declaration that can be called with arguments of different types.
- Based on the types of the arguments passed to the generic method, the compiler handles each method call appropriately.
- Generic Java method takes a parameter and returns some value after performing a task.
- It is exactly like a normal function, however, a generic method has type parameters that are cited by actual type.
- This allows the generic method to be used in a more general way.
- The compiler takes care of the type of safety which enables programmers to code easily since they do not have to perform long, individual type castings.
- Following are the rules to define Generic Methods −
  - All generic method declarations have a type parameter section delimited by angle brackets (< and >) that precedes the method's return type.
  - Each type parameter section contains one or more type parameters separated by commas. A type parameter, also known as a type variable, is an identifier that specifies a generic type name.
  - The type parameters can be used to declare the return type and act as placeholders for the types of the arguments passed to the generic method, which are known as actual type arguments.
  - A generic method's body is declared like that of any other method. **Note that type parameters can represent only reference types, not primitive types (like int, double and char).**

Types of Java Generics

Generic Classes

- A generic class is implemented exactly like a non-generic class.
- The only difference is that it contains a type parameter section.
- There can be more than one type of parameter, separated by a comma.
- The classes, which accept one or more parameters, are known as parameterized classes or parameterized types.
- we use the T type parameter to create the generic class of specific type.
- The type parameters naming conventions are important to learn generics thoroughly. The common type parameters are as follows:
  - T - Type
  - E - Element
  - K - Key
  - N - Number
  - V - Value

Generics Class Example

```
class GenericsClass<T> {              // create a Generic class
private T data;                       // variable of T type
public GenericsClass(T data) {      // constructor of Generic class
    this.data = data;
  }
public T getData() {                  // method that return T type variable
    return this.data;
  }
}

class Main {
public static void main(String[] args) {
GenericsClass<Integer> intObj = new GenericsClass<>(5);          // initialize generic class with Integer data
System.out.println("Generic Class returns: " + intObj.getData());

GenericsClass<String> stringObj = new GenericsClass<>("Java Programming"); // initialize generic class with String data
    System.out.println("Generic Class returns: " + stringObj.getData());
  }}
```

```
Generic Class returns: 5
Generic Class returns: Java Programming
```

Generics Method Example

```
class DemoClass {
public <T> void genericsMethod(T data) {                    // create a generics method
System.out.println("Data Passed: " + data);
  }
}

class Main {
  public static void main(String[] args) {
   DemoClass demo = new DemoClass();
   demo.<String>genericsMethod("Java Programming");     // generics method working with String
  demo.genericsMethod(25);        // generics method working with integer without including the type parameter
  }
}
```

```
Data Passed: Java Programming
Data Passed: 25
```

Generics Class Example 2

```
class GenericsClass<T> {              // create a Generic class
private T data, data1;                          // variables of T type
public GenericsClass(T data, T data1) {     // constructor of Generic class
    this.data = data;
    this.data1 = data1;
  }
public <T> void getData() {                  // method that prints T type variable
    System.out.println(this.data);
    System.out.println(this.data1);
  }
 }
class Main {
public static void main(String[] args) {
GenericsClass intObj = new GenericsClass(5,"10");          // initialize generic class with different data
intObj.getData();

GenericsClass stringObj = new GenericsClass("Java Programming",15);
   stringObj.getData();
 }}
```

```
5
10
Java Programming
15
```

Bounded Types

- In general, the type parameter can accept any data types.
- However, if we want to use generics for some specific types (such as accept data of number types) only, then we can use bounded types.
- In the case of bound types, we use the extends keyword.
- Syntax : <T extends A>

This means T can only accept data that are subtypes of A.

- Eg : class GenericsClass <T extends Number>

Here, GenericsClass is created with bounded type. This means GenericsClass can only work with data types that are subtypes of Number (Integer, Double, and so on).

Bounded Type Example

```
class GenericsClass <T extends Number> {
  public void display() {
    System.out.println("This is a bounded type generics class.");
  }}
class Main {
  public static void main(String[] args) {
    // create an object of GenericsClass
    GenericsClass<Integer/Float/Double/Long/Short> obj = new GenericsClass<>();
     obj.display();
  }}
```

```
This is a bounded type generics class.
```

```
class GenericsClass <T extends Number> {
  public void display() {
    System.out.println("This is a bounded type generics class.");
  }}
class Main {
  public static void main(String[] args) {
    // create an object of GenericsClass
    GenericsClass<String> obj = new GenericsClass<>();
     obj.display();
  }}
```

```
Main.java:12: error: type argument String is not within bounds of type-variable T
    GenericsClass<String> obj = new GenericsClass<>();
                  ^
  where T is a type-variable:
    T extends Number declared in class GenericsClass
Main.java:12: error: incompatible types: cannot infer type arguments for GenericsClass<>
    GenericsClass<String> obj = new GenericsClass<>();
                                                   ^
    reason: inference variable T has incompatible bounds
      equality constraints: String
      lower bounds: Number
  where T is a type-variable:
    T extends Number declared in class GenericsClass
2 errors
```

Generic Restrictions

- You cannot use generics in certain ways and in certain scenarios as listed below −
  - You cannot use datatypes with generics.
  - You cannot instantiate the generic parameters.
  - The generic type parameter cannot be static.
  - You cannot cast parameterized type of one datatype to other.
  - You cannot create an array of generic type objects.
  - A generic type class cannot extend the throwable class therefore, you cannot catch or throw these objects.

Generic Restrictions

- You cannot use primitive datatypes with generics.

```
class Student<T>{
   T age;
   Student(T age){
      this.age = age;
   }
}
public class GenericsExample {
   public static void main(String args[]) {
      Student<Float> std1 = new Student<Float>(25.5f);
      Student<String> std2 = new Student<String>("25");
      Student<int> std3 = new Student<int>(25);
   }
}
```

Int is a primitive datatype and hence cannot be used with generics.
We need to mention Integer in generics to work with integer data.

```
Main.java:11: error: unexpected type
      Student<int> std3 = new Student<int>(25);
              ^
  required: reference
  found:    int
Main.java:11: error: unexpected type
      Student<int> std3 = new Student<int>(25);
                                      ^
  required: reference
  found:    int
2 errors
```

Generic Restrictions

- You cannot instantiate the generic parameters.

```
class Student<T>{
   T age;
   Student(T age){
      this.age = age;
   }
   public void display() {
      System.out.println("Value of age: "+this.age);
   }
}
public class Main {
   public static void main(String args[]) {
      Student<Float> std1 = new Student<Float>(25.5f);
      std1.display();
      T obj = new T();
   }
}
```

```
Main.java:14: error: cannot find symbol
      T obj = new T();
      ^
  symbol:   class T
  location: class Main
Main.java:14: error: cannot find symbol
      T obj = new T();
              ^
  symbol:   class T
  location: class Main
2 errors
```

Generic Restrictions

- The generic type parameter cannot be static.

```
class Student<T>{
   static T age;
   Student(T age){
      this.age = age;
   }
   public void display() {
      System.out.println("Value of age: "+this.age);
   }
}
public class Main {
   public static void main(String args[]) {
      Student<Float> std1 = new Student<Float>(25.5f);
      std1.display();
   }
}
```

```
Main.java:2: error: non-static type variable T cannot be referenced from a static context
   static T age;
          ^
1 error
```

Generic Restrictions

- You cannot cast parameterized type of one datatype to other.

```
class Student<T>{
   T age;
   Student(T age){
      this.age = age;
   }
   public void display() {
      System.out.println("Value of age: "+this.age);
   }
}
public class Main {
   public static void main(String args[]) {
      Student<Float> std1 = new Student<Float>(25.5f);
      std1.display();
      Student<Double> std2 = std1;
      std2.display();
   }
}
```

```
Main.java:14: error: incompatible types: Student cannot be converted to Student
      Student<Double> std2 = std1;
                             ^
1 error
```

Generic Restrictions

- You cannot create an array of generic type objects.
- Note : syntax for creating array of objects : Student s[]=new Student[n];

```
class Student<T>{
   T age;
   Student(T age){
      this.age = age;
   }
   public void display() {
      System.out.println("Value of age: "+this.age);
   }
}
public class Main {
   public static void main(String args[]) {
      Student<Float> std1[ ] = new Student<Float>[5];
   }
}
```

```
Main.java:12: error: generic array creation
      Student<Float> std1[] = new Student<Float>[5];
                                                ^
1 error
```

Generic Class Hierarchies

- Generic classes can be part of a class hierarchy in just the same way as a non-generic class.
- Thus, a generic class can act as a superclass or be a subclass.
- The key difference between generic and non-generic hierarchies is that in a generic hierarchy, any type arguments needed by a generic superclass must be passed up the hierarchy by all subclasses.
- A subclass can freely add its own type parameters, if necessary.

