Quick and most likely asked interview questions guide for IT professionals with skill set: Java, OOP and Data structures

**Interview Guide**

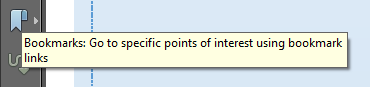
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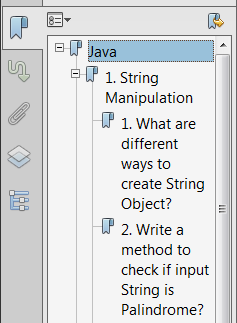
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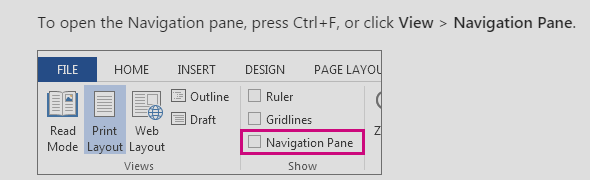
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# Java

## String Manipulation

### What are different ways to create String Object?

We can create String object using new operator like any normal java class or we can use double quotes to create a String object. There are several constructors available in String class to get String from char array, byte array, StringBuffer and StringBuilder.

String str = new String("abc");

String str1 = "abc";

When we create a String using double quotes, JVM looks in the String pool to find if any other String is stored with same value. If found, it just returns the reference to that String object else it creates a new String object with given value and stores it in the String pool.  
When we use new operator, JVM creates the String object but don’t store it into the String Pool. We can use intern() method to store the String object into String pool or return the reference if there is already a String with equal value present in the pool.

### Write a method to check if input String is Palindrome?

A String is said to be Palindrome if it’s value is same when reversed. For example “aba” is a Palindrome String.  
String class doesn’t provide any method to reverse the String but StringBuffer and StringBuilder class has reverse method that we can use to check if String is palindrome or not.

private static boolean isPalindrome(String str) {

if (str == null)

return false;

StringBuilder strBuilder = new StringBuilder(str);

strBuilder.reverse();

return strBuilder.toString().equals(str);

}

Sometimes interviewer asks not to use any other class to check this, in that case we can compare characters in the String from both ends to find out if it’s palindrome or not.

private static boolean isPalindromeString(String str) {

if (str == null)

return false;

int length = str.length();

System.out.println(length / 2);

for (int i = 0; i < length / 2; i++) {

if (str.charAt(i) != str.charAt(length - i - 1))

return false;

}

return true;

}

### Write a method that will remove given character from the String?

We can use replaceAll method to replace all the occurance of a String with another String. The important point to note is that it accepts String as argument, so we will use Character class to create String and use it to replace all the characters with empty String.

private static String removeChar(String str, char c) {

if (str == null)

return null;

return str.replaceAll(Character.toString(c), "");

}

### What is String subSequence method?

Java 1.4 introduced CharSequence interface and String implements this interface, this is the only reason for the implementation of subSequence method in String class. Internally it invokes the String substring method.

### Java String subSequence Example

Java 1.4 introduced CharSequence interface and String implements this interface, this is the only reason for the implementation of subSequence method in String class. Internally it invokes the [String substring](http://www.journaldev.com/807/java-string-substring-example) method.

public CharSequence subSequence(int beginIndex, int endIndex) {

return this.substring(beginIndex, endIndex);

}

String subSequence method returns a character sequence that is a subsequence of this sequence. An invocation of this method of the form str.subSequence(begin, end) behaves in exactly the same way as the invocation of str.substring(begin, end).

Below is a simple java String subSequence method example.

StringSubsequence.java

package com.journaldev.examples;

public class StringSubsequence {

/\*\*

\* This class shows usage of String subSequence method

\*

\* @param args

\*/

public static void main(String[] args) {

String str = "www.journaldev.com";

System.out.println("Last 4 char String: " + str.subSequence(str.length() - 4, str.length()));

System.out.println("First 4 char String: " + str.subSequence(0, 4));

System.out.println("website name: " + str.subSequence(4, 14));

// substring vs subSequence

System.out.println("substring == subSequence ? " + (str.substring(4, 14) == str.subSequence(4, 14)));

System.out.println("substring equals subSequence ? " + (str.substring(4, 14).equals(str.subSequence(4, 14))));

}

}

Output of the above String subSequence example program is:

Last 4 char String: .com

First 4 char String: www.

website name: journaldev

substring == subSequence ? false

substring equals subSequence ? true

There is no benefit in using subSequence method, ideally you should always use String substring method.

### How to compare two Strings in java program?

Java String implements Comparable interface and it has two variants of compareTo() methods.

compareTo(String anotherString) method compares the String object with the String argument passed lexicographically. If String object precedes the argument passed, it returns negative integer and if String object follows the argument String passed, it returns positive integer. It returns zero when both the String have same value, in this case equals(String str) method will also return true.

compareToIgnoreCase(String str): This method is similar to the first one, except that it ignores the case. It uses String CASE\_INSENSITIVE\_ORDER Comparator for case insensitive comparison. If the value is zero then equalsIgnoreCase(String str) will also return true.

### How to convert String to char and vice versa?

This is a tricky question because String is a sequence of characters, so we can't convert it to a single character. We can use use charAt method to get the character at given index or we can use toCharArray()method to convert String to character array.

String class has three methods related to char. Let’s look at them before we look at a java program to convert string to char array.

1. char[] toCharArray(): This method converts string to character array. The char array size is same as the length of the string.
2. char charAt(int index): This method returns character at specific index of string. This method throws StringIndexOutOfBoundsException if the index argument value is negative or greater than the length of the string.
3. getChars(int srcBegin, int srcEnd, char dst[], int dstBegin): This is a very useful method when you want to convert part of string to character array. First two parameters define the start and end index of the string; the last character to be copied is at index srcEnd-1. The characters are copied into the char array starting at index dstBegin and ending at dstBegin + (srcEnd-srcBegin) – 1.

Let’s look at a simple string to char array java program example.

package com.journaldev.string;

public class StringToCharJava {

public static void main(String[] args) {

String str = "journaldev";

//string to char array

char[] chars = str.toCharArray();

System.out.println(chars.length);

//char at specific index

char c = str.charAt(2);

System.out.println(c);

//Copy string characters to char array

char[] chars1 = new char[7];

str.getChars(0, 7, chars1, 0);

System.out.println(chars1);

}

}

In above program, toCharArray and charAt usage is very simple and clear.

In getChars example, first 7 characters of str will be copied to chars1 starting from it’s index 0.

That’s all for converting string to char array and string to char java program.

### How to convert String to byte array and vice versa?

We can use String getBytes() method to convert String to byte array and we can use String constructor new String(byte[] arr) to convert byte array to String.

|  |
| --- |
| package com.journaldev.util;    import java.util.Arrays;    public class StringByteArray {        /\*\*       \* This class shows how to convert String to byte array and       \* byte array to String in java       \* @param args       \*/      public static void main(String[] args) {          String str = "www.journaldev.com";          //convert String to byte array          byte[] byteArr = str.getBytes();          System.out.println("String to byte array : "+Arrays.toString(byteArr));          //convert byte array to String          String str1 = new String(byteArr);          System.out.println("byte array to String : "+str1);          //let's see if str and str1 are equals or not          System.out.println("str == str1? " + (str == str1));          System.out.println("str.equals(str1)? " + (str.equals(str1)));      }    } |

String class method *getBytes()* returns the **byte array from String** and String constructor can be used to create **String from byte array** in java.

Output of the above program is:

|  |  |
| --- | --- |
| 1  2  3  4 | String to byte array : [119, 119, 119, 46, 106, 111, 117, 114, 110, 97, 108, 100, 101, 118, 46, 99, 111, 109]  byte array to String : www.journaldev.com  str == str1? false  str.equals(str1)? true |

### Can we use String in switch case?

This is a tricky question used to check your knowledge of current Java developments. Java 7 extended the capability of switch case to use Strings also, earlier java versions doesn't support this.  
If you are implementing conditional flow for Strings, you can use if-else conditions and you can use switch case if you are using Java 7 or higher versions.

Keys points to know for java switch case String are:

1. Java switch case String make code more readable by removing the multiple if-else-if chained conditions.
2. Java switch case String is case sensitive, the output of example confirms it.
3. Java Switch case uses String.equals() method to compare the passed value with case values, so make sure to add a NULL check to avoid NullPointerException.
4. According to [Java 7 documentation for Strings in Switch](http://docs.oracle.com/javase/7/docs/technotes/guides/language/strings-switch.html), java compiler generates more efficient byte code for String in Switch statement than chained if-else-if statements.
5. Make sure to use java switch case String only when you know that it will be used with Java 7 else it will throw Exception.

Thats all for Java switch case String example.

**Tip**: We can use [**java ternary operator**](http://www.journaldev.com/963/java-ternary-operator) rather than switch to write smaller code.

package com.journaldev.util;

public class SwitchStringExample {

public static void main(String[] args) {

printColorUsingSwitch("red");

printColorUsingIf("red");

// switch case string is case sensitive

printColorUsingSwitch("RED");

printColorUsingSwitch(null);

}

private static void printColorUsingIf(String color) {

if (color.equals("blue")) {

System.out.println("BLUE");

} else if (color.equals("red")) {

System.out.println("RED");

} else {

System.out.println("INVALID COLOR CODE");

}

}

private static void printColorUsingSwitch(String color) {

switch (color) {

case "blue":

System.out.println("BLUE");

break;

case "red":

System.out.println("RED");

break;

default:

System.out.println("INVALID COLOR CODE");

}

}

### Difference between String, StringBuffer and StringBuilder?

String is immutable and final in java, so whenever we do String manipulation, it creates a new String. String manipulations are resource consuming, so java provides two utility classes for String manipulations - StringBuffer and StringBuilder.  
StringBuffer and StringBuilder are mutable classes. StringBuffer operations are thread-safe and synchronized where StringBuilder operations are not thread-safe. So when multiple threads are working on same String, we should use StringBuffer but in single threaded environment we should use StringBuilder.  
StringBuilder performance is fast than StringBuffer because of no overhead of synchronization.

### WAP to find number Alphabets, Numbers and Special characters are present inside the given string.

String s1 = "I 1@ve M@rgan & $tanley!";

**int** characters = 0;

**int** numbers = 0;

**int** specialChars = 0;

System.***out***.println(specialChars);

**for**(**int** i=0;i<s1.length();i++){

**char** c = s1.charAt(i);

System.***out***.println("Character at "+i+" is "+c);

**if**((c>='a' && c<='z') || (c>='A' && c<='Z') ){

System.***out***.println("It is the character");

characters++;

}**else** **if**(c>='0' && c<='9'){

System.***out***.println("Is the digit");

numbers++;

}**else**{

System.***out***.println("It is the special character");

specialChars++;

}

}

System.***out***.println("Characters: "+characters+ " digits:"+numbers+ " Special Chars:"+specialChars);

Output: Character at 0 is I

It is the character

Character at 1 is

It is the special character

Character at 2 is 1

Is the digit

Character at 3 is @

It is the special character

Character at 4 is v

It is the character

Character at 5 is e

It is the character

Character at 6 is

It is the special character

Character at 7 is M

It is the character

Character at 8 is @

It is the special character

Character at 9 is r

It is the character

Character at 10 is g

It is the character

Character at 11 is a

It is the character

Character at 12 is n

It is the character

Character at 13 is

It is the special character

Character at 14 is &

It is the special character

Character at 15 is

It is the special character

Character at 16 is $

It is the special character

Character at 17 is t

It is the character

Character at 18 is a

It is the character

Character at 19 is n

It is the character

Character at 20 is l

It is the character

Character at 21 is e

It is the character

Character at 22 is y

It is the character

Character at 23 is !

It is the special character

Characters: 14 digits:1 Special Chars:9

### WAP to create an immutable class.

public final class FinalClassExample {

private final int id;

private final String name;

private final HashMap<String,String> testMap;

public int getId() {

return id;

}

public String getName() {

return name;

}

/\*\*

\* Accessor function for mutable objects

\*/

public HashMap<String, String> getTestMap() {

//return testMap;

return (HashMap<String, String>) testMap.clone();

}

/\*\*

\* Constructor performing Deep Copy

\* @param i

\* @param n

\* @param hm

\*/

public FinalClassExample(int i, String n, HashMap<String,String> hm){

System.out.println("Performing Deep Copy for Object initialization");

this.id=i;

this.name=n;

HashMap<String,String> tempMap=new HashMap<String,String>();

String key;

Iterator<String> it = hm.keySet().iterator();

while(it.hasNext()){

key=it.next();

tempMap.put(key, hm.get(key));

}

this.testMap=tempMap;

}

/\*\*

\* Constructor performing Shallow Copy

\* @param i

\* @param n

\* @param hm

\*/

/\*\*

public FinalClassExample(int i, String n, HashMap<String,String> hm){

System.out.println("Performing Shallow Copy for Object initialization");

this.id=i;

this.name=n;

this.testMap=hm;

}

\*/

/\*\*

\* To test the consequences of Shallow Copy and how to avoid it with Deep Copy for creating immutable classes

\* @param args

\*/

public static void main(String[] args) {

HashMap<String, String> h1 = new HashMap<String,String>();

h1.put("1", "first");

h1.put("2", "second");

String s = "original";

int i=10;

FinalClassExample ce = new FinalClassExample(i,s,h1);

//Lets see whether its copy by field or reference

System.out.println(s==ce.getName());

System.out.println(h1 == ce.getTestMap());

//print the ce values

System.out.println("ce id:"+ce.getId());

System.out.println("ce name:"+ce.getName());

System.out.println("ce testMap:"+ce.getTestMap());

//change the local variable values

i=20;

s="modified";

h1.put("3", "third");

//print the values again

System.out.println("ce id after local variable change:"+ce.getId());

System.out.println("ce name after local variable change:"+ce.getName());

System.out.println("ce testMap after local variable change:"+ce.getTestMap());

HashMap<String, String> hmTest = ce.getTestMap();

hmTest.put("4", "new");

System.out.println("ce testMap after changing variable from accessor methods:"+ce.getTestMap());

}

}

Output:

Performing Deep Copy for Object initialization

true

false

ce id:10

ce name:original

ce testMap:{2=second, 1=first}

ce id after local variable change:10

ce name after local variable change:original

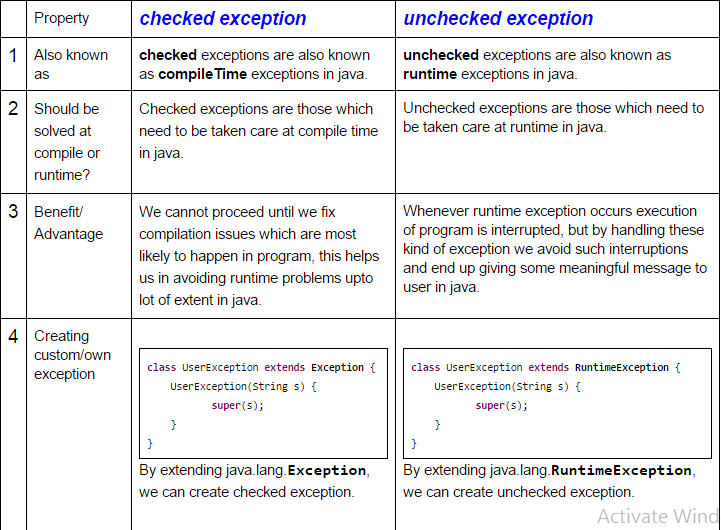
ce testMap after local variable change:{2=second, 1=first}

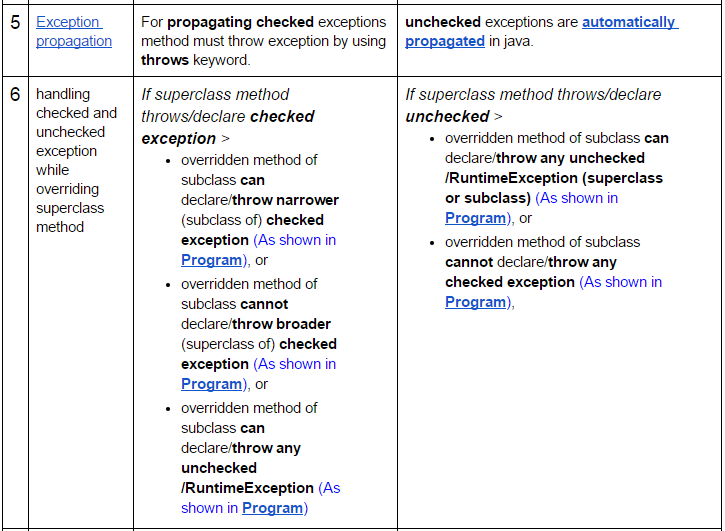
ce testMap after changing variable from accessor methods:{2=second, 1=first}

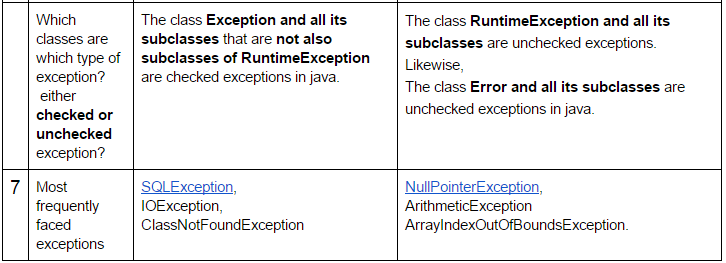
## Exception Handling

### What do you mean by the checked and the unchecked exceptions in java?

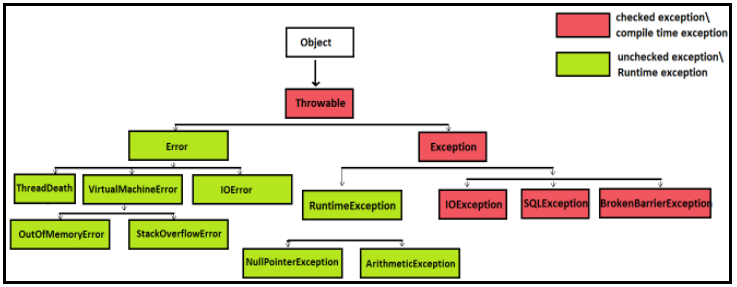
In **Java exceptions** under Error and RuntimeException classes are **unchecked exceptions**, everything else under throwable is **checked**. Consider the following**Java** program. It compiles fine, but it throws ArithmeticException when run. The compiler allows it to compile, because ArithmeticException is an **unchecked exception**.







### Explain exception hierarchy in java?



java.lang.**Object** is superclass of all classes in java.

java.lang.**Throwable** is superclass of java.lang.**Exception** and java.lang.**Error**

java.lang.**Exception** is superclass of java.lang.**RuntimeException, IOException, SQLException,** [**BrokenBarrierException**](http://www.javamadesoeasy.com/2015/03/cyclicbarrier-in-java.html)and many more other classes in java.

java.lang.[**RuntimeException**](http://www.javamadesoeasy.com/2015/05/checked-compile-time-exceptions-and.html)is superclass of java.lang.[**NullPointerException**](http://www.javamadesoeasy.com/2015/05/nullpointerexception-in-java.html)**, ArithmeticException** and many more other classesin java.

java.lang.[**Error**](http://www.javamadesoeasy.com/2015/05/javalangerror-in-exception-handling-in.html)is superclass of java.lang.**VirtualMachineError, IOError, AssertionError,** [**ThreadDeath**](http://www.javamadesoeasy.com/2015/04/threaddeath-error-calling-stop-method.html)and many more other classesin java.

java.lang.**VirtualMachineError** is superclass of java.lang.**OutOfMemoryError, StackOverflowError** and many more other classesin java.

### What are 5 exception handling keywords in java?

**Answer**. This is another very important exception handling interview question in java.

***5*** [***keyword***](http://www.javamadesoeasy.com/2015/05/keywords-in-java-language.html) ***in java exception handling in java***

* + [**try**](http://www.javamadesoeasy.com/2015/05/try-catch-finally-block-in-java.html) **- Any exception occurring in try block is catched by catch block.**
  + [**catch**](http://www.javamadesoeasy.com/2015/05/try-catch-finally-block-in-java.html) **-** catch block is always followed by try block in java.
  + [**finally**](http://www.javamadesoeasy.com/2015/05/try-catch-finally-block-in-java.html) ***finally block*** *can can only exist if try or try-catch block is there, finally block can’t be used alone in java.*

***Features*** *of finally >*

* finally block is **always executed** irrespective of exception is thrown or not.
  + finally is **keyword** in java.
  + finally block is optional in java, we may use it or not.

*finally block is* ***not executed*** *in following scenarios >*

* finally is not executed when **System.exit** is called.
* if in case **JVM crashes** because of some java.util.[**Error**](http://www.javamadesoeasy.com/2015/05/javalangerror-in-exception-handling-in.html).
  + [**throw**](http://www.javamadesoeasy.com/2015/05/throw-exception-in-java.html) **throw** is a **keyword** in java.
    - **throw** keyword allows us to throw [**checked** or **unchecked**](http://www.javamadesoeasy.com/2015/05/checked-compile-time-exceptions-and.html)[exception](http://www.javamadesoeasy.com/2015/05/exception-handling-exception-hierarchy.html).
  + [**throws**](http://www.javamadesoeasy.com/2015/05/throws-exception-in-java.html) **throws** is written in method’s definition to indicate that method can throw [exception](http://www.javamadesoeasy.com/2015/05/exception-handling-exception-hierarchy.html) in java.

### Explain what is Error in java?

**Answer**. Experienced developers must know in detail about Exception handling interview question in java. ***java.lang.***[***Error***](http://www.javamadesoeasy.com/2015/05/javalangerror-in-exception-handling-in.html)

* Error is a subclass of **Throwable  in java.**
* Error **indicates some serious problems** that our **application should not try to catch in java.**
* Errors are **abnormal conditions in application**.
* Error and its subclasses are regarded as **unchecked** exceptions in java

Must know :

[ThreadDeath](http://www.javamadesoeasy.com/2015/04/threaddeath-error-calling-stop-method.html) is an error which application must not try to catch but it is normal condition in java.

### What are differences between Exception and Error in java?

**Answer**. It is another very important exception interview question to differentiate between Exception and Error in java.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Property | [**Exception**](http://www.javamadesoeasy.com/2015/05/exception-handling-exception-hierarchy.html) | [**Error**](http://www.javamadesoeasy.com/2015/05/javalangerror-in-exception-handling-in.html) |
| 1 | serious problem? | Exception does **not indicate any serious problem**. | Error **indicates some serious problems** that our **application should not try to catch.** |
| 2 | divided into  [**checked** and **unchecked**](http://www.javamadesoeasy.com/2015/05/checked-compile-time-exceptions-and.html) | Exception are divided into **checked** and **unchecked exceptions in java**. | Error are **not divided** further into such classifications in java. |
| 3 | Which classes are which type of exception? either  **checked or** **unchecked** exception? | The class **Exception and all its subclasses** that are **not also subclasses of RuntimeException** are checked exceptions.  The class **RuntimeException and all its subclasses** are unchecked exceptions.  Likewise,  The class **Error and all its subclasses** are unchecked exceptions in java. | Error and its subclasses are regarded as **unchecked** exceptions in java |
| 4 | Most frequently faced exception and errors | **checked exceptions>**  SQLException,  IOException,  ClassNotFoundException  **unchecked exceptions>**  [NullPointerException](http://www.javamadesoeasy.com/2015/05/nullpointerexception-in-java.html), ArithmeticException, | **VirtualMachineError, IOError, AssertionError,** [**ThreadDeath**](http://www.javamadesoeasy.com/2015/04/threaddeath-error-calling-stop-method.html),  **OutOfMemoryError, StackOverflowError.** |
| 5 | Why to catch or not to catch? | Application **must catch** the Exception because they does not cause any major threat to application in java. | Application **must not catch** the Error because they does cause any major threat to application.  Example >  Let’s say errors like OutOfMemoryError and StackOverflowError occur and are caught then JVM might not be able to free up memory for rest of application to execute, so it will be better if application don’t catch these errors and is allowed to terminate in java. |

### How to create user defined checked and unchecked Exception in java?

**Answer**. Very important exception handling interview question. Interviewers generally expects interviewees to write code to create checked and unchecked Exception in java.

*Creating user defined* [***checked***](http://www.javamadesoeasy.com/2015/05/checked-compile-time-exceptions-and.html)*exception in java >*

|  |
| --- |
| **class** UserDefinedException **extends Exception** {     UserDefinedException(String s) {  **super**(s);     }  } |

By extending java.lang.**Exception**, we can create checked exception.

*Creating user defined* [***unchecked***](http://www.javamadesoeasy.com/2015/05/checked-compile-time-exceptions-and.html)*exception in java >*

|  |
| --- |
| **class** UserDefinedException **extends RuntimeException** {     UserDefinedException(String s) {  **super**(s);     }  } |

By extending java.lang.**RuntimeException**, we can create unchecked exception.

### How to create user defined checked and unchecked Exception in java?

**Answer**. Very important exception handling interview question. Interviewers generally expects interviewees  to write code to create checked and unchecked Exception in java.

*Creating user defined* [***checked***](http://www.javamadesoeasy.com/2015/05/checked-compile-time-exceptions-and.html)*exception in java >*

|  |
| --- |
| **class** UserDefinedException **extends Exception** {     UserDefinedException(String s) {  **super**(s);     }  } |

By extending java.lang.**Exception**, we can create checked exception.

*Creating user defined* [***unchecked***](http://www.javamadesoeasy.com/2015/05/checked-compile-time-exceptions-and.html)*exception in java >*

|  |
| --- |
| **class** UserDefinedException **extends RuntimeException** {     UserDefinedException(String s) {  **super**(s);     }  } |

By extending java.lang.**RuntimeException**, we can create unchecked exception.

### Is it allowed to use multiple catch block in java?

**Answer**. Another exception handling interview question which will test your practical knowledge and understanding of Exception handling in java. [Java exception handling](http://www.javamadesoeasy.com/2015/05/exception-handling-exception-hierarchy.html) allows us to use [multiple catch block](http://www.javamadesoeasy.com/2015/05/multiple-catch-block-in-java.html) in java.

**Important** Point  about **multiple catch block in java** >

1. **Exception class handled in starting catch block must be subclass of Exception class handled in following catch blocks (otherwise we will face compilation error).**
2. Either one of the multiple catch block will handle exception at time in java.

Program - Let’s understand the concept of multiple catch block in java>

|  |
| --- |
| /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  public class ExceptionTest {     public static void main(String[] args) {              try{                   int i=10/0; //will throw ArithmeticException            }**catch**(**ArithmeticException** ae){                   System.*out*.println("Exception handled - ArithmeticException");            }**catch**(**RuntimeException** re){                   System.*out*.println("Exception handled - RuntimeException");            }**catch**(**Exception** e){                   System.*out*.println("Exception handled - Exception");            }     }  }  /\*OUTPUT  Exception handled - ArithmeticException  \*/ |

In the above above >

**ArithmeticException** has been used in **first** catch block

**RuntimeException** has been used in **second** catch block

**Exception** has been used in **third** catch block

**Exception** is superclass of **RuntimeException** and

**RuntimeException** is superclass of **ArithmeticException.**

### What is Automatic resource management in java 7?

**Answer**. Java provides a feature to make the code more robust and to cut down the lines of code. This feature is known as Automatic Resource Management(ARM) using **try-with-resources** from Java 7 onwards. The try-with-resources statement is a try statement that declares one or more resources.  
This statement ensures that each resource is closed at the end of the statement which eases working with external resources that need to be disposed or closed in case of errors or successful completion of a code block.

**What is a resource?**  
A resource is an object that must be closed after the program is finished using it. Any object that implements java.lang.AutoCloseable, which includes all objects which implement java.io.Closeable, can be used as a resource.

In try-with-resources method there is no use of finally block. the file resource is opened in try block inside small brackets. Only the objects of those classes can be opened within the block which implements AutoCloseable interface and those object should also be local. The resource will be closed automatically regardless of whether try statement completes normally or abruptly.  
**Syntax:**  
The following example reads the first line from a file. It uses an instance of BufferedReader to read data from the file. BufferedReader is a resource that must be closed after the program is finished with it:

static String readFirstLineFromFile(String path) throws IOException

{

try (BufferedReader br = new BufferedReader(new FileReader(path)))

{

return br.readLine();

}

}

Example:

// Java program to illustrate

// Automatic Resource Management

// in Java without finally block

class Resource {

public static void main(String args[]) {

String str = "";

BufferedReader br = null;

System.out.println("Enter the file path");

br = new BufferedReader(new InputStreamReader(System.in));

try {

str=br.readLine();

} catch(IOException e) {

e.printStackTrace();

}

// try with Resource

// note the syntax difference

try (BufferedReader b = new BufferedReader(new FileReader(str))) {

String s;

while ((s = b.readLine()) != null) {

System.out.println(s);

}

}

catch (IOException e) {

e.printStackTrace();

}

}

}

*Features of* ***multi catch syntax in java*** *>*

* Has **improved way of catching multiple** [**exceptions**](http://www.javamadesoeasy.com/2015/05/exception-handling-exception-hierarchy.html)**.**
* This syntax does **not looks clumsy in java**.
* **Reduces developer efforts** of writing multiple catch blocks in java.
* Allows us to **catch more than one exception in one catch block**.

Here is the **multi catch syntax** >

|  |
| --- |
| **try**{                   //code . . . . .            }**catch**(IOException **|** SQLException ex){                   //code . . . . .            } |

We could separate different exceptions using **pipe** ( **|** ) in java.

### Explain try-with-resource in java?

**Answer**. Again experienced java developers must be well versed with this exception interview question. **Before java 7**, we used to write **explicit code for closing file in** [**finally**](http://www.javamadesoeasy.com/2015/05/finally-block-in-java.html) **block by using** [**try-finally block**](http://www.javamadesoeasy.com/2015/05/try-catch-finally-block-in-java.html)like this >

|  |
| --- |
| /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public** **class** TryWithResourseTest {  **public** **static** **void** main(String[] args) **throws** IOException {            InputStream inputStream = **null**;  **try**{                   inputStream = **new** FileInputStream("c:/txtFile.txt");                   //code......            }**finally**{  **if**(inputStream!=**null**)  **inputStream.close();**            }     }  } |

**In java 7**, using **Try-with-resources >**

* we need not to write **explicit code for closing file**.

|  |
| --- |
| **import** java.io.FileInputStream;  **import** java.io.IOException;  **import** java.io.InputStream;  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public** **class** TryWithResourseTest {  **public** **static** **void** main(String[] args) **throws** IOException {  **try (InputStream inputStream = new FileInputStream("c:/txtFile.txt"))** {               //code...           }    }  } |

*Using multiple resources inside* ***Try-with-resources is also allowed in java.***

### Now, question comes why we need not to close file when we are using Try-with-resources in java?

**Answer**.  Again experienced java developers must be well versed with this exception interview question. Because **FileInputStream** implements java.lang.**AutoCloseable** **interface** (**AutoCloseable** interface’s close method automatically closes resources which are no longer needed) in java.

Which classes can be used inside **Try-with-resources in java?**

All the classes which implements **AutoCloseable** interface can be used inside **Try-with-resources in java.**

### Discuss which checked and unchecked exception can be thrown/declared by subclass method while overriding superclass method in java?

**Answer**. It’s very very important exception handling interview question. Experienced and freshers all must be able to answer this question.

*If superclass method throws/declare* ***unchecked/RuntimeException in java*** *>*

* overridden method of subclass **can** declare/**throw any unchecked /RuntimeException (superclass or subclass)**, or
* overridden method of subclass **cannot** declare/**throw** **any checked exception in java**, or
* overridden method of subclass **can** declare/**throw** **same exception in java**, or
* overridden method of subclass **may not** declare/**throw any exception in java**.

*If superclass method throws/declare* ***checked****/****compileTime******exception in java*** *>*

* overridden method of subclass **can** declare/**throw** **narrower** (subclass of) **checked exception**, or
* overridden method of subclass **cannot** declare/**throw** **broader** (superclass of) **checked exception**, or
* overridden method of subclass **can** declare/**throw any unchecked /RuntimeException**, or
* overridden method of subclass **can** declare/**throw** **same exception**, or
* overridden method of subclass **may not** declare/**throw any exception in java**.

*If superclass method does* ***not throw****/declare any* ***exception in java*** *>*

* overridden method of subclass **can** declare/**throw any unchecked /RuntimeException** , or
* overridden method of subclass **cannot** declare/**throw** **any checked exception**, or
* overridden method of subclass **may not** declare/**throw any exception in java**.

### What will happen when catch and finally block both return value, also when try and finally both return value in java?

**Answer**. This is very important exception handling interview question for experienced developers.

When **catch and finally block** both return value, **method will ultimately return value returned by** [**finally**](http://www.javamadesoeasy.com/2015/05/finally-block-in-java.html) block irrespective of value returned by [catch](http://www.javamadesoeasy.com/2015/05/catch-block-and-automatic-resource.html) block.

|  |
| --- |
| /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public** **class** ExceptionTest {  **public** **static** **void** main(String[] args) {            System.*out*.println("method return -> "+*m*());     }    **static** String m(){  **try**{  **int** i=10/0; //will throw ArithmeticException            }**catch**(ArithmeticException e){  **return** "catch";            }**finally**{  **return** "finally";            }       }  }  /\*OUTPUT  method return -> finally  \*/ |

In above program, i=10/0 will throw ArithmeticException and enter catch block to return "catch", but ultimately control will enter finally block to return "finally".

Likewise, when [**try and finally**](http://www.javamadesoeasy.com/2015/05/try-catch-finally-block-in-java.html) **block** both return value, **method will ultimately return value returned by finally block** irrespective of value returned by try block

### What is exception propagation in java?

**Answer**.

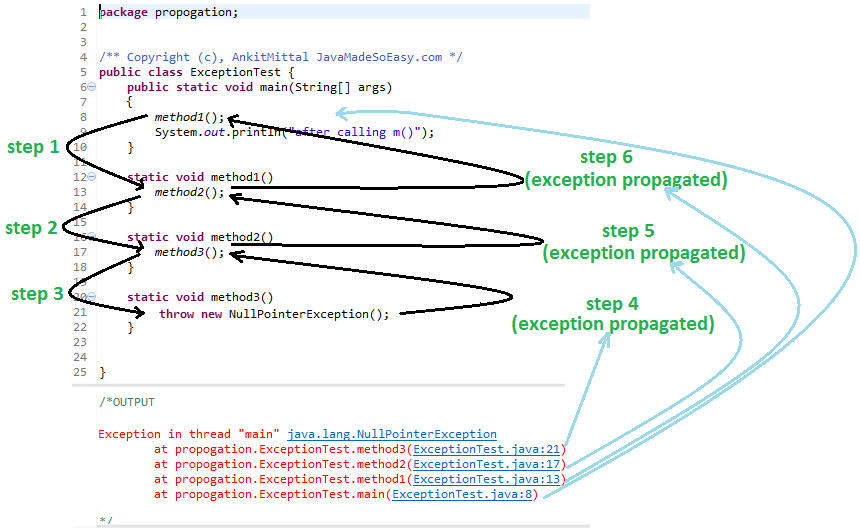
Experienced developers must know in detail about Exception handling interview question in java. Even freshers must try and understand this in depth concept of exception propagation in java.

Whenever methods are called [stack](http://javamadesoeasy.com/2015/01/stacks.html) is formed and an exception is first thrown from the top of the stack and if it is not caught, it starts coming down the stack to previous methods until it is not caught.

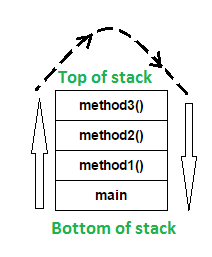
If exception remains uncaught even after reaching bottom of the stack it is propagated to JVM and program is terminated in java.

*Propagating* [***unchecked***](http://www.javamadesoeasy.com/2015/05/checked-compile-time-exceptions-and.html)*exception (NullPointerException) >*

**unchecked** exceptions are **automatically propagated** in java.

[](http://www.javamadesoeasy.com/2015/05/exception-propagation-in-java-deep.html)

[***stack***](http://javamadesoeasy.com/2015/01/stacks.html)*of methods is formed >*

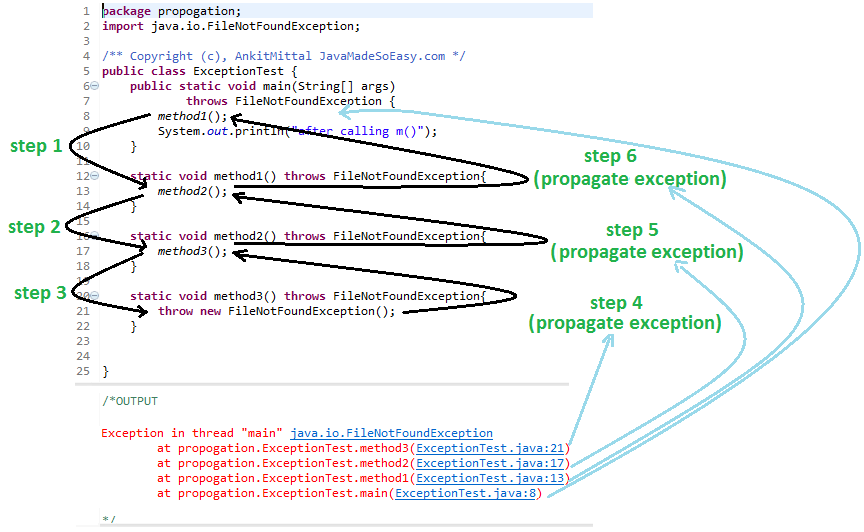


In the above program, stack is formed and an exception is first thrown from the top of the stack [ **method3()** ] and it remains uncaught there, and starts coming down the stack to previous methods to **method2()**,then to **method1()**,than to **main()** and it remains uncaught throughout.

exception remains uncaught even after reaching bottom of the stack [ **main()** ] so it is propagated to JVM and ultimately program is terminated by throwing exception [ as shown in output ] in java.

*Propagating* ***checked*** *exception (FileNotFoundException) using throws keyword >*

For **propagating checked** exceptions method must throw exception by using [**throws**](http://www.javamadesoeasy.com/2015/05/throws-exception-in-java.html)keyword.



### Can a catch or finally block throw exception in java?

**Answer**. Yes, catch or finally block can throw checked or unchecked exception but it must be handled accordingly. Please refer this post for [handling checked and unchecked exceptions](http://www.javamadesoeasy.com/2015/05/checked-compile-time-exceptions-and.html) in java.

### Why shouldn’t you use Exception for catching all exceptions in java?

**Answer**. Catching Exception rather than handling specific exception can be vulnerable to our application. [Multiple catch blocks](http://www.javamadesoeasy.com/2015/05/multiple-catch-block-in-java.html) must be used to catch specific exceptions, because handling specific exception gives developer the liberty of taking appropriate action and develop robust application

### What is Difference between [multiple catch block](http://www.javamadesoeasy.com/2015/05/multiple-catch-block-in-java.html) and [multi catch syntax](http://www.javamadesoeasy.com/2015/05/catch-block-and-automatic-resource.html)?

**Answer**. Experienced developers must know in detail about this Exception handling interview question in java

|  |  |  |
| --- | --- | --- |
|  | **multiple catch block** | **multi catch syntax** |
| 1 | multiple catch blocks were introduced in prior versions of Java 7 and does not provide any automatic resource management in java. | **multi catch syntax was introduced in** java 7 for improvements in multiple exception handling which helps in **automatic resource management in java.** |
| 2 | Here is the syntax for writing **multiple catch block in java** >   |  | | --- | | **try**{  //code . . . . .  }**catch**(**IOException** ex1){  //code . . . . .  } **catch**(**SQLException** ex2){  //code . . . . .  } | | Here is the **multi catch syntax in java** >   |  | | --- | | **try**{  //code . . . . .  }**catch**(IOException **|** SQLException ex){  //code . . . . .  } |   We could separate different exceptions using **pipe** ( **|** ) |
| 3 | For catching IOException and SQLException we need to write **two catch block** like this >  https://lh4.googleusercontent.com/Y8Pt2V80aY5BXlcs1viypo_8NBeNoVmA1Awad1o9oGIQhY02xSTW3M2fGrPGK0THNJP6yBczP-QuNHAiJjR9fMSGm1uawbwgaslhJh4KOihK-gbhHaBsPD7UYSsU2inbOxb4JPdn | with the help of multi catch syntax we can catch IOException and SQLException in one catch block using **multi catch syntax** like this >  https://lh5.googleusercontent.com/EDfjTrfY38x6H8uhRZ4ebbMwEdssvXcHaVb7dRVIr7r58vkNW4rtA8dpntIaHul_whEsS5no1B2EaawfQPTwwmOIyhjX-f0gAaRPzIHCpY36LafMmBjFpb6qPM4rQEhVb-XCEk0W |
| 4 | **When multiple catch blocks** are used , first catch block could be subclass of Exception class handled in following catch blocks like this >  IOException is subclass of Exception in java.https://lh5.googleusercontent.com/dDTyOichrPKc2g2d_KU_BLjUdPs1LpRqNum51I_x0iSD4KRaXe4T-gHeXLHEUELu4vE3W1jYt2ifV80dl0ZMaZZeRBYuIqSekdNpbUW_LdoQ30ms9gSi5Oj8kY43yAzcly5m29UC | If **Multi catch syntax** is used to catch subclass and its superclass than compilation error will be thrown.  IOException and Exception in **multi catch syntax** will cause compilation error “The exception **IOException** is already caught by the alternative **Exception**”.  https://lh4.googleusercontent.com/SFnwBVq0EsP5hKSaU7EdH35tTemyCbiqh35H-A_yd2KPEvoyzVJ7WU0y3yyafvAa0lFqSFW40Gm4b64_YaiopsmSx-hObaF6EoTNEhKihbyCIFwCb0k0lTyLU3F1pPjd5YNxuimg  **Solution >**  We must use only **Exception** to catch its subclass like this >  https://lh3.googleusercontent.com/ClWKvKo_sJKavB7eyyAgwQOHmkx_uCo3xZGxhX3_9kRUaavmPVd6dN6MM3Ix7HJ7m9ZXd5pbwyLwZ3ex8raeVavEkunmc3OyWemcUmra2fuaNtSZG1pNqz58wmSepXcuaUnaU2QF |
| 5 | Does not provide such features. | *Features of* ***multi catch syntax*** *>*   * Has **improved way of catching multiple** [**exceptions**](http://www.javamadesoeasy.com/2015/05/exception-handling-exception-hierarchy.html)**.** * This syntax does **not looks clumsy**. * **Reduces developer efforts** of writing multiple catch blocks. * Allows us to **catch more than one exception in one catch block**. * Helps in **automatic resource management.** |

### can a method be overloaded on basis of  exceptions in java ?

**Answer**.

Another Exception handling interview question which will test your practical understanding of exception in java.

Yes a method be overloaded on basis of  exceptions in java.

But now question which overloaded exception will be called.

Let’s take an example :

***Ques****. Let's say one method handles Exception and other handles ArithmeticException. Which method will be invoked when ArithmeticException is thrown?*

**Ans**. Method which handles more specific exception will be called.

Program >

|  |
| --- |
| **import** java.io.IOException;  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com  \* Main class \*/  **public** **class** ExceptionTest {    **void** method(Exception e){            System.*out*.println(e+" caught in Exception method");     }  **void** method(ArithmeticException ae){            System.*out*.println(ae+" caught in ArithmeticException method");     }    **public** **static** **void** main(String[] args) {            ExceptionTest obj=**new** ExceptionTest();            obj.method(**new** ArithmeticException());            obj.method(**new** IOException());     }  }  /\* OUTPUT  java.lang.ArithmeticException caught in ArithmeticException method  java.io.IOException caught in Exception method  \*/ |

### What are the differences between [between ClassNotFoundException and NoClassDefFoundError in java ?](http://www.javamadesoeasy.com/2015/12/what-is-difference-between.html)

**Answer**.

|  |  |  |
| --- | --- | --- |
|  | ***ClassNotFoundException*** | ***NoClassDefFoundError*** |
| 1 | ClassNotFoundException is [Checked (compile time) **Exception** in java.](http://www.javamadesoeasy.com/2015/05/checked-compile-time-exceptions-and.html) | NoClassDefFoundError is a [Error](http://www.javamadesoeasy.com/2015/05/javalangerror-in-exception-handling-in.html) in java. Error and its subclasses are regarded as unchecked exceptions in java. |
| 2 | Here is the hierarchy of java.lang.ClassNotFoundException - -java.lang.Object  -java.lang.Throwable   -java.lang.[Exception](http://www.javamadesoeasy.com/2015/05/exception-handling-exception-hierarchy.html)    -java.lang.ReflectiveOperationException     -java.lang.ClassNotFoundException | Here is the hierarchy of java.lang.NoClassDefFoundError - -java.lang.Object  -java.lang.Throwable   -java.lang.[Error](http://www.javamadesoeasy.com/2015/05/javalangerror-in-exception-handling-in.html)    -java.lang.LinkageError     -java.lang.NoClassDefFoundError |
| 3 | **ClassNotFoundException** is thrown when JVM tries to class from classpath but it does not find that class. | **NoClassDefFoundError** is thrown when JVM tries to load class which >   * **was NOT** available at **runtime** but * **was** available at **compile** time. |
|  | **ExceptionInInitializerError** has got nothing to do with **ClassNotFoundException**. | You must ensure that class does not throws **java.lang.ExceptionInInitializerError** because that is likely to be followed by **NoClassDefFoundError**. |

### What are the most important frequently occurring Exception and Errors which you faced in java?

**Answer**. Most common and frequently occurring **checked (compile time)** and Errors in java >

[FileNotFoundException **in java**](http://www.javamadesoeasy.com/2015/05/filenotfoundexception-in-java.html)

[SQLException **in java**](http://www.javamadesoeasy.com/2015/05/sqlexception-in-java.html)

[**What is java.lang.**InterruptedException **in java**](http://www.javamadesoeasy.com/2015/12/what-is-javalanginterruptedexception-in.html)

[**when java.lang.**ClassNotFoundException **occurs in java**](http://www.javamadesoeasy.com/2015/12/when-javalangclassnotfoundexception.html)

Most common and frequently occurring unchecked **(runtime)** in java.

[**What is java.lang.**NullPointerException **in java, when it occurs,how to handle, avoid and fix it**](http://www.javamadesoeasy.com/2016/01/what-is-javalangnullpointerexception-in.html)

[NumberFormatException **in java**](http://www.javamadesoeasy.com/2015/05/numberformatexception-in-java.html)

[IndexOutOfBoundsException **in java**](http://www.javamadesoeasy.com/2016/01/indexoutofboundsexception-in-java.html)

[**When java.lang.**ArrayIndexOutOfBoundsException **occurs in java**](http://www.javamadesoeasy.com/2015/12/when-javalangarrayindexoutofboundsexcep.html)

[**When java.lang.**StringIndexOutOfBoundsException **occurs in java**](http://www.javamadesoeasy.com/2015/12/when-javalangstringindexoutofboundsexce.html)

[java.lang.ArithmeticException **in java - Divide number by zero**](http://www.javamadesoeasy.com/2015/12/javalangarithmeticexception-in-java.html)

[**When dividing by zero does not throw** ArithmeticException **in java**](http://www.javamadesoeasy.com/2015/12/when-dividing-by-zero-does-not-throw.html)

[**When java.lang.**IllegalStateException **occurs in java**](http://www.javamadesoeasy.com/2015/12/when-javalangillegalstateexception.html)

[**when java.lang.**IllegalMonitorStateException **is thrown in java**](http://www.javamadesoeasy.com/2015/12/when-javalangillegalmonitorstateexcepti.html)

[**Solve java.lang.**UnsupportedOperationException **in java**](http://www.javamadesoeasy.com/2015/12/solve-javalangunsupportedoperationexcep.html)

Most common and frequently occurring **Errors** in java >

[OutOfMemoryError **in java**](http://www.javamadesoeasy.com/2015/05/outofmemoryerror-in-java.html)

[**When java.lang.**StackOverflowError **occurs in java**](http://www.javamadesoeasy.com/2015/12/when-javalangstackoverflowerror-occurs.html)

[**Solve java.lang.**ExceptionInInitializerError **in java**](http://www.javamadesoeasy.com/2015/12/solve-javalangexceptionininitializererr.html)

[**How to solve java.lang.**NoClassDefFoundError **in java**](http://www.javamadesoeasy.com/2015/12/how-to-solve-javalangnoclassdeffounderr.html)

### What is stackTrace in exception handling?

The stack trace can be printed to the standard error by calling the public void printStackTrace() method of an exception.

From Java 1.4, the stack trace is encapsulated into an array of a java class called java.lang.StackTraceElement. The stack trace element array returned by Throwable.getStackTrace() method. Each element represents a single stack frame. All stack frames except for the one at the top of the stack represent a method invocation. The frame at the top of the stack represents the execution point at which the stack trace was generated. Typically, this is the point at which the throwable corresponding to the stack trace was created.

## Serialization

### What is Serialization in java?

Let’s start by understanding what is Serialization, it’s most basic question which **you will have to answer almost in each and every java interview**. Serialization is process of converting **object into byte stream**.

Serialized object (byte stream) can be:

>Transferred over network.

>Persisted/saved into file.

>Persisted/saved into database.

Once, object have have been transferred over network or persisted in file or in database, we could deserialize the object and retain its state as it is in which it was serialized.

### How do we Serialize object, write a program to serialize and deSerialize object and persist it in file (Important)?

In order to serialize object our class needs to implement **java.io.Serializable** interface. Serializable interface is **Marker interface** i.e. it **does not have any methods** of its own, **but** it **tells Jvm that object has to converted into byte stream**.

[**SERIALIZATION**](http://www.javamadesoeasy.com/2015/02/serialize-and-deserialize-object.html)**>**

Create object of ObjectOutput and give it’s reference variable name oout and call writeObject() method and pass our employee object as parameter [**oout.writeObject(object1) ]**

|  |
| --- |
| OutputStream fout = **new** FileOutputStream("ser.txt");  ObjectOutput oout = **new** ObjectOutputStream(fout);  System.*out*.println("Serialization process has started, serializing employee objects...");  **oout.writeObject(object1);** |

[**DESERIALIZATION**](http://www.javamadesoeasy.com/2015/02/serialize-and-deserialize-object.html)**>**

Create object of ObjectInput and give it’s reference variable name oin and call readObject() method [**oin.readObject() ]**

|  |
| --- |
| InputStream fin=**new** FileInputStream("ser.txt");  ObjectInput oin=**new** ObjectInputStream(fin);  System.*out*.println("DeSerialization process has started, displaying employee objects...");  Employee emp;  emp=(Employee)**oin.readObject();** |

### How can you customize Serialization and DeSerialization process when you have implemented Serializable interface (Important)?

Here comes the quite **challenging question**, where you could prove how strong your Serialization concepts are.We can [customize **Serialization** process by defining **writeObject()**  method & **DeSerialization** process by defining **readObject()** method](http://www.javamadesoeasy.com/2015/02/customize-serialization-process-by.html).

Let’s customize **Serialization** process by defining **writeObject()**  method :

|  |
| --- |
| **private void writeObject(ObjectOutputStream os) {**  System.*out*.println("In, writeObject() method.");  **try** {  os.writeInt(**this**.id);  os.writeObject(**this**.name);  } **catch** (Exception e) {  e.printStackTrace();  }  } |

We have serialized id and name manually by writing them in file.

Let’s customize **DeSerialization** process by defining **readObject()**  method :

|  |
| --- |
| **private void readObject(ObjectInputStream ois) {**  System.*out*.println("In, readObject() method.");  **try** {  id=ois.readInt();  name=(String)ois.readObject();  } **catch** (Exception e) {  e.printStackTrace();  }  } |

We have DeSerialized id and name manually by reading them from file.

### Wap to explain how can we Serialize and DeSerialize object by implementing Externalizable interface (Important)?

For [serializing object by implementing Externalizable interface](http://www.javamadesoeasy.com/2015/02/serialize-and-deserialize-object-by.html), we need to override writeExternal() and readExternal() for serialization process to happen.

For **Serialization** process override **writeExternal()**  method & for **DeSerialization** process by override **readExternal()** method.

Let’s customize **Serialization** process by overriding [**writeExternal()**](http://www.javamadesoeasy.com/2015/02/serialize-and-deserialize-object-by.html)method :

|  |
| --- |
| **public** **void** **writeExternal**(ObjectOutput oo) **throws** IOException {            System.*out*.println("in writeExternal()");            oo.writeInt(id);            oo.writeObject(name);    } |

We have serialized id and name manually by writing them in file.

  Let’s customize **DeSerialization** process by overriding [**readExternal()**](http://www.javamadesoeasy.com/2015/02/serialize-and-deserialize-object-by.html)  method :

|  |
| --- |
| **public** **void** **readExternal**(ObjectInput in) **throws** IOException, ClassNotFoundException {            System.*out*.println("in readExternal()");  **this**.id=in.readInt();  **this**.name=(String)in.readObject();    } |

We have DeSerialized id and name manually by reading them from file.

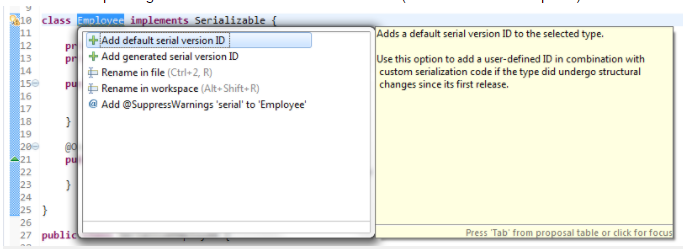
### How can you avoid certain member variables of class from getting Serialized?

Mark member variables as [**static**](http://www.javamadesoeasy.com/2015/05/static-keyword-in-java-variable-method.html)or **transient**, and those member variables will no more be a part of Serialization.

### What is serialVersionUID?

**Answer**. The serialization at runtime associates with each serializable class a version number, called a serialVersionUID, which is used during deserialization to verify that the sender and receiver of a serialized object have loaded classes for that object that are compatible with respect to serialization.

We can use eclipse to generate serialVersionUID for our class (as done in below snapshot)



How to avoid **warning** ‘The serializable class Employee does not declare a static final serialVersionUID field of type long’ ?

Again answer is we can use eclipse to generate serialVersionUID for our class (as mentioned in above screenshot, click on warning button on left in line 10).

### What will be [impact of not defining serialVersionUID](http://www.javamadesoeasy.com/2015/02/impact-of-not-defining-serialversionuid.html) in class (Important)?

This is one my favourite question, i am going to discuss it in a very detailed manner. serialVersionUID is used for **version control of object**.

If we  don’t define serialVersionUID in the class, and any **modification** is made in class, then we **won’t be able to deSerialize our class** because **serialVersionUID generated by java compiler for modified class will be different from old serialized object**. And deserialization process will end up throwing **java.io.InvalidClassException**  (because of serialVersionUID mismatch)

Let’s frame another question by twisting few words in it.

*If you have serialized a class & then added few fields in it and then deserialize already serialized version of class, how can you ensure that you don’t end up throwing* ***InvalidClassException****?*

**>**Simply we need to define **serialVersionUID** in class.

When we Deserialize class ( class which has been modified after Serialization and also class **doesn’t declare SerialVersionUID**) **InvalidClassException** is thrown.

When we Deserialize class ( class which has been modified after Serialization and also class **declare SerialVersionUID**) its gets DeSerialized **successfully**.

### What are compatible and incompatible changes in Serialization process?

**Compatible Changes :**Compatible changes are those changes which **does not affect** deSerialization process even if class was updated after being serialized (provided serialVersionUID has been declared)

* **Adding new fields** - We can add new member variables in class.
* **Adding writeObject()/readObject()  methods** - We may add these methods to customize serialization process.
* **Removing writeObject()/readObject() methods** - We may remove these methods and then default customization process will be used.
* **Changing access modifier of a field** - The change to access modifiers i.e. public, default, protected, and private have no effect on the ability of serialization to assign values to the fields.
* **Changing a field from static to non static OR changing transient filed to non transient field**. - it’s like addition of fields.

**InCompatible Changes :**InCompatible changes are those changes which affect deSerialization process if class was updated after being serialized (provided serialVersionUID has been declared)

* **Deletion of fields.**
* **Changing a nonstatic field to static or  non transient field to transient field. -** it’s equal to deletion of fields.
* **Modifying the writeObject() / readObject() method** - we must not modify these method, though adding or removing them completely is compatible change.

### What if Serialization is not available, is any other alternative way to transfer object over network?

We can can convert **JSON** to transfer the object. JSON is helpful in stringifying and de stringifying object.

>**Hibernate** (ORM tool) helps in persisting object as it in database and later we can read persisted object.

>We can convert object into **XML** (as done in web services) and transfer object over network.

### Why static member variables are not part of java serialization process (Important)?

**Answer**. Serialization is applicable on objects or primitive data types only, but [**static**](http://www.javamadesoeasy.com/2015/05/static-keyword-in-java-variable-method.html)members are **class level variables**, therefore, **different object’s of same class have same value for static member**.

So, serializing static member will consume unnecessary space and time.

Also, if modification is made in static member by any of the object, it won’t be in sync with other serialized object’s value.

### What is significance of transient variables?

**Answer**. Serialization is not applicable on transient variables (it helps in saving time and space during Serialization process), we **must mark all rarely used variables as transient**. We can initialize transient variables during deSerialization by customizing deSerialization process.

### What will happen if one the member of class does not implement Serializable interface (Important)?

This is classy question which will check your in depth knowledge of Serialization concepts. If any of the member does not implement Serializable than  NotSerializableException is thrown

### What will happen if we have used List, Set and Map as member of class?

**Answer**. This question which will check your in depth knowledge of Serialization and Java Api’s. ArrayList, HashSet and HashMap implements Serializable interface, so if we will use them as member of class they will get Serialized and DeSerialized as well.

### Is constructor of class called during DeSerialization process?

**Answer**. This question which will check your in depth knowledge of Serialization and constructor chaining concepts. It depends on whether our object has implemented Serializable or Externalizable.

If **Serializable** has been implemented - constructor is **not called** during DeSerialization process.

But, if **Externalizable** has been implemented - constructor **is called** during DeSerialization process.

### Are primitive types part of serialization process?

**Answer**. **Yes**, [primitive types are part of serialization process](http://www.javamadesoeasy.com/2015/02/are-primitive-types-part-of.html). Interviewer tends to check your basic java concepts over here.

### What values will int and Integer will be initialized to during DeSerialization process if they were not part of Serialization?

[int will be initialized to 0 and Integer will be initialized to null during DeSerialization](http://www.javamadesoeasy.com/2015/02/what-values-will-int-and-integer-will.html) (if they were not part of Serialization process).

### What is singleton?

In Java ,we can create objects by calling constructor.But imagine a scenario where we want to

control object instantiation.There could be many reasons why we want to control the object creation.

Normally in 3 tier architecture we create single instance of service and DAO objects since we don't want to create multiple DAO objects as number of database connections are limited and by creating multiple DAO objectswe donot want to exhaust database connections.

This is just one example ,there could be multiple such examples in real world.

**Code snippet for a singleton class**

Here I am using double check mechanism for creating a singleton instance.

package com.kunaal.algo;

import java.io.Serializable;

*/\*\**

*\* Here we are making ConnectionFactory as a singleton.*

*\* Since we want connection factory to be initiated once and used*

*\* by different classes of the project.*

*\**

*\* We also want to read the connection parameters once and use it as*

*\* a place holder for pooled connections.*

*\**

*\* @author KunaalATrehan*

*\**

*\*/*

public class ConnectionFactory implements Serializable{

*//Static variable for holding singleton reference object*

private static ConnectionFactory INSTANCE;

*/\*\**

*\* Private constructor*

*\*/*

private ConnectionFactory(){

}

*/\*\**

*\* Static method for fetching the instance*

*\* @return*

*\*/*

public static ConnectionFactory getInstance(){

*//Check whether instance is null or not*

if(INSTANCE ==null){

*//Locking the class object*

synchronized(ConnectionFactory.class){

*//Doing double check for the instance*

*//This is required in case first time two threads simultaneously invoke*

*//getInstance().So when another thread get the lock,it should not create the*

*//object again as its already created by the previous thread.*

if(INSTANCE==null)

INSTANCE=new ConnectionFactory();

}

}

return INSTANCE;

}

}

### What happens when we serialize the singleton?

Serialization allows storing the object in some data store and re create it later on.However when we serialize a singleton class and invoke deserialization multiple times.We can end up with multiple objects of the singleton class.Even though constructor is private,deserialization process gets hold of the private constructor while recreating the object from the serialized data store.

So can we avoid it**.Yes we can avoid it.**We will go through step by step and explain what needs to be done when we reconstruct the object from the serialized data store so that singleton behavior is not broken when object reconstruction happens.  
  
**Case-1: Serialization breaking singleton behavior**  
  
Here we are serializing the singleton instance and reading it multiple times.So we will see that INSTANCE reference is same,however multiple objects are created.

package com.kunaal.algo;

import java.io.FileInputStream;

import java.io.FileNotFoundException;

import java.io.FileOutputStream;

import java.io.IOException;

import java.io.ObjectInputStream;

import java.io.ObjectOutputStream;

*/\*\**

*\* @author KunaalATrehan*

*\**

*\*/*

public class SerializationTest {

*/\*\**

*\* @param args*

*\* @throws IOException*

*\* @throws FileNotFoundException*

*\* @throws ClassNotFoundException*

*\*/*

public static void main(String[] args) throws FileNotFoundException, IOException, ClassNotFoundException {

ConnectionFactory INSTANCE=ConnectionFactory.getInstance();

*//Here I am serializing the connection factory instance*

ObjectOutputStream oos = new ObjectOutputStream(new FileOutputStream("connFactory.ser"));

oos.writeObject(INSTANCE);

oos.close();

*//Here I am recreating the instance by reading the serialized object data store*

ObjectInputStream ois = new ObjectInputStream(new FileInputStream("connFactory.ser"));

ConnectionFactory factory1 = (ConnectionFactory) ois.readObject();

ois.close();

*//I am recreating the instance AGAIN by reading the serialized object data store*

ObjectInputStream ois2 = new ObjectInputStream(new FileInputStream("connFactory.ser"));

ConnectionFactory factory2 = (ConnectionFactory) ois2.readObject();

ois2.close();

*//Lets see how we have broken the singleton behavior*

System.out.println("Instance reference check->" +factory1.getInstance());

System.out.println("Instance reference check->" +factory2.getInstance());

System.out.println("=========================================================");

System.out.println("Object reference check->"+factory1);

System.out.println("Object reference check->"+factory2);

}

}

**Output is as follows:-**

Instance reference check->com.kunaal.algo.ConnectionFactory@763f5d

Instance reference check->com.kunaal.algo.ConnectionFactory@763f5d

Object reference check->com.kunaal.algo.ConnectionFactory@13a317a

Object reference check->com.kunaal.algo.ConnectionFactory@186768e

**Case-2: Serialization and singleton working properly**

In order to make serialization and singleton work properly,we have to introduce readResolve() method in the singleton class.readResolve() method lets developer control what object should be returned  on deserialization.

For the current ConnectionFactory singleton class,readResolve() method will look like this.

*/\*\**

*\* Special hook provided by serialization where developer can control what object needs to sent.*

*\* However this method is invoked on the new object instance created by de serialization process.*

*\* @return*

*\* @throws ObjectStreamException*

*\*/*

private Object readResolve() throws ObjectStreamException{

return INSTANCE;

}

**Output  is as follows:-**

Instance reference check->com.kunaal.algo.ConnectionFactory@13a317a

Instance reference check->com.kunaal.algo.ConnectionFactory@13a317a

=========================================================

Object reference check->com.kunaal.algo.ConnectionFactory@13a317a

Object reference check->com.kunaal.algo.ConnectionFactory@13a317a

So now serialization and singleton is working properly and it does not matter how many times we read the serialized format of singleton object.We will get the one instance.readResolve() did the trick

## Collections

### Can we use custom object as key in HashMap? If yes then how?

**For using** object as Key in HashMap, we must implements [equals and hashcode method](http://www.javamadesoeasy.com/2015/02/override-equals-and-hashcode-method.html).

### Why do we need to override equals and hashcode method?

Before understanding the concept of overriding equals() and hashCode() method, we must understand what is **bucket, Entry, and Entry.next**

[](http://javamadesoeasy.com/2015/02/hashmap-custom-implementation.html)

**Bucket** is [**ArrayList**](http://javamadesoeasy.com/2015/02/arraylist-custom-implementation.html) of Entry.

**Entry** is [**LinkedList**](http://javamadesoeasy.com/2015/01/doublylinkedlist-insert-and-delete-at.html) which contains information about key, value and next.

**Entry.next** points to next Entry in **LinkedList**.

### Why to override hashcode method?

It helps in finding bucket location, where entry(with key-value pair) will be stored .

**Entry (**of type **LinkedList)** is stored in **bucket (ArrayList).**

**If, hashCode() method is overridden properly**, we will find bucket location using hashCode() method, we will obtain **Entry** on that bucket location, then iterate over each and every **Entry** (by calling **Entry.next**) and check whether new and existing keys are equal or not. If keys are equal replace key-value in Entry with new one, else call Entry.next But, now the question comes how to check whether two keys are equal or not. So, it’s time to implement equals() method.

**If,** **hashcode method is not overridden** for same key every time hashCode() method is called it might produce different hashcode, there might happen **2 cases** i.e. when **put and get** **method** are called.

**Case 1 : when put() method is called-**

There might be possibility that same Entry (with key-value pair)  will

get stored at multiple locations in bucket.

***Conclusion>*** key- value pair may get stored multiple times in HashMap.

**Case 2 : when get() method is called-**

As there is possibility that hashCode() method might return different hashcode & rather than searching on bucket location where Entry(with key) exists we might be searching for key on some other bucket location.

***Conclusion>***  key existed in HashMap, but still we were not able to locate the bucket location in which it was stored.

### Why to override equals method?

Once we have located bucket location in which our Entry (with key-value pair) will be stored, **Equals** method helps us in finding whether **new and existing keys are equal or not**.

**If we equals method is not overridden -** though we will be able to find out correct bucket location if hashCode() method is overridden correctly, but still if equals method is not overridden, there might happen **2 cases** i.e. when **put and get** **method** are called.

**Case 1 : when put() method is called-**

we might end up storing new Entry (with new key-value pair) multiple times on same bucket location (because of absence of equals method, we don’t have any way of comparing key’s),

In this case, even if keys are equal, we will keep on calling Entry.next until we reach last Entry on that bucket location and ultimately we will end up storing new Entry (with new key) again in same bucket location.

***Conclusion>*** key- value pair stored multiple times in HashMap.

**Case 2 : when get() method is called-**

we won’t be able to compare two keys (new key with existing **Entry**.key) and we will call **Entry**.next and again we won’t be able to compare two keys and ultimately when Entry.next is null - we will return **false**.

***Conclusion>***  key existed in HashMap, but still we were not able to retrieve it.

So, it’s important to override equals method to check equality of two keys.

### If two objects have same hashcode, are they always equal?

**No**, It’s not necessary that object’s having same hashcode are always equal. Because same hashcode means object are stored on same bucket location, as key/object in bucket is stored in Entry([**Linked List**](http://javamadesoeasy.com/search/label/Linked%20List))**,** key**/**object’s might be stored on Entry.next (i.e. on some different entry)

### If two objects equals() method return true, do objects always have same hashcode?

**Yes**, two objects can return true only if they are stored on same bucket location.

First, hashCode() method must have returned same hashcode for both objects, than on that bucket location’s Entry key.equals()  is called, which returns true to confirm objects/keys are equal.

So, if object’s equals return true, they always have same hashcode.

### What classes should i prefer to use a key in HashMap?

This question will check your in depth knowledge of Java’s Collection Api’s. We should prefer **String, Integer, Long, Double, Float, Short and any other wrapper class.** Reason behind using them as a key is that they override equals() and hashCode() method, we need not to write any explicit code for overriding equals() and hashCode() method.

Let’s use Integer class as key in HashMap.

|  |
| --- |
| **import** java.util.HashMap;  **import** java.util.Map;  **public** **class** StringInMap {  **public** **static** **void** main(String...a){             //HashMap's key=Integer class  (Integer’s api has already overridden hashCode() and equals() method for us )            Map<Integer, String> hm=**new** HashMap<Integer, String>();            hm.put(1, "data");            hm.put(1, "data OVERRIDDEN");              System.*out*.println(hm.get(1));       }  }  /\*OUTPUT  data OVERRIDDEN  \*/ |

If, we note above program, what we will see is we didn’t override equals() and hashCode() method, but still we were able to store data in HashMap, override data and retrieve data using get method.

>Let’s check in **Integer’s API**, how Integer class has overridden equals() and hashCode() method :

|  |
| --- |
| **public** **int** **hashCode**() {  **return** value;  }  **public** **boolean** **equals**(Object obj) {  **if** (obj **instanceof** Integer) {  **return** value == ((Integer)obj).intValue();         }  **return** **false**;  } |

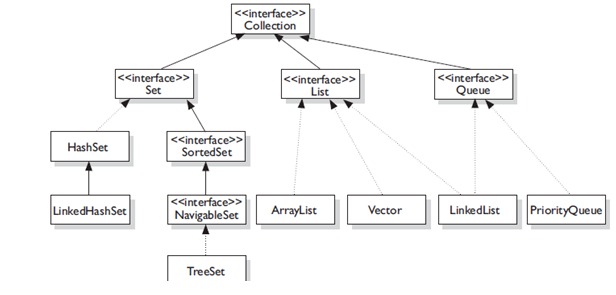
### Can overriding of hashcode() method cause any performance issues?

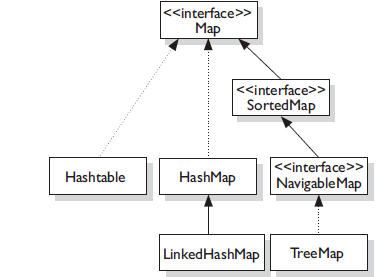
Improper implementation of hashCode() can cause performance issues, because in that most of the key-value pairs will be stored on same bucket location and unnecessary time will be consumed while fetching value corresponding to key.

### What are subinterfaces of Collection interface in java? Is Map interface also a subinterface of Collection interface in java?

[**List**](http://www.javamadesoeasy.com/2015/04/list-hierarchy-in-java-detailed.html) and [**Set**](http://www.javamadesoeasy.com/2015/04/set-hierarchy-in-java-detailed-hashset.html) are subinterfaces of java.util.[**Collection**](http://www.javamadesoeasy.com/2015/04/collection-in-java.html) in java.

*It’s important to note* [***Map***](http://www.javamadesoeasy.com/2015/04/map-hierarchy-in-java-detailed-hashmap.html) *interface is a member of the Java Collections Framework, but it does not implement Collection interface in java.*





### What are differences between [ArrayList and LinkedList](http://www.javamadesoeasy.com/2015/04/arraylist-vs-linkedlist-similarity-and.html) in java?

