Creating Threads with `Runnable`

Creating thread in Java

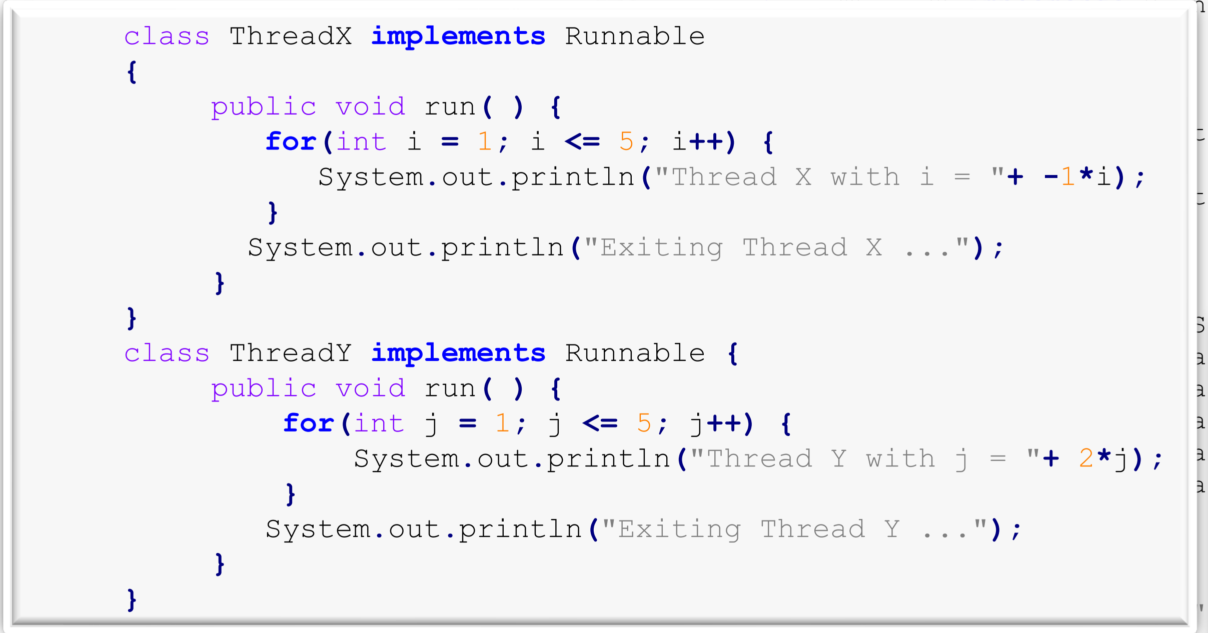
2. Runnable interface

- ➢ Create object implementing Runnable interface
- ➢ Pass it to Thread object via Thread constructor

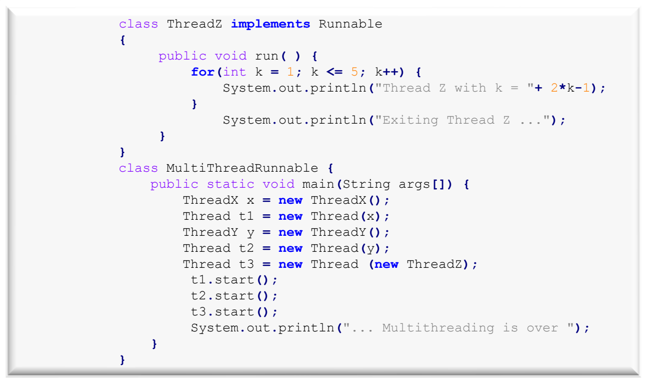
<u>Example</u>

```
public class MyT implements Runnable {
    public void run() {
         …                       // work for thread
    }
}
Thread T = new Thread(new MyT);    // create thread
T.start();                         // begin running thread
…                                  // thread executing in parallel
```

Creating thread : Example



```
class ThreadX implements Runnable
{
     public void run( ) {
        for(int i = 1; i <= 5; i++) {
           System.out.println("Thread X with i = "+ -1*i);
        }
       System.out.println("Exiting Thread X ...");
     }
}
class ThreadY implements Runnable {
     public void run( ) {
         for(int j = 1; j <= 5; j++) {
             System.out.println("Thread Y with j = "+ 2*j);
         }
        System.out.println("Exiting Thread Y ...");
     }
}
```



```
class ThreadZ implements Runnable
{
     public void run( ) {
          for(int k = 1; k <= 5; k++) {
               System.out.println("Thread Z with k = "+ 2*k-1);
          }
               System.out.println("Exiting Thread Z ...");
     }
}
class MultiThreadRunnable {
    public static void main(String args[]) {
        ThreadX x = new ThreadX();
        Thread t1 = new Thread(x);
        ThreadY y = new ThreadY();
        Thread t2 = new Thread(y);
        Thread t3 = new Thread (new ThreadZ);
         t1.start();
         t2.start();
         t3.start();
         System.out.println("... Multithreading is over ");
    }
}
```

nable
5; k++) {
ln("Thread Z with k = "+ 2*k-1);
ln("Exiting Thread Z ...");
}
}

States of a Thread

Threads : Thread states of a thread

Java thread can be in one of these states :

