Thread

What is a Thread in Java?

In Java, a <mark>thread is a lightweight process that allows a program to perform multiple tasks concurrently.</mark> It is the smallest unit of execution within a program. A thread runs within the context of a process, and a single process can have multiple threads running simultaneously, which is called multithreading.

Threads allow you to:

1. Improve performance: By performing multiple tasks concurrently (especially on multi-core processors), threads can make better use of system resources.
2. Handle multiple tasks: For example, in a GUI application, one thread can handle the user interface, while another handles background tasks like network communication or file I/O.
3. Better responsiveness: Threads can make a program more responsive by performing time-consuming tasks in the background.

Key Concepts:

- Main Thread: Every Java program starts with a single main thread (the main() method).
- Concurrency: Multiple threads making progress independently.
- Parallelism: Multiple threads running at the same time on different processors or cores.

<mark>Types of threads</mark>

1) User Threads
- These are the primary threads created by the user or the application for executing tasks. They are non-daemon threads by default.
- **Lifecycle:** User threads keep the JVM running until all such threads have completed their execution.
- **Examples:**
    ○ Main thread (created automatically when a Java program starts).
    ○ Threads for performing tasks like file reading, network requests, or computations.

Example:
```
class UserThreadExample extends Thread {
    public void run() {
```

```
    System.out.println("User thread is running...");
  }

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

---

2. Daemon Threads

- **Definition:** These are background threads designed to perform supporting tasks like garbage collection or monitoring. They are automatically terminated when all user threads are finished.
- **Characteristics:**
    - Do not prevent the JVM from exiting.
    - Used for tasks like logging, cleanup, or background monitoring.
    - Can be created by calling setDaemon(true) before starting the thread.

Example:
```
class DaemonThreadExample extends Thread {
  public void run() {
    System.out.println("Daemon thread running...");
    try {
      Thread.sleep(1000);
    } catch (InterruptedException e) {
      System.out.println("Interrupted");
    }
  }

  public static void main(String[] args) {
    DaemonThreadExample t1 = new DaemonThreadExample();
    t1.setDaemon(true); // Set thread as daemon
    t1.start();
    System.out.println("Main thread ends. Daemon thread will be terminated.");
  }
}
```

3) **Main Thread**

- The thread created by the JVM when a Java program starts. It is the entry point of the program.

```
public class MainThreadExample {
    public static void main(String[] args) {
        System.out.println("Main thread is running...");
    }
}
```

Q: How many ways we have to create a thread

Ways to Create a Thread in Java

In Java, there are **two main ways** to create a thread:

1) **By Extending the Thread Class**

You can create a thread by subclassing the Thread class and overriding its run() method.

2) **By Implementing the Runnable Interface**

We can implement the Runnable interface and pass it to a Thread object.

```
package com.ram.thread;
// there are 2 ways to create threads in java
/*1. Extending the Thread Class
You can create a thread by defining a new class that extends the Thread class and overrides its
run() method.*/
class MyThread extends Thread {
    @Override
    public void run() {
        System.out.println("Thread is running");
    }
}
/*
* 2. Implementing the Runnable Interface Another way to create a thread is to
* implement the Runnable interface and pass an instance of this implementation to a Thread
object.
```

```java
*/
class MyRunnable1 implements Runnable {
  @Override
  public void run() {
    System.out.println("Runnable thread is running");
  }
}
public class Threading {
  public static void main(String[] args) {
        // thread class
    MyThread thread = new MyThread();
    thread.start(); // Start the thread

    //for runnable interface
    Thread thread2 = new Thread(new MyRunnable1());//Create a new instance of the Thread
class, passing an instance of your Runnable implementation to its constructor.
    thread2.start(); // Start the thread
  }

}
```

Output

Thread is running
Runnable thread is running

Thread Life Cycle:

```java
package com.ram.thread;
public class ThreadLifeCycleExample2 {
  public static void main(String[] args) {

        // For every program main thread will execute first
        System.out.println("Thread name:"+Thread.currentThread().getName() +""+" status:"+
Thread.currentThread().getState());