**Answer**. This is very important collection framework interview question in java.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Property | ***java.util.ArrayList*** | **java.util.LinkedList** |
| 1 | Structure | java.util.ArrayList is index based structure in java.  [https://lh3.googleusercontent.com/wCfo_q1uxCzZZCgGpetqEQYMeVj9YMJokT9-WJ7QY4jxCF11u5-WVIjVheBCfKlPJtQ9Bp5zzxTJcPgYLMr0N3n6PvjXPzd-7O-FJr2KoW7qrUjERB-yXK2YxFkH6qrLAX6hvdg5](http://javamadesoeasy.com/2015/02/arraylist-custom-implementation.html) | A java.util.**LinkedList** is a data structure consisting of a group of **nodes** which together represent a sequence.  node is composed of a data and a reference (in other words, a **link**) to the next node in the sequence in java.  [https://lh3.googleusercontent.com/ykSE04usYkDTj50vuGVTWKtVGJootTOKa07Eub-E6D5KkOCNAb399G4agtbSKOyeaPAUvAngY6JjDMs-SBNmblDOXLv62eHNVIwEuGD5-GNXTP45Ubtyp0BYg0seOxGSpXHatWJP](http://www.javamadesoeasy.com/2015/01/doublylinkedlist-insert-and-delete-at.html) |
| 2 | **Resizable** | **ArrayList is Resizable-array in java.** | New node is created for storing new element in LinkedList in java. |
| 3 | **Initial capacity** | java.util.ArrayList is created with initial capacity of 10 in java. | For storing every element node is created in LinkedList, so linkedList’s initial capacity is 0 in java. |
| 4 | Ensuring **Capacity**/ resizing. | ArrayList is created with initial capacity of 10.  ArrayList’s size is **increased by 50%** i.e. after resizing it’s size become 15 in java. | For storing every element node is created, so linkedList’s initial capacity is 0, it’s size grow with addition of each and every element in java. |
| 5 | RandomAccess interface | ArrayList implements RandomAccess(Marker interface) to indicate that they support fast random access (i.e. index based access) in java. | LinkedList does not implement RandomAccess interface in java. |
| 6 | AbstractList and AbstractSequentialList | ArrayList extends AbstractList (abstract class) which provides implementation to  List interface to minimize the effort required to implement this interface backed by RandomAccess interface. | LinkedList extends AbstractSequentialList (abstract class), AbstractSequentialList extends AbstractList.  In LinkedList, data is accessed sequentially, so for obtaining data at specific index, iteration is done on nodes sequentially in java. |
| 7 | How **get(index)** method works?  (Though difference has been discussed briefly in above 2 points but in this in point we will figure difference in detail.) | Get method of ArrayList directly gets element on specified index. Hence, offering O(1) complexity in java. | Get method of LinkedList iterates on nodes sequentially to get element on specified index. Hence, offering O(n) complexity in java. |
| **8** | **When to use** | **Use ArrayList when get operations is more frequent than add and remove operations in java.** | **Use LinkedList when add and remove operations are more frequent than get operations in java.** |

### What are differences between [List and Set](http://www.javamadesoeasy.com/2015/04/list-vs-set-similarity-and-differences.html) interface in java?

**Answer**. Another very very important collection framework interview question to differentiate between **List and Set** in java.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Property | ***java.util.List*** | ***java.util.Set*** |
| 1 | Insertion order | java.util.List is ordered collection it **maintain insertion order** in java. | *Most of the java.util.Set implementation* does not **maintain insertion order**.  HashSet does not maintains insertion order in java.  Thought LinkedHashSet maintains insertion order in java.    TreeSet is sorted by natural order in java. |
| 2 | Duplicate elements | List **allows to store duplicate elements** in java. | *Set does* ***not allow to store duplicate elements*** in java*.* |
| 3 | Null keys | List allows to store **many null keys** in java. | Most of the Set implementations allow to add only **one null** in java**.**  TreeSet does not allow to add null in java. |
| 4 | Getting element on specific **index** | List implementations provide get method to get element on specific index in java.  ArrayList, Vector, copyOnWriteArrayList and LinkedList provides -  *get(int index)*  Method returns element on specified *index*.  **Get method directly gets element on specified index. Hence, offering O(1) complexity.** | Set implementations does not provide any such get method to get element on specified index in java. |
| 5 | Implementing classes | [**ArrayList**](http://www.javamadesoeasy.com/2015/04/arraylist-in-java.html)***,*** [**LinkedList**](http://www.javamadesoeasy.com/2015/04/linkedlist-in-java.html)***,*** [**Vector**](http://www.javamadesoeasy.com/2015/04/arraylist-vs-vector-similarity-and.html)***,*** [**CopyOnWriteArrayList**](http://www.javamadesoeasy.com/2015/04/arraylist-vs-copyonwritearraylist.html) classes implements [**List**](http://www.javamadesoeasy.com/2015/04/list-vs-set-similarity-and-differences.html) interface in java. | [**HashSet**](http://www.javamadesoeasy.com/2015/04/hashset-in-java.html)***,*** [**CopyOnWriteArraySet**](http://www.javamadesoeasy.com/2015/04/hashset-vs-copyonwritearrayset.html)***,*** [**LinkedHashSet**](http://www.javamadesoeasy.com/2015/04/hashset-vs-linkedhashset-vs-treeset.html)***,*** [**TreeSet**](http://www.javamadesoeasy.com/2015/04/hashset-vs-linkedhashset-vs-treeset.html), [**ConcurrentSkipListSet**](http://www.javamadesoeasy.com/2015/04/treeset-vs-concurrentskiplistset.html), [**EnumSet**](http://www.javamadesoeasy.com/2015/04/enumset-in-java-with-program.html) classes implements [**Set**](http://www.javamadesoeasy.com/2015/04/list-vs-set-similarity-and-differences.html) interface in java. |
| 6 | listIterator | **listIterator** method returns listIterator to iterate over elements in List in java.  **listIterator provides** additional methods as compared to iterator like  **hasPrevious(), previous(), nextIndex(), previousIndex(), add(E element), set(E element)** | Set does not provide anything like listIterator. It simply return Iterator in java. |
| 7 | Structure and resizable | **List** are Resizable-array implementation of the java.util.**List** interface in java. | Set uses [**Map**](http://www.javamadesoeasy.com/2015/04/map-hierarchy-in-java-detailed-hashmap.html)for their implementation.  Hence, structure is map based and resizing depends on Map implementation.  *Example >* [***HashSet***](http://www.javamadesoeasy.com/2015/04/hashset-in-java.html) *internally uses* [*HashMap*](http://javamadesoeasy.com/2015/02/hashmap-custom-implementation.html)*.* |
| 8 | Index based structure /RandomAccess | As **ArrayList** uses array for implementation it is index based structure, hence provides random access to elements.  But [**LinkedList**](http://www.javamadesoeasy.com/2015/04/linkedlist-in-java.html) is not indexed based structure in java. | Set is not index based structure at all in java. |

### What are differences between [Iterator and ListIterator](http://www.javamadesoeasy.com/2015/04/iterator-vs-listiterator-similarity-and.html)? in java

**Answer**. This collection framework interview question is tests your knowledge of iterating over different collection framework classes in java.

|  |  |  |
| --- | --- | --- |
|  | ***java.util.ListIterator*** | ***java.util.Iterator*** |
| 1 | **hasPrevious()**  method returns true if this listIterator has more elements when traversing the list in the reverse direction. | **No such method** in java.util.Iterator. |
| 2 | **previous()**  returns previous element in iteration (traversing in backward direction).  if the iteration has no previous elements than NoSuchElementException is thrown. | **No such method** in java.util.Iterator. |
| 3 | **nextIndex()**  method returns the index of the element that would be returned by a subsequent call to next() method. If listIterator is at the end of the list than method returns size of list. | **No such method** in java.util.Iterator. |
| 4 | **previousIndex()**  method returns the index of the element that would be returned by a subsequent call to previous() method. If listIterator is at the start of the list than method returns -1. | **No such method** in java.util.Iterator. |
| 5 | **add(E element)**  Method inserts the specified **element** into the list.  The element is inserted immediately before the element that would be returned by next (So, subsequent call to next would be unaffected), if any, and after the element that would be returned by previous (So,subsequent call to previous would return the new **element**), if any.  If the list does not contain any element than new **element** will be the sole element in the list. | **No such method** in java.util.Iterator. |
| 6 | **set(E element)**  Method replaces the last element returned by next() or previous() method with the specified **element**. This call can be made only if neither remove nor add have been called after the last call to next or previous.  If call to set() method is followed up by any call made to remove() or add() method after next() or previous() than UnsupportedOperationException is thrown. | **No such method** in java.util.Iterator. |
| 7 | All the implementations of [**List**](http://www.javamadesoeasy.com/2015/04/list-hierarchy-in-java-detailed.html) interface like [**ArrayList**](http://www.javamadesoeasy.com/2015/04/arraylist-in-java.html)***,*** [**LinkedList**](http://www.javamadesoeasy.com/2015/04/linkedlist-in-java.html), [**Vector**](http://www.javamadesoeasy.com/2015/04/arraylist-vs-vector-similarity-and.html)***,*** [**CopyOnWriteArrayList**](http://www.javamadesoeasy.com/2015/04/arraylist-vs-copyonwritearraylist.html) classes returns listIterator. | All Implementation classes of [**Collection**](http://www.javamadesoeasy.com/2015/04/collection-in-java.html) interface’s subinterfaces like [Set and List](http://www.javamadesoeasy.com/2015/04/list-vs-set-similarity-and-differences.html) return iterator. |

### What are differences between [Collection and Collections](http://www.javamadesoeasy.com/2015/04/collection-vs-collections-differences.html) in java?

java.util.[***Collection***](http://www.javamadesoeasy.com/2015/04/collection-in-java.html) ***​*** *is the* root **interface** in the ​*hierarchy of Java Collection framework​*.

The JDK does not provide any classes which directly implements java.util.Collection interface, but it  provides classes such as [**ArrayList**](http://www.javamadesoeasy.com/2015/04/arraylist-in-java.html), [**LinkedList**](http://www.javamadesoeasy.com/2015/04/linkedlist-in-java.html), [**vector**](http://www.javamadesoeasy.com/2015/04/arraylist-vs-vector-similarity-and.html), [**HashSet**](http://www.javamadesoeasy.com/2015/04/hashset-in-java.html), [**EnumSet**](http://www.javamadesoeasy.com/2015/04/enumset-in-java-with-program.html), [**LinkedHashSet**](http://www.javamadesoeasy.com/2015/04/hashset-vs-linkedhashset-vs-treeset.html), [**TreeSet**](http://www.javamadesoeasy.com/2015/04/hashset-vs-linkedhashset-vs-treeset.html), [CopyOnWriteArrayList](http://www.javamadesoeasy.com/2015/04/arraylist-vs-copyonwritearraylist.html), [CopyOnWriteArraySet](http://www.javamadesoeasy.com/2015/04/hashset-vs-copyonwritearrayset.html), [ConcurrentSkipListSet](http://www.javamadesoeasy.com/2015/04/treeset-vs-concurrentskiplistset.html)  which implements more specific subinterfaces like ​[Set and List​](http://www.javamadesoeasy.com/2015/04/list-vs-set-similarity-and-differences.html) in java.

java.util.**Collections** is a utility **class** which **consists** of **static methods** that **operate on** or return **Collection** in java.

**java.util.Collections provides method like >**

* **reverse** method for reversing [**List**](http://www.javamadesoeasy.com/2015/04/list-hierarchy-in-java-detailed.html) in java.
* **shuffle** method for shuffling elements of **List** in java.
* **unmodifiableCollection**, [**unmodifiableSet**](http://www.javamadesoeasy.com/2015/04/hashset-making-set-unmodifiable-using.html), [**unmodifiableList**](http://www.javamadesoeasy.com/2015/04/arraylist-making-list-unmodifiable.html), [**unmodifiableMap**](http://www.javamadesoeasy.com/2015/04/hashmap-making-map-unmodifiable-using.html) methods for making **List**, [**Set**](http://www.javamadesoeasy.com/2015/04/set-hierarchy-in-java-detailed-hashset.html) and [**Map**](http://www.javamadesoeasy.com/2015/04/map-hierarchy-in-java-detailed-hashmap.html) unmodifiable in java.
* **min** method to return smallest element in **Collection** in java.
* **max** method to return smallest element in **Collection**.
* **sort** method for sorting **List**.
* **synchronizedCollection**, [**synchronizedSet**](http://www.javamadesoeasy.com/2015/04/hashset-synchronizing-using.html), [**synchronizedList**](http://www.javamadesoeasy.com/2015/04/arraylist-synchronizing-using.html), [**synchronizedMap**](http://www.javamadesoeasy.com/2015/04/hashmap-synchronizing-map-using.html)methods for synchronizing **List**, **Set** and **Map** respectively in jav

### What are core classes and interfaces in java.util.List hierarchy in java?

**Answer**. Freshers must know core classes in List hierarchy but experienced developers must be able to explain this java.util.List hierarchy in detail.[](http://www.javamadesoeasy.com/2015/04/list-hierarchy-in-java-detailed.html)

### What are core classes and interfaces in java.util.Set hierarchy?

**Answer**. Freshers must know core classes in Set hierarchy but experienced developers must be able to explain this java.util.Set hierarchy in detail.

[](http://www.javamadesoeasy.com/2015/04/set-hierarchy-in-java-detailed-hashset.html)

### What are differences between [Iterator and Enumeration](http://www.javamadesoeasy.com/2015/04/iterator-vs-enumeration-differences-and.html) in java?

**Answer**. Experienced developers must be well versed to answer this collection framework interview question in java.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | ***Property*** |  | ***java.util.Enumeration*** | ***java.util.Iterator*** |
| 1 | Remove elements during iteration |  | java.util.Enumeration **doesn’t allows** to remove elements from collection during iteration in java. | java.util.Iterator **allows** to remove elements from collection during iteration by using **remove()** method in java. |
| 2 | Improved naming conventions in Iterator |  | **nextElement()**  Method Returns the next element of this enumeration if this enumeration object has at least one more element to provide.  **hasMoreElements()**  returns true if enumeration contains more elements. | **nextElement()** has been changed to **next()** in Iterator.  And  **hasMoreElements()** has been changed to **hasNext()** in Iterator. |
| 3 | Introduced in  which java  version |  | Enumeration was introduced in first version  of java i.e. ​**JDK 1.0** | Iterator was introduced in second version  of java i.e. ​**JDK 2.0**  Iterator was introduced to replace Enumeration in the Java Collections Framework. |
| 4 | Recommendation |  | **Java docs** recommends iterator over enumeration**.** | **Java docs** recommends iterator over enumeration**.** |
| 5 | Enumeration and Iterator over [**Vector**](http://www.javamadesoeasy.com/2015/04/arraylist-vs-vector-similarity-and.html) |  | **Enumeration** returned by Vector is [**fail-safe**](http://www.javamadesoeasy.com/2015/04/concurrentmodificationexception-fail.html), means any modification made to Vector during iteration using Enumeration don’t throw any exception in java. | **Iterator** returned by Vector are [**fail-fast**](http://www.javamadesoeasy.com/2015/04/concurrentmodificationexception-fail.html)**,** means any structural modification made to ArrayList during iteration will throw ConcurrentModificationException  in java. |

### What are differences between [HashMap and Hashtable](http://www.javamadesoeasy.com/2015/04/hashmap-and-hashtable-similarity-and.html) in java?

**Answer**. Fresher and Experienced developers must answer this important collection framework interview question in detail in java.

***Differences*** *between java.util.*[***HashMap***](http://www.javamadesoeasy.com/2015/04/hashmap-in-java.html) *and java.util.****Hashtable*** *in java >*

|  |  |  |  |
| --- | --- | --- | --- |
|  | Property | ***java.util.HashMap*** | ***java.util.Hashtable*** |
| 1 | synchronization | java.util.HashMap is **not synchronized**  (because 2 threads on same HashMap object can access it at same time) in java. | java.util.Hashtable is **synchronized** (because 2 threads on same Hashtable object cannot access it at same time) in java. |
| 2 | Performance | HashMap is not synchronized, hence its operations are **faster** as compared to Hashtable in java. | Hashtable is synchronized, hence its operations are **slower** as compared to HashMap in java.  If we are working not working in multithreading environment jdk recommends us to use HashMap. |
| 3 | Null keys and values | HashMap allows to store **one null key** and **many null values** i.e. many keys can have null value in java. | Hashtable does **not allow to store null key or null value**.  Any attempt to store null key or value throws runtimeException (NullPointerException) in java. |
| 4 | Introduced  in which java version | HashMap was introduced in second version of java i.e. **JDK 2.0** | Hashtable was introduced in first version of java i.e. **JDK 1.0**  But it was refactored in java 2 i.e. JDK 1.2 to implement the Map interface, hence making it a member of member of the [Java Collections Framework](http://download.oracle.com/javase/7/docs/technotes/guides/collections/index.html). |
| 5 | Recommendation | In non-multithreading environment it is recommended to use HashMap than using Hashtable in java. | I**n java 5 i.e. JDK 1.5**, it is **recommended** to use [ConcurrentHashMap](http://www.javamadesoeasy.com/2015/04/concurrenthashmap-in-java.html) than using Hashtable. |
| 6 | Extends Dictionary (Abstract class, which is obsolete) | HashMap does not extends Dictionary in java. | Hashtable extends Dictionary (which maps non-null keys to values. In a given Dictionary we can look up value corresponding to key) in java. |

### when to use [HashSet vs LinkedHashSet vs TreeSet](http://www.javamadesoeasy.com/2015/04/hashset-vs-linkedhashset-vs-treeset.html) in java?

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Property | *java.util.HashSet* | *java.util.LinkedHashSet* | *java.util.TreeSet* |
| 1 | Insertion order | java.util.HashSet does not maintains insertion order in java.  Example in java >  **set.add("b");**  **set.add("c");**  **set.add("a");**  Output >  **No specific order** | java.util.LinkedHashSet maintains insertion order in java.  Example in java >  **set.add("b");**  **set.add("c");**  **set.add("a");**  Output >  **b**  **c**  **a** | java.util.TreeSet is sorted by natural order in java.  Example in java >  **set.add("b");**  **set.add("c");**  **set.add("a");**  Output >  **a**  **b**  **c** |
| 2 | Null elements | HashSet allows to store **one null** in java**.** | LinkedHashSet allows to store **one null** in java. | TreeSet does **not** allows to store **any null** in java.  Any attempt to add null throws runtimeException (NullPointerException). |
| 3 | Data structure internally used for storing data | For storing elements HashSet internally uses HashMap. | For storing elements LinkedHashSet internally uses  LinkedHashMap. | For storing elements TreeSet internally uses TreeMap. |
| 4 | Introduced  in which java version | java.util.HashSet was introduced in second version of java (1.2) i.e. **JDK 2.0** | java.util.LinkedHashSet was introduced in second version of java (1.4) i.e. **JDK 4.0** | java.util.TreeSet was introduced in second version of java (1.2) i.e. **JDK 2.0** |
| 5 | Implements which; interface | HashSet implements **java.util.**[**Set**](http://www.javamadesoeasy.com/2015/04/set-hierarchy-in-java-detailed-hashset.html)interface. | LinkedHashSet implements **java.util.Set** interface. | TreeSet implements **java.util.Set**  **java.util.SortedSet**  **java.util.NavigableSet** interface. |

### What are differences between [HashMap and ConcurrentHashMap](http://www.javamadesoeasy.com/2015/04/hashmap-and-concurrenthashmap.html) in java?

**Answer**. Take my words java developers won’t be able to get away from this very important collection framework interview question.

***Differences*** *between java.util.*[***HashMap***](http://www.javamadesoeasy.com/2015/04/hashmap-in-java.html) *and java.util.concurrent.*[*ConcurrentHashMap*](http://www.javamadesoeasy.com/2015/04/concurrenthashmap-in-java.html) *in java >*

|  |  |  |
| --- | --- | --- |
| Property | *java.util.****HashMap*** | *java.util.concurrent.* ***ConcurrentHashMap*** |
| synchronization | HashMap is **not synchronized.** | ConcurrentHashMap is **synchronized**. |
| 2 threads on same Map object can access it at concurrently? | Yes, because HashMap is not synchronized**.** | Yes.  But how despite of being synchronized, 2 threads on same *ConcurrentHashMap* object can access it at same time?  *ConcurrentHashMap* is divided into different **segments** based on concurrency level. So different threads can access different **segments** concurrently. |
| Performance | We will **synchronize HashMap and then compare its performance with ConcurrentHashMap**.  *We can synchronize hashMap by using Collections’s class* ***synchronizedMap*** *method.*   |  | | --- | | *Map synchronizedMap = Collections.****synchronizedMap****(hashMap);* |   *Now, no 2 threads can access same instance of map concurrently.*  **Hence synchronized HashMap’s performance is slower as compared to ConcurrentHashMap.**  But why we didn’t compared HashMap (unSynchronized) with ConcurrentHashMap?  Because performance of unSynchronized collection is always better than some synchronized collection. As, default (unSynchronized) hashMap didn’t cause any locking. | **ConcurrentHashMap’s performance is faster as compared to HashMap (**because it is divided into segments, as discussed in above point**).**  [*Read this post for performance comparison between HashMap and ConcurrentHashMap.*](http://www.javamadesoeasy.com/2015/04/hashmap-and-concurrenthashmap.html) |
| Null keys and values | HashMap allows to store **one null key** and **many null values** i.e. any key can have null value. | ConcurrentHashMap does **not allow to store null key or null value**.  Any attempt to store null key or value throws runtimeException (NullPointerException). |
| Iterators | The iterators returned by the iterator() method of HashMap are [***fail-fast***](http://www.javamadesoeasy.com/2015/04/concurrentmodificationexception-fail.html) *>*  *hashMap.keySet().iterator()*  *hashMap.values().iterator()*  *hashMap.entrySet().iterator()*  all three iterators are ***fail-fast*** | iterators are [***fail-safe***](http://www.javamadesoeasy.com/2015/04/concurrentmodificationexception-fail.html)*.*  *concurrentHashMap.keySet().iterator()*  *concurrentHashMap.values().iterator()*  *concurrentHashMap.entrySet().iterator()*  all three iterators are ***fail-safe.*** |
| **putIfAbsent** | HashMap does not contain putIfAbsent method.  ***putIfAbsent*** *method is equivalent to writing following code >*   |  | | --- | | **synchronized** (map){  **if** (!*map*.containsKey(key))  **return** *map*.put(key, value);  **else**  **return** *map*.get(key);  } |   [**Program to create method that provides functionality similar to putIfAbsent method of ConcurrentHashMap and to be used with HashMap**](http://www.javamadesoeasy.com/2015/04/program-to-create-method-that-provides.html) | If map does not contain specified **key**, put specified **key-value** pair in map and return null.  If map already contains specified **key**, return value corresponding to specified **key**.    [**Program to use ConcurrentHashMap’s putIfAbsent method**](http://www.javamadesoeasy.com/2015/04/program-to-use-concurrenthashmaps.html) |
| Introduced  in which java version | HashMap was introduced in **java 2 i.e. JDK 1.2**, | ConcurrentHashMap was introduced in **java 5** i.e. **JDK 1.5**, since its introduction Hashtable has become obsolete, because of concurrency level its performance is better than Hashtable. |
| Implements which interface | HashMap implements **java.util.**[**Map**](http://www.javamadesoeasy.com/2015/04/map-hierarchy-in-java-detailed-hashmap.html) | ConcurrentHashMap implements  **java.util.Map** and  **java.util.concurrent.ConcurrentMap** |
| Package | HashMap is in **java.util** package | ConcurrentHashMap is in **java.util.concurrent** package. |

### When to use [HashMap vs Hashtable vs LinkedHashMap vs TreeMap](http://www.javamadesoeasy.com/2015/04/hashmap-vs-hashtable-vs-linkedhashmap.html) in java?

**Answer**. Another important collection framework interview question

to differentiate between **following Map implementations** in java.

***Differences*** *between java.util.*[***HashMap***](http://www.javamadesoeasy.com/2015/04/hashmap-in-java.html) *vs java.util.*[***Hashtable***](http://www.javamadesoeasy.com/2015/04/hashmap-and-hashtable-similarity-and.html)*vs java.util.****LinkedHashMap*** *vs java.util.*[***TreeMap***](http://www.javamadesoeasy.com/2015/04/treemap-vs-concurrentskiplistmap.html) ***>***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Property** | ***HashMap*** | ***Hashtable*** | ***LinkedHashMap*** | ***TreeMap*** |
| 1 | Insertion order | HashMap does not maintains insertion order in java. | Hashtable does not maintains insertion order in java. | LinkedHashMap  maintains insertion order in java. | TreeMap is sorted by natural order of keys in java. |
| 2 | Performance | HashMap is not synchronized, hence its operations are **faster** as compared to Hashtable. | Hashtable is synchronized, hence its operations are **slower** as compared HashMap.  If we are working not working in multithreading environment jdk recommends us to use HashMap. | LinkedHashMap must be used only when we want to maintain insertion order. **Time and space overhead** is there because for maintaining order it internally uses **Doubly Linked list**. | TreeMap must be used only when we want sorting based on natural order. Otherwise sorting operations cost performance. (Comparator is called for sorting purpose) |
| 3 | Null keys and values | HashMap allows to store **one null key** and **many null values** i.e. many keys can have null value in java. | Hashtable does **not allow to store null key or null value**.  Any attempt to store null key or value throws runtimeException (NullPointerException) in java. | LinkedHashMap allows to store **one null key** and **many null values** i.e. any key can have null value in java. | TreeMap does **not allow to store null key but allow many null values**.  Any attempt to store null key throws runtimeException (NullPointerException) in java. |
| 4 | Implements which interface | HashMap implements **java.util.**[**Map**](http://www.javamadesoeasy.com/2015/04/map-hierarchy-in-java-detailed-hashmap.html) | Hashtable implements **java.util.Map** | LinkedHashMap implements **java.util.Map** | TreeMap implements  **java.util.Map**  **java.util.SortedMap**  **java.util.NavigableMap** |
| 5 | Implementation uses? | HashMap use [**buckets**](http://javamadesoeasy.com/2015/02/hashmap-custom-implementation.html) | Hashtable use **buckets** | LinkedHashMap uses [**doubly linked lists**](http://www.javamadesoeasy.com/2015/02/linkedhashmap-custom-implementation.html) | TreeMap uses **Red black tree** |
| 6 | Complexity of put, get and remove methods | O(1) | O(1) | O(1)  **overhead** of updating **Doubly Linked list** for maintaining order it internally uses. | O(log(n)) |
| 7 | Extends java.util.**Dictionary** (Abstract class, which is obsolete) | HashMap **doesn’t** extends Dictionary. | Hashtable **extends** Dictionary (which maps non-null keys to values. In a given Dictionary we can look up value corresponding to key) | LinkedHashMap **doesn’t** extends Dictionary. | TreeMap **doesn’t** extends Dictionary. |
| 8 | Introduced in which java version? | HashMap was introduced in second version of java i.e. **JDK 2.0** | Hashtable was introduced in first version of java i.e. **JDK 1.0**  But it was refactored in java 2 i.e. JDK 1.2 to implement the Map interface, hence making it a member of member of the [Java Collections Framework](http://download.oracle.com/javase/7/docs/technotes/guides/collections/index.html). | LinkedHashMap was introduced in fourth version of java i.e. **JDK 4.0** | TreeMap was introduced in second version of java i.e. **JDK 2.0** |

### What are differences between [HashMap vs IdentityHashMap](http://www.javamadesoeasy.com/2015/04/hashmap-vs-identityhashmap-similarity.html) in java?

**Answer**. This is tricky and complex collection framework interview question for experienced developers in java.

***Differences*** *between java.util.*[***HashMap***](http://www.javamadesoeasy.com/2015/04/hashmap-in-java.html)*and java.util.*[***IdentityHashMap***](http://www.javamadesoeasy.com/2015/04/identityhashmap-in-java.html) *in java**>*

|  |  |  |  |
| --- | --- | --- | --- |
|  | Property | ***java.util.HashMap*** | ***java.util.IdentityHashMap*** |
| 1 | **Keys comparison***object-equality  vs reference-equality* | **HashMap** when comparing keys (and values) performs object-equality not reference-equality. In an HashMap, two keys k1 and k2 are equal if and only if (k1==null ? k2==null : k1.equals(k2)) | **IdentityHashMap** when comparing keys (and values) performs reference-equality in place of object-equality. In an IdentityHashMap, two keys k1 and k2 are equal if and only if (k1==k2) |
| 2 | Initial size | Constructs a new HashMap, Its initial capacity is 16 in java.   |  | | --- | | **new** HashMap(); | | Constructs a new IdentityHashMap, with maximum size of 21 in java.   |  | | --- | | **new** IdentityHashMap(); | |
| 3 | Introduced in which java version | HashMap was introduced in second version of java i.e. **JDK 2.0** | IdentityHashMap was introduced in fourth version of java i.e. **JDK 4.0** |
| 4 | *Program* | Program 1 shows > *comparing keys (and values) performs object-equality in place of reference-equality . In an HashMap, two keys k1 and k2 are equal if and only if* **(k1==null ? k2==null : k1.equals(k2)).** | Program 2 shows >  *comparing keys (and values) performs reference-equality in place of object-equality. In an IdentityHashMap, two keys k1 and k2 are equal if and only if* **(k1==k2).** |
| 5 | overridden equals() and hashCode() method call? | [*overridden equals() and hashCode() method*](http://www.javamadesoeasy.com/2015/02/override-equals-and-hashcode-method.html)are called when put, get methods are called in ***HashMap***.  As shown in Program 3. | *overridden equals() and hashCode() method* are not called when put, get methods are called in ***IdentityHashMap***.  *Because IdentityHashMap implements equals() and hashCode() method by itself and checks for reference-equality of keys.*  As shown in Program 4. |
| 6 | Application - can maintain *proxy object* | HashMap cannot be used to maintain *proxy object.* | IdentityHashMap can be used to maintain *proxy objects*. For example, we might need to maintain proxy object for each object debugged in the program. |

### What is WeakHashMap in java?

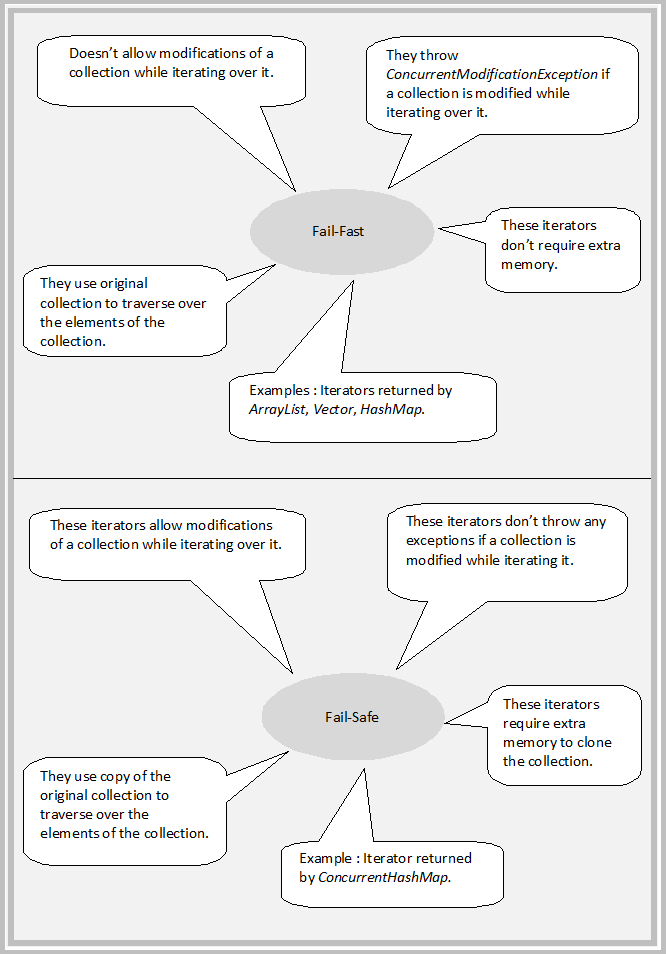
**Answer**.  Another tricky collection framework interview question for experienced developers in java.

java.util.[WeakHashMap](http://www.javamadesoeasy.com/2015/04/weakhashmap-in-java.html) is hash table based implementation of the Map interface, with *weak keys*.

An entry in a WeakHashMap will be automatically removed by garbage collector when its key is no longer in ordinary use. Mapping for a given key will not prevent the key from being discarded by the garbage collector, (i.e. made finalizable, finalized, and then reclaimed). When a key has been discarded its entry is removed from the map in java.

### What is the difference between fail fast and fail safe iterators?

|  |  |
| --- | --- |
| **Fail-Fast Iterators** | **Fail-Safe Iterators** |
| Fail-Fast iterators doesn’t allow modifications of a collection while iterating over it. | Fail-Safe iterators allow modifications of a collection while iterating over it. |
| These iterators throw *ConcurrentModificationException* if a collection is modified while iterating over it. | These iterators don’t throw any exceptions if a collection is modified while iterating over it. |
| They use original collection to traverse over the elements of the collection. | They use copy of the original collection to traverse over the elements of the collection. |
| These iterators don’t require extra memory. | These iterators require extra memory to clone the collection. |
| Ex : Iterators returned by *ArrayList*, *Vector*, *HashMap*. | Ex : Iterator returned by *ConcurrentHashMap.* |



## Multithreading

### What is Thread in java?

* Threads consumes CPU in best possible manner, hence enables multi processing. Multi threading reduces idle time of CPU which improves performance of application.
* Thread are light weight process.
* A thread class belongs to java.lang package.
* We can create multiple threads in java, even if we don’t create any Thread, one Thread at least  do exist i.e. main thread.
* Multiple threads run parallely in java.
* Threads have their own stack.
* Advantage of Thread : Suppose one thread needs 10 minutes to get certain task, 10 threads used at a time could complete that task in 1 minute, because threads can run parallely.

### What is difference between Process and Thread in java?

* Answer.  One process can have multiple Threads,
* Thread are subdivision of Process. One or more Threads runs in the context of process. Threads can execute any part of process. And same part of process can be executed by multiple Threads.
* Processes have their own copy of the data segment of the parent process while Threads have direct access to the data segment of its process.
* Processes have their own address while Threads share the address space of the process that created it.
* Process creation needs whole lot of stuff to be done, we might need to copy whole parent process, but Thread can be easily created.
* Processes can easily communicate with child processes but interprocess communication is difficult. While, Threads can easily communicate with other threads of the same process using [wait() and notify() methods](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html).
* In process all threads share system resource like heap Memory etc. while Thread has its own stack.
* Any change made to process does not affect child processes, but any change made to thread can affect the behavior of the other threads of the process.
* [Example to see where threads on are created on different processes and same process.](http://www.javamadesoeasy.com/2015/03/when-threads-are-not-lightweight.html)

### How to implement Threads in java?

Answer.  This is very basic threading question. Threads can be created in two ways i.e. by [implementing java.lang.Runnable interface or extending java.lang.Thread class](http://www.javamadesoeasy.com/2015/03/implementing-threads-in-java-by.html) and then extending run method.

Thread has its own variables and methods, it lives and dies on the heap. [But a thread of execution is an individual process that has its own call stack](http://www.javamadesoeasy.com/2015/03/threads-implement-their-own-stack.html). Thread are lightweight process in java.

1. Thread creation by  implementingjava.lang.Runnableinterface.

We will create object of class which implements Runnable interface :

MyRunnable runnable=new MyRunnable();

Thread thread=new Thread(runnable);

 2) And then create Thread object by calling constructor and passing reference of Runnable interface i.e.  runnable object :

Thread thread=new Thread(runnable);

### We should implement Runnable interface or extend Thread class. What are differences between implementing Runnable and extending Thread?

Answer. Well the answer is you must [extend Thread](http://www.javamadesoeasy.com/2015/03/implementing-threads-in-java-by.html) only when you are looking to modify run() and other methods as well. If you are simply looking to modify only the run() method [implementing Runnable](http://www.javamadesoeasy.com/2015/03/implementing-threads-in-java-by.html) is the best option (Runnable interface has only one abstract method i.e. run() ).

[Differences between implementing Runnable interface and extending Thread class](http://www.javamadesoeasy.com/2015/03/differences-between-implementing.html) -

1. Multiple inheritance in not allowed in java : When we [implement Runnable](http://www.javamadesoeasy.com/2015/03/implementing-threads-in-java-by.html) interface we can extend another class as well, but if we extend Thread class we cannot extend any other class because java does not allow multiple inheritance. So, same work is done by implementing Runnable and [extending Thread](http://www.javamadesoeasy.com/2015/03/implementing-threads-in-java-by.html) but in case of implementing Runnable we are still left with option of extending some other class. So, it’s better to implement Runnable.
2. [Thread safety](http://www.javamadesoeasy.com/2015/03/guidelines-to-thread-safe-code-most.html) : When we implement Runnable interface, same object is shared amongst multiple threads, but when we extend Thread class each and every thread gets associated with new object.
3. Inheritance (Implementing Runnable is lightweight operation) : When we extend Thread unnecessary all Thread class features are inherited, but when we implement Runnable interface no extra feature are inherited, as Runnable only consists only of one abstract method i.e. run() method. So, implementing Runnable is lightweight operation.
4. Coding to interface : Even java recommends coding to interface. So, we must implement Runnable rather than extending thread. Also, Thread class implements Runnable interface.
5. Don’t extend unless you wanna modify fundamental behaviour of class, Runnable interface has only one abstract method i.e. run()  : We must [extend Thread](http://www.javamadesoeasy.com/2015/03/implementing-threads-in-java-by.html) only when you are looking to modify run() and other methods as well. If you are simply looking to modify only the run() method [implementing Runnable](http://www.javamadesoeasy.com/2015/03/implementing-threads-in-java-by.html) is the best option (Runnable interface has only one abstract method i.e. run() ). We must not extend Thread class unless we're looking to modify fundamental behaviour of Thread class.
6. Flexibility in code when we implement Runnable : When we extend Thread first a fall all thread features are inherited and our class becomes direct subclass of Thread , so whatever action we are doing is in Thread class. But, when we implement Runnable we create a new thread and pass runnable object as parameter,we could pass runnable object to executorService & much more. So, we have more options when we implement Runnable and our code becomes more flexible.
7. ExecutorService : If we implement Runnable, we can start multiple thread created on runnable object  with ExecutorService (because we can start Runnable object with new threads), but not in the case when we extend Thread (because thread can be started only once).

### How can you say Thread behaviour is unpredictable? (Important)

Answer. The solution to question is quite simple, [Thread behaviour is unpredictable](http://www.javamadesoeasy.com/2015/03/thread-behaviour-is-unpredictable.html) because execution of Threads depends on Thread scheduler, thread scheduler may have different implementation on different platforms like windows, unix etc. Same threading program may produce different output in subsequent executions even on same platform.

To achieve we are going to create 2 threads on same Runnable Object, create for loop in run() method and start  both threads. There is no surety that which threads will complete first,  both threads will enter anonymously in for loop.

### When threads are not lightweight process in java?

Answer. Threads are [lightweight process](http://www.javamadesoeasy.com/2015/03/when-threads-are-not-lightweight.html) only if threads of same process are executing concurrently. But if threads of different processes are executing concurrently then threads are [heavy weight process](http://www.javamadesoeasy.com/2015/03/when-threads-are-not-lightweight.html).

### How can you ensure all threads that started from main must end in order in which they started and also main should end in last? (Important)

Answer.  Interviewers tend to know interviewees knowledge about Thread methods. So this is time to prove your point by answering correctly. We can use [join() method](http://www.javamadesoeasy.com/2015/03/join-method-ensure-all-threads-that.html)to ensure all threads that started from main must end in order in which they started and also main should end in last.In other words waits for this thread to die. Calling join() method internally calls join(0);

We can use **join() method** to ensure all threads that started from main must end in order in which they started and also main should end in last.In other words **waits for this thread to die**.

**Calling join() method internally calls join(0);**

10 salient features of **join()** method >

* **Definition** : join()We can use **join() method** to ensure all threads that started from main must end in order in which they started and also main should end in last.In other words **waits for thread to die on which thread has been called**.

* **Exception :** join**()** method [**throws**](http://www.javamadesoeasy.com/2015/05/throws-exception-in-java.html) **InterruptedException**, in our case we have thrown exception.

* **instance method :** join()is a **instance method**, hence we need to have thread  instance for calling this method.

* [**Thread state**](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) **: when** join() **method is called on thread it goes from running to waiting state. And wait for thread to die.**

* **Not a native method :** implementation of join() method is provided in java.lang.Thread class.

Let’s see definition of join() method as given in java.lang.Thread -

|  |
| --- |
| **public** **final** **void** join() **throws** InterruptedException; |

* **synchronized block :** thread **need not to to acquire object lock** before calling join()method i.e. join() method **can be called from outside synchronized block**.

* **Waiting time :** join() **method have got few options.**
  1. **join() :** Waits for this thread to die.

|  |
| --- |
| **public** **final** **void** join() **throws** InterruptedException; |

This method internally calls **join(0).** And timeout of 0 means to wait forever;

* 1. **join(long millis) -** Waits at most millis milliseconds for this thread to die. A timeout of 0 means to wait forever.

|  |
| --- |
| **public** **static** **native** **void** join(**long** millis) **throws** InterruptedException; |

* 1. **join(long millis, int nanos) -** Waits at most millis milliseconds plus nanos nanoseconds for this thread to die.

|  |
| --- |
| **public** **static** **native** **void** join(**long** millis,**int** nanos) **throws** InterruptedException; |

* **Belongs to which class :** join**() method belongs to java.lang.Thread** class.

### Write a program to demonstrate the join()

* To achieve we are going to create 2 threads on Runnable Object, create for loop in run() method and start  both threads. After starting each Thread call join() method on them to ensure they end in order in which they has started.
* **Full Program to show usage of join() method>**

|  |
| --- |
| **class** MyRunnable **implements** Runnable{  **public** **void** run(){        System.*out*.println("in run() method");  **for**(**int** i=0;i<5;i++){                   System.*out*.println("i="+i+" ,ThreadName="+Thread.*currentThread*().getName());            }     }  }  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public** **class** MyClass {  **public** **static** **void** main(String...args) **throws** InterruptedException{            System.*out*.println("In main() method");            MyRunnable runnable=**new** MyRunnable();            Thread thread1=**new** Thread(runnable);            Thread thread2=**new** Thread(runnable);            thread1.start();  **thread1.join();**            thread2.start();  **thread2.join();**            System.*out*.println("end main() method");     }  }  /\*OUTPUT  In main() method  in run() method  i=0 ,ThreadName=Thread-0  i=1 ,ThreadName=Thread-0  i=2 ,ThreadName=Thread-0  i=3 ,ThreadName=Thread-0  i=4 ,ThreadName=Thread-0  in run() method  i=0 ,ThreadName=Thread-1  i=1 ,ThreadName=Thread-1  i=2 ,ThreadName=Thread-1  i=3 ,ThreadName=Thread-1  i=4 ,ThreadName=Thread-1  end main() method  \*/ |

* If we note output, all threads ended in order in which they were called and main thread has ended last.
* First, main thread was called, it started Thread1 and then we called join() method on Thread1, once Thread1 ended main thread started Thread2 and we called join() method on Thread2, once Thread2 ended main thread also ended.
* **In short - calling thread1.join()  made main thread to wait until Thread-1 dies.**

### What are the versions of join() method?

**join() :** Waits for this thread to die.

|  |
| --- |
| **public** **final** **void** join() **throws** InterruptedException; |

This method internally calls **join(0).** And timeout of 0 means to wait forever;

**join(long millis) -** Waits at most millis milliseconds for this thread to die. A timeout of 0 means to wait forever.

|  |
| --- |
| **public** **static** **native** **void** join(**long** millis) **throws** InterruptedException; |

**join(long millis, int nanos) -** Waits at most millis milliseconds plus nanos nanoseconds for this thread to die.

|  |
| --- |
| **public** **static** **native** **void** join(**long** millis,**int** nanos) **throws** InterruptedException; |

Let’s create a program to use **join(long millis)** >

First, join(1000) will be called on Thread-1, **but once 1000 millisec are up, main thread can resume and start thread2 (main thread won’t wait for Thread-1 to die).**

|  |
| --- |
| **class MyRunnable implements Runnable{**  **public void run(){**  **System.*out*.println("in run() method");**  **for(int i=0;i<5;i++){**  **try {**  **Thread.*sleep*(500);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println("i="+i+" ,ThreadName="+Thread.*currentThread*().getName());**  **}**  **}**  **}**  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public class MyClass {**  **public static void main(String...args) throws InterruptedException{**  **System.*out*.println("In main() method");**  **MyRunnable runnable=new MyRunnable();**  **Thread thread1=new Thread(runnable);**  **Thread thread2=new Thread(runnable);**  **thread1.start();**  **thread1.join(1000);  //once 1000 millisec are up, main thread can resume and start thread2.**  **thread2.start();**  **thread2.join();**  **System.*out*.println("end main() method");**  **}**  **}**  **/\*OUTPUT**  **In main() method**  **in run() method**  **i=0 ,ThreadName=Thread-0**  **i=1 ,ThreadName=Thread-0**  **in run() method**  **i=2 ,ThreadName=Thread-0**  **i=0 ,ThreadName=Thread-1**  **i=1 ,ThreadName=Thread-1**  **i=3 ,ThreadName=Thread-0**  **i=2 ,ThreadName=Thread-1**  **i=4 ,ThreadName=Thread-0**  **i=3 ,ThreadName=Thread-1**  **i=4 ,ThreadName=Thread-1**  **end main() method**  **\*/** |

### What is difference between starting thread with run() and start() method? (Important)

Answer. This is quite interesting question, it might confuse you a bit and at time may make you think is there really any [difference between starting thread with run() and start() method](http://www.javamadesoeasy.com/2015/03/difference-between-starting-thread-with.html).

When you call start() method, main thread internally calls run() method to start newly created Thread, so run() method is ultimately called by newly created thread.

When you call run() method main thread rather than starting run() method with newly thread it start run() method by itself.

**Let’s use start() method to start a thread>**

|  |
| --- |
| **class** MyRunnable **implements** Runnable{  **public** **void** run(){   //overrides Runnable's run() method            System.*out*.println("in run() method");            System.*out*.println("currentThreadName= "+ Thread.*currentThread*().getName());     }  }  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public** **class** MyClass {  **public** **static** **void** main(String args[]){            System.*out*.println("currentThreadName= "+ Thread.*currentThread*().getName());            MyRunnable runnable=**new** MyRunnable();            Thread thread=**new** Thread(runnable);            thread.start();     }  }  /\*OUTPUT  currentThreadName= main  in run() method  **currentThreadName= Thread-0**  \*/ |

If we note output, when we called start() from main thread, **run() method was called by new Thread** (i.e. Thread-0).

**Let’s use run() method to start a thread>**

|  |
| --- |
| **class** MyRunnable **implements** Runnable{  **public** **void** run(){   //overrides Runnable's run() method            System.*out*.println("in run() method");            System.*out*.println("currentThreadName= "+ Thread.*currentThread*().getName());     }  }  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public** **class** MyClass {  **public** **static** **void** main(String args[]){            System.*out*.println("currentThreadName= "+ Thread.*currentThread*().getName());            MyRunnable runnable=**new** MyRunnable();            Thread thread=**new** Thread(runnable);            thread.run();     }  }  /\*OUTPUT  currentThreadName= main  in run() method  **currentThreadName= main**  \*/ |

If we note output, when we called run() from main thread, **run()** method was **called by main Thread**, not by newly created thread (i.e. Thread-0).

### What is significance of using [Volatile](http://www.javamadesoeasy.com/2015/03/volatile-keyword-in-java-difference.html) keyword? (Important)

To Understand example of volatile keyword in java let’s go back to [Singleton pattern in Java](http://javarevisited.blogspot.com/2011/03/10-interview-questions-on-singleton.html)and see [double checked locking in Singleton](http://javarevisited.blogspot.com/2014/05/double-checked-locking-on-singleton-in-java.html) with Volatile and without the volatile keyword in java.

/\*\*

\* Java program to demonstrate where to use Volatile keyword in Java.

\* In this example Singleton Instance is declared as volatile variable to ensure

\* every thread see updated value for \_instance.

\*

\* @author Javin Paul

\*/

**public** **class** **Singleton**{

**private** **static** **volatile** Singleton \_instance; //volatile variable

**public** **static** Singleton **getInstance**(){

**if**(\_instance == **null**){

**synchronized**(Singleton.class){

**if**(\_instance == **null**)

\_instance = **new** Singleton();

}

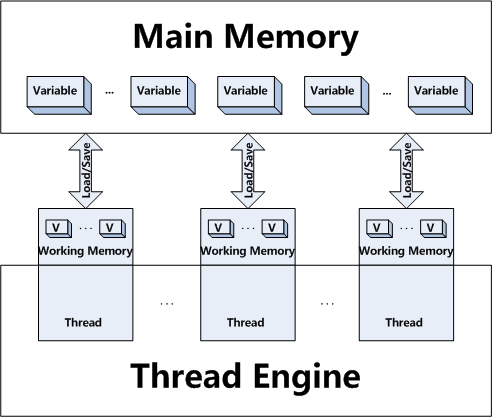
}

**return** \_instance;

}

If you look at the code carefully you will be able to figure out:  
1) We are only creating instance one time  
2) We are creating instance lazily at the time of the first request comes.

If we do not make the \_instance variable volatile than the Thread which is creating instance of Singleton is not able to communicate other thread, that instance has been created until it comes out of the Singleton block, so if Thread A is creating Singleton instance and just after creation lost the CPU, all other thread will not be able to see value of \_instance as not null and they will believe its still [null](http://javarevisited.blogspot.sg/2012/06/common-cause-of-javalangnullpointerexce.html).

[](http://3.bp.blogspot.com/-o2VBopq_Bcc/VKAXLDExe9I/AAAAAAAACTM/KtLZB1WVBGk/s1600/volatile+variable+in+Java.png)

Why? because reader threads are not doing any locking and until writer thread comes out of synchronized block, memory will not be synchronized and value of \_instance will not be updated in main memory. With Volatile keyword in Java, this is handled by Java itself and such updates will be visible by all reader threads.  
  
So in Summary apart from [synchronized keyword in Java](http://javarevisited.blogspot.com/2011/04/synchronization-in-java-synchronized.html), volatile keyword is also used to communicate the content of memory between threads.

Let’s see another example of volatile keyword in Java

* most of the time while writing game we use a variable bExit to check whether user has pressed exit button or not, value of this variable is updated in [event thread](http://javarevisited.blogspot.sg/2011/09/invokeandwait-invokelater-swing-example.html) and checked in game thread, So if we don't use volatile keyword with this variable, Game Thread might miss update from event handler thread if it's not synchronized in Java already. volatile keyword in java guarantees that value of the volatile variable will always be read from main memory and "*happens-before"* relationship in Java Memory model will ensure that content of memory will be communicated to different threads.

**private** **boolean** bExit**;**

**while(!**bExit**)** **{**

checkUserPosition**();**

updateUserPosition**();**

**}**

In this code example, One Thread (Game Thread) can cache the value of "bExit" instead of getting it from [main memory](http://javarevisited.blogspot.sg/2011/05/java-heap-space-memory-size-jvm.html) every time and if in between any other thread (Event handler Thread) changes the value; it would not be visible to this thread. Making boolean variable "bExit" as volatile in java ensures this will not happen.  
  
Also, If you have not read already then I also suggest you read the topic about volatile variable from [Java Concurrency in Practice](http://aax-us-east.amazon-adsystem.com/x/c/QtePjA-ivjjF5AlMShM0OBQAAAFf_nnkJgEAAAFKAZI_wDY/https:/assoc-redirect.amazon.com/g/r/http:/www.amazon.com/dp/0321349601/ref=as_at?creativeASIN=0321349601&linkCode=w61&imprToken=cZpWVb6kKOlXruXIOMBdaA&slotNum=0&tag=javamysqlanta-20) book by Brian Goetz, one of the must read to truly understand this complex concept.

When to use Volatile variable in Java

* One of the most important thing in learning of volatile keyword is understanding when to use volatile variable in Java. Many [programmer](http://javarevisited.blogspot.sg/2011/06/top-programming-interview-questions.html) knows what is volatile variable and how does it work but they never really used volatile for any practical purpose. Here are couple of example to demonstrate when to use Volatile keyword in Java:
* 1) You can use Volatile variable if you want to read and write long and [double](http://javarevisited.blogspot.sg/2011/10/convert-double-to-string-example.html) variable atomically. long and double both are [64 bit](http://javarevisited.blogspot.sg/2012/01/find-jvm-is-32-or-64-bit-java-program.html) data type and by default writing of long and double is not atomic and platform dependence. Many platform perform write in long and double variable 2 step, writing 32 bit in each step, due to this its possible for a Thread to see 32 bit from two different write. You can avoid this issue by making long and double variable volatile in Java.  
    
    
  2) A volatile variable can be used as an alternative way of achieving [synchronization in Java](http://javarevisited.blogspot.sg/2011/04/synchronization-in-java-synchronized.html) in some cases, like Visibility. with volatile variable, it's guaranteed that all reader thread will see updated value of the volatile variable once write operation completed, without volatile keyword different reader thread may see different values.  
    
    
  3) volatile variable can be used to inform the compiler that a particular field is subject to be accessed by multiple threads, which will prevent the compiler from doing any reordering or any kind of optimization which is not desirable in a multi-threaded environment. Without volatile variable compiler can re-order the code, free to cache value of volatile variable instead of always reading from main memory. like following example without volatile variable may result in an [infinite loop](http://javarevisited.blogspot.sg/2011/12/how-to-traverse-or-loop-hashmap-in-java.html)

**private** **boolean** isActive **=** thread**;**

**public** **void** printMessage**(){**

**while(**isActive**){**

System**.**out**.**println**(**"Thread is Active"**);**

**}**

**}**

without the *volatile modifier*, it's not guaranteed that one [Thread](http://javarevisited.blogspot.sg/2012/01/difference-thread-vs-runnable-interface.html) sees the updated value of isActive from other thread. The compiler is also free to cache value of isActive instead of reading it from main memory in every iteration. By making isActive a volatile variable you avoid these issue.  
  
  
4) Another place where a volatile variable can be used is to fixing double checked locking in Singleton pattern. As we discussed in [Why should you use Enum as Singleton](http://javarevisited.blogspot.gr/2012/07/why-enum-singleton-are-better-in-java.html) that double checked locking was broken in Java 1.4 environment.

Java allows threads to access shared variables. As a rule, to ensure that shared variables are consistently updated, a thread should ensure that it has exclusive use of such variables by obtaining a lock that enforces mutual exclusion for those shared variables.

If a field is declared [volatile](http://www.javamadesoeasy.com/2015/03/volatile-keyword-in-java-difference.html), in that case the Java memory model ensures that all threads see a consistent value for the variable.

Few small questions>

### Can we have [volatile](http://www.javamadesoeasy.com/2015/03/volatile-keyword-in-java-difference.html) methods in java?

1. No, volatile is only a keyword, can be used only with variables.

### Can we have synchronized variable in java?

1. No, synchronized can be used only with methods i.e. in method declaration or synchronized blocks in java.

### Can you again start Thread?

No, [we cannot start Thread again](http://www.javamadesoeasy.com/2015/03/can-we-start-thread-again.html), doing so will throw runtimeException java.lang.IllegalThreadStateException. The reason is once run() method is executed by Thread, it goes into [dead state](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html).

Let’s take an example-

Thinking of starting thread again and calling start() method on it (which internally is going to call run() method) for us is some what like asking dead man to wake up and run. As, after completing his life person goes to dead state.

### What is race condition in multithreading and how can we solve it? (Important)

Answer. This is very important question, this forms the core of multi threading, you should be able to explain about [race condition in detail](http://www.javamadesoeasy.com/2015/03/race-condition-in-multithreading-and.html). When more than one thread try to access same resource without synchronization causes race condition.

So we can [solve race condition](http://www.javamadesoeasy.com/2015/03/race-condition-in-multithreading-and.html) by using either [synchronized block or synchronized method](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html). When no two threads can access same resource at a time phenomenon is also called as mutual exclusion.

Few sub questions>

What if two threads try to read same resource without [synchronization](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html)?

When two threads try to read on same resource without synchronization, it’s never going to create any problem.

What if two threads try to write to same resource without [synchronization](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html)?

When two threads try to write to same resource without synchronization, it’s going to create synchronization problems.

### What is [deadlock](http://www.javamadesoeasy.com/2015/03/deadlock-in-multithreading-program-to.html) in multithreading? Write a program to form [DeadLock](http://www.javamadesoeasy.com/2015/03/deadlock-in-multithreading-program-to.html) in multi threading and also how to solve DeadLock situation. What measures you should take to avoid deadlock? (Important)

Deadlock is a situation where two threads are waiting for each other to release lock holded by them on resources.

But how [deadlock](http://www.javamadesoeasy.com/2015/03/deadlock-in-multithreading-program-to.html) could be formed :

Thread-1 acquires lock on String.class and then calls [sleep()](http://www.javamadesoeasy.com/2015/03/sleep-method-in-threads-10-key-features.html) method which gives Thread-2 the chance to execute immediately after Thread-1 has acquired lock on String.class and Thread-2 acquires lock on Object.class then calls sleep() method and now it waits for Thread-1 to release lock on String.class.

Conclusion:

Now, Thread-1 is waiting for Thread-2 to release lock on Object.class and Thread-2 is waiting for Thread-1 to release lock on String.class and deadlock is formed.

//Code called by Thread-1

public void run() {

synchronized (String.class) {

Thread.sleep(100);

synchronized (Object.class) {

}

}

}

//Code called by Thread-2

publicvoid run() {

synchronized (Object.class) {

Thread.sleep(100);

synchronized (String.class) {

}

}

}

Few important measures to avoid [Deadlock](http://www.javamadesoeasy.com/2015/03/deadlock-in-multithreading-program-to.html) >

1. Lock specific member variables of class rather than locking whole class: We must try to lock specific member variables of class rather than locking whole class.
2. Use join() method: If possible try touse join() method, although it may refrain us from taking full advantage of multithreading environment because threads will start and end sequentially, but it can be handy in avoiding deadlocks.
3. If possible try avoid using nested synchronization blocks.

### Why wait(), notify()  and notifyAll() are in Object class and not in Thread class? (Important)

1. Every Object has a monitor, acquiring that monitors allow thread to hold lock on object. But Thread class does not have any monitors.
2. wait(), notify() and notifyAll()are called on objects only >When wait() method is called on object by thread it waits for another thread on that object to release object monitor by calling [notify() or notifyAll()](http://www.javamadesoeasy.com/2015/03/difference-between-notify-and-notifyall.html) method on that object.

When notify() method is called on object by thread it notifies all the threads which are waiting for that object monitor that object monitor is available now.So, this shows that wait(), notify() and notifyAll() are called on objects only.

[Now, Straight forward question that comes to mind is how thread acquires object lock by](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html)

[acquiring object monitor? Let’s try to understand this basic concept in detail?](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html)

1. Wait(), notify() and notifyAll() method being in Object class allows all the threads created on that object to communicate with other.  .
2. As multiple threads exists on same object. Only one thread can hold object monitor at a time. As a result thread can notify other threads of same object that lock is available now. But, thread having these methods does not make any sense because multiple threads exists on object its not other way around (i.e. multiple objects exists on thread).
3. Now let’s discuss one hypothetical scenario, what will happen if Thread class contains wait(), notify() and notifyAll() methods?

Having wait(), notify() and notifyAll() methods means Thread class also must have their monitor.

Every thread having their monitor will create few problems -

>Thread communication problem.

>Synchronization on object won’t be possible- Because object has monitor, one object can have multiple threads and thread hold lock on object by holding object monitor. But if each thread will have monitor, we won’t have any way of achieving synchronization.

>Inconsistency in state of object (because synchronization won't be possible).

### Is it important to acquire object lock before calling wait(), notify() and notifyAll()?

Answer.Yes, it’s mandatory to acquire object lock before calling these methods on object. As discussed above wait(), notify()  and notifyAll() methods are always called from [Synchronized block](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) only, and as soon as thread enters synchronized block it acquires object lock (by holding object monitor). If we call these methods without acquiring object lock i.e. from outside synchronize block then java.lang. IllegalMonitorStateException is thrown at runtime.

Wait() method needs to enclosed in try-catch block, because it throws compile time exception i.e. InterruptedException.

### Have you ever generated thread dumps or analyzed Thread Dumps? (Important)

[VisualVM](http://www.javamadesoeasy.com/2015/03/visualvm-thread-dumps-generating-and_74.html)  is most popular way to generate Thread Dump and is most widely used by developers. It’s important to understand usage of VisualVM for in depth knowledge of VisualVM. I’ll recommend every developer must understand this topic to become master in multi threading.

It helps us in analyzing threads performance, [thread states](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html), CPU consumed by threads, garbage collection and much more.

Link:

[VisualVM link for understanding](http://www.javamadesoeasy.com/2015/03/jstack-thread-dumps-generating-and.html)

[jstack](http://www.javamadesoeasy.com/2015/03/jstack-thread-dumps-generating-and.html) is very easy way to generate Thread dump and is widely used by developers. I’ll recommend every developer must understand this topic to become master in multi threading. For creating Thread dumps we need not to download any jar or any extra software.

[**jStack link for understanding**](http://www.javamadesoeasy.com/2015/03/jstack-thread-dumps-generating-and.html)

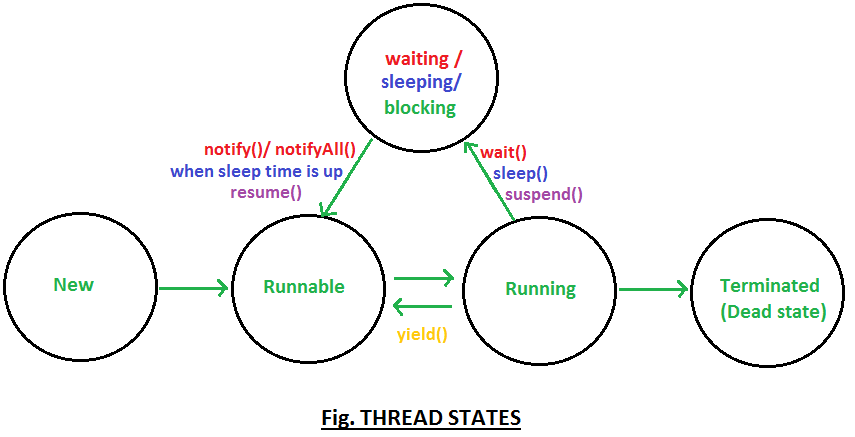
### What is life cycle of Thread, explain thread states? (Important)

[Thread states/ Thread life cycle](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) is very basic question, before going deep into concepts we must understand Thread life cycle.

Thread have following states >

* New
* Runnable
* Running
* Waiting/blocked/sleeping
* Terminated (Dead)

Thread states/ Thread life cycle in diagram >



Thread states in detail >

New : When instance of thread is created using new operator it is in new state, but the start() method has not been invoked on the thread yet, thread is not eligible to run yet.

Runnable : When start() method is called on thread it enters runnable state.

Running : Thread scheduler selects thread to go fromrunnable to running state. In running state Thread starts executing by entering run() method.

Waiting/blocked/sleeping : In this state a thread is not eligible to run.

>Thread is still alive, but currently it’s not eligible to run. In other words.

> How can Thread go from running to waiting state?

 By calling wait()[method](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) thread go from running to waiting state. In waiting state it will wait for other threads to release object monitor/lock.

> How can Thread go from running to sleeping state?

 By calling sleep() [method](http://www.javamadesoeasy.com/2015/03/sleep-method-in-threads-10-key-features.html)thread go from running to sleeping state. In sleeping state it will wait for sleep time to get over.

Terminated (Dead) : A thread is considered dead when its run() method completes.

### Are you aware of preemptive scheduling and time slicing?

* In preemptive scheduling, the highest priority thread executes until it enters into the [waiting or dead state](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html).
* In time slicing, a thread executes for a certain predefined time and then enters runnable pool. Than thread can enter running state when selected by thread scheduler.

### What are [daemon threads](http://www.javamadesoeasy.com/2015/03/daemon-threads-12-salient-features-of.html)?

[Daemon threads](http://www.javamadesoeasy.com/2015/03/daemon-threads-12-salient-features-of.html) are low priority threads which runs intermittently in background for doing garbage collection.

 12 Few salient features of [daemon() threads](http://www.javamadesoeasy.com/2015/03/daemon-threads-12-salient-features-of.html)>

* Thread scheduler schedules these threads only when CPU is idle.
* [Daemon threads](http://www.javamadesoeasy.com/2015/03/daemon-threads-12-salient-features-of.html) are service oriented threads, they serves all other threads.
* These threads are created before user threads are created and die after all other user threads dies.
* Priority of daemon threads is always 1 (i.e. MIN\_PRIORITY).
* User created threads are non daemon threads.
* JVM can exit when only daemon threads exist in system.
* we can use isDaemon() method to check whether thread is daemon thread or not.
* we can use setDaemon(boolean on) method to make any user method a daemon thread.
* If setDaemon(boolean on) is called on thread after calling start() method than IllegalThreadStateException is thrown.
* You may like to see how daemon threads work, for that you can use VisualVM or jStack. I have provided Thread dumps over there which shows daemon threads which were intermittently running in background.

Some of the daemon threads which intermittently run in background are >

|  |
| --- |
| "RMI TCP Connection(3)-10.175.2.71" daemon"RMI TCP Connection(idle)" daemon"RMI Scheduler(0)" daemon"C2 CompilerThread1" daemon  "GC task thread#0 (ParallelGC)" |
| /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  public class DaemonTest {     public static void main(String[] args) throws InterruptedException {              final Thread thread1=new Thread("Thread-1"){                   public void run() {                         System.out.println(Thread.currentThread().getName()+" has started");                         System.out.println(Thread.currentThread().getName()+" has ended");                   }              };            thread1.setDaemon(true);   //setting thread to daemon.            System.out.println("is thread1 daemon thread : "                                       +thread1.isDaemon());   //checking thread isDeamon ?            thread1.start(); //start daemon thread         }  }  /\*  is thread1 daemon thread : true  Thread-1 has started  Thread-1 has ended  \*/ |

### Why [suspend() and resume() methods are deprecated](http://www.javamadesoeasy.com/2015/03/reason-why-suspend-and-resume-methods.html)?

**A**nswer.[Suspend()](http://www.javamadesoeasy.com/2015/03/using-suspend-and-resume-method-in.html) method is [deadlock](http://www.javamadesoeasy.com/2015/03/deadlock-in-multithreading-program-to.html) prone. If the target thread holds a lock on object when it is suspended, no thread can lock this object until the target thread is [resumed](http://www.javamadesoeasy.com/2015/03/using-suspend-and-resume-method-in.html). [If the thread that would resume the target thread attempts to lock this monitor prior to calling resume, it results in deadlock formation](http://www.javamadesoeasy.com/2015/03/reason-why-suspend-and-resume-methods.html).

These [deadlocks](http://www.javamadesoeasy.com/2015/03/deadlock-in-multithreading-program-to.html)are generally called Frozen processes.

Suspend() method puts thread from [running to waiting state](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html). And thread can go from waiting to runnable state only when resume() method is called on thread. It is deprecated method.

Resume() method is only used with suspend() method that’s why it’s also deprecated method.

### Why destroy() methods is deprecated?

Answer. This question is again going to check your in depth knowledge of thread methods i.e. [destroy() method](http://www.javamadesoeasy.com/2015/03/destroy-method-in-java-usage-reason-why.html) is [deadlock](http://www.javamadesoeasy.com/2015/03/deadlock-in-multithreading-program-to.html) prone. If the target thread holds a lock on object when it is destroyed, no thread can lock this object (Deadlock formed are similar to deadlock formed when suspend() and resume() methods are used improperly). It results in deadlock formation. These [deadlocks](http://www.javamadesoeasy.com/2015/03/deadlock-in-multithreading-program-to.html)are generally called Frozen processes.

Additionally you must know calling destroy() method on Threads throw runtimeException i.e. NoSuchMethodError. [Destroy() method](http://www.javamadesoeasy.com/2015/03/destroy-method-in-java-usage-reason-why.html) puts thread from running to [dead state](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html).

### As stop() method is deprecated,  How can we terminate or stop infinitely running thread in java? (Important)

Answer. This is very interesting question where interviewees thread basics will be tested. Interviewers tend to know user’s knowledge about main thread’s and thread invoked by main thread.

We will try to address the problem by creating new thread which will run infinitely until certain condition is satisfied and will be called by main Thread.

1. Infinitely running thread can be stopped using boolean variable.
2. [Infinitely running thread can be stopped using interrupt() method](http://www.javamadesoeasy.com/2015/03/2-alternate-ways-to-stop-thread-as-stop.html).

Let’s understand Why stop() method is deprecated :

Stopping a thread with Thread.stop() causes it to **release all of the monitors that it has locked**. If any of the objects previously protected by these monitors were in an inconsistent state, the damaged objects become visible to other threads, which might lead to unpredictable behavior.

### what is significance of yield() method, what state does it put thread in?

[yield()](http://www.javamadesoeasy.com/2015/03/yield-method-in-threads-8-key-features.html) is a native method it’s implementation in java 6 has been changed as compared to its implementation java 5. As method is native it’s implementation is provided by JVM.

In java 5, yield() method internally used to call [sleep()](http://www.javamadesoeasy.com/2015/03/sleep-method-in-threads-10-key-features.html) method giving all the other threads of same or higher priority to execute before yielded thread by leaving allocated CPU for time gap of 15 millisec.

But java 6, calling yield() method gives a hint to the thread scheduler that the current thread is willing to yield its current use of a processor. The thread scheduler is free to ignore this hint. So, sometimes even after using yield() method, you may not notice any difference in output.

salient features of [yield()](http://www.javamadesoeasy.com/2015/03/yield-method-in-threads-8-key-features.html) method >

* Definition : [yield()](http://www.javamadesoeasy.com/2015/03/yield-method-in-threads-8-key-features.html) method when called on thread gives a hint to the thread scheduler that the current thread is willing to yield its current use of a processor.The thread scheduler is free to ignore this hint.
* [Thread state](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) : when yield() method is called on thread it goes from running to runnable state, not in waiting state. Thread is eligible to run but not running and could be picked by scheduler at anytime.
* Waiting time : yield() method stops thread for unpredictable time.
* Static method : yield()is a static method, hence calling Thread.yield() causes currently executing thread to yield.
* Native method : implementation of yield() method is provided by JVM.

Let’s see definition of yield() method as given in java.lang.Thread -

|  |
| --- |
| public static native void yield(); |

* [synchronized block](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) : thread need not to to acquire object lock before calling yield()method i.e. yield() method can be called from outside synchronized block.

### What is significance of sleep() method in detail, what [state](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) does it put thread in ?

[sleep()](http://www.javamadesoeasy.com/2015/03/sleep-method-in-threads-10-key-features.html) is a native method, it’s implementation is provided by JVM.

10 salient features of [sleep()](http://www.javamadesoeasy.com/2015/03/sleep-method-in-threads-10-key-features.html) method >

* Definition : [sleep()](http://www.javamadesoeasy.com/2015/03/sleep-method-in-threads-10-key-features.html) methods causes current thread to sleep for specified number of milliseconds (i.e. time passed in sleep method as parameter). Ex- Thread.sleep(10) causes currently executing thread to sleep for 10 millisec.
* [Thread state](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) : when sleep() is called on thread it goes from running to waiting state and can return to runnable state when sleep time is up.
* Exception : sleep() method must catch or throw compile time exception i.e. InterruptedException.
* Waiting time : sleep() method have got few options.
  1. sleep(long millis) - Causes the currently executing thread to sleep for the specified number of milliseconds

|  |
| --- |
| public static native void sleep(long millis) throws InterruptedException; |

1. sleep(long millis, int nanos) - Causes the currently executing thread to sleep for the specified number of milliseconds plus the specified number of nanoseconds.

|  |
| --- |
| public static native void sleep(long millis,int nanos) throws InterruptedException; |

* static method : sleep()is a static method, causes the currently executing thread to sleep for the specified number of milliseconds.
* Belongs to which class :[sleep()](http://www.javamadesoeasy.com/2015/03/sleep-method-in-threads-10-key-features.html) method belongs to java.lang.Thread class.
* synchronized block : thread need not to to acquire object lock before calling sleep()method i.e. sleep() method can be called from outside synchronized block.