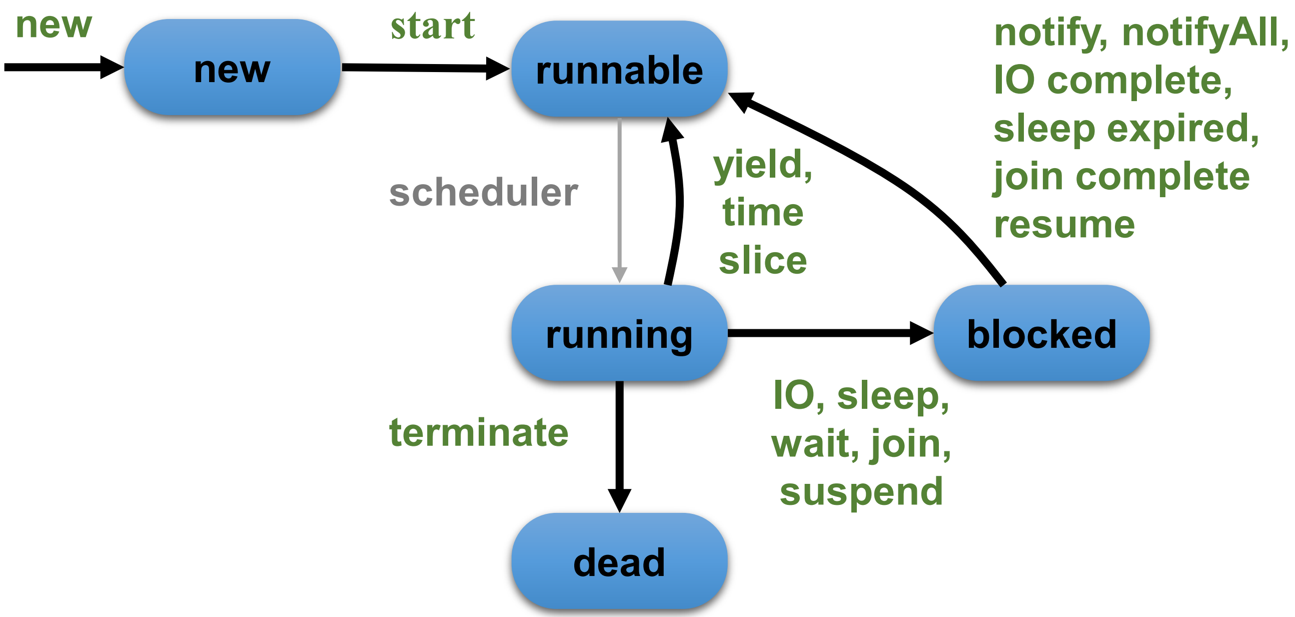
- ➢New – thread allocated & waiting for start()
- ➢Runnable – thread can begin execution
- ➢Running – thread currently executing
- ➢Blocked – thread waiting for event (I/O, etc.)
- ➢Dead – thread finished

Transitions between states caused by

- ➢Invoking methods in class Thread
  - ❖ new(), start(), yield(), sleep(), wait(), notify()…
- ➢Other (external) events
  - ❖ Scheduler, I/O, returning from run()…

Thread States

State diagram



Thread control methods

start () :→ A newborn thread with this method enter into Runnable state and Java run time create a system thread context and starts it running. This method for a thread object can be called once only

suspend() :→ This method is different from stop( ) method. It takes the thread and causes it to stop running and later on can be restored (by resume())

resume() :→ This method is used to revive a suspended thread. There is no gurantee that the thread will start running right way, since there might be a higher priority thread running already, but, resume() causes the thread to become eligible for running

sleep(int n):→ This method causes the run time to put the current thread to sleep for n milliseconds

yield() :→ This method causes the run time to switch the context from the current thread to the next available runnable thread. This is one way to ensure that the threads at lower priority do not get started

Scheduling of Threads

Daemon threads

Java threads types

- User
- Daemon
  - Provide general services.
  - Typically never terminate.
  - Call setDaemon() before start().

Program termination

- All user threads finish.
- Daemon threads are terminated by JVM.
- Main program finishes.

Threads : Scheduling

Scheduler

- ➢Determines which runnable threads to run.
- ➢Can be based on thread priority.
- ➢Part of OS or Java Virtual Machine (JVM) .

