

## SPOSL C1

Title : Scheduling Algorithms

Problem Statement:

Write a Java program (using oop) to implement following Scheduling Algorithms: FCFS, SJF (Preemptive), Priority (Non-preemptive) & Round Robin (preemptive).

Objective:

To implement scheduling Algorithms

Outcomes:

Students will be able to implement OS scheduling algorithms for CPU scheduling.

Theory:

Scheduler:

An operating system program that selects the job to be admitted for execution.

The performance criteria are:

- |                     |                        |
|---------------------|------------------------|
| 1) Throughput       | 5) Priority            |
| 2) CPU utilization  | 6) Avg. TA             |
| 3) Turn around Time | 7) Avg. waiting time   |
| 4) Response Time.   | 8) Avg. Response time. |

Scheduling Policy:

It determines when it is time for process to be removed from CPU & which should be allocated next.



CPU scheduling is divided into 2 types:

1) Preemptive:

It integrates the processing of a process & transfers the CPU to another process.

2) Non-preemptive:

Uninterrupted completion of process execution takes place.

### Types of Scheduling Algorithms

1) FCFS

First Come First Serve

- non-preemptive scheduler

Process	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>
Arrival Time	0	1	2
execution:	P <sub>1</sub> → P <sub>2</sub> → P <sub>3</sub>		

2) SJF

Shortest Job First.

- Preemptive / Non-Preemptive

- Smaller burst times

Process	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>
Burst Time	6	4	2
execution:	P <sub>3</sub> → P <sub>2</sub> → P <sub>1</sub>		



### 3) Round Robin Preemptive

- CPU time divided into quantum time.

Process	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>
Burst time	6	4	2

time quantum = 2 units

execution: P<sub>1</sub> → P<sub>2</sub> → P<sub>3</sub> → P<sub>1</sub> → P<sub>2</sub> → P<sub>1</sub>

### 4) Priority Scheduling

- Preemptive / Non-Preemptive
- Process with higher priority executed.
- Processes with same priority: RR / FCFS is used.

Process	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>
BT	3	4	2
Priority	2	1	1

execution: P<sub>2</sub> → P<sub>3</sub> → P<sub>1</sub>

### Algorithms:

#### 1) FCFS:

- 1) JIP processes with Burst Time.
- 2) JIP arrival times
- 3) Sort according to arrival time
- 4) Perform processes in that order
- 5) end.

#### 2) SJF

- 1) Calc. burst time.
- 2) Sort burst time in ascending order
- 3) Apply FCFS, perform processes, stop.



## 3) Round Robin

- 1) Get input for processes with arrival & burst time.
- 2) Sort according to arrival time
- 3) Process till all are done
- 4) end.

## 4) Priority

- 1) Get input with arrival time, burst time & priority
- 2) Sort according to arrival time.
- 3) If arrival is same sort by priority
- 4) end.

## Test Cases:

## 1) FCFS

Process	Input		Output			
	BT	AT	BT	AT	TAT	WT
P1	6	0	6	0	6	0
P2	4	4	4	4	9	5
P3	3	2	3	2	7	4

## 2) SJF

Process	Input		Output			
	BT	AT	BT	AT	TAT	WT
P1	4	0	4	0	4	0
P2	7	2	2	2	13	6
P3	2	3	2	3	8	1
P4	2	3	2	3	5	3

## 3) Round Robin:

Process	Input		Output			
	BT	AT	BT	AT	TAT	WT
P1	5	1	5	1	12	7
P2	4	0	4	0	8	4
P3	7	2	7	2	14	7

## 4) Priority

Process	Input			Output				
	AT	BT	Priority	AT	BT	Priority	TAT	WT
P1	0	3	2	0	3	2	3	0
P2	2	5	6	2	5	6	16	11
P3	1	4	3	1	4	3	6	2
P4	4	2	5	4	2	5	9	7
P5	6	9	7	6	9	7	21	12
P6	5	4	4	5	4	4	6	7
P7	7	10	10	7	10	10	30	18

Result = Success

## Conclusion:

Hence we successfully implemented all the scheduling algorithms in JAVA

```

import java.util.*;

class Process
{
    int pNo=0;
    int arrivalTime=0;
    int burstTime=0;
    int turnAroundTime=0;
    int waitTime=0;
}

class FCFS
{
    Queue<Process> arrivalQueue = new LinkedList<Process>();
    Queue<Process> readyQueue = new LinkedList<Process>();
    Queue<Process> finishQueue= new LinkedList<Process>();

    int numProcess;
    int elapsed=0;
    Process p[];

    FCFS()
    {
        Scanner sc = new Scanner(System.in);
        System.out.print("Enter no. of processes : ");
        numProcess = sc.nextInt();
        p = new Process[numProcess];
        for(int i=0;i<numProcess;i++)
        {
            p[i] = new Process();
            p[i].pNo=i;
            System.out.println("Enter Arrival Time for Process: "+i);
            p[i].arrivalTime = sc.nextInt();
            System.out.println("Enter Burst Time for Process: "+i);
            p[i].burstTime=sc.nextInt();
        }
    }

    void setArrivalQueue()
    {
        Process temp;
        for(int i=0; i<numProcess-1 ;i++)
        {
            for(int j=i+1; j<numProcess ; j++)
            {
                if(p[j].arrivalTime < p[i].arrivalTime)
                {
                    temp = p[j];
                    p[j] = p[i];

