22. Multithreading in Java

Multithreading in java is a process of executing multiple threads simultaneously.

Thread is basically a lightweight sub-process, a smallest unit of processing. Multiprocessing and multithreading, both are used to achieve multitasking.

- But we use multithreading than multiprocessing because threads share a common memory area. They don't allocate separate memory area so saves memory, and context-switching between the threads takes less time than process.

Java Multithreading is mostly used in games, animation etc.

- **Advantages of Java Multithreading**

1) It **doesn't block the user** because threads are independent and you can perform multiple operations at same time.

2) You **can perform many operations together so it saves time**.

3) Threads are **independent** so it doesn't affect other threads if exception occur in a single thread.

22.1 <u>Multitasking</u>

Multitasking is a process of executing multiple tasks simultaneously. We use multitasking to utilize the CPU. Multitasking can be achieved by two ways:

- Process-based Multitasking(Multiprocessing)
- Thread-based Multitasking(Multithreading)

1) Process-based Multitasking (Multiprocessing)

- Each process have its own address in memory i.e. each process allocates separate memory area.
- Process is heavyweight.
- Cost of communication between the process is high.
- Switching from one process to another require some time for saving and loading registers, memory maps, updating lists etc.

2) Thread-based Multitasking (Multithreading)

- Threads share the same address space.

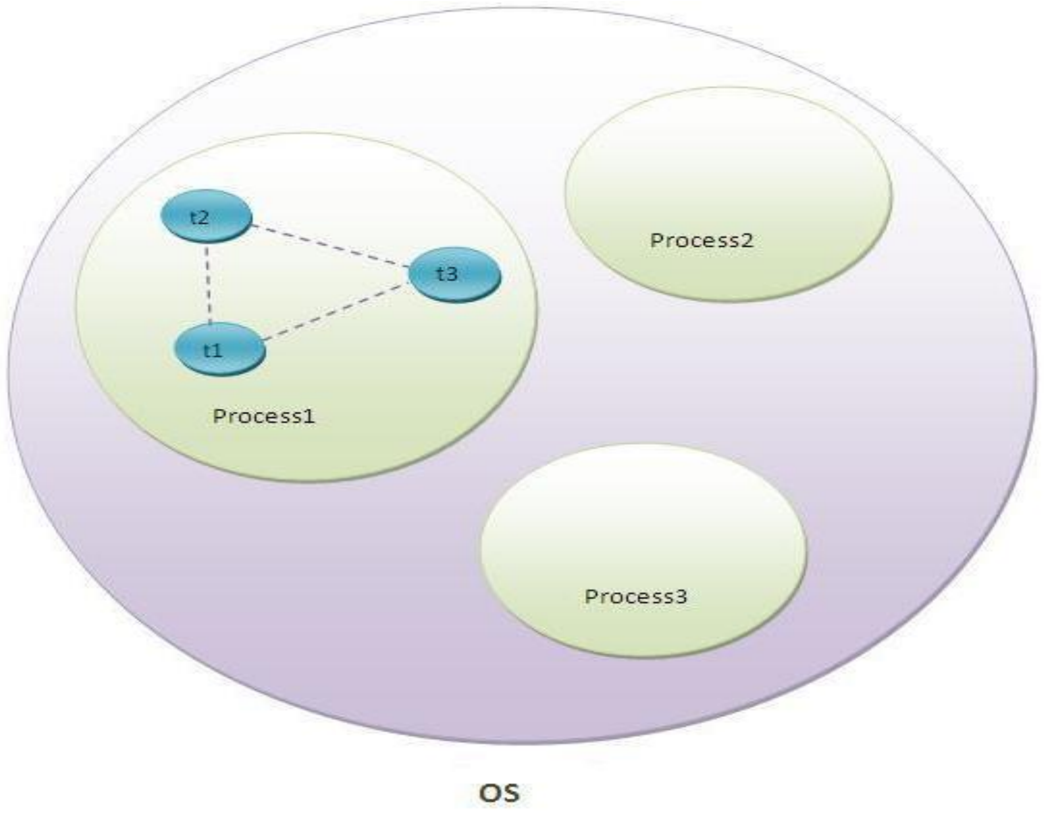
- Thread is lightweight.
- Cost of communication between the thread is low.