Generic Class Hierarchies

Eg 1 : Generic Super Class and Generic Sub Class

```
import java.io.*;
class Base<T> {                    // Class 1 - Parent class
        T obj;                     // Member variable of parent class
    Base(T o1) {                   // Constructor of parent class
        obj = o1;
    }
    T getobj1() {                  // Member function of parent class that returns an object
        return obj;
    }}

class Child<T> extends Base<T> {     // Class 2 - Child class
     T obj2;                       // Member variable of child class
    Child(T o1, T o2)  {           // Constructor of Child class
        super(o1);                 // Calling super class using super keyword
        obj2 = o2;
    }
    T getobj2() {                  // Member function of child class that returns an object
        return obj2;
    }}
```

Generic Class hierarchies

```
class Main {                        // Class 3 -  Main class
    public static void main(String[] args)
    {
        Child x = new Child("value : ",100);
        System.out.println(x.getobj1());
        System.out.println(x.getobj2());
    }}
```

```
value :
100
```

Generic Class Hierarchies

Eg 1 : Non-Generic Super Class and Generic Sub Class

```
import java.io.*;
class Base {                // non-generic super-class
    int n;
   Base(int i) {
       n = i;
   }
    int getval() {
    return n;
    }}

class Child<T> extends Base {      // generic sub-class
    T obj;
    Child(T o1, int i)     {
        super(i);
        obj = o1;
    }
    T getobj() {
    return obj;
    }}
```

```
class Main {
    public static void main(String[] args)
    {
        Child c = new Child("Java Programming", 2023);
       System.out.println(c.getobj() + " " + c.getval());
    }
}
```

```
Java Programming 2023
```

Java Collections

Collections

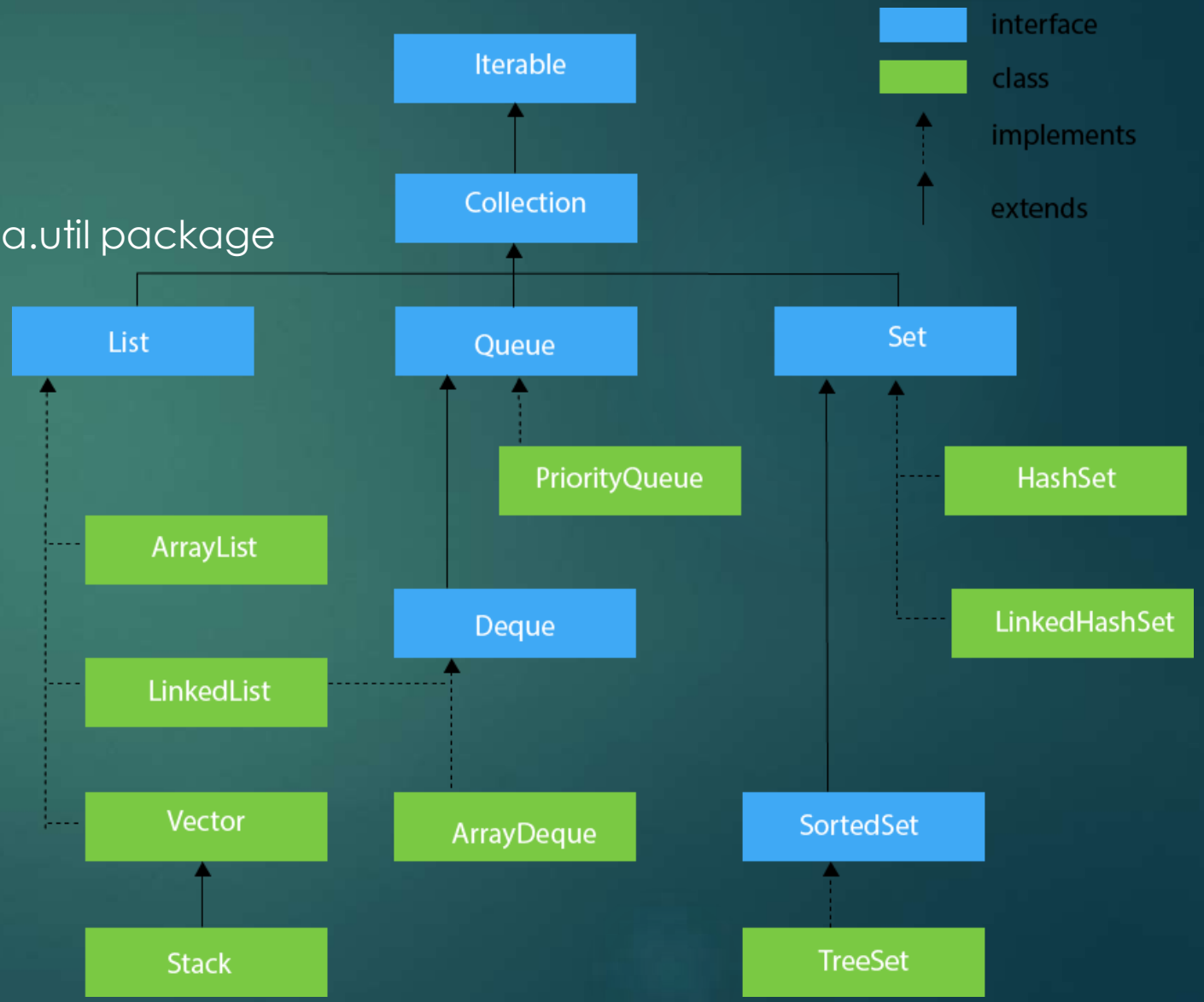
- The Collection in Java is a framework that provides an architecture to store and manipulate the group of objects. A Collection represents a single unit of objects, i.e., a group.
- Java Collections can achieve all the operations that you perform on a data such as searching, sorting, insertion, manipulation, and deletion.
- Java Collection means a single unit of objects. Java Collection framework provides many interfaces (Set, List, Queue, Deque) and classes (ArrayList, Vector, LinkedList, PriorityQueue, HashSet, LinkedHashSet, TreeSet).

Why to use Java Collections

- There are several benefits of using Java collections such as:
  - Reducing the effort required to write the code by providing useful data structures and algorithms
  - Java collections provide high-performance and high-quality data structures and algorithms thereby increasing the speed and quality
  - Unrelated APIs can pass collection interfaces back and forth
  - Decreases extra effort required to learn, use, and design new API's
  - Supports reusability of standard data structures and algorithms

Collection Framework

- The Collection framework represents a unified architecture for storing and manipulating a group of objects. It has:
  - Interfaces and its implementations
  - Classes
  - Algorithm
- The Collections framework is defined in the java.util package



Java Collections : Interface

Iterator interface

- Iterator is an interface that iterates the elements.
- It is used to traverse the list and modify the elements.
- Iterator interface has three methods which are mentioned below:
  - public boolean hasNext() – This method returns true if the iterator has more elements otherwise it returns false.
  - public object next() – It returns the element and moves the cursor pointer to the next element.
  - public void remove() – This method removes the last element returned by the iterator.
- There are three components that extend the collection interface i.e List, Queue and Sets.

Iterable interface

- The Iterable interface is the root interface for all the collection classes.
- The Collection interface extends the Iterable interface and therefore all the subclasses of Collection interface also implement the Iterable interface.
- It contains only one abstract method. i.e., Iterator<T> iterator()
- It returns the iterator over the elements of type T.