### Difference between [wait()](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) and [sleep()](http://www.javamadesoeasy.com/2015/03/sleep-method-in-threads-10-key-features.html) ? (Important)

Answer.

* Should be called from [**synchronized block**](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) :wait() method is always called from synchronized block i.e. [wait()](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) method needs to lock object monitor before object on which it is called.  But sleep() method can be called from outside synchronized block i.e. sleep() method doesn’t need any object monitor.
* **IllegalMonitorStateException** : if wait() method is called without acquiring object lock than IllegalMonitorStateException is thrown at runtime, but sleep() methodnever throws such exception.
* Belongs to which **class** : wait() method belongs to java.lang.Object class but sleep() method belongs to java.lang.Thread class.
* Called on object or **thread** : wait() method is called on objects but sleep() method is called on Threads not objects.
* [Thread state](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) : when wait() method is called on object, thread that holded object’s monitor goes from running to waiting state and can return to runnable state only when notify() or notifyAll()method is called on that object. And later thread scheduler schedules that thread to go from from runnable to running state.

when sleep() is called on thread it goes from running to waiting state and can return to runnable state when sleep time is up.

* When called from [synchronized block](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) :when wait() method is called thread leaves the object lock.  But sleep()method when called from synchronized block or method thread doesn’t leaves object lock.

### Does thread leaves object lock when wait() method is called?

* Answer. When [wait()](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) method is called Thread leaves the object lock and goes from [running to waiting state](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html). Thread waits for other threads on same object to call notify() or notifyAll() and once any of [notify() or notifyAll()](http://www.javamadesoeasy.com/2015/03/difference-between-notify-and-notifyall.html) is called it goes from waiting to runnable state and again acquires object lock.

### What will happen if we don’t override run method?

### When we call start() method on thread, it internally calls run() method with newly created thread. So, if we don’t override run() method newly created thread won’t be called and nothing will happen.

class MyThread extends Thread {

//don't override run() method

}

publicclass DontOverrideRun {

publicstaticvoid main(String[] args) {

System.out.println("main has started.");

MyThread thread1=new MyThread();

thread1.start();

System.out.println("main has ended.");

}

}

/\*OUTPUT

main has started.

main has ended.

\*/

* As we saw in output, we didn’t override run() method that’s why on calling start() method nothing happened.

### What will happen if we override start method?

Answer. When we call start() method on thread, it internally calls run() method with newly created thread. So, if we override start() method, run() method will not be called until we write code for calling run() method.

class MyThread extends Thread {

@Override

publicvoid run() {

System.out.println("in run() method");

}

@Override

publicvoid start(){

System.out.println("In start() method");

}

}

publicclass OverrideStartMethod {

publicstaticvoid main(String[] args) {

System.out.println("main has started.");

MyThread thread1=new MyThread();

thread1.start();

System.out.println("main has ended.");

}

}

/\*OUTPUT

main has started.

In start() method

main has ended.

\*/

### Can we acquire lock on class? What are ways in which you can acquire lock on class?

Answer.  Yes, we can acquire lock on [class’s class object in 2 ways to acquire lock on class](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html). Thread can acquire lock on class’s class object by-

* 1. **Entering synchronized block** or Let’s say there is one class MyClass. Now we can create synchronization block, and parameter passed with synchronization tells which class has to be synchronized. In below code, we have synchronized MyClass:

 synchronized (MyClass.class) {

   //thread has acquired lock on MyClass’s class object.

 }

* 1. **by entering static synchronized methods.**

 public static synchronized void method1() {

   //thread has acquired lock on MyRunnable’s class object.

 }

As soon as thread entered Synchronization method, thread acquired lock on class’s class object. Thread will leave lock when it exits static synchronized method.

### Difference between object lock and class lock?

|  |  |
| --- | --- |
| [**Object lock**](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) | [**Class lock**](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) |
| Thread can acquire [object lock](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) by-   1. Entering **synchronized block or** 2. by entering **synchronized methods.** | Thread can acquire lock on [class’s class object](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) by-   1. Entering **synchronized block or** 2. by entering **static synchronized methods.** |
| [Multiple threads may exist on same object but only one thread of that object can enter **synchronized method** at a time.](http://www.javamadesoeasy.com/2015/03/suppose-you-have-2-threads-thread-1-and_5.html)  [Threads on different object can enter same method at same time.](http://www.javamadesoeasy.com/2015/03/suppose-you-have-2-threads-thread-1-on.html) | Multiple threads may exist on [same](http://www.javamadesoeasy.com/2015/03/suppose-you-have-2-threads-thread-1-and_46.html) or [different objects](http://www.javamadesoeasy.com/2015/03/suppose-you-have-2-threads-thread-1-on_5.html) of class but only one thread can enter **static synchronized method** at a time. |
| **Multiple objects of class may exist and every object has it’s own lock.** | **Multiple objects of class may exist but there is always one class’s class object lock available**. |
| First let’s acquire [object lock](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) by entering **synchronized block**.  Example- Let’s say there is one class MyClass and we have created it’s object and reference to that object is myClass. Now we can create synchronization block, and parameter passed with synchronization tells which object has to be synchronized. In below code, we have synchronized object reference by myClass.  MyClass myClass=**new** Myclass();  **synchronized** (myClass) {       }  As soon thread entered Synchronization block, thread acquired object lock on object referenced by myClass (by acquiring object’s monitor.)  Thread will leave lock when it exits synchronized block. | First let’s acquire lock on [class’s class object](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) by entering **synchronized block.**  Example- Let’s say there is one class MyClass. Now we can create synchronization block, and parameter passed with synchronization tells which class has to be synchronized. In below code, we have synchronized MyClass  **synchronized** (MyClass.class) {     }  As soon as thread entered Synchronization block, thread acquired MyClass’s class object. Thread will leave lock when it exits synchronized block. |
| **public** **synchronized void** method1() {  }  As soon as thread entered **Synchronization method**, thread acquired [object lock](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html).  Thread will leave lock when it exits synchronized method. | **public static** **synchronized void** method1() {}  As soon as thread entered **static Synchronization method**, thread acquired lock on [class’s class object](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html).  Thread will leave lock when it exits synchronized method. |

### Suppose you have 2 threads (Thread-1 and Thread-2) on same object. Thread-1 is in synchronized method1(), can Thread-2 enter synchronized method2() at same time?

**Answer.** **No**, here when Thread-1 is in **synchronized method1()** it must be **holding** [**lock on object’s monitor**](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) and will release lock on object’s monitor only when it exits **synchronized method1()**. So, Thread-2 will have to [wait](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) for Thread-1 to release lock on object’s monitor so that it could enter **synchronized method2()**.

**Likewise**, Thread-2 even cannot enter **synchronized method1()** which is being executed by Thread-1. Thread-2 will have to [wait](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) for Thread-1 to release lock on object’s monitor so that it could enter **synchronized method1()**.

>

|  |
| --- |
| **class MyRunnable1 implements Runnable{**  **@Override**  **public void run(){**  **if(Thread.*currentThread*().getName().equals("Thread-1"))**  **method1();**  **else**  **method2();**  **}**  **synchronized void method1(){**  **System.*out*.println(Thread.*currentThread*().getName()**  **+" in synchronized void method1() started");**  **try {**  **Thread.*sleep*(2000);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println(Thread.*currentThread*().getName()**  **+" in synchronized void method1() ended");**  **}**    **synchronized void method2(){**  **System.*out*.println(Thread.*currentThread*().getName()**  **+" in synchronized void method2() started");**  **try {**  **Thread.*sleep*(2000);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in synchronized void method2() ended");**  **}**    **}**  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public class MyClass {**  **public static void main(String args[]) throws InterruptedException{**    **MyRunnable1 myRunnable1=new MyRunnable1();**    **Thread thread1=new Thread(myRunnable1,"Thread-1");**  **Thread thread2=new Thread(myRunnable1,"Thread-2");**  **thread1.start();**  **Thread.*sleep*(10);//Just to ensure Thread-1 starts before Thread-2**  **thread2.start();**      **}**  **}**  **/\*OUTPUT**  **Thread-1 in synchronized void method1() started**  **Thread-1 in synchronized void method1() ended**  **Thread-2 in synchronized void method2() started**  **Thread-2 in synchronized void method2() ended**  **\*/** |

If you note output, when Thread-1 was is in **synchronized method1()** it was **holding lock on object’s monitor**. So, Thread-2 waited for Thread-1 to release lock on object’s monitor to enter **synchronized method2()**.

### Suppose you have 2 threads (Thread-1 and Thread-2) on same object. Thread-1 is in static synchronized method1(), can Thread-2 enter static synchronized method2() at same time?

**Answer.** **No**, here when Thread-1 is in **static synchronized method1()** it must be **holding lock on** [**class class’s object**](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) and will release lock on class’s classobject only when it exits **static synchronized method1()**. So, Thread-2 will have to [wait](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) for Thread-1 to release lock on class’s classobject so that it could enter **static synchronized method2()**.

**Likewise**, Thread-2 even cannot enter **static synchronized method1()** which is being executed by Thread-1. Thread-2 will have to [wait](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) for Thread-1 to release lock on  class’s classobject so that it could enter **static synchronized method1()**.

Program >

|  |
| --- |
| **class MyRunnable1 implements Runnable{**  **@Override**  **public void run(){**  **if(Thread.*currentThread*().getName().equals("Thread-1"))**  ***method1*();**  **else**  ***method2*();**  **}**  **static synchronized void method1(){**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in static synchronized void method1() started");**  **try {**  **Thread.*sleep*(2000);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in static synchronized void method1() ended");**  **}**    **static synchronized void method2(){**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in static synchronized void method2() started");**  **try {**  **Thread.*sleep*(2000);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in static synchronized void method2() ended");**  **}**    **}**  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public class MyClass {**  **public static void main(String args[]) throws InterruptedException{**    **MyRunnable1 myRunnable1=new MyRunnable1();**    **Thread thread1=new Thread(myRunnable1,"Thread-1");**  **Thread thread2=new Thread(myRunnable1,"Thread-2");**  **thread1.start();**  **Thread.*sleep*(10);//Just to ensure Thread-1 starts before Thread-2**  **thread2.start();**      **}**  **}**  **/\*OUTPUT**  **Thread-1 in static synchronized void method1() started**  **Thread-1 in static synchronized void method1() ended**  **Thread-2 in static synchronized void method2() started**  **Thread-2 in static synchronized void method2() ended**  **\*/** |

If you note output, when Thread-1 was in **static synchronized method1()** it was **holding lock on class class’s object**. So, Thread-2 waited for Thread-1 to release lock on class’s classobject to enter **static synchronized method2()**.

### Suppose you have 2 threads (Thread-1 and Thread-2) on same object. Thread-1 is in synchronized method1(), can Thread-2 enter static synchronized method2() at same time?

**Answer.** **Yes**, here when Thread-1 is in **synchronized method1()** it must be **holding** [**lock on object’s monitor**](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) and Thread-2 can enter **static synchronized method2()** by acquiring lock on [class’s class object](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html).

Program >

|  |
| --- |
| **class MyRunnable1 implements Runnable{**  **@Override**  **public void run(){**  **if(Thread.*currentThread*().getName().equals("Thread-1"))**  ***method1*();**  **else**  **method2();**  **}**  **static synchronized void method1(){**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in static synchronized void method1() started");**  **try {**  **Thread.*sleep*(2000);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in static synchronized void method1() ended");**  **}**    **synchronized void method2(){**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in synchronized void method2() started");**  **try {**  **Thread.*sleep*(2000);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in synchronized void method2() ended");**  **}**    **}**  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public class MyClass {**  **public static void main(String args[]) throws InterruptedException{**    **MyRunnable1 myRunnable1=new MyRunnable1();**    **Thread thread1=new Thread(myRunnable1,"Thread-1");**  **Thread thread2=new Thread(myRunnable1,"Thread-2");**  **thread1.start();**  **Thread.*sleep*(10);//Just to ensure Thread-1 starts before Thread-2**  **thread2.start();**      **}**  **}**  **/\*OUTPUT**  **Thread-1 in static synchronized void method1() started**  **Thread-2 in synchronized void method2() started**  **Thread-1 in static synchronized void method1() ended**  **Thread-2 in synchronized void method2() ended**  **\*/** |

If you note output, when Thread-1 was in **synchronized method1()** it was **holding lock on object’s monitor** and Thread-2 entered **static synchronized method2()** by acquiring lock on [class’s class object](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html).

### Suppose you have thread and it is in synchronized method and now can thread enter other synchronized method from that method?

**Answer.** **Yes**, here when thread is in **synchronized method** it must be **holding** [**lock on object’s monitor**](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) and **using that lock** thread can **enter other synchronized method**

Program >

|  |
| --- |
| **class MyRunnable1 implements Runnable{**  **@Override**  **public void run(){**  **method1();**  **}**  **synchronized void method1(){**  **System.*out*.println("synchronized method1() started");**  **method2();**  **System.*out*.println("synchronized method1() ended");**  **}**  **synchronized void method2(){**  **System.*out*.println("in synchronized method2()");**  **}**    **}**  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public class MyClass {**  **public static void main(String args[]) throws InterruptedException{**    **MyRunnable1 myRunnable1=new MyRunnable1();**  **Thread thread1=new Thread(myRunnable1,"Thread-1");**  **thread1.start();**    **}**  **}**  **/\*OUTPUT**  **synchronized method1() started**  **in synchronized method2()**  **synchronized method1() ended**  **\*/** |

If you note output, when thread was in **synchronized method1()** it was **holding lock on object’s monitor** and **using that lock** thread **entered synchronized method2()**.

### Suppose you have thread and it is in static synchronized method and now can thread enter other static synchronized method from that method?

**Answer.**  **Yes**, here when thread is in **static synchronized method** it must be **holding lock on** [**class’s class object**](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) and **using that lock** thread can **enter other static synchronized method**.

Program >

|  |
| --- |
| **class MyRunnable1 implements Runnable{**  **@Override**  **public void run(){**  ***method1*();**  **}**    **static synchronized void method1(){**  **System.*out*.println("static synchronized void method1() started");**  ***method2*();**  **System.*out*.println("static synchronized void method1() ended");**  **}**    **static synchronized void method2(){**  **System.*out*.println("in static synchronized method2()");**  **}**      **}**  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public class MyClass {**  **public static void main(String args[]) throws InterruptedException{**  **MyRunnable1 myRunnable1=new MyRunnable1();**  **Thread thread1=new Thread(myRunnable1,"Thread-1");**  **thread1.start();**  **}**  **}**  **/\*OUTPUT**  **static synchronized void method1() started**  **in static synchronized method2()**  **static synchronized void method1() ended**  **\*/** |

If you note output, when thread was in **static synchronized method1()** it was **holding lock on** [**class’s class object**](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) and **using that lock** thread **entered static synchronized method2()**.

### Suppose you have thread and it is in static synchronized method and now can thread enter other non static synchronized method from that method?

**Answer.** **Yes**, here when thread is in **static synchronized method** it must be **holding lock on** [**class’s class object**](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) and when it **enters synchronized method** it will **hold** [**lock on object’s monitor**](http://v/) **as well**.

So, now thread holds 2 locks (it’s also called nested synchronization)-

**>**first one on **class’s class object.**

**>**second one on **object’s monitor** (This lock will be released when thread exits non static method

Program >

|  |
| --- |
| **class MyRunnable1 implements Runnable{**  **@Override**  **public void run(){**  ***method1*();**  **}**  **static synchronized void method1(){**  **System.*out*.println("static synchronized method1() started");**  **MyRunnable1 myRunnable1=new MyRunnable1();**  **myRunnable1.method2();**  **System.*out*.println("static synchronized method1() ended");**  **}**  **synchronized void method2(){**  **System.*out*.println("in synchronized method2()");**  **}**    **}**  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public class MyClass {**  **public static void main(String args[]) throws InterruptedException{**    **MyRunnable1 myRunnable1=new MyRunnable1();**  **Thread thread1=new Thread(myRunnable1,"Thread-1");**  **thread1.start();**      **}**  **}**  **/\*OUTPUT**  **static synchronized method1() started**  **in synchronized method2()**  **static synchronized method1() ended**  **\*/** |

If you note output, when thread was in **static synchronized method1()** it was **holding lock on** [**class’s class object**](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) and it entered **synchronized method2()** by acquiring **lock on object’s monitor as well**.

### Suppose you have thread and it is in synchronized method and now can thread enter other static synchronized method from that method?

**Answer.** **Yes**, here when thread is in synchronized method it must be holding [**lock on object’s monitor**](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) and when it enters static synchronized method it will hold lock on [class’s class object](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) as well.

So, now thread holds 2 locks (it’s also called nested synchronization)-

**>**first one on [**object’s monitor**](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html)**.**

**>**second one on **class’s class object.**(This lock will be released when thread exits static method)**.**

Program >

|  |
| --- |
| **class MyRunnable1 implements Runnable{**  **@Override**  **public void run(){**  **method1();**  **}**    **synchronized void method1(){**  **System.*out*.println("synchronized void method1() started");**  ***method2*();**  **System.*out*.println("synchronized void method1() ended");**  **}**    **static synchronized void method2(){**  **System.*out*.println("in static synchronized method2()");**  **}**      **}**  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public class MyClass {**  **public static void main(String args[]) throws InterruptedException{**    **MyRunnable1 myRunnable1=new MyRunnable1();**  **Thread thread1=new Thread(myRunnable1,"Thread-1");**  **thread1.start();**      **}**  **}**  **/\*OUTPUT**  **synchronized void method1() started**  **in static synchronized method2()**  **synchronized void method1() ended**  **\*/** |

If you note output, when thread was in synchronized method1() it was holding [lock on object’s monitor](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) and when it entered static synchronized method2() it acquired lock on [class’s class object](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) as well.

### Suppose you have 2 threads (Thread-1 on object1 and Thread-2 on object2). Thread-1 is in synchronized method1(), can Thread-2 enter synchronized method2() at same time?

**Answer.** **Yes**, here when Thread-1 is in **synchronized method1()** it must be **holding** [**lock on object1’s monitor**](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html). Thread-2 will acquire lock on **object2’s monitor** and enter **synchronized method2()**.

**Likewise**, Thread-2 even enter **synchronized method1()** as well which is being executed by Thread-1 (because threads are created on different objects).

Program >

|  |
| --- |
| **class MyRunnable1 implements Runnable{**  **@Override**  **public void run(){**  **if(Thread.*currentThread*().getName().equals("Thread-1"))**  **method1();**  **else**  **method2();**  **}**  **synchronized void method1(){**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in synchronized void method1() started");**  **try {**  **Thread.*sleep*(2000);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in synchronized void method1() ended");**  **}**    **synchronized void method2(){**  **System.*out*.println(Thread.*currentThread*().getName()**  **+" in synchronized void method2() started");**  **try {**  **Thread.*sleep*(2000);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println(Thread.*currentThread*().getName()**  **+" in synchronized void method2() ended");**  **}**    **}**  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public class MyClass {**  **public static void main(String args[]) throws InterruptedException{**  **MyRunnable1 object1=new MyRunnable1();**  **MyRunnable1 object2=new MyRunnable1();**    **Thread thread1=new Thread(object1,"Thread-1");**  **Thread thread2=new Thread(object2,"Thread-2");**  **thread1.start();**  **Thread.*sleep*(10);//Just to ensure Thread-1 starts before Thread-2**  **thread2.start();**      **}**  **}**  **/\*OUTPUT**  **Thread-1 in synchronized void method1() started**  **Thread-2 in synchronized void method2() started**  **Thread-1 in synchronized void method1() ended**  **Thread-2 in synchronized void method2() ended**  **\*/** |

If you note output, when Thread-1 was in **synchronized method1()** it was **holding lock on object1’s monitor**. Thread-2 acquired lock on **object2’s monitor** and entered **synchronized method2()**.

### Suppose you have 2 threads (Thread-1 on object1 and Thread-2 on object2). Thread-1 is in static synchronized method1(), can Thread-2 enter static synchronized method2() at same time?

**Answer.** **No**, it might confuse you a bit that threads are created on different objects. But, not to forgot that **multiple objects may exist but there is always one** [**class’s class object**](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) **lock available**.

Here, when Thread-1 is in **static synchronized method1()** it must be **holding lock on class class’s object** and will release lock on class’s classobject only when it exits **static synchronized method1()**. So, Thread-2 will have to [wait](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) for Thread-1 to release lock on class’s classobject so that it could enter **static synchronized method2()**.

Program >

|  |
| --- |
| **class MyRunnable1 implements Runnable{**  **@Override**  **public void run(){**  **if(Thread.*currentThread*().getName().equals("Thread-1"))**  ***method1*();**  **else**  ***method2*();**  **}**  **static synchronized void method1(){**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in synchronized void method1() started");**  **try {**  **Thread.*sleep*(2000);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println(Thread.*currentThread*().getName()**  **+" in synchronized void method1() ended");**  **}**    **static synchronized void method2(){**  **System.*out*.println(Thread.*currentThread*().getName()**  **+" in synchronized void method2() started");**  **try {**  **Thread.*sleep*(2000);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println(Thread.*currentThread*().getName()**  **+" in synchronized void method2() ended");**  **}**    **}**  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public class MyClass {**  **public static void main(String args[]) throws InterruptedException{**  **MyRunnable1 object1=new MyRunnable1();**  **MyRunnable1 object2=new MyRunnable1();**    **Thread thread1=new Thread(object1,"Thread-1");**  **Thread thread2=new Thread(object2,"Thread-2");**  **thread1.start();**  **Thread.*sleep*(10);//Just to ensure Thread-1 starts before Thread-2**  **thread2.start();**      **}**  **}**  **/\*OUTPUT**  **Thread-1 in synchronized void method1() started**  **Thread-1 in synchronized void method1() ended**  **Thread-2 in synchronized void method2() started**  **Thread-2 in synchronized void method2() ended**  **\*/** |

If you note output, when Thread-1 was in **static synchronized method1()** it was **holding lock on class’s class object**. So, Thread-2 waited for Thread-1 to release lock on [class’s classobject](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) so that it could enter **static synchronized method2()**.

**Likewise**, Thread-2 even cannot enter **static synchronized method1()** which is being executed by Thread-1. Thread-2 will have to [wait](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) for Thread-1 to release lock on  [class’s classobject](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) so that it could enter **static synchronized method1()**.

### Difference between wait() and wait(long timeout), What are [thread states](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) when these method are called?

**Answer.**

|  |  |
| --- | --- |
| [**wait()**](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) | **wait(long timeout)** |
| When [wait()](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) method is called on object, it causes causes the current thread to wait until another thread invokes the notify() or notifyAll() method for this object. | **wait(long timeout) -** Causes the current thread to wait until either another thread invokes the notify() or notifyAll() methods for this object, or a specified timeout time has elapsed. |
| **When** [**wait()**](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) **is called** on object - Thread enters from [**running to waiting state**](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html).  **It** [**waits**](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) **for some other thread to call notify so that it could enter runnable state**. | **When wait(1000) is called** on object - Thread enters from **running to waiting state**. Than **even if notify() or notifyAll() is not called after  timeout time has elapsed thread will go from** [**waiting to runnable state**](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html)**.** |

### Can a constructor be synchronized?

No, constructor cannot be synchronized. Because constructor is used for instantiating object, when we are in constructor object is under creation. So, until object is not instantiated it does not need any synchronization.

**Enclosing** constructor in synchronized block will generate compilation error.

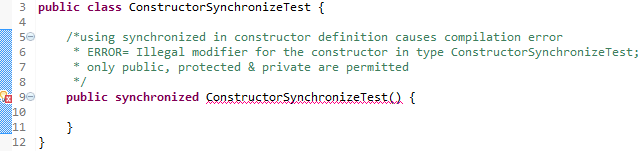
Using synchronized in **constructor definition** will also show compilation error.

COMPILATION ERROR = Illegal modifier for the constructor in type ConstructorSynchronizeTest; only public, protected & private are permitted

**Though we can use synchronized block inside constructor.**

*Using synchronized in constructor definition will also show compilation error >*

COMPILATION ERROR = Illegal modifier for the constructor in type ConstructorSynchronizeTest; only public, protected & private are permitted



*Though we can use synchronized block inside constructor >*

|  |
| --- |
| /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public** **class** ConstructorSynchronizeTest {       //constructor  **public** ConstructorSynchronizeTest() {  **synchronized** (**this**) {                   //...Here you can write your thread safe code...            }     }    } |

### Can you find whether thread holds lock on object or not?

**Answer.**  holdsLock(object) method can be used to find out whether current thread holds the lock on monitor of specified object.

holdsLock(object) method returns true if the current thread holds the lock on monitor of specified object.

### . What do you mean by thread starvation?

**Answer.**   When thread does not enough CPU for its execution **Thread starvation happens.**

**Thread starvation** may happen in following scenarios >

* Low priority threads gets less CPU (time for execution) as compared to high priority threads. **Lower priority thread** may **starve** away waiting to get enough CPU to perform calculations.
* In [deadlock](http://www.javamadesoeasy.com/2015/03/deadlock-in-multithreading-program-to.html) two threads waits for each other to release lock holded by them on resources. There both **Threads starves away to get CPU.**
* Thread might be waiting indefinitely for lock on object’s monitor (by calling [wait()](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) method), because no other thread is calling [notify()/notifAll()](http://www.javamadesoeasy.com/2015/03/difference-between-notify-and-notifyall.html) method on object. In that case, **Thread starves** away to get CPU.
* Thread might be waiting indefinitely for lock on object’s monitor (by calling wait() method), but notify() may be repeatedly awakening some other threads. In that case also **Thread starves** away to get CPU.

### What is addShutdownHook method in java?

**Answer.**  [addShutdownHook](http://www.javamadesoeasy.com/2015/03/threads-addshutdownhook-method-in-java.html) method in java >

* addShutdownHook method **registers a new virtual-machine shutdown hook**.
* A shutdown hook is a **initialized but unstarted thread**.
* When **JVM starts its shutdown** it will **start all registered shutdown hooks** in some unspecified order and let them run concurrently.

When JVM (Java virtual machine)  shuts down >

* When the last non-[daemon](http://www.javamadesoeasy.com/2015/03/daemon-threads-12-salient-features-of.html) thread finishes, or
* when the System.exit is called.

*Once JVM’s shutdown has begun* **new shutdown hook cannot be registered** neither  **previously-registered hook can be de-registered**. Any attempt made to do any of these operations causes an IllegalStateException.

### How you can handle uncaught runtime exception generated in run method?

**Answer.**  We can use [setDefaultUncaughtExceptionHandler](http://www.javamadesoeasy.com/2015/03/handling-uncaught-runtime-exception.html) method which can handle uncaught unchecked(runtime) exception generated in run() method.

What is setDefaultUncaughtExceptionHandler method?

setDefaultUncaughtExceptionHandler method sets the default handler which is called when a thread terminates due to an uncaught unchecked(runtime) exception.

*setDefaultUncaughtExceptionHandler method features >*

* **setDefaultUncaughtExceptionHandler** method sets the default handler which is called when a thread terminates due to an uncaught unchecked(runtime) exception.
* **setDefaultUncaughtExceptionHandler** is a static method method, so we can directly call  Thread.***setDefaultUncaughtExceptionHandler*** to set the default handler to handle uncaught unchecked(runtime) exception.
* It avoids abrupt termination of thread caused by uncaught runtime exceptions.

Defining setDefaultUncaughtExceptionHandler method >

|  |
| --- |
| Thread.***setDefaultUncaughtExceptionHandler***(**new** Thread.UncaughtExceptionHandler(){  **public** **void** uncaughtException(Thread thread, Throwable throwable) {     System.*out*.println(thread.getName() + " has thrown " + throwable);     }    }); |

|  |
| --- |
| **class** MyRunnable **implements** Runnable {       String str;              /\*            \* method will terminate due to an uncaught unchecked(runtime) exception.            \*/  **public** **void** run() {              /\* String wasn't initialized, so performing any operation            \* on it will throw NullPointerException and it will caught by            \* default handler defined in main method.            \*/              str.equals("abc");       }  }  /\*\* Copyright (c), AnkitMittal JavaMadeSoEasy.com \*/  **public** **class** MyClass {  **public** **static** **void** main(String[] args) {       Thread thread1 = **new** Thread(**new** MyRunnable(),"thread-1");       /\*       \* setDefaultUncaughtExceptionHandler method sets the default handler       \* which is called when a thread terminates due to an       \* uncaught unchecked(runtime) exception.       \*       \*/     Thread.***setDefaultUncaughtExceptionHandler***(**new** Thread.UncaughtExceptionHandler(){  **public** **void** uncaughtException(Thread thread, Throwable throwable) {            System.*out*.println(thread.getName() + " has thrown " + throwable);         }     });       thread1.start();       }  }  /\*OUTPUT  thread-1 has thrown java.lang.NullPointerException  \*/ |

*Output analyzation >*

In the above program we have defined ***setDefaultUncaughtExceptionHandler*** method. And in run method  str wasn't initialized, calling str.equals("abc"); throwed NullPointerException and it was caught by default handler defined in main method.

### What is ThreadGroup in java, What is default priority of newly created threadGroup, mention some important ThreadGroup methods ?

**Answer.**  When program starts **JVM creates  a ThreadGroup** named ***main***. Unless specified, all  newly created threads become members of the ***main*** thread group.

**ThreadGroup is initialized with default priority of 10.**

*ThreadGroup* ***important methods*** *>*

* **getName()** 
  + name of ThreadGroup.
* **activeGroupCount()** 
  + count of active groups in ThreadGroup.
* **activeCount()** 
  + count of active threads in ThreadGroup.
* **list()** 
  + list() method has prints ThreadGroups information
* **getMaxPriority()**
  + Method returns the maximum priority of ThreadGroup.
* **setMaxPriority(int pri)**
  + Sets the maximum priority of ThreadGroup.

### What are thread priorities?

**Answer.**

[*Thread Priority*](http://www.javamadesoeasy.com/2015/03/thread-priorities-setpriority-and.html) *range is from 1 to 10.*

Where **1 is minimum priority** and **10 is maximum priority.**

Thread class provides variables of **final static int** type for setting thread priority.

|  |
| --- |
| /\* The minimum priority that a thread can have. \*/  **public** **final** **static** **int** ***MIN\_PRIORITY*** = 1;      /\* The default priority that is assigned to a thread. \*/  **public** **final** **static** **int** ***NORM\_PRIORITY*** = 5;     /\* The maximum priority that a thread can have. \*/  **public** **final** **static** **int** ***MAX\_PRIORITY*** = 10; |

Thread with **MAX\_PRIORITY is likely to get more CPU** as compared to low priority threads. But **occasionally low priority thread might get more CPU**. Because thread scheduler schedules thread on discretion of implementation and [thread behaviour is totally unpredictable](http://www.javamadesoeasy.com/2015/03/thread-behaviour-is-unpredictable.html).

Thread with **MIN\_PRIORITY is likely to get less CPU** as compared to high priority threads. But **occasionally high priority thread might less CPU**. Because thread scheduler schedules thread on discretion of implementation and thread behaviour is totally unpredictable.

***setPriority()* method is used for Changing the priority of thread.**

***getPriority()* method returns the thread’s priority.**

### Output question 1.

|  |
| --- |
| **class** MyRunnable **implements** Runnable {  **public** **void** run(){  **for**(**int** i=0;i<3;i++){                   System.*out*.println("i="+i+" ,ThreadName="+Thread.*currentThread*().getName());            }     }  }  **public** **class** MyClass {  **public** **static** **void** main(String...args){            MyRunnable runnable=**new** MyRunnable();            System.*out*.println("start main() method");            Thread thread1=**new** Thread(runnable);            Thread thread2=**new** Thread(runnable);            thread1.start();            thread2.start();            System.*out*.println("end main() method");     }  } |

**Answer.** [Thread behaviour is unpredictable](http://www.javamadesoeasy.com/2015/03/thread-behaviour-is-unpredictable.html) because execution of Threads depends on Thread scheduler,

start main() method will be the printed first, but after that we cannot guarantee the order of thread1, thread2 and main thread they might run simultaneously or sequentially, so order of end main() method will not be guaranteed.

/\*OUTPUT

start main() method

end main() method

i=0 ,ThreadName=Thread-0

i=0 ,ThreadName=Thread-1

i=1 ,ThreadName=Thread-0

i=2 ,ThreadName=Thread-0

i=1 ,ThreadName=Thread-1

i=2 ,ThreadName=Thread-1

\*/

### Output question 2.

|  |
| --- |
| **class** MyRunnable **implements** Runnable{  **public** **void** run(){  **for**(**int** i=0;i<3;i++){                   System.*out*.println("i="+i+" ,ThreadName="+Thread.*currentThread*().getName());            }     }  }  **public** **class** MyClass {  **public** **static** **void** main(String...args) **throws** InterruptedException{            System.*out*.println("In main() method");            MyRunnable runnable=**new** MyRunnable();            Thread thread1=**new** Thread(runnable);            Thread thread2=**new** Thread(runnable);            thread1.start();            thread1.join();            thread2.start();            thread2.join();            System.*out*.println("end main() method");     }  } |

**Answer.**  We use [**join() method**](http://www.javamadesoeasy.com/2015/03/join-method-ensure-all-threads-that.html)to ensure all threads that started from main must end in order in which they started and also main should end in last. In other words [**join() method**](http://www.javamadesoeasy.com/2015/03/join-method-ensure-all-threads-that.html) **waited for this thread to die**.

/\*OUTPUT

In main() method

i=0 ,ThreadName=Thread-0

i=1 ,ThreadName=Thread-0

i=2 ,ThreadName=Thread-0

i=0 ,ThreadName=Thread-1

i=1 ,ThreadName=Thread-1

i=2 ,ThreadName=Thread-1

end main() method

\*/

### Output question 3.

|  |
| --- |
| **class MyRunnable implements Runnable {**  **public void run() {**  **try {**  **while (!Thread.*currentThread*().isInterrupted()) {**  **Thread.*sleep*(1000);**  **System.*out*.println("x");**  **}**  **} catch (InterruptedException e) {**  **System.*out*.println(Thread.*currentThread*().getName() + " ENDED");**  **}**  **}**  **}**  **public class MyClass {**  **public static void main(String args[]) throws Exception {**  **MyRunnable obj = new MyRunnable();**  **Thread t = new Thread(obj, "Thread-1");**  **t.start();**  **System.*out*.println("press enter");**  **System.*in*.read();**  **t.interrupt();**  **}**  **}** |

**Answer.**  **"press enter"** will be printed first then [thread1 will keep on printing x until enter is pressed](http://www.javamadesoeasy.com/2015/03/2-alternate-ways-to-stop-thread-as-stop.html), once enter is pressed **"Thread-1 ENDED"** will be printed. **System.*in*.read()** causes main thread to go from [running to waiting state](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) (thread waits for user input)

**/\* OUTPUT**

**press enter**

**x**

**x**

**x**

**x**

**Thread-1 ENDED**

**\*/**

### Output question 4.

|  |
| --- |
| **class** MyRunnable **implements** Runnable{    **public** **void** run(){  **synchronized** (**this**) {                   System.*out*.println("1 ");  **try** {  **this**.wait();                         System.*out*.println("2 ");                   } **catch** (InterruptedException e) {                         e.printStackTrace();                   }            }     }  }  **public** **class** MyClass  {  **public** **static** **void** main(String[] args) {            MyRunnable myRunnable=**new** MyRunnable();            Thread thread1=**new** Thread(myRunnable,"Thread-1");            thread1.start();       }  } |

**Answer.**  Thread acquires lock on myRunnable object so 1 was printed but notify wasn't called so 2 will never be printed, this is called frozen process. Deadlock is formed, these type of [**deadlocks**](http://www.javamadesoeasy.com/2015/03/deadlock-in-multithreading-program-to.html)are called **Frozen processes**.

/\*OUTPUT

1

\*/

### Output question 5.

|  |
| --- |
| **import** java.util.ArrayList;  /\* Producer is producing, Producer will allow consumer to  \* consume only when 10 products have been produced (i.e. when production is over).  \*/  **class** Producer **implements** Runnable{     ArrayList<Integer> sharedQueue;     Producer(){            sharedQueue=**new** ArrayList<Integer>();     }     @Override  **public** **void** run(){  **synchronized** (**this**) {  **for**(**int** i=1;i<=3;i++){ //Producer will produce 10 products                         sharedQueue.add(i);                         System.*out*.println("Producer is still Producing, Produced : "+i);    **try**{                                Thread.*sleep*(1000);                         }**catch**(InterruptedException e){e.printStackTrace();}                     }                   System.*out*.println("Production is over, consumer can consume.");  **this**.notify();            }     }    }  **class** Consumer **extends** Thread{     Producer prod;       Consumer(Producer obj){      prod=obj;     }    **public** **void** run(){  **synchronized** (**this**.prod) {                     System.*out*.println("Consumer waiting for production to get over.");  **try**{  **this**.prod.wait();                         }**catch**(InterruptedException e){e.printStackTrace();}              }      **int** productSize=**this**.prod.sharedQueue.size();  **for**(**int** i=0;i<productSize;i++)                   System.*out*.println("Consumed : "+ **this**.prod.sharedQueue.remove(0) +" ");       }    }  **public** **class** MyClass {  **public** **static** **void** main(String args[]) **throws** InterruptedException{              Producer prod=**new** Producer();            Consumer cons=**new** Consumer(prod);              Thread prodThread=**new** Thread(prod,"prodThread");            Thread consThread=**new** Thread(cons,"consThread");              consThread.start();            Thread.*sleep*(100);     //minor delay.            prodThread.start();         }  } |

**Answer.** Because of minor delay delay consThread surely started before producer thread. "Consumer waiting for production to get over." printed first

than producer produced

than "Production is over, consumer can consume."

than consumer consumed.

The above program is classical example of [how to solve **Consumer Producer** problem by using **wait() and notify()** methods](http://www.javamadesoeasy.com/2015/03/solve-consumer-producer-problem-by_2.html).

/\*OUTPUT

Consumer waiting for production to get over.

Producer is still Producing, Produced : 1

Producer is still Producing, Produced : 2

Producer is still Producing, Produced : 3

Production is over, consumer can consume.

Consumed : 1

Consumed : 2

Consumed : 3

\*/

### Output question 6.

|  |
| --- |
| **class** MyRunnable **implements** Runnable{    **public** **void** run(){  **synchronized** (**this**) {                   System.*out*.print("1 ");  **try** {  **this**.wait(1000);                         System.*out*.print("2");                   } **catch** (InterruptedException e) {                         e.printStackTrace();                   }            }     }  }  **public** **class** MyClass  {  **public** **static** **void** main(String[] args) {            MyRunnable myRunnable=**new** MyRunnable();            Thread thread1=**new** Thread(myRunnable,"Thread-1");            thread1.start();     }  } |

**Answer.**  First 1 will be printed then even if [notify() or notifyAll()](http://www.javamadesoeasy.com/2015/03/difference-between-notify-and-notifyall.html) is not called, thread will be [notified after 1000 millisec](http://www.javamadesoeasy.com/2015/03/difference-between-wait-and-waitlong.html) and 2 will be printed.

/\*OUTPUT

1 2

\*/

### Output question 7.

|  |
| --- |
| **class** MyRunnable **implements** Runnable {  **public** **void** run() {            System.*out*.println(Thread.*currentThread*().getName() + " has started");  **try** {                   Thread.*sleep*(100); //ensure that main thread don’t complete before Thread-1            } **catch** (InterruptedException e) {                   e.printStackTrace();            }            System.*out*.println(Thread.*currentThread*().getName() + " has ended");     }  }  **public** **class** MyClass {  **public** **static** **void** main(String... args) **throws** InterruptedException {            System.*out*.println(Thread.*currentThread*().getName() + " has started");            Thread thread1 = **new** Thread(**new** MyRunnable(), "Thread-1");            thread1.start();            thread1.*sleep*(10000);            System.*out*.println(Thread.*currentThread*().getName() + " has ended");     }  }  /\*OUTPUT  main has started  Thread-1 has started  Thread-1 has ended  main has ended  \*/ |

**Answer.**

[sleep()](http://www.javamadesoeasy.com/2015/03/sleep-method-in-threads-10-key-features.html)is a static method, causes the currently executing thread to sleep for the specified number of milliseconds.

Calling thread1.*sleep*(10000);  will show warning - The static method sleep(long) from the type Thread should be accessed in a static way.

In the program first main thread started, than it invoked Thread-1, then Thread-1 called sleep(100) method to ensure that main thread don’t complete before Thread-1, than execution control went to  main thread  and it called thread1.*sleep*(10000) **but rather than putting Thread-1 on sleep it made main thread to sleep.** And Thread-1 ended before main thread.

### Output question 8.

|  |
| --- |
| **class** MyRunnable1 **implements** Runnable{     @Override  **public** **void** run(){  **synchronized** (**this**) {  **try**{                                System.*out*.print("2 ");                               Thread.*sleep*(1000);                        }**catch**(InterruptedException e){e.printStackTrace();}  **this**.notify();                  System.*out*.print("3 ");              }     }    }  **class** MyRunnable2 **extends** Thread{     MyRunnable1 prod;       MyRunnable2(MyRunnable1 obj){      prod=obj;     }    **public** **void** run(){  **synchronized** (**this**.prod) {                     System.*out*.print("1 ");  **try**{  **this**.prod.wait();                         }**catch**(InterruptedException e){e.printStackTrace();}              }              System.*out*.print("4 ");       }    }  **public** **class** MyClass {  **public** **static** **void** main(String args[]) **throws** InterruptedException{              MyRunnable1 myRunnable1=**new** MyRunnable1();            MyRunnable2 myRunnable2=**new** MyRunnable2(myRunnable1);              Thread thread1=**new** Thread(myRunnable1,"Thread-1");            Thread thread2=**new** Thread(myRunnable2,"Thread-2");              thread2.start();            Thread.*sleep*(100);   //This minor delay will ensure that Thread-1 thread starts Thread-2            thread1.start();         }  } |

**Answer.** [Wait()](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) method causes the current thread to wait until another thread invokes the notify() or notifyAll() method for this object.

Now, as soon as [notify() or notifyall()](http://www.javamadesoeasy.com/2015/03/difference-between-notify-and-notifyall.html) method is called it **notifies the waiting thread**, **but object monitor is not yet available**. **Object monitor is available only when thread exits synchronized block or synchronized method**. So, what happens is code after notify() is also executed and execution is done until we reach end of synchronized block.

[**The awakened threads will not be able to proceed until the current thread relinquishes the lock on this object**](http://www.javamadesoeasy.com/2015/03/the-awakened-threads-will-not-be-able.html)

/\*OUTPUT

1 2 3 4

\*/

### Output question 9.

|  |
| --- |
| **class** MyThread **extends** Thread {     MyThread() {            System.*out*.print("1 ");     }  **public** **void** run() {            System.*out*.print("2 ");     }  }  **public** **class** MyClass {  **public** **static** **void** main(String[] args) {            Thread thread1 = **new** MyThread() {  **public** **void** run() {                         System.*out*.print("3 ");                   }            };            thread1.start();     }  } |

**Answer.**

new MyThread() > created instance of an anonymous inner class.

constructor was called which printed 1

than overridden run() method of anonymous inner class was invoked, which printed 3.

/\*OUTPUT

1 3

\*/

### Output question 10.

|  |
| --- |
| **class** MyRunnable **implements** Runnable{  **public** **void** run(){            method();     }  **synchronized** **void** method(){  **for**(**int** i=0;i<2;i++){                   System.*out*.println(Thread.*currentThread*().getName());            }     }  }  **public** **class** MyClass {  **public** **static** **void** main(String...args){            MyRunnable runnable=**new** MyRunnable();            Thread thread1=**new** Thread(runnable,"Thread-1");            Thread thread2=**new** Thread(runnable,"Thread-2");            thread1.start();            thread2.start();     }  }  //q6 |

**Answer.** Thread behavior is unpredictable because execution of Threads depends on Thread scheduler, either of thread1 and thread2 can start first and synchronized method [will be executed by one thread at a time](http://www.javamadesoeasy.com/2015/03/suppose-you-have-2-threads-thread-1-and_5.html).

/\*OUTPUT if Thread-1 entered first in synchronized block.

Thread-1

Thread-1

Thread-2

Thread-2

\*/

/\*OUTPUT if Thread-2 entered first in synchronized block.

Thread-2

Thread-2

Thread-1

Thread-1

\*/

### Output question 11.

|  |
| --- |
| **public** **class** MyClass {  **public** **static** **void** main(String[] args) {            Thread thread1=**new** Thread("Thread-1"){  **public** **void** run() {    **synchronized** (String.**class**) {    **try** {                                       Thread.*sleep*(100);                                } **catch** (InterruptedException e) {e.printStackTrace();}                                  System.*out*.println("1 ");  **synchronized** (Object.**class**) {                                       System.*out*.println("2 ");                                }                         }                           System.*out*.println("3 ");                   }            };            Thread thread2=**new** Thread("Thread-2"){  **public** **void** run() {    **synchronized** (Object.**class**) {                                System.*out*.println("4 ");    **try** {                                       Thread.*sleep*(100);                                } **catch** (InterruptedException e) {e.printStackTrace();}      **synchronized** (String.**class**) {                                       System.*out*.println("5 ");                                }                         }                           System.*out*.println("6 ");                   }            };            thread1.start();            thread2.start();     }  } |

**Answer.** [Deadlock](http://www.javamadesoeasy.com/2015/03/deadlock-in-multithreading-program-to.html) is formed in above program :

**Thread-1 acquires lock on String.class** and then calls [sleep()](http://www.javamadesoeasy.com/2015/03/sleep-method-in-threads-10-key-features.html) method which gives Thread-2 the chance to execute immediately after Thread-1 has acquired lock on String.class and **Thread-2 acquires lock on Object.class** then calls [sleep()](http://www.javamadesoeasy.com/2015/03/sleep-method-in-threads-10-key-features.html) method and **now it waits for Thread-1 to release lock on String.class**.

**Conclusion:**

Now, **Thread-1 is** [**waiting**](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) **for Thread-2 to release lock on Object.class** and **Thread-2 is** [**waiting**](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) **for Thread-1 to release lock on String.class** and [deadlock](http://www.javamadesoeasy.com/2015/03/deadlock-in-multithreading-program-to.html) is formed.

/\*OUTPUT

4

1

\*/

### Output question 12.

|  |
| --- |
| **public** **class** MyClass  {    **public** **static** **void** main(String[] args) **throws** InterruptedException {    **synchronized** (args) {                   System.*out*.print("1 ");                   args.wait();                   System.*out*.print("2 ");            }       }  } |

**Answer.** Though this question looks bit similar to output question 4 but intention is to show args is object and we can acquire lock on it.

Thread acquires lock on args object but notify wasn't called so 2 will never be printed, this is called frozen process.

/\*OUTPUT

1

\*/

### Output question 13.

|  |
| --- |
| **package** o13\_k15;  **class** Class2 {  **void** method2(String name) {  **for** (**int** x = 1; x <=2; x++) {                   System.*out*.println(Thread.*currentThread*().getName());            }     }  }  **public** **class** MyClass **implements** Runnable {     Class2 obj2;  **public** **static** **void** main(String[] args) {  **new** MyClass().method1();     }  **void** method1() {            obj2 = **new** Class2();  **new** Thread(**new** MyClass()).start();  **new** Thread(**new** MyClass()).start();     }  **public** **void** run() {            obj2.method2(Thread.*currentThread*().getName());     }  } |

**Answer.**  Program will face NullPointerException at Class2 obj2, we must make it static. As **new** Thread(**new** MyClass()).start(); creates thread on new instance of MyClass.

If Class2 obj2 is made static, than

Thread-0 and Thread-1 will be printed twice but in unpredictable order.

So, output will be different in subsequent executions,(as shown below)-

/\*OUTPUT

Thread-1

Thread-1

Thread-0

Thread-0

\*/

/\*OUTPUT

Thread-0

Thread-1

Thread-1

Thread-0

\*/

### Output question 14.

|  |
| --- |
| **class MyRunnable1 implements Runnable{**  **@Override**  **public void run(){**  **if(Thread.*currentThread*().getName().equals("Thread-1"))**  **method1();**  **else**  **method2();**  **}**  **synchronized void method1(){**  **System.*out*.println(Thread.*currentThread*().getName()**  **+" in synchronized void method1() started");**  **try {**  **Thread.*sleep*(2000);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println(Thread.*currentThread*().getName()**  **+" in synchronized void method1() ended");**  **}**    **synchronized void method2(){**  **System.*out*.println(Thread.*currentThread*().getName()**  **+" in synchronized void method2() started");**  **try {**  **Thread.*sleep*(2000);**  **} catch (InterruptedException e) {**  **e.printStackTrace();**  **}**  **System.*out*.println(Thread.*currentThread*().getName()+**  **" in synchronized void method2() ended");**  **}**    **}**  **public class MyClass {**  **public static void main(String args[]) throws InterruptedException{**    **MyRunnable1 myRunnable1=new MyRunnable1();**    **Thread thread1=new Thread(myRunnable1,"Thread-1");**  **Thread thread2=new Thread(myRunnable1,"Thread-2");**  **thread1.start();**  **Thread.*sleep*(10);//Just to ensure Thread-1 starts before Thread-2**  **thread2.start();**      **}**  **}** |

**Answer.**  Here when Thread-1 is in **synchronized method1()** it must be **holding** [**lock on object’s monitor**](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) and will release lock on object’s monitor only when it exits **synchronized method1()**. So, Thread-2 will have to [wait](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) for Thread-1 to release lock on object’s monitor so that it could enter **synchronized method2()**.

**Likewise**, Thread-2 even cannot enter **synchronized method1()** which is being executed by Thread-1. Thread-2 will have to [wait](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) for Thread-1 to release lock on object’s monitor so that it could enter **synchronized method1()**.

**/\*OUTPUT**

**Thread-1 in synchronized void method1() started**

**Thread-1 in synchronized void method1() ended**

**Thread-2 in synchronized void method2() started**

**Thread-2 in synchronized void method2() ended**

**\*/**

### Output question 15.

|  |
| --- |
| **class** MyRunnable **implements** Runnable{    **public** **void** run(){              System.*out*.println("1 ");  **try** {  **this**.wait();            } **catch** (InterruptedException e) {                   e.printStackTrace();            }            System.*out*.println("2 ");       }  }  **public** **class** WaitNoParaMethod  {  **public** **static** **void** main(String[] args) {            MyRunnable myRunnable=**new** MyRunnable();            Thread thread1=**new** Thread(myRunnable,"Thread-1");            thread1.start();       }  } |

**Answer.**

IllegalMonitorStateException is thrown at runtime, as [wait()](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) method was called without acquiring lock on object monitor.

/\*OUTPUT

1

Exception in thread "Thread-1" java.lang.IllegalMonitorStateException

   at java.lang.Object.wait(Native Method)

   at java.lang.Object.wait(Object.java:503)

   at o15\_wait\_IllegalMoni.MyRunnable.run(WaitNoParaMethod.java:9)

   at java.lang.Thread.run(Unknown Source)

\*/

### Output question 16.

|  |
| --- |
| **public** **class** MyClass **implements** Runnable{       @Override  **public** **void** run() {            System.*out*.println("1");     }    **public** **static** **void** main(String[] args) {                   MyClass obj=**new** MyClass();        Thread thread1=**new** Thread(obj,"Thread-1");        thread1.start();        thread1.start();     }  } |

**Answer.**  [we cannot start Thread again](http://www.javamadesoeasy.com/2015/03/can-we-start-thread-again.html), doing so will throw runtimeException java.lang.IllegalThreadStateException. The reason is once run() method is executed by Thread, it goes into [**dead state**](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html).

Let’s take an example-

Thinking of starting thread again and calling start() method on it (which internally is going to call run() method) for us is some what like asking dead man to wake up and run. As, after completing his life person goes to **dead state**.

/\*OUTPUT

1

Exception in thread "main" java.lang.IllegalThreadStateException

   at java.lang.Thread.start(Unknown Source)

\*/

### Output question 17.

|  |
| --- |
| **class** MyThread **extends** Thread {  }  **public** **class** MyClass {  **public** **static** **void** main(String[] args) {            Thread thread1=**new** MyThread();            thread1.start();     }  } |

**Answer.**  Nothing will be printed in output.

**When we call start() method** on thread, **it internally calls run() method** with newly created thread. **So, if we don’t override run() method newly created thread won’t be called and nothing will happen**.

### Output question 18.

|  |
| --- |
| **class** MyThread **extends** Thread {  **public** **void** run() {            System.*out*.println("1");     }  **public** **void** start(){            System.*out*.println("2");     }    }  **public** **class** MyClass {  **public** **static** **void** main(String[] args) {            MyThread thread1=**new** MyThread();            thread1.start();       }  } |

**Answer.** **When we call start() method** on thread, **it internally calls run()** method with newly created thread. **So, if we override start() method, run() method will not be called** until we write code for calling run() method.

/\*OUTPUT

2

\*/

### Output question 19.

|  |
| --- |
| **class** MyRunnable1 **implements** Runnable{     @Override  **public** **void** run(){  **if**(Thread.*currentThread*().getName().equals("Thread-1"))  *method1*();  **else**  *method2*();     }  **static** **synchronized** **void** method1(){            System.*out*.println(Thread.*currentThread*().getName()+                         " in synchronized void method1() started");  **try** {                   Thread.*sleep*(2000);            } **catch** (InterruptedException e) {                   e.printStackTrace();            }            System.*out*.println(Thread.*currentThread*().getName()                         +" in synchronized void method1() ended");     }    **static** **synchronized** **void** method2(){            System.*out*.println(Thread.*currentThread*().getName()                         +" in synchronized void method2() started");  **try** {                   Thread.*sleep*(2000);            } **catch** (InterruptedException e) {               e.printStackTrace();            }            System.*out*.println(Thread.*currentThread*().getName()                         +" in synchronized void method2() ended");     }    }  **public** **class** MyClass {  **public** **static** **void** main(String args[]) **throws** InterruptedException{            MyRunnable1 object1=**new** MyRunnable1();            MyRunnable1 object2=**new** MyRunnable1();              Thread thread1=**new** Thread(object1,"Thread-1");            Thread thread2=**new** Thread(object2,"Thread-2");            thread1.start();            Thread.*sleep*(10);//Just to ensure Thread-1 starts before Thread-2            thread2.start();         }  } |

**Answer.**  It might confuse you a bit that threads are created on different objects. But, not to forgot that **multiple objects may exist but there is always one** [**class’s class object**](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html) **lock available**.

Here, when Thread-1 is in **static synchronized method1()** it must be **holding lock on class class’s object** and will release lock on class’s classobject only when it exits **static synchronized method1()**. So, Thread-2 will have to [wait](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) for Thread-1 to release lock on class’s classobject so that it could enter **static synchronized method2()**.

/\*OUTPUT

Thread-1 in synchronized void method1() started

Thread-1 in synchronized void method1() ended

Thread-2 in synchronized void method2() started

Thread-2 in synchronized void method2() ended

\*/

### Output question 20.

|  |
| --- |
| **class** MyRunnable1 **implements** Runnable{     @Override  **public** **void** run(){  **if**(Thread.*currentThread*().getName().equals("Thread-1"))                   method1();  **else**                   method2();     }  **synchronized** **void** method1(){            System.*out*.println(Thread.*currentThread*().getName()+                         " in synchronized void method1() started");  **try** {                   Thread.*sleep*(2000);            } **catch** (InterruptedException e) {                   e.printStackTrace();            }            System.*out*.println(Thread.*currentThread*().getName()+                         " in synchronized void method1() ended");     }    **synchronized** **void** method2(){            System.*out*.println(Thread.*currentThread*().getName()                         +" in synchronized void method2() started");  **try** {                   Thread.*sleep*(2000);            } **catch** (InterruptedException e) {                   e.printStackTrace();            }            System.*out*.println(Thread.*currentThread*().getName()                         +" in synchronized void method2() ended");     }    }  **public** **class** MyClass {  **public** **static** **void** main(String args[]) **throws** InterruptedException{            MyRunnable1 object1=**new** MyRunnable1();            MyRunnable1 object2=**new** MyRunnable1();              Thread thread1=**new** Thread(object1,"Thread-1");            Thread thread2=**new** Thread(object2,"Thread-2");            thread1.start();            Thread.*sleep*(10);//Just to ensure Thread-1 starts before Thread-2            thread2.start();         }  } |

**Answer.** Here when Thread-1 is in **synchronized method1()** it must be **holding** [**lock on object1’s monitor**](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html). Thread-2 will acquire lock on **object2’s monitor** and enter **synchronized method2()**.

/\*OUTPUT

Thread-1 in synchronized void method1() started

Thread-2 in synchronized void method2() started

Thread-1 in synchronized void method1() ended

Thread-2 in synchronized void method2() ended

\*/

### Output question 21.

|  |
| --- |
| **public** **class** MyClass **extends** Thread{  **public** **void** run() {  *method1*();     }    **public** **static** **void** method1() {  **synchronized** (**this**) {            System.out.println("2 ");            }     }    **public** **static** **void** main(String[] args) {  **new** Thread(**new** MyClass()).start();     }    } |

**Answer.**  We will face compilation error at line **synchronized** (**this**) can’t use in static context, because it’s not possible to [obtain lock on object](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) from static method. Though we can obtain lock on [**class’s class object**](http://www.javamadesoeasy.com/2015/03/acquiring-lock-on-class-2-ways-to.html), so **synchronized** (MyClass.class) will be a valid statement.

### Question 82.  Output question 22.

|  |
| --- |
| **public** **class** MyClass {  **public** **static** **void** main(String[] args) {            System.*out*.println("1 ");            InnerClass i=**new** InnerClass();            i.start();            System.*out*.println("2 ");     }    **static** **class** InnerClass **extends** Thread{  **public** **void** run()**throws** RuntimeException{  **throw** **new** RuntimeException();            }     }  } |

**Answer.** Program will compile as run() method can throw RuntimeException. 1 & 2 will be present in output and will throw java.lang.RuntimeException at runtime.

/\*OUTPUT

1

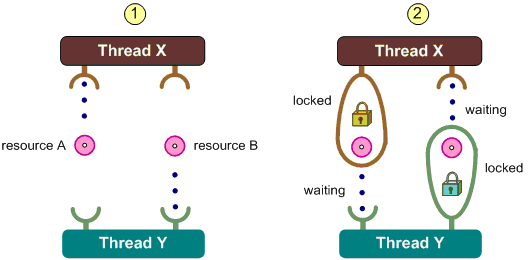
2

Exception in thread "Thread-0" java.lang.RuntimeException

   at o22.s$InnerClass.run(s.java:13)

\*/

### Deadlock in Java Multithreading

[**synchronized**](http://quiz.geeksforgeeks.org/synchronized-in-java/) keyword is used to make the class or method thread-safe which means only one thread can have lock of synchronized method and use it, other threads have to wait till the lock releases and anyone of them acquire that lock.  
It is important to use if our program is running in multi-threaded environment where two or more threads execute simultaneously. But sometimes it also causes a problem which is called [**Deadlock**](http://quiz.geeksforgeeks.org/operating-system-process-management-deadlock-introduction/). Below is a simple example of Deadlock condition.  
[](http://cdncontribute.geeksforgeeks.org/wp-content/uploads/threads_deadlock.gif)  
Image source: https://software.intel.com/en-us/articles/multi-threading-in-the-net-environment

|  |
| --- |
| // Java program to illustrate Deadlock  // in multithreading.  class Util  {      // Util class to sleep a thread      static void sleep(long millis)      {          try          {              Thread.sleep(millis);          }          catch (InterruptedException e)          {              e.printStackTrace();          }      }  }    // This class is shared by both threads  class Shared  {      // first synchronized method      synchronized void test1(Shared s2)      {          System.out.println("test1-begin");          Util.sleep(1000);            // taking object lock of s2 enters          // into test2 method          s2.test2(this);          System.out.println("test1-end");      }        // second synchronized method      synchronized void test2(Shared s1)      {          System.out.println("test2-begin");          Util.sleep(1000);            // taking object lock of s1 enters          // into test1 method          s1.test1(this);          System.out.println("test2-end");      }  }      class Thread1 extends Thread  {      private Shared s1;      private Shared s2;        // constructor to initialize fields      public Thread1(Shared s1, Shared s2)      {          this.s1 = s1;          this.s2 = s2;      }        // run method to start a thread      @Override      public void run()      {          // taking object lock of s1 enters          // into test1 method          s1.test1(s2);      }  }      class Thread2 extends Thread  {      private Shared s1;      private Shared s2;        // constructor to initialize fields      public Thread2(Shared s1, Shared s2)      {          this.s1 = s1;          this.s2 = s2;      }        // run method to start a thread      @Override      public void run()      {          // taking object lock of s2          // enters into test2 method          s2.test2(s1);      }  }      public class GFG  {      public static void main(String[] args)      {          // creating one object          Shared s1 = new Shared();            // creating second object          Shared s2 = new Shared();            // creating first thread and starting it          Thread1 t1 = new Thread1(s1, s2);          t1.start();            // creating second thread and starting it          Thread2 t2 = new Thread2(s1, s2);          t2.start();            // sleeping main thread          Util.sleep(2000);      }  } |

Run on IDE

Output : test1-begin

test2-begin

It is not recommended to run the above program with online IDE. We can copy the source code and run it on our local machine. We can see that it runs for indefinite time, because threads are in deadlock condition and doesn’t let code to execute. Now let’s see step by step what is happening there.

1. Thread t1 starts and calls test1 method by taking the object lock of s1.
2. Thread t2 starts and calls test2 method by taking the object lock of s2.
3. t1 prints test1-begin and t2 prints test-2 begin and both waits for 1 second, so that both threads can be started if any of them is not.
4. t1 tries to take object lock of s2 and call method test2 but as it is already acquired by t2 so it waits till it become free. It will not release lock of s1 until it gets lock of s2.
5. Same happens with t2. It tries to take object lock of s1 and call method test1 but it is already acquired by t1, so it has to wait till t1 release the lock. t2 will also not release lock of s2 until it gets lock of s1.
6. Now, both threads are in wait state, waiting for each other to release locks. Now there is a race around condition that who will release the lock first.
7. As none of them is ready to release lock, so this is the Dead Lock condition.
8. When you will run this program, it will be look like execution is paused.

**Detect Dead Lock condition**

We can also detect deadlock by running this program on cmd. We have to collect Thread Dump. Command to collect depends on OS type. If we are using Windows and Java 8, command is jcmd $PID Thread.print  
We can get PID by running jps command. Thread dump for above program is below:

5524:

2017-04-21 09:57:39

Full thread dump Java HotSpot(TM) 64-Bit Server VM (25.25-b02 mixed mode):

"DestroyJavaVM" #12 prio=5 os\_prio=0 tid=0x0000000002690800 nid=0xba8 waiting on condition [0x0000000000000000]

java.lang.Thread.State: RUNNABLE

"Thread-1" #11 prio=5 os\_prio=0 tid=0x0000000018bbf800 nid=0x12bc waiting for monitor entry [0x000000001937f000]

java.lang.Thread.State: BLOCKED (on object monitor)

at Shared.test1(GFG.java:15)

- waiting to lock (a Shared)

at Shared.test2(GFG.java:29)

- locked (a Shared)

at Thread2.run(GFG.java:68)

"Thread-0" #10 prio=5 os\_prio=0 tid=0x0000000018bbc000 nid=0x1d8 waiting for monitor entry [0x000000001927f000]

java.lang.Thread.State: BLOCKED (on object monitor)

at Shared.test2(GFG.java:25)

- waiting to lock (a Shared)

at Shared.test1(GFG.java:19)

- locked (a Shared)

at Thread1.run(GFG.java:49)

"Service Thread" #9 daemon prio=9 os\_prio=0 tid=0x000000001737d800 nid=0x1680 runnable [0x0000000000000000]

java.lang.Thread.State: RUNNABLE

"C1 CompilerThread2" #8 daemon prio=9 os\_prio=2 tid=0x000000001732b800 nid=0x17b0 waiting on condition [0x0000000000000000]

java.lang.Thread.State: RUNNABLE

"C2 CompilerThread1" #7 daemon prio=9 os\_prio=2 tid=0x0000000017320800 nid=0x7b4 waiting on condition [0x0000000000000000]

java.lang.Thread.State: RUNNABLE

"C2 CompilerThread0" #6 daemon prio=9 os\_prio=2 tid=0x000000001731b000 nid=0x21b0 waiting on condition [0x0000000000000000]

java.lang.Thread.State: RUNNABLE

"Attach Listener" #5 daemon prio=5 os\_prio=2 tid=0x0000000017319800 nid=0x1294 waiting on condition [0x0000000000000000]

java.lang.Thread.State: RUNNABLE

"Signal Dispatcher" #4 daemon prio=9 os\_prio=2 tid=0x0000000017318000 nid=0x1efc runnable [0x0000000000000000]

java.lang.Thread.State: RUNNABLE

"Finalizer" #3 daemon prio=8 os\_prio=1 tid=0x0000000002781800 nid=0x5a0 in Object.wait() [0x000000001867f000]

java.lang.Thread.State: WAITING (on object monitor)

at java.lang.Object.wait(Native Method)

- waiting on (a java.lang.ref.ReferenceQueue$Lock)

at java.lang.ref.ReferenceQueue.remove(Unknown Source)

- locked (a java.lang.ref.ReferenceQueue$Lock)

at java.lang.ref.ReferenceQueue.remove(Unknown Source)

at java.lang.ref.Finalizer$FinalizerThread.run(Unknown Source)

"Reference Handler" #2 daemon prio=10 os\_prio=2 tid=0x000000000277a800 nid=0x15b4 in Object.wait() [0x000000001857f000]

java.lang.Thread.State: WAITING (on object monitor)

at java.lang.Object.wait(Native Method)

- waiting on (a java.lang.ref.Reference$Lock)

at java.lang.Object.wait(Unknown Source)

at java.lang.ref.Reference$ReferenceHandler.run(Unknown Source)

- locked (a java.lang.ref.Reference$Lock)

"VM Thread" os\_prio=2 tid=0x00000000172e6000 nid=0x1fec runnable

"GC task thread#0 (ParallelGC)" os\_prio=0 tid=0x00000000026a6000 nid=0x21fc runnable

"GC task thread#1 (ParallelGC)" os\_prio=0 tid=0x00000000026a7800 nid=0x2110 runnable

"GC task thread#2 (ParallelGC)" os\_prio=0 tid=0x00000000026a9000 nid=0xc54 runnable

"GC task thread#3 (ParallelGC)" os\_prio=0 tid=0x00000000026ab800 nid=0x704 runnable

"VM Periodic Task Thread" os\_prio=2 tid=0x0000000018ba0800 nid=0x610 waiting on condition

JNI global references: 6

Found one Java-level deadlock:

=============================

"Thread-1":

waiting to lock monitor 0x0000000018bc1e88 (object 0x00000000d5d645a0, a Shared),

which is held by "Thread-0"

"Thread-0":

waiting to lock monitor 0x0000000002780e88 (object 0x00000000d5d645b0, a Shared),

which is held by "Thread-1"

Java stack information for the threads listed above:

===================================================

"Thread-1":

at Shared.test1(GFG.java:15)

- waiting to lock (a Shared)

at Shared.test2(GFG.java:29)

- locked (a Shared)

at Thread2.run(GFG.java:68)

"Thread-0":

at Shared.test2(GFG.java:25)

- waiting to lock (a Shared)

at Shared.test1(GFG.java:19)

- locked (a Shared)

at Thread1.run(GFG.java:49)

Found 1 deadlock.

As we can see there is clearly mentioned that found 1 deadlock. It is possible that the same message appears when you try on your machine.

**Avoid Dead Lock condition**

We can avoid dead lock condition by knowing its possibilities. It’s a very complex process and not easy to catch. But still if we try, we can avoid this. There are some methods by which we can avoid this condition. We can’t completely remove its possibility but we can reduce.

* **Avoid Nested Locks :**This is the main reason for dead lock. Dead Lock mainly happens when we give locks to multiple threads. Avoid giving lock to multiple threads if we already have given to one.
* **Avoid Unnecessary Locks :**We should have lock only those members which are required. Having lock on unnecessarily can lead to dead lock.
* **Using thread join :**Dead lock condition appears when one thread is waiting other to finish. If this condition occurs we can use Thread.join with maximum time you think the execution will take.

**Important Points :**

* If threads are waiting for each other to finish, then the condition is known as Deadlock.
* Deadlock condition is a complex condition which occurs only in case of multiple threads.
* Deadlock condition can break our code at run time and can destroy business logic.
* We should avoid this condition as much as we can.

## Concurrency

### What is ThreadPool?

ThreadPool is a pool of threads which **reuses a fixed number of threads**  to execute tasks.

At any point, **at most nThreads threads will be active processing tasks**. **If additional tasks are submitted when all threads are active, they will wait in the queue until a thread is available**.

ThreadPool implementation internally uses [LinkedBlockingQueue](http://www.javamadesoeasy.com/2015/03/custom-implementation-of.html) for adding and removing tasks.

In this post i will be using LinkedBlockingQueue provided by java Api, you can refer this post for [implementing ThreadPool using custom LinkedBlockingQueue](http://www.javamadesoeasy.com/2015/03/implementing-threadpool-using-custom.html).

We may use [Executor and ExecutorService framework in java](http://www.javamadesoeasy.com/2015/03/executor-and-executorservice-framework.html) for managing thread life cycle.

### What is ThreadFactory? Why is it implemented?

An object that creates new threads on demand. Using thread factories removes hardwiring of calls to [new Thread](https://docs.oracle.com/javase/8/docs/api/java/lang/Thread.html#Thread-java.lang.Runnable-), enabling applications to use special thread subclasses, priorities, etc.

The simplest implementation of this interface is just:

class SimpleThreadFactory implements ThreadFactory {

public Thread newThread(Runnable r) {

return new Thread(r);

}

}

The [Executors.defaultThreadFactory()](https://docs.oracle.com/javase/8/docs/api/java/util/concurrent/Executors.html#defaultThreadFactory--) method provides a more useful simple implementation, that sets the created thread context to known values before returning it.

**Since:**

1.5

### What is ThreadGroup? Why is it used?

Java provides a convenient way to group multiple threads in a single object. In such way, we can suspend, resume or interrupt group of threads by a single method call.

Java thread group is implemented by java.lang.ThreadGroup class.

|  |  |  |
| --- | --- | --- |
| **No.** | **Constructor** | **Description** |
| 1) | ThreadGroup(String name) | creates a thread group with given name. |
| 2) | ThreadGroup(ThreadGroup parent, String name) | creates a thread group with given parent group and name. |

Important methods of ThreadGroup class

There are many methods in ThreadGroup class. A list of important methods are given below.

|  |  |  |
| --- | --- | --- |
| **No.** | **Method** | **Description** |
| 1) | int activeCount() | returns no. of threads running in current group. |
| 2) | int activeGroupCount() | returns a no. of active group in this thread group. |
| 3) | void destroy() | destroys this thread group and all its sub groups. |
| 4) | String getName() | returns the name of this group. |
| 5) | ThreadGroup getParent() | returns the parent of this group. |
| 6) | void interrupt() | interrupts all threads of this group. |
| 7) | void list() | prints information of this group to standard console. |

Let's see a code to group multiple threads.