Note: At least one process is required for each thread.

Q.What is Thread in java?

A thread is a lightweight sub process, a smallest unit of processing. It is a separate path of execution.

Threads are independent, if there occurs exception in one thread, it doesn't affect other threads. It shares a common memory area.



- As shown in the above figure, thread is executed inside the process. There is context-switching between the threads.
- There can be multiple processes inside the OS and one process can have multiple threads.

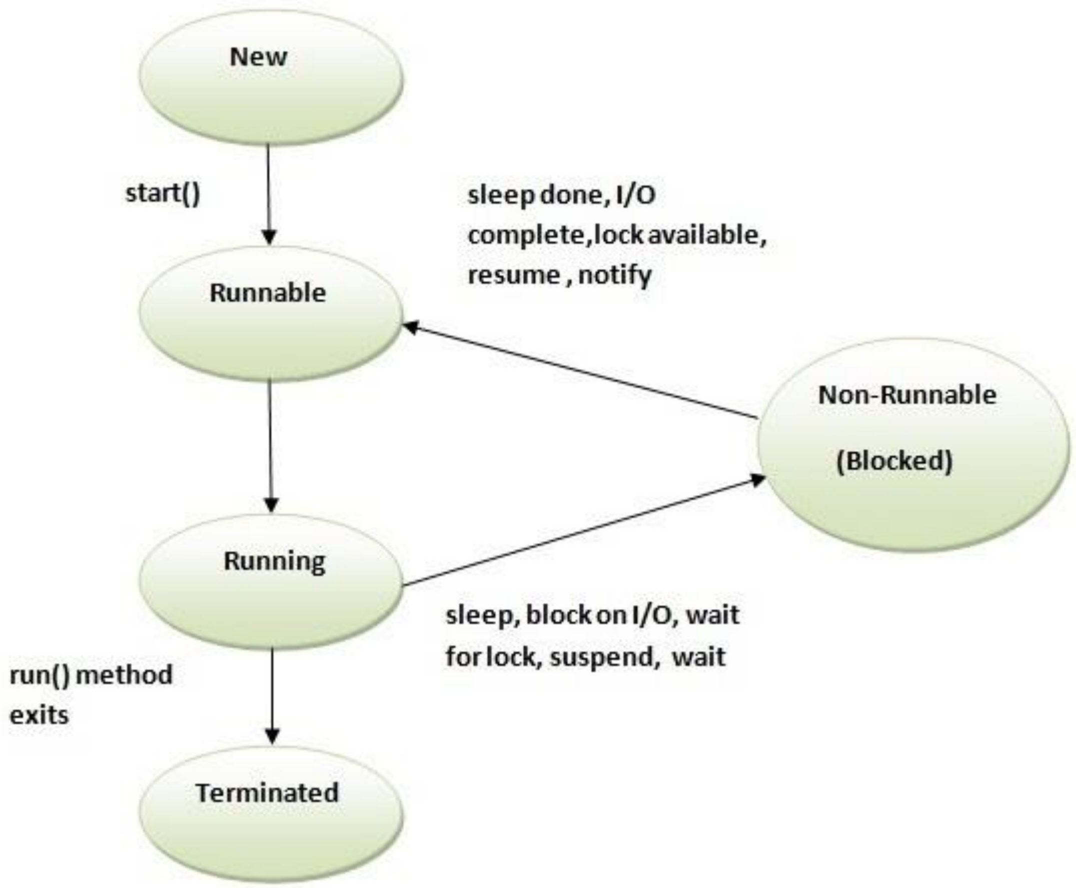
Note: At a time one thread is executed only.

22.2 Life cycle of a Thread (Thread States)

- A thread can be in one of the five states.
- According to sun, there is only 4 states in **thread life cycle in java** new, runnable, non-runnable and terminated. There is no running state.
- The life cycle of the thread in java is controlled by JVM.