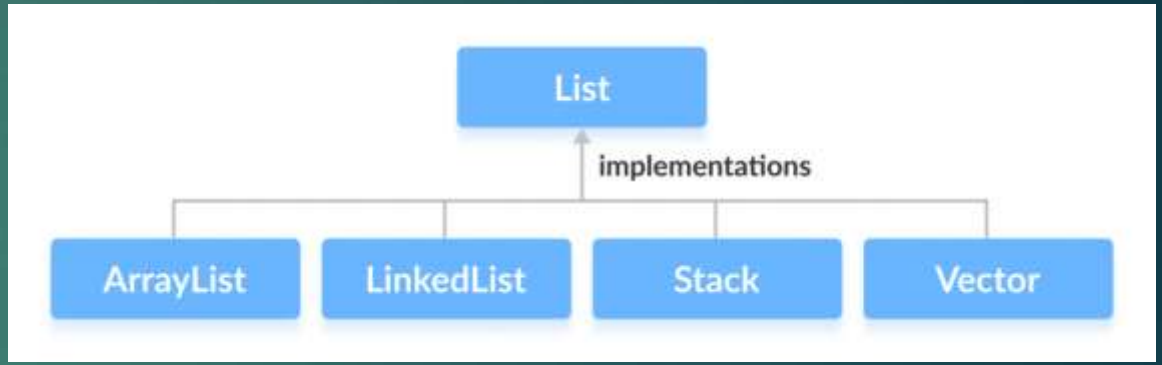
Java Collections : Interface

Collection interface

- The Collection interface is the root interface of the collections framework hierarchy.
- Java does not provide direct implementations of the Collection interface but provides implementations of its sub-interfaces like List, Set, and Queue
- The Collection interface is the interface which is implemented by all the classes in the collection framework.
- the Collection interface builds the foundation on which the collection framework depends.
- **Methods of Collection** : The Collection interface includes various methods that can be used to perform different operations on objects. These methods are available in all its sub interfaces.
  - add() - inserts the specified element to the collection
  - size() - returns the size of the collection
  - remove() - removes the specified element from the collection
  - iterator() - returns an iterator to access elements of the collection
  - addAll() - adds all the elements of a specified collection to the collection
  - removeAll() - removes all the elements of the specified collection from the collection
  - clear() - removes all the elements of the collection

Java Collections : List Interface

- A List is an ordered Collection of elements **which may contain duplicates.**
- It allows us to add and remove elements like an array
- It is an interface that extends the Collection interface.
- Since List is an interface, we cannot create objects from it.
- List interface is implemented by the following classes -
  - ArrayList
  - LinkedList
  - Vectors
  - Stack
- To instantiate the List interface, we must use :
  - List <data-type> list1= new ArrayList();
  - List <data-type> list2 = new LinkedList();
  - List <data-type> list3 = new Vector();
  - List <data-type> list4 = new Stack();

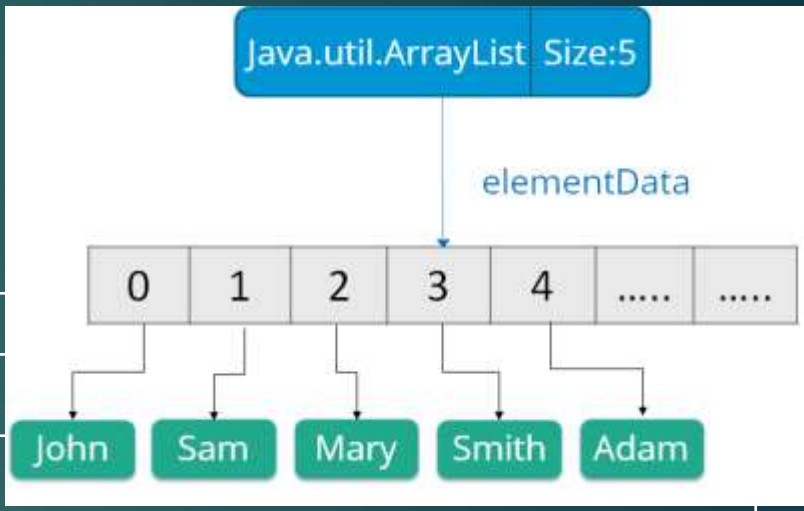


Java Collections : List Interface

- **Methods of List** : The List interface includes all the methods of the Collection interface. Its because Collection is a super interface of List. Some of the commonly used methods of the Collection interface that's also available in the List interface are:
  - add() - adds an element to a list
  - addAll() - adds all elements of one list to another
  - get() - helps to randomly access elements from lists
  - iterator() - returns iterator object that can be used to sequentially access elements of lists
  - set() - changes elements of lists
  - remove() - removes an element from the list
  - removeAll() - removes all the elements from the list
  - clear() - removes all the elements from the list (more efficient than removeAll())
  - size() - returns the length of lists
  - toArray() - converts a list into an array
  - contains() - returns true if a list contains specified element

ArrayList

- ArrayList is the implementation of List Interface where the elements can be dynamically added or removed from the list.
- It uses a dynamic array to store the duplicate element of different data types.
- Also, the size of the list is increased dynamically if the elements are added more than the initial size.
- The ArrayList class maintains the insertion order and is non-synchronized.
- The elements stored in the ArrayList class can be randomly accessed.
- Syntax: ArrayList object = new ArrayList ();
- Some of the methods in array list are listed below:



Method	Description
boolean add(Collection c)	Appends the specified element to the end of a list.
void add(int index, Object element)	Inserts the specified element at the specified position.
void clear()	Removes all the elements from this list.
int lastIndexOf(Object o)	Return the index in this list of the last occurrence of the specified element, or -1 if the list does not contain this element.
Object clone()	Return a shallow copy of an ArrayList.
Object[] toArray()	Returns an array containing all the elements in the list.
void trimToSize()	Trims the capacity of this ArrayList instance to be the list's current size.

ArrayList

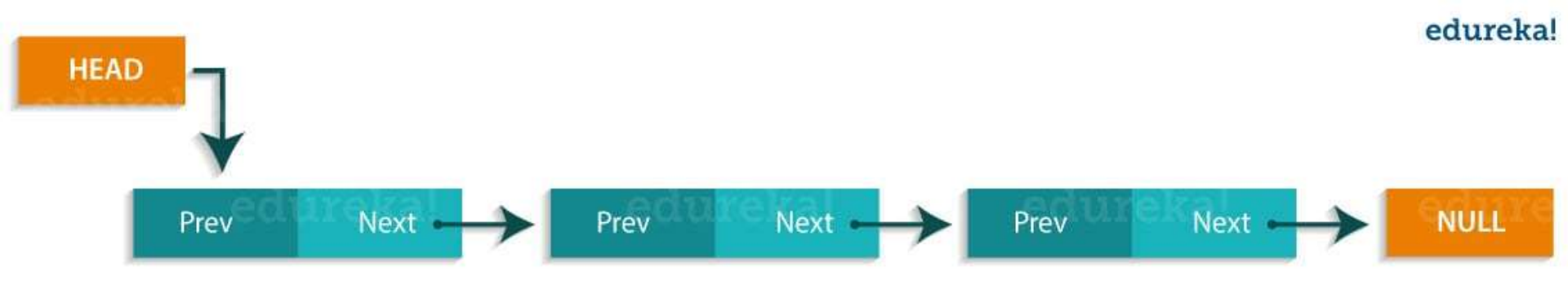
```
import java.util.*;
 class Main{
 public static void main(String args[]){
 ArrayList<String> animals=new ArrayList<String>();  // creating array list
 animals.add("Dog");
 animals.add("Cat");
 animals.add("Horse");
 Iterator itr=animals.iterator();
 System.out.println("Array List : ");
 while(itr.hasNext()){
 System.out.println(itr.next());
 }

 String a1 = animals.get(2);                // Access element from the list
 System.out.println("Accessed Element: " + a1);
 System.out.println(animals);

String r = animals.remove(1);               // Remove element from the list
System.out.println("Removed Element: " + r);
System.out.println(animals);

animals.set(1,"Cow");          // Changing element in the list
System.out.println("Array List with Modified Element: " + animals);
}}
```

```
Dog
Cat
Horse
Accessed Element: Horse
[Dog, Cat, Horse]
Removed Element: Cat
[Dog, Horse]
Array List with Modified Element: [Dog, Cow]
```