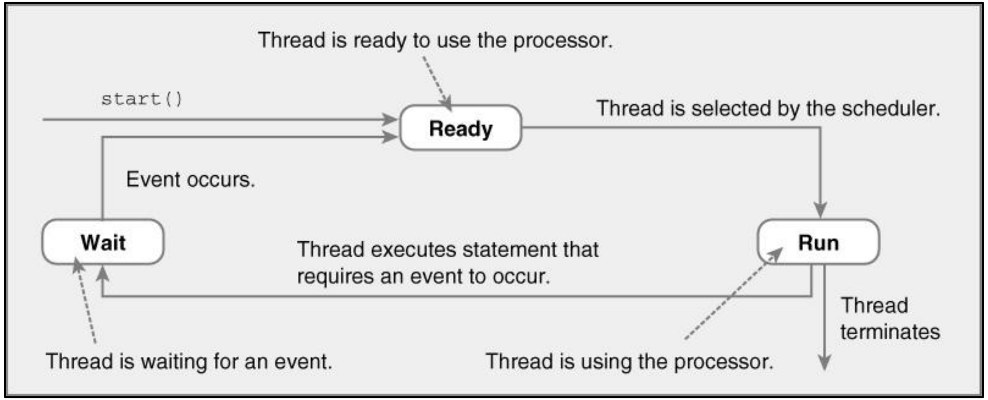
Scheduling policy

- ➢Nonpreemptive (cooperative) scheduling.
- ➢Preemptive scheduling.

Threads: Non-preemptive scheduling

Threads continue execution until

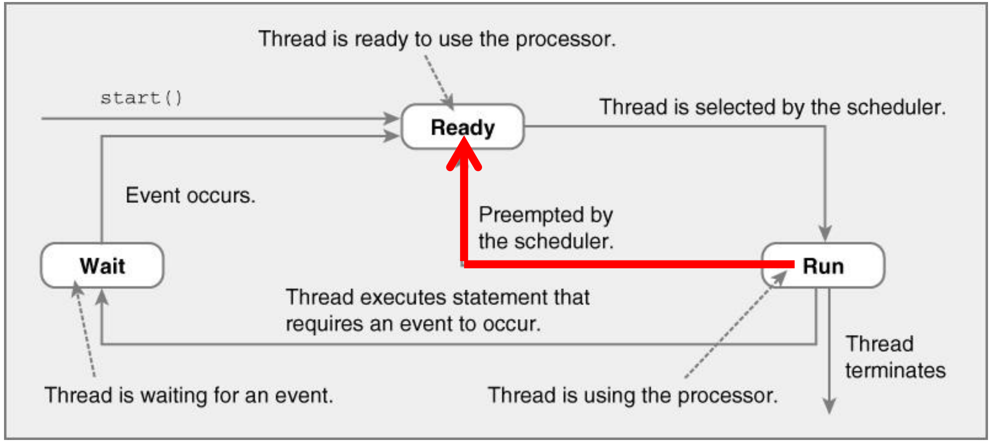
- ➢Thread terminates.
- ➢Executes instruction causing wait (e.g., IO).
- ➢Thread volunteering to stop (invoking yield or sleep).


Thread is ready to use the processor.
start()
Ready
Thread is selected by the scheduler.
Event occurs.
Wait
Thread executes statement that requires an event to occur.
Run
Thread terminates
Thread is waiting for an event.
Thread is using the processor.

Threads: Preemptive scheduling

Threads continue execution until

- ➢Same reasons as non-preemptive scheduling.
- ➢Preempted by scheduler.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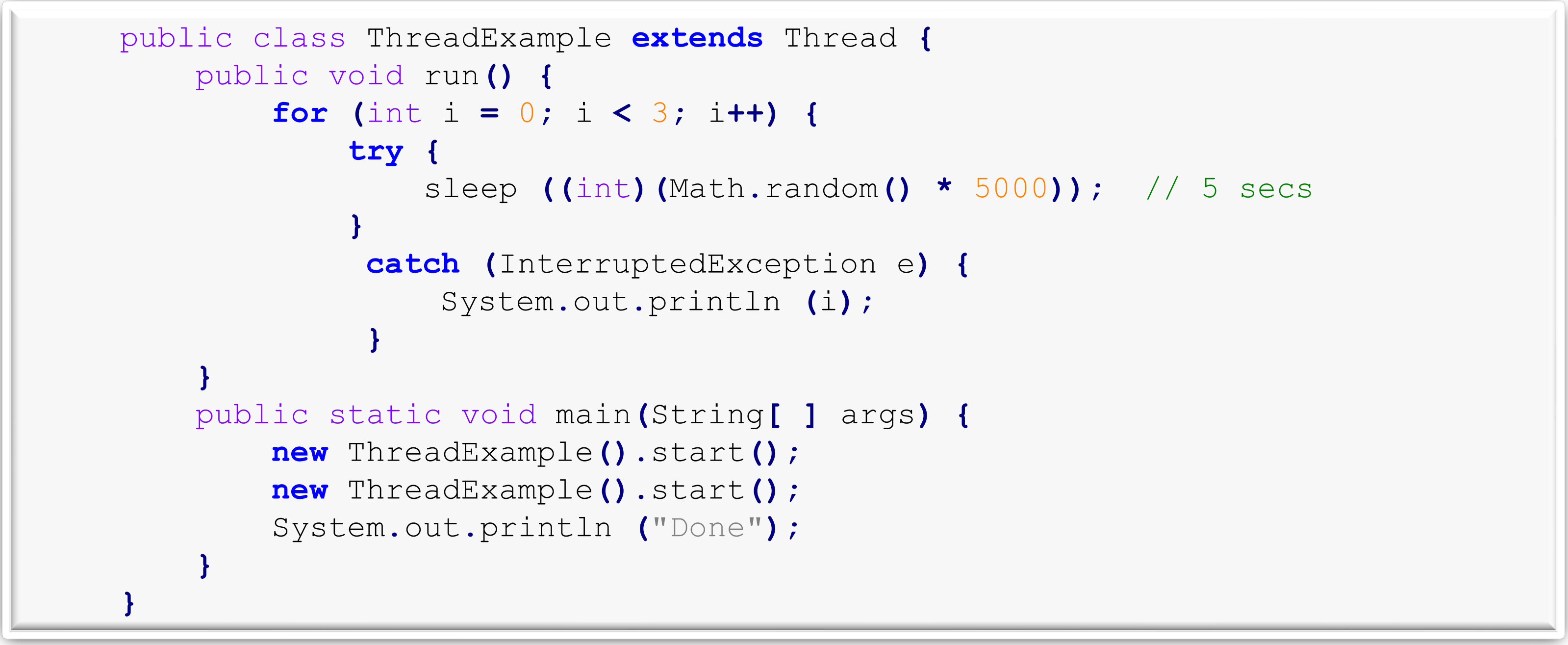
Thread
terminates
Thread is waiting for an event.
Thread is using the processor.