The java thread states are as follows:

1. New
2. Runnable
3. Running
4. Non-Runnable (Blocked)
5. Terminated


New
start()
Runnable
sleep done, I/O complete,lock available, resume , notify
Non-Runnable (Blocked)
Running
sleep, block on I/O, wait for lock, suspend, wait
run() method exits
Terminated

1) New

The thread is in new state if you create an instance of Thread class but before the invocation of start() method.

2) Runnable

The thread is in runnable state after invocation of start() method, but the thread scheduler has not selected it to be the running thread.

3) Running

The thread is in running state if the thread scheduler has selected it.

4) Non-Runnable (Blocked)

This is the state when the thread is still alive, but is currently not eligible to run.

5) Terminated

A thread is in terminated or dead state when its run() method exits.

22.3 How to create thread :

There are two ways to create a thread:

1. By extending Thread class
2. By implementing Runnable interface.

- **Thread class:**

Thread class provide constructors and methods to create and perform operations on a thread.Thread class extends Object class and implements Runnable interface.

Commonly used Constructors of Thread class:

- Thread()
- Thread(String name)
- Thread(Runnable r)
- Thread(Runnable r,String name)

Commonly used methods of Thread class:

1. **public void run():** is used to perform action for a thread.
2. **public void start():** starts the execution of the thread.JVM calls the run() method on the thread.

3. **public void sleep(long miliseconds):** Causes the currently executing thread to sleep (temporarily cease execution) for the specified number of milliseconds.
4. **public void join():** waits for a thread to die.
5. **public void join(long miliseconds):** waits for a thread to die for the specified miliseconds.
6. **public int getPriority():** returns the priority of the thread.
7. **public int setPriority(int priority):** changes the priority of the thread.
8. **public String getName():** returns the name of the thread.
9. **public void setName(String name):** changes the name of the thread.
10. **public Thread currentThread():** returns the reference of currently executing thread.
11. **public int getId():** returns the id of the thread.
12. **public Thread.State getState():** returns the state of the thread.
13. **public boolean isAlive():** tests if the thread is alive.
14. **public void yield():** causes the currently executing thread object to temporarily pause and allow other threads to execute.
15. **public void suspend():** is used to suspend the thread(depricated).
16. **public void resume():** is used to resume the suspended thread(depricated).
17. **public void stop():** is used to stop the thread(depricated).
18. **public boolean isDaemon():** tests if the thread is a daemon thread.
19. **public void setDaemon(boolean b):** marks the thread as daemon or user thread.
20. **public void interrupt():** interrupts the thread.
21. **public boolean isInterrupted():** tests if the thread has been interrupted.
22. **public static boolean interrupted():** tests if the current thread has been interrupted.

➢ Runnable interface:

The Runnable interface should be implemented by any class whose instances are intended to be executed by a thread. Runnable interface have only one method named run().

1. **public void run():** is used to perform action for a thread.

➢ **Starting a thread:**

start() method of Thread class is used to start a newly created thread. It performs following tasks:

- A new thread starts(with new callstack).
- The thread moves from New state to the Runnable state.
- When the thread gets a chance to execute, its target run() method will run.

---

1) Java Thread Example by extending Thread class

```
class Multi extends Thread{
public void run(){
System.out.println("thread is running...");
}
public static void main(String args[]){
Multi t1=new Multi();
t1.start();
 }
}
```

Output: thread is running...

---

2) Java Thread Example by implementing Runnable interface

```
class Multi3 implements Runnable{
public void run(){
System.out.println("thread is running...");
}

public static void main(String args[]){
Multi3 m1=new Multi3();
Thread t1 =new Thread(m1);
t1.start();
 }
}
```

Output: thread is running...

22.4 Sleep method in java

The sleep() method of Thread class is used to sleep a thread for the specified amount of time.