LinkedList

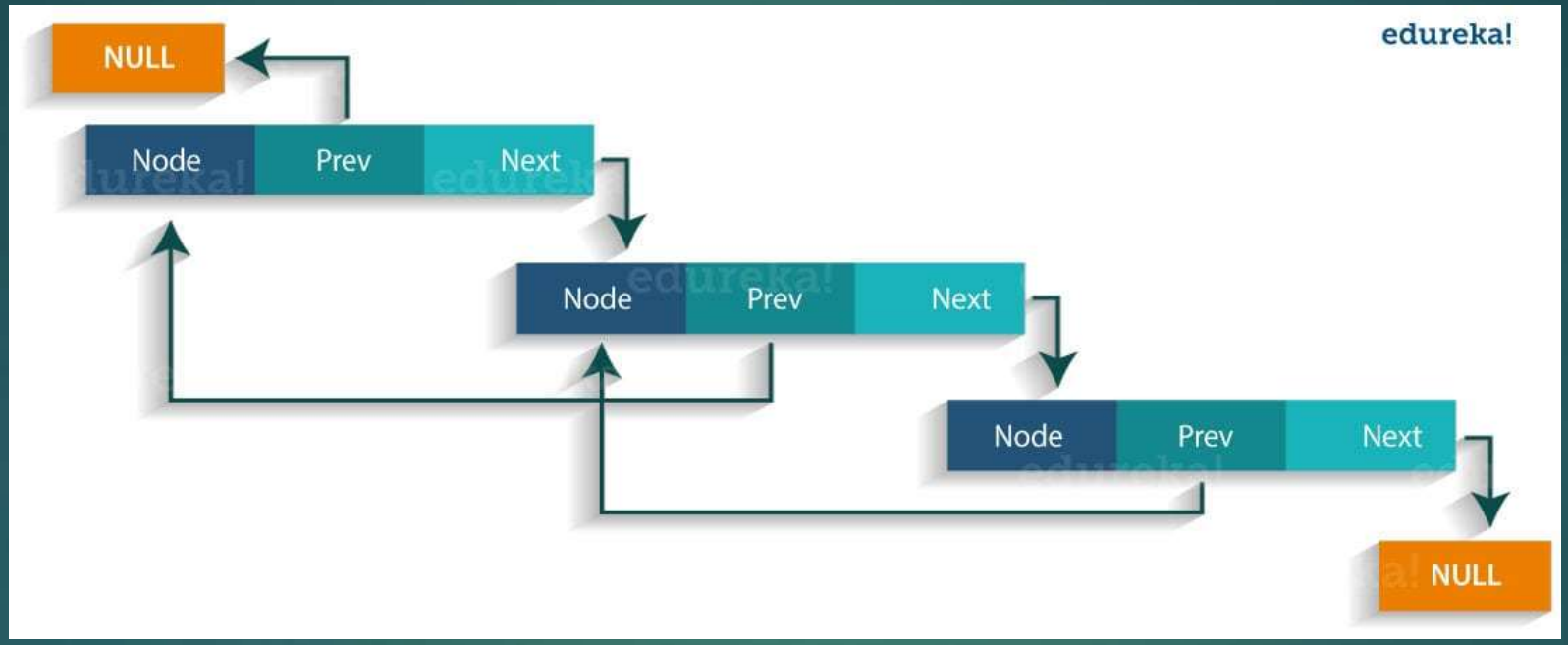
- Linked List is a sequence of links which contains items. Each link contains a connection to another link.
- Linked List implements the Collection interface.
- It uses a doubly linked list internally to store the elements.
- It can store the duplicate elements.
- It maintains the insertion order and is not synchronized.
- In Linked List, the manipulation is fast because no shifting is required.
- Syntax: Linkedlist object = new Linkedlist();
- Java Linked List class uses two types of Linked list to store the elements:

1. Singly Linked List: In a singly Linked list each node in this list stores the data of the node and a pointer or reference to the next node in the list. Refer to the below image to get a better understanding of single Linked list.



LinkedList

2. Doubly Linked List: In a doubly Linked list, it has two references, one to the next node and another to previous node. You can refer to the below image to get a better understanding of doubly linked list.



LinkedList

- Some of the methods in the linked list are listed below:

Method	Description
boolean add(Object o)	It is used to append the specified element to the end of the vector.
boolean contains(Object o)	Returns true if this list contains the specified element.
void add (int index, Object element)	Inserts the element at the specified element in the vector.
void addFirst(Object o)	It is used to insert the given element at the beginning.
void addLast(Object o)	It is used to append the given element to the end.
int size()	It is used to return the number of elements in a list
boolean remove(Object o)	Removes the first occurrence of the specified element from this list.
int indexOf(Object element)	Returns the index of the first occurrence of the specified element in this list, or -1.
int lastIndexOf(Object element)	Returns the index of the last occurrence of the specified element in this list, or -1.

LinkedList

```
import java.util.*;
class Main {
    public static void main(String[] args) {
        // Creating list using the LinkedList clas
        List<Integer> numbers = new LinkedList<>();

        // Add elements to the list
        numbers.add(1);
        numbers.add(2);
        numbers.add(3);
        System.out.println("List: " + numbers);

        // Access element from the list
        int number = numbers.get(2);
        System.out.println("Accessed Element: " + number);

        // Using the indexOf() method
        int index = numbers.indexOf(2);
        System.out.println("First occurrance of 2 is at index : " + index);

        // Remove element from the list
        int removedNumber = numbers.remove(1);
        System.out.println("Removed Element: " + removedNumber);

        Iterator itr = numbers.iterator();
        System.out.println("Updated List: ");
        while(itr.hasNext()){
            System.out.println(itr.next());
        }
    }
}
```

```
List: [1, 2, 3]
Accessed Element: 3
First occurrance of 2 is at index : 1
Removed Element: 2
Updated List:
1
3
```

Vector

- Vectors are similar to arrays, where the elements of the vector object can be accessed via an index into the vector.
- Vector implements a dynamic array.
- Also, the vector is not limited to a specific size, it can shrink or grow automatically whenever required. It is similar to ArrayList, but with two differences :
  - Vector is synchronized.
  - Vector contains many legacy methods that are not part of the collections framework.
- Syntax: Vector object = new Vector(size,increment)
- Below are some of the methods of the Vector class:

Method	Description
boolean add(Object o)	Appends the specified element to the end of the list.
void clear()	Removes all of the elements from this list.
void add(int index, Object element)	Inserts the specified element at the specified position.
boolean remove(Object o)	Removes the first occurrence of the specified element from this list.
boolean contains(Object element)	Returns true if this list contains the specified element.
int indexOfObject (Object element)	Returns the index of the first occurrence of the specified element in the list, or -1.
int size()	Returns the number of elements in this list.
int lastIndexOf(Object o)	Return the index of the last occurrence of the specified element in the list, or -1 if the list does not contain any element.

Vector

- Vector is synchronized. This means whenever we want to perform some operation on vectors, the Vector class automatically applies a lock to that operation.
- It is because when one thread is accessing a vector, and at the same time another thread tries to access it, an exception called ConcurrentModificationException is generated. Hence, this continuous use of lock for each operation makes vectors less efficient.
- However, in array lists, methods are not synchronized. Instead, it uses the Collections.synchronizedList() method that synchronizes the list as a whole.
- Hence, It is recommended to use ArrayList in place of Vector because vectors less efficient.