    // Create a new thread object (New state)
    Thread thread1 = new Thread(new MyRunnable2());
    // Print the state of the new thread (NEW)
    System.out.println("Thread1 state (NEW): " + thread1.getState());
```

```java
        // Start the new thread (Transition from New to Runnable)
        thread1.start();
        // Print the state of the new thread (RUNNABLE)
        System.out.println("Thread1 state (RUNNABLE): " + thread1.getState());
        // Main thread sleeps for a while to observe the behavior of the new thread
        try {
            Thread.sleep(2000); // Wait for thread1 to finish
            /*
             * we can use thread1.join(); Main thread waits for thread1 to finish (join()
             * lets the main thread wait for the child thread to complete
             */

        } catch (InterruptedException e) {
            e.printStackTrace();
        }
        // Print the state of the thread after it has finished (TERMINATED)
        System.out.println("Thread1 state after 2 seconds: " + thread1.getState());
        // Main thread completes execution
        System.out.println("Main thread has finished execution");
    }
}
class MyRunnable2 implements Runnable {
    public void run() {
        try {
            // Thread starts running (Runnable state)
            System.out.println("Thread1 is running");
            // Simulating some work with sleep
            Thread.sleep(1000);
            // Simulate some more work or operations
            System.out.println("Thread1 has finished running");
        } catch (InterruptedException e) {
            System.out.println("Thread1 was interrupted");
        }
    }
}
```

Output

thread name:main status:RUNNABLE

Thread1 state (NEW): NEW

Thread1 state (RUNNABLE): RUNNABLE
Thread1 is running
Thread1 has finished running
Thread1 state after 2 seconds: TERMINATED
Main thread has finished execution

Exp:

1. Program Starts (Main Thread)

public static void main(String[] args) {

- The main thread starts execution. This thread is responsible for executing the main method.
- The JVM creates this thread automatically and assigns it the name main.

2. Create a New Thread

Thread thread1 = new Thread(new MyRunnable());

System.out.println("Thread1 state (NEW): " + thread1.getState());

- A new thread (thread1) is created, but it has not started yet.
- The state of thread1 is NEW. At this point, the thread exists but has no CPU time.

Output:
Thread1 state (NEW): NEW

3. Start the New Thread

thread1.start();

System.out.println("Thread1 state (RUNNABLE): " + thread1.getState());

- The start() method is called, which transitions thread1 from the NEW state to the RUNNABLE state.
- In the RUNNABLE state, the thread is ready to run and is waiting for the CPU to schedule its execution.
- Immediately after calling start(), the thread1 state is printed as RUNNABLE.

Output:
Thread1 state (RUNNABLE): RUNNABLE

4. Execution of run() Method (thread1)

- The JVM starts executing the run() method in MyRunnable on thread1.

Inside the run() method:
System.out.println("Thread1 is running");

Thread.sleep(1000);

System.out.println("Thread1 has finished running");

-

  1. "Thread1 is running" is printed when the thread begins execution.
  2. Thread.sleep(1000) pauses thread1 for 1 second, transitioning it to the TIMED_WAITING state.
  3. After sleeping, the thread finishes execution, and "Thread1 has finished running" is printed.

Output (from thread1):

Thread1 is running

Thread1 has finished running

5. Main Thread Sleeps

Thread.sleep(2000);

- The main thread pauses for 2 seconds, allowing thread1 to finish its execution.
- During this time:
  - thread1 executes its run() method and transitions to the TERMINATED state when completed.

6. Check Thread1 State After 2 Seconds

System.out.println("Thread1 state after 2 seconds: " + thread1.getState());

- After the main thread wakes up, it checks the state of thread1.
- By this time, thread1 has completed its run() method and transitioned to the TERMINATED state.

Output:
Thread1 state after 2 seconds: TERMINATED

7. Main Thread Finishes Execution

System.out.println("Main thread has finished execution");

- The main thread prints a final message and terminates.
- Once the main thread finishes execution, the program ends.

Output:
Main thread has finished execution

Final Execution Order

1. Main thread creates thread1 and prints its state as NEW.
2. Main thread starts thread1 and prints its state as RUNNABLE.
3. Thread1 begins execution:
   - Prints "Thread1 is running".
   - Sleep for 1 second.
   - Prints "Thread1 has finished running".
4. Main thread sleeps for 2 seconds.
5. After 2 seconds, the main thread checks thread1 state (TERMINATED).
6. Main thread prints the final message and terminates.

Multithreading in Java

==**Multithreading is the ability of a program to execute multiple threads simultaneously.**== A thread is the smallest unit of a process that can execute independently. Java provides built-in support for multithreading through the java.lang.Thread class and the java.util.concurrent package.

Key Concepts

- **Thread**: A lightweight process. Multiple threads can exist within a single process, sharing resources like memory.

- **Concurrency**: Allows multiple threads to execute simultaneously, improving the performance of applications, especially on multi-core processors.
- **Thread Lifecycle**: A thread can be in one of the following states:
  - **New**: Thread is created but not yet started.
  - **Runnable**: Thread is ready to run but waiting for CPU time.
  - **Running**: Thread is executing.
  - **Blocked/Waiting**: Thread is waiting for a resource.
  - **Terminated**: Thread has finished execution.