1. ThreadGroup tg1 = **new** ThreadGroup("Group A");
2. Thread t1 = **new** Thread(tg1,**new** MyRunnable(),"one");
3. Thread t2 = **new** Thread(tg1,**new** MyRunnable(),"two");
4. Thread t3 = **new** Thread(tg1,**new** MyRunnable(),"three");

Now all 3 threads belong to one group. Here, tg1 is the thread group name, MyRunnable is the class that implements Runnable interface and "one", "two" and "three" are the thread names.

Now we can interrupt all threads by a single line of code only.

1. Thread.currentThread().getThreadGroup().interrupt();

### Explain about the shutDownHook in java.

The shutdown hook can be used to perform cleanup resource or save the state when JVM shuts down normally or abruptly. Performing clean resource means closing log file, sending some alerts or something else. So if you want to execute some code before JVM shuts down, use shutdown hook.

**When does the JVM shut down?**

The JVM shuts down when:

* user presses ctrl+c on the command prompt
* System.exit(int) method is invoked
* user logoff
* user shutdown etc.

**The addShutdownHook(Thread hook) method**

The addShutdownHook() method of Runtime class is used to register the thread with the Virtual Machine. Syntax:

1. **public** **void** addShutdownHook(Thread hook){}

The object of Runtime class can be obtained by calling the static factory method getRuntime(). For example:

Runtime r = Runtime.getRuntime();

**Factory method**

The method that returns the instance of a class is known as factory method.

**Simple example of Shutdown Hook**

1. **class** MyThread **extends** Thread{
2. **public** **void** run(){
3. System.out.println("shut down hook task completed..");
4. }
5. }
7. **public** **class** TestShutdown1{
8. **public** **static** **void** main(String[] args)**throws** Exception {
10. Runtime r=Runtime.getRuntime();
11. r.addShutdownHook(**new** MyThread());
13. System.out.println("Now main sleeping... press ctrl+c to exit");
14. **try**{Thread.sleep(3000);}**catch** (Exception e) {}
15. }
16. }

Output:Now main sleeping... press ctrl+c to exit

shut down hook task completed..

### Difference between call() and the run() methods?

Callable needs to implement call() method while a Runnable needs to implement run() method.

A Callable can return a value but a Runnable cannot.

A Callable can throw checked exception but a Runnable cannot.

A Callable can be used with ExecutorService#invokeXXX methods but a Runnable cannot be.

public interface Runnable {

void run();

}

public interface Callable<V> {

V call() throws Exception;

}

### What is Java.util.concurrent.CyclicBarrier ?

yclicBarrier is used to make threads wait for each other. It is used when different threads process a part of computation and when all threads have completed the execution, the result needs to be combined in the parent thread. In other words, a CyclicBarrier is used when multiple thread carry out different sub tasks and the output of these sub tasks need to be combined to form the final output. After completing its execution, threads call await() method and wait for other threads to reach the barrier. Once all the threads have reached, the barriers then give the way for threads to proceed.

**Working of CyclicBarrier**

CyclicBarriers are defined in java.util.concurrent package. First a new instance of a CyclicBarriers is created specifying the number of threads that the barriers should wait upon.

**CyclicBarrier newBarrier = new CyclicBarrier(numberOfThreads);**

Each and every thread does some computation and after completing it’s execution, calls await() methods as shown:

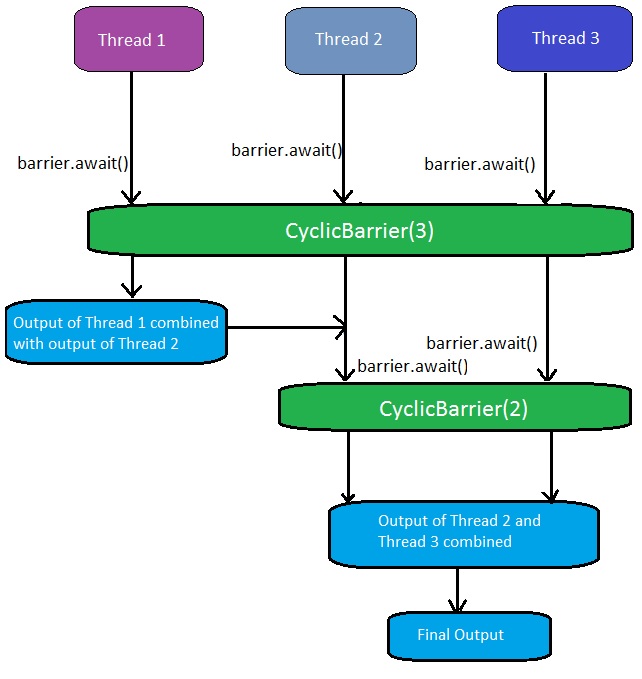
public void run()

{

// thread does the computation

newBarrier.await();

}

**Image to represent the working of CyclicBarrier:**  
[](http://cdncontribute.geeksforgeeks.org/wp-content/uploads/barrier.jpg)  
Once the number of threads that called await() equals **numberOfThreads**, the barrier then gives a way for the waiting threads. The CyclicBarrier can also be initialized with some action that is performed once all the threads have reached the barrier. This action can combine/utilize the result of computation of individual thread waiting in the barrier.

Runnable action = ...

//action to be performed when all threads reach the barrier;

CyclicBarrier newBarrier = new CyclicBarrier(numberOfThreads, action);

**Important Methods of CyclicBarrier:**

1. **getParties:** Returns the number of parties required to trip this barrier.  
   **Syntax:**

public int getParties()

**Returns:**  
the number of parties required to trip this barrier

1. **reset:** Resets the barrier to its initial state.  
   **Syntax:**

public void reset()

**Returns:**  
void but resets the barrier to its initial state. If any parties are currently waiting at the barrier, they will return with a BrokenBarrierException.

1. **isBroken:** Queries if this barrier is in a broken state.  
   **Syntax:**

public boolean isBroken()

**Returns:**  
true if one or more parties broke out of this barrier due to interruption or timeout since construction or the last reset, or a barrier action failed due to an exception; false otherwise.

1. **getNumberWaiting:** Returns the number of parties currently waiting at the barrier.  
   **Syntax:**

public int getNumberWaiting()

**Returns:**  
the number of parties currently blocked in await()

1. **await:** Waits until all parties have invoked await on this barrier.  
   **Syntax:**

public int await() throws InterruptedException, BrokenBarrierException

**Returns:**  
the arrival index of the current thread, where index getParties() – 1 indicates the first to arrive and zero indicates the last to arrive.

1. **await:** Waits until all parties have invoked await on this barrier, or the specified waiting time elapses.  
   **Syntax:**
2. public int await(long timeout, TimeUnit unit)
3. throws InterruptedException,

BrokenBarrierException, TimeoutException

**Returns:**  
the arrival index of the current thread, where index getParties() – 1 indicates the first to arrive and zero indicates the last to arrive

|  |
| --- |
| //JAVA program to demonstrate execution on Cyclic Barrier    import java.util.concurrent.TimeUnit;  import java.util.concurrent.TimeoutException;  import java.util.concurrent.BrokenBarrierException;  import java.util.concurrent.CyclicBarrier;    class Computation1 implements Runnable  {      public static int product = 0;      public void run()      {          product = 2 \* 3;          try          {              Tester.newBarrier.await();          }          catch (InterruptedException | BrokenBarrierException e)          {              e.printStackTrace();          }      }  }    class Computation2 implements Runnable  {      public static int sum = 0;      public void run()      {          // check if newBarrier is broken or not          System.out.println("Is the barrier broken? - " + Tester.newBarrier.isBroken());          sum = 10 + 20;          try          {              Tester.newBarrier.await(3000, TimeUnit.MILLISECONDS);                // number of parties waiting at the barrier              System.out.println("Number of parties waiting at the barrier "+              "at this point = " + Tester.newBarrier.getNumberWaiting());          }          catch (InterruptedException | BrokenBarrierException e)          {              e.printStackTrace();          }          catch (TimeoutException e)          {              e.printStackTrace();          }      }  }      public class Tester implements Runnable  {      public static CyclicBarrier newBarrier = new CyclicBarrier(3);        public static void main(String[] args)      {          // parent thread          Tester test = new Tester();            Thread t1 = new Thread(test);          t1.start();      }      public void run()      {          System.out.println("Number of parties required to trip the barrier = "+          newBarrier.getParties());          System.out.println("Sum of product and sum = " + (Computation1.product +          Computation2.sum));            // objects on which the child thread has to run          Computation1 comp1 = new Computation1();          Computation2 comp2 = new Computation2();            // creation of child thread          Thread t1 = new Thread(comp1);          Thread t2 = new Thread(comp2);            // moving child thread to runnable state          t1.start();          t2.start();            try          {              Tester.newBarrier.await();          }          catch (InterruptedException | BrokenBarrierException e)          {              e.printStackTrace();          }            // barrier breaks as the number of thread waiting for the barrier          // at this point = 3          System.out.println("Sum of product and sum = " + (Computation1.product +          Computation2.sum));            // Resetting the newBarrier          newBarrier.reset();          System.out.println("Barrier reset successful");      }  } |

**Output:**

<Number of parties required to trip the barrier = 3

Sum of product and sum = 0

Is the barrier broken? - false

Number of parties waiting at the barrier at this point = 0

Sum of product and sum = 36

Barrier reset successful

**Explanation:** The value of (sum + product) = 0 is printed on the console because the child thread has’t yet ran to set the values of sum and product variable. Following this, (sum + product) = 36 is printed on the console because the child threads ran setting the values of sum and product. Furthermore, the number of waiting thread on the barrier reached 3, due to which the barrier then allowed all thread to pass and finally 36 was printed. The value of “Number of parties waiting at the barrier at this point” = 0 because all the three threads had already called await() method and hence, the barrier is no longer active. In the end, newBarrier is reset and can be used again.

**BrokenBarrierException**

A barrier breaks when any of the waiting thread leaves the barrier. This happens when one or more waiting thread is interrupted or when the waiting time is completed because the thread called the await() methods with a timeout as follows:

newBarrier.await(1000, TimeUnit.MILLISECONDS);

// thread calling this await()

// methods waits for only 1000 milliseconds.

When the barrier breaks due to one of more participating threads, the await() methods of all the other threads throws a BrokenThreadException. Whereas, the threads that are already waiting in the barriers have their await() call terminated.

**Difference between a CyclicBarrier and a CountDownLatch**

* A CountDownLatch can be used only once in a program(until it’s count reaches 0).
* A CyclicBarrier can be used again and again once all the threads in a barriers is released.

### Important point of CyclicBarrier in Java

1. CyclicBarrier can perform a completion task once all thread reaches to the barrier, This can be provided while creating CyclicBarrier.

2. If CyclicBarrier is initialized with 3 parties means 3 thread needs to call await method to break the barrier.

3. [The thread will block](http://javarevisited.blogspot.sg/2012/02/what-is-blocking-methods-in-java-and.html) on await() until all parties reach to the barrier, another thread interrupt or await timed out.

4. If another thread interrupts the thread which is waiting on barrier it will throw BrokernBarrierException as shown below:

java.util.concurrent.**BrokenBarrierException**  
        at java.util.concurrent.**CyclicBarrier**.dowait(**CyclicBarrier**.java:172)  
        at java.util.concurrent.**CyclicBarrier**.await(**CyclicBarrier**.java:327)

5.CyclicBarrier.reset() put Barrier on its initial state, other thread which is waiting or not yet reached barrier will terminate with java.util.concurrent.BrokenBarrierException.

That's all on  What is CyclicBarrier in Java When to use CyclicBarrier in Java and a Simple Example of How to use CyclicBarrier in Java . We have also seen the difference between CountDownLatch and CyclicBarrier in Java and got some idea where we can use CyclicBarrier in Java Concurrent code.

### What is executor framework in java?

**Answer.** This is very important question to start your interview with. [Executor and ExecutorService](http://www.javamadesoeasy.com/2015/03/executor-and-executorservice-framework.html) are used for  following purposes >

* creating thread in java,
* starting threads in java,
* managing whole [life cycle of Threads](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html) in java.

Executor creates [pool of threads](http://www.javamadesoeasy.com/2015/03/implement-thread-pool-in-java.html) and manages life cycle of all threads in it.

In Executor framework, **Executor** interface and  **ExecutorService**  class are most prominently used in java.

*Executor* interface defines very important execute() method which executes command in java.

*ExecutorService* interface extends **Executor** interface.

An Executor interface provides following type of methods >

* methods for managing termination and
* methods that can produce a Future for tracking progress of tasks in java.

An Executor that provides methods to manage termination and methods that can produce a Future for tracking progress of one or more asynchronous tasks.

### What are differences between execute() and submit() method of executor framework in java?

**Answer.** This is basic thread concurrency interview question, beforehand you must know about [Executor Service Framework](http://www.javamadesoeasy.com/2015/03/executor-and-executorservice-framework.html).

|  |  |
| --- | --- |
| **execute()** method | **submit()** method |
| **execute()** method is defined in *Executor* interface in java. | **submit()** method is defined in *ExecutorService* interface in java. |
| It can be used for executing **runnable task in java in java**. | It can be used for executing **runnable  task** or **callable task**, submitted callable returns future and Future's get method will return the task's result in java. |
| **Signature of execute method is  >*****void*** *execute****(Runnable*** *task****)*** | submit method has 3 forms >  *<T> Future<T>* ***submit****(Callable<T>* ***task****)*  Submits a callable ***task*** for execution.  Method **returns** a Future which represents pending results of the task.  Once task is completed Future's get method will return the task's result.  *<T> Future<T>* ***submit****(Runnable* ***task****, T* ***result****)*  Submits a Runnable ***task*** for execution.  Method **returns** a Future which represents that task. Once task is completed Future's get method will return ***result***.  *Future<?>* ***submit****(Runnable* ***task****)*  Submits a Runnable ***task*** for execution.  Method **returns** a Future which represents that task. Once task is completed Future's get method will return null. |

### What is Semaphore in java 7?

**Answer.**  This is very important thread concurrency interview question for freshers and experienced. A [**semaphore**](http://www.javamadesoeasy.com/2015/03/semaphore-in-java.html) controls access to a shared resource by using permits in java.

* **If permits are greater than zero**, then semaphore **allow access to shared resource**.
* **If permits are zero or less than zero**, then semaphore **does not allow access to shared resource in java**.

These permits are sort of counters, which allow access to the shared resource. Thus, to access the resource, a thread must be granted a permit from the semaphore in java.

*Semaphore has 2 constructors >*

* **Semaphore**(int ***permits***)

***permits*** is the **initial number of permits available**.

This value can be negative, in which case releases must occur before any acquires will be granted, ***permits*** is number of threads that can access shared resource at a time.

If ***permits*** is 1, then only one threads that can access shared resource at a time in java.

* **Semaphore**(int **permits**, boolean **fair**)

**permits** is the initial number of permits available.

This value can be negative, in which case releases must occur before any acquires will be granted.

By setting **fair** to **true**, we ensure that **waiting threads are granted a permit in the order in which they requested access**.

*Semaphore’s acquire( ) method has 2 forms :*

* void **acquire**( ) throws InterruptedException

Acquires a permit if one is available and **reduces the number of available permits by 1**.

If no permit is available then the current thread becomes dormant until

>some other thread calls release() method on this semaphore or,

>some other thread interrupts the current thread.

* void **acquire**(int **permits**) throws InterruptedException

Acquires **permits** number of permits if available and **reduces the number of available permits by permits.**

If **permits** *number of* permits are not available then the current thread becomes dormant until  one of the following things happens -

>some other thread calls release() method on this semaphore and available permits become equal to **permits** or,

>some other thread interrupts the current thread.

*Semaphore’s release( ) method has 2 forms in java :*

* void **release**( )

Releases a permit and **increases the number of available permits by 1**.

For releasing lock by calling release() method it’s not mandatory that thread must have acquired permit by calling acquire() method in java.

* void **release**(int **permits**)

Releases **permits** number of permits and **increases the number of available permits by permits.**

For releasing lock by calling release(int *permits*) method it’s not mandatory that thread must have acquired permit by calling acquire()/acquire(int permit) method in java.

### How can you implement Producer Consumer pattern using Semaphore in java?

**Answer.** This is tricky thread concurrency interview question for even experienced guys. [**Semaphore**](http://www.javamadesoeasy.com/2015/03/semaphore-in-java.html) **on producer is created with permit =1**. So, that **producer can get the permit to produce**.

**Semaphore on consumer is created with permit =0**. So, that **consumer could wait for permit to consume**. [because initially producer hasn’t produced any product]

**Producer gets permit by** calling **semaphoreProducer.acquire()** and **starts producing**, **after producing** it calls **semaphoreConsumer.release()**. So, that **consumer could get the  permit to consume**.

|  |
| --- |
| **semaphoreProducer.acquire();**  **System.*out*.println("Produced : "+i);**  **semaphoreConsumer.release();** |

**Consumer gets permit by** calling **semaphoreConsumer.acquire()** and **starts consuming**, **after consuming** it calls **semaphoreProducer.release()**. So, that **producer could get the  permit to produce**.

|  |
| --- |
| **semaphoreConsumer.acquire();**  **System.*out*.println("Consumed : "+i);**  **semaphoreProducer.release();** |

|  |
| --- |
| **import** java.util.concurrent.Semaphore;  /\*\* Copyright (c), AnkitMittal [JavaMadeSoEasy.com](http://javamadesoeasy.com/) \*/  **public** **class** ConsumerProducer{    **public** **static** **void** main(String[] args) {            Semaphore semaphoreProducer=**new** Semaphore(1);            Semaphore semaphoreConsumer=**new** Semaphore(0);            System.*out*.println("semaphoreProducer permit=1 | semaphoreConsumer permit=0");          Producer producer=**new** Producer(semaphoreProducer,semaphoreConsumer);        Consumer consumer=**new** Consumer(semaphoreConsumer,semaphoreProducer);           Thread producerThread = **new** Thread(producer, "ProducerThread");         Thread consumerThread = **new** Thread(consumer, "ConsumerThread");         producerThread.start();         consumerThread.start();     }  }  /\*\*  \* Producer Class.  \*/  **class** Producer **implements** Runnable{       Semaphore semaphoreProducer;     Semaphore semaphoreConsumer;      **public** Producer(Semaphore semaphoreProducer,Semaphore semaphoreConsumer) {  **this**.semaphoreProducer=semaphoreProducer;  **this**.semaphoreConsumer=semaphoreConsumer;     }  **public** **void** run() {  **for**(**int** i=1;i<=5;i++){  **try** {  **semaphoreProducer.acquire();**  **System.*out*.println("Produced : "+i);**  **semaphoreConsumer.release();**                     } **catch** (InterruptedException e) {                         e.printStackTrace();                   }            }     }  }  /\*\*  \* Consumer Class.  \*/  **class** Consumer **implements** Runnable{     Semaphore semaphoreConsumer;     Semaphore semaphoreProducer;    **public** Consumer(Semaphore semaphoreConsumer,Semaphore semaphoreProducer) {  **this**.semaphoreConsumer=semaphoreConsumer;  **this**.semaphoreProducer=semaphoreProducer;     }  **public** **void** run() {    **for**(**int** i=1;i<=5;i++){  **try** {  **semaphoreConsumer.acquire();**  **System.*out*.println("Consumed : "+i);**  **semaphoreProducer.release();**                   } **catch** (InterruptedException e) {                         e.printStackTrace();                   }            }     }    }  /\*OUTPUT  semaphoreProducer permit=1 | semaphoreConsumer permit=0  Produced : 1  Consumed : 1  Produced : 2  Consumed : 2  Produced : 3  Consumed : 3  Produced : 4  Consumed : 4  Produced : 5  Consumed : 5  \*/ |

Let’s discuss output in detail, to get better understanding of how we have used Semaphore for implementing Producer Consumer pattern >

**Note** : (I have mentioned output in **green** text and it’s explanation is given in line immediately followed by it)

semaphoreProducer permit=1 | semaphoreConsumer permit=0

semaphoreProducer created with permit=1. So, that producer can get the permit to produce |

semaphoreConsumer created with permit=0. So, that consumer could wait for permit to consume.

semaphoreProducer.acquire() is called, Producer has got the permit and it can produce [Now, semaphoreProducer permit=0]

Produced : 1   [as producer has got permit, it is producing]

semaphoreConsumer.release() is called, Permit has been released on semaphoreConsumer means consumer can consume [Now, semaphoreConsumer permit=1]

semaphoreConsumer.acquire() is called, Consumere has got the permit and it can consume [Now, semaphoreConsumer permit=0]

Consumed : 1 [as consumer has got permit, it is consuming]

semaphoreProducer.release() is called, Permit has been released on semaphoreProducer means producer can produce [Now, semaphoreProducer permit=1]

Produced : 2

Consumed : 2

Produced : 3

Consumed : 3

Produced : 4

Consumed : 4

Produced : 5

Consumed : 5

### How can you implement your own Semaphore?

**Answer.** Experienced developers must be able to answer this thread concurrency interview question.

1) Custom Semaphore in java >

In previous tutorial we read how to use  [**Semaphore in java**](http://www.javamadesoeasy.com/2015/03/semaphore-in-java.html). In this post we will be implementing **custom Semaphore**. **This post intends you give you basic functionality of Semaphore using your own java code**

A custom  **semaphore** controls access to a shared resource by using permits.

* **If permits are greater than zero**, then semaphore **allow access to shared resource**.
* **If permits are zero or less than zero**, then semaphore **does not allow access to shared resource**.

These permits are sort of counters, which allow access to the shared resource. Thus, to access the resource, a thread must be granted a permit from the semaphore.

1.1) Custom Semaphore’s **constructors** in java>

* **SemaphoreCustom** (int ***permits***)

***permits*** is the **initial number of permits available**.

This value can be negative, in which case releases must occur before any acquires will be granted, ***permits*** is number of threads that can access shared resource at a time.

If ***permits*** is 1, then only one threads that can access shared resource at a time.

**CODE >**

|  |
| --- |
| **public SemaphoreCustom(int permits) {**  **this.permits=permits;**  **}** |

1.2) Custom Semaphore’s **acquire()** method :

* void **acquire**( ) throws InterruptedException

Acquires a permit if one is available and **decrements the number of available permits by 1**.

If no permit is available then the current thread waits until one of the following things happen >

>some other thread calls release() method on this semaphore or,

>some other thread interrupts the current thread.

**CODE >**

|  |
| --- |
| **public synchronized void acquire() throws InterruptedException {**  **//Acquires a permit, if permits is greater than 0 decrements**  **//the number of available permits by 1.**  **if(permits > 0){**  **permits--;**  **}**  **//permit is not available wait, when thread**  **//is notified it decrements the permits by 1**  **else{**  **this.wait();**  **permits--;**  **}**  **}** |

1.3) Custom Semaphore’s **release()** method :

* void **release**( )

Releases a permit and **increases the number of available permits by 1**.

For releasing lock by calling release() method it’s not mandatory that thread must have acquired permit by calling acquire() method.

**CODE >**

|  |
| --- |
| **public synchronized void release() {**  **//increases the number of available permits by 1.**  **permits++;**    **//If permits are greater than 0, notify waiting threads.**  **if(permits > 0)**  **this.notify();**  **}** |

2) Custom Semaphore’s code in java >

|  |
| --- |
| /\*\* Copyright (c), AnkitMittal [JavaMadeSoEasy.com](http://javamadesoeasy.com/) \*/  **/\*\***  **\* @author AnkitMittal**  **\* Copyright (c), AnkitMittal .**  **\* All Contents are copyrighted and must not be reproduced in any form.**  **\* A semaphore controls access to a shared resource by using permits.**  **- If permits are greater than zero, then semaphore**  **allow access to shared resource.**  **- If permits are zero or less than zero, then semaphore**  **does not allow access to shared resource.**  **\*/**  **class SemaphoreCustom{**    **private int permits;**    **/\*\* permits is the initial number of permits available.**  **This value can be negative, in which case releases must occur**  **before any acquires will be granted, permits is number of threads**  **that can access shared resource at a time.**  **If permits is 1, then only one threads that can access shared**  **resource at a time.**  **\*/**  **public SemaphoreCustom(int permits) {**  **this.permits=permits;**  **}**  **/\*\*Acquires a permit if one is available and decrements the**  **number of available permits by 1.**  **If no permit is available then the current thread waits**  **until one of the following things happen >**  **>some other thread calls release() method on this semaphore or,**  **>some other thread interrupts the current thread.**  **\*/**  **public synchronized void acquire() throws InterruptedException {**  **//Acquires a permit, if permits is greater than 0 decrements**  **//the number of available permits by 1.**  **if(permits > 0){**  **permits--;**  **}**  **//permit is not available wait, when thread**  **//is notified it decrements the permits by 1**  **else{**  **this.wait();**  **permits--;**  **}**  **}**  **/\*\* Releases a permit and increases the number of available permits by 1.**  **For releasing lock by calling release() method it’s not mandatory**  **that thread must have acquired permit by calling acquire() method.**  **\*/**  **public synchronized void release() {**  **//increases the number of available permits by 1.**  **permits++;**    **//If permits are greater than 0, notify waiting threads.**  **if(permits > 0)**  **this.notify();**  **}**  **}** |

**3) Program** to demonstrate usage of Custom Semaphore in java >

|  |
| --- |
| /\*\* Copyright (c), AnkitMittal [JavaMadeSoEasy.com](http://javamadesoeasy.com/) \*/  **/\*\***  **\* @author AnkitMittal**  **\* Copyright (c), AnkitMittal .**  **\* All Contents are copyrighted and must not be reproduced in any form.**  **\* A semaphore controls access to a shared resource by using permits.**  **- If permits are greater than zero, then semaphore**  **allow access to shared resource.**  **- If permits are zero or less than zero, then semaphore**  **does not allow access to shared resource.**  **\*/**  **class SemaphoreCustom{**    **private int permits;**    **/\*\* permits is the initial number of permits available.**  **This value can be negative, in which case releases must occur**  **before any acquires will be granted, permits is number of threads**  **that can access shared resource at a time.**  **If permits is 1, then only one threads that can access shared**  **resource at a time.**  **\*/**  **public SemaphoreCustom(int permits) {**  **this.permits=permits;**  **}**  **/\*\*Acquires a permit if one is available and decrements the**  **number of available permits by 1.**  **If no permit is available then the current thread waits**  **until one of the following things happen >**  **>some other thread calls release() method on this semaphore or,**  **>some other thread interrupts the current thread.**  **\*/**  **public synchronized void acquire() throws InterruptedException {**  **//Acquires a permit, if permits is greater than 0 decrements**  **//the number of available permits by 1.**  **if(permits > 0){**  **permits--;**  **}**  **//permit is not available wait, when thread**  **//is notified it decrements the permits by 1**  **else{**  **this.wait();**  **permits--;**  **}**  **}**  **/\*\* Releases a permit and increases the number of available permits by 1.**  **For releasing lock by calling release() method it’s not mandatory**  **that thread must have acquired permit by calling acquire() method.**  **\*/**  **public synchronized void release() {**  **//increases the number of available permits by 1.**  **permits++;**    **//If permits are greater than 0, notify waiting threads.**  **if(permits > 0)**  **this.notify();**  **}**  **}**  /\*\*  \* Main class, for testing SemaphoreCustom  \*/  **public** **class** SemaphoreCustomTest {  **static** **int** *SharedValue*=0;    **public** **static** **void** main(String[] args) {            SemaphoreCustom semaphore=**new** SemaphoreCustom(1);            System.*out*.println("Semaphore with 1 permit has been created");              IncrementThread incrementThread=**new** IncrementThread(semaphore);  **new** Thread(incrementThread,"incrementThread").start();              DecrementThread decrementThread=**new** DecrementThread(semaphore);  **new** Thread(decrementThread,"decrementThread").start();       }  }    **class** IncrementThread **implements** Runnable{     SemaphoreCustom semaphoreCustom;    **public** IncrementThread(SemaphoreCustom semaphoreCustom) {  **this**.semaphoreCustom=semaphoreCustom;     }    **public** **void** run(){            System.*out*.println(Thread.*currentThread*().getName()+                         " is waiting for permit");  **try** {                   semaphoreCustom.acquire();                   System.*out*.println(Thread.*currentThread*().getName()+                                " has got permit");    **for**(**int** i=0;i<5;i++){                         Thread.*sleep*(1000);                         System.*out*.println(Thread.*currentThread*().getName()+                                       " > "+SemaphoreCustomTest.*SharedValue*++);                   }              } **catch** (InterruptedException e) {                   e.printStackTrace();            }              System.*out*.println(Thread.*currentThread*().getName()+                         " has released permit");            semaphoreCustom.release();       }    }    **class** DecrementThread **implements** Runnable{     SemaphoreCustom semaphoreCustom;  **public** DecrementThread(SemaphoreCustom semaphoreCustom){  **this**.semaphoreCustom=semaphoreCustom;     }    **public** **void** run(){            System.*out*.println(Thread.*currentThread*().getName()+                         " is waiting for permit");    **try** {                   semaphoreCustom.acquire();                   System.*out*.println(Thread.*currentThread*().getName()+                                " has got permit");    **for**(**int** i=0;i<5;i++){                         Thread.*sleep*(1000);                         System.*out*.println(Thread.*currentThread*().getName()+                                       " >"+SemaphoreCustomTest.*SharedValue*--);                   }              } **catch** (InterruptedException e) {                   e.printStackTrace();            }                System.*out*.println(Thread.*currentThread*().getName()+                         " has released permit");            semaphoreCustom.release();         }    }  /\*OUTPUT  Semaphore with 1 permit has been created  incrementThread is waiting for permit  incrementThread has got permit  decrementThread is waiting for permit  incrementThread > 0  incrementThread > 1  incrementThread > 2  incrementThread > 3  incrementThread > 4  incrementThread has released permit  decrementThread has got permit  decrementThread >5  decrementThread >4  decrementThread >3  decrementThread >2  decrementThread >1  decrementThread has released permit  \*/ |

### What is significance of atomic classes in java 7?

**Answer.** Another important and basic thread concurrency interview question for freshers. Java provides some classes in [**java.util.concurrent.atomic**](http://www.javamadesoeasy.com/2015/03/atomic-operations-in-java.html) which offers an alternative to the other [synchronization](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) in java.

*Classes found in* ***java.util.concurrent.atomic*** *are >*

* **AtomicInteger**,
* **AtomicLong,** and
* **AtomicBoolean.**

*Methods provided by these classes >*

* **get( ),**
* **set( ),**
* **getAndSet( )**,
* **compareAndSet( ), and**
* **decrementAndGet( ).**

In [multithreading](http://www.javamadesoeasy.com/2015/03/what-is-thread-in-java.html) environment we can use these classes without any explicit synchronization, as all these classes are [thread safe](http://www.javamadesoeasy.com/2015/03/guidelines-to-thread-safe-code-most.html) in java.

For more information on atomic read [**Atomic operations in java**](http://www.javamadesoeasy.com/2015/03/atomic-operations-in-java.html).

### What are Future and Callable? How are they related in java?

**Answer.**  This is **very very important** thread concurrency interview question. They are widely used in thread concurrency.

[*Future<V>*](http://www.javamadesoeasy.com/2015/03/executor-and-executorservice-framework.html) interface provides methods >

* for **returning result** of computation, wait until computation is not completed and
* for **cancelling** the computation in between.

*Future Methods >*

*V* ***get****()* method returns the result of computation, method waits for computation to complete.

*cancel method* cancels the task.

[*Callable<V>*](http://www.javamadesoeasy.com/2015/03/executor-and-executorservice-framework.html) interface provides method for computing a result and returning that computed result or throws an exception if unable to do so

Any class implementing Callable interface must override ***call****()* method for computing a result.

Method returns computed result or throws an exception if unable to do so in java.

what type of results Callable’s call() method can return in java?

The Callable<V> is a generic interface, so its call method can return generic result specified by *V*.

How Callable and Future are related?

If you submit a Callable object to an Executor returned object is of Future type.

|  |
| --- |
| Future<Double> futureDouble=executor.submit(**new** SquareDoubleCallable(2.2)); |

where, SquareDoubleCallable is a class which implements Callable.

This Future object can check the status of a Callable call’s method and wait until Callable’s call() method is not completed.

### Similarity and differences between java.util.concurrent.Callable and  java.lang.Runnable in java?

**Answer.** This is basic thread concurrency interview question.

Similarity between java.util.concurrent.Callable and  java.lang.Runnable in java?

Instances of class which implements callable are executed by another thread.

Difference between java.util.concurrent.Callable and  java.lang.Runnable in java?

Class implementing Callable interface must override call() method. call() method returns computed result or throws an exception if unable to do so.

Class implementing Runnable interface must override run() method.

A Runnable does not return a result and can neither throw a checked exception in java.

### What is CountDownLatch in java?

**Answer.**  This is very important thread concurrency interview question. Fresher and experienced bost be well versed with this. There might be situation where we might like our thread to wait until one or more threads completes certain operation in java.

A [CountDownLatch](http://www.javamadesoeasy.com/2015/03/countdownlatch-in-java.html) is initialized with a given ***count*** .

***count*** specifies the number of events that must occur before latch is released.

Every time a event happens ***count*** is reduced by 1. Once count reaches 0 latch is released.

*CountDownLatch’s  constructor >*

* **CountDownLatch**(int ***count***)

CountDownLatch is initialized with given ***count***.

***count*** specifies the number of events that must occur befor latch is released.

*CountDownLatch’s await() method has 2 forms :*

* void **await**( ) throws InterruptedException

Causes the current thread to wait until  one of the following things happens-

* latch ***count*** has down to reached 0, or
* unless the thread is interrupted.

* boolean **await**(long **timeout**, TimeUnit **unit**)

Causes the current thread to wait until  one of the following things happens-

* latch ***count*** has down to reached 0,
* unless the thread is interrupted, or
* specified **timeout** elapses.

*CountDownLatch’s countDown() method in java :*

* void **countDown**( )

Reduces latch ***count*** by 1.

If ***count*** reaches 0, all waiting threads are released.

Read more about [**CountDownLatch in java**](http://www.javamadesoeasy.com/2015/03/countdownlatch-in-java.html).

### Where can you use CountDownLatch in real world?

**Answer.**  Very interesting question. It will test your real time thread concurrency implementation skills. When you go in amusement park, you must have seen on certain rides there is mandate that at least 3 people (**3 is count**) should be there to take a ride. So, ride keeper (**ride keeper is main thread**) waits for 3 persons (**ride keeper has called await()**).

Every time a person comes count is reduced by 1 (**let’s say every person is calling countDown() method**). Ultimately when 3 persons reach count becomes 0 & wait for ride keeper comes to end.

### How can you implement your own CountDownLatch in java?

**Answer.**   
There might be situation where we might like our thread to wait until one or more threads completes certain operation.

A CountDownLatch is initialized with a given ***count*** .

***count*** specifies the number of events that must occur before latch is released.

Every time a event happens ***count*** is reduced by 1. Once count reaches 0 latch is released.

1.1) Custom CountDownLatch’s  **constructor** in java>

* **CountDownLatch**(int ***count***)

CountDownLatch is initialized with given ***count***.

***count*** specifies the number of events that must occur before latch is released.

**CODE >**

|  |
| --- |
| **public CountDownLatchCustom(int count) {**  **this.count=count;**  **}** |

1.2) Custom CountDownLatch’s **await()** method  in java:

* void **await**( ) throws InterruptedException

Causes the current thread to wait until  one of the following things happens-

* latch ***count*** has down to reached 0, or
* unless the thread is interrupted.

**CODE >**

|  |
| --- |
| **public synchronized void await() throws InterruptedException {**  **//If count is greater than 0, thread waits.**  **if(count>0)**  **this.wait();**  **}** |

1.3) Custom CountDownLatch’s **countDown()** method  in java:

* void **countDown**( )

Reduces latch ***count*** by 1.

If ***count*** reaches 0, all waiting threads are released.

**CODE >**

|  |
| --- |
| **public synchronized void countDown() {**  **//decrement the count by 1.**  **count--;**    **//If count is equal to 0, notify all waiting threads.**  **if(count == 0)**  **this.notify();**  **}** |

2) Custom CountDownLatch’s code in java >

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| /\*\* Copyright (c), AnkitMittal [JavaMadeSoEasy.com](http://javamadesoeasy.com/) \*/  **/\*\***  **\* @author AnkitMittal**  **\* Copyright (c), AnkitMittal .**  **\* All Contents are copyrighted and must not be reproduced in any form.**  **CountDownLatchCustom wait until one or more threads completes certain operation.**  **A CountDownLatch is initialized with a given count .**  **count specifies the number of events that must occur before**  **latch is released.**  **Every time a event happens count is reduced by 1. Once count**  **reaches 0 latch is released.**  **\*/**  **class CountDownLatchCustom{**  **private int count;**  **/\*\***  **\* CountDownLatch is initialized with given count.**  **\* count specifies the number of events that must occur**  **\* before latch is released.**  **\*/**  **public CountDownLatchCustom(int count) {**  **this.count=count;**  **}**  **/\*\***  **\* Causes the current thread to wait until  one of the following things happens-**  **- latch count has down to reached 0, or**  **- unless the thread is interrupted.**  **\*/**  **public synchronized void await() throws InterruptedException {**  **//If count is greater than 0, thread waits.**  **if(count>0)**  **this.wait();**  **}**  **/\*\***  **\* Reduces latch count by 1.**  **\* If count reaches 0, all waiting threads are released.**  **\*/**  **public synchronized void countDown() {**  **//decrement the count by 1.**  **count--;**    **//If count is equal to 0, notify all waiting threads.**  **if(count == 0)**  **this.notify();**  **}**    **}** |

2) Program to demonstrate usage of Custom CountDownLatch in java >

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| **/\*\***  **\* @author AnkitMittal**  **\* Copyright (c), AnkitMittal .**  **\* All Contents are copyrighted and must not be reproduced in any form.**  **CountDownLatchCustom wait until one or more threads completes certain operation.**  **A CountDownLatch is initialized with a given count .**  **count specifies the number of events that must occur before**  **latch is released.**  **Every time a event happens count is reduced by 1. Once count**  **reaches 0 latch is released.**  **\*/**  **class CountDownLatchCustom{**  **private int count;**  **/\*\***  **\* CountDownLatch is initialized with given count.**  **\* count specifies the number of events that must occur**  **\* before latch is released.**  **\*/**  **public CountDownLatchCustom(int count) {**  **this.count=count;**  **}**  **/\*\***  **\* Causes the current thread to wait until  one of the following things happens-**  **- latch count has down to reached 0, or**  **- unless the thread is interrupted.**  **\*/**  **public synchronized void await() throws InterruptedException {**  **//If count is greater than 0, thread waits.**  **if(count>0)**  **this.wait();**  **}**  **/\*\***  **\* Reduces latch count by 1.**  **\* If count reaches 0, all waiting threads are released.**  **\*/**  **public synchronized void countDown() {**  **//decrement the count by 1.**  **count--;**    **//If count is equal to 0, notify all waiting threads.**  **if(count == 0)**  **this.notify();**  **}**    **}**  /\*\*  \* Main class  \*/  **public** **class** CountDownLatchCustomTest {    **public** **static** **void** main(String[] args) {  **CountDownLatchCustom countDownLatchCustom=new CountDownLatchCustom(3);**            System.*out*.println("CountDownLatch has been created with count=3");    **new** Thread(**new** MyRunnable(countDownLatchCustom),"Thread-1").start();    **try** {  **countDownLatchCustom.await();**            } **catch** (InterruptedException e) {                   e.printStackTrace();            }              System.*out*.println("count has reached zero, "+                         Thread.*currentThread*().getName()+" thread has ended");     }  }  **class** MyRunnable **implements** Runnable{       CountDownLatchCustom countDownLatchCustom;       MyRunnable(CountDownLatchCustom countDownLatchCustom){  **this**.countDownLatchCustom=countDownLatchCustom;     }    **public** **void** run(){    **for**(**int** i=2;i>=0;i--){    **countDownLatchCustom.countDown();**                   System.*out*.println(Thread.*currentThread*().getName()+                                " has reduced latch count to : "+ i);    **try** {                         Thread.*sleep*(1000);                   } **catch** (InterruptedException e) {                         e.printStackTrace();                   }            }       }    }  /\*OUTPUT  CountDownLatch has been created with count=3  Thread-1 has reduced latch count to : 2  Thread-1 has reduced latch count to : 1  Thread-1 has reduced latch count to : 0  count has reached zero, main thread has ended  \*/ |

2.1) Let’s discuss output in detail, to get better understanding of **Custom** CountDownLatch usage in program >

**Note** : I have mentioned output in **green** text.

CountDownLatch has been created with count=3  
Initially, **custom CountDownLatch** is created with count=3

main thread called **countDownLatchCustom**.await() and it is waiting for count to become 0.

Thread-1 called **countDownLatchCustom**.countDown()  method. [Now, count=2]

Thread-1 has reduced latch count to : 2

Thread-1 called **countDownLatchCustom**.countDown()  method. [Now, count=1]

Thread-1 has reduced latch count to : 1

Thread-1 called **countDownLatchCustom**.countDown()  method. [Now, count=0]

Thread-1 has reduced latch count to : 0

count has reached zero, main thread has ended

As, count has reached zero, main thread has ended.

2.3) Occasionally, because of threads unpredictable behaviour output may be bit awkward in java >

/\*OUTPUT

CountDownLatch has been created with count=3

Thread-1 has reduced latch count to : 2

Thread-1 has reduced latch count to : 1

count has reached zero, main thread has ended

Thread-1 has reduced latch count to : 0

\*/

This may happen because as soon as count reaches 0 waiting threads are released. Here, as soon as Thread-1 called countDown() method third time main thread was released and its sysout statement was executed before Thread-1’s sysout statement.

### What is CyclicBarrier in java?

**Answer.**   This is very important thread concurrency interview question. Fresher and experienced bost be well versed with this. There might be situation where we might have to trigger event only when one or more threads completes certain operation in java.

**2 or more threads wait for each other to reach a common barrier point**. When all **threads** have **reached** common **barrier point** (i.e. when all threads have called await() method) >

* **All waiting threads are released**, and
* **Event can be triggered** as well.

[*CyclicBarrier’s*](http://www.javamadesoeasy.com/2015/03/cyclicbarrier-in-java.html) *constructor in java >*

* **CyclicBarrier(**int **parties)**

New CyclicBarrier is created where **parties** number of thread wait for each other to reach common barrier point, when all threads have reached common barrier point, **parties** number of waiting threads are released.

* **CyclicBarrier(**int **parties,** Runnable **barrierAction)**

New CyclicBarrier is created where **parties** number of thread wait for each other to reach common barrier point, when all threads have reached common barrier point, **parties** number of waiting threads are released and **barrierAction** (event)is triggered.

*CyclicBarrier’s await() method has 2 forms :*

* int **await**() throws InterruptedException, BrokenBarrierException

If the current thread is not the last to arrive(i.e. call await() method) then it waits until one of the following things happens -

* The last thread to call arrive(i,.e. call await() method), or
* Some other thread interrupts the current thread, or
* Some other thread interrupts one of the other waiting threads, or
* Some other thread times out while waiting for barrier, or
* Some other thread invokes reset() method on this cyclicBarrier.

* int **await**(long **timeout**, TimeUnit **unit**) throws InterruptedException, BrokenBarrierException, TimeoutException

If the current thread is not the last to arrive(i.e. call await() method) then it waits until one of the following things happens -

* The last thread to call arrive(i,.e. call await() method), or
* The specified **timeout** elapses, or
* Some other thread interrupts the current thread, or
* Some other thread interrupts one of the other waiting threads, or
* Some other thread times out while waiting for barrier, or
* Some other thread invokes reset() method on this cyclicBarrier.

Read more about [**CyclicBarrier in java**](http://www.javamadesoeasy.com/2015/03/cyclicbarrier-in-java.html).

### Why is CyclicBarrier cyclic in java?

**Answer.**  This is very interesting thread concurrency interview question for developers. The barrier is called *cyclic* because [CyclicBarrier](http://www.javamadesoeasy.com/2015/03/cyclicbarrier-in-java.html) can be reused after -

* All the waiting threads are released in java and
* event has been triggered in java.

### Where could we use [CyclicBarrier](http://www.javamadesoeasy.com/2015/03/cyclicbarrier-in-java.html) in real world?

**Answer.** Another very interesting question. It will test your real time thread concurrency implementation skills. Let’s say 10 friends (**friends are threads**) have planned for picnic on place A (Here **place A is common barrier** point). And they all decided to play certain game (**game is event**) only on everyones arrival at place A. So, all 10 friends must wait for each other to reach place A before launching event.

Now, when all **threads** have **reached** common **barrier point** (i.e. all friends have reached place A) >

* **All waiting threads are released**(All friends can play game), and
* **Event can be triggered** (they will start playing game).

### How can you implement your own [CyclicBarrier](http://www.javamadesoeasy.com/2015/03/cyclicbarrier-in-java.html) in java?

**Answer.  This is another important and complex interview for developers.** Please see [**Implementation of custom/own CyclicBarrier in java**](http://www.javamadesoeasy.com/2015/03/implementation-of-customown_39.html).

**Thread concurrency interview Question 16. Similarity and Difference between CyclicBarrier and CountDownLatch in Java?**

**Answer.**   This is **very very important** thread concurrency interview question. Fresher and experienced both must be well versed with this.

1. [**CyclicBarrier**](http://www.javamadesoeasy.com/2015/03/cyclicbarrier-in-java.html) and [**CountDownLatch**](http://www.javamadesoeasy.com/2015/03/countdownlatch-in-java.html) **are similar because** they wait for specified number of thread to reach certain point and make count/parties equal to 0. But,

for completing wait in CountDownLatch specified number of threads must call **countDown()** method in java.

for completing wait in CyclicBarrier specified number of threads must call **await()** method.

1. Let’ see there constructor’s >

|  |  |
| --- | --- |
| **CountDownLatch**(int ***count***)  CountDownLatch is initialized with given ***count***.  ***count*** specifies the number of events that must occur before latch is released. | **CyclicBarrier(**int **parties)**  New CyclicBarrier is created where **parties** number of thread wait for each other to reach common barrier point, when all threads have reached common barrier point, **parties** number of waiting threads are released. |

1. **CyclicBarrier** can be **awaited repeatedly**, but **CountDownLatch** can’t be awaited repeatedly. i.e. once count has become 0 cyclicBarrier can be used again but CountDownLatch cannot be used again in java.

1. **CyclicBarrier** can be used to trigger event, but **CountDownLatch** can’t be used to launch event. i.e. once count has become 0 cyclicBarrier can trigger event but CountDownLatch can’t in java.

**How can cyclicBarrier launch event?**

CyclicBarrier provides constructor for triggering event.

**CyclicBarrier(**int **parties,** Runnable **barrierAction)**

New CyclicBarrier is created where **parties** number of thread wait for each other to reach common barrier point, when all threads have reached common barrier point, **parties** number of waiting threads are released and **barrierAction (event) is triggered**.

**Thread concurrency interview Question 17. What is Phaser in java? Is Phaser similar to CyclicBarrier?**

**Answer.** This is **another very important** thread concurrency interview question. [Phaser](http://www.javamadesoeasy.com/2015/03/phaser-in-java_21.html) is somewhat **similar** in functionality of [CyclicBarrier](http://www.javamadesoeasy.com/2015/03/cyclicbarrier-in-java.html) and [CountDownLatch](http://www.javamadesoeasy.com/2015/03/countdownlatch-in-java.html) but it provides more flexibility than both of them.

Phaser provides us flexibility of registering and deRegistering parties at any time.

**For registering parties**, we may use any of the following -

* constructors, or
* int register(), or
* bulkRegister().

**For deRegistering parties**, we may use any of the following -

* arriveAndDeregister()

we have methods like **getPhase()** which returns the current phase number. And

**isTerminated()** method returns **true** if phaser has been **terminated**.

Read more about [**Phaser in java**](http://www.javamadesoeasy.com/2015/03/phaser-in-java_21.html)

**Thread concurrency interview Question 18. Differences and similarity between Phaser and CyclicBarrier in java?**

**Answer.**  Another interesting thread concurrency interview question. Like a [**CyclicBarrier**](http://www.javamadesoeasy.com/2015/03/cyclicbarrier-in-java.html), a [Phaser](http://www.javamadesoeasy.com/2015/03/phaser-in-java_21.html) can be **awaited repeatedly**.

But, in CyclicBarrier we used to register parties in constructor but Phaser provides us flexibility of registering and deRegistering parties at any time in java.

**Thread concurrency interview Question 19.Difference between arrive() and arriveAndAwaitAdvance() method of Phaser in java?**

**Answer.** This is thread concurrency interview question for experienced developers. **arrive**() method of [Phaser](http://www.javamadesoeasy.com/2015/03/phaser-in-java_21.html) **does not cause current thread to wait for other registered threads to complete current phase**. That means current thread can immediately start next phase without waiting for any other registered thread to complete current phase.

But, **arriveAndAwaitAdvance**() **method causes current thread to wait for other registered threads to complete current phase.** That means current thread can proceed to next phase only when all other threads have completed current phase (i.e. by calling **arriveAndAwaitAdvance() method**).

**Thread concurrency interview Question 20. When is phaser terminated in java?**

**Answer.**  This is another thread concurrency interview question for experienced developers. When calling arriveAndDeregister() method of [Phaser](http://www.javamadesoeasy.com/2015/03/phaser-in-java_21.html) has caused the number of registered parties to become 0. Termination can also be triggered when an **onAdvance()** method returns **true**.

**Question 21. How can you control number of phase you want to execute in Phaser in java?**

**Answer.**  Yet another thread concurrency interview question for experienced developers. We can override the **onAdvance( )** method of [Phaser](http://www.javamadesoeasy.com/2015/03/phaser-in-java_21.html) to control number of phases which we want to execute.

Signature of onAdavance method is *boolean onAdvance(int* ***phase****, int* ***registeredParties****).*

Where, **phase** is the current phase number when we enter onAdvance() method i.e. before advancing to next phase.

**registeredParties** is the current number of registered parties

**Every Time before advancing to next phase overridden onAdvance() method is called** and returns either true or false.

If method returns **true** than **phaser is** **terminated** ,or

If method returns **false** then **phaser continues** and can **advance to next phase**.

[*Program to demonstrate usage of how we can* ***override*** *Phaser’s* ***onAdvance*** *method to control number of phase we want to execute*](http://www.javamadesoeasy.com/2015/03/phaser-in-java_21.html)

**Thread concurrency interview Question 22. Where could we use** [**Phaser**](http://www.javamadesoeasy.com/2015/03/phaser-in-java_21.html) **in real world?**

**Answer.** Another interesting thread concurrency interview question. Software process management is done in phases.

* First phase could be **requirement gathering**,
* second could be **software development** and
* third could be **testing**.

Second phase will not start until first is not completed, like wise third phase will not start until second is not completed.

**Thread concurrency interview Question 23. What is maximum number of parties that could be registered with phaser at a time in java ?**

**Answer.** Complex and challenging interview question even for experienced. Maximum number of parties that could be registered with phaser at a time is **65535**, if we try to register more parties **IllegalStateException** will be thrown in java.

**Thread concurrency interview Question 24. What is exchanger in Java?**

**Answer.**  This is very important thread concurrency interview question for freshers and experienced. [Exchanger](http://www.javamadesoeasy.com/2015/03/exchanger-in-java.html) enables two threads to exchange their data between each other. Exchanger can be handy in solving Producer Consumer pattern where Producer and consumer threads can exchange their data.

* **exchange**(V **x**)

exchange() method enables two threads to exchange their data between each other.

**If current thread is first one to call exchange()** method then it will until one of following things happen >

* Some other thread calls exchange() method, or
* Some other thread interrupts the current thread, or

**If some other thread has already called exchanger()** method then it resumes its execution and following things happen -

* waiting thread is resumed and receives data from current thread.
* current thread receives data from that waiting thread and it returns immediately.

* V **exchange**(V **x**, long **timeout**, TimeUnit **unit**)

exchanger() method enables two threads to exchange their data between each other.

**If current thread is first one to call exchange()** method then it will until one of following things happen >

* Some other thread calls exchange() method, or
* Some other thread interrupts the current thread, or
* The specified **timeout** elapses.

**If some other thread has already called exchanger()** method then it resumes its execution and following things happen -

* waiting thread is resumed and receives data from current thread.
* current thread receives data from that waiting thread and it returns immediately.

Read more about [**Exchanger in java**](http://www.javamadesoeasy.com/2015/03/exchanger-in-java.html).

**Thread concurrency interview Question 25. How can you implement Producer Consumer pattern using Exchanger in java?**

**Answer.**  Very interesting thread concurrency interview question for experienced developers. Exchanger is created,  which will enable Producer and consumer threads to exchange their data.

Producer thread produces and called exchanger() method, now it will wait for consumer thread to call exchange() method.

Consumer thread calls exchanger() method and following things will happens >

* current thread(consumerThread) will receive data from that waiting thread(producerThread) and it returns immediately.
* waiting thread (producerThread) will resume and receive data from current thread (consumerThread).

[Read program to implement Producer Consumer pattern using Exchanger](http://www.javamadesoeasy.com/2015/03/exchanger-in-java.html)

**Question 26. How can you solve consumer producer pattern by using BlockingQueue in java?**

**Answer.** It is **very very important** thread concurrency interview question for all developers.. Now it’s time to gear up to face question which is most probably going to be followed up by previous question i.e. after how to solve consumer producer problem using [wait() and notify() method](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html). Generally you might wonder why interviewer's are so much interested in asking about [solving consumer producer problem using BlockingQueue](http://www.javamadesoeasy.com/2015/03/solve-consumer-producer-problem-by.html), answer is they want to know how strong knowledge you have about java concurrent Api’s, this Api use consumer producer pattern in very optimized manner, BlockingQueue is designed is such a manner that it offer us the best performance.

[**BlockingQueue is a interface** and we will use its **implementation class LinkedBlockingQueue**.](http://www.javamadesoeasy.com/2015/03/solve-consumer-producer-problem-by.html)

Key methods for solving consumer producer pattern are >

|  |
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| **put(i);**   //used by producer to put/produce in sharedQueue.  **take();** //used by consumer to take/consume from sharedQueue. |

**Question 27. How can you implement your own LinkedBlockingQueue to solve consumer producer pattern in java?**

**Answer.**  Another challenging, logical and complex thread concurrency interview question, Please read [Producer Consumer pattern using Custom implementation of BlockingQueue interface](http://www.javamadesoeasy.com/2015/03/producer-consumer-pattern-using-custom.html)

**Thread concurrency interview Question 28. What is Lock in java?**

**Answer.** Important thread concurrency interview question. The java.util.concurrent.locks.**Locks** is a  interface and its implementations provide more extensive locking operations than can be obtained using synchronized methods and statements.

**A lock helps in controlling access to a shared resource by multiple threads. Only one thread at a time can acquire the lock and access the shared resource in java.**

If a second thread attempts to acquire the lock on shared resource when it is acquired by another thread, the second thread will wait until the lock is released. In this way we can achieve [synchronization](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) and [race conditions](http://www.javamadesoeasy.com/2015/03/race-condition-in-multithreading-and.html) can be avoided in java.

Read lock of a ReadWriteLock may allow concurrent access to a shared resource in java.

Read more about [**locks** and **ReEntrantLocks** in java](http://www.javamadesoeasy.com/2015/03/reentrantlocks-in-java.html)

**Thread concurrency interview Question 29. Explain key methods of Lock interface in java?**

**Answer.**  This is very important thread concurrency interview question for freshers and experienced.

[*Lock interface*](http://www.javamadesoeasy.com/2015/03/reentrantlocks-in-java.html) *key methods in java >*

*void lock()*

Acquires the lock if it is not held by another thread. And sets **lock hold count** to 1.

If current thread already holds lock then **lock hold count** is increased by 1.

If the lock is held by another thread then the current thread waits for another thread to release lock.

*void unLock()*

If the current thread is the holding the lock then the **lock hold count** is decremented by 1. If the **lock hold count** has reached 0, then the lock is released.

If **lock hold count** is still greater than 0 then lock is not released.

If the current thread is not holding the lock then IllegalMonitorStateException is thrown.

*boolean tryLock()*

Acquires the lock if it is not held by another thread and returns true. And sets **lock hold count** to 1.

If current thread already holds lock then method returns true. And increments **lock hold count** by 1.

If lock is held by another thread then method return false.

*boolean tryLock(long timeout, TimeUnit unit)*

*throws InterruptedException*

Acquires the lock if it is not held by another thread and returns true.  And sets **lock hold count** to 1.

If current thread already holds lock then method returns true. And increments **lock hold count** by 1.

If lock is held by another thread then current thread will wait until one of the following things happen -

* **Another thread releases lock and the lock is acquired by the current thread, or**
* **Some other thread interrupts the current thread, or**
* **The specified timeout elapses .**

**If** the **lock is acquired** then method **returns true.** And sets **lock hold count** to 1.

**If specified timeout elapses then** method return false.

*Condition newCondition()*

Method returns a Condition instance to be used with this Lock instance.

Condition instance are similar to using [**Wait(), notify() and notifyAll()**](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) methods.

* IllegalMonitorStateException is thrown **if this lock is not held when** any of the **Condition waiting** or **signalling methods** are called.

* **Lock is released** when the **condition waiting methods are called** and before they return, the lock is reacquired and the **lock hold count** restored to what it was when the method was called.

* If a **thread is interrupted while waiting** then InterruptedException will be thrown and following things will happen -
  + the **wait will be over**, and
  + **thread's interrupted status will be cleared**.

* Waiting threads are signalled in FIFO (first in first out order) order.
* When lock is  ***fair***, first lock is obtained by longest-waiting thread.

If lock is not  ***fair***, any waiting thread could get lock, at discretion of implementation.

Read more about [**locks** in java](http://www.javamadesoeasy.com/2015/03/reentrantlocks-in-java.html)

**Thread concurrency interview Question 30. Explain usage of newCondition() method of Lock interface in detail in java? And can it be used to implement producer consumer pattern in java?**

### Answer.  It is very complex thread concurrency interview question.Even most of the experienced developers are not aware of this question. Please read [ReentrantLock class provides implementation of Lock’s newCondition() method in java - description and solving producer consumer program using this method.](http://www.javamadesoeasy.com/2015/03/reentrantlock-class-provides.html)

**Thread concurrency interview Question 31. Explain key methods of ReentrantLock class in java?**

**Answer.** This is very important thread concurrency interview question for freshers and experienced.

[ReentrantLock class](http://www.javamadesoeasy.com/2015/03/reentrantlocks-in-java.html) provides implementation of all Lock interface methods

*void lock()*

*void unLock()*

*boolean tryLock()*

*boolean tryLock(long timeout, TimeUnit unit)*

**Additional methods provided by** ReentrantLock class are >

*void lockInterruptibly() throws InterruptedException*

If current thread already holds lock then method returns true. And increments **lock hold count** by 1.

If the lock is held by another thread then the current thread waits until one of the following thing happens -

* The lock is acquired by the current thread, or
* Some other thread **interrupts the current thread**.

As soon as current thread acquires the lock it sets **lock hold count** to 1.

*int getWaitQueueLength(Condition condition)*

Method returns number of threads that may be waiting to acquire this lock.

Method is used just for monitoring purposes and not for any kind of synchronization purposes.

*boolean isHeldByCurrentThread()*

Method returns true if lock is held by current thread. Its similar to **Thread.holdsLock()** method.

Read more about [**ReEntrantLocks** in java](http://www.javamadesoeasy.com/2015/03/reentrantlocks-in-java.html)

**Thread concurrency interview Question 32. Write Program to demonstrate usage of ReentrantLock in java?**

**Answer.**   Interesting question for developers. [Read program  to demonstrate usage of ReentrantLock](http://www.javamadesoeasy.com/2015/03/reentrantlocks-in-java.html).

**Thread concurrency interview Question 33. How can you implement your own ReentrantLock in java?**

**Answer. This is important and complex interview question for developers.** [**Implementation of custom/own Lock and ReEntrantLock in java**](http://www.javamadesoeasy.com/2015/03/implementation-of-customown-lock-and.html)

**Thread concurrency interview Question 34. What is Fork/Join Framework in java ?**

**Answer.**  This is **very very important** thread concurrency interview question. Fresher and experienced both must be well versed with this..

*Fork/Join Framework has been added in* JDK 7 and is defined in the **java.util.concurrent** package in java.

*Fork/Join framework enables* ***parallel programming***. Parallel programming means taking **advantage two or more processors (multicore) in computers**.  Parallel programming improves program performance in java.

*The Fork/Join Framework also* ***improves program performance*** *in following ways >*

* Fork/Join framework makes use of multiple processors available in computer. Hence enabling parallel processing, and
* It managing whole [life cycle of Threads](http://www.javamadesoeasy.com/2015/03/thread-states-thread-life-cycle-in-java.html).

### Read more about [Fork/Join Framework - Parallel programming in java](http://www.javamadesoeasy.com/2015/03/forkjoin-framework-parallel-programming.html).

**Thread concurrency interview Question 35. What is Divide-and-conquer in Fork/Join framework in java ?**

**Answer.** Basic thread concurrency interview question, which tests the developers in depth knowledge about the fork join framework in java. The **divide-and-conquer** strategy recursively divides a task into smaller subtasks until  subtask isn’t small enough to be solved independently.

**Thread concurrency interview Question 36. What approach does ForkJoinPool uses for managing tasks in java?**

**Answer.** Another basic thread concurrency interview question, which tests the developers in depth knowledge about the fork join framework in java. [**ForkJoinPool**](http://www.javamadesoeasy.com/2015/03/forkjoin-framework-parallel-programming.html)uses ***work-stealing approach*** *for managing threads*. Each thread in ForkJoinPool maintains a queue of tasks. If one thread’s queue is empty, it can take task from another thread. This overall improves the program/applications performance in java.

**Thread concurrency interview Question 37. What are ForkJoinPool and ForkJoinTask in java?**

##### Answer.

##### [***ForkJoinPool in java***](http://www.javamadesoeasy.com/2015/03/forkjoin-framework-parallel-programming.html)

**ForkJoinPool** implements ExecutorService framework. The execution of **ForkJoinTasks** takes place within a **ForkJoinPool**, which also manages the execution of the tasks.

*ForkJoinPool constructors >*

* ***ForkJoinPool( )***
* Creates a pool in java.
* **level of parallelism = number of processors available in the system**
* ***ForkJoinPool****(int* ***parallelism****)*
* The ***parallelism*** is the **level of parallelism**. Its value must be greater than 0 and must not be more than number of processors in system.
* **level of parallelism** determines the number of threads that can execute simultaneously. As a number of threads are determined it also determines number of tasks that could be executed **parallely** in java.

*ForkJoinPool important methods in java >*

After you have created an instance of **ForkJoinPool**, you can start a task in a number of different ways. **The first task started is the main task. Main task begins subtasks that are also managed by the pool**. Different methods for starting tasks have been discussed below >

* *<T> T* ***invoke****(ForkJoinTask<T>* ***task****)*

This method starts the ***task*** and returns the result of the ***task***.  Calling code waits until method returns.

* *void* ***execute****(ForkJoinTask<?>* ***task****)*

The execute() method can be used to start a ***task*** without waiting for its completion.

This method starts the ***task***. Calling code continues its execution asynchronously and does not waits for method completion like in invoke method.

* ***submit****() method comes in 4 different forms.*

submit() method can also be used for submitting task.

* *int* ***getParallelism****()*

The method returns **level of parallelism** i.e. number of processors available in the system.

* *void* ***shutdown****()*

Initiates shutdown, previously submitted tasks are executed, but no new tasks will be accepted.

* *List<Runnable>* ***shutdownNow****()*
* attempts to stop all actively executing tasks,
* submitted tasks may or may not execute.
* awaiting tasks will never execute, and
* method cancels both existing and unexecuted tasks, so it returns empty list.

##### [**ForkJoinTask<V> in java**](http://www.javamadesoeasy.com/2015/03/forkjoin-framework-parallel-programming.html)

**ForkJoinTask is abstract class for tasks that run within a ForkJoinPool.**

**ForkJoinTask<V>** is an abstract class that defines a task that can be managed by a **ForkJoinPool**.

The *V* specifies the result type of the task in java.

**Threads managed by ForkJoinPool executes ForkJoinTasks**. Small number of threads are used to serve large number of tasks.

*ForkJoinTask* ***important methods*** *>*

**ForkJoinTask** core methods are **fork( )** and **join()**

* *ForkJoinTask<V>* ***fork( )***  
  The fork( ) method **submits the task** for asynchronous execution, means that the thread that calls fork( ) method to submit task continues to run. Task are executed in the compute() method, which is running within a ForkJoinPool.

* *V* ***join( )***

The **join( )** method waits for task completion on which it is called. The method returns result of the task.

* *In short, about* ***fork( )*** *and* ***join( )*** are used for starting one or more new tasks and then wait for them to complete.

* *V* ***invoke****( )*

**The invoke() method combines the functionally of fork() and join()** methods. invoke() submits the task and waits for completion of submitted task.

The method returns result of task.

* *static void* ***invokeAll****(ForkJoinTask<?>* ***t1****, ForkJoinTask<?>* ***t2****)*

invokeAll() method  submits ***t1*** and ***t2*** and waits for completion of ***t1*** and ***t1***.

* *static void* ***invokeAll****(ForkJoinTask<?> …* ***tasks****)*

invokeAll() method submits list of tasks i.e. ***tasks*** and waits for completion of all tasks in list.

The ***invokeAll*( )** method can only be called from within the overridden compute() method of another **ForkJoinTask**, which is running within a **ForkJoinPool**.

*Some* ***other important methods*** *for checking status of submitted task -*

* *boolean* ***isDone****()* method returns true if a task completes.

* *boolean* ***isCompletedNormally****()* method returns true if a task completed normally without cancellation or without throwing any exception.

* *boolean* ***isCompletedAbnormally****()* returns true if a task completed abnormally either by cancellation or by throwing any exception.

* *boolean* ***isCancelled****()* returns true if the task was cancelled.

**Question 38. Similarity and Difference between RecursiveAction and RecursiveTask in java?**

**Answer.** Another important thread concurrency interview question.

##### ***Difference between RecursiveAction and RecursiveTask in java***

|  |  |
| --- | --- |
| *RecursiveAction* | *RecursiveTask<V>* |
| This **submits a task** and **does not return a result in java**. | This **submits a task** and **returns a result in java**. |
| Definition of compute method  *protected abstract void* ***compute()*** | *protected abstract V* ***compute()*** The *V* specifies the result type of the task. |

##### ***Similarity between RecursiveAction and RecursiveTask***

> Both **extends ForkJoinPool**.

> All **computations by tasks are performed inside compute() method**.

**Question 39. How can we use Fork/Join framework in real world?**

**Answer.** This thread concurrency interview question will test your real time thread concurrency implementation skills. We can use Fork/Join framework for calculating sum of array of 100000 or even may be more numbers. *Fork/Join framework uses* **divide-and-conquer** strategy for *enabling* ***parallel programming***. Divide-and-conquer strategy recursively divides a array into smaller subarrays until  subarray isn’t small enough to be solved independently.

Also, **ForkJoinPool** uses ***work-stealing approach*** *for managing threads*. Each thread in **ForkJoinPool** maintains a queue of tasks. If one thread’s queue is empty, it can take task from another thread. This overall improve the programs performance. Please see [program](http://www.javamadesoeasy.com/2015/03/forkjoin-framework-parallel-programming.html) to calculate sum of array of 100000 numbers.

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**Thread concurrency interview Question 40. Difference between synchronized and ReentrantLock in java?**

**Answer.**   This is another **very very important** thread concurrency interview question. Fresher and experienced both must be well versed with this.

|  |  |
| --- | --- |
| ***synchronized in java*** | ***ReentrantLock in java*** |
| **Does not provide any** **fair locks in java**. | **provides fair locks**, when lock is fair - first lock is obtained by longest-waiting thread in java.  Constructor to provide fairness -  ***ReentrantLock****(boolean* ***fair****)*  Creates an instance of ReentrantLock.  When ***fair*** is set true, first lock is obtained by longest-waiting thread in java.  If  ***fair*** is set false, any waiting thread could get lock, at discretion of implementation in java. |
| **Does not provide tryLock() method or its functionality**. Thread always waits for lock in java. | **Provide tryLock() method. If lock is held by another thread then method return false in java.**  *boolean tryLock()*  Acquires the lock if it is not held by another thread and returns true. And sets **lock hold count** to 1.  If current thread already holds lock then method returns true. And increments **lock hold count** by 1.  If lock is held by another thread then method return false in java. |
| There is **no method for lock interruptibility**, though current thread waits until one of the following thing happens -   * The **lock is acquired** **by** the **current thread in java**, or * Some other thread **interrupts the current thread in java**. | *void lockInterruptibly()*  If current thread already holds lock then method returns true. And increments **lock hold count** by 1.  If the lock is held by another thread then the current thread waits until one of the following thing happens -   * The **lock is acquired** **by** the **current thread in java**, or * Some other thread **interrupts the current thread**.   As soon as current thread acquires the lock it sets **lock hold count** to 1. |
| **Does not provide any method to return number of threads that may be waiting to acquire this lock in java**. | provide *int getQueueLength()* method to return number of threads that may be waiting to acquire this lock in java. |
| **holdsLock()** method is used to **find out whether lock is held by current thread or not**. If current thread holds lock method returns true in java. | *isHeldByCurrentThread()*method is **used to find out whether lock is held by current thread or not**. If current thread holds lock method returns true in java. |
| Thread can hold lock on object monitor only once in java. | if current thread **already holds lock** then **lock hold count** is increased by 1 when lock() method is called.  method to maintain **lock hold count** -  *void lock()*  Acquires the lock if it is not held by another thread. And sets **lock hold count** to 1.  If current thread already holds lock then **lock hold count** is increased by 1. |
| Does not provide any new condition() method in java. | provides *newCondition()* method.  Method returns a Condition instance to be used with this Lock instance.  Condition instance are similar to using [**Wait(), notify() and notifyAll()**](http://www.javamadesoeasy.com/2015/03/wait-and-notify-methods-definition-8.html) methods on object.   * IllegalMonitorStateException is thrown **if this lock is not held when** any of the **Condition waiting** or **signalling methods** are called. * **Lock is released** when the **condition waiting methods are called** and before they return, the lock is reacquired and the **lock hold count** restored to what it was when the method was called. * If a **thread is interrupted while waiting** then InterruptedException will be thrown and following things will happen -   + the **wait will be over**, and   + **thread's interrupted status will be cleared**. * Waiting threads are signalled in FIFO (first in first out order) order in java. * When lock is  ***fair***, first lock is obtained by longest-waiting thread in java.   If lock is not  ***fair***, any waiting thread could get lock, at discretion of implementation in java. |

**Question 41. Difference between traditional** [**multithreading**](http://www.javamadesoeasy.com/2015/03/what-is-thread-in-java.html) **and parallel programming in java?**

**Answer.** Basic interview question. Not a important one. MultiThreading primarily was designed to work with single CPU and utilize idle time of CPU. If two or more processors are there multithreading won’t be able to utilize multi processors but parallel programing using Fork/Join framework can utilize multiple processors available in computer in java.

**Question 42. Explain atomic operations in java?**

### Answer. Developers must have knowledge of atomic operations in thread concurrency java. Java provides some classes in java.util.concurrent.atomic which offers an alternative to the other [synchronization](http://www.javamadesoeasy.com/2015/03/synchronization-blocks-and-methods.html) in java.