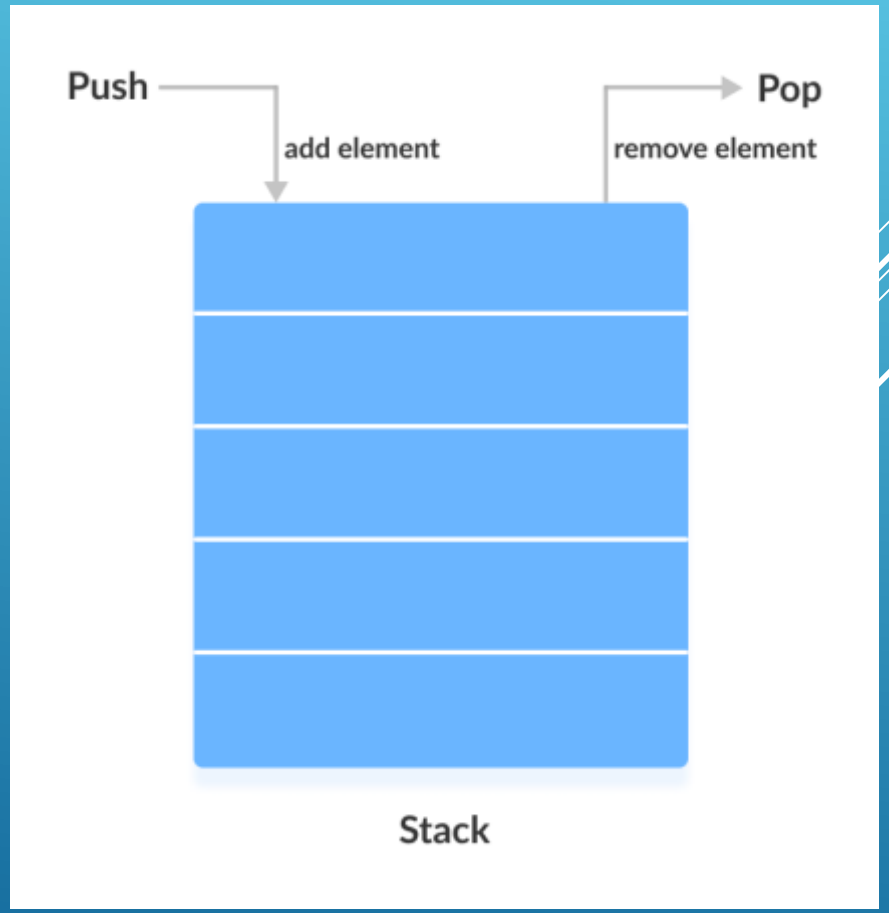
Vector

```
import java.util.*;

class Main {

    public static void main(String[] args) {

        Vector<String> mammals= new Vector<>();


        // Using the add() method

        mammals.add("Dog");

        mammals.add("Horse");

        mammals.add(2, "Cat");    // Using index number

        System.out.println("Vector: " + mammals);


        // Using addAll()

        Vector<String> animals = new Vector<>();

        animals.add("Crocodile");

        animals.addAll(mammals);    // copy mammals vector to animals vector

        System.out.println("New Vector Animals: " + animals);


         String element = animals.get(2);  // access elements from a vector

        System.out.println("Element at index 2: " + element);

        // Remove Element

        System.out.println("Removed Element: " + animals.remove(2));

        System.out.println("New Vector: " + animals);


        // Using iterator()

        Iterator<String> iterate = animals.iterator();

        System.out.print("Vector: ");

        while(iterate.hasNext()) {

        System.out.print(iterate.next() + " ");

        }

        System.out.println();


        animals.clear();     // Using clear()

        System.out.println("Vector after clear(): " + animals);

    }}
```

```
Vector: [Dog, Horse, Cat]
New Vector Animals: [Crocodile, Dog, Horse, Cat]
Element at index 2: Horse
Removed Element: Horse
New Vector: [Crocodile, Dog, Cat]
Vector: Crocodile Dog Cat
Vector after clear(): []
```

Stack

- The stack is the subclass of Vector.
- It implements the last-in-first-out data structure i.e. elements are added to the top of the stack and removed from the top of the stack.
- The stack contains all of the methods of Vector class and also provides its methods like boolean push(), boolean peek(), boolean push(object o), which defines its properties.



Stack

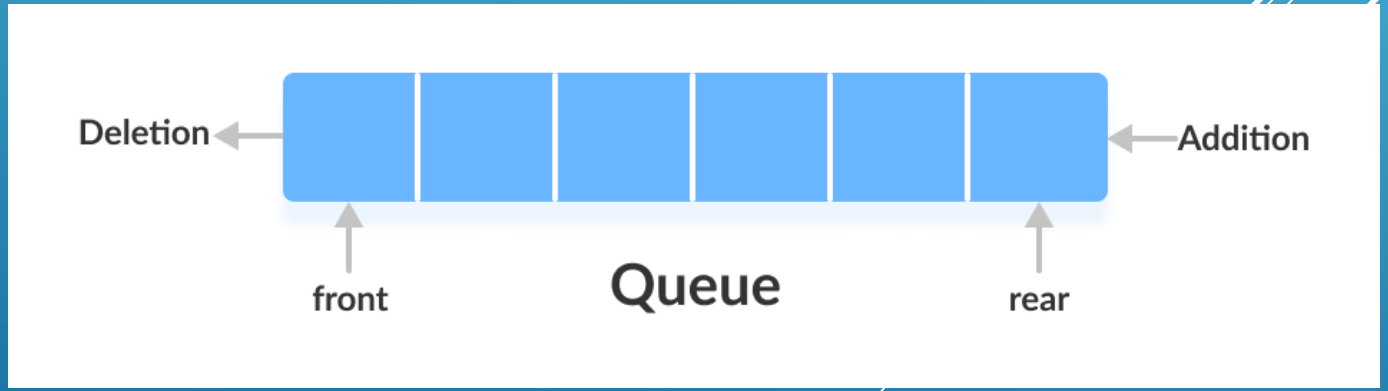
```
import java.util.*;

class Main {

    public static void main(String[] args) {

        Stack<Integer> nos= new Stack<>();


        // Add elements to Stack using push method

        for(int i=1;i<=10;i++)

        {

        nos.push(i);

        }

        System.out.println("Stack: " + nos);


        // Remove element from stack using pop method

        System.out.println("Removed Element: " + nos.pop());

        System.out.println("Stack after pop : " + nos);


        // Access element from the top

        System.out.println("Element at top: " + nos.peek());


        // Searching an element in the stack

        // search method returns the position of the element from the top of the stack.

        // It returns position and not the index

        int position = nos.search(7);

        System.out.println("Position of 7 in stack: " + position);


        // Check if stack is empty

        System.out.println("Is the stack empty? " + nos.empty());


        nos.clear();    // clear the stack

        System.out.println("Stack : " + nos);

        System.out.println("Is the stack empty? " + nos.empty());

    }}
```

```
Stack: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
Removed Element: 10
Stack after pop : [1, 2, 3, 4, 5, 6, 7, 8, 9]
Element at top: 9
Position of 7 in stack: 3
Is the stack empty? false
Stack : []
Is the stack empty? true
```

Java Collections : Queue Interface

- Queue interface maintains the first-in-first-out order.
- It can be defined as an ordered list that is used to hold the elements which are about to be processed.
- There are various classes like PriorityQueue, Deque, and ArrayDeque which implements the Queue interface.
- In a queue, the first element is removed first and last element is removed in the end.
- Since the Queue is an interface, we cannot provide the direct implementation of it.
- In order to use the functionalities of Queue, we need to use classes that implement it:
  - ArrayDeque
  - PriorityQueue
- Queue interface can be instantiated as:

```
Queue<String> q1 = new PriorityQueue();
Queue<String> q2 = new ArrayDeque();
```



Java Collections : Queue Interface

- Some of the commonly used methods of the Queue interface are:
  - add() - Inserts the specified element into the queue. If the task is successful, add() returns true, if not it throws an exception.
  - offer() - Inserts the specified element into the queue. If the task is successful, offer() returns true, if not it returns false.
  - element() - Returns the head of the queue. Throws an exception if the queue is empty.
  - peek() - Returns the head of the queue. Returns null if the queue is empty.
  - remove() - Returns and removes the head of the queue. Throws an exception if the queue is empty.
  - poll() - Returns and removes the head of the queue. Returns null if the queue is empty.