- **Syntax of sleep() method in java**

The Thread class provides two methods for sleeping a thread:

- public static void sleep(long miliseconds)throws InterruptedException
- public static void sleep(long miliseconds, int nanos)throws InterruptedException

Example of sleep method in java

```
class TestSleepMethod1 extends Thread{
 public void run(){
  for(int i=1;i<5;i++){
    try{Thread.sleep(500);}catch(InterruptedException e){System.out.println(e);}
    System.out.println(i);
  }
 }
 public static void main(String args[]){
  TestSleepMethod1 t1=new TestSleepMethod1();
  TestSleepMethod1 t2=new TestSleepMethod1();

  t1.start();
  t2.start();
 }
}
```

Output:

```
1
1
2
2
3
3
4
4
```

- As you know well that at a time only one thread is executed. If you sleep a thread for the specified time,the thread shedular picks up another thread and so on.

22.5 Priority of a Thread (Thread Priority):

- Each thread have a priority. Priorities are represented by a number between 1 and 10.
- In most cases, thread schedular schedules the threads according to their priority (known as preemptive scheduling).
- But it is not guaranteed because it depends on JVM specification that which scheduling it chooses.
- If two threads have same priority then we can't expect which thread will execute first. It depends on thread scheduler's algorithm(Round-Robin, First Come First Serve, etc)

3 constants defined in Thread class:

1. public static int MIN_PRIORITY
2. public static int NORM_PRIORITY
3. public static int MAX_PRIORITY

Default priority of a thread is 5 (NORM_PRIORITY).
The value of MIN_PRIORITY is 1.
The value of MAX_PRIORITY is 10.

Example of priority of a Thread:

```
class TestMultiPriority1 extends Thread{
 public void run(){
   System.out.println("running thread name is:"+Thread.currentThread().getName());
   System.out.println("running thread priority is:"+Thread.currentThread().getPriority());

  }
 public static void main(String args[]){
  TestMultiPriority1 m1=new TestMultiPriority1();
  TestMultiPriority1 m2=new TestMultiPriority1();
  m1.setPriority(Thread.MIN_PRIORITY);
  m2.setPriority(Thread.MAX_PRIORITY);
  m1.start();
  m2.start();

 }
}
```

Output:
```
running thread name is: Thread-0
running thread priority is: 10
running thread name is: Thread-1
running thread priority is: 1
```

22.6 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.

Q. 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:

```
Employee e=new Employee();
e=null;
```

2) By assigning a reference to another:

```
Employee e1=new Employee();
Employee e2=new Employee();
e1=e2;//now the first object referred by e1 is available for garbage collection
```

3) By annonymous object:

```
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:

```java
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.

```java
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

```java
public class TestGarbage1{
 public void finalize(){System.out.println("object is garbage collected");}
 public static void main(String args[]){
  TestGarbage1 s1=new TestGarbage1();
  TestGarbage1 s2=new TestGarbage1();
  s1=null;
  s2=null;
  System.gc();
 }
}
```

Output:
```
object is garbage collected
object is garbage collected
```

22.7 Daemon Thread in Java

Daemon thread in java is a service provider thread that provides services to the user thread. Its life depend on the mercy of user threads i.e. when all the user threads dies, JVM terminates this thread automatically.

- There are many java daemon threads running automatically e.g. gc, finalizer etc.
- You can see all the detail by typing the jconsole in the command prompt. The jconsole tool provides information about the loaded classes, memory usage, running threads etc.

Points to remember for Daemon Thread in Java

- It provides services to user threads for background supporting tasks. It has no role in life than to serve user threads.
- Its life depends on user threads.
- It is a low priority thread.

Q. Why JVM terminates the daemon thread if there is no user thread?

The sole purpose of the daemon thread is that it provides services to user thread for background supporting task. If there is no user thread, why should JVM keep running this thread. That is why JVM terminates the daemon thread if there is no user thread.

Methods for Java Daemon thread by Thread class

The **java.lang.Thread** class provides two methods for java daemon thread.

No.	Method	Description
1)	public void setDaemon(boolean status)	is used to mark the current thread as daemon thread or user thread.
2)	public boolean isDaemon()	is used to check that current is daemon.

Simple example of Daemon thread in java

File: MyThread.java