### Please see [Atomic operations in java](http://www.javamadesoeasy.com/2015/03/atomic-operations-in-java.html).

**Question 43. What is AtomicInteger in java? Explain key methods of AtomicInteger?**

**Answer.** Another very important thread concurrency interview question for freshers and experienced. *AtomicInteger  provides you with* ***int value*** *that is updated atomically. i.e. we can use these classes without any explicit synchronization in* [*multithreading*](http://www.javamadesoeasy.com/2015/03/what-is-thread-in-java.html) *environment, because any operation done on these classes is* [*thread safe*](http://www.javamadesoeasy.com/2015/03/guidelines-to-thread-safe-code-most.html) *in java.*

[*AtomicInteger*](http://www.javamadesoeasy.com/2015/03/atomicinteger-in-java.html) *important Methods >*

* *int* ***get****()*

method returns the current value

* *void* ***set****(int newValue)*

Sets to **newValue.**

* *int* ***getAndSet****(int newValue)*

Sets to **newValue** and returns the old value.

* *boolean* ***compareAndSet****(int expect, int update)*

Compare with *expect*, if equal, set to *update* and return true.

*Addition methods >*

* *int* ***addAndGet****(int value)*

adds *value* to the current value. And **return updated value.**

* *int* ***incrementAndGet****()*

increments current value by 1. And **return updated value.**

* *int* ***getAndAdd****(int value)*

Method **return current value**. And adds *value* to the current value.

* *int* ***getAndIncrement****()*

Method **return current value**. And increments current value by 1.

*Subtraction methods >*

* *int* ***decrementAndGet****()*

decrements current value by 1. And **return updated value.**

* *int* ***getAndDecrement****()*

Method **return current value**. And decrements current value by 1.

**Thread concurrency interview Question 44. How can you implement your own AtomicInteger in java?**

**Answer.** Another important and complex interview question for developers. Please see [**Implementation of custom/own AtomicInteger in java**](http://www.javamadesoeasy.com/2015/03/implementation-of-customown.html).

**Question 45. What is AtomicLong? Explain key methods of AtomicLong in java?**

**Answer.** This is another important thread concurrency interview question for freshers and experienced.AtomicLong  provides you with **long value** that is updated atomically. i.e. we can use these classes without any explicit synchronization in [multithreading](http://www.javamadesoeasy.com/2015/03/what-is-thread-in-java.html) environment, because any operation done on these classes is [thread safe](http://www.javamadesoeasy.com/2015/03/guidelines-to-thread-safe-code-most.html).

[*AtomicLong*](http://www.javamadesoeasy.com/2015/03/atomiclong-in-java.html) *important Methods >*

* *long* ***get****()*

method returns the current value

* *void* ***set****(long newValue)*

Sets to **newValue.**

* *long* ***getAndSet****(long newValue)*

Sets to **newValue** and returns the old value.

* *boolean* ***compareAndSet****(long expect, long update)*

*Addition methods >*

* *long* ***addAndGet****(long value)*

adds *value* to the current value. And **return updated value.**

* *long* ***incrementAndGet****()*

increments current value by 1. And **return updated value.**

* *long* ***getAndAdd****(long value)*

Method **return current value**. And adds *value* to the current value.

* *long* ***getAndIncrement****()*

Method **return current value**. And increments current value by 1.

*Subtraction methods >*

* *long* ***decrementAndGet****()*

decrements current value by 1. And **return updated value.**

* *long* ***getAndDecrement****()*

Method **return current value**. And decrements current value by 1.

**Thread concurrency interview Question 46. How can you implement your own AtomicLong in java?**

**Answer.** Another important and complex interview question for developers. Please see [**Implementation of custom/own AtomicLong in java**](http://www.javamadesoeasy.com/2015/03/implementation-of-customown-atomiclong.html).

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**Thread concurrency interview Question 47. What will be the output of below question in java?**



**Answer.**

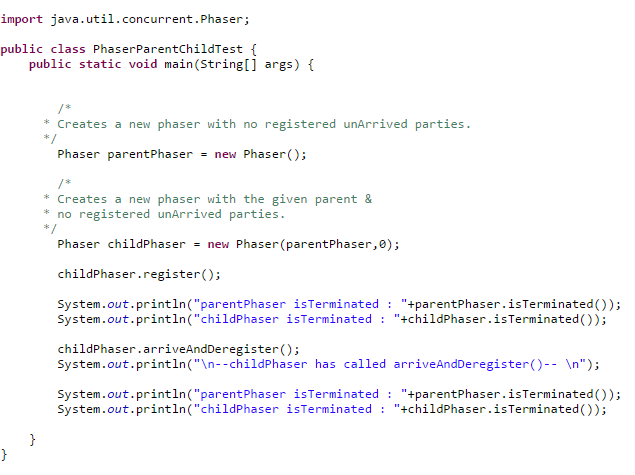
Thread-1 is Waiting to acquire lock

Thread-2 is Waiting to acquire lock

Thread-1 has acquired lock.

Thread-2 didn't got lock.

**Thread concurrency interview Question 48. What will be the output of below question in java?**



**Answer.**

parentPhaser isTerminated : false

childPhaser isTerminated : false

--childPhaser has called arriveAndDeregister()--

parentPhaser isTerminated : true

childPhaser isTerminated : true

**Thread concurrency interview Question 49. Which  atomic classes are available and which are not available in java 7? And why jdk developers didn’t created those classes?**

**Answer.** This is confusing thread concurrency interview question for freshers.

Java provides following classes in [**java.util.concurrent.atomic**](http://www.javamadesoeasy.com/2015/03/atomic-operations-in-java.html) >

*Classes found in* ***java.util.concurrent.atomic*** *are >*

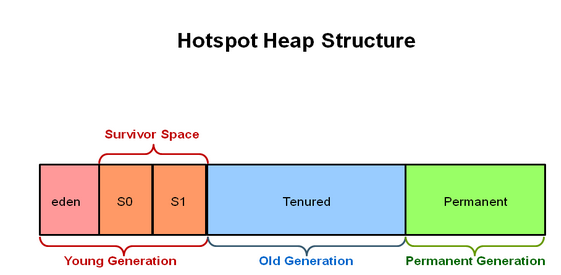
* **AtomicInteger**,
* **AtomicLong,** and
* **AtomicBoolean.**

*Classes* ***NOT*** *found in* ***java.util.concurrent.atomic*** *are >*

* **AtomicByte,**
* **AtomicShort,**
* **AtomicFloat,**
* **AtomicDouble and**
* **AtomicCharacter**

## Garbage Collection

### Give digramatic JVM Heap memory (Hotspot heap structure).

JVM Heap memory (Hotspot heap structure) with diagram in java >

### What is Throughput in gc(garbage collection) in java ?

In short, Throughput is the **time not spent** in garbage collection (GC) (in percent).

Throughput focuses on maximizing the amount of work by an application in a specific period of time. Examples of how throughput might be measured include >

* The number of transactions completed in a given time.
* The number of jobs that a batch program can complete in an hour.
* The number of database queries that can be completed in an hour.

### What are pauses in gc(garbage collection) in java?

Pauses is applications pauses i.e. when **application doesn’t gives any response** because of garbage collection (GC).

### JVM Heap memory (Hotspot heap structure)  in java consists of which elements?

1. **Young** Generation
   * 1a) **Eden**,
   * 1b) **S0 (Survivor** space 0**)**
   * 1c) **S1 (Survivor** space 1**)**
2. **Old** Generation (Tenured)
3. **Permanent** Generation.

So, JVM Heap memory (Hotspot heap structure) is divided into three parts **Young** Generation, **Old** Generation (tenured) and **Permanent** Generation.

**Young** Generation is further divided into **Eden**, **S0 (Survivor** space 0**)** and **S1 (Survivor** space 1**).**

### What is Young Generation (Minor garbage collection occurs in Young Generation)?

New objects are allocated in Young generation. ***Minor garbage collection*** *occurs in* **Young Generation.**

***When minor garbage collection?***

When the young generation fills up, this causes a ***minor garbage collection***.

All the unreferenced (dead) objects are cleaned up from young generation.

***When objects are moved from young to old generation in JVM heap?***

Some of the objects which aren't cleaned up **survive in young generation and gets aged**.  Eventually such objects are **moved from young to old generation**.

***What is Stop the World Event?***

Minor garbage collections are called **Stop the World** events. **All the non-daemon threads running in application are stopped during minor garbage collections** (i.e. the application stops for while)**.**

[**Daemon threads**](http://www.javamadesoeasy.com/2015/03/daemon-threads-12-salient-features-of.html) **performs minor garbage collection**. (Daemon threads are low [priority threads](http://www.javamadesoeasy.com/2015/03/thread-priorities-setpriority-and.html) which runs intermittently in background for doing garbage collection).

* + 1a) **Eden**,
  + 1b) **S0 (Survivor** space 0**)**
  + 1c) **S1 (Survivor** space 1**)**

### What is Old Generation or (tenured generation) - (Major garbage collection occurs in Old Generation)?

The **Old Generation** is used for storing the long surviving aged objects (Some of the objects which aren't cleaned up **survive in young generation and gets aged**.  Eventually such objects are **moved from young to old generation**).

***Major garbage collection*** *occurs in* **Old Generation.**

***At what time (or what age) objects are moved from young to old generation in JVM heap?***

There is some threshold set for young generation object and when that age is met, the object gets moved to the old generation during gc(garbage collection) in java.

***What is major garbage collection in java?***

**When the old generation fills up**, this causes a ***major garbage collection***. Objects are cleaned up from old generation. Major collection is much slower than minor garbage collection in jvm heap **because it involves all live objects**.

***Major garbage collection are Stop the World Event in java?***

Major garbage collections are also called Stop the World events. All the non-daemon threads running in application are stopped during major garbage collections. [Daemon threads](http://www.javamadesoeasy.com/2015/03/daemon-threads-12-salient-features-of.html) performs major garbage collection.

***Major gc(garbage collections) in responsive applications in java?***

Major garbage collections should be minimized for responsive applications because applications must not be stopped for long.

***Optimizing Major gc(garbage collections) in responsive applications in java?***

**Selection of appropriate garbage collector for the old generation** space affects the length of the “Stop the World” event for a major garbage collection.

### What is Permanent Generation or (Permgen) - (full garbage collection occurs in permanent generation in java)?

Permanent generation Space contains metadata required by JVM to describe the classes and methods used in the application.

The permanent generation is included in a **full garbage collection** in java.The permanent generation space is populated at runtime by JVM based on classes in use in the application.

The permanent generation space also contains **Java SE library classes and methods** in java.

JVM garbage collects those classes when classes are no longer required and space may be needed for other classes in java.

### What are the most important VM (JVM) PARAMETERS in JVM Heap memory?

**-Xms** : Xms is **minimum heap size** which is allocated at initialization of JVM.

**Examples** of using **-Xms** VM (JVM) option in java >

Example1 of using **-Xms** VM (JVM) option in java >

java -Xms512m MyJavaProgram

It will set the minimum heap size of JVM to 512 megabytes.

Example2 of using **-Xms** VM (JVM) option in java >

java -Xms1g MyJavaProgram

It will set the minimum heap size of JVM to 1 gigabyte.

**-Xmx** : Xmx is the **maximum heap size** that JVM can use.

**Examples** of using **-Xmx** VM option in java >

Example1 of using **-Xmx** VM (JVM) option in java >

java -Xmx512m MyJavaProgram

It will set the maximum heap size of JVM to 512 megabytes.

Example2 of using **-Xmx** VM (JVM) option in java >

java -Xmx1g MyJavaProgram

It will set the maximum heap size of JVM to 1 gigabyte.

### What are parameters for Young Generation(VM PARAMETERS for Young Generation) ?

**-Xmn** : -Xmn sets the size of young generation.

**Examples** of using **-Xmn** VM (JVM) option in java >

Example1 of using **-Xmn** VM (JVM) option in java >

java -Xmn512m MyJavaProgram

Example2 of using **-Xmn** VM (JVM) option in java >

java -Xmn1g MyJavaProgram

**-XX:NewRatio :** NewRatio controls the size of young generation.

**Example** of using -XX:NewRatio VM option in java >

**-XX:NewRatio=3 means that the ratio between the young and old/tenured generation is 1:3.**

In other words, the combined size of the eden and survivor spaces will be one fourth of the total heap size.

**-XX:NewSize** - NewSize is **minimum size of young generation** which is allocated at initialization of JVM.

Note : If you have specified -XX:NewRatio than minimum size of the young generation is allocated automatically at initialization of JVM.

**-XX:MaxNewSize** - MaxNewSize is the **maximum size of young generation** that JVM can use.

* + 1a) **Eden**,
  + 1b) **S0 (Survivor** space 0**)**
  + 1c) **S1 (Survivor** space 1**)**

**-XX:SurvivorRatio :   (for survivor space)**

SurvivorRatio can be used to **tune the size of the survivor spaces**, but this is often not as important for performance.

Example of using -XX:SurvivorRatio > **-XX:SurvivorRatio=6 sets the ratio between each survivor space and eden to be 1:6**.

In other words, each survivor space will be one eighth of the young generation (not one seventh, because there are two survivor spaces).

### What are the parameters for the old Generation (tenured) - (VM PARAMETERS for Old Generation) ?

**-XX:NewRatio :** NewRatio controls the size of young and old generation.

**Example** of using -XX:NewRatio, **-XX:NewRatio=3 means that the ratio between the young and old/tenured generation is 1:3.** In other words, the combined size of the eden and survivor spaces will be one fourth of the total heap size.

### What are the parameters for Permanent Generation (VM PARAMETERS for Permanent Generation)?

**-XX:PermSize:** It’s is initial value of Permanent Space which is allocated at startup of JVM.

**Examples of using -XX:PermSize VM (JVM) option in java >**

Example1 of using **-XX:PermSize** VM (JVM) option in java >

java -XX:PermSize=512m MyJavaProgram

It will set initial value of Permanent Space as 512 megabytes to JVM

Example2 of using **-XX:PermSize** VM (JVM) option in java >

java -XX:PermSize=1g MyJavaProgram

It will set initial value of Permanent Space as 512 gigabyte to JVM

**-XX:MaxPermSize:** It’s maximum value of Permanent Space that JVM can allot up to.

**Examples of using -XX:MaxPermSize VM option in java >**

Example1 of using **-XX:MaxPermSize** VM (JVM) option in java >

java -XX:MaxPermSize=512m MyJavaProgram

It will set maximum value of Permanent Space as 512 megabytes to JVM

Example2 of using **-XX:MaxPermSize** VM (JVM) option in java >

java -XX:MaxPermSize=1g MyJavaProgram

It will set maximum value of Permanent Space as 1 gigabyte to JVM

### Name the other important VM (JVM) parameters for java heap in java.

**-XX:MinHeapFreeRatio and -XX:MaxHeapFreeRatio**

JVM can grows or shrinks the heap to keep the proportion of free space to live objects within a specific range.

**-XX:+AggressiveHeap** is used for Garbage Collection Tuning setting. This VM option inspects the server resources and attempts to set various parameters in optimal manner for for long running and memory consuming applications. There must be minimum of 256MB of physical memory on the servers before the AggressiveHeap can be used.

**-Xss** > Use this VM option to **adjust the maximum thread stack size.**

Also you must know that -Xss option is same as **-XX:ThreadStackSize**.

**Examples of using** -Xss **VM option in java >**

Example1 of using -Xss >

java -Xss512m MyJavaProgram

It will set the default stack size of JVM  to 512 megabytes.

Example2 of using -Xss >

java -Xss1g MyJavaProgram

It will set the default stack size of JVM  to 1 gigabyte.

### What are the different Garbage collectors in java?

1. Serial collector / Serial GC (Garbage collector)
2. Throughput GC (Garbage collector) or Parallel collector
3. Incremental low pause garbage collector (train low pause garbage collector)
4. Concurrent Mark Sweep (CMS) Collector / concurrent low pause collector
5. G1 Garbage Collector (or Garbage First)

### What is [Serial collector / Serial GC (Garbage collector)](http://www.javamadesoeasy.com/2016/10/serial-collector-serial-gc-garbage.html) ?

**Features of Serial GC (Garbage collector) in java  :**

Serial collector is also called Serial GC (Garbage collector) in java.

Serial collector is simply also called Serial collector in java.

Serial GC (Garbage collector) is rarely used in java.

Serial GC (Garbage collector) is designed for the single threaded environments in java.

In Serial GC (Garbage collector) , both minor and major garbage collections are done serially by one thread (using a single virtual CPU) in java.

Serial GC (Garbage collector) uses a mark-compact collection method. This method moves older memory to the beginning of the heap so that new memory allocations are made into a single continuous chunk of memory at the end of the heap. This compacting of memory makes it faster to allocate new chunks of memory to the heap in java.

The serial garbage collector is the default for client style machines in Java SE 5 and 6.

***When to Use the Serial GC (garbage Collector) in java?***

The Serial GC is the garbage collector of choice for most applications that do not have low pause time requirements and run on client-style machines. It takes advantage of only a single virtual processor for garbage collection work in java.

Serial GC (garbage collector) is also popular in environments where a high number of JVMs are run on the same machine. In such environments when a JVM does a garbage collection it is better to use only one processor to minimize the interference on the remaining JVMs in java.

***Vm (JVM) option for enabling serial GC (garbage Collector) in java.***

-XX:+UseSerialGC

Example of Passing Serial GC in Command Line for starting jar>

java -Xms256m -Xms512m  -XX:+UseSerialGC -jar d:\MyJar.jar

### What is Throughput GC (Garbage collector) or Parallel collector in java?

***Features of Throughput GC (Garbage collector) in java .***

* [Throughput collector](http://www.javamadesoeasy.com/2016/10/throughput-gc-garbage-collector-or.html) is also called
* Throughput GC (garbage collector)
* ParallelGC (garbage collector)
* Throughput collector
* ParallelGC collector
* Throughput garbage collector is the default garbage collector for JVM in java.
* Throughput garbage collector uses multiple threads to execute a minor collection and so reduces the serial execution time of the application in java.
* The throughput garbage collector is similar to the serial garbage collector but uses multiple threads to do the minor collection in java.
* This garbage collector uses a parallel version of the young generation garbage collector in java.
* The tenured generation collector is the same as the serial garbage collector in java.

***When to Use the Throughput GC (Garbage collector) in java ?***

* The Throughput garbage collector should be used when application can afford low pauses in java.
* And application is running on host with multiple CPU’s (to derive advantage of using multiple threads for garbage collection) in java.

***Vm (JVM) option for enabling throughput GC (Garbage collector) in java .***

**-XX:+UseParallelGC**

**Example** of using **throughput** collector in Command Line for starting jar>

java -Xms256m -Xms512m  **-XX:+UseParallelGC** -jar d:\MyJar.jar

With this **Vm** (JVM) option you get a

* **Multi-threaded young** generation garbage collector in java,
* **single-threaded old** generation garbage collector in java and
* **single-threaded compaction** of **old** generation in java.

**Vm** (JVM) option for enabling **throughput collector** with **n number of threads** in java>

-XX:ParallelGCThreads=<numberOfThreads>

**Another Vm** (JVM) option for enabling **throughput collector** in java>

-XX:+UseParallelOldGC

**5.2.4. Goals** for Throughput GC (Garbage collector) in java >

* Maximum pause time goal (Highest priority)
* Throughput goal
* Minimum footprint goal (Lowest priority)

**Performance of Throughput GC (garbage Collector) host with different number of CPU’s in java**

**Vm** (JVM) option for enabling **throughput collector** with **n number of threads** in java>

**Another Vm** (JVM) option for enabling **throughput collector** in java>

**Controlling maximum pause time and throughput** for the application in java >

**Vm** (JVM) option for **maximum pause time** in java **>**

**Vm** (JVM) option for **throughput** in java **>**

Adjusting Generation Sizes in throughput GC (Garbage collector).

### What is Incremental low pause garbage collector (train low pause garbage collector) in java?

We won’t be discussing in detail about incremental low pause garbage collector because is **not used these days** in java**.** Incremental low pause collector was used in Java 4.

Vm (JVM) option which was used for enabling Incremental low pause garbage collector in java >

-XX:+UseTrainGC.

### What is Concurrent Mark Sweep (CMS) Collector / concurrent low pause collector in java?

***Features of Concurrent Mark Sweep (CMS) Collector / concurrent low pause collector in java***

[Concurrent Mark Sweep Collector](http://www.javamadesoeasy.com/2016/10/concurrent-mark-sweep-cms-collector.html) is also called concurrent low pause collector

concurrent low pause GC (garbage collector). Concurrent Mark Sweep (CMS) collector **collects the old/tenured generation** in java**.**

Concurrent Mark Sweep (CMS) Collector **minimize the pauses** by doing most of the **garbage collection work concurrently with the application threads** in java.

Concurrent Mark Sweep (CMS) Collector **on live objects.** Concurrent Mark Sweep (CMS) Collector **does not copy or compact the live objects**. A garbage collection is done **without moving the live objects**. If fragmentation becomes a problem, allocate a larger heap in java.

***When to Use the Concurrent Low Pause Collector in java***

Concurrent Low Pause Collector should be used if your **applications that require low garbage collection pause times** in java**.**

Concurrent Low Pause Collector should be used when your **application can** afford to **share processor resources with the garbage collector while** the **application is running** in java.

Concurrent Low Pause Collector is beneficial to applications which have a relatively **large set of long-lived data** (a large tenured generation) and run on machines with **two or more processors** in java.

**Examples** when to use  Concurrent Mark Sweep (CMS) collector / concurrent low pause collector should be used for >

**Example 1 - Desktop UI application** that **respond to events**,

**Example 2 - Web server responding to a request** and

**Example 3 - Database responding to queries.**

***Vm (JVM) option for enabling Concurrent Mark Sweep (CMS) Collector in java.***

**-XX:+UseConcMarkSweepGC**

**Example** of using Concurrent Mark Sweep (CMS) collector **/ concurrent low pause collector** in Command Line for starting jar>

java -Xms256m -Xms512m  **-XX:+UseConcMarkSweepGC** -jar d:\MyJar.jar

***Concurrent Mark Sweep (CMS) Collector / concurrent low pause collector working in detail in java***

As mentioned above Concurrent Mark Sweep (CMS) collector **collects the old/tenured generation (i.e.** performs ***Major garbage collection*** process**).**

***Major gc(garbage collection) in Concurrent Mark Sweep (CMS) Collector / concurrent low pause collector in java.***

**For each major collection** the CMS collector will **pause all** the **application threads for a brief period** at the **beginning** of the collection and toward the **middle** of the collection.

The **second pause** tends to be the **longer** than first pause and **uses multiple threads to do the collection** work during that pause in java. The remainder of the collection is done with a garbage collector thread that runs concurrently with the application.

***Minor gc (garbage collection) in Concurrent Mark Sweep (CMS) Collector / concurrent low pause collector.***

The minor collections is done in a manner **similar to the serial collector** although **multiple threads are used** to do the collection in java.

***Heap Structure for CMS garbage Collector***

CMS garbage collectors didies heap into three sections: **young** generation, **old** generation, and **permanent** generation of a fixed memory size.**Young** Generation is further divided into **Eden**, **S0 (Survivor** space 0**)** and **S1 (Survivor** space 1**).**

**Young Generation GC** (garbage Collection) in java

**Live objects** are **copied** from the **Eden space and survivor space** to the **other survivor space**.

Any **older objects** that have reached their aging threshold are **promoted to old generation**.

After a young GC, the **Eden space and one of the survivor spaces is cleared**.

promoted objects (**older objects** that have reached their aging threshold in young GC) are are **available in old generation**.

**Old Generation** **GC** (garbage Collection) **with CMS** in java

**Initial mark** phase **-** (**First pause** happens/ stop the world event ) - **mark live/reachable objects** (Example - objects on thread stack, static objects etc.) and elsewhere in the **heap** (Example - the young generation).

**Concurrent marking** phase **- (**No pause phase ) **-**  finds **live objects** while the application continues to execute.

**Remark -** (**Second pause** happens/ stop the world events) - It **finds objects** that were **missed during the concurrent marking phase due to the concurrent execution of the application threads**.

Old Generation GC (garbage Collection) **- Sweep phase** (Concurrent Sweep phase) in java  
**Sweep** phase -  do the concurrent **sweep**, memory is freed up.

Objects that were not marked in the previous phase are deallocated in place.

There is no compaction. **Unmarked objects** are equal to **Dead Objects.**

Old Generation GC (garbage Collection) **- After Sweeping**

**Reset** phase - do the concurrent **reset**.

### What is G1 Garbage Collector (or Garbage First) in java?

The G1 garbage collector **features** -

* [G1 garbage collector](http://www.javamadesoeasy.com/2016/10/g1-garbage-collector-garbage-first.html) is also called
  + G1 garbage collector
  + G1 collector
  + G1 GC (garbage collector)
  + Garbage first collector
* G1 garbage collector was **introduced in Java 7**
* G1 garbage collector was designed to replace CMS collector(Concurrent Mark-Sweep garbage Collector).
* G1 garbage collector is **parallel**,
  + G1 garbage collector is **concurrent**, and
  + G1 garbage collector is **incrementally compacting low-pause** garbage collector in java.
* G1 garbage collector has much better layout from the other garbage collectors like serial, throughput and CMS garbage collectors in java.
* G1(Garbage First) collector **compacts sufficiently to completely avoid the use of fine-grained free lists for allocation**, and instead relies on regions.
* G1(Garbage First) collector **allows customizations** by allowing users to specify pause times.
* G1 Garbage Collector (or Garbage First) limits GC **pause times and maximizes throughput.**

**Vm** (JVM) option for enabling G1 Garbage Collector (or Garbage First) in java >

**-XX:+UseG1GC**

Example of using G1 Garbage Collector in Command Line for starting jar>

java -Xms256m -Xms512m  **-XX:+UseG1GC** -jar d:\MyJar.jar

G1(Garbage First) collector functioning >

CMS garbage collectors divides heap into three sections: young generation, old generation, and permanent generation of a fixed memory size.All memory objects end up in one of these three sections. The G1 collector takes a different approach than CMS garbage collector in partitioning java heap memory.The heap is split/**partitioned** into **many fixed sized regions** (eden, survivor, old generation regions), **but** there is not a **fixed size** for them. This provides **greater flexibility in memory usage.**

***When to use G1 garbage collector ?***

G1 must be used when applications that require **large heaps** with limited GC latency.

Example - Application that require

* **heaps around 5-6GB or larger** and
* **pause time** required **below 0.5 seconds**

***When to switch from CMS (or old garbage collectors) to G1 garbage collector?***

Applications using CMS garbage collector may switch to G1 when >

* **Full GC** durations are too **long** or too **frequent**.
* The **rate** of **object allocation** or **promotion varies** significantly.
* **Long garbage collection** (longer than 0.5 to 1 second)

***The G1(Garbage First) collector working Step by Step?***

The G1 collector takes a different approach than CMS garbage collector in partitioning java heap memory.

G1(Garbage First) garbage collector Heap Structure

The heap is split/**partitioned** into **many fixed sized regions** (eden, survivor, old generation regions), but there is not a fixed size for them. This provides greater flexibility in memory usage**.** Each **region’s size** is chosen **by JVM at startup**. Generally heap is divided into **2000 regions** by JVM varying in size from **1 to 32Mb**.

G1(Garbage First) garbage collector Heap Allocation

As mentioned above there are following region in heap >**Eden**, **survivor** and **old** generation region. Also, **Humongous and unused** regions are there in heap.

Young Generation in G1 garbage collector

Generally heap is divided into **2000 regions** by JVM.**Minimum** size of region can be **1Mb** and **Maximum** size of region can be **32Mb**. Regions are not required to be contiguous like CMS garbage collector.

Young GC in G1 garbage collector

* **Live objects** are copied or moved **to survivor regions.**
* If objects aging threshold is met it get promoted to **old** generation regions.
* It is **STW** (stop the world) event. Eden size and survivor size is calculated for the next young GC.
* The young GC is done parallely using multiple threads.

End of a Young GC with G1 garbage collector At this stage **Live objects have been evacuated (copied or moved) to** >

* **survivor** regions or
* **old** generation regions.

Old Generation Collection with G1 garbage collector

G1 collector is low pause collector for old generation objects.

Initial Mark -

* It is **STW** (stop the world) event.
* With G1, it is **piggybacked on a normal young GC**. Mark survivor regions (root regions) which may have references to objects in old generation.

Root Region Scanning -

* **Scan survivor regions for references into the old generation**.
* This happens while the **application continues to run**. The phase must be **completed before** a young GC can occur.

Concurrent Marking -

* **Find live objects over the entire heap.**
* This happens while the **application is running**.
* This phase can be interrupted by young generation garbage collections.

Remark (Stop the World Event) -

* **Completes the marking of live object in the heap**.
* Uses an algorithm called **snapshot-at-the-beginning** (SATB) which is much **faster** than algorithm used in the **CMS** collector.

Cleanup (Stop the World Event and Concurrent) -

* **Performs accounting on live objects and completely free regions**. (Stop the world)
* Young generation and old generation are reclaimed at the same time
* Old generation regions are selected based on their liveness.

* **Scrubs** the Remembered Sets. (Stop the world)
* **Reset** the **empty regions** and return them to the free list. (Concurrent)

### Difference between Serial GC (Garbage collector)  vs Throughput GC (Garbage collector) in java?

**Difference Serial and Throughput gc (garbage Collector)**.

Serial collector **uses one thread to execute garbage collection.**

Throughput collector **uses multiple threads to execute garbage collection.**

Serial GC is the garbage collector of choice for applications that do **not** have **low pause time requirements** and run on client-style machines. Throughput GC is the garbage collector of choice for applications that have **low pause time requirements**.

### What is ParNew collector ?

Is the young generation collector. It is the parallel copy collector, it uses multiple threads in parallel. Vm parameter for enabling ParNew collector is -XX:+UseParNewGC.

### What is Automatic Garbage Collection in JVM heap memory in java?

**Automatic garbage collection** is the process of

* **Identifying objects which are in use** in java heap memory and
* **Which objects are not in use** in java heap memory and
* **deleting the unused objects** in java heap memory.

*How to* ***Identify objects which are in use*** *in JVM heap memory in java?*

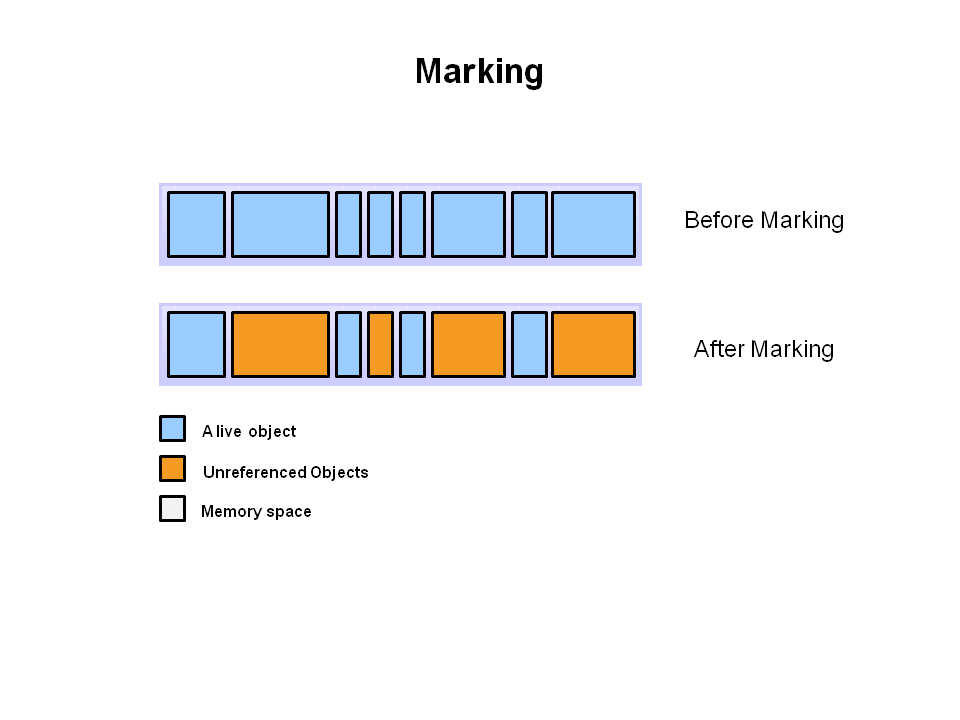
**Objects** in use (or **referenced objects**) are those objects which are still needed by java program, some part of java program is still pointing to that object.

***Which objects are not in use*** *in JVM heap memory in java?*

**Objects not** in use (or **unreferenced objects**) are those objects which are not needed by java program, no part of java program is pointing to that object. So, these unused objects can be cleaned in GC (garbage collection) process and memory used by an unreferenced object can be reclaimed.

### How garbage collection is done using Marking and deletion in java?

***7.1) Step 1 > Marking***

Marking is a process in which gc (garbage collector) identifies which parts of memory (occupied by objects) are in use and which are not.

Before Marking >

All the objects are shown in **blue,** at this stage

* some of objects might be **in use** (referenced objects)  and
* some of objects might **not be in use** (unreferenced objects) .

After Marking >

**Objects in use** (or **referenced objects** or **Alive objects**) are shown in **blue**.

**Objects not** in use (or **unreferenced objects**) objects are shown in **Orange**.

**7.2) Step 2 > Deletion**

**Step 2a : Normal Deletion**

* **Normal deletion removes all the unreferenced objects** and
* **leaves referenced objects and pointers to free space**.

**Step 2b : Deletion with Compacting**

Deletion with Compacting is done to improve the performance than normal deleting.

Deletion with Compacting is done to improve the performance than normal deleting.

* Deletion with Compacting **removes all the unreferenced objects** and
* **compacts the remaining referenced objects** by **moving all the referenced objects together.**
* As all the referenced objects are moved together **new memory allocation becomes easier and much faster.**

### Very important points about GC (Garbage Collection) in Java

1. All Java objects are always created on heap in java.
2. **What is GC (Garbage collection) process in java**?

GC (Garbage collection) is the process by which JVM cleans objects (unused objects) from heap to reclaim heap space in java.

OR

**What is Automatic Garbage Collection in JVM heap memory in java?**

**Automatic garbage collection** is the process of

* **Identifying objects which are in use** in java heap memory and
* **Which objects are not in use** in java heap memory and
* **deleting the unused objects** in java heap memory.

1. How to **Identify objects which are in use** in java heap memory?

**Objects** in use (or **referenced objects**) are those objects which is still needed by java program, some part of java program is still pointing to that object.

1. **Which objects are NOT in use** in java heap memory?

**Objects not** in use (or **unreferenced objects** or **unused objects**) are those objects which is not needed by java program, no part of java program is pointing to that object.

So, these unused objects can be cleaned in garbage collection process and memory used by an unreferenced object can be reclaimed.

1. GC (Garbage collection) process **automatically clears objects from heap to reclaim heap space**. You just need to specify the type of garbage collector type you want to use at JVM startup.
2. **Gc** (garbage collector) **calls finalize** method **for garbage collection**. finalize **method is called only once by garbage collector for an object in java**.
3. [***Daemon threads***](http://www.javamadesoeasy.com/2015/03/daemon-threads-12-salient-features-of.html) are low priority threads which **runs intermittently in background** for doing **garbage collection (gc) in java**.
4. We can ***force early gc*** *(garbage collection) in java* by using following methods >

**System.*gc*();**

**Runtime.*getRuntime*().gc();**

**System.*runFinalization*();**

**Runtime.*getRuntime*().runFinalization();**

1. *By calling these methods JVM runs the finalize() methods of any objects pending finalization i.e. objects which have been discarded but there finalize method is yet to be run. After finalize method is executed JVM reclaims space from all the discarded objects in java.*

***Note*** *: Calling these methods does* ***not guarantee*** *that it will* ***immediately start performing garbage collection****.*

1. **Finalize method** execution is not assured - We must not override finalize method to write some critical code of application because methods execution is not assured. Writing some critical code in finalize method and relying on it may make application to go horribly wrong in java.
2. Dealing with **OutOfMemoryError** in java.
3. **WeakhashMap** in java - java.util.WeakHashMap is hash table based implementation of the [Map](http://www.javamadesoeasy.com/2015/04/map-hierarchy-in-java-detailed-hashmap.html) interface, with *weak keys*.

**An entry in a WeakHashMap will be automatically removed by garbage collector when its key is no longer in ordinary use**. Read in detail about WeakhashMap.

1. Object which is set explicitly set to **null** becomes **eligible for gc** (garbage collection) in java .

Example 1 >

  String s=”abc”; //s is currently **not eligible** for gc (garbage collection) in java.

  s = null;   //Now, s is currently  **eligible** for gc (garbage collection) in java.

Example 2 >

  List list =new ArrayList(); //list is currently **not eligible** for gc (garbage collection).

  list = null;   //Now, list is currently  **eligible** for gc (garbage collection).

1. **Difference in garbage collection in C/C++ and Java** (Hint : In terms of memory allocation and deallocation of objects)?

In java garbage collection (memory allocation and deallocation of objects) is an **automatic** process.

But, In C and C++ memory allocation and deallocation of objects) is a **manual** process.

1. All the **variables** declared **inside block** becomes **eligible for gc** (garbage collection) **when** we **exit** that **block** (As scope of those variable is only that block) in java.

Example of garbage collection while using block in java -

|  |
| --- |
| **class** MyClass {  **public** **static** **void** main(String[] args) {  **boolean** var = **false**;  **if** (var) { // begin block 1  **int x = 1; // x is declared inside block**                   //..........                   //code inside block...                   //..........            } // end block 1 //And **now x is eligible for gc (garbage collection)**  **else** { // begin block 2  **int** y = 1;                   //..........                   //code inside block...                   //..........            } // end block 2 //And **now y is eligible for gc (garbage collection)**     }  } |

### Summary of garbage collection in java-

* **1) Terms frequently used in Garbage Collection (GC) in java-**
  + What is **Throughput** in gc(garbage collection) in java ?

Throughput is the **time not spent** in garbage collection (GC) ( in percent).

* + What are **pauses** in gc(garbage collection) in java ?

Pauses is applications pauses when **application is paused beacuse** because of garbage collection (GC).

* **2) JVM Heap memory (Hotspot heap structure) with diagram in java >**
  + **2.1) JVM Heap memory (Hotspot heap structure)  in java consists of following elements>**

JVM Heap memory (Hotspot heap structure) is divided into three parts **Young** Generation, **Old** Generation (tenured) and **Permanent** Generation.

**Young** Generation is further divided into **Eden**, **S0 (Survivor** space 0**)** and **S1 (Survivor** space 1**).**

* **3) GARBAGE COLLECTION** (**Minor and major** garbage collection) in JVM Heap memory (i.e. in young, old and permanent generation) >
  + **3.1) Young** Generation ***(Minor garbage collection*** *occurs in* ***Young Generation)***

**New objects are allocated in Young generation.**When the young generation fills up, this causes a ***minor garbage collection***. All the unreferenced (dead) objects are cleaned up from young generation.

* + **3.2) Old** Generation or (tenured generation) - (***Major garbage collection*** *occurs in* **Old Generation**)

The **Old Generation** is used for storing the long surviving aged objects. **When the old generation fills up**, this causes a ***major garbage collection***. Objects are cleaned up from old generation.

* + **3.3) Permanent** Generation or (Permgen) - (**full garbage collection** occurs in permanent generation in java).

**Permanent generation Space contains metadata required by JVM to describe the classes and methods used in the application.**

The permanent generation is included in a **full garbage collection** in java.

* 4) Most important **VM** (JVM) **PARAMETERS in** JVM Heap memory >

**-Xms** : Xms is **minimum heap size** which is allocated at initialization of JVM.

**-Xmx** : Xmx is the **maximum heap size** that JVM can use.

* + **4.1) Young** Generation(**VM** **PARAMETERS for** Young Generation)

**-Xmn** : -Xmn sets the size of young generation.

**-XX:NewRatio :** NewRatio controls the size of young generation.

**-XX:NewSize** - NewSize is **minimum size of young generation** which is allocated at initialization of JVM.

**-XX:MaxNewSize** - MaxNewSize is the **maximum size of young generation** that JVM can use.

**-XX:SurvivorRatio :  (for survivor space)** SurvivorRatio can be used to **tune the size of the survivor spaces**.

* + **4.2) Old** Generation (tenured) - (**VM** **PARAMETERS for** Old Generation)

**-XX:NewRatio :** NewRatio controls the size of young and **old** generation.

* + **4.3) Permanent** Generation (**VM** **PARAMETERS for** Permanent Generation)

**-XX:PermSize:** It’s is initial value of Permanent Space which is allocated at startup of JVM.

**-XX:MaxPermSize:** It’s maximum value of Permanent Space that JVM can allot up to.

**-XX:PermSize**: It’s is initial value of Permanent Space which is allocated at startup of JVM.

**-XX:MaxPermSize:** It’s maximum value of Permanent Space that JVM can allot up to.

* + **4.4) Other important VM (JVM) parameters for java heap in java >**

**-Xss** > Use this VM option to **adjust the maximum thread stack size.**

**-XX:MinHeapFreeRatio and -XX:MaxHeapFreeRatio**

JVM can grows or shrinks the heap to keep the proportion of free space to live objects within a specific range.

**-XX:+AggressiveHeap** is used for Garbage Collection Tuning setting.

* **5) Different Garbage collectors in detail >**
  + **5.1) Serial collector / Serial GC (Garbage collector)** in java
    - **5.1.1. Features of Serial GC (Garbage collector) in java  >**

[Serial GC (Garbage collector)](http://www.javamadesoeasy.com/2016/10/serial-collector-serial-gc-garbage.html) is designed **for** the **single threaded environments** in java.

In Serial GC (Garbage collector) , both **minor and major garbage collections are done serially** by **one thread** (using a single virtual CPU) in java.

* + - **5.1.2. When to Use the Serial GC (garbage Collector) in java >**

**applications that do not have low pause time requirements**

* + - **5.1.3. Vm** (JVM) option for enabling **serial GC (garbage Collector)** in java>

**-XX:+UseSerialGC**

* + **5.2) Throughput GC (Garbage collector) or Parallel collector in java**
    - **5.2.1. Features of Throughput GC (Garbage collector) in java  >**

[Throughput garbage collector](http://www.javamadesoeasy.com/2016/10/throughput-gc-garbage-collector-or.html) **uses multiple threads to execute a minor collection** and so reduces the serial execution time of the application in java.

* + - **5.2.2. When to Use the Throughput GC (Garbage collector) in java >**

The Throughput collector should be used when application can **afford low pauses** in java.

* + - **5.2.3. Vm** (JVM) option for enabling throughput GC (Garbage collector) in java >

**-XX:+UseParallelGC**

* + - **5.2.4. Goals** for Throughput GC (Garbage collector) in java >

Maximum pause time goal (Highest priority)

Throughput goal

Minimum footprint goal (Lowest priority)

* + - **5.2.5.**Read in more **detail** about following features of Throughput GC (Garbage collector) in java
  + **5.3) Incremental low pause garbage collector (train low pause garbage collector) in java :**

Not used these days, was used in java 4.

* + **5.4) Concurrent Mark Sweep (CMS) Collector / concurrent low pause collector in java**
    - **5.4.1. Features** of Concurrent Mark Sweep (CMS) Collector / concurrent low pause collector in java  >

Concurrent Mark Sweep (CMS) collector **collects the old/tenured generation** in java**.**

Concurrent Mark Sweep (CMS) Collector **minimize the pauses** by doing most of the **garbage collection work concurrently with the application threads** in java.

* + - **5.4.2. When to Use the Concurrent Low Pause Collector in java**

Concurrent Low Pause Collector should be used if your **applications that require low garbage collection pause times** in java**.**

* + - **5.4.3. Vm** (JVM) option for enabling **Concurrent Mark Sweep** (CMS) Collector in java >

**-XX:+UseConcMarkSweepGC**

* + - **5.4.4. Concurrent Mark Sweep (CMS) Collector / concurrent low pause collector working in detail in java >**
      * **5.4.4.1 Major gc(garbage collection)** in Concurrent Mark Sweep (CMS) Collector / concurrent low pause collector in java >

**For each major collection** the CMS collector will **pause all** the **application threads for a brief period** at the **beginning** of the collection and toward the **middle** of the collection.

* + - * **5.4.4.2 Minor gc (garbage collection)** in Concurrent Mark Sweep (CMS) Collector / concurrent low pause collector >

The minor collections is done in a manner **similar to the serial collector** although **multiple threads are used** to do the collection in java.

* + - **5.4.5. Heap Structure for CMS garbage Collector**

CMS garbage collectors didies heap into three sections: **young** generation, **old** generation, and **permanent** generation of a fixed memory size.

**Young** Generation is further divided into **Eden**, **S0 (Survivor** space 0**)** and **S1 (Survivor** space 1**).**

* + - **5.4.6. Steps (in short)** in GC (garbage collection) cycle in Concurrent Mark Sweep (CMS) Collector / concurrent low pause garbage collector in java >

**Young GC (Generation garbage) Collection happens. Then,**

**Than Old Generation** **GC** (garbage Collection) **happens.**

1. **initial mark > stop** all application threads; mark all live **objects**; **resume** all application threads
2. **concurrent mark**  > do the concurrent **mark** (one processor is used for concurrent work)
3. **Remark > stop** all application threads; do the **remark**; **resume** all application threads
4. **sweep** > do the concurrent **sweep**, memory is freed up (one processor is used for concurrent work)
5. **reset**  > do the concurrent **reset** (one processor is used for concurrent work)
   * **5.5) G1 Garbage Collector (or Garbage First) in java**
     + 5.5.1. The G1 garbage collector **features** -

[G1 garbage collector](http://www.javamadesoeasy.com/2016/10/g1-garbage-collector-garbage-first.html) was **introduced in Java 7**

G1 garbage collector was designed to replace CMS garbage Collector.

G1 garbage collector is **parallel** and **concurrent**, and

G1 Garbage Collector (or Garbage First) **limits GC pause times** and **maximizes throughput.**

* + - **5.5.2**. **Vm** (JVM) option for enabling G1 Garbage Collector (or Garbage First) in java >

**-XX:+UseG1GC**

* + - 5.5.3. G1(Garbage First) collector functioning >

CMS garbage collectors divides heap into three sections: young generation, old generation, and permanent generation of a fixed memory size.

The heap is split/**partitioned** into **many fixed sized regions** (eden, survivor, old generation regions), **but** there is not a **fixed size** for them. This provides **greater flexibility in memory usage.**

* + - 5.5.4. When to use G1 garbage collector >

G1 must be used when applications that require **large heaps** with limited GC latency.

* + - 5.5.5. When to switch from CMS (or old garbage collectors) to G1 garbage collector >

**Full GC** durations are too **long** or too **frequent**.

* + - **5.5.6.** The G1(Garbage First) collector working Step by Step >

The G1 collector takes a different approach than CMS garbage collector in partitioning java heap memory.

* + - 5.5.6.1. G1(Garbage First) garbage collector Heap Structure >

The heap is split/**partitioned** into **many fixed sized regions** (eden, survivor, old generation regions).

* + - 5.5.6.2. G1(Garbage First) garbage collector Heap Allocation >

**Live objects** are **moved or copied** from **one region to another**.

As mentioned above there are following region in heap >

**Eden**, **survivor** and **old** generation region.

Also, **Humongous and unused** regions are there in heap.

* + - 5.5.6.3. Young Generation in G1 garbage collector

Generally heap is divided into **2000 regions** by JVM.

**Minimum** size of region can be **1Mb** and

**Maximum** size of region can be **32Mb**.

Young GC in G1 garbage collector

* **Live objects** are copied or moved **to survivor regions.**
* If objects aging threshold is met it get promoted to **old** generation regions.
* It is **STW** (stop the world) event. Eden size and survivor size is calculated for the next young GC.

End of a Young GC with G1 garbage collector

At this stage **Live objects have been evacuated (copied or moved) to**  **survivor** regions or **old** generation regions.

* + - 5.5.6.4. Old Generation Collection with G1 garbage collector

Initial Mark -

* It is **STW** (stop the world) event.
* Mark survivor regions (root regions) which may have references to objects in old generation.

Root Region Scanning -

* **Scan survivor regions for references into the old generation**.
* This happens while the **application continues to run**.

Concurrent Marking -

* **Find live objects over the entire heap.**
* This happens while the **application is running**.

Remark (Stop the World Event) -

* **Completes the marking of live object in the heap**.

Cleanup (Stop the World Event and Concurrent) -

* **Performs accounting on live objects and completely free regions**. (Stop the world)
* Young generation and old generation are reclaimed at the same time
* **Reset** the **empty regions** and return them to the free list. (Concurrent)
  + **5.6) Difference between Serial GC (Garbage collector)  vs Throughput GC (Garbage collector) in java?**

Serial collector **uses one thread to execute garbage collection.**

Throughput collector **uses multiple threads to execute garbage collection.**

* **6) What is Automatic Garbage Collection in JVM heap memory in java?**
  + How to **Identify objects which are in use** in JVM heap memory in java?

**Objects** in use are those objects which are still needed by java program.

* + **Which objects are not in use** in JVM heap memory in java?

**Objects** in use are those objects which are NOT still needed by java program.

* 7) Now let’s understand how garbage collection is done using **Marking** and **deletion** in java**.**
  + **7.1) Step 1 > Marking**

Marking is a process in which gc (garbage collector) identifies which parts of memory (occupied by objects) are in use and which are not.

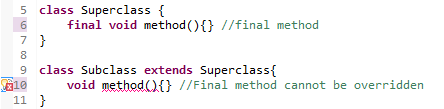
* + **7.2) Step 2 > Deletion**

**Normal deletion removes all the unreferenced objects during process of garabage collection in java.**

## Miscellaneous Topics

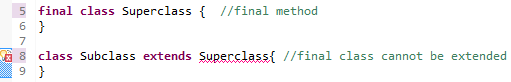
### What is significance of final in java?

1. **Final memberVariable/instanceVariable** of class must be initialized at time of declaration, once initialized final memberVariable cannot be assigned a new value.
2. **Final method** cannot be overridden, any attempt to do so will cause compilation error.



Runtime polymorphism is not applicable on final methods because they cannot be overridden.

1. **Final class** cannot be extended, any attempt to do so will cause compilation error.



### What is difference between using instanceOf operator and getClass() in equals method?

If we use **instanceOf** it will return true for comparing current class with its subclass as well,

but **getClass**() will return true only if exactly same class is compared. Comparison with any subclass will return false.

### What is Immutable class?

**Any change made to object of immutable class produces new object.**

Example- [**String is Immutable class in java**](http://www.javamadesoeasy.com/2015/05/string-is-immutable-in-java.html), any changes made to Sting object produces new String object.

***Creating*** *Immutable class >*

1) [**Final**](http://www.javamadesoeasy.com/2015/05/final-keyword-in-java-20-salient.html) **class** - Make class final so that it cannot be inherited

2) **private member variable** -> Making member variables private ensures that fields cannot be accessed outside class.   
3) **final member variable** -> Make member variables final so that they can be assigned only once.

4) **Constructor** -> Initialize all fields in constructor.

     assign all mutable member variable using new keyword.

5) **Don't provide setter methods** in class/ provide only getter methods.

6) **object of immutable class** - Any change made to object of immutable class proabstaduces new object.

**object of mutable class** -  Any change made to object of mutable class doesn't produces new object.

   - **Integer,** [**String**](http://www.javamadesoeasy.com/2015/05/string-is-immutable-in-java.html) **are immutable class**,

         any changes made to object of these classes produces new object.

       so return reference variable of Integer.

   - [**HashMap**](http://javamadesoeasy.com/2015/02/hashmap-custom-implementation.html) **is mutable class,**

         any changes made to HashMap object won't produce new HashMap object.

         so return copy/clone of object, not reference variable of HashMap.\*/

### Java Garbage Collection

In java, garbage means unreferenced objects.

Garbage Collection is process of reclaiming the runtime unused memory automatically. In other words, it is a way to destroy the unused objects.

To do so, we were using free() function in C language and delete() in C++. But, in java it is performed automatically. So, java provides better memory management.

**Advantage of Garbage Collection**

* It makes java **memory efficient** because garbage collector removes the unreferenced objects from heap memory.
* It is **automatically done** by the garbage collector(a part of JVM) so we don't need to make extra efforts.

**How can an object be unreferenced?**

There are many ways:

* By nulling the reference
* By assigning a reference to another
* By annonymous object etc.

**1) By nulling a reference:**

1. Employee e=**new** Employee();
2. e=**null**;

**2) By assigning a reference to another:**

1. Employee e1=**new** Employee();
2. Employee e2=**new** Employee();
3. e1=e2;//now the first object referred by e1 is available for garbage collection

**3) By annonymous object:**

1. **new** Employee();

**finalize() method**

The finalize() method is invoked each time before the object is garbage collected. This method can be used to perform cleanup processing. This method is defined in Object class as:

1. **protected** **void** finalize(){}

**Note: The Garbage collector of JVM collects only those objects that are created by new keyword. So if you have created any object without new, you can use finalize method to perform cleanup processing (destroying remaining objects).**

**gc() method**

The gc() method is used to invoke the garbage collector to perform cleanup processing. The gc() is found in System and Runtime classes.

1. **public** **static** **void** gc(){}

**Note: Garbage collection is performed by a daemon thread called Garbage Collector(GC). This thread calls the finalize() method before object is garbage collected.**

**Simple Example of garbage collection in java**

1. **public** **class** TestGarbage1{
2. **public** **void** finalize(){System.out.println("object is garbage collected");}
3. **public** **static** **void** main(String args[]){
4. TestGarbage1 s1=**new** TestGarbage1();
5. TestGarbage1 s2=**new** TestGarbage1();
6. s1=**null**;
7. s2=**null**;
8. System.gc();
9. }
10. }

[**Test it Now**](http://www.javatpoint.com/opr/test.jsp?filename=TestGarbage1)

object is garbage collected

object is garbage collected

### Ways to create an object of a class?

There are five total ways to create objects in Java, which are explained below with their examples followed by bytecode of the line which is creating the object.

|  |  |
| --- | --- |
| Using new keyword | } → constructor gets called |
| Using [newInstance()](https://docs.oracle.com/javase/8/docs/api/java/lang/Class.html#newInstance--) method of Class class | } → constructor gets called |
| Using [newInstance()](https://docs.oracle.com/javase/8/docs/api/java/lang/reflect/Constructor.html#newInstance-java.lang.Object...-) method of Constructor class | } → constructor gets called |
| Using clone() method | } → no constructor call |
| Using deserialization | } → no constructor call |

If you will execute program given in end, you will see method 1, 2, 3 uses the constructor to create the object while 4, 5 doesn’t call the constructor to create the object.

**1. Using new keywords**

It is the most common and regular way to create an object and a very simple one also. By using this method we can call whichever constructor we want to call (no-arg constructor as well as parameterized).

Employee emp1 = new Employee();

0: new #19 // class org/programming/mitra/exercises/Employee

3: dup

4: invokespecial #21 // Method org/programming/mitra/exercises/Employee."":()V

**2.** Using newInstance() method of Class class

We can also use the newInstance() method of a Class class to create an object. This newInstance() method calls the no-arg constructor to create the object.

We can create an object by newInstance() in the following way:

Employee emp2 = (Employee) Class.forName("org.programming.mitra.exercises.Employee").newInstance();

Or

Employee emp2 = Employee.class.newInstance();

51: invokevirtual #70 // Method java/lang/Class.newInstance:()Ljava/lang/Object;

**4. Using newInstance() method of Constructor class**

Similar to the newInstance() method of Class class, There is one newInstance() method in the java.lang.reflect.Constructor class which we can use to create objects. We can also call parameterized constructor, and private constructor by using this newInstance() method.

Constructor<Employee> constructor = Employee.class.getConstructor();

Employee emp3 = constructor.newInstance();

111: invokevirtual #80 // Method java/lang/reflect/Constructor.newInstance:([Ljava/lang/Object;)Ljava/lang/Object;

Both newInstance() methods are known as reflective ways to create objects. In fact newInstance() method of Class class internally uses newInstance() method of Constructor class. That's why the later one is preferred and also used by different frameworks like Spring, Hibernate, Struts etc. To know differences between both newInstance() methods read [Creating objects through Reflection in Java with Example](https://programmingmitra.blogspot.in/2016/05/creating-objects-through-reflection-in-java-with-example.html).

**4. Using clone() method:**

Whenever we call clone() on any object, the JVM actually creates a new object for us and copies all content of the previous object into it. Creating an object using the clone method does not invoke any constructor.

To use clone() method on an object we need to implement Cloneable and define the clone() method in it.

Employee emp4 = (Employee) emp3.clone();

162: invokevirtual #87 // Method org/programming/mitra/exercises/Employee.clone ()Ljava/lang/Object;

Java cloning is the most debatable topic in Java community and it surely does have its drawbacks but it is still the most popular and easy way of creating a copy of any object until that object is full filling mandatory conditions of Java cloning. I have covered cloning in details in a 3 article long [Java Cloning Series](https://programmingmitra.blogspot.in/search/label/Java%20Cloning) which includes ([Java Cloning And Types Of Cloning (Shallow And Deep) In Details With Example](https://programmingmitra.blogspot.in/2016/11/Java-Cloning-Types-of-Cloning-Shallow-Deep-in-Details-with-Example.html), [Java Cloning - Copy Constructor Versus Cloning](https://programmingmitra.blogspot.in/2017/01/Java-cloning-copy-constructor-versus-Object-clone-or-cloning.html), [Java Cloning - Even Copy Constructors Are Not Sufficient](https://programmingmitra.blogspot.in/2017/01/java-cloning-why-copy-constructors-are-not-sufficient-or-good.html)), go ahead and read them if you want to know more about cloning.

**5. Using deserialization:**

Whenever we serialize and deserialize an object, the JVM creates a separate object for us. In deserialization, the JVM doesn’t use any constructor to create the object.

To deserialize an object we need to implement a Serializable interface in our class.

ObjectInputStream in = new ObjectInputStream(new FileInputStream("data.obj"));

Employee emp5 = (Employee) in.readObject();

261: invokevirtual #118 // Method java/io/ObjectInputStream.readObject:()Ljava/lang/Object;

As we can see in the above bytecode snippets, all 4 methods are called and get converted to invokevirtual (object creation is directly handled by these methods) except the first one, which got converted to two calls: one is new and other is invokespecial (call to constructor).

**Example**

Let’s consider an Employee class for which we are going to create the objects:

class Employee implements Cloneable, Serializable {

private static final long serialVersionUID = 1L;

private String name;

public Employee() {

System.out.println("Employee Constructor Called...");

}

public String getName() {

return name;

}

public void setName(String name) {

this.name = name;

}

@Override

public int hashCode() {

final int prime = 31;

int result = 1;

result = prime \* result + ((name == null) ? 0 : name.hashCode());

return result;

}

@Override

public boolean equals(Object obj) {

if (this == obj)

return true;

if (obj == null)

return false;

if (getClass() != obj.getClass())

return false;

Employee other = (Employee) obj;

if (name == null) {

if (other.name != null)

return false;

} else if (!name.equals(other.name))

return false;

return true;

}

@Override

public String toString() {

return "Employee [name=" + name + "]";

}

@Override

public Object clone() {

Object obj = null;

try {

obj = super.clone();

} catch (CloneNotSupportedException e) {

e.printStackTrace();

}

return obj;

}

}

In the below Java program we are going to create Employee objects in all 5 ways. You can also find the source code at [GitHub](https://github.com/njnareshjoshi/exercises/tree/master/src/org/programming/mitra/exercises).

public class ObjectCreation {

public static void main(String... args) throws Exception {

// By using new keyword

Employee emp1 = new Employee();

emp1.setName("Naresh");

System.out.println(emp1 + ", hashcode : " + emp1.hashCode());

// By using Class class's newInstance() method

Employee emp2 = (Employee) Class.forName("org.programming.mitra.exercises.Employee")

.newInstance();

// Or we can simply do this

// Employee emp2 = Employee.class.newInstance();

emp2.setName("Rishi");

System.out.println(emp2 + ", hashcode : " + emp2.hashCode());

// By using Constructor class's newInstance() method

Constructor<Employee> constructor = Employee.class.getConstructor();

Employee emp3 = constructor.newInstance();

emp3.setName("Yogesh");

System.out.println(emp3 + ", hashcode : " + emp3.hashCode());

// By using clone() method

Employee emp4 = (Employee) emp3.clone();

emp4.setName("Atul");

System.out.println(emp4 + ", hashcode : " + emp4.hashCode());

// By using Deserialization

// Serialization

ObjectOutputStream out = new ObjectOutputStream(new FileOutputStream("data.obj"));

out.writeObject(emp4);

out.close();

//Deserialization

ObjectInputStream in = new ObjectInputStream(new FileInputStream("data.obj"));

Employee emp5 = (Employee) in.readObject();

in.close();

emp5.setName("Akash");

System.out.println(emp5 + ", hashcode : " + emp5.hashCode());

}

}

This program will give the following output:

Employee Constructor Called...

Employee [name=Naresh], hashcode : -1968815046

Employee Constructor Called...

Employee [name=Rishi], hashcode : 78970652

Employee Constructor Called...

Employee [name=Yogesh], hashcode : -1641292792

Employee [name=Atul], hashcode : 2051657

Employee [name=Akash], hashcode : 63313419

### What are the types of references in Java?

In Java there are four types of references differentiated on the way by which they are garbage collected.

1. Strong References
2. Weak References
3. Soft References
4. Phantom References

### What are ‘Strong References’?

This is the default type/class of Reference Object. Any object which has an active strong reference are not eligible for garbage collection. The object is garbage collected only when the variable which was strongly referenced points to null.

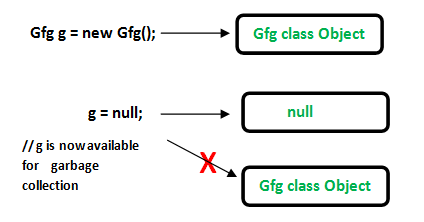
MyClass obj = new MyClass ();

Here ‘obj’ object is strong reference to newly created instance of MyClass, currently obj is active object so can’t be garbage collected.

obj = null;

//'obj' object is no longer referencing to the instance.

So the 'MyClass type object is now available for garbage collection.

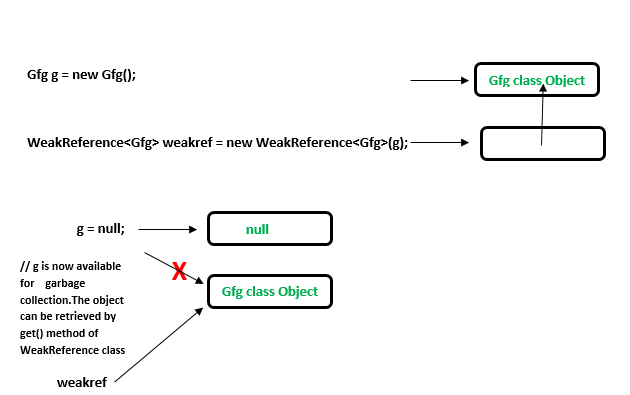


|  |
| --- |
| // Java program to illustrate Strong reference  class Gfg  {      //Code..  }  public class Example  {      public static void main(String[] args)      {           //Strong Reference - by default          Gfg g = new Gfg();            //Now, object to which 'g' was pointing earlier is          //eligible for garbage collection.          g = null;      }  } |
|  |

### What are ‘Weak References’?

Weak Reference Objects are not the default type/class of Reference Object and they should be explicitly specified while using them.

* This type of reference is used in WeakHashMap to reference the entry objects .
* If JVM detects an object with only weak references (i.e. no strong or soft references linked to any object object), this object will be marked for garbage collection.
* To create such references [java.lang.ref.WeakReference](https://docs.oracle.com/javase/7/docs/api/java/lang/ref/WeakReference.html) class is used.
* These references are used in real time applications while establishing a DBConnection which might be cleaned up by Garbage Collector when the application using the database gets closed.



|  |
| --- |
| //Java Code to illustrate Weak reference  import java.lang.ref.WeakReference;  class Gfg  {      //code      public void x()      {          System.out.println("GeeksforGeeks");      }  }    public class Example  {      public static void main(String[] args)      {          // Strong Reference          Gfg g = new Gfg();          g.x();            // Creating Weak Reference to Gfg-type object to which 'g'          // is also pointing.          WeakReference<Gfg> weakref = new WeakReference<Gfg>(g);            //Now, Gfg-type object to which 'g' was pointing earlier          //is available for garbage collection.          //But, it will be garbage collected only when JVM needs memory.          g = null;            // You can retrieve back the object which          // has been weakly referenced.          // It succesfully calls the method.          g = weakref.get();            g.x();      }  } |

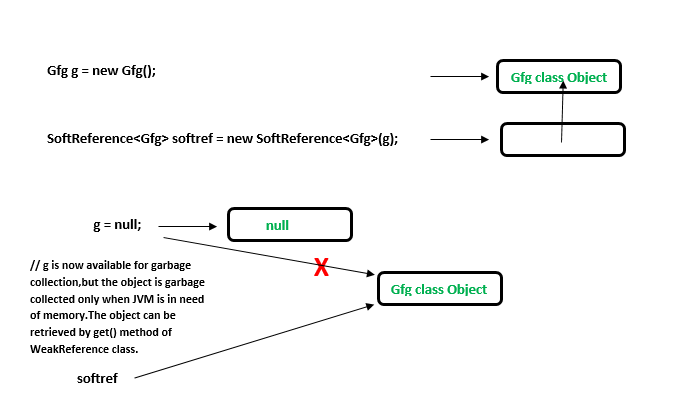
Output:

GeeksforGeeks

GeeksforGeeks

Two different levels of weakness can be enlisted: **Soft and Phantom**

### What are ‘Soft References’?

In Soft reference, even if the object is free for garbage collection then also its not garbage collected, until JVM is in need of memory badly.The objects gets cleared from the memory when JVM runs out of memory.To create such references [java.lang.ref.SoftReference](https://docs.oracle.com/javase/7/docs/api/java/lang/ref/SoftReference.html) class is used.  


|  |
| --- |
| //Code to illustrate Soft reference  import java.lang.ref.SoftReference;  class Gfg  {      //code..      public void x()      {          System.out.println("GeeksforGeeks");      }  }    public class Example  {      public static void main(String[] args)      {          // Strong Reference          Gfg g = new Gfg();          g.x();            // Creating Soft Reference to Gfg-type object to which 'g'          // is also pointing.          SoftReference<Gfg> softref = new SoftReference<Gfg>(g);            // Now, Gfg-type object to which 'g' was pointing          // earlier is available for garbage collection.          g = null;            // You can retrieve back the object which          // has been weakly referenced.          // It succesfully calls the method.          g = softref.get();            g.x();      }  } |

Output:

GeeksforGeeks

GeeksforGeeks

### What are ‘Phantom/Ghost References’?

The objects which are being referenced by phantom references are eligible for garbage collection. But, before removing them from the memory, JVM puts them in a queue called ‘reference queue’ . They are put in a reference queue after calling finalize() method on them.To create such references [java.lang.ref.PhantomReference](https://docs.oracle.com/javase/7/docs/api/java/lang/ref/PhantomReference.html) class is used.

|  |
| --- |
| //Code to illustrate Phantom reference  import java.lang.ref.\*;  class Gfg  {      //code      public void x()      {          System.out.println("GeeksforGeeks");      }  }    public class Example  {      public static void main(String[] args)      {          //Strong Reference          Gfg g = new Gfg();          g.x();            //Creating reference queue          ReferenceQueue<Gfg> refQueue = new ReferenceQueue<Gfg>();            //Creating Phantom Reference to Gfg-type object to which 'g'          //is also pointing.          PhantomReference<Gfg> phantomRef = null;            phantomRef = new PhantomReference<Gfg>(g,refQueue);            //Now, Gfg-type object to which 'g' was pointing          //earlier is available for garbage collection.          //But, this object is kept in 'refQueue' before          //removing it from the memory.          g = null;            //It always returns null.          g = phantomRef.get();            //It shows NullPointerException.          g.x();      }  } |

Runtime Error:

Exception in thread "main" java.lang.NullPointerException

at Example.main(Example.java:31)

Output:

GeeksforGeeks

### Difference between FileReader and BufferedReader in java file IO

|  |  |  |
| --- | --- | --- |
|  | **BufferedReader** | **FileReader** |
| 1 | BufferedReader is **buffered.** | FileReader is **not buffered.** |
| 2 | BufferedReader [**reads characters from another Reader** (Eg - FileReader)](http://www.javamadesoeasy.com/2015/08/program-to-read-text-from-file-using_42.html) | FileReader [**reads characters from a file**](http://www.javamadesoeasy.com/2015/08/program-to-read-text-from-file-using_72.html)**.** |
| 3 | when **BufferedReader.read() is called mostly data is read from the buffer**.  When data is not available available in buffer a call is made to read system file and lot of characters are kept in buffer. | Every time **FileReader.read() is called a call is made to read a system file.**  FileReader.read()  reads **2 byte** (16-bit) at a time. |
| 4 | A BufferedReader enables another  Reader to **buffer the characters** and **supports the** [**mark and reset methods**](http://www.javamadesoeasy.com/2015/08/program-to-how-to-use-mark-and-reset_22.html)**.**  An internal buffer array is created when the BufferedReader is created.  As characters from the Reader are read or skipped, the internal buffer is refilled as necessary from the contained  Reader, many characters at a time. | A FileReader obtains  characters from a file in a file system.  And does **not supports mark and reset methods**. |
| 5 | BufferedReader is much **faster** as compared to FileReader. | FileReader is **slower** as compared to BufferedReader. |
| 6 | Example -  As we discussed above that when BufferedReader.read() is called mostly data is read from the buffer.  **A BufferedReader reads from FileReader, will request lot of data from the FileReader (128 characters or so… not exact figure). Thus only 2 calls will be made for reading 256 characters from file.** | Example -  As we discussed in point above that every time FileReader.read() is called a call is made to read a system file.  **A FileReader will make 256 calls for reading 256 characters from file.** |
|  | Another Example - **Real world Example** - You must have seen youtube videos where video is buffered before you actually start watching it, **buffering** overall improves your video watching experience. | No buffering will make your videos watching experience a nightmare. |

### [Why do we assign a parent reference to the child object in Java?](https://stackoverflow.com/questions/12159601/why-do-we-assign-a-parent-reference-to-the-child-object-in-java)

|  |  |
| --- | --- |
|  | First, a clarification of terminology: we are assigning a Child object to a variable of type Parent. Parent is a reference to an object that happens to be a subtype of Parent, a Child.  It is only useful in a more complicated example. Imagine you add getEmployeeDetails to the class Parent:  public String getEmployeeDetails() {  return "Name: " + name;  }  We could override that method in Child to provide more details:  @Override  public String getEmployeeDetails() {  return "Name: " + name + " Salary: " + salary;  }  Now you can write one line of code that gets whatever details are available, whether the object is a Parent or Child:  parent.getEmployeeDetails();  The following code:  Parent parent = new Parent();  parent.name = 1;  Child child = new Child();  child.name = 2;  child.salary = 2000;  Parent[] employees = new Parent[] { parent, child };  for (Parent employee : employees) {  employee.getEmployeeDetails();  }  Will result in the output:  Name: 1  Name: 2 Salary: 2000  We used a Child as a Parent. It had specialized behavior unique to the Child class, but when we called getEmployeeDetails() we could ignore the difference and focus on how Parent and Child are similar. This is called [subtype polymorphism](http://en.wikipedia.org/wiki/Subtype_polymorphism).  Your updated question asks why Child.salary is not accessible when the Childobject is stored in a Parent reference. The answer is the intersection of "polymorphism" and "static typing". Because Java is statically typed at compile time you get certain guarantees from the compiler but you are forced to follow rules in exchange or the code won't compile. Here, the relevant guarantee is that every instance of a subtype (e.g. Child) can be used as an instance of its supertype (e.g. Parent). For instance, you are guaranteed that when you access employee.getEmployeeDetailsor employee.name the method or field is defined on any non-null object that could be assigned to a variable employee of type Parent. To make this guarantee, the compiler considers only that static type (basically, the type of the variable reference, Parent) when deciding what you can access. So you cannot access any members that are defined on the runtime type of the object, Child.  When you truly want to use a Child as a Parent this is an easy restriction to live with and your code will be usable for Parent and all its subtypes. When that is not acceptable, make the type of the reference Child. |

# Java 8

## Functional Interface

### What are **Functional interface** in java 8?

Functional interface are those interfaces that can exactly have one abstract method in java

### How can we **create**/make interface a FunctionalInterface in java 8?

We can make interface a FunctionalInterface by using **annotation @FunctionalInterface** in java 8.