PriorityQueue Class

- The PriorityQueue class implements the Queue interface.
- It holds the elements or objects which are to be processed by their priorities.
- PriorityQueue doesn't allow null values to be stored in the queue.
- The elements of the priority queue are ordered according to their natural ordering, or by a Comparator provided at the queue construction time.
- The head of this queue is the least element with respect to the specified ordering.

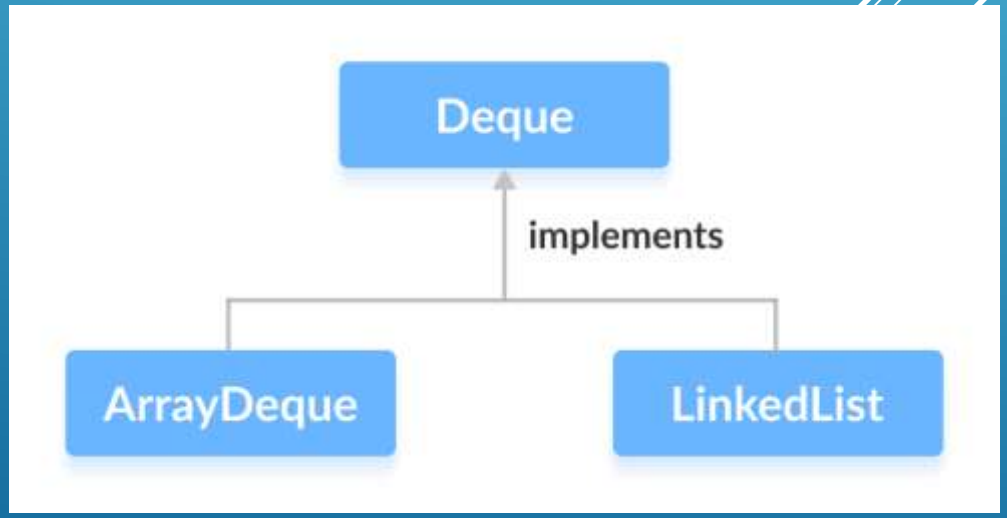
Priority Queue

```
import java.util.*;

class Main {

    public static void main(String args[]){

        // creating priority queue

        PriorityQueue<String> queue=new PriorityQueue<String>();


// adding elements

        queue.add("Cat");    // add() Inserts the specified element into the queue. If the task is successful, it returns true, if not it throws an exception.

        queue.add("Dog");

        queue.offer("Monkey"); // offer() Inserts the specified element into the queue. If the task is successful, it returns true, if not it returns false.

        queue.offer("Horse");

        System.out.println("head:"+queue.element()); //element() method returns head of the queue. It throws an exception if the queue is empty.

        System.out.println("head:"+queue.peek()); // peek() method returns head of the queue. It returns null if the queue is empty.

         System.out.println(queue);

        queue.remove();  //remove() method returns and removes the head of the queue. Throws an exception if the queue is empty.

        queue.poll();    // poll() method returns and removes the head of the queue. Returns null if the queue is empty.

        System.out.println("after removing two elements:");

        System.out.println(queue);


        System.out.println("Accessed Element: " + queue.peek());
System.out.println(queue);

    }}
```

```
head:Cat
head:Cat
[Cat, Dog, Monkey, Horse]
after removing two elements:
[Horse, Monkey]
Accessed Element: Horse
[Horse, Monkey]
```

Deque Interface (Double Ended Queue)

- The Deque interface of the Java collections framework provides the functionality of a double-ended queue.
- It extends the Queue interface.
- In a regular queue, elements are added from the rear and removed from the front.
- However, in a deque, we can insert and remove elements from both front and rear.
- In order to use the functionalities of the Deque interface, we need to use classes that implement it:
  - ArrayDeque
  - LinkedList
- ArrayDeque is faster than ArrayList and Stack and has no capacity restrictions.



Deque Interface (Double Ended Queue)

- **Methods of Deque :** Since Deque extends the Queue interface, it inherits all the methods of the Queue interface.
- Besides methods available in the Queue interface, the Deque interface also includes the following methods:
  - addFirst() - Adds the specified element at the beginning of the deque. Throws an exception if the deque is full.
  - addLast() - Adds the specified element at the end of the deque. Throws an exception if the deque is full.
  - offerFirst() - Adds the specified element at the beginning of the deque. Returns false if the deque is full.
  - offerLast() - Adds the specified element at the end of the deque. Returns false if the deque is full.
  - getFirst() - Returns the first element of the deque. Throws an exception if the deque is empty.
  - getLast() - Returns the last element of the deque. Throws an exception if the deque is empty.
  - peekFirst() - Returns the first element of the deque. Returns null if the deque is empty.
  - peekLast() - Returns the last element of the deque. Returns null if the deque is empty.
  - removeFirst() - Returns and removes the first element of the deque. Throws an exception if the deque is empty.
  - removeLast() - Returns and removes the last element of the deque. Throws an exception if the deque is empty.
  - pollFirst() - Returns and removes the first element of the deque. Returns null if the deque is empty.
  - pollLast() - Returns and removes the last element of the deque. Returns null if the deque is empty.

Deque interface

```
import java.util.*;

class Main {


    public static void main(String[] args) {
        // Creating Deque using the ArrayDeque class
        Deque<Integer> numbers = new ArrayDeque<>();


        // add elements to the Deque
        numbers.offer(1);
        numbers.offerLast(2);
        numbers.offerFirst(3);
        System.out.println("Deque: " + numbers);


        // Access elements of the Deque
        System.out.println("First Element: " + numbers.peekFirst());
        System.out.println("Last Element: " + numbers.peekLast());


        // Remove elements from the Deque
        System.out.println("Removed First Element: " + numbers.pollFirst());
        System.out.println("Removed Last Element: " + numbers.pollLast());
        System.out.println("Updated Deque: " + numbers);
    }
}
```

```
Deque: [3, 1, 2]
First Element: 3
Last Element: 2
Removed First Element: 3
Removed Last Element: 2
Updated Deque: [1]
```

Java Collections : Set Interface

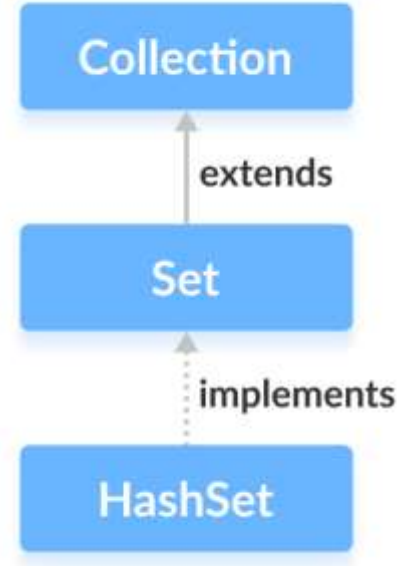
- The Set interface of the Java Collections framework provides the features of the mathematical set in Java.
- It extends the Collection interface.
- Unlike the List interface, sets cannot contain duplicate elements.
- Since Set is an interface, we cannot create objects from it.
- In order to use functionalities of the Set interface, we can use these classes:
  - HashSet
  - LinkedHashSet
  - EnumSet
  - TreeSet
- These classes are defined in the Collections framework and implement the Set interface.
- Syntax : Set<String> abc = new HashSet<>();
- **Set Operations :** The Java Set interface allows us to perform basic mathematical set operations like -
- Union - to get the union of two sets x and y, we can use x.addAll(y)
- Intersection - to get the intersection of two sets x and y, we can use x.retainAll(y)
- Subset - to check if x is a subset of y, we can use y.containsAll(x)