```java
package com.ram.thread;
public class MultiThreadingEx {
    public static void main(String[] args) {
        Exthread thread1 = new Exthread();
        Exthread thread2 = new Exthread();
        thread1.start();
        thread2.start();
    }
}
class Exthread extends Thread {
    @Override
    public void run() {
        for (int i = 0; i < 6; i++) {
            System.out.println(Thread.currentThread().getName() + " "
            + i);

            try {
                Thread.sleep(1000); // sleep for 1000 milli sec
            } catch (InterruptedException e) {
                // TODO Auto-generated catch block
                e.printStackTrace();
            }
        }
    }
}
```

Output
Thread-0 0
Thread-1 0
Thread-1 1
Thread-0 1
Thread-0 2
Thread-1 2

Thread-0 3
Thread-1 3
Thread-1 4
Thread-0 4
Thread-0 5
Thread-1 5

Join()

Using the join() method in Java for synchronizing threads is a form of thread synchronization that ensures the execution order of threads. When you call join() on a thread, the calling thread (usually the main thread or another thread) will pause its execution until the thread on which join() was called has finished executing. It **pauses the calling thread until the thread on which join() was called finishes its execution**.

This is a form of thread coordination, but it is not about preventing access to shared resources (which is typically handled by locks, synchronized blocks, or ReentrantLock). Instead, it's about ensuring that one thread waits for another to finish before proceeding.

In short:

- join() ensures that the calling thread waits for the specified thread to complete, providing a mechanism for thread coordination.
- This is useful when you need the calling thread to wait for the completion of other threads before proceeding with further operations, but it does not manage shared resource synchronization like preventing race conditions.

```java
package com.ram.thread;
public class SynchronizationEx2 {
    public static void main(String[] args) {
        Exthread1 thread1 = new Exthread1();
        Exthread1 thread2 = new Exthread1();
        thread1.start(); // Start Thread-0
        try {
            thread1.join(); // Wait for Thread-0 to finish
        } catch (InterruptedException e) {
            e.printStackTrace();
        }
        thread2.start(); // Start Thread-1 after Thread-0 completes
    }
}
```

```java
class Exthread1 extends Thread {
    @Override
    public void run() {
        for (int i = 0; i < 6; i++) {
            System.out.println(Thread.currentThread().getName() + " " + i);
            try {
                Thread.sleep(1000); // Sleep for 1000 milliseconds
            } catch (InterruptedException e) {
                e.printStackTrace();
            }
        }
    }
}
```

Output
Thread-0 0
Thread-0 1
Thread-0 2
Thread-0 3
Thread-0 4
Thread-0 5
Thread-1 0
Thread-1 1
Thread-1 2
Thread-1 3
Thread-1 4
Thread-1 5

Synchronization in Java

Synchronization is a mechanism to control the access of multiple threads to shared resources. **It ensures that only one thread can access the critical section of the code at a time**, preventing data inconsistencies and race conditions.

Why Synchronization is Needed

When multiple threads try to modify a shared resource concurrently, it can lead to unpredictable behavior or incorrect results. Synchronization resolves this issue by making the resource access thread-safe.

Types of Synchronization

1. **Synchronized Method**: Locks the entire method for a single thread.
2. **Synchronized Block**: Locks only a specific block of code for a single thread, allowing better performance by reducing the scope of the lock.
3. **Static Synchronization**: Locks on the class-level object.

EX1:

Synchronized Block

Shared Lock Object:

- Introduced a private static final Object lock to act as a shared lock between threads. Declaring it static ensures all threads of the class share the same lock.

Synchronized Block:

- Added synchronized (lock) to ensure that the code inside the block is executed by only one thread at a time.