### Advantage of making Functional interface in java 8?

It is very handy in ensuring that your interface has exactly defined one abstract method in java 8.

Functional interface can be used with Lambda expression, which makes code much neat, clean and easy to read

### **Program**/Example of defining/**creating** **@FunctionalInterface** and using it in java 8 OR Full **Program**/Example of defining/**creating** **@FunctionalInterface** - And write **Anonymous inner class** to implement method of FunctionalInterface in java 8 >

|  |
| --- |
| //Define/Create @FunctionalInterface in java 8  **@FunctionalInterface**  **interface MyInterface {**  **public abstract void myMethod();**  **}**  **public** **class** MainClass{  **public** **static** **void** main(String...args) {              //Write Anonymous inner class to implement method of MyInterface (FunctionalInterface)            MyInterface myInterface = **new MyInterface() {**  **@Override**  **public void myMethod() {**  **System.*out*.println("xx");**  **}**  **};**              //Call myMethod()            myInterface.myMethod();     }  }  /\* OUTPUT  xx  \*/ |

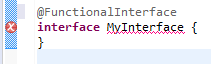
So. in this program we **created @FunctionalInterface**

And then in main method We wrote **Anonymous inner class to implement MyInterface** (FunctionalInterface)

### Full **Program**/Example of defining/**creating** **@FunctionalInterface**  - And write **Lambda expression** to implement method of FunctionalInterface in java 8 >

|  |
| --- |
| //Define/Create @FunctionalInterface in java 8  **@FunctionalInterface**  **interface MyInterface {**  **public abstract void myMethod();**  **}**  **public** **class** MainClass{  **public** **static** **void** main(String...args) {              //Write LAMBDA EXPRESSION to implement method of MyInterface (FunctionalInterface)            MyInterface myInterface = **() -> {**  **System.*out*.println("xx");**  **};**              //Call myMethod()            myInterface.myMethod();     }  }  /\* OUTPUT  xx  \*/ |

### If no abstract method is defined in functional interface we will face compilation error in java 8

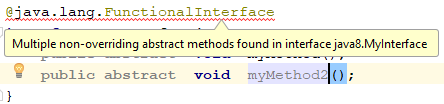




### What’s exact error in eclipse in java 8 ?

“Invalid '@FunctionalInterface' annotation; MyInterface is not a functional interface”

### If more than one abstract method is defined in functional interface we will face compilation error in java 8



### Can @FunctionalInterface can have **static and default method** in java 8 ?

Yes. Example of FunctionalInterface having static and default method in java 8 >

|  |
| --- |
| @FunctionalInterface  **interface** MyInterface1 {  **abstract** **void** myMethod();  **default** **void** defaultMethod() {}  **static** **void** staticMethod() {}  } |

## Default Methods

### What is default method in interface in java 8?

Now, we can add add default(non-abstract) method in interfaces in java 8 (Before java 8, we could only write [abstract method](http://www.javamadesoeasy.com/2015/06/abstract-class-in-java-when-to-use.html) in interfaces in java 8)

By making method as **default** in Interface we can make concrete (non-abstract) method in interface. [i.e. we can define method in [interface](http://www.javamadesoeasy.com/2015/06/interface-in-java-multiple-inheritance.html)]

default method are also called

* **defender** methods or
* **extension** methods in java 8.

default method are **public** by default.

### Full Program/Example to create and use default method of interface in Java 8 >

|  |
| --- |
| **interface** Animals {       /\*     \* Define default method in java 8     \*/  **default** **void** food() {         System.***out***.println("Animal eat food");     }  }  **class** Lion **implements** Animals {  //No no need to override any method of interface (As there is no abstract method in interface)  }  **public** **class** MainClass{  **public** **static** **void** main(String...args) {            Animals animals = **new** Lion();            animals.food();     }  }  /\* OUTPUT  Animal eat food  \*/ |

### What is **Advantage** of default methods in java 8>

There is no need to override default methods of interface in implementing class.

Example - Lion class didn't override default method food.

Before java 8 - Every class implementing interface was needed to override all the methods of interface (As we could only define abstract methods in interface).

### Can we override default method of interface in java 8?

Yes, we can override default method of interface in java 8.

|  |
| --- |
| **interface** Animals {     /\* Define default method in java 8 \*/  **default** **void** food() {         System.***out***.println("Animal eat food");     }  }  **class** Lion **implements** Animals {  **/\*If we want - we can override default method of interface in java 8\*/**     @Override  **public** **void** food() {         System.***out***.println("Lion eat - flesh");     }  }  **public** **class** MainClass{  **public** **static** **void** main(String...args) {            Animals animals = **new** Lion();            animals.food();     }  }  /\* OUTPUT  Lion eat - flesh  \*/ |

### How to Override default methods in java 8 - in anonymous inner class >

|  |
| --- |
| **interface** Animals {     /\* Define default method in java 8 \*/  **default** **void** food() {         System.***out***.println("Animal eat food");     }  }  **public** **class** MainClass{  **public** **static** **void** main(String...args) {  **/\*override default methods in java 8 - in anonymous inner class\*/**            Animals lion = **new** Animals() **{**  **@Override**  **public void food() {**  **System.*out*.println("Lion eat - flesh");**  **}**  **}**;              lion.food();     }  }  /\* OUTPUT  Lion eat - flesh  \*/ |

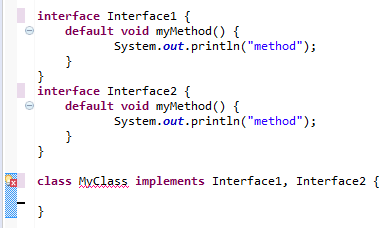
### What if two interfaces have declared a default method with same name and a class tries to implement both the interface in java 8 ?

We will face **compilation error** that Interface1 and Interface2 have same name for default myMethod.

It is also called **DIAMOND** problem in java

Exact [**error**](http://www.javamadesoeasy.com/2015/05/javalangerror-in-exception-handling-in.html) shown in [eclipse](http://www.javamadesoeasy.com/search/label/eclipse) >

"Duplicate default methods named method with the parameters () and () are inherited from the types Interface1 and Interface2"



**Solution >**

We need to override myMethod in MyClass to avoid this error in java 8.

|  |
| --- |
| **interface** Interface1 {  **default** **void** myMethod() {         System.***out***.println("method");     }  }  **interface** Interface2 {  **default** **void** myMethod() {         System.***out***.println("method");     }  }  **class** MyClass **implements** Interface1, Interface2 {  **public** **void** myMethod() {         System.***out***.println("myMethod");     }  } |

## Static Methods

### static method in interface in java 8

Now, we can **write** static method in interface in java 8. (Before java 8, we could only write [abstract method](http://www.javamadesoeasy.com/2015/06/abstract-class-in-java-when-to-use.html) in interfaces in java 8)

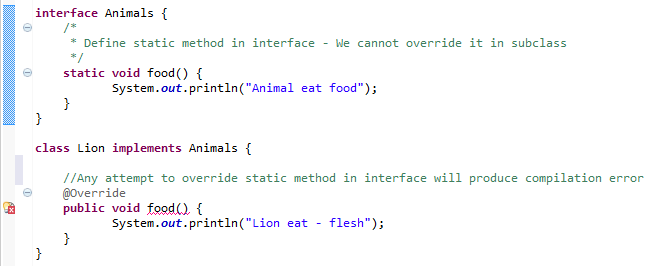
We can **define** these static methods in interface, just like normal static method. static method are **public** by default in java 8.

### Can we override [static method](http://www.javamadesoeasy.com/2015/05/static-keyword-in-java-variable-method.html) of interface in subclass in java 8?

We **cannot** override [static method](http://www.javamadesoeasy.com/2015/05/static-keyword-in-java-variable-method.html) of interface in subclass in java 8.

**No**, we cannot override static method of interface in subclass in java 8.

Let’s see program -



First, we defined static method in interface, we cannot override it in subclass.

Then, we saw **attempt to override static method of interface produced compilation error in java 8.**

### Full Program/Example to create and use static method of interface in Java 8 >

|  |
| --- |
| /\*  Full Example to use static method of interface in Java 8  \*/  **interface** Animals {     /\*     \* Create/Define static method in interface     \*/     public **static** void food() {         System.*out*.println("Animal eat food");     }  }  **public** **class** MainClass{  **public** **static** **void** main(String...args) {            //Call static method of interface            Animals.*food*();     }  }  /\* OUTPUT  Animal eat food  \*/ |

### Full Program/Example to create and use static method of interface in Java 8 >

|  |
| --- |
| /\*  Full Example to use static method of interface in Java 8  \*/  **interface** Animals {     /\*     \* Create/Define static method in interface     \*/     public **static** void food() {         System.*out*.println("Animal eat food");     }  }  **public** **class** MainClass{  **public** **static** **void** main(String...args) {            //Call static method of interface            Animals.*food*();     }  }  /\* OUTPUT  Animal eat food  \*/ |

### Advantage of static method in interface in java 8?

We can make **utility interface** which consists of static methods in java 8.

For example -

[java.util.**Collections**](http://www.javamadesoeasy.com/2015/04/collection-vs-collections-differences.html) is a **utility class** which consists of static methods that operate on or return Collection in java.

## Lambda Expressions

### What is lambda expressions?

* we can write lambda expression to replace the [anonymous inner class](http://www.javamadesoeasy.com/2015/06/inner-class-nested-class-static-local.html).
* lambda expression make code very neat and clean.
* lambda expression are very to read. So, they make code more readable.

### How to use Lambda expression?

Example 1.1 > **Before Java 8** -  Sort String using Using Local class - **Without Lambda expression >**

|  |
| --- |
| **import** java.util.Arrays;  **import** java.util.Comparator;  **public** **class** SortStringArray**WithoutLambdaExpression**Example {    **public** **static** **void** main(String... args) {         String[] stringArray = {"ab", "ef", "cd"};           //Create **Local class**  **class** **StringSort implements** Comparator<String> {  **public** **int** compare(String a, String b) {  **return** a.compareTo(b);            }         }           //**Before Java 8** -  Sort String using Using Local class - **Without Lambda expression**         System.***out***.println("Before Java 8 - Sort StringArray using Using **"**  **+ "** > Local class - i.e. Without Lambda expression");  **Arrays.*sort***(stringArray, **new StringSort()**);           //Display StringArray  **for** (String str : stringArray) {                System.***out***.print(str + " ");           }     }  }  /\* Output  Before Java 8 - Sort StringArray using Using > Local class - i.e. Without Lambda expression  ab cd ef  \*/ |

Example 1.2 >Before Java 8 - Sort StringArray using > **Anonymous Inner class** - i.e. Without Lambda expression >

|  |
| --- |
| Arrays.*sort*(stringArray, **new Comparator<String>() {**  **@Override**  **public int compare(String a, String b) {**  **return a.compareTo(b);**  **}**  **}**); |

Example 1.3 > **In Java 8** - Sort StringArray using > **Lambda expression (Replace Anonymous Inner class** with **Lambda expression)**

|  |
| --- |
| **import** java.util.Arrays;  **public** **class** SortStringArray**LambdaExpression**Example2 {  **public** **static** **void** main(String... args) {            String[] stringArray = { "ab", "ef", "cd" };            System.***out***.println("In Java 8 - Sort StringArray using > Lambda expression");  **Arrays.*sort*(stringArray, (String a, String b) -> {**  **return a.compareTo(b);**  **});**            // Display StringArray  **for** (String str : stringArray) {                   System.***out***.print(str + " ");            }     }  }  /\* Output  In Java 8 - Sort StringArray using > Lambda expression  ab cd ef  \*/ |

Example 1.4 >You can shorten up the above lambda expression >

|  |
| --- |
| **Arrays.*sort*(stringArray, (a, b) -> {**  **return a.compareTo(b);**  **});** |

Example 1.5 > **If there is only** Single line in implementation, we can also remove curly braces  (With single line you can also remove return statement) >

|  |
| --- |
| **Arrays.*sort*(stringArray, (a, b) -> a.compareTo(b));** |

Example 1.6 > **In Java 8** - Sort [String**List**](http://www.javamadesoeasy.com/2015/04/list-hierarchy-in-java-detailed.html) using > **Lambda expression (using only** Single line) >

|  |
| --- |
| **import java.util.Arrays;**  **import java.util.Collections;**  **import java.util.List;**  **public class SortStringListExpressionExample {**  **public static void main(String... args) {**  **//Declare StringArray**  **String[] stringArray = { "ab", "ef", "cd" };**    **//Convert String Array to String List**  **List<String> stringList = Arrays.*asList*(stringArray);**    **//In Java 8 - Sort StringList using > Lambda expression - in one line**  **Collections.*sort*(stringList, (a, b) -> a.compareTo(b));**    **//Display StringList**  **System.*out*.println(stringList);**  **}**  **}**  **/\* Output**  **[ab, cd, ef]**  **\*/** |

### Sum of numbers

Example 2.1  > **In Java 8** - Sum of two numbers program using > **Lambda expression**

|  |
| --- |
| @FunctionalInterface  **interface** CalculatorInterface<A> {  **public** **abstract** A sumMethod(A val1, A val2);  }  **public** **class** LambdaExpression\_FunctionalInterface\_calculatorSum {  **public** **static** **void** main(String[] args) {            // Provide implementation (definition) of sumMethod - using Lambda expression            // A will be type Integer            CalculatorInterface<Integer> sum = **(Integer val1, Integer val2) -> {**  **return val1 + val2;**  **};**              // Call sumMethod            Integer result = sum.sumMethod(2, 3);            System.***out***.println(result); // 5     }  }  /\* OUTPUT  5  \*/ |

Example 2.2 >You can shorten up the above lambda expression >

|  |
| --- |
| CalculatorInterface<Integer> sum = (val1, val2) -> {  **return** val1 + val2;  }; |

Example 2.3 > **If there is only** Single line in implementation, we can also remove curly braces  (With single line you can also remove return statement) >

|  |
| --- |
| CalculatorInterface<Integer> sum = (val1, val2) -> val1 + val2; |

### To square a number

Example 3.1 > **In Java 8** - square of number program using > **Lambda expression**

|  |
| --- |
| @FunctionalInterface  **interface** CalculatorInterface<A> {     A squareMethod(A val);  }  **public** **class** LambdaExpression\_FunctionalInterface\_calculatorSquare {  **public** **static** **void** main(String[] args) {            //Provide implementation (definition) of squareMethod **using > Lambda expression**            // A will be type Integer            CalculatorInterface<Integer> square = **(val) -> (val \* val)**;            // Call squareMethod            Integer result = square.squareMethod(2);            System.***out***.println(result); // 4     }  }  /\* Output  4  \*/ |

Example 3.2 > **Before Java 8** -  square of number program Using anonymousInnerClass - **Without Lambda expression >**

|  |
| --- |
| **CalculatorInterface<Integer> square = new CalculatorInterface() {**  **@Override**  **public Object squareMethod(Object val) {**  **return ((Integer)val \* (Integer)val);**  **}**  **};** |

### How to use Lambda expression **with threads?**

Example 4.1 >Before Java 8 - Create thread, Implement Runnable interface using > **Anonymous Inner class** - i.e. Without Lambda expression

|  |
| --- |
| **public** **class** **Without**LambdaExpressionThreadExample {  **public** **static** **void** main(String[] args) {            System.***out***.println("1 - Create thread, Implement Runnable interface using > Anonymous inner class");            // Create thread, Implement Runnable interface using Anonymous inner class  **new Thread(new Runnable() {**  **@Override**  **public void run() {**  **System.*out*.println("Thread-1");**  **}**  **}).start();**     }  }  /\*OUTPUT  1 - Create thread, Implement Runnable interface using > Anonymous inner class  Thread-1  \*/ |

Example 4.2  > **In Java 8** - Create thread, Implement Runnable interface using > **Lambda expression**

|  |
| --- |
| **public** **class** LambdaExpressionThreadExample2 {  **public** **static** **void** main(String[] args) {            System.***out***.println("1 - Implement Runnable interface using > Lambda expression");            // Implement Runnable interface using > Lambda expression  **new** Thread(**() -> {**  **System.*out*.println("Thread-1");**  **}**).start();     }  }  /\*OUTPUT  1 - Implement Runnable interface using > Lambda expression  Thread-1  \*/ |

Example  > **If there is only** Single line in implementation, we can also remove curly braces  (With single line you can also remove return statement) >

|  |
| --- |
| **new** Thread(() -> System.***out***.println("Thread1") ).start(); |

### How to use Lambda expression - String to Integer conversion?

Example  > **In Java 8** - convert String To Integer using Lambda expression

|  |
| --- |
| /\*  convert String To Integer using Lambda expression  \*/  @FunctionalInterface  **interface** MyInterface<A, B> {     A convertStringToIntegerMethod(B stringVal);  }  **public** **class** LambdaExpressionExample {  **public** **static** **void** main(String[] args) {          // Provide implementation of convertStringToInteger **using Lambda expression**          // A will be type Integer          // B will be of type String          MyInterface<Integer,String> integerVal= **(stringVal) -> Integer.*valueOf*(stringVal)**;          // Call convertStringToInteger          Integer result = integerVal.convertStringToIntegerMethod("12");          System.***out***.println("Integer = "+result); // 12     }  }  /\* OUTPUT  Integer = 12  \*/ |

### [Final variable](http://www.javamadesoeasy.com/2015/05/final-keyword-in-java-20-salient.html) can be accessed in lambda expression in java 8 (Behavior same as [anonymous inner class](http://www.javamadesoeasy.com/2015/06/inner-class-nested-class-static-local.html))

|  |
| --- |
| @FunctionalInterface  **interface** CalculatorInterface {     Integer sumMethod(Integer val1, Integer val2);  }  **public** **class** LambdaExpressionScopeExample {  **public** **static** **void** main(String[] args) {            // Final Local variable can be accessed in lambda expression in java 8  **final int x = 1**; // Final Local variable            // Provide implementation (definition) of sumMethod - using Lambda expression            CalculatorInterface sum = (val1, val2) -> {  **return** val1 + val2 **+ x**;            };            // Call sumMethod            Integer result = sum.sumMethod(2, 3);            System.***out***.println("sumResult = "+result); // 6     }  }  /\*  sumResult = 6  \*/ |

### **non-Final** variable can be **accessed** in lambda expression in java 8

Though **non-Final** variable can be **accessed** in lambda expression, **But it is effectively final in lambda expression** in java 8( Again Behavior same as [anonymous inner class](http://www.javamadesoeasy.com/2015/06/inner-class-nested-class-static-local.html))**.**

So, you use non-final variable in Lambda expression BUT you **cannot modify x i**n lambda expression.

Any attempt to modify x will produce compilation error.

What will be exact compilation error in eclipse in java 8 ?

“Local variable x defined in an enclosing scope must be final or effectively final.”

|  |
| --- |
| @FunctionalInterface  **interface** CalculatorInterface {     Integer sumMethod(Integer val1, Integer val2);  }  **public** **class** LambdaExpressionScopeExample {  **public** **static** **void** main(String[] args) {            // Though non-Final local variable can be accessed in lambda expression            // But it is effectively final in lambda expression.            //So, you cannot modify x in lambda expression.            //Any attempt to modify x will produce compilation error in java 8.  **int x = 1;** // Non-Final Local variable            CalculatorInterface sum = (val1, val2) -> {  **x = x + 1; //COMPILATION ERROR**  **return** val1 + val2 + x;            };     }  } |

### Accessing Instance and static variable in Lambda Expression in java 8 >

1. Instance variable **can be accessed (and modified unlike local variable)** in lambda expression in java 8
2. Static variable **can be accessed (and modified unlike local variable)** in lambda expression in java 8

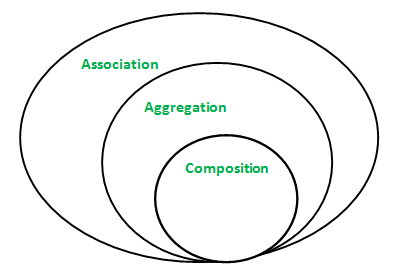
|  |
| --- |
| @FunctionalInterface  **interface** CalculatorInterface {     Integer sumMethod(Integer val1, Integer val2);  }  **public** **class** LambdaExpressionScopeExample {     // Instance variable can be accessed in lambda expression in java 8  **int** **instanceVariable** = 1; // Instance variable       // Static variable can be accessed in lambda expression in java 8  **static** **int** ***staticVariable*** = 2; // Static variable    **public** **static** **void** main(String[] args) {              LambdaExpressionScopeExample obj = **new** LambdaExpressionScopeExample();            // Provide implementation (definition) of sumMethod - using Lambda expression            CalculatorInterface sum = (val1, val2) -> {  **return** val1 + val2 +                     + obj.**instanceVariable** // Access Instance variable in lambda expression                     + ***staticVariable***;  // Access static variable in lambda expression            };            // Call sumMethod            Integer sumResult = sum.sumMethod(2, 3);            System.***out***.println("sumResult = "+sumResult); // 8     }  }  /\*OUTPUT  sumResult = 8  \*/ |

# OOP

## **SOLID principles**



## **Association**

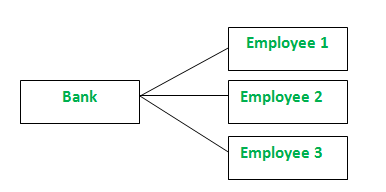
Association is relation between two separate classes which establishes through their Objects. Association can be one-to-one, one-to-many, many-to-one, many-to-many.  
In Object-Oriented programming, an Object communicates to other Object to use functionality and services provided by that object. **Composition** and **Aggregation**are the two forms of association.  
[](http://cdncontribute.geeksforgeeks.org/wp-content/uploads/AssociationAggregation-and-Composition.png)

|  |
| --- |
| // Java program to illustrate the  // concept of Association  import java.io.\*;  // class bank  class Bank {      private String name;      // bank name      Bank(String name)    {          this.name = name;      }      public String getBankName()    {          return this.name;      }  }  // employee class  class Employee{      private String name;      // employee name      Employee(String name)     {          this.name = name;      }      public String getEmployeeName()    {          return this.name;      }  }   // Association between both the  // classes in main method  class Association {      public static void main (String[] args)     {          Bank bank = new Bank("Axis");          Employee emp = new Employee("Neha");            System.out.println(emp.getEmployeeName() +                 " is employee of " + bank.getBankName());      }  } |

Run on IDE

Output:

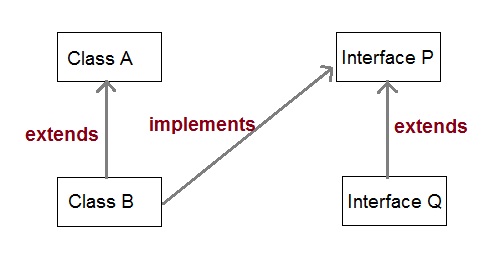
Neha is employee of Axis

In above example two separate classes Bank and Employee are associated through their Objects. Bank can have many employees, So it is a one-to-many relationship.  
[](http://cdncontribute.geeksforgeeks.org/wp-content/uploads/Association-in-Java.png)

## **Inheritance**

Inheritance is one of the key features of Object Oriented Programming. Inheritance provided mechanism that allowed **a class to inherit property of another class**. When a Class extends another class it inherits all non-private members including fields and methods. Inheritance in Java can be best understood in terms of Parent and Child relationship, also known as **Super class**(Parent) and **Sub class**(child) in Java language.

Inheritance defines **is-a** relationship between a Super class and its Sub class. extends and implements keywords are used to describe inheritance in Java.



Let us see how **extends** keyword is used to achieve Inheritance.

class Vehicle.

{

......

}

class Car extends Vehicle

{

....... //extends the property of vehicle class.

}

Now based on above example. In OOPs term we can say that,

* **Vehicle** is super class of **Car**.
* **Car** is sub class of **Vehicle**.
* Car IS-A Vehicle.

#### Purpose of Inheritance

1. It promotes the code reusabilty i.e the same methods and variables which are defined in a parent/super/base class can be used in the child/sub/derived class.
2. It promotes polymorphism by allowing method overriding.

#### Disadvantages of Inheritance

Main disadvantage of using inheritance is that the two classes (parent and child class) gets **tightly coupled**.

This means that if we change code of parent class, it will affect to all the child classes which is inheriting/deriving the parent class, and hence, **it cannot be independent of each other**.

#### Simple example of Inheritance

class Parent

{

public void p1()

{

System.out.println("Parent method");

}

}

public class Child extends Parent {

public void c1()

{

System.out.println("Child method");

}

public static void main(String[] args)

{

Child cobj = new Child();

cobj.c1(); //method of Child class

cobj.p1(); //method of Parent class

}

}

Child method

Parent method

#### Another example of Inheritance

class Vehicle

{

String vehicleType;

}

public class Car extends Vehicle {

String modelType;

public void showDetail()

{

vehicleType = "Car"; //accessing Vehicle class member

modelType = "sports";

System.out.println(modelType+" "+vehicleType);

}

public static void main(String[] args)

{

Car car =new Car();

car.showDetail();

}

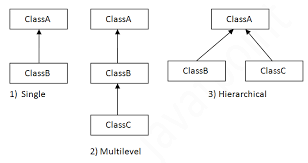
}

sports Car

#### Types of Inheritance

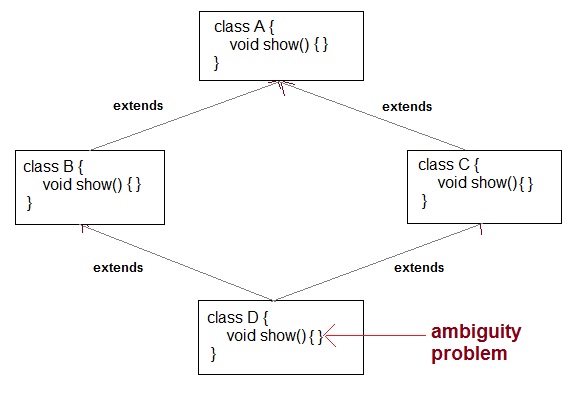
1. Single Inheritance
2. Multilevel Inheritance
3. Heirarchical Inheritance

**NOTE :**Multiple inheritance is not supported in java



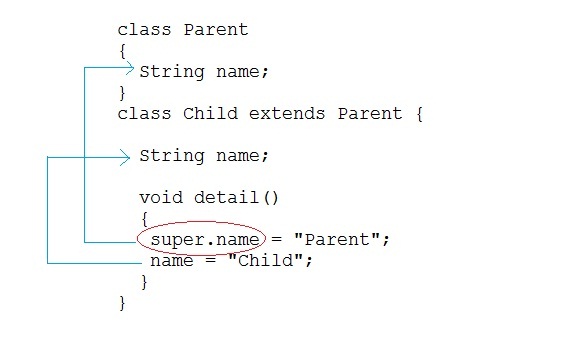
#### Why multiple inheritance is not supported in Java

* To remove ambiguity.
* To provide more maintainable and clear design.



#### super keyword

In Java, super keyword is used to refer to immediate parent class of a child class. In other words **super** keyword is used by a subclass whenever it need to refer to its immediate super class.



#### Example of Child class refering Parent class property using super keyword

class Parent

{

String name;

}

public class Child extends Parent {

String name;

public void details()

{

super.name = "Parent"; //refers to parent class member

name = "Child";

System.out.println(super.name+" and "+name);

}

public static void main(String[] args)

{

Child cobj = new Child();

cobj.details();

}

}

Parent and Child

#### Example of Child class refering Parent class methods using super keyword

class Parent

{

String name;

public void details()

{

name = "Parent";

System.out.println(name);

}

}

public class Child extends Parent {

String name;

public void details()

{

super.details(); //calling Parent class details() method

name = "Child";

System.out.println(name);

}

public static void main(String[] args)

{

Child cobj = new Child();

cobj.details();

}

}

Parent

Child

#### Example of Child class calling Parent class constructor using super keyword

class Parent

{

String name;

public Parent(String n)

{

name = n;

}

}

public class Child extends Parent {

String name;

public Child(String n1, String n2)

{

super(n1); //passing argument to parent class constructor

this.name = n2;

}

public void details()

{

System.out.println(super.name+" and "+name);

}

public static void main(String[] args)

{

Child cobj = new Child("Parent","Child");

cobj.details();

}

}

Parent and Child

**Note:**When calling the parent class constructor from the child class using super keyword, super keyword should always be the first line in the method/constructor of the child class.

#### Super class reference pointing to Sub class object.

In context to above example where Class B extends class A.

A a=new B();

is legal syntax because of IS-A relationship is there between class A and Class B.

#### Q. Can you use both this() and super() in a Constructor?

NO, because both super() and this() must be first statement inside a constructor. Hence we cannot use them together.

## **Aggregation**

It is a special form of Association where:

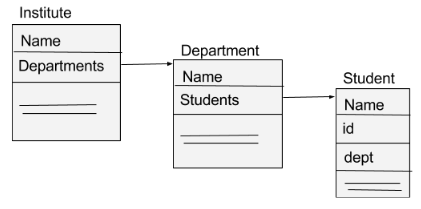
* It represents **Has-A** relationship.
* It is a **unidirectional association** i.e. a one way relationship. For example, department can have students but vice versa is not possible and thus unidirectional in nature.
* In Aggregation,**both the entries can survive individually** which means ending one entity will not effect the other entity

|  |
| --- |
| // Java program to illustrate  //the concept of Aggregation.  import java.io.\*;  import java.util.\*;    // student class  class Student {      String name;      int id ;      String dept;        Student(String name, int id, String dept)     {          this.name = name;          this.id = id;          this.dept = dept;      }  }    /\* Department class contains list of student  Objects. It is associated with student  class through its Object(s). \*/  class Department {      String name;      private List<Student> students;      Department(String name, List<Student> students)     {          this.name = name;          this.students = students;      }        public List<Student> getStudents()     {          return students;      }  }    /\* Institute class contains list of Department  Objects. It is asoociated with Department  class through its Object(s).\*/  class Institute {       String instituteName;      private List<Department> departments;        Institute(String instituteName, List<Department> departments)    {          this.instituteName = instituteName;          this.departments = departments;      }        // count total students of all departments      // in a given institute      public int getTotalStudentsInInstitute()      {          int noOfStudents = 0;          List<Student> students;          for(Department dept : departments)        {              students = dept.getStudents();              for(Student s : students)            {                  noOfStudents++;              }          }          return noOfStudents;      }     }    // main method  class GFG{      public static void main (String[] args)     {          Student s1 = new Student("Mia", 1, "CSE");          Student s2 = new Student("Priya", 2, "CSE");          Student s3 = new Student("John", 1, "EE");          Student s4 = new Student("Rahul", 2, "EE");            // making a List of          // CSE Students.          List <Student> cse\_students = new ArrayList<Student>();          cse\_students.add(s1);          cse\_students.add(s2);            // making a List of          // EE Students          List <Student> ee\_students = new ArrayList<Student>();          ee\_students.add(s3);          ee\_students.add(s4);            Department CSE = new Department("CSE", cse\_students);          Department EE = new Department("EE", ee\_students);            List <Department> departments = new ArrayList<Department>();          departments.add(CSE);          departments.add(EE);            // creating an instance of Institute.          Institute institute = new Institute("BITS", departments);            System.out.print("Total students in institute: ");          System.out.print(institute.getTotalStudentsInInstitute());      }  } |

Run on IDE

Output:

Total students in institute: 4

In this example, there is an Institute which has no. of departments like CSE, EE. Every department has no. of students. So, we make a Institute class which has a reference to Object or no. of Objects (i.e. List of Objects) of the Department class. That means Institute class is associated with Department class through its Object(s). And Department class has also a reference to Object or Objects (i.e. List of Objects) of Student class means it is associated with Student class through its Object(s).  
It represents a **Has-A** relationship.  
[](http://cdncontribute.geeksforgeeks.org/wp-content/uploads/Aggregation_1.png)

**When do we use Aggregation ??**  
Code reuse is best achieved by aggregation.

## **Composition**

Composition is a restricted form of Aggregation in which two entities are highly dependent on each other.

* It represents **part-of** relationship.
* In composition, both the entities are dependent on each other.
* When there is a composition between two entities, the composed object **cannot exist** without the other entity.

Lets take example of**Library**.

|  |
| --- |
| // Java program to illustrate  // the concept of Composition  import java.io.\*;  import java.util.\*;    // class book  class Book {      public String title;      public String author;      Book(String title, String author)    {           this.title = title;          this.author = author;      }  }   // Libary class contains  // list of books.  class Library {       // reference to refer to list of books.      private final List<Book> books;        Library (List<Book> books)    {          this.books = books;      }       public List<Book> getTotalBooksInLibrary(){         return books;      }  }    // main method  class GFG  {      public static void main (String[] args)     {          // Creating the Objects of Book class.          Book b1 = new Book("EffectiveJ Java", "Joshua Bloch");          Book b2 = new Book("Thinking in Java", "Bruce Eckel");          Book b3 = new Book("Java: The Complete Reference", "Herbert Schildt");            // Creating the list which contains the          // no. of books.          List<Book> books = new ArrayList<Book>();          books.add(b1);          books.add(b2);          books.add(b3);            Library library = new Library(books);            List<Book> bks = library.getTotalBooksInLibrary();          for(Book bk : bks){                System.out.println("Title : " + bk.title + " and "              +" Author : " + bk.author);          }      }  } |

Run on IDE

Output

Title : EffectiveJ Java and Author : Joshua Bloch

Title : Thinking in Java and Author : Bruce Eckel

Title : Java: The Complete Reference and Author : Herbert Schildt

In above example a library can have no. of **books** on same or different subjects. So, If Library gets destroyed then All books within that particular library will be destroyed. i.e. book can not exist without library. That’s why it is composition.

**Aggregation vs Composition**

1. **Dependency:** Aggregation implies a relationship where the child **can exist independently** of the parent. For example, Bank and Employee, delete the Bank and the Employee still exist. whereas Composition implies a relationship where the child **cannot exist independent** of the parent. Example: Human and heart, heart don’t exist separate to a Human
2. **Type of Relationship:** Aggregation relation is **“has-a”** and composition is **“part-of”** relation.
3. **Type of association:**Composition is a **strong** Association whereas Aggregation is a **weak** Assocation.

|  |
| --- |
| // Java program to illustrate the  // difference between Aggregation  // Composition.    import java.io.\*;    // Engine class which will  // be used by car. so 'Car'  // class will have a field  // of Engine type.  class Engine  {      // starting an engine.      public void work()      {            System.out.println("Engine of car has been started ");        }    }    // Engine class  final class Car  {        // For a car to move,      // it need to have a engine.      private final Engine engine; // Composition      //private Engine engine;     // Aggregation        Car(Engine engine)      {          this.engine = engine;      }        // car start moving by starting engine      public void move()      {            //if(engine != null)          {              engine.work();              System.out.println("Car is moving ");          }      }  }    class GFG  {      public static void main (String[] args)      {            // making an engine by creating          // an instance of Engine class.          Engine engine = new Engine();            // Making a car with engine.          // so we are passing a engine          // instance as an argument while          // creating instace of Car.          Car car = new Car(engine);          car.move();        }  } |

Run on IDE

Output:

Engine of car has been started

Car is moving

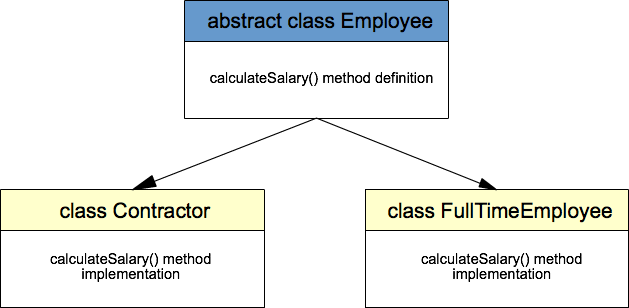
In case of aggregation, the Car also performs its functions through an Engine. but the Engine is not always an internal part of the Car. An engine can be swapped out or even can be removed from the car. That’ why we make The Engine type field non-final.

## What is Abstraction

Abstraction is a process of hiding the implementation details from the user. Оnly the functionality will be provided to the user. In Java, abstraction is achieved using abstract classes and interfaces.

**Java Abstraction Example**

To give an example of abstraction we will create one superclass called Employee and two subclasses –  Contractor and FullTimeEmployee. Both subclasses have common properties to share, like the name of the employee and the the amount of money the person will be paid per hour. There is one major difference between contractors and full-time employees – the tyme they work for the company. Full-time employees work constantly 8 hours per day and the working time of contractors may vary.

[](https://javatutorial.net/wp-content/uploads/2017/10/abstract-class-example.png)

Java abstract class example

Lets first create the superclass Employee. Note the usage of **abstract** keyword in class definition. This marks the class to be abstract, which means it can not be instantiated directly. We define a method called calculateSalary() as an abstract method. This way you leave the implementation of this method to the inheritors of the Employee class.

**package net.javatutorial;**

**public abstract class Employee {**

**private String name;**

**private int paymentPerHour;**

**public Employee(String name, int paymentPerHour) {**

**this.name = name;**

**this.paymentPerHour = paymentPerHour;**

**}**

**public abstract int calculateSalary();**

**public String getName() {**

**return name;**

**}**

**public void setName(String name) {**

**this.name = name;**

**}**

**public int getPaymentPerHour() {**

**return paymentPerHour;**

**}**

**public void setPaymentPerHour(int paymentPerHour) {**

**this.paymentPerHour = paymentPerHour;**

**}**

**}**

The Contractor class inherits all properties from its parent Employee but have to provide it’s own implementation to calculateSalary() method. In this case we multiply the value of payment per hour with given working hours.

**package net.javatutorial;**

**public class Contractor extends Employee {**

**private int workingHours;**

**public Contractor(String name, int paymentPerHour, int workingHours) {**

**super(name, paymentPerHour);**

**this.workingHours = workingHours;**

**}**

**@Override**

**public int calculateSalary() {**

**return getPaymentPerHour() \* workingHours;**

**}**

**}**

The FullTimeEmployee also has it’s own implementation ofcalculateSalary()method. In this case we just multiply by constant 8 hours.

**package net.javatutorial;**

**public class FullTimeEmployee extends Employee {**

**public FullTimeEmployee(String name, int paymentPerHour) {**

**super(name, paymentPerHour);**

**}**

**@Override**

**public int calculateSalary() {**

**return getPaymentPerHour() \* 8;**

**}**

**}**

## What is Encapsulation?

**Encapsulation** is one of the four fundamental OOP concepts. The other three are inheritance, polymorphism, and abstraction.

Encapsulation in Java is a mechanism of wrapping the data (variables) and code acting on the data (methods) together as a single unit. In encapsulation, the variables of a class will be hidden from other classes, and can be accessed only through the methods of their current class. Therefore, it is also known as **data hiding**.

To achieve encapsulation in Java −

Declare the variables of a class as private.

Provide public setter and getter methods to modify and view the variables values.

**Example**

Following is an example that demonstrates how to achieve Encapsulation in Java −

/\* File name : EncapTest.java \*/

public class EncapTest {

private String name;

private String idNum;

private int age;

public int getAge() {

return age;

}

public String getName() {

return name;

}

public String getIdNum() {

return idNum;

}

public void setAge( int newAge) {

age = newAge;

}

public void setName(String newName) {

name = newName;

}

public void setIdNum( String newId) {

idNum = newId;

}

}

The public setXXX() and getXXX() methods are the access points of the instance variables of the EncapTest class. Normally, these methods are referred as getters and setters. Therefore, any class that wants to access the variables should access them through these getters and setters.

The variables of the EncapTest class can be accessed using the following program −

/\* File name : RunEncap.java \*/

public class RunEncap {

public static void main(String args[]) {

EncapTest encap = new EncapTest();

encap.setName("James");

encap.setAge(20);

encap.setIdNum("12343ms");

System.out.print("Name : " + encap.getName() + " Age : " + encap.getAge());

}

}

This will produce the following result −

**Output**

Name : James Age : 20

**Benefits of Encapsulation**

The fields of a class can be made read-only or write-only.

A class can have total control over what is stored in its fields.

## Difference between Abstraction and Encapsulation ?

|  |  |  |
| --- | --- | --- |
|  | **Abstraction** | **Encapsulation** |
| Short description | Abstraction is a process, which extracts the essential details about an item, or group of items, and ignores the inessential details. | Encapsulation is a process which wraps or encloses the data in a capsule or makes the data concise. |
| They are | Abstraction relates to the idea of hiding data that is not needed for presentation. | Encapsulation is grouping together of data and functionality. |
| Basic functions | Basically, abstraction is used for hiding the unwanted data and it gives the relevant data. | Basically, encapsulation means hiding the code and data into a single unit in order to protect the data from the outside world. |
| When are they Operated | It operates the problem in the design level. | It operates the problem in the implementation level. |
| Beneficial to the roles | It helps the user to focus on what the object does instead of how it does any function. | It helps the programmer in hiding the internal details or mechanics of how an object does something. |
| Information is | Here information is separated from the real data. | Here information is wrapped in a hidden format. |
| Layouts | It is concerned with the outer layout, which is used in terms of design. | It is concerned with the inner layout, which is used in terms of implementation. |
| For Example | The Outer Look of a Mobile Phone, which has a display screen and keypad buttons to dial a number. | Inner Implementation detail of a Mobile Phone, how the keypad button and Display Screen are connected with each other using circuits. |

## Difference between Data hiding and Abstraction?

**Data Hiding**

1. The data should not go out directly i.e outside person is not allowed to access the data this is nothing but **“Data Hiding”**.
2. The main advantage of data hiding is we can achieve security.
3. By using **private**modifier we can achieve this.

E.g

1. **class** Employee {
2. **private** **int** empId;
3. **private** String empName;
4. **private** Date empDOB;
5. ...
6. ...
7. }

**Note**

It is highly recommended to declare data members with private modifier.

**Data Abstraction**

1. Hiding implementation details is nothing but abstraction. The main advantages of abstraction are we can achieve security as we are not highlighting internal implementation
2. Enhancement will become easy. With out effecting outside person we can change our internal implementation.
3. It improves maintainability.
4. By using interfaces and abstract classes we can achieve abstraction.

**Note**

1. If we don’t know about implementation just we have to represent the specification then we should go for **interface**.
2. If we don’t know about complete implementation just we have partial implementation then we should go for **abstract**.
3. If we know complete implementation and if we r ready to provide service then we should go for **concrete class**

## Polymorphism

### **Rules for method overriding:**

#### Overriding and Access-Modifiers **:**

The [access modifier](https://www.geeksforgeeks.org/access-modifiers-java/) for an overriding method can allow more, but not less, access than the overridden method. For example, a protected instance method in the super-class can be made public, but not private, in the subclass. Doing so, will generate compile-time error.

|  |
| --- |
| // A Simple Java program to demonstrate  // Overriding and Access-Modifiers    class Parent  {      // private methods are not overridden      private void m1() { System.out.println("From parent m1()");}        protected void m2() { System.out.println("From parent m2()"); }  }    class Child extends Parent  {      // new m1() method      // unique to Child class      private void m1() { System.out.println("From child m1()");}        // overriding method      // with more accessibility      @Override      public void m2() { System.out.println("From child m2()");}    }    // Driver class  class Main  {      public static void main(String[] args)      {          Parent obj1 = new Parent();          obj1.m2();          Parent obj2 = new Child();          obj2.m2();      }  } |

Output :

From parent m2()

From child m2()

#### **Final methods can not be overridden**

If we don’t want a method to be overridden, we declare it as [final](https://www.geeksforgeeks.org/final-keyword-java/). Please see [Using final with Inheritance](https://www.geeksforgeeks.org/using-final-with-inheritance-in-java/).

|  |
| --- |
| // A Java program to demonstrate that  // final methods cannot be overridden    class Parent  {      // Can't be overridden      final void show() {  }  }    class Child extends Parent  {      // This would produce error      void show() {  }  } |

Output :

13: error: show() in Child cannot override show() in Parent

void show() { }

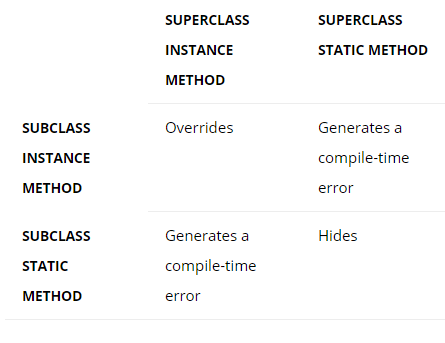
^

overridden method is final

#### Static methods can not be overridden(Method Overriding vs Method Hiding)

When you defines a static method with same signature as a static method in base class, it is known as [method hiding](https://www.geeksforgeeks.org/can-we-overload-or-override-static-methods-in-java/).

The following table summarizes what happens when you define a method with the same signature as a method in a super-class.



|  |
| --- |
| /\* Java program to show that if static method is redefined by  a derived class, then it is not overriding,it is hiding \*/    class Parent  {      // Static method in base class which will be hidden in subclass      static void m1() { System.out.println("From parent static m1()");}        // Non-static method which will be overridden in derived class      void m2() { System.out.println("From parent non-static(instance) m2()"); }  }    class Child extends Parent  {      // This method hides m1() in Parent      static void m1() { System.out.println("From child static m1()");}        // This method overrides m2() in Parent      @Override      public void m2() { System.out.println("From child non-static(instance) m2()");}    }    // Driver class  class Main  {      public static void main(String[] args)      {          Parent obj1 = new Child();            // As per overriding rules this should call to class Child static          // overridden method. Since static method can not be overridden, it          // calls Parent's m1()          obj1.m1();            // Here overriding works and Child's m2() is called          obj1.m2();      }  } |

Output :

From parent static m1()

From child non-static(instance) m2()

#### **Private methods can not be overridden**

[Private methods](https://www.geeksforgeeks.org/can-override-private-methods-java/)cannot be overridden as they are bonded during compile time. Therefore we can’t even override private methods in a subclass.

#### The overriding method must have same return type (or subtype)

From Java 5.0 onwards it is possible to have different return type for a overriding method in child class, but child’s return type should be sub-type of parent’s return type. This phenomena is known as [**covariant return type**](https://www.geeksforgeeks.org/covariant-return-types-java/).

#### Overriding and constructor:

We can not override constructor as parent and child class can never have constructor with same name(Constructor name must always be same as Class name).

#### **Overriding and Exception-Handling**

Below are two rules to note when overriding methods related to exception-handling.

* **Rule#1 :** If the super-class overridden method does not throws an exception, subclass overriding method can only throws the [unchecked exception](https://www.geeksforgeeks.org/checked-vs-unchecked-exceptions-in-java/), throwing checked exception will lead to compile-time error.

|  |
| --- |
| /\* Java program to demonstrate overriding when    superclass method does not declare an exception  \*/    class Parent  {      void m1() { System.out.println("From parent m1()");}        void m2() { System.out.println("From parent  m2()"); }  }    class Child extends Parent  {      @Override      // no issue while throwing unchecked exception      void m1() throws ArithmeticException      { System.out.println("From child m1()");}        @Override      // compile-time error      // issue while throwin checked exception      void m2() throws Exception{ System.out.println("From child m2");}    } |

* Output:
* error: m2() in Child cannot override m2() in Parent
* void m2() throws Exception{ System.out.println("From child m2");}
* ^
* overridden method does not throw Exception
* **Rule#2 :** If the super-class overridden method does throws an exception, subclass overriding method can only throw same, subclass exception. Throwing parent exception in [Exception hierarchy](https://www.geeksforgeeks.org/exceptions-in-java/) will lead to compile time error.Also there is no issue if subclass overridden method is not throwing any exception.

|  |
| --- |
| /\* Java program to demonstrate overriding when    superclass method does declare an exception  \*/    class Parent  {      void m1() throws RuntimeException      { System.out.println("From parent m1()");}    }    class Child1 extends Parent  {      @Override      // no issue while throwing same exception      void m1() throws RuntimeException      { System.out.println("From child1 m1()");}    }  class Child2 extends Parent  {      @Override      // no issue while throwing subclass exception      void m1() throws ArithmeticException      { System.out.println("From child2 m1()");}    }  class Child3 extends Parent  {      @Override      // no issue while not throwing any exception      void m1()      { System.out.println("From child3 m1()");}    }  class Child4 extends Parent  {      @Override      // compile-time error      // issue while throwing parent exception      void m1() throws Exception      { System.out.println("From child4 m1()");}    } |

* Output:
* error: m1() in Child4 cannot override m1() in Parent
* void m1() throws Exception
* ^
* overridden method does not throw Exception

#### Overriding and abstract method

Abstract methods in an interface or abstract class are meant to be overridden in derived concrete classes otherwise compile-time error will be thrown.

#### Overriding and synchronized/stricfp method

* The presence of synchronized/stricfp modifier with method have no effect on the rules of overriding, i.e. it’s possible that a synchronized/stricfp method can override a non synchronized/stricfp one and vice-versa.

# Design Patterns

**Design Patterns** are very popular among software developers. A design pattern is a well-described solution to a common software problem.

Some of the benefits of using design patterns are:

* Design Patterns are already defined and provides industry standard approach to solve a recurring problem, so it saves time if we sensibly use the design pattern.
* Using design patterns promotes reusability that leads to more robust and highly maintainable code. It helps in reducing total cost of ownership (TCO) of the software product.
* Since design patterns are already defined, it makes our code easy to understand and debug. It leads to faster development and new members of team understand it easily.

**Java Design Patterns** are divided into three categories – **creational**, **structural**, and **behavioral** design patterns.

## Creational Design Patterns

Creational design patterns provide solution to instantiate an object in the best possible way for specific situations.

The basic form of object creation could result in design problems or add unwanted complexity to the design. Creational design patterns solve this problem by controlling the object creation by different ways.

There are five creational design patterns that we will discuss in this eBook.

1. Singleton Pattern

2. Factory Pattern

3. Abstract Factory Pattern

4. Builder Pattern

5. Prototype Pattern

All these patterns solve specific problems with object creation, so you should understand and use them when needed.

### Singleton Pattern

**Singleton** is one of the **Gangs of Four Design patterns** and comes in the **Creational Design Pattern** category. From the definition, it seems to be

a very simple design pattern but when it comes to implementation, it comes with a lot of implementation concerns. The implementation of Singleton pattern has always been a controversial topic among developers. Here we will learn about Singleton design pattern principles, different ways to implement Singleton and some of the best practices for its usage. Singleton pattern restricts the instantiation of a class and ensures that only one instance of the class exists in the java virtual machine. The singleton class must provide a global access point to get the instance of the class. Singleton pattern is used for logging, driver objects, caching and thread pool. Singleton design pattern is also used in other design patterns like Abstract Factory, Builder, Prototype, Facade etc. Singleton design pattern is used in core java classes also, for example java.lang.Runtime, java.awt.Desktop. To implement Singleton pattern, we have different approaches but all of them have following common concepts.

􀁸 Private constructor to restrict instantiation of the class from other classes.

􀁸 Private static variable of the same class that is the only instance of the class.

􀁸 Public static method that returns the instance of the class, this is the global access point for outer world to get the instance of the singleton class.

In further sections, we will learn different approaches of Singleton pattern implementation and design concerns with the implementation.

#### Eager Initialization

In eager initialization, the instance of Singleton Class is created at the time of class loading, this is the easiest method to create a singleton class but it has a drawback that instance is created even though client application might not be using it.

Here is the implementation of static initialization singleton class.

**package** com.journaldev.singleton;

**public class EagerInitializedSingleton** {

**private static final** EagerInitializedSingleton instance = **new**

EagerInitializedSingleton();

//private constructor to avoid client applications to use

constructor

**private EagerInitializedSingleton**(){}

**public static** EagerInitializedSingleton **getInstance**(){

**return** instance;

}

}

If your singleton class is not using a lot of resources, this is the approach to use. But in most of the scenarios, Singleton classes are created for resources such as File System, Database connections etc and we should avoid the instantiation until unless client calls the *getInstance* method. Also this method doesn’t provide any options for exception handling.

#### Static block initialization

Static block initialization implementation is similar to eager initialization, except that instance of class is created in the static block that provides option for exception handling.

**package** com.journaldev.singleton;

**public class StaticBlockSingleton** {

**private static** StaticBlockSingleton instance;

**private StaticBlockSingleton**(){}

//static block initialization for exception handling

**static**{

**try**{

instance = **new** StaticBlockSingleton();

}**catch**(Exception e){

**throw new RuntimeException**("Exception occured in creating

singleton instance");

}

}

**public static** StaticBlockSingleton **getInstance**(){

**return** instance;

}

}

Both eager initialization and static block initialization creates the instance

even before it’s being used and that is not the best practice to use. So in

further sections, we will learn how to create Singleton class that supports

lazy initialization.

#### Lazy Initialization

Lazy initialization method to implement Singleton pattern creates the

instance in the global access method. Here is the sample code for creating

Singleton class with this

**package** com.journaldev.singleton;

**public class LazyInitializedSingleton** {

**private static** LazyInitializedSingleton instance;

**private LazyInitializedSingleton**(){}

**public static** LazyInitializedSingleton **getInstance**(){

**if**(instance == **null**){

instance = **new** LazyInitializedSingleton();

}

**return** instance;

}

}

The above implementation works fine in case of single threaded

environment but when it comes to multithreaded systems, it can cause issues

if multiple threads are inside the if loop at the same time. It will destroy the

singleton pattern and both threads will get the different instances of

singleton class. In next section, we will see different ways to create a threadsafe

singleton class.

#### Thread Safe Singleton

The easier way to create a thread-safe singleton class is to make the global

access method synchronized, so that only one thread can execute this

method at a time. General implementation of this approach is like the below

class.

**package** com.journaldev.singleton;

**public class ThreadSafeSingleton** {

**private static** ThreadSafeSingleton instance;

**private ThreadSafeSingleton**(){}

**public static synchronized** ThreadSafeSingleton **getInstance**(){

**if**(instance == **null**){

instance = **new** ThreadSafeSingleton();

}

**return** instance;

}

}

Above implementation works fine and provides thread-safety but it reduces

the performance because of cost associated with the synchronized method,

although we need it only for the first few threads who might create the

separate instances (Read: Java Synchronization). To avoid this extra

overhead every time, **double checked locking** principle is used. In this

approach, the synchronized block is used inside if condition with an

additional check to ensure that only one instance of singleton class is

created.

Below code snippet provides the double checked locking implementation.

**public static** ThreadSafeSingleton **getInstanceUsingDoubleLocking**(){

**if**(instance == **null**){

**synchronized** (ThreadSafeSingleton.class) {

**if**(instance == **null**){

instance = **new** ThreadSafeSingleton();

}

}

}

**return** instance;

}

#### Bill Pugh Singleton Implementation

Prior to Java 5, java memory model had a lot of issues and above approaches

used to fail in certain scenarios where too many threads try to get the

instance of the Singleton class simultaneously. So Bill Pugh came up with a

different approach to create the Singleton class using an inner static helper

class. The Bill Pugh Singleton implementation goes like this;

**package** com.journaldev.singleton;

**public class BillPughSingleton** {

**private BillPughSingleton**(){}

**private static class SingletonHelper**{

**private static final** BillPughSingleton INSTANCE = **new**

BillPughSingleton();

}

**public static** BillPughSingleton **getInstance**(){

**return** SingletonHelper.INSTANCE;

}

}

Notice the **private inner static class** that contains the instance of the

singleton class. When the singleton class is loaded, SingletonHelper class is

not loaded into memory and only when someone calls the *getInstance*

method, this class gets loaded and creates the Singleton class instance.

This is the most widely used approach for Singleton class as it doesn’t

require synchronization. I am using this approach in many of my projects

and it’s easy to understand and implement also.

#### Using Reflection to destroy Singleton Pattern

Reflection can be used to destroy all the above singleton implementation

approaches. Let’s see this with an example class.

**package** com.journaldev.singleton;

**import java.lang.reflect.Constructor**;

**public class ReflectionSingletonTest** {

**public static void main**(String[] args) {

EagerInitializedSingleton instanceOne =

EagerInitializedSingleton.getInstance();

EagerInitializedSingleton instanceTwo = **null**;

**try** {

Constructor[] constructors =

EagerInitializedSingleton.class.getDeclaredConstructors();

**for** (Constructor constructor : constructors) {

//Below code will destroy the singleton pattern

constructor.setAccessible(**true**);

instanceTwo = (EagerInitializedSingleton)

constructor.newInstance();

**break**;

}

} **catch** (Exception e) {

e.printStackTrace();

}

System.out.println(instanceOne.hashCode());

System.out.println(instanceTwo.hashCode());

}

}

When you run the above test class, you will notice that hashCode of both the

instances are not same that destroys the singleton pattern. Reflection is very

powerful and used in a lot of frameworks like Spring and Hibernate, do

check out **Java Reflection Tutorial**.

#### Enum Singleton

To overcome this situation with Reflection, Joshua Bloch suggests the use of

Enum to implement Singleton design pattern as Java ensures that any enum

value is instantiated only once in a Java program. Since Java Enum values

are globally accessible, so is the singleton. The drawback is that the enum

type is somewhat inflexible; for example, it does not allow lazy

initialization.

**package** com.journaldev.singleton;

**public enum** EnumSingleton {

INSTANCE;

**public static void doSomething**(){

//do something

}

}

#### Serialization and Singleton

Sometimes in distributed systems, we need to implement Serializable

interface in Singleton class so that we can store its state in file system and

retrieve it at later point of time. Here is a small singleton class that

implements Serializable interface also.

**package** com.journaldev.singleton;

**import java.io.Serializable**;

**public class SerializedSingleton implements** Serializable{

**private static final long** serialVersionUID = -**7604766932017737115L**;

**private SerializedSingleton**(){}

**private static class SingletonHelper**{

**private static final** SerializedSingleton instance = **new**

SerializedSingleton();

}

**public static** SerializedSingleton **getInstance**(){

**return** SingletonHelper.instance;

}

}

The problem with above serialized singleton class is that whenever we

deserialize it, it will create a new instance of the class. Let’s see it with a

simple program.

**package** com.journaldev.singleton;

**import java.io.FileInputStream**;

**import java.io.FileNotFoundException**;

**import java.io.FileOutputStream**;

**import java.io.IOException**;

**import java.io.ObjectInput**;

**import java.io.ObjectInputStream**;

**import java.io.ObjectOutput**;

**import java.io.ObjectOutputStream**;

**public class SingletonSerializedTest** {

**public static void main**(String[] args) **throws**

FileNotFoundException, IOException, ClassNotFoundException {

SerializedSingleton instanceOne =

SerializedSingleton.getInstance();

ObjectOutput out = **new** ObjectOutputStream(**new** FileOutputStream(

"filename.ser"));

out.writeObject(instanceOne);

out.close();

//deserailize from file to object

ObjectInput in = **new** ObjectInputStream(**new** FileInputStream(

"filename.ser"));

SerializedSingleton instanceTwo = (SerializedSingleton)

in.readObject();

in.close();

System.out.println("instanceOne

hashCode="+instanceOne.hashCode());

System.out.println("instanceTwo

hashCode="+instanceTwo.hashCode());

}

}

Output of the above program is;

instanceOne hashCode=**2011117821**

instanceTwo hashCode=**109647522**

So it destroys the singleton pattern, to overcome this scenario all we need to

do it provide the implementation of readResolve() method.

**protected** Object **readResolve**() {

**return getInstance**();

}

After this you will notice that hashCode of both the instances are same in

test program.

### Factory Pattern

**Factory Pattern** is one of the **Creational Design pattern** and it’s widely used in JDK as well as frameworks like Spring and Struts.Factory design pattern is used when we have a super class with multiple subclasses and based on input, we need to return one of the sub-class. This pattern take out the responsibility of instantiation of a class from client program to the factory class. Let’s first learn how to implement factory pattern in java and then we will learn its benefits and we will see its usage in JDK.

#### Super Class

Super class in factory pattern can be an interface, abstract class or a normal java class. For our example, we have super class as abstract class with overridden toString() method for testing purpose.

**package** com.journaldev.design.model;

**public abstract class Computer** {

**public abstract** String **getRAM**();

**public abstract** String **getHDD**();

**public abstract** String **getCPU**();

**@Override**

**public** String **toString**(){

**return** "RAM= "+**this**.getRAM()+", HDD="+**this**.getHDD()+",CPU="+**this**.getCPU();

}

}

#### Sub Classes

Let’s say we have two sub-classes PC and Server with below implementation.

**package** com.journaldev.design.model;

**public class PC extends** Computer {

**private** String ram;

**private** String hdd;

**private** String cpu;

**public PC**(String ram, String hdd, String cpu){

**this**.ram=ram;

**this**.hdd=hdd;

**this**.cpu=cpu;

}

**@Override**

**public** String **getRAM**() {

**return this**.ram;

}

**@Override**

**public** String **getHDD**() {

**return this**.hdd;

}

**@Override**

**public** String **getCPU**() {

**return this**.cpu;

}

}

Notice that both the classes are extending Computer class.

**package** com.journaldev.design.model;

**public class Server extends** Computer {

**private** String ram;

**private** String hdd;

**private** String cpu;

**public Server**(String ram, String hdd, String cpu){

**this**.ram=ram;

**this**.hdd=hdd;

**this**.cpu=cpu;

}

**@Override**

**public** String **getRAM**() {

**return this**.ram;

}

**@Override**

**public** String **getHDD**() {

**return this**.hdd;

}

**@Override**

**public** String **getCPU**() {

**return this**.cpu;

}

}

#### Factory Class

Now that we have super classes and sub-classes ready, we can write our factory class. Here is the basic implementation.

**package** com.journaldev.design.factory;

**import com.journaldev.design.model.Computer**;

**import com.journaldev.design.model.PC**;

**import com.journaldev.design.model.Server**;

**public class ComputerFactory** {

**public static** Computer **getComputer**(String type, String ram, String hdd, String cpu){

**if**("PC".equalsIgnoreCase(type)) **return new** PC(ram, hdd, cpu);

**else if**("Server".equalsIgnoreCase(type)) **return new** Server(ram,hdd, cpu);

**return null**;

}

}

1. We can keep Factory class Singleton or we can keep the method that returns the subclass as static.

2. Notice that based on the input parameter, different subclass is created and returned.

Here is a simple test client program that uses above factory pattern implementation.

**package** com.journaldev.design.test;

**import com.journaldev.design.abstractfactory.PCFactory**;

**import com.journaldev.design.abstractfactory.ServerFactory**;

**import com.journaldev.design.factory.ComputerFactory**;

**import com.journaldev.design.model.Computer**;

**public class TestFactory** {

**public static void main**(String[] args) {

Computer pc = ComputerFactory.getComputer("pc","2 GB","500GB","2.4 GHz");

Computer server = ComputerFactory.getComputer("server","16GB","1 TB","2.9 GHz");

System.out.println("Factory PC Config::"+pc);

System.out.println("Factory Server Config::"+server);

}

}

Output of above program is:

Factory PC **Config:**:RAM= **2** GB, HDD=**500** GB, CPU=**2.4** GHz

Factory Server **Config:**:RAM= **16** GB, HDD=**1** TB, CPU=**2.9** GHz

#### Benefits of Factory Pattern

1. Factory pattern provides approach to code for interface rather than implementation.

2. Factory pattern removes the instantiation of actual implementation classes from client code, making it more robust, less coupled and easy to extend. For example, we can easily change PC class implementation because client program is unaware of this.

3. Factory pattern provides abstraction between implementation and client classes through inheritance.

#### Factory Pattern Examples in JDK

1. java.util.Calendar, ResourceBundle and NumberFormat getInstance() methods uses Factory pattern.

2. valueOf() method in wrapper classes like Boolean, Integer etc.

### Abstract Factory Pattern

Abstract Factory is one of the **Creational pattern** and almost similar to

**Factory Pattern** except the fact that it’s more like factory of factories.

If you are familiar with **factory design pattern in java**, you will notice that we have a single Factory class that returns the different sub-classes based on the input provided and factory class uses if-else or switch statement to achieve this.

In Abstract Factory pattern, we get rid of if-else block and have a factory class for each sub-class and then an Abstract Factory class that will return the sub-class based on the input factory class. At first it seems confusing but once you see the implementation, it’s really easy to grasp and understand the minor difference between Factory and Abstract Factory pattern.

Like our factory pattern post, we will use the same super class and subclasses.

#### Super Class and Sub-Classes

**package** com.journaldev.design.model;

**public abstract class Computer** {

**public abstract** String **getRAM**();

**public abstract** String **getHDD**();

**public abstract** String **getCPU**();

**@Override**

**public** String **toString**(){

**return** "RAM= "+**this**.getRAM()+", HDD="+**this**.getHDD()+",CPU="+**this**.getCPU();

}

}

**package** com.journaldev.design.model;

**public class PC extends** Computer {

**private** String ram;

**private** String hdd;

**private** String cpu;

**public PC**(String ram, String hdd, String cpu){

**this**.ram=ram;

**this**.hdd=hdd;

**this**.cpu=cpu;

}

**@Override**

**public** String **getRAM**() {

**return this**.ram;

}

**@Override**

**public** String **getHDD**() {

**return this**.hdd;

}

**@Override**

**public** String **getCPU**() {

**return this**.cpu;

}

}

**package** com.journaldev.design.model;

**public class Server extends** Computer {

**private** String ram;

**private** String hdd;

**private** String cpu;

**public Server**(String ram, String hdd, String cpu){

**this**.ram=ram;

**this**.hdd=hdd;

**this**.cpu=cpu;

}

**@Override**

**public** String **getRAM**() {

**return this**.ram;

}

**@Override**

**public** String **getHDD**() {

**return this**.hdd;

}

**@Override**

**public** String **getCPU**() {

**return this**.cpu;

}

}

#### Factory Classes for Each sub-class

First of all we need to create an Abstract Factory interface or **abstract class**.

**package** com.journaldev.design.abstractfactory;

**import com.journaldev.design.model.Computer**;

**public interface ComputerAbstractFactory** {

**public** Computer **createComputer**();

}

Notice that *createComputer()* method is returning an instance of super class *Computer*. Now our factory classes will implement this interface and return their respective sub-class.

**package** com.journaldev.design.abstractfactory;

**import com.journaldev.design.model.Computer**;

**import com.journaldev.design.model.PC**;

**public class PCFactory implements** ComputerAbstractFactory {

**private** String ram;

**private** String hdd;

**private** String cpu;

**public PCFactory**(String ram, String hdd, String cpu){

**this**.ram=ram;

**this**.hdd=hdd;

**this**.cpu=cpu;

}

**@Override**

**public** Computer **createComputer**() {

**return new PC**(ram,hdd,cpu);

}

}

Similarly we will have a factory class for Server sub-class.

**package** com.journaldev.design.abstractfactory;

**import com.journaldev.design.model.Computer**;

**import com.journaldev.design.model.Server**;

**public class ServerFactory implements** ComputerAbstractFactory {

**private** String ram;

**private** String hdd;

**private** String cpu;

**public ServerFactory**(String ram, String hdd, String cpu){

**this**.ram=ram;

**this**.hdd=hdd;

**this**.cpu=cpu;

}

**@Override**

**public** Computer **createComputer**() {

**return new Server**(ram,hdd,cpu);

}

}

Now we will create a consumer class that will provide the entry point for the

client classes to create sub-classes.

**package com.journaldev.design.abstractfactory;**

**import com.journaldev.design.model.Computer;**

**public class ComputerFactory {**

**public static Computer getComputer(ComputerAbstractFactory factory){**

**return factory.createComputer();**

**}**

**}**

Notice that it’s a simple class and *getComputer* method is accepting

*ComputerAbstractFactory* argument and returning *Computer* object. At this point the implementation must be getting clear.Let’s write a simple test method and see how to use the abstract factory to get the instance of sub-classes.

**package** com.journaldev.design.test;

**import com.journaldev.design.abstractfactory.PCFactory**;

**import com.journaldev.design.abstractfactory.ServerFactory**;

**import com.journaldev.design.factory.ComputerFactory**;

**import com.journaldev.design.model.Computer**;

**public class TestDesignPatterns** {

**public static void main**(String[] args) {

testAbstractFactory();

}

**private static void testAbstractFactory**() {

Computer pc=com.journaldev.design.abstractfactory.ComputerFactory.getComputer(**new**

PCFactory("2 GB","500 GB","2.4 GHz"));

Computer server=com.journaldev.design.abstractfactory.ComputerFactory.getComputer(**new** ServerFactory("16 GB","1 TB","2.9 GHz"));

System.out.println("AbstractFactory PC Config::"+pc);

System.out.println("AbstractFactory Server Config::"+server);

}

}

**Output of the above program will be:**

AbstractFactory PC Config::RAM= 2 GB, HDD=500 GB, CPU=2.4 GHz

AbstractFactory Server Config::RAM= 16 GB, HDD=1 TB, CPU=2.9 GHz

Here is the class diagram of abstract factory implementation.

#### Benefits of Abstract Factory Pattern

􀁸 Abstract Factory pattern provides approach to code for interface rather

than implementation.

􀁸 Abstract Factory pattern is “factory of factories” and can be easily

extended to accommodate more products, for example we can add

another sub-class Laptop and a factory LaptopFactory.

􀁸 Abstract Factory pattern is robust and avoid conditional logic of

Factory pattern.

#### Abstract Factory Pattern Examples in JDK

􀁸 javax.xml.parsers.DocumentBuilderFactory#newInstance()

􀁸 javax.xml.transform.TransformerFactory#newInstance()

􀁸 javax.xml.xpath.XPathFactory#newInstance()

### Builder Pattern

Builder design pattern is a **creational design pattern** like **Factory Pattern** and **Abstract Factory Pattern**. This pattern was introduced to solve some of the problems with Factory and Abstract Factory design patterns when the Object contains a lot of attributes. There are three major issues with Factory and Abstract Factory design patterns when the Object contains a lot of attributes.

1. Too Many arguments to pass from client program to the Factory class that can be error prone because most of the time, the type of arguments are same and from client side it’s hard to maintain the order of the argument.

2. Some of the parameters might be optional but in Factory pattern, we are forced to send all the parameters and optional parameters need to send as NULL.

3. If the object is heavy and its creation is complex, then all that complexity will be part of Factory classes that is confusing. We can solve the issues with large number of parameters by providing a constructor with required parameters and then different setter methods to set the optional parameters but the problem with this is that the Object state will be **inconsistent** until unless all the attributes are set explicitly. Builder pattern solves the issue with large number of optional parameters and inconsistent state by providing a way to build the object step-by-step and provide a method that will actually return the final Object.

#### Builder Pattern Implementation

1. First of all you need to create a static nested class and then copy all the arguments from the outer class to the Builder class. We should follow the naming convention and if the class name is *Computer* then builder class should be named as *ComputerBuilder.*

2. The Builder class should have a public constructor with all the required attributes as parameters.

3. Builder class should have methods to set the optional parameters and

it should return the same Builder object after setting the optional attribute.

4. The final step is to provide a *build()* method in the builder class that will return the Object needed by client program. For this we need to have a private constructor in the Class with Builder class as argument.