Java Collections : Set Interface

- **Methods of Set**
- The Set interface includes all the methods of the Collection interface. It's because Collection is a super interface of Set.
- Some of the commonly used methods of the Collection interface that's also available in the Set interface are:
  - add() - adds the specified element to the set
  - addAll() - adds all the elements of the specified collection to the set
  - iterator() - returns an iterator that can be used to access elements of the set sequentially
  - remove() - removes the specified element from the set
  - removeAll() - removes all the elements from the set that is present in another specified set
  - retainAll() - retains all the elements in the set that are also present in another specified set
  - clear() - removes all the elements from the set
  - size() - returns the length (number of elements) of the set
  - toArray() - returns an array containing all the elements of the set
  - contains() - returns true if the set contains the specified element
  - containsAll() - returns true if the set contains all the elements of the specified collection
  - hashCode() - returns a hash code value (address of the element in the set)

HashSet Class

- Java HashSet class is used to create a collection that uses a hash table for storage. It inherits the AbstractSet class and implements Set interface.
- The important points about Java HashSet class are:
  - HashSet stores the elements by using a mechanism called hashing.
  - HashSet contains unique elements only.
  - HashSet allows null value.
  - HashSet class is non synchronized.
  - HashSet doesn't maintain the insertion order. Here, elements are inserted on the basis of their hashcode.
  - HashSet is the best approach for search operations.
  - The initial default capacity of HashSet is 16, and the load factor is 0.75.
- Syntax : HashSet<Integer> numbers = new HashSet<>(8, 0.75);
- The above syntax creates HashSet with 8 capacity and 0.75 load factor
- HashSet is commonly used if we have to access elements randomly. It is because elements in a hash table are accessed using hash codes.
- The hashcode of an element is a unique identity that helps to identify the element in a hash table.
- HashSet cannot contain duplicate elements. Hence, each hash set element has a unique hashcode.



HashSet Class

```
class Main {

    public static void main(String[] args) {

        HashSet<Integer> evenNumber = new HashSet<>();


        // Using add() method

        evenNumber.add(2);

        evenNumber.add(4);

        evenNumber.add(6);

        System.out.println("HashSet evenNumber: " + evenNumber);


        // Using addAll() method

        HashSet<Integer> numbers = new HashSet<>();

        numbers.addAll(evenNumber);     // aka Union operation. Union of numbers and evenNumber sets

        numbers.add(5);

        System.out.println("New HashSet numbers: " + numbers);


        //to check if a set is a subset of another set or not, we can use the containsAll() method.

        boolean result = numbers.containsAll(evenNumber);

        //using remove() method

        numbers.remove(4);

        System.out.println("HashSet numbers after removing an element : " + numbers);


        //intersection of two sets

        numbers.retainAll(evenNumber);

        System.out.println("Intersection is: " + numbers);


        numbers.add(5);

        //difference of two sets

        numbers.removeAll(evenNumber);

        System.out.println("Difference is: " + numbers);


        //using removeAll() method

        numbers.removeAll(numbers);

        System.out.println("HashSet after removing all the elements : " + numbers);

    }
}
```

HashSet Class

```
HashSet evenNumber: [2, 4, 6]
New HashSet numbers: [2, 4, 5, 6]
Is evenNumber subset of numbers? true
HashSet numbers after removing an element : [2, 5, 6]
Intersection is: [2, 6]
Difference is: [5]
HashSet after removing all the elements : []
```

LinkedHashSet Class

- Java LinkedHashSet class is a Hashtable and Linked list implementation of the Set interface. It inherits the HashSet class and implements the Set interface.
- The important points about the Java LinkedHashSet class are:
  - Java LinkedHashSet class contains unique elements only like HashSet.
  - Java LinkedHashSet class provides all optional set operations and permits null elements.
  - Java LinkedHashSet class is non-synchronized.
  - Java LinkedHashSet class maintains insertion order.
- linked hash sets maintain a doubly-linked list internally for all of its elements. The linked list defines the order in which elements are inserted in hash tables.

LinkedHashSet Class

```
class Main {

    public static void main(String[] args) {

        // Creating an arrayList of even numbers

        ArrayList<Integer> evenNumbers = new ArrayList<>();

        evenNumbers.add(2);

        evenNumbers.add(4);

        System.out.println("ArrayList: " + evenNumbers);


        // Creating a LinkedHashSet from an ArrayList

        LinkedHashSet<Integer> numbers = new
LinkedHashSet<>(evenNumbers);

        numbers.add(5);

        numbers.add(6);

        numbers.add(3);

        System.out.println("LinkedHashSet: " + numbers);


        numbers.remove(5);

        System.out.println("LinkedHashSet numbers after deleting an
element : " + numbers);

        evenNumbers.retainAll(numbers);

        System.out.println("Intersection is : " + evenNumbers);


        numbers.removeAll(evenNumbers);

        System.out.println("Difference : " + numbers);


        boolean result = numbers.containsAll(evenNumbers);

        System.out.println("Is LinkedHashSet2 subset of LinkedHashSet1? " +
result);

    }

}
```

```
ArrayList: [2, 4]
LinkedHashSet: [2, 4, 5, 6, 3]
LinkedHashSet numbers after deleting an element : [2, 4, 6, 3]
Intersection is : [2, 4]
Difference : [6, 3]
Is LinkedHashSet2 subset of LinkedHashSet1? false
```

SortedSet Interface

- The SortedSet interface of the Java Collections framework is used to store elements with some order in a set.
- It extends the Set interface.
- In order to use the functionalities of the SortedSet interface, we need to use the TreeSet class that implements it.
- Syntax : `SortedSet<String> abc=new TreeSet<>();`
- Here we have used no arguments to create a sorted set. Hence the set will be sorted naturally.
- **Methods of SortedSet**
- The SortedSet interface includes all the methods of the Set interface. It's because Set is a super interface of SortedSet. Besides it, the SortedSet interface also includes these methods:
  - comparator() - returns a comparator that can be used to order elements in the set
  - first() - returns the first element of the set
  - last() - returns the last element of the set
  - headSet(element) - returns all the elements of the set before the specified element
  - tailSet(element) - returns all the elements of the set after the specified element including the specified element
  - subSet(element1, element2) - returns all the elements between the element1 and element2 including element1

TreeSet Class

- Java TreeSet class implements the Set interface that uses a tree for storage. The objects of the TreeSet class are stored in ascending order.
- The important points about the Java TreeSet class are:
  - Java TreeSet class contains unique elements only like HashSet.
  - Java TreeSet class access and retrieval times are quite fast.
  - Java TreeSet class doesn't allow null element.
  - Java TreeSet class is non synchronized.
  - Java TreeSet class maintains ascending order.
  - The TreeSet can only allow those generic types that are comparable.
- Syntax : `TreeSet<Integer> abc=new TreeSet<>();`
- TreeSet is being implemented using a binary search tree

TreeSet Class

- **Methods of TreeSet :** Apart from the methods of SortedSet, Set and Collections interface, the TreeSet interface also includes these methods:
  - higher(element) - Returns the lowest element among those elements that are strictly greater than the specified element or else returns NULL
  - lower(element) - Returns the greatest element among those elements that are strictly less than the specified element or else returns NULL
  - ceiling(element) - Returns the lowest element among those elements that are greater than or equal to the specified element. If the element passed exists in a tree set, it returns the element passed as an argument or else returns NULL.
  - floor(element) - Returns the greatest element among those elements that are less than or equal to the specified element. If the element passed exists in a tree set, it returns the element passed as an argument or else returns NULL.
  - pollFirst() - returns and removes the first element from the set
  - pollLast() - returns and removes the last element from the set

TreeSet Class

- headSet(element, booleanValue) - The headSet() method returns all the elements of a tree set before the specified element (which is passed as an argument). The booleanValue parameter is optional. Its default value is false. If true is passed as a booleanValue, the method returns all the elements before the specified element **including the specified element**.
- tailSet(element, booleanValue) - The tailSet() method returns all the elements of a tree set after the specified element (which is passed as a parameter) including the specified element. The booleanValue parameter is optional. Its default value is true. If false is passed as a booleanValue, the method returns all the elements after the specified element **without including the specified element.**
- subSet(e1, bv1, e2, bv2) - The subSet() method returns all the elements between e1 and e2 including e1. The bv1 and bv2 are optional parameters. The default value of bv1 is true, and the default value of bv2 is false. If false is passed as bv1, the method returns all the elements between e1 and e2 without including e1. If true is passed as bv2, the method returns all the elements between e1 and e2, including e1.