```
public class TestDaemonThread1 extends Thread{
 public void run(){
  if(Thread.currentThread().isDaemon()) //checking for daemon thread
{
   System.out.println("daemon thread work");
  }
  else{
  System.out.println("user thread work");
 }
 }
 public static void main(String[] args){
  TestDaemonThread1 t1=new TestDaemonThread1();//creating thread
  TestDaemonThread1 t2=new TestDaemonThread1();
  TestDaemonThread1 t3=new TestDaemonThread1();

  t1.setDaemon(true);//now t1 is daemon thread

  t1.start();//starting threads
  t2.start();
  t3.start();
 }
}
```

Output

```
daemon thread work
user thread work
user thread work
```

Note: If you want to make a user thread as Daemon, it must not be started otherwise it will throw IllegalThreadStateException.

File: MyThread.java

```
class TestDaemonThread2 extends Thread{
 public void run(){
  System.out.println("Name: "+Thread.currentThread().getName());
  System.out.println("Daemon: "+Thread.currentThread().isDaemon());
 }

 public static void main(String[] args){
  TestDaemonThread2 t1=new TestDaemonThread2();
  TestDaemonThread2 t2=new TestDaemonThread2();
  t1.start();
  t1.setDaemon(true);//will throw exception here
  t2.start();
 }
}
```

Output: exception in thread main: java.lang.IllegalThreadStateException

22.8 Synchronized in Java

- **Multi-threaded** programs may often come to a situation where multiple threads try to access the same resources and finally produce erroneous and unforeseen results.
- So it needs to be made sure by some synchronization method that only one thread can access the resource at a given point of time.
- Java provides a way of creating threads and synchronizing their task by using synchronized blocks. Synchronized blocks in Java are marked with the synchronized keyword. A synchronized block in Java is synchronized on some object.
- All synchronized blocks synchronized on the same object can only have one thread executing inside them at a time.
- All other threads attempting to enter the synchronized block are blocked until the thread inside the synchronized block exits the block.
- This synchronization is implemented in Java with a concept called monitors. Only one thread can own a monitor at a given time.
- When a thread acquires a lock, it is said to have entered the monitor. All other threads attempting to enter the locked monitor will be suspended until the first thread exits the monitor.

Following is an example of multi threading with synchronized.

```
// A Java program to demonstrate working of
// synchronized.
import java.io.*;
import java.util.*;

// A Class used to send a message
class Sender
{
   public void send(String msg)
   {
      System.out.println("Sending\t"  + msg );
      try
      {
         Thread.sleep(1000);
      }
      catch (Exception e)
      {
         System.out.println("Thread  interrupted.");
      }
      System.out.println("\n" + msg + "Sent");
   }
}

// Class for send a message using Threads
class ThreadedSend extends Thread
{
   private String msg;
```

```
    private Thread t;
    Sender  sender;

    // Recieves a message object and a string
    // message to be sent
    ThreadedSend(String m,  Sender obj)
    {
        msg = m;
        sender = obj;
    }

    public void run()
    {
        // Only one thread can send a message
        // at a time.
        synchronized(sender)
        {
            // synchronizing the snd object
            sender.send(msg);
        }
    }
}

// Driver class
class SyncDemo
{
    public static void main(String args[])
    {
        Sender snd = new Sender();
        ThreadedSend S1 = new ThreadedSend( " Hi " , snd );
        ThreadedSend S2 = new ThreadedSend( " Bye " , snd );

        // Start two threads of ThreadedSend type
        S1.start();
        S2.start();

        // wait for threads to end
        try
        {
            S1.join();
            S2.join();
        }
        catch(Exception e)
        {
            System.out.println("Interrupted");
        }
    }
}
```

Output:

```
Sending  Hi


 Hi Sent
Sending  Bye


 Bye Sent
```

- In the above example, we chose to synchronize the Sender object inside the **run()** method of the ThreadedSend class.

- Alternately, we could define the **whole send() block as synchronized** and it would produce the same result. Then we don't have to synchronize the Message object inside the run() method in ThreadedSend class.