Java thread : An example

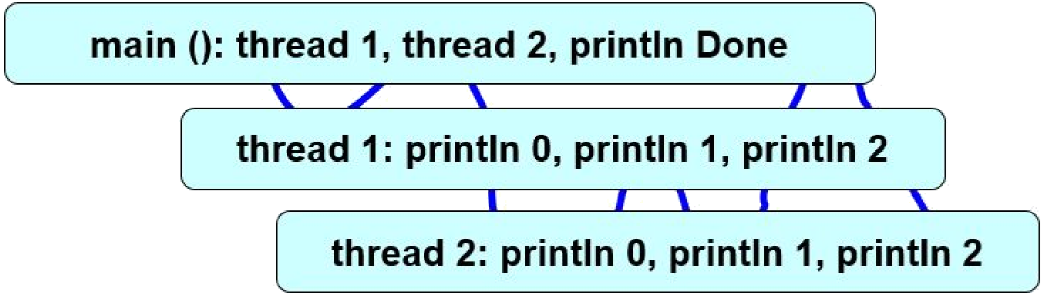


```
public class ThreadExample extends Thread {
    public void run() {
        for (int i = 0; i < 3; i++) {
            try {
                sleep ((int)(Math.random() * 5000));  // 5 secs
            }
             catch (InterruptedException e) {
                 System.out.println (i);
             }
    }
    public static void main(String[ ] args) {
        new ThreadExample().start();
        new ThreadExample().start();
        System.out.println ("Done");
    }
}
```

Java Thread Example

Possible outputs

- 0,1,2,0,1,2,Done // thread 1, thread 2, main()
- 0,1,2,Done,0,1,2 // thread 1, main(), thread 2
- Done,0,1,2,0,1,2 // main(), thread 1, thread 2
- 0,0,1,1,2,Done,2 // main() & threads interleaved


main (): thread 1, thread 2, println Done

thread 1: println 0, println 1, println 2

thread 2: println 0, println 1, println 2

Data races

```java
public class DataRace extends Thread {
    static int x;
    public void run() {
        for (int i = 0; i < 100000; i++) {
            x = x + 1;
            x = x - 1;
        }
    }
    public static void main(String[] args) {
        x = 0;
        for (int i = 0; i < 100000; i++)
            new DataRace().start();
        System.out.println(x); // x not always 0!
    }
}
```

Thread scheduling observations

The order in which threads are selected for execution is indeterminate.

- Depends on scheduler.

Thread can block indefinitely (starvation).

- If other threads always execute first.

Thread scheduling may cause data races.

- Modifying same data from multiple threads.
- Result depends on thread execution order.

Synchronization

- Control thread execution order.
- Eliminate data races.