```
package com.ram.thread;
public class SynchronizationEx1 {
  public static void main(String[] args) {
    Exthread thread1 = new Exthread();
    Exthread thread2 = new Exthread();
    thread1.start();
    thread2.start();
  }
}
class Exthread extends Thread {
  private static final Object lock = new Object(); // Shared lock for synchronization
  @Override
  public void run() {
```

```java
        synchronized (lock) { // Synchronize the block of code
            for (int i = 0; i < 6; i++) {
                System.out.println(Thread.currentThread().getName() + " " + i);
                try {
                    Thread.sleep(1000); // sleep for 1000 milliseconds
                } catch (InterruptedException e) {
                    e.printStackTrace();
                }
            }
        }
    }
}
```

Output
Thread-0 0
Thread-0 1
Thread-0 2
Thread-0 3
Thread-0 4
Thread-0 5
Thread-1 0
Thread-1 1
Thread-1 2
Thread-1 3
Thread-1 4
Thread-1 5

Synchronized Method:

The increment() method is synchronized so that only one thread can execute it at a time.

```java
package com.ram.thread;
class Counting {
        private int count = 0;
        // Synchronized method
        public synchronized void increment() {
                count++;
        }
        public int getCount() {
```

```java
            return count;
        }
    }
    // Thread class
    class CounterThread extends Thread {
        private Counting counter;
        public CounterThread(Counting counter) {
            this.counter = counter;
        }
        @Override
        public void run() {
            for (int i = 0; i < 100; i++) {
                counter.increment();
            }
        }
    }
    public class MethodLevelSynchronization {
        public static void main(String[] args) throws InterruptedException {
            Counting counter = new Counting();
            // Create threads by extending Thread class
            CounterThread thread1 = new CounterThread(counter);
            CounterThread thread2 = new CounterThread(counter);
            thread1.start();
            thread2.start();
            thread1.join();
            thread2.join();
            System.out.println("Final count: " + counter.getCount());
        }
    }
```

Output
Final count: 200

Synchronized static method


```java
package com.ram.thread;
class Counting {
    private static int count = 0;
    // Synchronized method
```

```java
        public synchronized static void increment() {
                count++;
        }
        public int getCount() {
                return count;
        }
}
// Thread class
class CounterThread extends Thread {
        private Counting counter;
        public CounterThread(Counting counter) {
                this.counter = counter;
        }
        @Override
        public void run() {
                for (int i = 0; i < 100; i++) {
                        counter.increment();
                }
        }
}
public class MethodLevelSynchronization {
        public static void main(String[] args) throws InterruptedException {
                Counting counter = new Counting();
                // Create threads by extending Thread class
                CounterThread thread1 = new CounterThread(counter);
                CounterThread thread2 = new CounterThread(counter);
                thread1.start();
                thread2.start();
                thread1.join();
                thread2.join();
                System.out.println("Final count: " + counter.getCount());
        }
}
```

Output
Final count: 2000

Inter-Thread Communication

Inter-thread communication in Java refers to the mechanisms used to enable communication and coordination between threads that are executing concurrently. It allows threads to communicate, wait for conditions, and notify each other when certain events or actions need to occur, ensuring smooth execution of multi-threaded programs.

Thread Synchronization Thread synchronization ensures that only one thread can access a particular block of code or resource at a time. This is critical in preventing race conditions when multiple threads interact with shared resources.

Wait/Notify Mechanism The wait(), notify(), and notifyAll() methods are used to facilitate communication between threads.

wait()

- **Purpose**: A thread can invoke wait() on an object to release the lock it holds on the object and enter the **waiting state**. The thread remains in this state until another thread calls notify() or notifyAll() on the same object.
- **Usage**: A thread typically waits for some condition to be met before continuing its execution.

  Syntax:

  ```
  synchronized (object) {

      object.wait();

  }
  ```

  It releases the lock on the object and enters the waiting state.

  The thread will be re-awakened when another thread sends a signal via notify() or notifyAll().

notify()

- **Purpose**: This method is used to wake up one thread that is currently waiting on the object's monitor (lock).
- **Usage**: It is typically used to signal a waiting thread that a certain condition has been met, allowing it to resume execution.

Syntax:
synchronized (object) {

   object.notify();

}

-   ○ It only wakes up one thread that is waiting on the object. If multiple threads are waiting, one is chosen arbitrarily.
-   ○ The thread that is woken up will continue executing when it can acquire the lock.

notifyAll()

- **Purpose**: Similar to notify(), but it wakes up all the threads that are currently waiting on the object's monitor.
- **Usage**: It is useful when multiple threads are waiting for the same condition to be met.

   Syntax:
   synchronized (object) {

      object.notifyAll();

   }

- **Details**:
  - ○ All waiting threads are awakened and compete to acquire the lock to proceed with their execution.
  - ○ This method is often used when the conditions for waiting are no longer valid, and all waiting threads need to be notified.

Ex

```
package com.ram.thread;

// Class to represent a shared message object between threads
class Message {
    private String message; // Holds the message to be shared
    // Synchronized method to read the message
    public synchronized String read() {
        return message; // Return the current message
    }
    // Synchronized method to write a message
```

```java
    public synchronized void write(String message) {
        this.message = message; // Set the message to the provided value
    }
}
// Producer thread, which generates and writes a message to the shared object
class Producer extends Thread {
    private Message message; // The shared message object
    // Constructor to initialize the Producer with the shared message object
    public Producer(Message message) {
        this.message = message;
    }
    // The thread's run method which defines what the Producer does
    public void run() {
        try {
            // Simulate some work by sleeping for 1 second
            Thread.sleep(1000);
            // Synchronize access to the shared message object
            synchronized (message) {
                // Write the message to the shared object
                message.write("Hello from Producer!");
                // Notify the Consumer thread that the message is ready
                message.notify();
            }
        } catch (InterruptedException e) {
            // Handle any interruption during sleep
            e.printStackTrace();
        }
    }
}
// Consumer thread, which waits for and reads the message from the shared object
class Consumer extends Thread {
    private Message message; // The shared message object
    // Constructor to initialize the Consumer with the shared message object
    public Consumer(Message message) {
        this.message = message;
    }
    // The thread's run method which defines what the Consumer does
    public void run() {
        // Synchronize access to the shared message object
        synchronized (message) {
```

```java
                try {
                        // Wait until the Producer writes a message
                        // If the message is null, wait until the Producer provides a message
                        while (message.read() == null) {
                                message.wait(); // Wait for a notification from the Producer
                        }
                        // Once the message is available, print the received message
                        System.out.println("Consumer received: " + message.read());
                } catch (InterruptedException e) {
                        // Handle any interruption while waiting or reading the message
                        e.printStackTrace();
                }
        }
    }
}
// Main class to run the program
public class ThreadInterCommunication {
        public static void main(String[] args) {
                // Create a shared Message object that will be used by both threads
                Message message = new Message();
                // Create a Consumer thread, passing the shared Message object
                Consumer consumer = new Consumer(message);
                // Create a Producer thread, passing the shared Message object
                Producer producer = new Producer(message);
                // Start the Consumer thread, it will begin executing the run() method
                consumer.start();
                // Start the Producer thread, it will begin executing the run() method
                producer.start();
        }
}
```

//**notifyAll()**: In the Producer thread, I replaced notify() with notifyAll() to notify all waiting threads. This will be useful if you have multiple consumer threads.

Output

Consumer received: Hello from Producer!

DeadLock

. This typically occurs when threads acquire locks on multiple resources in different orders.

A Java multithreaded program may suffer from the deadlock condition because the **synchronized** keyword causes the executing thread to block while waiting for the lock, or monitor, associated with the specified object

In simpler terms, deadlock happens when:

1. Thread A holds Resource 1 and waits for Resource 2.
2. Thread B holds Resource 2 and waits for Resource 1

Ex

package com.threadex;

public class DeadlockExample {

    // Two lock objects to simulate resource locking

    private static final Object lock1 = new Object(); // Lock 1

    private static final Object lock2 = new Object(); // Lock 2

    public static void main(String[] args) {

        // Thread 1 attempts to acquire lock1 first, then lock2

        Thread thread1 = new Thread(() -> {

            synchronized (lock1) { // Acquiring lock1

                System.out.println("Thread 1: Holding lock 1...");

                try {

                    Thread.sleep(100); // Simulate some work while holding lock1