TreeSet Class

```
import java.util.*;
class Main {
    public static void main(String[] args) {
        TreeSet<Integer> evenNumbers = new TreeSet<>();
        // Using the add() method
        evenNumbers.add(4);
        evenNumbers.add(2);
        evenNumbers.add(6);
        evenNumbers.add(6);
        evenNumbers.add(8);
        System.out.println("TreeSet: " + evenNumbers);
        evenNumbers.remove(4);
        System.out.println("Updated TreeSet: " + evenNumbers);
        System.out.println("First element of TreeSet: " +
evenNumbers.first());
        System.out.println("Last element of TreeSet: " +
evenNumbers.last());
        // Using higher()
        System.out.println("Using higher: " + evenNumbers.higher(4));
      // Using lower()
        System.out.println("Using lower: " + evenNumbers.lower(4));
// Using ceiling()
        System.out.println("Using ceiling: " + evenNumbers.ceiling(4));

        // Using floor()
        System.out.println("Using floor: " + evenNumbers.floor(3));

        // Using pollFirst()
        System.out.println("Removed First Element: " +
evenNumbers.pollFirst());

        // Using pollLast()
        System.out.println("Removed Last Element: " +
evenNumbers.pollLast());

        System.out.println("TreeSet after Polling: " + evenNumbers);
        evenNumbers.add(10);
        evenNumbers.add(12);
        evenNumbers.add(14);
        System.out.println("New TreeSet: " + evenNumbers);
```

```
E:\JP>java Main
TreeSet: [2, 4, 6, 8]
Updated TreeSet: [2, 6, 8]
First element of TreeSet: 2
Last element of TreeSet: 8
```

(code further continued on slide 58)

TreeSet Class

```
Using higher: 6
Using lower: 2
Using ceiling: 6
Using floor: 2
Removed First Element: 2
Removed Last Element: 8
TreeSet after Polling: [6]
New TreeSet: [6, 10, 12, 14]
```

TreeSet Class

```
System.out.println("New TreeSet: " + evenNumbers);

        // using headSet()

        // Using headSet() with default boolean value
        System.out.println("Using headSet without boolean value: " +
evenNumbers.headSet(12));

        // Using headSet() with specified boolean value
        System.out.println("Using headSet with boolean value: " +
evenNumbers.headSet(12, true));

        // using tailSet()

        // Using tailSet() with default boolean value
        System.out.println("Using tailSet without boolean value: " +
evenNumbers.tailSet(12));

        // Using tailSet() with specified boolean value
        System.out.println("Using tailSet with boolean value: " +
evenNumbers.tailSet(12, false));

        //using subSet()

        // Using subSet() with default boolean value
        System.out.println("Using subSet without boolean value: " +
evenNumbers.subSet(6, 12));

        // Using subSet() with specified boolean value
        System.out.println("Using subSet with boolean value: " +
evenNumbers.subSet(6, false, 12, true));
    }
}
```

(code further continued on slide 59)

```
New TreeSet: [6, 10, 12, 14]
Using headSet without boolean value: [6, 10]
Using headSet with boolean value: [6, 10, 12]
Using tailSet without boolean value: [12, 14]
Using tailSet with boolean value: [14]
Using subSet without boolean value: [6, 10]
Using subSet with boolean value: [10, 12]
```

TreeSet Class

```
// Union of two sets
      TreeSet<Integer> numbers = new TreeSet<>();
      numbers.addAll(evenNumbers);
      System.out.println("Union is: " + numbers);
      numbers.add(3);
      numbers.add(5);
       System.out.println("Updated numbers TreeSet is: " + numbers);

      // Intersection of two sets
      numbers.retainAll(evenNumbers);
      System.out.println("Intersection is: " + numbers);
      numbers.add(3);
      numbers.add(5);

      // Difference between two sets
      numbers.removeAll(evenNumbers);
      System.out.println("Difference is: " + numbers);

   }
}
```

```
Union is: [6, 10, 12, 14]
Updated numbers TreeSet is: [3, 5, 6, 10, 12, 14]
Intersection is: [6, 10, 12, 14]
Difference is: [3, 5]
```

TreeSet Class

- By default, tree set elements are sorted naturally i.e in ascending order. However, we can also traverse the set in descending order

```
import java.util.*;
class Main{
 public static void main(String args[]){
  //Creating and adding elements
  TreeSet<String> animals=new TreeSet<String>();
  animals.add("Dog");
  animals.add("Cat");
  animals.add("Monkey");
  animals.add("Elephant");
  animals.add("Cow");

  //Traversing elements in ascending order
  Iterator<String> itr=animals.iterator();
  System.out.println("Ascending Order : ");
  while(itr.hasNext()){
   System.out.print(itr.next() + " ");
  }
  System.out.println("\n");
  //Traversing elements in descending order
  Iterator<String> des=animals.descendingIterator();
  System.out.println("Descending Order : ");
  while(des.hasNext()){
   System.out.print(des.next() + " ");
  }
 }
}
```

```
Ascending Order :
Cat Cow Dog Elephant Monkey

Descending Order :
Monkey Elephant Dog Cow Cat
```

LinkedHashSet vs HashSet

- Both LinkedHashSet and HashSet implements the Set interface. However, there exist some differences between them.

  - LinkedHashSet maintains a linked list internally. Due to this, it maintains the insertion order of its elements.
  - The LinkedHashSet class requires more storage than HashSet. This is because LinkedHashSet maintains linked lists internally.
  - The performance of LinkedHashSet is slower than HashSet. It is because of linked lists present in LinkedHashSet.

LinkedHashSet Vs. TreeSet

- Here are the major differences between LinkedHashSet and TreeSet:

  - The TreeSet class implements the SortedSet interface. That's why elements in a tree set are sorted. However, the LinkedHashSet class only maintains the insertion order of its elements.
  - A TreeSet is usually slower than a LinkedHashSet. It is because whenever an element is added to a TreeSet, it has to perform the sorting operation.
  - LinkedHashSet allows the insertion of null values. However, we cannot insert a null value to TreeSet.

TreeSet vs HashSet

- Both the TreeSet as well as the HashSet implements the Set interface. However, there exist some differences between them.

  - Unlike HashSet, elements in TreeSet are stored in some order. It is because TreeSet implements the SortedSet interface as well.
  - TreeSet provides some methods for easy navigation. For example, first(), last(), headSet(), tailSet(), etc. It is because TreeSet also implements the NavigableSet interface.
  - HashSet is faster than the TreeSet for basic operations like add, remove, contains and size.

Programming Practice Questions

- Implement a generic stack class GenericStack<T> that supports the following operations:
  - push(T item): Add an item to the stack.
  - pop(): Remove and return the top item from the stack.
  - peek(): Return the top item without removing it.
  - isEmpty(): Check if the stack is empty.
- Extend the above program to implement a generic stack class BoundedStack that can only hold numbers.
- Write a program that creates a List of integers. Populate the list with the first 10 positive integers, then:
  - Print the list.
  - Remove the third element from the list.
  - Add the number 100 at the end of the list.
  - Print the updated list.
- Write a program that accepts a List<Double> of floating-point numbers and sorts the list in descending order. Print the sorted list.
- Write a method that merges two List<Integer> objects into a single list. The resulting list should contain all elements from both lists, but without any duplicates.
- Write a program that creates a Set<Integer> and adds the first 10 positive integers. Then, attempt to add a duplicate integer. Print the set to show that duplicates are not allowed.
- WAP that creates two Set<Integer> objects and
  - returns a new set that contains the union of both sets.
  - returns a new set containing only the elements that are present in both sets.
  - returns a new set containing the difference of both sets.
  - check if one Set is a subset of another Set. Return true if it is, and false otherwise.