```
// An alternate implementation to demonstrate

// that we can use synchronized with method also.

class Sender

{

   public synchronized void send(String msg)

   {

      System.out.println("Sending\t" + msg );

      try

      {

         Thread.sleep(1000);

      }

      catch (Exception e)

      {

         System.out.println("Thread interrupted.");

      }

      System.out.println("\n" + msg + "Sent");

   }

}
```

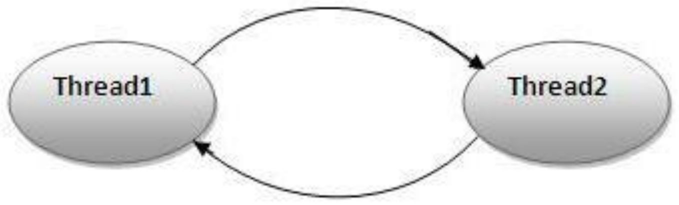
- We do not always have to synchronize a whole method. Sometimes it is preferable to **synchronize only part of a method**. Java synchronized blocks inside methods makes this possible.

```
// One more alternate implementation to demonstrate

// that synchronized can be used with only a part of

// method

class Sender

{

   public void send(String msg)

   {

      synchronized(this)
```

```
        {
           System.out.println("Sending\t" + msg );
           try
           {
              Thread.sleep(1000);
           }
           catch (Exception e)
           {
              System.out.println("Thread interrupted.");
           }
           System.out.println("\n" + msg + "Sent");
        }
    }
}
```

22.9 Deadlock in java

Deadlock in java is a part of multithreading. Deadlock can occur in a situation when a thread is waiting for an object lock, that is acquired by another thread and second thread is waiting for an object lock that is acquired by first thread. Since, both threads are waiting for each other to release the lock, the condition is called deadlock.



Example of Deadlock in java

```
public class TestDeadlockExample1 {
  public static void main(String[] args) {
    final String resource1 = "Virat Kohli";
    final String resource2 = "MS Dhoni";
    // t1 tries to lock resource1 then resource2
    Thread t1 = new Thread() {
      public void run() {
          synchronized (resource1) {
           System.out.println("Thread 1: locked resource 1");

           try { Thread.sleep(100);}  catch (Exception e) {}

           synchronized (resource2) {
            System.out.println("Thread 1: locked resource 2");
           }
         }
      }
    };

    // t2 tries to lock resource2 then resource1
    Thread t2 = new Thread() {
      public void run() {
        synchronized (resource2) {
          System.out.println("Thread 2: locked resource 2");

          try { Thread.sleep(100);} catch (Exception e) {}

          synchronized (resource1) {
            System.out.println("Thread 2: locked resource 1");
          }
        }
      }
    };