Priority of Threads

Thread priority

- In Java, each thread is assigned priority, which affects the order in which it is scheduled for running.
- The threads so far had same default priority (NORM_PRIORITY) and they are served using FCFS policy.
  - ➢Java allows users to change priority:

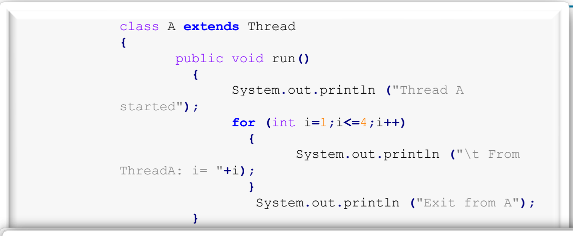
    ThreadName.setPriority (int Number)

    ❑MIN_PRIORITY = 1

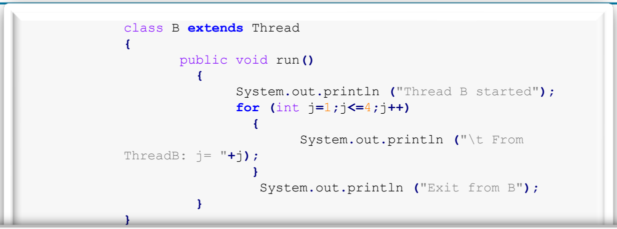
    ❑NORM_PRIORITY = 5

    ❑MAX_PRIORITY = 10

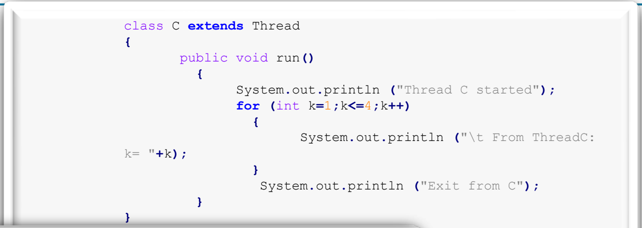
Thread priority : An example



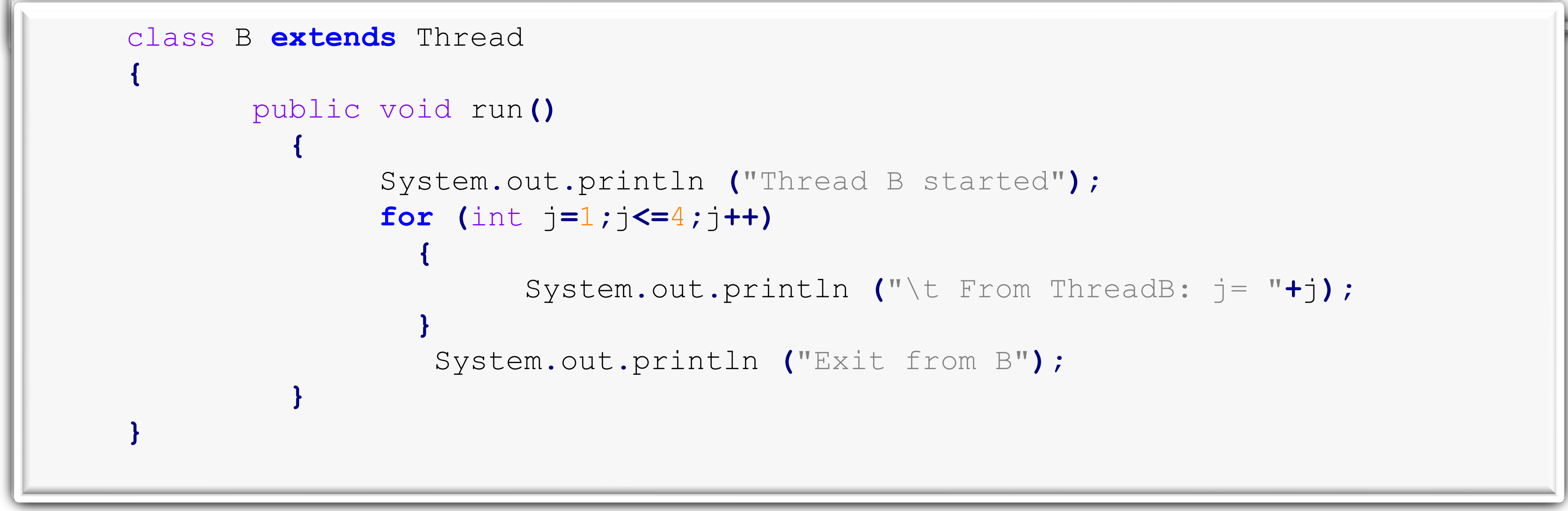
```
class A extends Thread
{
        public void run()
          {
                System.out.println ("Thread A
started");
                for (int i=1;i<=4;i++)
                  {
                        System.out.println ("\t From
ThreadA: i= "+i);
                  }
                 System.out.println ("Exit from A");
          }
```



```
class B extends Thread
{
        public void run()
          {
                System.out.println ("Thread B started");
                for (int j=1;j<=4;j++)
                  {
                        System.out.println ("\t From
ThreadB: j= "+j);
                  }
                 System.out.println ("Exit from B");
          }
}
```