```java
                    } catch (InterruptedException e) {

                        e.printStackTrace();

                    }

                    System.out.println("Thread 1: Waiting for lock 2...");

                    synchronized (lock2) { // Attempts to acquire lock2

                        System.out.println("Thread 1: Acquired lock 2!");

                    }

                } // Releases lock1 when the block ends

            });


            // Thread 2 attempts to acquire lock2 first, then lock1

            Thread thread2 = new Thread(() -> {

                synchronized (lock2) { // Acquiring lock2

                    System.out.println("Thread 2: Holding lock 2...");

                    try {

                        Thread.sleep(100); // Simulate some work while
holding lock2

                    } catch (InterruptedException e) {

                        e.printStackTrace();

                    }

                    System.out.println("Thread 2: Waiting for lock 1...");

                    synchronized (lock1) { // Attempts to acquire lock1

                        System.out.println("Thread 2: Acquired lock 1!");

                    }
```

```
                    } // Releases lock2 when the block ends

            });


            // Start both threads

            thread1.start(); // Start thread1 execution

            thread2.start(); // Start thread2 execution

    }

}
```

Output

Thread 1: Holding lock 1...

Thread 2: Holding lock 2...

Thread 1: Waiting for lock 2...

Thread 2: Waiting for lock 1...

<mark>We can prevent Deadlock using **Lock Ordering**</mark>

Example: Preventing Deadlock Using Lock Ordering

Both threads acquire locks in the same order (lock1 first, then lock2).


```
package com.threadex;

public class PreventDeadlockWithOrder {
    private static final Object lock1 = new Object();
    private static final Object lock2 = new Object();
```

```java
public static void main(String[] args) {
    // Thread 1 acquires lock1, then lock2
    Thread thread1 = new Thread(() -> {
        synchronized (lock1) {
            System.out.println("Thread 1: Acquired lock1");
            synchronized (lock2) {
                System.out.println("Thread 1: Acquired lock2");
            }
        }
    });

    // Thread 2 also acquires lock1 first, then lock2
    Thread thread2 = new Thread(() -> {
        synchronized (lock1) {
            System.out.println("Thread 2: Acquired lock1");
            synchronized (lock2) {
                System.out.println("Thread 2: Acquired lock2");
            }
        }
    });

    thread1.start();
    thread2.start();
}
}
```

Output

Thread 1: Acquired lock1

Thread 1: Acquired lock2

Thread 2: Acquired lock1

Thread 2: Acquired lock2

What about the daemon threads?

The daemon threads are the low priority threads that provide the background support and services to the user threads. Daemon thread gets automatically terminated by the JVM if the program remains with the daemon thread only, and all other user threads are ended/died. There are two methods for daemon thread available in the Thread class:

- public void **setDaemon**(boolean status): It used to mark the thread daemon thread or a user thread.
- public boolean **isDaemon()**: It checks if the thread is daemon or not.

Ex:

package com.threadex;

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();

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

　　　　t1.start();// starting threads

　　　　t2.start();

　　}

}

Output

daemon 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.

```
        t1.start();
        t1.setDaemon(true);//will throw exception here
```