Here is the sample code where we have a Computer class and

ComputerBuilder class to build it.

package com.journaldev.design.builder;

**public class Computer** {

//required parameters

**private** String HDD;

**private** String RAM;

//optional parameters

**private boolean** isGraphicsCardEnabled;

**private boolean** isBluetoothEnabled;

**public** String **getHDD**() {

**return** HDD;

}

**public** String **getRAM**() {

**return** RAM;

}

**public boolean isGraphicsCardEnabled**() {

**return** isGraphicsCardEnabled;

}

**public boolean isBluetoothEnabled**() {

**return** isBluetoothEnabled;

}

**private Computer**(ComputerBuilder builder) {

**this**.HDD=builder.HDD;

**this**.RAM=builder.RAM;

**this**.isGraphicsCardEnabled=builder.isGraphicsCardEnabled;

**this**.isBluetoothEnabled=builder.isBluetoothEnabled;

}

//Builder Class

**public static class ComputerBuilder**{

// required parameters

**private** String HDD;

**private** String RAM;

// optional parameters

**private boolean** isGraphicsCardEnabled;

**private boolean** isBluetoothEnabled;

**public ComputerBuilder**(String hdd, String ram){

**this**.HDD=hdd;

**this**.RAM=ram;

}

**public** ComputerBuilder **setGraphicsCardEnabled**(**Boolean** isGraphicsCardEnabled) {

**this**.isGraphicsCardEnabled = isGraphicsCardEnabled;

**return this**;

}

**public** ComputerBuilder **setBluetoothEnabled**(**Boolean** isBluetoothEnabled) { **this**.isBluetoothEnabled = isBluetoothEnabled;

**return this**;

}

**public** Computer **build**(){

**return new Computer**(**this**);

}

}

}

Notice that Computer class has only getter methods and no public constructor, so the only way to get a Computer object is through the ComputerBuilder class.

Here is a test program showing how to use Builder class to get the object.

**package** com.journaldev.design.test;

**import com.journaldev.design.builder.Computer**;

**public class TestBuilderPattern** {

**public static void main**(String[] args) {

//Using builder to get the object in a single line of code and

//without any inconsistent state or arguments management issues

Computer comp = **new** Computer.ComputerBuilder("500 GB", "2 GB").setBluetoothEnabled(**true**).setGraphicsCardEnabled(**true**).build();

}

}

#### Builder Design Pattern Example in JDK

􀁸 java.lang.StringBuilder#append() (unsynchronized)

􀁸 java.lang.StringBuffer#append() (synchronized)

### Prototype Pattern

**Prototype pattern** is one of the Creational Design pattern, so it provides a mechanism of object creation. Prototype pattern is used when the Object creation is a costly affair and requires a lot of time and resources and you have a similar object already existing. So this pattern provides a mechanism to copy the original object to a new object and then modify it according to our needs. This pattern uses java cloning to copy the object. It would be easy to understand this pattern with an example, suppose we have an Object that loads data from database. Now we need to modify this data in our program multiple times, so it’s not a good idea to create the Object using *new* keyword and load all the data again from database. So the better approach is to clone the existing object into a new object and then do the data manipulation. Prototype design pattern mandates that the Object which you are copying should provide the copying feature. It should not be done by any other class. However whether to use shallow or deep copy of the Object properties depends on the requirements and it’s a design decision.

#### Implementation

Here is a sample program showing implementation of Prototype pattern.

**package** com.journaldev.design.prototype;

**import java.util.ArrayList**;

**import java.util.List**;

**public class Employees implements** Cloneable{

**private** List<String> empList;

**public Employees**(){

empList = **new** ArrayList<String>();

}

**public Employees**(List<String> list){

**this**.empList=list;

}

**public void loadData**(){

//read all employees from database and put into the list

empList.add("Pankaj");

empList.add("Raj");

empList.add("David");

empList.add("Lisa");

}

**public** List<String> **getEmpList**() {

**return** empList;

}

**@Override**

**public** Object **clone**() **throws** CloneNotSupportedException{

List<String> temp = **new** ArrayList<String>();

**for**(String s : **this**.getEmpList()){

temp.add(s);

}

**return new Employees**(temp);

}

}

Notice that the clone method is overridden to provide a deep copy of the employees list. Here is the test program that will show the benefit of prototype pattern

usage.

**package** com.journaldev.design.test;

**import java.util.List**;

**import com.journaldev.design.prototype.Employees**;

**public class PrototypePatternTest** {

**public static void main**(String[] args) **throws** CloneNotSupportedException {

Employees emps = **new** Employees();

emps.loadData();

//Use the clone method to get the Employee object

Employees empsNew = (Employees) emps.clone();

Employees empsNew1 = (Employees) emps.clone();

List<String> list = empsNew.getEmpList();

list.add("John");

List<String> list1 = empsNew1.getEmpList();

list1.remove("Pankaj");

System.out.println("emps List: "+emps.getEmpList());

System.out.println("empsNew List: "+list);

System.out.println("empsNew1 List: "+list1);

}

}

**Output of the above program is:**

emps **HashMap:** [Pankaj, Raj, David, Lisa]

empsNew **HashMap:** [Pankaj, Raj, David, Lisa, John]

empsNew1 **HashMap:** [Raj, David, Lisa]

If the object cloning was not provided, every time we need to make database call to fetch the employee list and then do the manipulations that would have been resource and time consuming.

## Structural Design Patterns

Structural patterns provide different ways to create a class structure, for example using inheritance and composition to create a large object from small objects.

### Adapter Design Pattern

**Adapter design pattern** is one of the **structural design pattern** and it’s used so that two unrelated interfaces can work together. The object that joins these unrelated interface is called an **Adapter**. As a real life example, we can think of a mobile charger as an adapter because mobile battery needs 3 volts to charge but the normal socket produces either 120V (US) or 240V (India). So the mobile charger works as an adapter between mobile charging socket and the wall socket. We will try to implement multi-adapter using adapter design pattern in this tutorial. So first of all we will have two classes – Volt (to measure volts) and Socket (producing constant volts of 120V).

#### Implementation

**package** com.journaldev.design.adapter;

**public class Volt** {

**private int** volts;

**public Volt**(**int** v){

**this**.volts=v;

}

**public int getVolts**() {

**return** volts;

}

**public void setVolts**(**int** volts) {

**this**.volts = volts;

}

}

**package** com.journaldev.design.adapter;

**public class Socket** {

**public** Volt **getVolt**(){

**return new Volt**(**120**);

}

}

Now we want to build an adapter that can produce 3 volts, 12 volts and default 120 volts. So first of all we will create an adapter interface with these methods.

**package** com.journaldev.design.adapter;

**public interface SocketAdapter** {

**public** Volt **get120Volt**();

**public** Volt **get12Volt**();

**public** Volt **get3Volt**();

}

#### Two Way Adapter Pattern

While implementing Adapter pattern, there are two approaches – class adapter and object adapter, however both these approaches produce same result.

1. **Class Adapter** – This form uses **java inheritance** and extends the source interface, in our case Socket class.

2. **Object Adapter** – This form uses **Java Composition** and adapter contains the source object.

#### Class Adapter Implementation

Here is the **class adapter** approach implementation of our adapter.

**package** com.journaldev.design.adapter;

//Using inheritance for adapter pattern

**public class SocketClassAdapterImpl extends** Socket **implements**

SocketAdapter{

**@Override**

**public** Volt **get120Volt**() {

**return getVolt**();

}

**@Override**

**public** Volt **get12Volt**() {

Volt v= getVolt();

**return convertVolt**(v,**10**);

}

**@Override**

**public** Volt **get3Volt**() {

Volt v= getVolt();

**return convertVolt**(v,**40**);

}

**private** Volt **convertVolt**(Volt v, **int** i) {

**return new Volt**(v.getVolts()/i);

}

}

#### Object Adapter Implementation

Here is the **Object adapter** implementation of our adapter.

**package** com.journaldev.design.adapter;

**public class SocketObjectAdapterImpl implements** SocketAdapter{

//Using Composition for adapter pattern

**private** Socket sock = **new** Socket();

**@Override**

**public** Volt **get120Volt**() {

**return** sock.getVolt();

}

**@Override**

**public** Volt **get12Volt**() {

Volt v= sock.getVolt();

**return convertVolt**(v,**10**);

}

**@Override**

**public** Volt **get3Volt**() {

Volt v= sock.getVolt();

**return convertVolt**(v,**40**);

}

**private** Volt **convertVolt**(Volt v, **int** i) {

**return new Volt**(v.getVolts()/i);

}

}

Notice that both the adapter implementations are almost same and they implement the *SocketAdapter* interface. The adapter interface can also be an **abstract class**.

Here is a test program to consume our adapter implementation.

**package** com.journaldev.design.test;

**import com.journaldev.design.adapter.SocketAdapter**;

**import com.journaldev.design.adapter.SocketClassAdapterImpl**;

**import com.journaldev.design.adapter.SocketObjectAdapterImpl**;

**import com.journaldev.design.adapter.Volt**;

**public class AdapterPatternTest** {

**public static void main**(String[] args) {

testClassAdapter();

testObjectAdapter();

}

**private static void testObjectAdapter**() {

SocketAdapter sockAdapter = **new** SocketObjectAdapterImpl();

Volt v3 = getVolt(sockAdapter,**3**);

Volt v12 = getVolt(sockAdapter,**12**);

Volt v120 = getVolt(sockAdapter,**120**);

System.out.println("v3 volts using Object Adapter="+v3.getVolts());

System.out.println("v12 volts using Object Adapter="+v12.getVolts());

System.out.println("v120 volts using Object Adapter="+v120.getVolts());

}

**private static void testClassAdapter**() {

SocketAdapter sockAdapter = **new** SocketClassAdapterImpl();

Volt v3 = getVolt(sockAdapter,**3**);

Volt v12 = getVolt(sockAdapter,**12**);

Volt v120 = getVolt(sockAdapter,**120**);

System.out.println("v3 volts using Class

Adapter="+v3.getVolts());

System.out.println("v12 volts using Class Adapter="+v12.getVolts());

System.out.println("v120 volts using Class Adapter="+v120.getVolts());

}

**private static** Volt **getVolt**(SocketAdapter sockAdapter, **int** i) {

**switch** (i){

**case 3**: **return** sockAdapter.get3Volt();

**case 12**: **return** sockAdapter.get12Volt();

**case 120**: **return** sockAdapter.get120Volt();

**default**: **return** sockAdapter.get120Volt();

}

}

}

When we run above test program, we get following output.

v3 volts using Class Adapter=**3**

v12 volts using Class Adapter=**12**

v120 volts using Class Adapter=**120**

v3 volts using Object Adapter=**3**

v12 volts using Object Adapter=**12**

v120 volts using Object Adapter=**120**

#### Adapter Pattern Class Diagram

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#### Adapter Pattern Example in JDK

􀁸 java.util.Arrays#asList()

􀁸 java.io.InputStreamReader(InputStream) (returns a Reader)

􀁸 java.io.OutputStreamWriter(OutputStream) (returns a Writer)

### Composite Pattern

**Composite pattern** is one of the **Structural design pattern** and is used when we have to represent a part-whole hierarchy. When we need to reate a structure in a way that the objects in the structure has to be treated the same way, we can apply composite design pattern.

Let’s understand it with a real life example – A diagram is a structure that consists of Objects such as Circle, Lines, Triangle etc and when we fill the drawing with color (say Red), the same color also gets applied to the objects in the drawing. Here drawing is made up of different parts and they all have same operations. Composite Pattern consists of following objects.

#### Components

1. **Base Component** – Base component is the interface for all objects in the composition, client program uses base component to work with the objects in the composition. It can be an interface or an **abstract class** with some methods common to all the objects.

2. **Leaf** – Defines the behaviour for the elements in the composition. It is the building block for the composition and implements base component. It doesn’t have references to other Components.

3. **Composite** – It consists of leaf elements and implements the operations in base component.

Here I am applying composite design pattern for the drawing scenario.

#### Base Component

Base component defines the common methods for leaf and composites, we

can create a *class Shape* with a method *draw(String fillColor)* to draw the

shape with given color.

**package** com.journaldev.design.composite;

**public interface Shape** {

**public void draw**(String fillColor);

}

#### Leaf Objects

Leaf implements base component and these are the building block for the composite. We can create multiple leaf objects such as Triangle, Circle etc.

**package** com.journaldev.design.composite;

**public class Triangle implements** Shape {

**@Override**

**public void draw**(String fillColor) {

System.out.println("Drawing Triangle with color "+fillColor);

}

}

**package** com.journaldev.design.composite;

**public class Circle implements** Shape {

**@Override**

**public void draw**(String fillColor) {

System.out.println("Drawing Circle with color "+fillColor);

}

}

#### Composite

A composite object contains group of leaf objects and we should provide

some helper methods to add or delete leafs from the group. We can also

provide a method to remove all the elements from the group.

**package** com.journaldev.design.composite;

**import java.util.ArrayList**;

**import java.util.List**;

**public class Drawing implements** Shape{

//collection of Shapes

**private** List<Shape> shapes = **new** ArrayList<Shape>();

**@Override**

**public void draw**(String fillColor) {

**for**(Shape sh : shapes){

sh.draw(fillColor);

}

}

//adding shape to drawing

**public void add**(Shape s){

**this**.shapes.add(s);

}

//removing shape from drawing

**public void remove**(Shape s){

shapes.remove(s);

}

//removing all the shapes

**public void clear**(){

System.out.println("Clearing all the shapes from drawing");

**this**.shapes.clear();

}

}

Notice that composite also implements component and behaves similar to

leaf except that it can contain group of leaf elements.

Our composite pattern implementation is ready and we can test it with a

client program.

**package** com.journaldev.design.test;

**import com.journaldev.design.composite.Circle**;

**import com.journaldev.design.composite.Drawing**;

**import com.journaldev.design.composite.Shape**;

**import com.journaldev.design.composite.Triangle**;

**public class TestCompositePattern** {

**public static void main**(String[] args) {

Shape tri = **new** Triangle();

Shape tri1 = **new** Triangle();

Shape cir = **new** Circle();

Drawing drawing = **new** Drawing();

drawing.add(tri1);

drawing.add(tri1);

drawing.add(cir);

drawing.draw("Red");

drawing.clear();

drawing.add(tri);

drawing.add(cir);

drawing.draw("Green");

}

}

Output of the above program is:

Drawing Triangle with color Red

Drawing Triangle with color Red

Drawing Circle with color Red

Clearing all the shapes from drawing

Drawing Triangle with color Green

Drawing Circle with color Green

#### Important Points about Composite Pattern

􀁸 Composite pattern should be applied only when the group of objects

should behave as the single object.

􀁸 Composite pattern can be used to create a tree like structure.

*java.awt.Container#add(Component)* is a great example of Composite

pattern in java and used a lot in Swing.

### Proxy Pattern

**Proxy Design pattern** is one of the **Structural design pattern** and in my opinion one of the simplest pattern to understand. Proxy pattern intent according to GoF is:

The definition itself is very clear and proxy pattern is used when we want to provide controlled access of a functionality. Let’s say we have a class that can run some command on the system. Now if we are using it, its fine but if we want to give this program to a client application, it can have severe issues because client program can issue command to delete some system files or change some settings that you don’t want. Here a proxy class can be created to provide controlled access of the program.

“Provide a surrogate or placeholder for another object to control access to it”

#### Main Class

Since we code Java in terms of interfaces, here is our interface and its

implementation class.

**package** com.journaldev.design.proxy;

**public interface CommandExecutor** {

**public void runCommand**(String cmd) **throws** Exception;

}

**package** com.journaldev.design.proxy;

**import java.io.IOException**;

**public class CommandExecutorImpl implements** CommandExecutor {

**@Override**

**public void runCommand**(String cmd) **throws** IOException {

//some heavy implementation

Runtime.getRuntime().exec(cmd);

System.out.println("'" + cmd + "' command executed.");

}

}

#### Proxy Class

Now we want to provide only admin users to have full access of above class, if the user is not admin then only limited commands will be allowed. Here is our very simple proxy class implementation.

**package** com.journaldev.design.proxy;

**public class CommandExecutorProxy implements** CommandExecutor {

**private boolean** isAdmin;

**private** CommandExecutor executor;

**public CommandExecutorProxy**(String user, String pwd){

**if**("Pankaj".equals(user) && "J@urnalD$v".equals(pwd))

isAdmin=**true**;

executor = **new** CommandExecutorImpl();

}

**@Override**

**public void runCommand**(String cmd) **throws** Exception {

**if**(isAdmin){

executor.runCommand(cmd);

}**else**{

**if**(cmd.trim().startsWith("rm")){

**throw new Exception**("rm command is not allowed for nonadmin users.");

}**else**{

executor.runCommand(cmd);

}

}

}

}

#### Proxy Pattern Client Test Program

**package** com.journaldev.design.test;

**import com.journaldev.design.proxy.CommandExecutor**;

**import com.journaldev.design.proxy.CommandExecutorProxy**;

**public class ProxyPatternTest** {

**public static void main**(String[] args){

CommandExecutor executor = **new** CommandExecutorProxy("Pankaj","wrong\_pwd");

**try** {

executor.runCommand("ls -ltr");

executor.runCommand(" rm -rf abc.pdf");

} **catch** (Exception e) {

System.out.println("Exception Message::"+e.getMessage());

}

}

}

Output of above test program is:

'ls -ltr' command executed.

Exception **Message:**:rm command is not allowed **for** non-admin users.

Proxy pattern common uses are to control access or to provide a wrapper

implementation for better performance. Java RMI whole package uses proxy pattern.

### Flyweight Pattern

According to GoF, **flyweight design pattern** intent is:

Flyweight design pattern is a **Structural design pattern** like Facade pattern, Adapter Pattern and Decorator pattern. Flyweight design pattern is used when we need to create a lot of Objects of a class. Since every object

consumes memory space that can be crucial for low memory devices, such

as mobile devices or embedded systems, flyweight design pattern can be

applied to reduce the load on memory by sharing objects. Before we apply flyweight design pattern, we need to consider following factors:

􀁸 The number of Objects to be created by application should be huge.

􀁸 The object creation is heavy on memory and it can be time consuming

too.

􀁸 The object properties can be divided into intrinsic and extrinsic properties, extrinsic properties of an Object should be defined by the client program.

To apply flyweight pattern, we need to divide Object property into **intrinsic** and **extrinsic** properties. Intrinsic properties make the Object unique whereas extrinsic properties are set by client code and used to perform different operations. For example, an Object Circle can have extrinsic properties such as color and width.

For applying flyweight pattern, we need to create a **Flyweight factory** that returns the shared objects. For our example, let’s say we need to create a drawing with lines and Ovals. So we will have an interface Shape and its concrete implementations as *Line* and *Oval*. Oval class will have intrinsic property to determine whether to fill the Oval with given color or not whereas Line will not have any intrinsic property.

“Use sharing to support large numbers of fine-grained objects efficiently”

#### Flyweight Interface and Concrete Classes

**/\*\***

**\***

**\*/**

**package com.game.structural;**

**import java.util.HashMap;**

**interface ShapeFlyweight {**

**void draw();**

**}**

**class CircleFlyweight implements ShapeFlyweight {**

**private int x;**

**private int y;**

**private String color;**

**private int radius;**

**CircleFlyweight(String color) {**

**setColor(color);**

**System.out.println("Created new circle with Color:" + getColor());**

**}**

**@Override**

**public void draw() {**

**System.out.println(**

**"Drawn circle with x:" + getX() + " y:" + y + " Radius:" + getRadius() + " color:" + getColor());**

**}**

**public int getX() {**

**return x;**

**}**

**public void setX(int x) {**

**this.x = x;**

**}**

**public int getY() {**

**return y;**

**}**

**public void setY(int y) {**

**this.y = y;**

**}**

**public String getColor() {**

**return color;**

**}**

**public void setColor(String color) {**

**this.color = color;**

**}**

**public int getRadius() {**

**return radius;**

**}**

**public void setRadius(int radius) {**

**this.radius = radius;**

**}**

**}**

**class FactoryCircle {**

**private static HashMap circleMap = new HashMap();**

**public static CircleFlyweight getCircle(String color) {**

**CircleFlyweight circle = (CircleFlyweight) circleMap.get(color);**

**if (circle == null) {**

**circle = new CircleFlyweight(color);**

**circleMap.put(color, circle);**

**}**

**return circle;**

**}**

**}**

**/\*\***

**\* @author bittu**

**\***

**\*/**

**public class Flyweight {**

**private static String []colors = {"Red","Green","Blue","Black","White"};**

**/\*\***

**\***

**\*/**

**public Flyweight() {**

**// TODO Auto-generated constructor stub**

**}**

**/\*\***

**\* @param args**

**\*/**

**public static void main(String[] args) {**

**for(int i = 0; i<20;i++) {**

**CircleFlyweight circle = FactoryCircle.getCircle(getRandomColor());**

**circle.setX(getRandomX());**

**circle.setY(getRandomY());**

**circle.setRadius(100);**

**circle.draw();**

**}**

**}**

**private static int getRandomX() {**

**// TODO Auto-generated method stub**

**return (int)Math.random()\*100;**

**}**

**private static int getRandomY() {**

**// TODO Auto-generated method stub**

**return (int)Math.random()\*100;**

**}**

**private static String getRandomColor() {**

**return colors[(int) (Math.random()\*colors.length)];**

**}**

**}**

Notice that I have intentionally introduced delay in creating the Object of

concrete classes to make the point that flyweight pattern can be used for

Objects that takes a lot of time while instantiated.

#### Flyweight Pattern Example in JDK

All the wrapper classes valueOf() method uses cached objects showing use

of Flyweight design pattern. The best example is Java String class String

Pool implementation.

#### Important Points

􀁸 In our example, the client code is not forced to create object using

Flyweight factory but we can force that to make sure client code uses

flyweight pattern implementation but its a complete design decision

for particular application.

􀁸 Flyweight pattern introduces complexity and if number of shared

objects are huge then there is a trade of between memory and time, so

we need to use it judiciously based on our requirements.

􀁸 Flyweight pattern implementation is not useful when the number of

intrinsic properties of Object is huge, making implementation of

Factory class complex.

### Facade Pattern

**Facade Pattern** is one of the **Structural design patterns** (such as Adapter pattern and Decorator pattern) and used to help client applications to easily interact with the system. According to GoF Facade design pattern is:

Provide a unified interface to a set of interfaces in a subsystem. Facade

Pattern defines a higher-level interface that makes the subsystem easier to

use.

Suppose we have an application with set of interfaces to use MySql/Oracle

database and to generate different types of reports, such as HTML report,

PDF report etc. So we will have different set of interfaces to work with

different types of database. Now a client application can use these interfaces

to get the required database connection and generate reports. But when the

complexity increases or the interface behavior names are confusing, client

application will find it difficult to manage it. So we can apply Facade pattern

here and provide a wrapper interface on top of the existing interface to help

client application.

#### Set of Interfaces

We can have two helper interfaces, namely MySqlHelper and OracleHelper.

**package** com.journaldev.design.facade;

**import java.sql.Connection**;

**public class MySqlHelper** {

**public static** Connection **getMySqlDBConnection**(){

//get MySql DB connection using connection parameters

**return null**;

}

**public void generateMySqlPDFReport**(String tableName, Connection con){

//get data from table and generate pdf report

}

**public void generateMySqlHTMLReport**(String tableName, Connection con){

//get data from table and generate pdf report

}

}

**package** com.journaldev.design.facade;

**import java.sql.Connection**;

**public class OracleHelper** {

**public static** Connection **getOracleDBConnection**(){

//get MySql DB connection using connection parameters

**return null**;

}

**public void generateOraclePDFReport**(String tableName, Connection con){

//get data from table and generate pdf report

}

**public void generateOracleHTMLReport**(String tableName, Connection con){

//get data from table and generate pdf report

}

}

#### Facade Interface

We can create a Facade interface like below. Notice the use of Java Enum

for type safety.

**package** com.journaldev.design.facade;

**import java.sql.Connection**;

**public class HelperFacade** {

**public static void generateReport**(DBTypes dbType, ReportTypes reportType, String tableName){

Connection con = **null**;

**switch** (dbType){

**case MYSQL:**

con = MySqlHelper.getMySqlDBConnection();

MySqlHelper mySqlHelper = **new** MySqlHelper();

**switch**(reportType){

**case HTML:**

mySqlHelper.generateMySqlHTMLReport(tableName, con);

**break**;

**case PDF:**

mySqlHelper.generateMySqlPDFReport(tableName, con);

**break**;

}

**break**;

**case ORACLE:**

con = OracleHelper.getOracleDBConnection();

OracleHelper oracleHelper = **new** OracleHelper();

**switch**(reportType){

**case HTML:**

oracleHelper.generateOracleHTMLReport(tableName, con);

**break**;

**case PDF:**

oracleHelper.generateOraclePDFReport(tableName, con);

**break**;

}

**break**;

}

}

**public static enum** DBTypes{

MYSQL,ORACLE;

}

**public static enum** ReportTypes{

HTML,PDF;

}

}

#### Client Program

Now let’s see client code without using Facade and using Facade interface.

**package** com.journaldev.design.test;

**import java.sql.Connection**;

**import com.journaldev.design.facade.HelperFacade**;

**import com.journaldev.design.facade.MySqlHelper**;

**import com.journaldev.design.facade.OracleHelper**;

**public class FacadePatternTest** {

**public static void main**(String[] args) {

String tableName="Employee";

//generating MySql HTML report and Oracle PDF report without using Facade

Connection con = MySqlHelper.getMySqlDBConnection();

MySqlHelper mySqlHelper = **new** MySqlHelper();

mySqlHelper.generateMySqlHTMLReport(tableName, con);

Connection con1 = OracleHelper.getOracleDBConnection();

OracleHelper oracleHelper = **new** OracleHelper();

oracleHelper.generateOraclePDFReport(tableName, con1);

//generating MySql HTML report and Oracle PDF report using Facade

HelperFacade.generateReport(HelperFacade.DBTypes.MYSQL,

HelperFacade.ReportTypes.HTML, tableName);

HelperFacade.generateReport(HelperFacade.DBTypes.ORACLE,

HelperFacade.ReportTypes.PDF, tableName);

}

}

As you can see that using Facade interface is a lot easier and cleaner way

and avoid having a lot of logic at client side. JDBC Driver Manager Class to

get the database connection is a wonderful example of facade pattern.

#### Important Points

􀁸 Facade pattern is more like a helper for client applications, it doesn’t

hide subsystem interfaces from the client. Whether to use Facade or

not is completely dependent on client code.

􀁸 Facade pattern can be applied at any point of development, usually

when the number of interfaces grow and system gets complex.

􀁸 Subsystem interfaces are not aware of Facade and they shouldn’t have

any reference of the Facade interface.

􀁸 Facade pattern should be applied for similar kind of interfaces, its

purpose is to provide a single interface rather than multiple interfaces

that does the similar kind of jobs.

􀁸 We can use Factory pattern with Facade to provide better interface to

client systems.

### Bridge Pattern

When we have interface hierarchies in both interfaces as well as implementations, then **builder design pattern** is used to decouple the interfaces from implementation and hiding the implementation details from

the client programs. Like Adapter pattern, its one of the **Structural design**

**pattern**.

According to GoF bridge design pattern is:

The implementation of bridge design pattern follows the notion to prefer

Composition over inheritance.

If we look into this design pattern with example, it will be easy to

understand. Let’s say we have an interface hierarchy in both interfaces and

implementations like below image.

“Decouple an abstraction from its implementation so that the two can vary independently”

Now we will use bridge design pattern to decouple the interfaces from

implementation and the UML diagram for the classes and interfaces after

applying bridge pattern will look like below image.

Notice the bridge between *Shape* and *Color* interfaces and use of

composition in implementing the bridge pattern.

#### Implementation

Here is the java code for Shape and Color interfaces.

**package** com.journaldev.design.bridge;

**public interface Color** {

**public void applyColor**();

}

**package** com.journaldev.design.bridge;

**public abstract class Shape** {

//Composition - implementor

**protected** Color color;

//constructor with implementor as input argument

**public Shape**(Color c){

**this**.color=c;

}

**abstract public void applyColor**();

}

}

We have Triangle and Pentagon implementation classes as below.

package com.journaldev.design.bridge;

**public class Triangle extends** Shape{

**public Triangle**(Color c) {

**super**(c);

}

**@Override**

**public void applyColor**() {

System.out.print("Triangle filled with color ");

color.applyColor();

}

}

**package** com.journaldev.design.bridge;

**public class Pentagon extends** Shape{

**public Pentagon**(Color c) {

**super**(c);

}

**@Override**

**public void applyColor**() {

System.out.print("Pentagon filled with color ");

color.applyColor();

}

}

Here are the implementation classes for RedColor and GreenColor.

package com.journaldev.design.bridge;

public class RedColor implements Color{

public void applyColor(){

System.out.println("red.");

}

}

**package** com.journaldev.design.bridge;

**public class GreenColor implements** Color{

**public void applyColor**(){

System.out.println("green.");

}

}

Let’s test our bridge pattern implementation with a test program.

**package** com.journaldev.design.test;

**import com.journaldev.design.bridge.GreenColor**;

**import com.journaldev.design.bridge.Pentagon**;

**import com.journaldev.design.bridge.RedColor**;

**import com.journaldev.design.bridge.Shape**;

**import com.journaldev.design.bridge.Triangle**;

**public class BridgePatternTest** {

**public static void main**(String[] args) {

Shape tri = **new** Triangle(**new** RedColor());

tri.applyColor();

Shape pent = **new** Pentagon(**new** GreenColor());

pent.applyColor();

}

}

Output of above class is:

Triangle filled with color red.

Pentagon filled with color green.

#### Importance

Bridge design pattern can be used when both abstraction and implementation can have different hierarchies independently and we want to hide the implementation from the client application.

### Decorator Pattern

**Decorator design pattern** is used to modify the functionality of an object at runtime. At the same time other instances of the same class will not be

affected by this, so individual object gets the modified behavior. Decorator

design pattern is one of the structural design pattern (such as Adapter

Pattern, Bridge Pattern, Composite Pattern) and uses abstract classes or

interface with composition to implement. We use inheritance or composition to extend the behavior of an object but this is done at compile time and its applicable to all the instances of the class. We can’t add any new functionality of remove any existing behavior at runtime – this is when Decorator pattern comes into picture. Suppose we want to implement different kinds of cars – we can create interface Car to define the assemble method and then we can have a Basic car, further more we can extend it to Sports car and Luxury Car. The implementation hierarchy will look like below image.

But if we want to get a car at runtime that has both the features of sports car and luxury car, then the implementation gets complex and if further more we want to specify which features should be added first, it gets even more complex. Now image if we have ten different kind of cars, the

implementation logic using inheritance and composition will be impossible

to manage. To solve this kind of programming situation, we apply decorator

pattern.

We need to have following types to implement decorator design pattern.

#### Component Interface

The interface or **abstract class** defining the methods that will be

implemented. In our case *Car* will be the component interface.

**package** com.journaldev.design.decorator;

**public interface Car** {

**public void assemble**();

}

#### Component Implementation

The basic implementation of the component interface. We can have

BasicCar class as our component implementation.

**package** com.journaldev.design.decorator;

**public class BasicCar implements** Car {

**@Override**

**public void assemble**() {

System.out.print("Basic Car.");

}

}

#### Decorator

Decorator class implements the component interface and it has a HAS-A

relationship with the component interface. The component variable should

be accessible to the child decorator classes, so we will make this variable

protected.

**package** com.journaldev.design.decorator;

**public class CarDecorator implements** Car {

**protected** Car car;

**public CarDecorator**(Car c){

**this**.car=c;

}

**@Override**

**public void assemble**() {

**this**.car.assemble();

}

}

#### Concrete Decorators

Extending the base decorator functionality and modifying the component

behavior accordingly. We can have concrete decorator classes as LuxuryCar

and SportsCar.

**package** com.journaldev.design.decorator;

**public class SportsCar extends** CarDecorator {

**public SportsCar**(Car c) {

**super**(c);

}

**@Override**

**public void assemble**(){

car.assemble();

System.out.print(" Adding features of Sports Car.");

}

}

**package** com.journaldev.design.decorator;

**public class LuxuryCar extends** CarDecorator {

**public LuxuryCar**(Car c) {

**super**(c);

}

**@Override**

**public void assemble**(){

car.assemble();

System.out.print(" Adding features of Luxury Car.");

}

}

#### Decorator Pattern Class Diagram



#### Decorator Pattern Client Program

**package** com.journaldev.design.test;

**import com.journaldev.design.decorator.BasicCar**;

**import com.journaldev.design.decorator.Car**;

**import com.journaldev.design.decorator.LuxuryCar**;

**import com.journaldev.design.decorator.SportsCar**;

**public class DecoratorPatternTest** {

**public static void main**(String[] args) {

Car sportsCar = **new** SportsCar(**new** BasicCar());

sportsCar.assemble();

System.out.println("\n\*\*\*\*\*");

Car sportsLuxuryCar = **new** SportsCar(**new** LuxuryCar(**new** BasicCar()));

sportsLuxuryCar.assemble();

}

}

Notice that client program can create different kinds of Object at runtime

and they can specify the order of execution too.

Output of above test program is:

Basic Car. Adding features of Sports Car.

\*\*\*\*\*

Basic Car. Adding features of Luxury Car. Adding features of Sports Car.

#### Important Points

􀁸 Decorator pattern is helpful in providing runtime modification

abilities and hence more flexible. It’s easy to maintain and extend

when the number of choices are more.

􀁸 The disadvantage of decorator pattern is that it uses a lot of similar

kind of objects (decorators).

􀁸 Decorator pattern is used a lot in Java IO classes, such as FileReader,

BufferedReader etc.

## Behavioral Design Patterns

Behavioral patterns provide solution for the better interaction between

objects and how to provide lose coupling and flexibility to extend easily.

### Template Method Pattern

**Template Method** is a **behavioral design pattern** and it’s used to create a method stub and deferring some of the steps of implementation to the subclasses. **Template method** defines the steps to execute an algorithm and it can provide default implementation that might be common for all or some of the subclasses. Let’s understand this pattern with an example, suppose we want to provide an algorithm to build a house. The steps need to be performed to build a house are – building foundation, building pillars, building walls and windows. The important point is that we can’t change the order of execution because we can’t build windows before building the foundation. So in this case we can create a template method that will use different methods to build the house.

Now building the foundation for a house is same for all type of houses,

whether it’s a wooden house or a glass house. So we can provide base

implementation for this, if subclasses want to override this method, they can but mostly it’s common for all the types of houses.

To make sure that subclasses don’t override the template method, we should make it final.

#### Template Method Abstract Class

Since we want some of the methods to be implemented by subclasses, we

have to make our base class as abstract class.

**package** com.journaldev.design.template;

**public abstract class HouseTemplate** {

//template method, final so subclasses can't override

**public final void buildHouse**(){

buildFoundation();

buildPillars();

buildWalls();

buildWindows();

System.out.println("House is built.");

}

//default implementation

**private void buildWindows**() {

System.out.println("Building Glass Windows");

}

//methods to be implemented by subclasses

**public abstract void buildWalls**();

**public abstract void buildPillars**();

**private void buildFoundation**() {

System.out.println("Building foundation with cement,iron rods and sand");

}

}

*buildHouse()* is the template method and defines the order of execution for

performing several steps.

#### Template Method Concrete Classes

We can have different type of houses, such as Wooden House and Glass

House.

**package** com.journaldev.design.template;

**public class WoodenHouse extends** HouseTemplate {

**@Override**

**public void buildWalls**() {

System.out.println("Building Wooden Walls");

}

**@Override**

**public void buildPillars**() {

System.out.println("Building Pillars with Wood coating");

}

}

We could have overridden other methods also, but for simplicity I am not

doing that.

**package** com.journaldev.design.template;

**public class GlassHouse extends** HouseTemplate {

**@Override**

**public void buildWalls**() {

System.out.println("Building Glass Walls");

}

**@Override**

**public void buildPillars**() {

System.out.println("Building Pillars with glass coating");

}

}

#### Template Method Pattern Client

Let’s test our template method pattern example with a test program.

**package** com.journaldev.design.template;

**public class HousingClient** {

**public static void main**(String[] args) {

HouseTemplate houseType = **new** WoodenHouse();

//using template method

houseType.buildHouse();

System.out.println("\*\*\*\*\*\*\*\*\*\*\*\*");

houseType = **new** GlassHouse();

houseType.buildHouse();

}

}

Notice that client is invoking the template method of base class and

depending of implementation of different steps, it’s using some of the

methods from base class and some of them from subclass.

Output of the above program is:

Building foundation with cement,iron rods and sand

Building Pillars with Wood coating

Building Wooden Walls

Building Glass Windows

House is built.

\*\*\*\*\*\*\*\*\*\*\*\*

Building foundation with cement,iron rods and sand

Building Pillars with glass coating

Building Glass Walls

Building Glass Windows

House is built.

#### Template Method Class Diagram

****

#### Template Method Pattern in JDK

􀁸 All non-abstract methods of java.io.InputStream,

java.io.OutputStream, java.io.Reader and java.io.Writer.

􀁸 All non-abstract methods of java.util.AbstractList,

java.util.AbstractSet and java.util.AbstractMap.

#### Important Points

􀁸 Template method should consists of certain steps whose order is fixed

and for some of the methods, implementation differs from base class

to subclass. Template method should be final.

􀁸 Most of the times, subclasses calls methods from super class but in

template pattern, superclass template method calls methods from

subclasses, this is known as Hollywood Principle – “don’t call us,

we’ll call you”.

􀁸 Methods in base class with default implementation are referred as

**Hooks** and they are intended to be overridden by subclasses, if you

want some of the methods to be not overridden, you can make them

final, for example in our case we can make buildFoundation() method

final because if we don’t want subclasses to override it.

### Mediator Pattern

**Mediator Pattern** is one of the **behavioral design pattern**, so it deals with

the behaviors of objects. Mediator design pattern is used to provide a

centralized communication medium between different objects in a system.

According to GoF, mediator pattern intent is: Mediator design pattern is very helpful in an enterprise application where multiple objects are interacting with each other. If the objects interact with each other directly, the system components are tightly-coupled with each other that makes maintainability cost higher and not flexible to extend easily. Mediator pattern focuses on provide a mediator between objects for communication and help in implementing lose-coupling between objects.Air traffic controller is a great example of mediator pattern where the airport control room works as a mediator for communication between different flights. Mediator works as a router between objects and it can have it’s own logic to provide way of communication.

The system objects that communicate each other are called Colleagues. Usually we have an interface or abstract class that provides the contract for

communication and then we have concrete implementation of mediators.

For our example, we will try to implement a chat application where users can do group chat. Every user will be identified by its name and they can send and receive messages. The message sent by any user should be received by all the other users in the group.

**“Allows loose coupling by encapsulating the way disparate sets of objects interact and communicate with each other. Allows for the actions of each object set to vary independently of one another”**

#### Mediator Interface

First of all we will create Mediator interface that will define the contract for

concrete mediators.

**package** com.journaldev.design.mediator;

**public interface ChatMediator** {

**public void sendMessage**(String msg, User user);

**void addUser**(User user);

}

#### Colleague Interface

Users can send and receive messages, so we can have User interface or

abstract class. I am creating User as abstract class like below.

**package** com.journaldev.design.mediator;

**public abstract class User** {

**protected** ChatMediator mediator;

**protected** String name;

**public User**(ChatMediator med, String name){

**this**.mediator=med;

**this**.name=name;

}

**public abstract void send**(String msg);

**public abstract void receive**(String msg);

}

Notice that User has a reference to the mediator object, it’s required for the

communication between different users.

#### Concrete Mediator

Now we will create concrete mediator class, it will have a list of users in the

group and provide logic for the communication between the users.

**package** com.journaldev.design.mediator;

**import java.util.ArrayList**;

**import java.util.List**;

**public class ChatMediatorImpl implements** ChatMediator {

**private** List<User> users;

**public ChatMediatorImpl**(){

**this**.users=**new** ArrayList<>();

}

**@Override**

**public void addUser**(User user){

**this**.users.add(user);

}

**@Override**

**public void sendMessage**(String msg, User user) {

**for**(User u : **this**.users){

//message should not be received by the user sending it

**if**(u != user){

u.receive(msg);

}

}

}

}

#### Concrete Colleague

Now we can create concrete User classes to be used by client system.

**package** com.journaldev.design.mediator;

**public class UserImpl extends** User {

**public UserImpl**(ChatMediator med, String name) {

**super**(med, name);

}

**@Override**

**public void send**(String msg){

System.out.println(**this**.name+": Sending Message="+msg);

mediator.sendMessage(msg, **this**);

}

**@Override**

**public void receive**(String msg) {

System.out.println(**this**.name+": Received Message:"+msg);

}

}

Notice that send() method is using mediator to send the message to the users and it has no idea how it will be handled by the mediator.

#### Mediator Pattern Client

Let’s test this our chat application with a simple program where we will

create mediator and add users to the group and one of the user will send a

message.

**package** com.journaldev.design.mediator;

**public class ChatClient** {

**public static void main**(String[] args) {

ChatMediator mediator = **new** ChatMediatorImpl();

User user1 = **new** UserImpl(mediator, "Pankaj");

User user2 = **new** UserImpl(mediator, "Lisa");

User user3 = **new** UserImpl(mediator, "Saurabh");

User user4 = **new** UserImpl(mediator, "David");

mediator.addUser(user1);

mediator.addUser(user2);

mediator.addUser(user3);

mediator.addUser(user4);

user1.send("Hi All");

}

}

Notice that client program is very simple and it has no idea how the message is getting handled and if mediator is getting user or not.

Output of the above program is:

Pankaj: Sending Message=Hi All

Lisa: Received Message:Hi All

Saurabh: Received Message:Hi All

David: Received Message:Hi All

#### Mediator Pattern Class Diagram



#### Mediator Pattern in JDK

java.util.Timer class scheduleXXX() methods

Java Concurrency Executor execute() method.

java.lang.reflect.Method invoke() method.

#### Important Points

􀁸 Mediator pattern is useful when the communication logic between

objects is complex, we can have a central point of communication that

takes care of communication logic.

􀁸 Java Message Service (JMS) uses Mediator pattern along with

**Observer pattern** to allow applications to subscribe and publish data

to other applications.

􀁸 We should not use mediator pattern just to achieve lose-coupling because if the number of mediators will grow, then it will become

hard to maintain them.

# Data Structures

Note: Considering the importance for coding by own, the links added are to the websites for the appropriate solution to the problem.

[Recommended: Please solve it on “**PRACTICE** ” first, before moving on to the solution.](https://practice.geeksforgeeks.org/problems/reverse-the-string/0)**Do it on Write Board and then on IDE.**

**Notes:**

* 2 Pointers solution is applicable mostly for sorted arrays
* Inorder to divide the problem(array) into subproblems – do take gcd()

## Arrays

### [Find a pair in an array of size 'n', whose sum is X](https://www.geeksforgeeks.org/given-an-array-a-and-a-number-x-check-for-pair-in-a-with-sum-as-x/)

Write a program that, given an array A[] of n numbers and another number x, determines whether or not there exist two elements in S whose sum is exactly x.

**Examples:**

**Input:** arr[] = {0, -1, 2, -3, 1}

sum = -2

**Output:** -3, 1

If we calculate the sum of the output,

1 + (-3) = -2

**Input:** arr[] = {1, -2, 1, 0, 5}

sum = 0

**Output:** -1

No valid pair exists.

### [Find a majority element in an array of size 'n'](https://www.geeksforgeeks.org/majority-element/)

Write a function which takes an array and prints the majority element (if it exists), otherwise prints “No Majority Element”. A ***majority element*** in an array A[] of size n is an element that appears more than n/2 times (and hence there is at most one such element).

**Examples :**

**Input :** {3, 3, 4, 2, 4, 4, 2, 4, 4}

**Output :** 4

**Explanation:** The frequency of 4 is 5 which is greater

than the half of the size of the array size.

**Input :** {3, 3, 4, 2, 4, 4, 2, 4}

**Output :** No Majority Element

**Explanation:** There is no element whose frequency is

greater than the half of the size of the array size.

### [Find the number occuring odd number of times in a given array of size 'n'](https://www.geeksforgeeks.org/find-the-number-occurring-odd-number-of-times/)

Given an array of positive integers. All numbers occur even number of times except one number which occurs odd number of times. Find the number in O(n) time & constant space.  
**Examples :**

**Input :** arr = {1, 2, 3, 2, 3, 1, 3}

**Output :** 3

**Input :** arr = {5, 7, 2, 7, 5, 2, 5}

**Output :** 5

### [Algorithm to reverse an array](https://www.geeksforgeeks.org/write-a-program-to-reverse-an-array-or-string/)

Given an array (or string), the task is to reverse the array/string.  
**Examples :** 

Input : arr[] = {1, 2, 3}

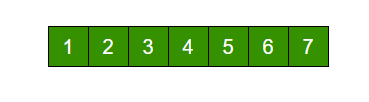
Output : arr[] = {3, 2, 1}

Input : arr[] = {4, 5, 1, 2}

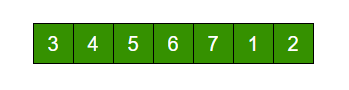
Output : arr[] = {2, 1, 5, 4}

### [Algorithm to rotate array of size 'n' by 'd' elements](https://www.geeksforgeeks.org/array-rotation/)

Write a function rotate(ar[], d, n) that rotates arr[] of size n by d elements. 



Rotation of the above array by 2 will make array



### [Algorithm to segregate 0's and 1's in an array](https://www.geeksforgeeks.org/segregate-0s-and-1s-in-an-array-by-traversing-array-once/)

You are given an array of 0s and 1s in random order. Segregate 0s on left side and 1s on right side of the array. Traverse array only once. 

Input array = [0, 1, 0, 1, 0, 0, 1, 1, 1, 0]

Output array = [0, 0, 0, 0, 0, 1, 1, 1, 1, 1]

### [Find the maximum difference between two elements such that larger element appears after the smaller element](https://www.geeksforgeeks.org/maximum-difference-between-two-elements/)

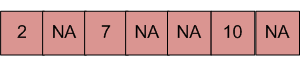
You are given an array of 0s and 1s in random order. Segregate 0s on left side and 1s on right side of the array. Traverse array only once. 

Input array = [0, 1, 0, 1, 0, 0, 1, 1, 1, 0]

Output array = [0, 0, 0, 0, 0, 1, 1, 1, 1, 1]

### [Algorithm to merge an array of size 'n' into another array of size 'm+n'.](https://www.geeksforgeeks.org/merge-one-array-of-size-n-into-another-one-of-size-mn/)

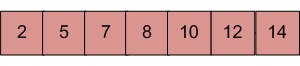
There are two sorted arrays. First one is of size m+n containing only m elements. Another one is of size n and contains n elements. Merge these two arrays into the first array of size m+n such that the output is sorted.   
Input: array with m+n elements (mPlusN[]). 



NA => Value is not filled/available in array mPlusN[]. There should be n such array blocks.  
Input: array with n elements (N[]). 

MergeN

Output: N[] merged into mPlusN[] (Modified mPlusN[]) 



### [Algorithm to find two repeating numbers in a given array](https://www.geeksforgeeks.org/find-the-two-repeating-elements-in-a-given-array/)

You are given an array of n+2 elements. All elements of the array are in range 1 to n. And all elements occur once except two numbers which occur twice. Find the two repeating numbers.

**Example:**

***Input:*** *arr = [4, 2, 4, 5, 2, 3, 1]   
n = 5****Output:*** *4 2****Explanation:*** *The above array has n + 2 = 7 elements with all elements occurring once except 2 and 4 which occur twice. So the output should be 4 2.*

### [Algorithm to find duplicate elements in O(n) time and O(1) extra space, for a given array of size 'n'](https://www.geeksforgeeks.org/find-duplicates-in-on-time-and-constant-extra-space/)

Given an array of n elements that contains elements from 0 to n-1, with any of these numbers appearing any number of times. Find these repeating numbers in O(n) and using only constant memory space.

**Example:**

**Input :** n = 7 and array[] = {1, 2, 3, 6, 3, 6, 1}

**Output:** 1, 3, 6

**Explanation:** The numbers 1 , 3 and 6 appears more

than once in the array.

**Input :** n = 5 and array[] = {1, 2, 3, 4 ,3}

**Output:** 3

**Explanation:** The number 3 appears more than once

in the array.

### [Find the index in an array such that the sum of elements at lower indices is equal to the sum of elements at higher indices.](https://www.geeksforgeeks.org/find-element-array-sum-left-array-equal-sum-right-array/)

Given, an array of size n. Find an element that divides the array into two sub-arrays with equal sum.  
**Examples:**

**Input:** 1 4 2 5

**Output:** 2

**Explanation:** If 2 is the partition,

subarrays are : {1, 4} and {5}

**Input:** 2 3 4 1 4 5

**Output:** 1

**Explanation:** If 1 is the partition,

Subarrays are : {2, 3, 4} and {4, 5}

### [Algorithm to find the maximum difference of j - i such that a[j] > a[i], for a given an array of 'n' elements.](https://www.geeksforgeeks.org/given-an-array-arr-find-the-maximum-j-i-such-that-arrj-arri/)

Given an array arr[], find the maximum j – i such that arr[j] > arr[i].

**Examples :**

**Input:** {34, 8, 10, 3, 2, 80, 30, 33, 1}

**Output:** 6 (j = 7, i = 1)

**Input:** {9, 2, 3, 4, 5, 6, 7, 8, 18, 0}

Output: 8 ( j = 8, i = 0)

**Input:**  {1, 2, 3, 4, 5, 6}

**Output:** 5 (j = 5, i = 0)

**Input:**  {6, 5, 4, 3, 2, 1}

**Output:** -1

### [Algorithm to find the triplet whose sum is X](https://www.geeksforgeeks.org/find-a-triplet-that-sum-to-a-given-value/)

Given an array and a value, find if there is a triplet in array whose sum is equal to the given value. If there is such a triplet present in array, then print the triplet and return true. Else return false.   
**Example:**

**Input:** array = {12, 3, 4, 1, 6, 9}, sum = 24;

**Output:** 12, 3, 9

**Explanation:** There is a triplet (12, 3 and 9) present

in the array whose sum is 24.

**Input:** array = {1, 2, 3, 4, 5}, sum = 9

**Output:** 5, 3, 1

**Explanation:** There is a triplet (5, 3 and 1) present

in the array whose sum is 9.

### [Algorithm to find a sub array whose sum is X](https://www.geeksforgeeks.org/find-subarray-with-given-sum-in-array-of-integers/)

Given an unsorted array of integers, find a subarray which adds to a given number. If there are more than one subarrays with the sum as the given number, print any of them.

**Examples:**

**Input:** arr[] = {1, 4, 20, 3, 10, 5}, sum = 33

**Output:** Sum found between indexes 2 and 4

**Explantion:** Sum of elements between indices

2 and 4 is 20 + 3 + 10 = 33

**Input:** arr[] = {10, 2, -2, -20, 10}, sum = -10

**Output:** Sum found between indexes 0 to 3

**Explantion:** Sum of elements between indices

0 and 3 is 10 + 2 - 2 - 20 = -10

**Input:** arr[] = {-10, 0, 2, -2, -20, 10}, sum = 20

**Output:** No subarray with given sum exists

**Explantion:** There is no subarray with the given sum

### [Algorithm to find the largest sub array with equal number of 0's and 1's](https://www.geeksforgeeks.org/largest-subarray-with-equal-number-of-0s-and-1s/)

Given an array containing only 0s and 1s, find the largest subarray which contains equal no of 0s and 1s. The expected time complexity is O(n).   
**Examples:**

**Input:** arr[] = {1, 0, 1, 1, 1, 0, 0}

**Output:** 1 to 6

(Starting and Ending indexes of output subarray)

**Input:** arr[] = {1, 1, 1, 1}

**Output:** No such subarray

**Input:** arr[] = {0, 0, 1, 1, 0}

**Output:** 0 to 3 Or 1 to 4

### [Algorithm to find the number of triangles that can be formed with three different array elements as three sides of triangles, for a given unsorted array of n elements](https://www.geeksforgeeks.org/find-number-of-triangles-possible/)

Given an unsorted array of positive integers, find the number of triangles that can be formed with three different array elements as three sides of triangles. For a triangle to be possible from 3 values, the sum of any of the two values (or sides) must be greater than the third value (or third side).   
**Examples:** 

**Input:** arr= {4, 6, 3, 7}

**Output:** 3

**Explanation:** There are three triangles

possible {3, 4, 6}, {4, 6, 7} and {3, 6, 7}.

Note that {3, 4, 7} is not a possible triangle.

**Input:** arr= {10, 21, 22, 100, 101, 200, 300}.

**Output:** 6

**Explanation:** There can be 6 possible triangles:

{10, 21, 22}, {21, 100, 101}, {22, 100, 101},

{10, 100, 101}, {100, 101, 200} and {101, 200, 300}

### [Algorithm to find the smallest integer value that can't be represented as sum of any subset of a given array.](https://www.geeksforgeeks.org/find-smallest-value-represented-sum-subset-given-array/)

Given a sorted array (sorted in non-decreasing order) of positive numbers, find the smallest positive integer value that cannot be represented as sum of elements of any subset of given set.  
Expected time complexity is O(n).

Examples:

Input: arr[] = {1, 3, 6, 10, 11, 15};

Output: 2

Input: arr[] = {1, 1, 1, 1};

Output: 5

Input: arr[] = {1, 1, 3, 4};

Output: 10

Input: arr[] = {1, 2, 5, 10, 20, 40};

Output: 4

Input: arr[] = {1, 2, 3, 4, 5, 6};

Output: 22

### [Algorithm to find the common element in given three sorted arrays](https://www.geeksforgeeks.org/find-common-elements-three-sorted-arrays/)

Given three arrays sorted in non-decreasing order, print all common elements in these arrays.

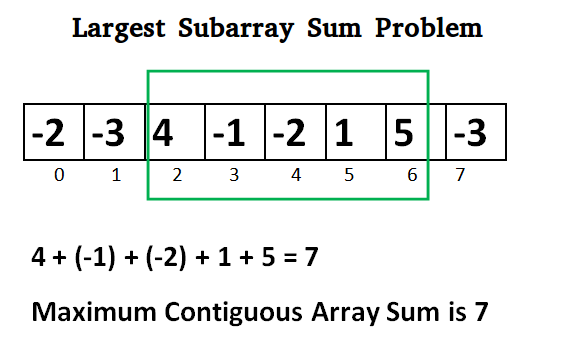
**Examples:**

***Input****:   
ar1[] = {1, 5, 10, 20, 40, 80}   
ar2[] = {6, 7, 20, 80, 100}   
ar3[] = {3, 4, 15, 20, 30, 70, 80, 120}****Output****: 20, 80*

***Input****:   
ar1[] = {1, 5, 5}   
ar2[] = {3, 4, 5, 5, 10}   
ar3[] = {5, 5, 10, 20}****Output****: 5, 5*

### [Algorithm to find the contiguous sub-array with maximum sum, for a given array of postive and negative numbers.](https://www.geeksforgeeks.org/largest-sum-contiguous-subarray/)

Write an efficient program to find the sum of contiguous subarray within a one-dimensional array of numbers which has the largest sum.



### Given an array of integers, sort the array into a wave like array and return it. (arrange the element into a sequence such that a1>=a2<=a3>=a4<=a5----etc.

### Algorithm to find the next greater number formed after permuting the digits of given number

### Algorithm to find the sum of bit difference in all pairs that can be formed from array of n elements.

### Trapping rain water problem

### Algorithm to find the minimum number of platforms required for the railway station so that no train waits according to arrival and departure time

### Rotate 2-Dimentional array

### Lock and Key problem

### Rearrange an array so that a[i] becomes a[a[i]] with O(1) extra space

### Traverse a matrix of integers in spiral form

### Given an array consisting 0's, 1's and 2's, write a algorithm to sort it

### Given a positive number X, print all jumping numbers(all adjacent digits in it differ by 1) smaller than or equal to X

### Given an array and an integer 'k', find the maximum, for each and every contiguous subarray of size 'k'

### Search an element in a sorted rotated array

### Find the maximum value of a[j]-a[i]+a[l]-a[k], for every four indices i, j, k, l such that i< j < k < l.

## Linked List

### [Algorithm to find the nth node from end of the linked list](https://www.geeksforgeeks.org/nth-node-from-the-end-of-a-linked-list/)

Given a Linked List and a number n, write a function that returns the value at the n’th node from the end of the Linked List.  
For example, if the input is below list and n = 2, then output is “B”

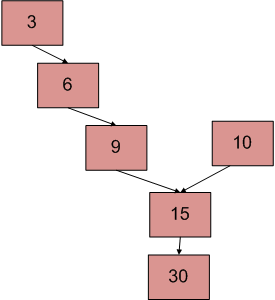
[](https://media.geeksforgeeks.org/wp-content/cdn-uploads/gq/2013/03/Linkedlist.png)

### [Algorithm to find the middle node in a linked list](https://www.geeksforgeeks.org/write-a-c-function-to-print-the-middle-of-the-linked-list/)

Given a singly linked list, find the middle of the linked list. For example, if the given linked list is 1->2->3->4->5 then the output should be 3.   
If there are even nodes, then there would be two middle nodes, we need to print the second middle element. For example, if given linked list is 1->2->3->4->5->6 then output should be 4.

### [Algorithm to find the intersection point of two linked lists](https://www.geeksforgeeks.org/write-a-function-to-get-the-intersection-point-of-two-linked-lists/)

There are two singly linked lists in a system. By some programming error, the end node of one of the linked list got linked to the second list, forming an inverted Y shaped list. Write a program to get the point where two linked list merge. 



Above diagram shows an example with two linked list having 15 as intersection point.

### [Reversal of linked list](https://www.geeksforgeeks.org/reverse-a-linked-list/)

Given pointer to the head node of a linked list, the task is to reverse the linked list. We need to reverse the list by changing the links between nodes.

**Examples**:

***Input****: Head of following linked list   
1->2->3->4->NULL****Output****: Linked list should be changed to,   
4->3->2->1->NULL*

***Input****: Head of following linked list   
1->2->3->4->5->NULL****Output****: Linked list should be changed to,   
5->4->3->2->1->NULL*

***Input****: NULL****Output****: NULL*

***Input****: 1->NULL****Output****: 1->NULL*

### [Algorithm to detect loop in linked list](https://www.geeksforgeeks.org/detect-loop-in-a-linked-list/)

Given a linked list, check if the linked list has loop or not. Below diagram shows a linked list with a loop. 



### [Algorithm to find starting node of a loop in a linked list](https://www.geeksforgeeks.org/find-first-node-of-loop-in-a-linked-list/)

Write a function *findFirstLoopNode()* that checks whether a given Linked List contains a loop. If the loop is present then it returns point to the first node of the loop. Else it returns NULL.

**Example :**

Input : Head of below linked list

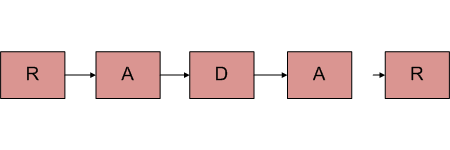


Output : Pointer to node 2

[Good explaination](https://www.ideserve.co.in/learn/detect-a-loop-in-a-linked-list)

### [Algorithm to check given linked list is palindrome (or) not](https://www.geeksforgeeks.org/function-to-check-if-a-singly-linked-list-is-palindrome/)

Given a singly linked list of characters, write a function that returns true if the given list is a palindrome, else false.



### [Algorithm to reverse alternative K nodes in a single linked list](https://www.geeksforgeeks.org/reverse-alternate-k-nodes-in-a-singly-linked-list/)

Given a linked list, write a function to reverse every alternate k nodes (where k is an input to the function) in an efficient way. Give the complexity of your algorithm.

**Example:**

Inputs: 1->2->3->4->5->6->7->8->9->NULL and k = 3

Output: 3->2->1->4->5->6->9->8->7->NULL.

### [Algorithm to clone a linked list with next and random pointer are given.](https://www.geeksforgeeks.org/a-linked-list-with-next-and-arbit-pointer/)

You are given a Double Link List with one pointer of each node pointing to the next node just like in a single link list. The second pointer however CAN point to any node in the list and not just the previous node. Now write a program in**O(n) time**to duplicate this list. That is, write a program which will create a copy of this list.

Let us call the second pointer as arbit pointer as it can point to any arbitrary node in the linked list.

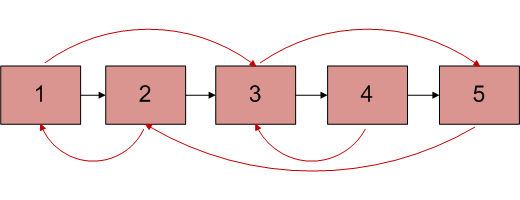


Figure 1

Arbitrary pointers are shown in red and next pointers in black

## Stack

From here we need to solve the problems based upon the foundation programs :

There are few foundation programs and using those you can solve most of the problems. Following are the foundation programs story:

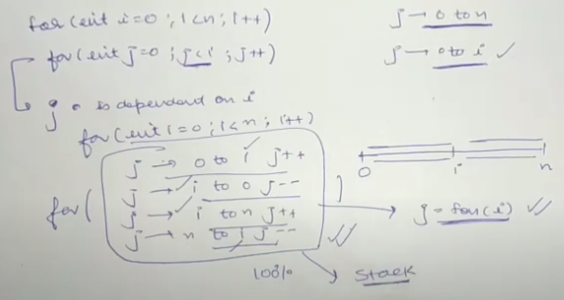
1. Next greater element to left
2. Next greater element to right
3. Next smaller element to left
4. Next smaller element to right
5. Stock span problem
6. Maximum area of histogram
7. Maximum area of rectangle in binary matrix

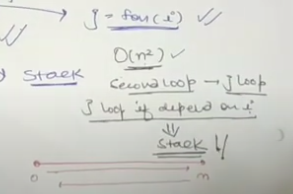
Following are the beautiful and important conceptual problems we should know:

1. Rain water trapping
2. Implementing a min stack
3. Implementing stack using heap
4. The celebrity problem
5. Longest valid parenthesis
6. Iterative Tower of Hanoi (TOH)

How to identify stack is used:

* In array questions mostly stack is used.
* Where brute force is present : for (i) followed by for(j)





### [Reversal of a stack](https://www.geeksforgeeks.org/reverse-stack-without-using-extra-space/)

Reverse a [Stack](https://www.geeksforgeeks.org/stack-data-structure/) without using recursion and extra space. Even the functional Stack is not allowed.

**Examples:**

Input : 1->2->3->4

Output : 4->3->2->1

Input : 6->5->4

Output : 4->5->6

### [Algorithm to find next greater element on the right side of an array.](https://www.geeksforgeeks.org/next-greater-element/)

Given an array, print the Next Greater Element (NGE) for every element. The Next greater Element for an element x is the first greater element on the right side of x in the array. Elements for which no greater element exist, consider next greater element as -1.

**Examples:**

1. For an array, the rightmost element always has the next greater element as -1.
2. For an array which is sorted in decreasing order, all elements have next greater element as -1.
3. For the input array [4, 5, 2, 25}, the next greater elements for each element are as follows.

Element NGE

4 --> 5

5 --> 25

2 --> 25

25 --> -1

**d)** For the input array [13, 7, 6, 12}, the next greater elements for each element are as follows.

Element NGE

13 --> -1

7 --> 12

6 --> 12

12 --> -1

### [Implemention of the following operations in stack in O(1) time. Push(), pop(), isEmpty(), isFull() and getMin().](https://www.geeksforgeeks.org/design-a-stack-that-supports-getmin-in-o1-time-and-o1-extra-space/)

**Question:** Design a Data Structure SpecialStack that supports all the stack operations like push(), pop(), isEmpty(), isFull() and an additional operation getMin() which should return minimum element from the SpecialStack. All these operations of SpecialStack must be O(1). To implement SpecialStack, you should only use standard Stack data structure and no other data structure like arrays, list, .. etc.   
Example: 

Consider the following SpecialStack

16 --> TOP

15

29

19

18

When getMin() is called it should return 15,

which is the minimum element in the current stack.

If we do pop two times on stack, the stack becomes

29 --> TOP

19

18

When getMin() is called, it should return 18

which is the minimum in the current stack.

### [Algorithm to find the celebrity in minimum number of questions in a party.](https://www.geeksforgeeks.org/the-celebrity-problem/)

*In a party of N people, only one person is known to everyone. Such a person****may be present****in the party, if yes, (s)he doesn’t know anyone in the party. We can only ask questions like “****does A know B?****“. Find the stranger (celebrity) in the minimum number of questions.*  
We can describe the problem input as an array of numbers/characters representing persons in the party. We also have a hypothetical function *HaveAcquaintance(A, B)* which returns *true* if A knows B, *false* otherwise. How can we solve the problem.

**Examples:**

**Input:**

MATRIX = { {0, 0, 1, 0},

{0, 0, 1, 0},

{0, 0, 0, 0},

{0, 0, 1, 0} }

**Output:**id = 2

**Explanation:** The person with ID 2 does not

know anyone but everyone knows him

**Input:**

MATRIX = { {0, 0, 1, 0},

{0, 0, 1, 0},

{0, 1, 0, 0},

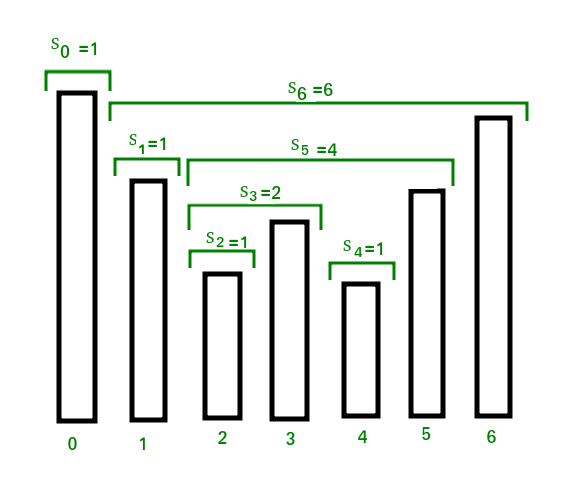
{0, 0, 1, 0} }

**Output:** No celebrity

**Explanation:** There is no celebrity.

### [Algorithm to the stock span problem is a financial problem where we have a series of 'n' daily price for a stock and we need to calculate span of stock’s price for all n days](https://www.geeksforgeeks.org/the-stock-span-problem/)

[The stock span problem](http://en.wikipedia.org/wiki/Stack_(abstract_data_type)#The_Stock_Span_Problem) is a financial problem where we have a series of n daily price quotes for a stock and we need to calculate span of stock’s price for all n days.   
The span Si of the stock’s price on a given day i is defined as the maximum number of consecutive days just before the given day, for which the price of the stock on the current day is less than or equal to its price on the given day.   
For example, if an array of 7 days prices is given as {100, 80, 60, 70, 60, 75, 85}, then the span values for corresponding 7 days are {1, 1, 1, 2, 1, 4, 6}



### [Algorithm to merge overlapping intervals](https://www.geeksforgeeks.org/merging-intervals/#:~:text=Below%20are%20detailed%20steps.,merge%20it%20with%20previous%20interval.)

Given a set of time intervals in any order, merge all overlapping intervals into one and output the result which should have only mutually exclusive intervals. Let the intervals be represented as pairs of integers for simplicity.   
For example, let the given set of intervals be {{1,3}, {2,4}, {5,7}, {6,8}}. The intervals {1,3} and {2,4} overlap with each other, so they should be merged and become {1, 4}. Similarly, {5, 7} and {6, 8} should be merged and become {5, 8}

### [Find the largest rectangular area possible in a given histogram](https://www.geeksforgeeks.org/largest-rectangle-under-histogram/).

Find the largest rectangular area possible in a given histogram where the largest rectangle can be made of a number of contiguous bars. For simplicity, assume that all bars have same width and the width is 1 unit.

For example, consider the following histogram with 7 bars of heights {6, 2, 5, 4, 5, 1, 6}. The largest possible rectangle possible is 12 (see the below figure, the max area rectangle is highlighted in red)

[](https://media.geeksforgeeks.org/wp-content/cdn-uploads/histogram1.png)

### [Maximum size rectangle binary sub-matrix with all 1s](https://www.geeksforgeeks.org/maximum-size-rectangle-binary-sub-matrix-1s/)

Given a binary matrix, find the maximum size rectangle binary-sub-matrix with all 1’s.

**Example:**

**Input:**

0 1 1 0

1 1 1 1

1 1 1 1

1 1 0 0

**Output :**

1 1 1 1

1 1 1 1

**Explanation :**

The largest rectangle with only 1's is from

(1, 0) to (2, 3) which is

1 1 1 1

1 1 1 1

**Input:**

0 1 1

1 1 1

0 1 1

**Output:**

1 1

1 1

1 1

**Explanation :**

The largest rectangle with only 1's is from

(0, 1) to (2, 2) which is

1 1

1 1

1 1

### [Given an integer array of size 'n', find the maximum of the minimum’s of every window size in the array](https://www.geeksforgeeks.org/find-the-maximum-of-minimums-for-every-window-size-in-a-given-array/).

Given an integer array of size n, find the maximum of the minimum’s of every window size in the array. Note that window size varies from 1 to n.  
**Example:**

*Input: arr[] = {10, 20, 30, 50, 10, 70, 30}   
Output: 70, 30, 20, 10, 10, 10, 10  
The first element in the output indicates the maximum of minimums of all   
windows of size 1.   
Minimums of windows of size 1 are {10}, {20}, {30}, {50}, {10},   
{70} and {30}. Maximum of these minimums is 70  
The second element in the output indicates the maximum of minimums of all   
windows of size 2.   
Minimums of windows of size 2 are {10}, {20}, {30}, {10}, {10},   
and {30}. Maximum of these minimums is 30  
The third element in the output indicates the maximum of minimums of all   
windows of size 3.   
Minimums of windows of size 3 are {10}, {20}, {10}, {10} and {10}.   
Maximum of these minimums is 20  
Similarly, other elements of output are computed.*

### [Calculate minimum number of bracket reversals needed to make an expression balenced](https://www.geeksforgeeks.org/minimum-number-of-bracket-reversals-needed-to-make-an-expression-balanced/#:~:text=Let%20m%20be%20the%20total,%E2%8C%88n%2F2%E2%8C%89%20reversals.).

Given an expression with only ‘}’ and ‘{‘. The expression may not be balanced. Find minimum number of bracket reversals to make the expression balanced.  
**Examples:**

**Input:** exp = "}{"

**Output:** 2

We need to change '}' to '{' and '{' to

'}' so that the expression becomes balanced,

the balanced expression is '{}'

**Input:** exp = "{{{"

**Output:** Can't be made balanced using reversals

**Input:** exp = "{{{{"

**Output:** 2

**Input:** exp = "{{{{}}"

**Output:** 1

**Input:** exp = "}{{}}{{{"

**Output:** 3

### [Design a stack, to find getmin() in O(1) time and O(1) space complexity.](https://www.geeksforgeeks.org/design-a-stack-that-supports-getmin-in-o1-time-and-o1-extra-space/)

**Question:** Design a Data Structure SpecialStack that supports all the stack operations like push(), pop(), isEmpty(), isFull() and an additional operation getMin() which should return minimum element from the SpecialStack. All these operations of SpecialStack must be O(1). To implement SpecialStack, you should only use standard Stack data structure and no other data structure like arrays, list, .. etc.   
Example: 

Consider the following SpecialStack

16 --> TOP

15

29

19

18

When getMin() is called it should return 15,

which is the minimum element in the current stack.

If we do pop two times on stack, the stack becomes

29 --> TOP

19

18

When getMin() is called, it should return 18

which is the minimum in the current stack.

### [Find if an expression has duplicate or not](https://www.geeksforgeeks.org/find-expression-duplicate-parenthesis-not/#:~:text=The%20idea%20is%20to%20use,the%20top%20of%20the%20stack.&text=For%20example%2C%20(((a%2Bb,around%20%E2%80%9Ca%2Bb%E2%80%9D.)