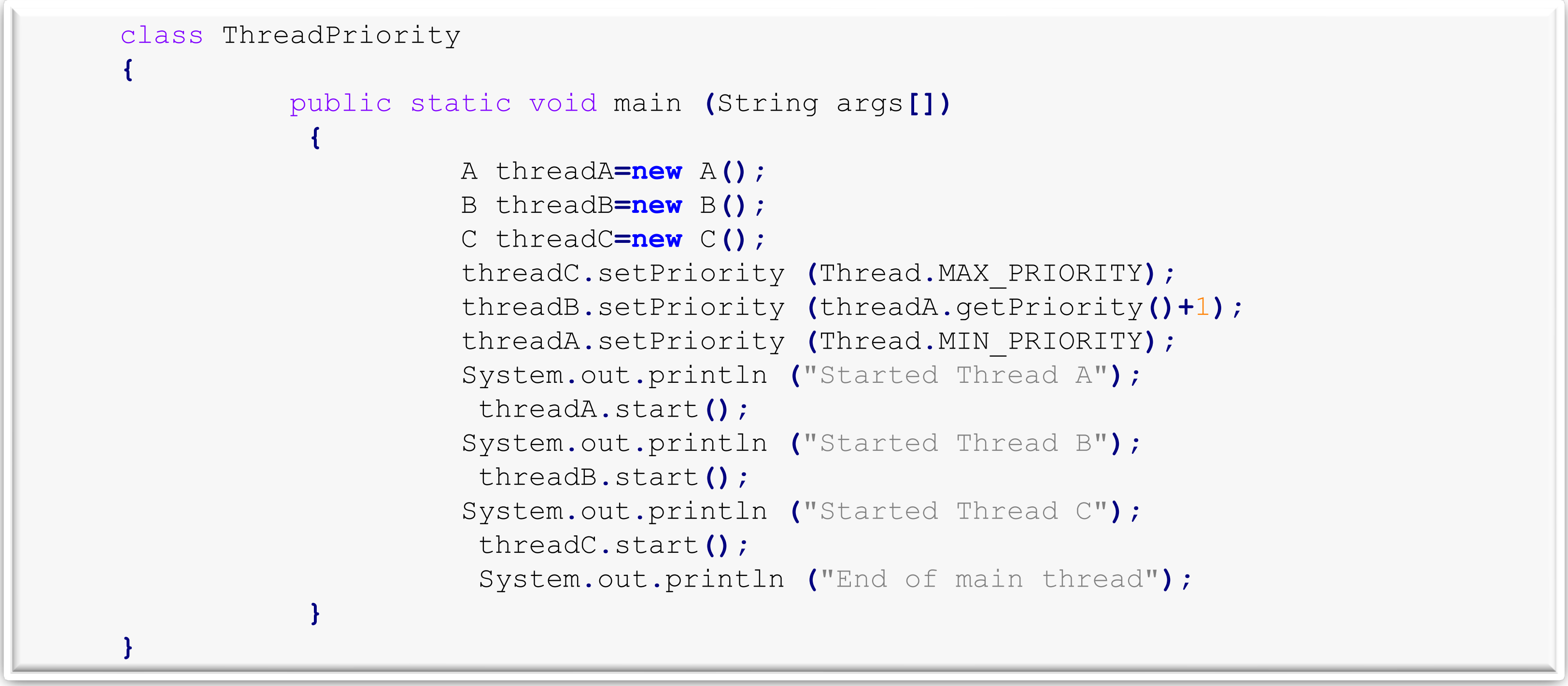


```
class C extends Thread
{
        public void run()
          {
                System.out.println ("Thread C started");
                for (int k=1;k<=4;k++)
                  {
                        System.out.println ("\t From ThreadC:
k= "+k);
                  }
                 System.out.println ("Exit from C");
          }
}
```



```
class B extends Thread
{
        public void run()
          {
                System.out.println ("Thread B started");
                for (int j=1;j<=4;j++)
                  {
                        System.out.println ("\t From ThreadB: j= "+j);
                  }
                 System.out.println ("Exit from B");
          }
}
```

Thread priority : An example



```
class ThreadPriority
{
          public static void main (String args[])
           {
                    A threadA=new A();
                    B threadB=new B();
                    C threadC=new C();
                    threadC.setPriority (Thread.MAX_PRIORITY);
                    threadB.setPriority (threadA.getPriority()+1);
                    threadA.setPriority (Thread.MIN_PRIORITY);
                    System.out.println ("Started Thread A");
                     threadA.start();
                    System.out.println ("Started Thread B");
                     threadB.start();
                    System.out.println ("Started Thread C");
                     threadC.start();
                     System.out.println ("End of main thread");
           }
}
```

Thread class : Join

```
public class Test1 {
     static void main(String[] args){
               Thread t1 = new Thread(new R(1));
               Thread t2 = new Thread(new R(2));
               t1.start();
               t2.start();
               try {
                         t1.join();     // waits until t1 has terminated
                         t2.join();     // waits until t2 has terminated
               }
               catch(InterruptedException e){ }
               System.out.println("done");
     }
}
```