    t1.start();
    t2.start();
  }
}
```

Output: Thread 1: locked resource 1

```
Thread 2: locked resource 2
```

22.10 Inter-thread communication in Java

Inter-thread communication or **Co-operation** is all about allowing synchronized threads to communicate with each other.

Cooperation (Inter-thread communication) is a mechanism in which a thread is paused running in its critical section and another thread is allowed to enter (or lock) in the same critical section to be executed.It is implemented by following methods of **Object class**:

- wait()
- notify()
- notifyAll()

---

1) wait() method

Causes current thread to release the lock and wait until either another thread invokes the **notify()** method or the **notifyAll()** method for this object, or a specified amount of time has elapsed.

The current thread must own this object's monitor, so it must be called from the synchronized method only otherwise it will throw exception.

Method	Description
public final void wait()throws InterruptedException	waits until object is notified.
public final void wait(long timeout)throws InterruptedException	waits for the specified amount of time.

---

2) notify() method

Wakes up a single thread that is waiting on this object's monitor. If any threads are waiting on this object, one of them is chosen to be awakened. The choice is arbitrary and occurs at the discretion of the implementation.

Syntax:

public final void notify()

---

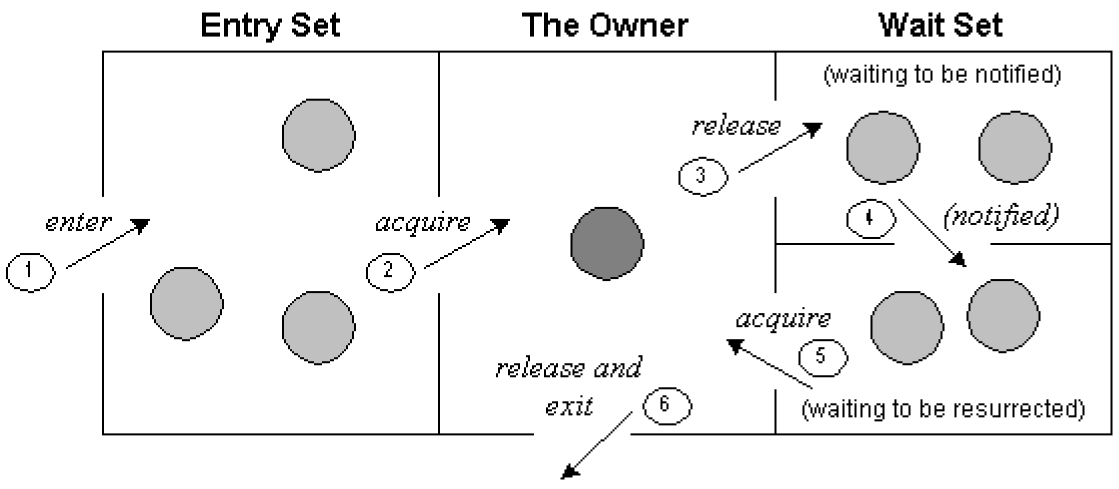
3) notifyAll() method

Wakes up all threads that are waiting on this object's monitor.

Syntax:

public final void notifyAll()

- **Understanding the process of inter-thread communication**



The point to point explanation of the above diagram is as follows:

1. Threads enter to acquire lock.
2. Lock is acquired by on thread.
3. Now thread goes to waiting state if you call wait() method on the object. Otherwise it releases the lock and exits.
4. If you call notify() or notifyAll() method, thread moves to the notified state (runnable state).
5. Now thread is available to acquire lock.
6. After completion of the task, thread releases the lock and exits the monitor state of the object.

Q. Why wait(), notify() and notifyAll() methods are defined in Object class not Thread class?

It is because they are related to lock and object has a lock.

Q. Difference between wait and sleep?

Let's see the important differences between wait and sleep methods.

wait()	**sleep()**
wait() method releases the lock	sleep() method doesn't release the lock.
is the method of Object class	is the method of Thread class
is the non-static method	is the static method
should be notified by notify() or notifyAll() methods	after the specified amount of time, sleep is completed.

➢ Example of inter thread communication in java

Let's see the simple example of inter thread communication.

```
class Customer{
int amount=10000;

synchronized void withdraw(int amount) {
System.out.println("going to withdraw...");

if(this.amount<amount) {
System.out.println("Less balance; waiting for deposit...");
try{
wait();
}catch(Exception e){}
}
this.amount -= amount;
System.out.println("withdraw completed...");
}

synchronized void deposit(int amount) {
System.out.println("going to deposit...");
this.amount += amount;
System.out.println("deposit completed... ");
notify();
}
}  //Class close

class Test{
public static void main(String args[]){
final Customer c=new Customer();
new Thread() {
public void run()
{
c.withdraw(15000);
}
}.start();
new Thread(){
public void run()
{
c.deposit(10000);
}
}.start();

}
}
```

Output: going to withdraw...

```
going to withdraw...
        Less balance; waiting for deposit...
        going to deposit...
        deposit completed...
        withdraw completed
```