Given a balanced expression, find if it contains duplicate parenthesis or not. A set of parenthesis are duplicate if the same subexpression is surrounded by multiple parenthesis.

**Examples:**

**Below expressions have duplicate parenthesis -**

((a+b)+((c+d)))

The subexpression "c+d" is surrounded by two

pairs of brackets.

(((a+(b)))+(c+d))

The subexpression "a+(b)" is surrounded by two

pairs of brackets.

(((a+(b))+c+d))

The whole expression is surrounded by two

pairs of brackets.

**Below expressions don't have any duplicate parenthesis -**

((a+b)+(c+d))

No subsexpression is surrounded by duplicate

brackets.

((a+(b))+(c+d))

No subsexpression is surrounded by duplicate

brackets.

It may be assumed that the given expression is valid and there are not any white spaces present.

## Recursion

### [Print the given number from 1 to n using recursion](https://www.techiedelight.com/print-numbers-1-n-without-using-loop-4-methods/#:~:text=Method%201%3A%20Using%20static%20variable,variable%20will%20also%20work%20fine).)

### [Print the given number from n to 1 using recursion](https://www.geeksforgeeks.org/program-to-print-numbers-from-n-to-1-in-reverse-order/)

Given a number **N**, the task is to print the numbers from **N to 1**.  
**Examples:**

***Input:****N = 10****Output:****10 9 8 7 6 5 4 3 2 1****Input:****N = 7****Output:****7 6 5 4 3 2 1*

## Queues

### Given an array and an integer k, find the maximum for each and every contiguous subarray of size k.

### Implement LRU Cache.

### Find the first cicular tour that visits all petrol pumps

### Find the largest multiple of 3.

## Trees

### Implement in order traversal without stack and recursion

### Convert a binary tree into its mirror tree

### Check if a given binary tree is sum tree or not

### Determine if the given two trees are identical or not

### Print out all of its roof to leaf paths in a given binary tree

### Find a lowest common ancestor of a given two nodes in a abinary search tree

### Find a lowest common ancestor of a given two nodes in a binary tree

### Level order traversal in spiral form

### Convert an arbitrary binary tree to a tree that holds children sum property

### Find the Diameter of a BST

### Construct tree from given inorder and post order traversal

### Convert a Binary Tree to a circular DLL

### Evaluation of expression tree

### Print extreme node of each level of Binary Tree in alternative order

### Print cousins of a given node in Binary Tree

### Diagonal traversal of Binary Tree

### Construct tree from ancestor matrix

### Given a Binary Tree, find vertical sum of the nodes that are in same vertical line.

### Find multiplication of sums of data of leaves at same level.

### Given a binary tree, find maximum value we can get by subtracting value of node B from value of node A

### Print nodes in a top view of Binary Tree.

### Given a Binary Tree and a number k, remove all nodes that lie only on root to leaf path(s) of length smaller than k.

### Serialize and deserialize an N-ary tree.

### Reverse alternate levels of a perfect Binary Tree.

### Print all nodes that are at distance k from a leaf node.

### Custom tree problem.

### Construct complete binary tree from its linked list representation.

### Find next right nodes of given leafs in a binary tree.

### Given a binary tree, print boundary nodes of the binary tree Anti-Clockwise starting from the root.

### Convert a given tree to its sum tree.

### Given a binary tree, find out if the tree can be folded or not.

### Find largest sub tree having identical left and right sub tree.

### Convert a normal binary search tree to balanced BST.

### Check if removing an edge can divide a binary tree in the form of n-ary tree.

### locking and unlocking of resource arranged on the form of n-ary tree.

## Heaps

### Find K largest (or smallest) elements in array.

### Tournament tree method using binary heap .

### Find a Median in a stream of integers.

### Sort a nearly sorted array(or k sorted).

### Given array representation of min Heap, convert it to max Heap.

### Check if a given binary tree is Heap.

### Find kth largest element in a stream.

### Print all elements in sorted order from row and column wise sorted matrix.

### Given n ropes of different length, connect with minimum cost.

### Given k sorted arrays of size n each, merge them.

### Design an efficient data structure for given operations find min(), findmax(), deletemin(), Insert(),delete().

## Strings

### Given a directed graph G=(V,E), find whether G has a cycle.

### Given an undirected graph G=(V,E), find whether G has a cycle or not.

### Given a directed graph G=(V,E), find whether there is path between two vertices vi and vj.

### Given a 2D boolean matrix, find the number of islands.

### Given a connected undirected graph, find all the articulation points

### Given an undirected graph, find all the bridges in the graph.

### Given a directed graph, find all the strongly connected components.

### Given a weighted directed acyclic graph, find the shortest path from a vertex to all the other vertices.

### Given a weighted directed acyclic graph, find the longest path from a vertex to all the other vertices.

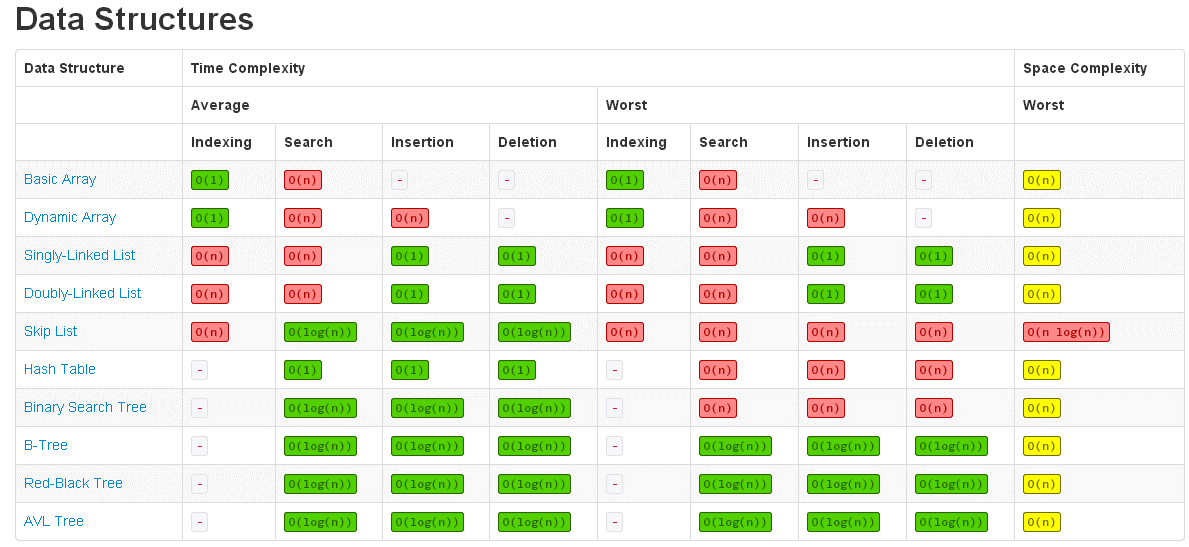
### Check whether a given graph is bipartite or not.

### Find number of connections a person till nth level.

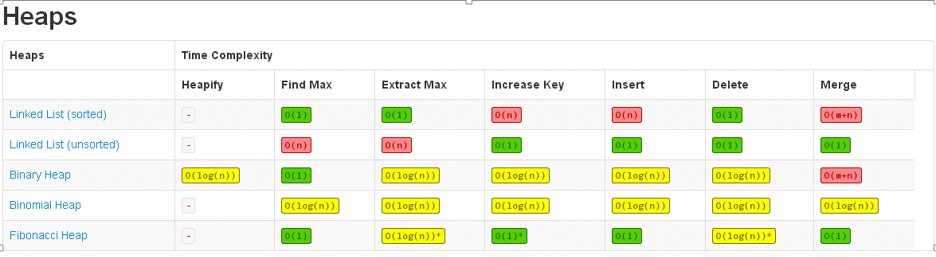
## Bit Manipulation

# Algorithm

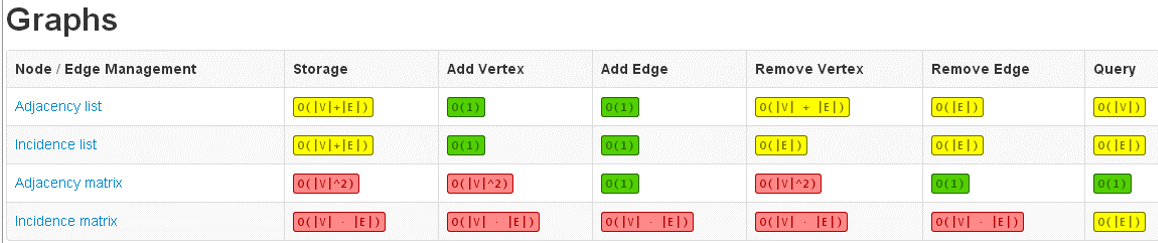
### Data Structures complexities



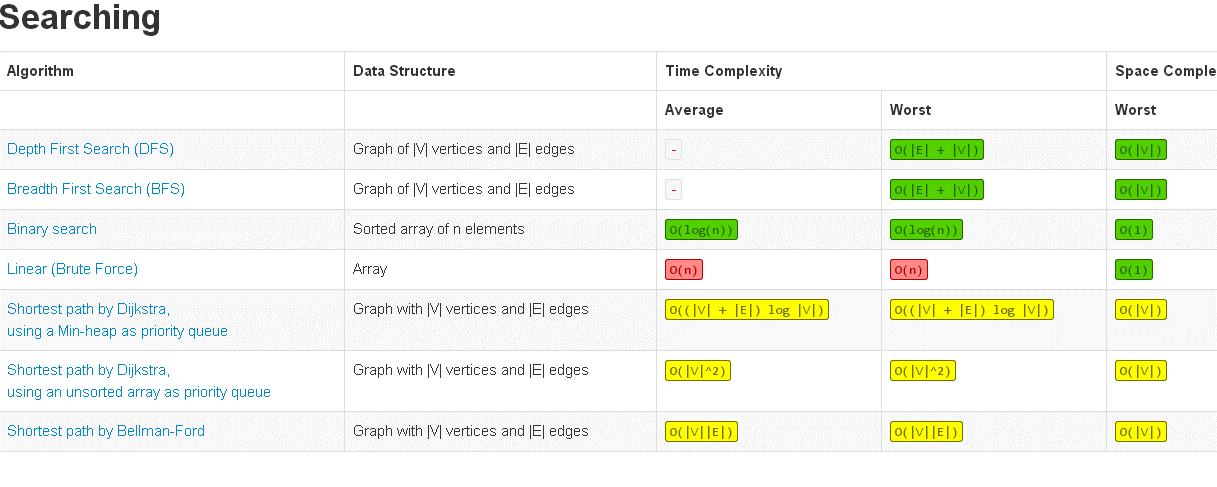
### Heaps complexities



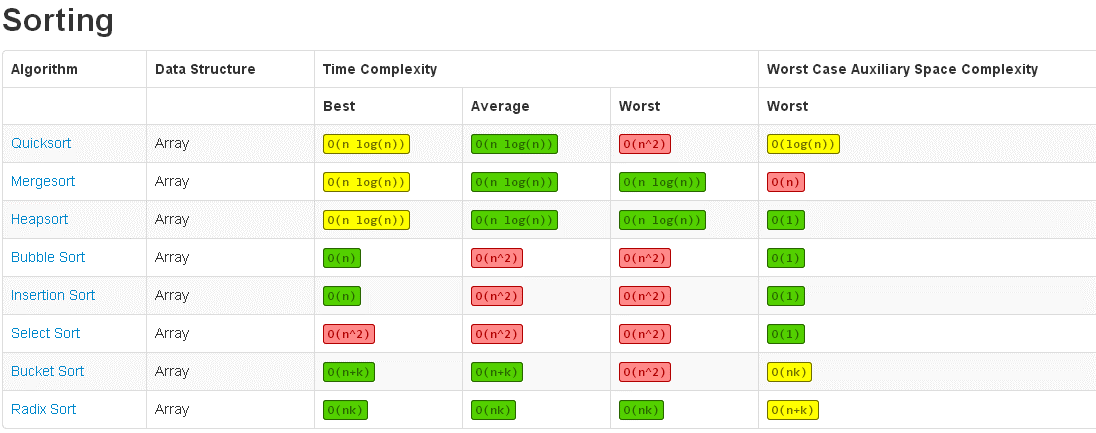
### Graph Complexities



### Searching complexities



### Sorting complexities



|  |
| --- |
|  |
| Sorting AlgorithmsBubble Sort **static** **int**[] sort(**int**[] a) {  **for**(**int** i=0;i<a.length-1;i++)  **for**(**int** j=i+1;j<a.length;j++) {  **if**(a[i]>a[j]) {  **int** s = a[i];  a[i] = a[j];  a[j] = s;  }  }  **return** a;  } Selection Sort **public** **static** **void** sort(**int**[] a) {  **for**(**int** i = 0;i<a.length;i++) {  **int** min = i;  **for**(**int** j=i+1;j<a.length;j++) {  **if**(a[min]>a[j])min= j;  }  **int** swap = a[i];  a[i] = a[min];  a[min] = swap;  }  } Insertion Sort **public** **static** **void** sort(**int**[] a) {  **for**(**int** i = 1;i<a.length;i++) {  **int** j = i;  **int** temp = a[j];  **while**(j>0 && a[j-1]>temp) {  a[j] = a[j-1];  j--;  }  a[j] = temp;  }  } Merge Sort **private** **static** **void** sort(**int**[] a,**int** l,**int** r) {  **if**(l<r) {  **int** m = (l+r)/2;  *sort*(a,l,m);  *sort*(a,m+1,r);  *merge*(a,l,m,r);  }  }  **private** **static** **void** merge(**int**[] arr, **int** l, **int** m, **int** r) {  **int** n1 = m-l+1;  **int** n2 = r-m;    **int**[] L= **new** **int**[n1];  **int**[] R = **new** **int**[n2];  /\*Copy data to temp arrays\*/  **for** (**int** i=0; i<n1; ++i)  L[i] = arr[l + i];  **for** (**int** j=0; j<n2; ++j)  R[j] = arr[m + 1+ j];      /\* Merge the temp arrays \*/    // Initial indexes of first and second subarrays  **int** i = 0, j = 0;    // Initial index of merged subarry array  **int** k = l;    **while** (i < n1 && j < n2)  {  **if** (L[i] <= R[j])  {  arr[k] = L[i];  i++;  }  **else**  {  arr[k] = R[j];  j++;  }  k++;  }    /\* Copy remaining elements of L[] if any \*/  **while** (i < n1)  {  arr[k] = L[i];  i++;  k++;  }    /\* Copy remaining elements of R[] if any \*/  **while** (j < n2)  {  arr[k] = R[j];  j++;  k++;  }  } Quick sort **private** **static** **void** sort(**int**[] a, **int** low, **int** high) {  **if**(low<high) {  **int** pivot = *partition*(a,low,high);  *sort*(a,low,pivot-1);  *sort*(a,pivot+1,high);  }  }  **private** **static** **int** partition(**int**[] a, **int** low, **int** high) {  **int** i = low-1;  **int** pivot = high;  **for**(**int** j=low;j<high;j++) {  **if**(a[j]<=a[pivot]) {  i++;  **int** s1= a[j];  a[j] = a[i];  a[i] = s1;  }  }  **int** s2 = a[i+1];  a[i+1] = a[high];  a[high] = s2;  **return** i+1;  } Heap Sort **public** **static** **void** sort(**int**[] a) {  **for**(**int** i = 0;i<a.length;i++) {  **int** min = i;  **for**(**int** j=i+1;j<a.length;j++) {  **if**(a[min]>a[j])min= j;  }  **int** swap = a[i];  a[i] = a[min];  a[min] = swap;  }  } Divide & ConquerFind the median of two sorted arraysCount inversions in an arrayFind majority Element in a sorted arrayFind the maximum and minimum of an array using minimum number of comparisonsThe skyline problemGiven two binary strings that represent value of two integers, find the product of two strings.Given an array of integers. Find a peak element in it.Find the missing number in Arithmetic ProgressionGiven an array of n points in the plane, find out the closest pair of points in the array. |
| Back TrackingPrint all permutations of a given string.Find subset of elements that are selected from a given set whose sum adds up to a given number K.Given a set of n integers, divide the set in two subsets of n/2 sizes each such that the difference of the sum of two subsets is as minimum as possible.Solve Sudoku using backtracking.Given a maze, NxN matrix. A rat has to find a path from source to destination. Left top corner is the source and right bottom corner is destination. There are few cells which are blocked, means rat can¬not enter into those cells. |
| Pattern searchingGiven a text and a pattern, find all occurrences of pattern in a given text. Using naive approach.Given a text and a pattern, find all occurrences of pattern in a given text. Using Rabin-Karp algorithm.Given a text and a pattern, find all occurrences of pattern in a given text. Using Finite automata approach.Given a text and a pattern, find all occurrences of pattern in a given text. Using Boyer moore algorithm.Given a text and a pattern, find all occurrences of pattern in a given text. Using KMP algorithm.Given a string, find the longest sub string which is palindrome using manacher’s algorithmFind all occurrences of a given word in a matrix. |
| Greedy AlgorithmsGiven an array of jobs with different time intervals. Find the minimum time to finish all jobs.Given a universe of n elements, collection of subsets. Find a minimum cost sub collection that covers all elements.Given n cities and distances between every pair of cities, select k cities to place warehouses, such that the maximum distance of a city to a warehouse is minimized. |
| Dynamic ProgrammingFind the length of the longest sub sequence of a given sequence such that all elements of the sub sequence are sorted in increasing order.Given two sequences, find the length of longest sub sequence present in both of them.Given a cost matrix and a position (m, n) , Find cost of minimum cost path to reach (m, n) from (0, 0).Coin change problem.Find the length of the longest palindrome sub sequence.Find th sum of maximum sum sub sequence of the given array.You have a rectangular grid of dimension 2 x n. You need to find out the maximum sum such that no two chosen numbers are adjacent , vertically, diagonally (or) horizontally.Given an array A with n elements and array B with m elements. With m you have to insert (n-m) zero's in between array B such that the dot product of array A and array B is maximum.Transform a string into palindrome on removing at most k characters from it.Find the longest even length sub string such that sum of first and second half is same..Count number of ways to reach a given score in a game.Compute sum of digits in all number from 1 to n.Collect maximum points in a grid using two traversalsGiven a 2xn board and titles of size 2x1, count the number of ways to tile he given board using the 2x1 tiles..Count the number of ways we can parenthesize the expression so that the value of expression evaluates to true.Given a Binary Tree, find size of the Largest Independent Set(LIS) in it.There are n stairs, a person standing at the bottom wants to reach the top. The person can climb either 1 stair or 2 stairs at a time. Count the number of ways, the person can reach the top.Find total number of non-decreasing numbers with n digits.Egg dropping problem.Given a rod of length n inches and an array of prices that contains prices of all pieces of size smaller than n. Determine the maximum value obtainable by cutting up the rod and selling the pieces.Given N jobs where every job is represented by Start Time, Finish Time, Profit or Value Associated. Find the maximum profit subset of jobs such that no two jobs in the subset overlap.Box stacking problem.Given an input string and a dictionary of words, find out if the input string can be segmented into a space-separated sequence of dictionary words.Given a binary matrix, find out the maximum size square sub-matrix with all 1s.Find the maximum coins you can collect by bursting the balloons wisely. |
|  |
|  |

# Databases

## Inteview questions

**able - EmployeeDetails**

|  |  |  |  |
| --- | --- | --- | --- |
| **EmpId** | **FullName** | **ManagerId** | **DateOfJoining** |
| 121 | John Snow | 321 | 01/31/2014 |
| 321 | Walter White | 986 | 01/30/2015 |
| 421 | Kuldeep Rana | 876 | 27/11/2016 |

**Table - EmployeeSalary**

|  |  |  |
| --- | --- | --- |
| **EmpId** | **Project** | **Salary** |
| 121 | P1 | 8000 |
| 321 | P2 | 1000 |
| 421 | P1 | 12000 |

### Write a SQL query to fetch the count of employees working in project 'P1'.

Ans. Here, we would be using aggregate function count() with the SQL where clause-

**SELECT** **COUNT**(\*) **FROM** EmployeeSalary **WHERE** Project = 'P1';

### Write a SQL query to fetch employee names having salary greater than or equal to 5000 and less than or equal 10000.

Ans. Here, we will use BETWEEN in the 'where' clause to return the empId of the employees with salary satifying the required criteria and then use it as subquery to find the fullName of the employee form EmployeeDetails table.

**SELECT** FullName

**FROM** EmployeeDetails

**WHERE** EmpId **IN**

(**SELECT** EmpId **FROM** EmpolyeeSalary

**WHERE** Salary **BETWEEN** 5000 **AND** 10000);

### Write a SQL query to fetch project-wise count of employees sorted by project's count in descending order.

Ans. The query has two requirements - first to fetch the project-wise count and then to sort the result by that count. For project wise count, we will be using GROUPBY clause and for sorting, we will use ORDER BY clause on the alias of the project-count.

**SELECT** Project, **count**(EmpId) EmpProjectCount

**FROM** EmployeeSalary

**GROUP** **BY** Project

**ORDER** **BY** EmpProjectCount **DESC**;

### Write a query to fetch only the first name(string before space) from the FullName column of EmployeeDetails table.

Ans. In this question, we are required to first fetch the location of the space character in the FullName field and then extract the first name out of the FullName field. For finding the location we will use LOCATE method in mySQL and CHARINDEX in SQL SERVER and for fetching the string before space, we will use SUBSTRING OR MID method.

**mySQL- Using MID**

**SELECT** MID(FullName, 0, LOCATE(' ',FullName)) **FROM** EmployeeDetails;

**SQL Server-Using SUBSTRING**

**SELECT** SUBSTRING(FullName, 0, CHARINDEX(' ',FullName)) **FROM** EmployeeDetails;

**Also, we can use LEFT which returns the left part of a string till specified number of characters.**

**SELECT** **LEFT**(FullName, CHARINDEX(' ',FullName) - 1) **FROM** EmployeeDetails;

### Write a query to fetch employee names and salary records. Return employee details even if the salary record is not present for the employee.

Ans. Here, we can use left join with EmployeeDetail table on the left side.

**SELECT** E.FullName, S.Salary

**FROM** EmployeeDetails E **LEFT** **JOIN** EmployeeSalary S

**ON** E.EmpId = S.EmpId;

### Write a SQL query to fetch all the Employees who are also managers from EmployeeDetails table.

Ans. Here, we have to use Self-Join as the requirement wants us to analyze the EmployeeDetails table as two different tables, each for Employee and manager records.

**SELECT DISTINCT** E.FullName

**FROM** EmpDetails E

**INNER** **JOIN** EmpDetails M

**ON** E.EmpID = M.ManagerID;

### Write a SQL query to fetch all employee records from EmployeeDetails table who have a salary record in EmployeeSalary table.

Ans. Using 'Exists'-

**SELECT** \* **FROM** EmployeeDetails E

**WHERE** **EXISTS**

(**SELECT** \* **FROM** EmployeeSalary S **WHERE** E.EmpId = S.EmpId);

### Write a SQL query to fetch duplicate records from a table.

Ans. In order to find duplicate records from table we can use GROUP BY on all the fields and then use HAVING clause to return only those fields whose count is greater than 1 i.e. the rows having duplicate records.

**SELECT** EmpId, Project, Salary, **COUNT**(\*)

**FROM** EmployeeSalary

**GROUP** **BY** EmpId, Project, Salary

**HAVING** **COUNT**(\*) > 1;

### Write a SQL query to remove duplicates from a table without using temporary table.

Ans. Using Group By and Having clause-

**DELETE** **FROM** EmployeeSalary

**WHERE** EmpId **IN** (

**SELECT** EmpId

**FROM** EmployeeSalary

**GROUP** **BY** Project, Salary

**HAVING** **COUNT**(\*) > 1));

Using rowId in Oracle-

**DELETE** **FROM** EmployeeSalary

**WHERE** rowid **NOT** **IN**

(**SELECT** **MAX**(rowid) **FROM** EmployeeSalary **GROUP** **BY** EmpId);

### Write a SQL query to fetch only odd rows from table.

Ans. This can be achieved by using Row\_number in SQL server-

**SELECT** E.EmpId, E.Project, E.Salary

**FROM** (

**SELECT** \*, Row\_Number() OVER(**ORDER** **BY** EmpId) **AS** RowNumber

**FROM** EmployeeSalary

) E

**WHERE** E.RowNumber % 2 = 1

### Write a SQL query to fetch only even rows from table.

Ans. Using the same Row\_Number() and checking that the remainder when divided by 2 is 0-

**SELECT** E.EmpId, E.Project, E.Salary

**FROM** (

**SELECT** \*, Row\_Number() OVER(**ORDER** **BY** EmpId) **AS** RowNumber

**FROM** EmployeeSalary

) E

**WHERE** E.RowNumber % 2 = 0

### Write a SQL query to create a new table with data and structure copied from another table.

Ans. Using SELECT INTO command-

**SELECT** \* **INTO** newTable **FROM** EmployeeDetails;

### Write a SQL query to create an empty table with same structure as some other table.

Ans. Using SELECT INTO command with False 'WHERE' condition-

**SELECT** \* **INTO** newTable **FROM** EmployeeDetails **WHERE** 1 = 0;

This can also done using mySQL 'Like' command with CREATE statement-

**CREATE** **TABLE** newTable **LIKE** EmployeeDetails;

### Write a SQL query to fetch common records between two tables.

Ans. Using INTERSECT-

**SELECT** \* **FROM** EmployeeSalary

**INTERSECT**

**SELECT** \* **FROM** ManagerSalary

### Write a SQL query to fetch records that are present in one table but not in another table.

Ans. Using MINUS-

**SELECT** \* **FROM** EmployeeSalary

**MINUS**

**SELECT** \* **FROM** ManagerSalary

### Write a SQL query to find current date-time.

Ans. mySQL-

**SELECT** NOW();

SQL Server-

**SELECT** getdate();

Oracle-

**SELECT** SYSDATE **FROM** DUAL;

### Write a SQL query to fetch all the Employees details from EmployeeDetails table who joined in Year 2016.

Ans. Using BETWEEN for the date range '01-01-2016' AND '31-12-2016'-

**SELECT** \* **FROM** EmployeeDetails

**WHERE** DateOfJoining **BETWEEN** '01-01-2016' **AND** date '31-12-2016';

Also, we can extract year part from the joining date (using YEAR in mySQL)-

**SELECT** \* **FROM** EmployeeDetails

**WHERE** **YEAR**(DateOfJoining) = '2016';

### Write a SQL query to fetch top n records?

Ans. In mySQL using LIMIT-

**SELECT** \* **FROM** EmployeeSalary **ORDER** **BY** Salary **DESC** **LIMIT** N

In SQL server using TOP command-

**SELECT** TOP N \* **FROM** EmployeeSalary **ORDER** **BY** Salary **DESC**

In Oracle using ROWNUM-

**SELECT** \* **FROM** (**SELECT** \* **FROM** EmployeeSalary **ORDER** **BY** Salary **DESC**)

**WHERE** ROWNUM <= 3;

### Write SQL query to find the nth highest salary from table.

Ans. Using Top keyword (SQL Server)-

**SELECT** TOP 1 Salary

**FROM** (

**SELECT** **DISTINCT** TOP N Salary

**FROM** Employee

**ORDER** **BY** Salary **DESC**

)

**ORDER** **BY** Salary **ASC**

Using limit clause(mySQL)-

**SELECT** Salary **FROM** Employee **ORDER** **BY** Salary **DESC** **LIMIT** N-1,1;

### Write SQL query to find the 3rd highest salary from table without using TOP/limit keyword.

Ans. The below SQL query make use of correlated subquery wherein in order to find the 3rd highest salary the inner query will return the count of till we find that there are two rows that salary greater than other distinct salaries.

**SELECT** Salary

**FROM** EmployeeSalary Emp1

**WHERE** 2 = (

**SELECT** **COUNT**( **DISTINCT** ( Emp2.Salary ) )

**FROM** EmployeeSalary Emp2

**WHERE** Emp2.Salary > Emp1.Salary

)

For nth highest salary-

**SELECT** Salary

**FROM** EmployeeSalary Emp1

**WHERE** N-1 = (

**SELECT** **COUNT**( **DISTINCT** ( Emp2.Salary ) )

**FROM** EmployeeSalary Emp2

**WHERE** Emp2.Salary > Emp1.Salary

)

## SQL Queries Basics

## SELECT statement and syntax

## SQL Data Types

## WHERE operators: comparison operators, LIKE, BETWEEN, IN

## Scalar Functions

## Aggregate Functions (SUM, COUNT, MIN, MAX, AVG)

## GROUP BY

## ORDER BY

## JOINS (INNER JOIN, RIGHT and LEFT JOIN, OUTER JOIN, CROSS JOIN)

## Set Theory (INTERSECT, UNION, MINUS)

## Subqueries

## INSERT, UPDATE, DELETE

## DML vs DDL vs DCL

## DDL: CREATE, DROP, ALTER

## Constraints

## Indexes

## DCL privileges: GRANT, REVOKE

## Transactions

## Views

## Triggers

## Cursors

# Spring

### Please list down the various features of Spring Framework and the advantages of using the same.

**Answer:**

Features of Spring Framework:

* Allows creating and managing the configuration and lifecycle of application objects
* AOP (Aspect Oriented Programming) provides support for unified development by separating application business logic from system services
* Highly configurable MVC web application framework with the ability to easily switch to other frameworks
* Instead of looking for or creating dependent objects, the objects give their dependencies. This design principle is known as IoC (Inversion of Control)
* Lightweight
* Offers a generic abstraction layer for transaction management that can also be used in container-less environments
* The JDBC abstraction layer offers an exception hierarchy that simplifies error handling

Advantages:

* Enables [POJO (Plain Old Java Object)](https://en.wikipedia.org/wiki/Plain_old_Java_object) Programming that further enables continuous integration and testability
* Open-source with no vendor lock-in
* Simplified JDBC because of DI (Dependency Injection) and Inversion of Control
* Thanks to the layered architecture, it’s easy to keep what you want and discard what you don’t

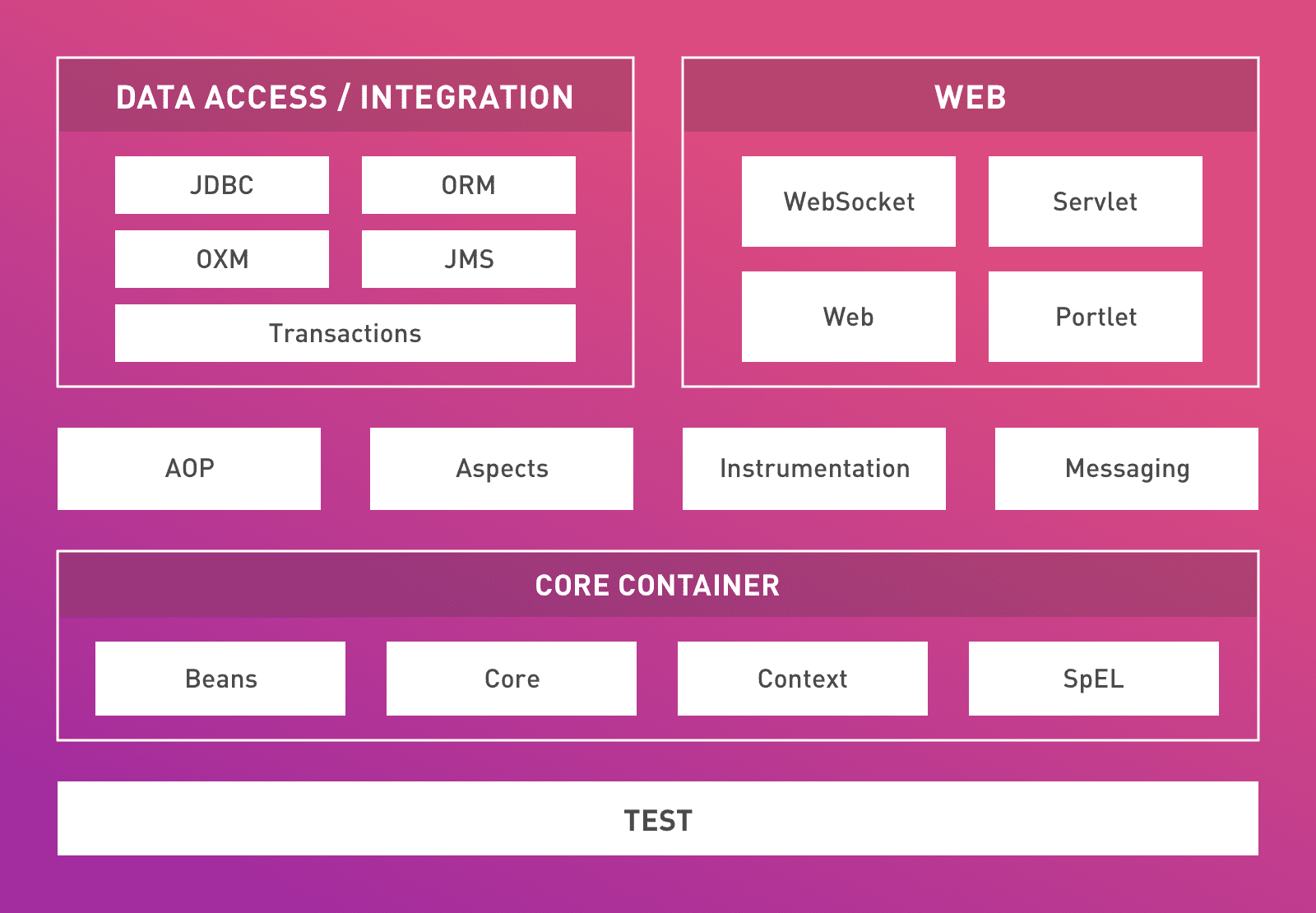
### **H**ow many modules does the Spring Framework have?

**Answer:** Spring Framework has about 20 modules. Each of them is classified into one of the following layers:

* Spring Core Container – The basic core layer of the Spring Framework. It has the following modules:
* SpEL (Spring Expression Language)
* Spring Bean
* Spring Core
* Spring Context
* Data Access/Integration – This is the layer responsible for providing support for interacting with the database. It contains the following modules:
* JDBC (Java DataBase Connectivity)
* JMS (Java Messaging Service)
* ORM (Object Relational Mapping)
* OXM (Object XML Mappers)
* Transaction
* Web – Providing support for creating web applications is the responsibility of this layer. It has these modules:
* Web
* Web – MVC
* Web – Portlet
* Web – Socket
* Aspect-Oriented Programming – Allows using Advice, Pointcuts, and others to decouple the code
* Instrumentation – Provides support for class instrumentation and classloader implementations
* Test – Responsible for providing support for accomplishing testing using JUnit and TestNG

Some additional Spring Framework modules are:

* Aspects – Offers support for integrating with AspectJ
* Messaging – Provides support for STOMP and an annotation programming model used for processing as well as routing STOMP messages from WebSocket clients



### What components does a Spring application have?

**Answer:** A typical Spring application can be subdivided into the following components:

* Bean Class – Contains properties, functions, setter and getter methods, et cetera
* Bean Configuration File – Contains information on classes as well as how to configure the same
* Interface – Defines the functions
* Spring Aspect Oriented Programming – Provides the functionality of cross-cutting concerns
* User Program – Uses the function

### What do you understand by the Spring IoC Container? Explain their types.

**Answer:** The Spring IoC container lies at the core of the Spring Framework. The container uses Dependency Injection for managing various Spring application components.

The IoC container is responsible for creating the objects, configuring them, wiring them together, and managing their lifecycle. The container receives instructions about the same from the provided configuration metadata.

Means for providing the configuration metadata can include Java annotations, Java code, or XML. There are two types of IoC containers in Spring:

* ApplicationContext – Provides additional functionality. It is built on top of the BeanFactory interface.
* BeanFactory – A prepackaged class containing a collection of beans. Instantiates the bean whenever as required by the clients

### Please explain the Dependency Injection in Spring. In how many ways can the same be used?

**Answer:** Instead of creating objects directly, Dependency Injection allows defining how objects should be created. As such, the code doesn’t directly contain connecting components and services together.

The configuration file has the information on which services are needed by which components. The IoC container is responsible for connecting components with the appropriate services. Dependency Injection can be used in the following forms:

1. Construction Injection
2. Setter Injection

### Can you differentiate between ApplicationContext and BeanFactory in Spring?

**Answer:**

* Annotation Based Dependency – BeanFactory doesn’t support annotation-based dependency while ApplicationContext does
* Interface Definition – BeanFactory interface is defined in org.springframework.beans.factory.BeanFactory while the ApplicationContext interface is defined in org.springframework.context.ApplicationContext
* Internationalization Support – While ApplicationContext supports internationalization, BeanFactory doesn’t
* Object Management – BeanFactory uses syntax for providing a resource object. Contrarily, ApplicationContext creates as well as manages resource objects on its own
* Type of Initialization – ApplicationContext makes use of eager or aggressive initialization. On the other hand, BeanFactory uses lazy initialization

### How is the configuration metadata provided to the Spring container?

**Answer:** There are three ways in which the configuration metadata is provided to the Spring container, enumerated as follows:

* Annotation-based Configuration – By default, annotation wiring is turned off in the Spring container. Using annotations on the applicable class, field, or method declaration allows it to be used as a replacement of using XML for describing a bean wiring.
* Java-based Configuration – This is the newest form of configuration metadata in Spring Framework. It has two important components:
  1. @Bean annotation – Same as that of the <bean/> element
  2. @Configuration annotation – Allows defining inter-bean dependencies by simply calling other @Bean methods in the same @Configuration class
* XML-based Configuration – The dependencies, as well as the services required by beans, are specified in configuration files that follow the XML format. Typically, these configuration files contain several application-specific configuration options and bean definitions.

### **W**hat do you understand by Spring Beans? How many bean scopes are supported by Spring Framework?

**Answer:** Configured, instantiated, managed, and wired by the Spring IoC container, Spring Beans are the objects that form the core of a Spring application. Spring Beans are created with the configuration metadata supplied to the Spring IoC container.

Spring Framework provides support for a total of 5 scopes:

* Global-session\* – Provides scope for a bean definition to a Global HTTP-session
* Prototype – Provides scope for a single bean definition for having any number of object instances
* Request\* – Provides scope for a bean definition to an HTTP-request
* Session\* – Provides scope for the bean definition to a single instance per Spring IoC container
* Singleton – Provides scope for the bean definition to a single instance per Spring IoC container \* ? Available only when using a web-aware ApplicationContext.

### **P**lease explain the Bean lifecycle in Spring Bean Factory Container?

**Answer:**

1. The bean lifecycle starts with the Spring IoC container instantiating the bean from the bean’s definition present in the XML file
2. As specified in the bean definition, Spring then populates all properties using DI
3. If the bean implements the BeanNameAware interface then the setBeanName() method is called by passing the bean ID
4. If the bean implements the BeanFactoryAware interface, the setBeanFactory() method is called by passing an instance of the bean
5. If there are any BeanPostProcessors associated with the bean then the preProcessBeforeInitialization() methods are called
6. The [init method](https://stackoverflow.com/questions/5419695/init-method-in-spring-controller-annotation-version) is called if it is specified for the bean
7. At last, the postProcessAfterInitialization() methods are called if there are any BeanPostProcessors associated with the bean.

**What is a Spring Configuration File?**

**Answer:**Since Spring is based on the concept of Dependency Injection, all the classes, interfaces, and their dependencies are stored in a file termed as the spring configuration file. It is a .xml file. The spring container uses this file to control the lifecycle of spring beans. A bean is configured as:

<bean id = "..." **class** = "..." init-method = "..." lazy-init="true" destroy-method="....">  
      <!-- bean dependencies and configurations -->  
</**bean**>

### **What are the benefits of IoC (Inversion of Control)?**

**Answer:** The advantages are:

* No need to write extensive code on how services are created and getting object references. Everything can be achieved through simple configurations. New dependencies and services can be added just by adding a constructor or setter method.
* Code is more accessible to unit test as it is designed as several components, and developers can inject their objects and switch implementations.
* Loose coupling of components.
* Allows for lazy loading of objects and dependencies.

### **What is the Bean life cycle in Spring Bean Factory Container?**

**Answer:** The bean lifecycle is as follows:

* The bean is instantiated by the Spring container from the bean definition found in the spring configuration file.
* Using dependency injection, all the properties specified in the bean definition are populated.
* If the bean implements the BeanNameAware interface, setBeanName() is called by the bean factory bypassing the bean's ID.
* If the bean implements the BeanNameAware interface, setBeanFactory() is called by passing the bean's instance.
* If any BeanPreProcessors are associated with the bean, preProcessBeforeInitialization(), methods are called.
* Init-method, if defined for the bean, will be called.
* Lastly, postProcessAfterInitialization() methods are called, if required.

### **Explain inner beans in Spring.**

**Answer:** Inner beans are the beans that exist within the scope of another bean. The concept is similar to inner classes in Java. The inner bean is defined as the target inside the outer bean id tag.

<bean id = "outerBean" **class** = "...">  
      <**property** name = "target">  
         <**bean** id = "innerBean" class = "..."/>  
      </**property**>  
</**bean**>

### What is Annotation-based container configuration? Also, explain how to turn on annotation wiring in Spring Framework.

**Answer:** Annotation-based container configuration is an alternative to XML setups. Rather than using XML for describing a bean wiring, the developer moves the configuration to the component class by using annotations on the appropriate class, field, or method declaration.

Because annotation wiring is turned off by default, it needs to be turned on before it can be used. It is done by configuring the <context:annotation-config/> element in the Spring configuration file.

### Please explain the various annotations supported by Spring.

**Answer:**

* @Autowired – Used for autowiring bean on the setter methods, a property, constructor or methods with arbitrary names or several arguments. It provides precise control over how and where the autowiring needs to be done.
* @Component – A generic stereotype for a Spring-managed component, it marks a Java class as a bean that can be picked up by a component-scanning mechanism and pull it into the application context.
* @Controller – Marks a class as a Spring Web MVC controller. Beans marked with this annotation are automatically imported into the Dependency Injection container.
* @Qualifier – Used along with @Autowired annotation for specifying that only one of the several yet alike beans, needs to be wired.
* @Repository – A specialization of the component annotation with almost identical use and functionality. Specifically, it provides additional benefits for [DAOs (Data Access Objects)](https://docs.spring.io/spring/docs/4.2.x/spring-framework-reference/html/dao.html).
* @RequestMapping – Maps a particular HTTP request method to a specific class or method in controller responsible for handling the respective request.
* @Required – Applied to bean property setter methods, it indicates that the bean property needs to be populated at the configuration time with the use of an explicit property value present in a bean definition or via autowiring. In case the bean property is not populated, the container throws the BeanInitializationException message.
* @Service – Another specialization of the component annotation. Although it doesn’t offer any additional behavior over the component annotation, it can be used over the @component annotation in service-layer classes for specifying the intent in a better way.

### **W**hat do you mean by Spring DAO support?

**Answer:** The Spring DAO support eases working with data access technologies, such as JDBC, JDO, and Hibernate, in a reliable way. Also, it allows coding without worrying about catching specific-technology exceptions and easily makes a switch amongst persistence technologies.

### What classes does the JDBC API contain?

**Answer:**

* JdbcTemplate
* NamedParameterJdbcTemplate
* SimpleJdbcCall
* SimpleJdbcInsert
* SimpleJdbcTemplate

### How will you access Hibernate using Spring Framework?

**Answer:** [Hibernate](https://hackr.io/tutorials/learn-hibernate-framework?ref=blog-post) can be accessed using Spring Framework in the following two ways:

1. Extending HibernateDAOSupport and then applying an AOP Interceptor node
2. Inversion of Control with a Hibernate Template and Callback

### Enumerate the types of transaction management supported by Spring.

**Answer:**Spring Framework provides support for two types of transaction management:

* Declarative transaction management – While the transaction management is separated from the business code, only annotations or XML-based configurations are used for managing transactions.
* Programmatic transaction management – The transaction is managed with programming. Although extremely flexible, it is very difficult to maintain.

### Please explain the AOP technique.

**Answer:** AOP or Aspect-Oriented Programming is a programming technique that allows programmers to modularize behavior that cuts across the typical division of responsibility or cross-cutting concerns. Logging and transaction management are examples of cross-cutting concerns.

### What is Advice in Spring? Explain its various types.

**Answer:** Any action taken by an aspect at some particular joinpoint in Spring Framework is called an Advice. Spring AOP makes use of advice for maintaining a chain of interceptors “around” the joinpoint i.e. as an interceptor. Advice can be of the following types:

1. After (finally) – Configured using the @After annotation mark, it is executed after a joinpoint method, whether exiting normally or throwing an exception
2. After returning – Configured using the @AfterReturning annotation mark, it is executed right after the joinpoint method completes normal execution
3. After throwing – Configured using the @AfterThrowing annotation mark, it is executed if and only if the jointpoint method exits by throwing an exception
4. Around – Configured using the @Around annotation mark, it is executed before as well as after a joinpoint method
5. Before – Configured using the @Before annotation mark, it is executed before the joinpoint method

### Could you draw a comparison between concern and crosscutting concerns in Spring AOP?

**Answer:** While the concern is a behavior that the developer wants to have in a particular module of a Spring application, the cross-cutting concern is a concern that is applicable throughout the entire Spring application.

### What do you understand by the Spring MVC framework?

**Answer:** The Spring MVC framework is responsible for providing model-view-controller architecture as well as ready-to-use components, used for developing flexible and loosely coupled web apps.

The MVC pattern helps in separating out the various aspects of the application, such as business logic, input logic, and UI logic, in addition to providing a loose coupling amongst these separated elements.

### Please explain DispatcherServlet.

**Answer:** The DispatcherServlet is the essence of Spring Web MVC framework and handles all the HTTP requests as well as responses. Upon receiving the entry of handler mapping from the configuration file, the DispatcherServlet forwards the request to the controller.

Thereafter, the controller returns an object of Model and View. Afterward, the Dispatcher Servlet checks the configuration file for the entry of view resolver and calls the specified view component.

### **What is Spring?**

**Answer:**Spring is an integrated framework that is used for developing enterprise applications in Java language.

### **Are there any differences between the Bean Factory and Application Context?**

**Answer:**Yes, there are many differences between the Bean Factory and Application Context. These are stated as under:

|  |  |
| --- | --- |
| Bean Factory | Application Context |
| It is a basic container | It is an advanced container |
| It has a limited interface. | It extends the Bean Factory interface |
| It offers various fundamental facilities. | It offers additional facilities than Bean Factory, including integration with Spring AOP, Message Resource Handling for i18n, and various others. |

### What are the differences between the Constructor Injection and Setter Injection?

**Answer:**The differences between the Constructor Injection and Setter Injection can be stated as under

|  |  |
| --- | --- |
| Constructor Injection | Setter Injection |
| It has a complete injection | It has a partial injection |
| It does not override the setter property | It overrides the constructor property when they both are defined. |
| It creates new Instances when modifications are required. | It does not create a new Instance when the property value is changed. |
| It is better for many more properties than Setter Injection | It is good for a few properties. |

### **Define Autowriting in Spring?**

**Answer:**Autowiring in Spring helps the computer programmers to apply bean automatically without writing explicit injection logic. The various auto writing modes include the following.

1. No.
2. byname.
3. byType.
4. Constructor.

### **What are the different types of Bean scopes in Spring framework?**

**Answer:**There are mainly five types of Bean scopes in the Spring framework. These include the following.

1. Singleton.
2. Prototype.
3. Request.
4. Session.
5. Global session.

### **What is a Pointcut in Spring?**

**Answer:**Pointcut is an expression language of Spring AOP.

What are the different latest versions of Spring framework?

The latest versions of the Spring framework are as follows.

1. Spring 2.5
2. Spring 3.0
3. Spring 4.0

### **What is a JoinPoint?**

**Answer:**A JoinPoint is a point during the execution of a program and represents the method execution. It includes the execution of a method or even handling of an exception.

### **What are the differences between Spring AOP and AspectJ AOP?**

**Answer:**There are several differences between Spring AOP and AspectJ AOP, which are stated as under:

|  |  |
| --- | --- |
| Spring AOP | AspectJ AOP |
| The proxy is done through Runtime weaving. | Compile-time weaving is done through AspectJ Java tools |
| Method level PointCut is applied | Field level PointCut is applied |
| It is based on DTD | It is based on schema and annotation configuration |

### **What is a proxy in Spring Framework?**

**Answer:**A proxy in the Spring framework is referred to as the creation of an object after applying advice to a particular target object.

### **When are the target object and proxy objects the same?**

**Answer:**The target object and proxy object are the same in the case of client objects.

### **What is weaving in the Spring framework?**

**Answer:**Weaving in Spring framework is the process of linking a particular aspect with other application types or objects so that an advised object is created. It is performed mostly during Runtime.

### **What is Spring Security?**

**Answer:**Spring Security is a separate module in the Spring framework that focuses on offering authentication and authorization methods that can be used in Java Applications.

### **What is the Spring Boot?**

**Answer:**Spring Boot is the name given to a project which offers a pre-configured set of the framework, which is meant to reduce the boilerplate configuration. It helps in getting spring applications up and running with lesser codes.

### **What is Reactive Programming?**

**Answer:**Reactive programming is a non-blocking and event-driven application. It scales with a small number of threads. The backpressure is on the key ingredient, which ascertains that the producers do not overwhelm consumers.

### **What are the benefits of Reactive Programming?**

**Answer:**There are various benefits of Reactive Programming, which include the following.

1. It helps in increasing the utilization of computing resources, including multicore and multi-CPU hardware.
2. It helps in increasing performance by a reduction in the serialization process.

### **What are the important characteristics of the Reactive system?**

**Answer:**The important characteristics of the Reactive system includes the following.

1. Message-driven.
2. Resilient.
3. Responsive.
4. Elastic.

### **Define Spring Webflux?**

**Answer:**Spring Web flux is a highly reactive web framework of Spring. It acts as an alternative to Spring MVC and offers a highly scalable and non-blocking stack.

### **Define Mono and Flux types?**

**Answer:**Mono and Flux types, are both the reactor of the Spring Framework 5. The Mono represents the single async value, while the Flux represents the stream of async value. Together they help to implement the publisher interface, which is defined clearly in the reactive streams specifications.

### **What is the basic difference between Mono and Flux in Spring?**

**Answer:**Mono implements the publisher and returns 0 or even one element while the Flux implements the publisher and return N elements.

### **What are the common features of Mono and Flux?**

**Answer:**The common features of Mono and Flux include the following.

1. They represent streams.
2. They can’t be executed without consuming the stream using the subscribe method.
3. They are immutable and can be called again and again to create a new instance of Flux or Mono.

### **Difference between the Web client and Webtestclient?**

**Answer:**The difference between the Web client and Webtestclient can be stated as follows.

|  |  |
| --- | --- |
| Web client | Webtestclient |
| Web client acts as a reactive client who performs non-blocking HTTP requests. | Webtestclient also acts as a reactive client that can be used in tests. |
| It can handle reactive streams with backpressure. | It can bind directly to WebFlux application by applying mock request and response objects. |
| It can take advantage of JAVA 8 Lambdas. | It can connect to any server over an HTTP connection. |

### **Do you think that Spring 5 compatible with older versions of JAVA?**

**Answer:**No, Spring 5 is not compatible with the older versions of JAVA. It requires at least JAVA 8 for attaining compatibility.

### **Can Spring Boot allow Spring MVC or Spring WebFlux in the same application?**

**Answer:**Yes, Spring Boot can allow either Spring MVC or Spring WebFlux in the same application but with the condition to apply only one at a time. This is because MVC is a blocking paradigm, and WebFlux is a non-blocking paradigm and hence cannot be used together.

### **Can Spring MVC run on Netty?**

**Answer:**No, Spring MVC cannot run on Netty.

### **Can Spring 5 Integrate with the Jdk9 Modularity?**

**Answer:**Yes, Spring 5 could integrate with the Jdk9 Modularity. This can be stated as follows.

Step 1: Creating a new class:

**package** com.hello;  
**public** **class** **HelloWorld** {  
    **public** String **sayHello**(){  
        **return** "HelloWorld";  
    }  
}

Step 2: Creating a new module:

module com.hello {  
    **export** com.hello;  
}

Step 3: Creating a new Java Project:

**module** com.hello.client {  
    **requires** com.hello;  
}

Step 4: Testing the new module:

**public** **class** **HelloWorldClient** {  
    **public** **static** **void** **main**(String[] args){  
        HelloWorld helloWorld = **new** HelloWorld();  
        log.info(helloWorld.sayHello());  
    }  
}

# Hibernate

### **What is Hibernate?**

[*Hibernate*](https://www.edureka.co/blog/what-is-hibernate-in-java/) is one of the most popular [*Java frameworks*](https://www.edureka.co/blog/java-frameworks/) that simplify the development of Java application to interact with the database. It is an Object-relational mapping (ORM) tool. Hibernate also provides a reference implementation of Java API.

It is referred as a framework which comes with an abstraction layer and also handles the implementations internally. The implementations include tasks like writing a query for [*CRUD*](https://www.edureka.co/blog/node-js-mysql-tutorial/) operations or establishing a connection with the databases, etc.

Hibernate develops persistence logic, which stores and processes the data for longer use. It is a lightweight tool and most importantly **open-sourced**which gives it an edge over other frameworks.

### **What are the major advantages of Hibernate Framework?**

* It is open-sourced and lightweight.
* Performance of Hibernate is very fast.
* Helps in generating database independant queries.
* Provides facilities to automatically create a table.
* It provides query statistics and database status.

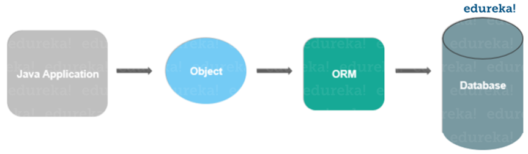
### **What are the advantages of using Hibernate over JDBC?**

Major advantages of using Hibernate over JDBC are:

1. Hibernate eliminates a lot of boiler-plate code that comes with [*JDBC API*](https://www.edureka.co/blog/connect-mysql-database-in-java/), the code looks cleaner and readable.
2. This Java framework supports [*inheritance*](https://www.edureka.co/blog/inheritance-in-java/), associations, and collections. These features are actually not present in JDBC.
3. HQL (Hibernate Query Language) is more object-oriented and close to Java. But for JDBC, you need to write native SQL queries.
4. Hibernate implicitly provides transaction management whereas, in JDBC API, you need to write code for transaction management using commit and rollback.
5. JDBC throws SQLException that is a checked exception, so you have to write a lot of try-catch block code. Hibernate wraps JDBC exceptions and throw JDBCException or HibernateException which are the unchecked exceptions, so you don’t have to write code to handle it has built-in transaction management which helps in removing the usage of try-catch blocks.

### **What is an ORM tool?**

It is basically a technique that maps the object that is stored in the database. An ORM tool helps in simplifying data creation, manipulation, and access. It internally uses the Java API to interact with the databases.



### **Why use Hibernate Framework?**

Hibernate overcomes the shortcomings of other technologies like [*JDBC*](https://www.edureka.co/blog/connect-mysql-database-in-java).

* It overcomes the database dependency faced in the JDBC.
* Changing of the databases cost a lot working on JDBC, hibernate overcomes this problem with flying colors.
* Code portability is not an option while working on JDBC. This is easily handled by Hibernate.
* Hibernate strengthens the object level relationship.
* It overcomes the [*exception-handling*](https://www.edureka.co/blog/java-exception-handling) part which is mandatory while working on JDBC.
* It reduces the length of code with increased readability by overcoming the boilerplate problem.

### **What are the different functionalities supported by Hibernate?**

* Hibernate is an ORM tool.
* Hibernate uses Hibernate Query Language(HQL) which makes it database-independent.
* It supports auto DDL operations.
* This Java framework also has an Auto Primary Key Generation support.
* Supports cache memory.
* Exception handling is not mandatory in the case of Hibernate.

### **What are the technologies that are supported by Hibernate?**

Hibernate supports a variety of technologies, like:

* XDoclet Spring
* [*Maven*](https://www.edureka.co/blog/create-selenium-maven-project/)
* Eclipse Plug-ins
* J2EE

### **What is HQL?**

HQL is the acronym of Hibernate Query Language. It is an Object-Oriented Query Language and is independent of the database.

### **How to achieve mapping in Hibernate?**

Association mappings are one of the key features of Hibernate. It supports the same associations as the relational database model. They are:

* One-to-One associations
* Many-to-One associations
* Many-to-Many associations

You can map each of them as a uni- or bidirectional association.

### **Name some of the important interfaces of Hibernate framework?**

Hibernate interfaces are:

* **SessionFactory** (org.hibernate.SessionFactory)
* **Session** (org.hibernate.Session)
* **Transaction** (org.hibernate.Transaction)

### **What is One-to-One association in Hibernate?**

In this type of mapping,  you only need to model the system for the entity for which you want to navigate the relationship in your query or domain model. You need an entity attribute that represents the association, so annotate it with an @OneToOne annotation.

### **What is One-to-Many association in Hibernate?**

In this type of association, one object can be associated with multiple/different objects. Talking about the mapping, the One-to-Many mapping is implemented using a [*Set Java*](https://www.edureka.co/blog/sets-in-java/) collection that does not have any redundant element. This One-to-Many element of the set indicates the relation of one object to multiple objects.

### **What is Many-to-Many association in Hibernate?**

Many-to-Many mapping requires an entity attribute and a @ManyToMany annotation. It can either be unidirectional and bidirectional. In **Unidirectional**, the attributes model the association and you can use it to navigate it in your domain model or JPQL queries. The annotation tells Hibernate to map a Many-to-Many association. The **bidirectional** relationship, mapping allows you to navigate the association in both directions.

### **How to integrate Hibernate and Spring?**

[*Spring*](https://www.edureka.co/blog/spring-tutorial/) is also one of the most commonly used Java frameworks in the market today. Spring is a JavaEE Framework and Hibernate is the most popular ORM framework. This is why Spring Hibernate combination is used in a lot of enterprise applications.

Following are the steps you should follow to integrate Spring and Hibernate.

1. Add Hibernate-entity manager, Hibernate-core and Spring-ORM dependencies.
2. Create Model classes and corresponding DAO implementations for database operations. The DAO classes will use SessionFactory that will be injected by the Spring Bean configuration.
3. Note that you don’t need to use Hibernate Transaction Management, as you can leave it to the Spring declarative transaction management using @Transactional annotation.

### **What do you mean by Hibernate Configuration File?**

Hibernate Configuration File mainly contains database-specific configurations and are used to initialize SessionFactory. Some important parts of the Hibernate Configuration File are Dialect information, so that hibernate knows the database type and mapping file or class details.

### **Mention some important annotations used for Hibernate mapping?**

Hibernate supports JPA annotations. Some of the major annotations are:

1. **javax.persistence.Entity:** This is used with model classes to specify they are entity beans.
2. **javax.persistence.Table:** It is used with entity beans to define the corresponding table name in the database.
3. **javax.persistence.Access:** Used to define the access type, field or property. The default value is field and if you want Hibernate to use the getter/setter methods then you need to set it to a property.
4. **javax.persistence.Id:** Defines the primary key in the entity bean.
5. **javax.persistence.EmbeddedId:** It defines a composite primary key in the entity bean.
6. **javax.persistence.Column:** Helps in defining the column name in the database table.
7. **javax.persistence.GeneratedValue:**It defines the strategy to be used for the generation of the primary key. It is also used in conjunction with javax.persistence.GenerationType enum.

### **What is Session in Hibernate and how to get it?**

Hibernate Session is the interface between Java application layer and Hibernate. It is used to get a physical connection with the database. The Session object created is lightweight and designed to be instantiated each time an interaction is needed with the database. This Session provides methods to create, read, update and delete operations for a constant object. To get the Session, you can execute HQL queries, SQL native queries using the Session object.

### **What is Hibernate SessionFactory?**

SessionFactory is the factory class that is used to get the Session objects. The SessionFactory is a heavyweight object so usually, it is created during application startup and kept for later use. This SessionFactory is a thread-safe object which is used by all the threads of an application. If you are using multiple databases then you would have to create multiple SessionFactory objects.

### **What is the difference between openSession and getCurrentSession?**

This getCurrentSession() method returns the session bound to the context and for this to work, you need to configure it in Hibernate configuration file. Since this session object belongs to the context of Hibernate, it is okay if you don’t close it. Once the SessionFactory is closed, this session object gets closed.

openSession() method helps in opening a new session. You should close this session object once you are done with all the database operations. And also, you should open a new session for each request in a multi-threaded environment.

### **What do you mean by Hibernate configuration file?**

The following steps help in configuring Hibernate file:

1. First, identify the POJOs (Plain Old Java Objects) that have a database representation.
2. Identify which properties of POJOs need to be continued.
3. Annotate each of the POJOs in order to map the Java objects to columns in a database table.
4. Create a database schema using the schema export tool which uses an existing database, or you can create your own database schema.
5. Add Hibernate Java libraries to the application’s classpath.
6. Create a Hibernate XML configuration file that points to the database and the mapped classes.
7. In the Java application, you can create a Hibernate Configuration object that refers to your XML configuration file.
8. Also, build a Hibernate SessionFactory object from the Configuration object.
9. Retrieve the Hibernate Session objects from the SessionFactory and write down the data access logic for your application (create, retrieve, update, and delete).

### **What are the key components of a Hibernate configuration object?**

The configuration provides 2 key components, namely:

* Database Connection: This is handled by one or more configuration files.
* Class Mapping setup: It helps in creating the connection between Java classes and database tables.

### **Discuss the Collections in Hibernate**

Hibernate provides the facility to persist the Collections. A [*Collection*](https://www.edureka.co/blog/java-collections/) basically can be a List, Set, Map, Collection, Sorted Set, Sorted Map. java.util.List, java.util.Set, java.util.Collection, etc, are some of the real interface types to declared the persistent collection-value fields. Hibernate injects persistent Collections based on the type of interface. The collection instances generally behave like the types of value behavior.

### **What are the collection types in Hibernate?**

There are five collection types in hibernate used for one-to-many relationship mappings.

* Bag
* Set
* List
* Array
* Map

### **What is a Hibernate Template class?**

When you integrate Spring and Hibernate, Spring ORM provides two helper classes – HibernateDaoSupport and HibernateTemplate. The main reason to use them was to get two things, the Session from Hibernate and Spring Transaction Management. However, from Hibernate 3.0.1, you can use the SessionFactory getCurrentSession() method to get the current session. The major advantage of using this Template class is the **exception translation** but that can be achieved easily by using @Repository annotation with service classes.

### **What are the benefits of using Hibernate template?**

The following are the benefits of using this Hibernate template class:

* Automated Session closing ability.
* The interaction with the Hibernate Session is simplified.
* Exception handling is automated.

### **Which are the design patterns that are used in Hibernate framework?**

There are a few design patterns used in Hibernate Framework, namely:

* Domain Model Pattern: An object model of the domain that incorporates both behavior as well as data.
* Data Mapper: A layer of the map that moves data between objects and a database while keeping it independent of each other and the map itself.
* Proxy Pattern: It is used for lazy loading.
* Factory Pattern: Used in SessionFactory.

### **Define Hibernate Validator Framework**

Data validation is considered as an integral part of any application. Also, data validation is used in the presentation layer with the use of Javascript and the server-side code before processing. It occurs before persisting it in order to make sure it follows the correct format. Validation is a cross-cutting task, so we should try to keep it apart from the business logic. This Hibernate Validator provides the reference implementation of bean validation specs.

### **What is Dirty Checking in Hibernate?**

Hibernate incorporates Dirty Checking feature that permits developers and users to avoid time-consuming write actions. This Dirty Checking feature changes or updates fields that need to be changed or updated, while keeping the remaining fields untouched and unchanged.

### **How can you share your views on mapping description files?**

* Mapping description files are used by the Hibernate to configure functions.
* These files have the **\*.hbm** extension, which facilitates the mapping between database tables and Java class.
* Whether to use mapping description files or not this entirely depends on business entities.

### **What is meant by Light Object Mapping?**

The means that the syntax is hidden from the business logic using specific design patterns. This is one of the valuable levels of ORM quality and this Light Object Mapping approach can be successful in case of applications where there are very fewer entities, or for applications having data models that are metadata-driven.

### **What is meant by Hibernate tuning?**

Optimizing the performance of Hibernate applications is known as Hibernate tuning.

The performance tuning strategies for Hibernate are:

1. SQL Optimization
2. Session Management
3. Data Caching

### **What is Transaction Management in Hibernate? How does it work?**

Transaction Management is a property which is present in the Spring framework. Now, what role does it play in Hibernate?

Transaction Management is a process of managing a set of commands or statements. In hibernate, Transaction Management is done by transaction interface. It maintains abstraction from the transaction implementation (JTA, JDBC). A transaction is associated with Session and is instantiated by calling session.beginTransaction().

### **How do you integrate Hibernate with Struts2 or Servlet web applications?**

You can integrate any Struts application with Hibernate. There are no extra efforts required.

1. Register a custom ServletContextListener.
2. In the ServletContextListener class, first, initialize the Hibernate Session, store it in the servlet context.
3. Action class helps in getting the Hibernate Session from the servlet context, and perform other Hibernate task as normal.

### **What are the different states of a persistent entity?**

It may exist in one of the following 3 states:

* Transient: This is not associated with the Session and has no representation in the database.
* Persistent: You can make a transient instance persistent by associating it with a Session.
* Detached: If you close the Hibernate Session, the persistent instance will become a detached instance.

### **How can the primary key be created by using Hibernate?**

A Primary key is a special relational database table column designated to uniquely identify all table records. It is specified in the configuration file hbm.xml. The generator can also be used to specify how a Primary key can be created in the database.

|  |  |
| --- | --- |
| 1  2  3  4 | <id name="ClassID" type="string" >  <column name= "columnID" length="10" >  <generator/>  </id> |

### **Explain about Hibernate Proxy and how it helps in Lazy loading?**

* Hibernate uses a proxy object in order to support Lazy loading.
* When you try loading data from tables, Hibernate doesn’t load all the mapped objects.
* After you reference a child object through getter methods, if the linked entity is not present in the session cache, then the proxy code will be entered to the database and load the linked object.
* It uses Java assist to effectively and dynamically generate sub-classed implementations of your entity objects.

### **How can we see Hibernate generated SQL on console?**

In order to view the SQL on a console, you need to add following in Hibernate configuration file to enable viewing SQL on the console for debugging purposes:

|  |  |
| --- | --- |
| 1 | <property name="show\_sql">true</property> |

### **What is Query Cache in Hibernate?**

Hibernate implements a separate cache region for queries resultset that integrates with the Hibernate second-level cache. This is also an optional feature and requires a few more steps in code.

***Note:*** This is only useful for queries that are run frequently with the same parameters.

### **What is the benefit of Native SQL query support in Hibernate?**

Hibernate provides an option to execute Native SQL queries through the use of the [SQLQuery](https://www.edureka.co/blog/insert-query-sql/)object. For normal scenarios, it is however not the recommended approach because you might lose other benefits like Association and Hibernate first-level caching.

Native SQL Query comes handy when you want to execute database-specific queries that are not supported by Hibernate API such query hints or the Connect keyword in Oracle Database.

### **What is Named SQL Query?**

Hibernate provides another important feature called Named Query using which you can define at a central location and use them anywhere in the code.

You can create named queries for both HQL as well as for Native SQL. These Named Queries can be defined in Hibernate mapping files with the help of JPA annotations @NamedQuery and @NamedNativeQuery.

### **When do you use merge() and update() in Hibernate?**

This is one of the tricky Hibernate Interview Questions asked.

update(): If you are sure that the Hibernate Session does not contain an already persistent instance with the same id .  
*merge():*  Helps in merging your modifications at any time without considering the state of the Session.

### **Difference between get() vs load() method in Hibernate?**

This is one of the most frequently asked Hibernate Interview Questions. The key difference between the get() and load() method is:

load(): It will throw an exception if an object with an ID passed to them is not found.  
get():  Will return null.

load(): It can return proxy without hitting the database unless required.  
get(): It always goes to the database.

So sometimes using load() can be faster than the get() method.

### **Difference between the first and second level cache in Hibernate?**

The first-level cache is maintained at Session level while the second level cache is maintained at a SessionFactory level and is shared by all sessions.

### **Difference between Session and SessionFactory in Hibernate?**

This is yet another popular Hibernate Interview Question asked.

* *A Session* is a single-threaded, short-lived object. It provides the first-level cache.
* SessionFactory is immutable and shared by all Session. It also lives until the Hibernate is running. It also provides the second-level cache.

### **Difference between save() and saveOrUpdate() method of Hibernate?**

Even though save() and saveOrUpdate() method is used to store an object into Database, the key difference between them is that save() can only **Insert** records but saveOrUpdate() can either Insert or Update records.

### **Difference between sorted and ordered collection in Hibernate?**

sorted collection sort the data in JVM’s heap memory using Java’s collection framework sorting methods. The ordered collection is sorted using order by clause in the database itself.

***Note:*** A sorted collection is more suited for small dataset but for a large dataset, it’s better to use ordered collection to avoid

### **Difference between the transient, persistent and detached state in Hibernate?**

**Transient state:** New objects are created in the Java program but are not associated with any Hibernate Session.

**Persistent state:** An object which is associated with a Hibernate session is called Persistent object. While an object which was earlier associated with Hibernate session but currently it’s not associate is known as a detached object. You can call save() or persist() method to store those object into the database and bring them into the Persistent state.

**Detached state**: You can re-attach a detached object to Hibernate sessions by calling either update() or saveOrUpdate() method.

### **Difference between managed associations and Hibernate associations?**

**Managed associations:** Relate to container management persistence and are bi-directional.

**Hibernate Associations:** These associations are unidirectional.

### **What are the best practices that Hibernate recommends for persistent classes?**

* All Java classes that will be persisted need a default constructor.
* All classes should contain an ID in order to allow easy identification of your objects within Hibernate and the database. This property maps to the primary key column of a database table.
* All attributes that will be persisted should be declared private and have **getXXX** and **setXXX** methods defined in the JavaBean style.
* A central feature of Hibernate, proxies, depends upon the persistent class being either non-final, or the implementation of an interface that declares all public methods.
* All classes that do not extend or implement some specialized classes and interfaces required by the EJB framework.

### **What are the best practices to follow with Hibernate framework?**

* Always check the primary key field access, if it’s generated at the database layer then you should not have a setter for this.
* By default hibernate set the field values directly, without using setters. So if you want Hibernate to use setters, then make sure proper access is defined as @Access(value=AccessType.PROPERTY).
* If access type is property, make sure annotations are used with getter methods and not setter methods. Avoid mixing of using annotations on both filed and getter methods.
* Use native sql query only when it can’t be done using HQL, such as using the database-specific feature.
* If you have to sort the collection, use ordered list rather than sorting it using Collection API.
* Use named queries wisely, keep it at a single place for easy debugging. Use them for commonly used queries only. For entity-specific query, you can keep them in the entity bean itself.
* For web applications, always try to use JNDI DataSource rather than configuring to create a connection in hibernate.
* Avoid Many-to-Many relationships, it can be easily implemented using bidirectional One-to-Many and Many-to-One relationships.
* For collections, try to use Lists, maps and sets. Avoid array because you don’t get benefit of lazy loading.
* Do not treat exceptions as recoverable, roll back the Transaction and close the Session. If you do not do this, Hibernate cannot guarantee that the in-memory state accurately represents the persistent state.
* Prefer DAO pattern for exposing the different methods that can be used with entity bean
* Prefer lazy fetching for associations