Synchronization of Threads

Thread synchronization

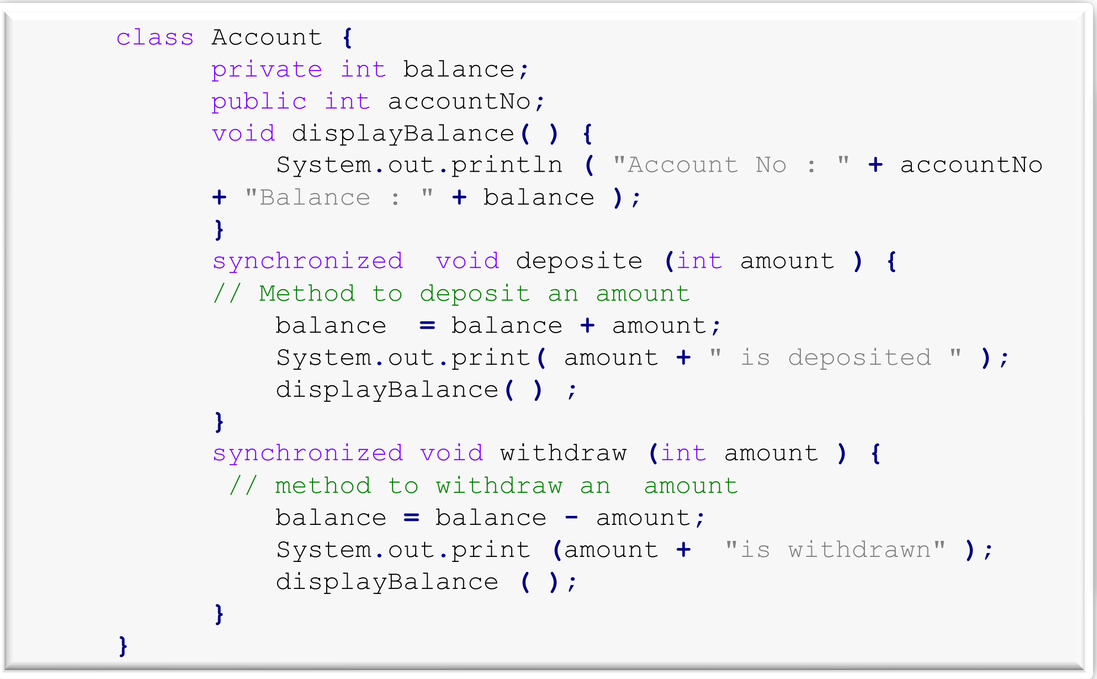
When two or more processes attempts to access a shared resource, it should be synchronized to avoid conflicts.

Java supports methods to be synchronized.

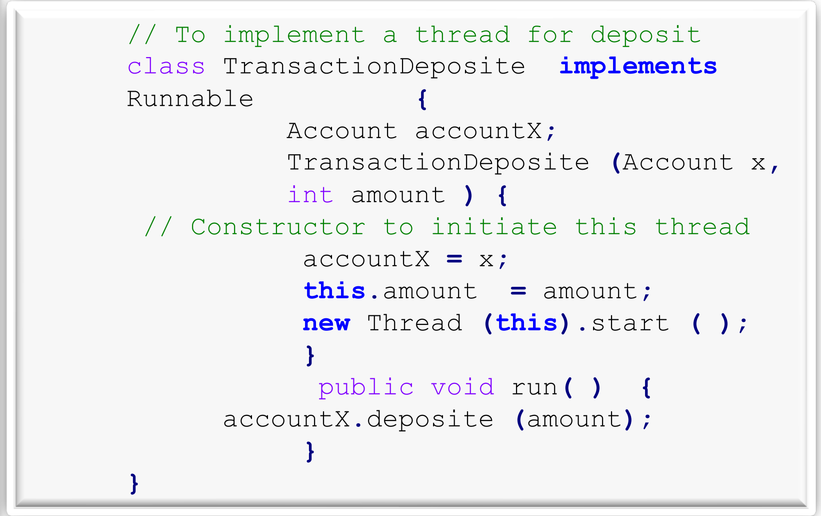
Following is the syntax by which methods can be made to protect from simultaneous access:

```
synchronized (object) { block of statement(s) }
```

Thread synchronization : An example



```
class Account {
        private int balance;
        public int accountNo;
        void displayBalance( ) {
             System.out.println ( "Account No : " + accountNo
        + "Balance : " + balance );
        }
        synchronized  void deposite (int amount ) {
        // Method to deposit an amount
             balance  = balance + amount;
             System.out.print( amount + " is deposited " );
             displayBalance( ) ;
        }
        synchronized void withdraw (int amount ) {
         // method to withdraw an  amount
             balance = balance - amount;
             System.out.print (amount +  "is withdrawn" );
             displayBalance ( );
        }
}
```



```
// To implement a thread for deposit
class TransactionDeposite  implements
Runnable            {
             Account accountX;
             TransactionDeposite (Account x,
             int amount ) {
 // Constructor to initiate this thread
              accountX = x;
              this.amount  = amount;
              new Thread (this).start ( );
              }
               public void run( )  {
        accountX.deposite (amount);
              }
}
```

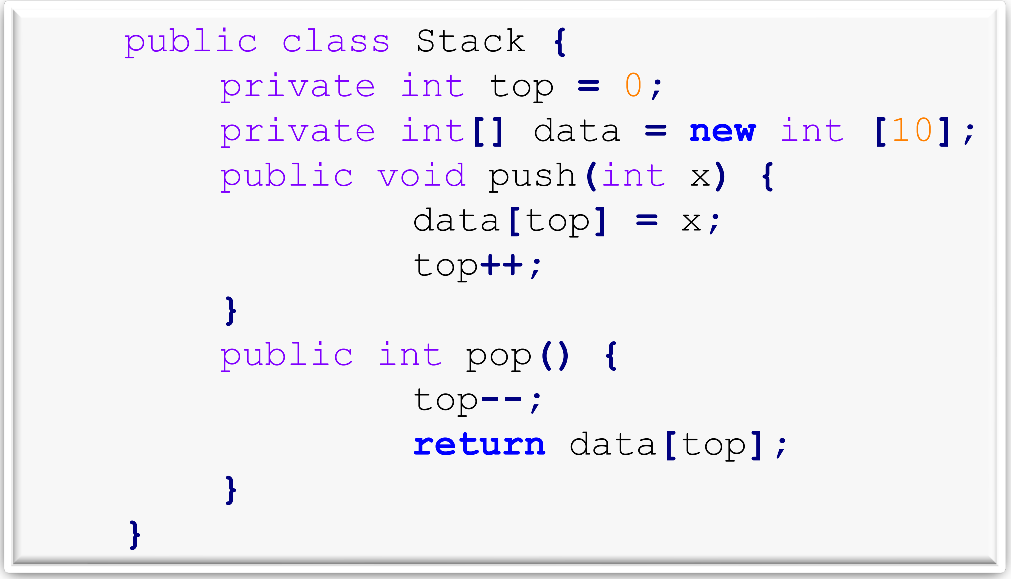
Thread synchronization : An example

```
// To implement a thread for withdraw
class TransactionWithdraw implements
Runnable {     Account accountY;
     int amount;
     TransactionWithdraw (Account y;
     int amount ) {
          accountY = y ;
          this.amount  = amount;
          new Thread (this).start( );
     }
     public void run ( )           {
           accountY.withdraw (amount);
     }
}
```

```
class Transaction {
          public static void main (String,
     args[ ] ) {
     Account ABC = new Account ( );
     // Create an account
     ABC.balance  = 1000;
     // initialize the account by Rs 1000
     TransactionDeposite t1;
     // A thread for deposite
     TransactionWithdraw t2
     // Another thread for withdarw
     t1 = new TransactionDeposite (ABC ,
     500 );
     t2 = new TransactionWithdraw (ABC,
     900);
      // Two threads are started
     }
}
```

Thread synchronization : Stack example

Example: Stack



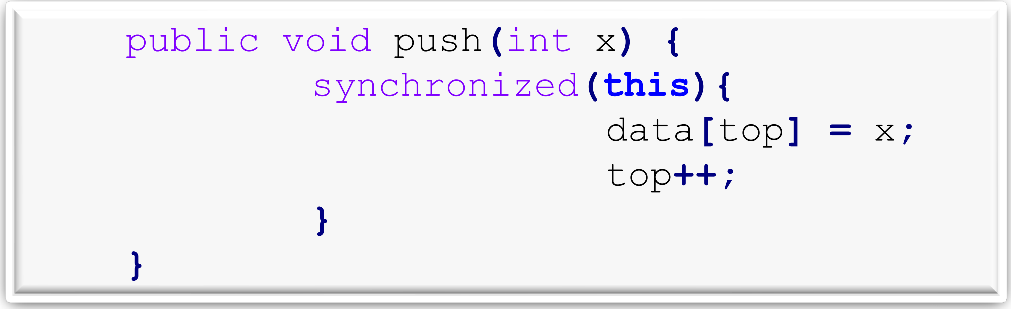
```
    public class Stack {
        private int top = 0;
        private int[] data = new int [10];
        public void push(int x) {
                data[top] = x;
                top++;
        }
        public int pop() {
                top--;
                return data[top];
        }
    }
```

Two threads, one is pushing, the other popping objects

Using blocks

Synchronized blocks

- every object contains a single lock
- lock is taken when synchronized section is entered
- if lock is not available, thread enters a waiting queue
- if lock is returned any (longest waiting?) thread is resumed



```
public void push(int x)  {
        synchronized(this){
                     data[top] = x;
                     top++;
        }
}
```

Instance methods

- Often a method is synchronized on “this”:

```
public void push(int x) {synchronized(this) {......}}
```

- Short form:

```
public synchronized void push(int x){......}
```

Question to think…

- In any software, Input-Output is a great concern. How Java facilitates I-O handling?
- What makes Java suitable for network programming?

Thank You