```



```

        p[i] = temp;
    }
}

for(int i=0;i<numProcess;i++)
{
    arrivalQueue.add(p[i]);
}
}

void setReadyQueue()
{
    for(int i=0 ; i<arrivalQueue.size() ;i++)
    {
        Process p = arrivalQueue.remove();
        if(p.arrivalTime <= elapsed)
        {
            readyQueue.add(p);
        }
        else
        {
            arrivalQueue.add(p);
        }
    }
}

void calculateFCFS()
{
    setArrivalQueue();
    while(!arrivalQueue.isEmpty() || !readyQueue.isEmpty())
    {
        if(!arrivalQueue.isEmpty())
        {
            setReadyQueue();
        }

        if(!readyQueue.isEmpty())
        {
            Process p = readyQueue.remove();
            elapsed = elapsed + p.burstTime;
            p.turnAroundTime = elapsed - p.arrivalTime;
            p.waitTime = p.turnAroundTime - p.burstTime;
            finishQueue.add(p);
        }
        else
        {
            elapsed = elapsed + 1;
        }
    }
}

```

```

        }
    }

    void display()
    {
        double avgWaitTime=0;
        double avgTurnAroundTime=0;
        System.out.println("PN \t AT \t BT \t TAT \t WT");
        while(!finishQueue.isEmpty())
        {
            Process p = finishQueue.remove();
            System.out.println(p.pNo + " \t " + p.arrivalTime + " \t " + p.burstTime + " \t " +
p.turnAroundTime + " \t " + p.waitTime);
            avgWaitTime = avgWaitTime + p.waitTime;
            avgTurnAroundTime = avgTurnAroundTime + p.turnAroundTime;
        }
        avgWaitTime = avgWaitTime/numProcess;
        avgTurnAroundTime = avgTurnAroundTime/numProcess;
        System.out.println("Average Waiting Time is: "+avgWaitTime);
        System.out.println("Average Turn Around Time is: "+avgTurnAroundTime);
    }

    public static void main(String args[])
    {
        FCFS f = new FCFS();
        f.calculateFCFS();
        f.display();
    }
}

```

```
import java.util.*;
```

```

class Process
{
    int pNo=0;
    int arrivalTime=0;
    int burstTime=0;
    int turnAroundTime=0;
    int waitTime=0;
    int priority=-1;
}

class Priority
{
    Queue<Process> arrivalQueue = new LinkedList<Process>();
    Queue<Process> readyQueue = new LinkedList<Process>();
    Queue<Process> finishQueue= new LinkedList<Process>();
}

```



```

int numProcess;
int elapsed=0;
Process p[];

Priority()
{
    Scanner sc = new Scanner(System.in);
    System.out.println("Enter no. of processes : ");
    numProcess = sc.nextInt();
    p = new Process[numProcess];

    for(int i=0;i<numProcess;i++)
    {
        p[i] = new Process();
        p[i].pNo=i;
        System.out.println("Enter arrival Time for Process: "+i);
        p[i].arrivalTime = sc.nextInt();
        System.out.println("Enter Burst Time for Process: "+i);
        p[i].burstTime=sc.nextInt();
        System.out.println("Enter Priority for Process: "+i);
        p[i].priority=sc.nextInt();
    }
}

void setArrivalQueue()
{
    Process temp;
    for(int i=0; i<numProcess-1 ;i++)
    {
        for(int j=i+1; j<numProcess ; j++)
        {
            if(p[j].priority < p[i].priority)
            {
                temp = p[j];
                p[j] = p[i];
                p[i] = temp;
            }
        }
    }

    for(int i=0;i<numProcess;i++)
    {
        arrivalQueue.add(p[i]);
    }
}

void setReadyQueue()
{
    int asize = arrivalQueue.size();

```

```

for(int i=0;i<asize;i++)
{
    Process p = arrivalQueue.remove();
    if(p.arrivalTime <= elapsed)
    {
        readyQueue.add(p);
    }
    else
    {
        arrivalQueue.add(p);
    }
}

void cal()
{
    setArrivalQueue();

    while(!arrivalQueue.isEmpty() || !readyQueue.isEmpty())
    {
        if(!arrivalQueue.isEmpty())
        {
            setReadyQueue();
        }

        if(!readyQueue.isEmpty())
        {
            //System.out.println("In readyQueue Queue");
            Process p = readyQueue.remove();
            elapsed = elapsed + p.burstTime;
            p.turnAroundTime = elapsed - p.arrivalTime;
            p.waitTime = p.turnAroundTime - p.burstTime;
            finishQueue.add(p);
        }
        else
        {
            elapsed = elapsed + 1;
        }
    }
}

void display()
{
    double avgWaitTime=0, avgTurnAroundTime=0;
    System.out.println("PN \t AT \t BT \t TAT \t WT \t PT");
    while(!finishQueue.isEmpty())
    {
        Process p = finishQueue.remove();
    }
}

```

```

        System.out.println(p.pNo + " \t " + p.arrivalTime + " \t " + p.burstTime + " \t " +
p.turnAroundTime + " \t " + p.waitTime + " \t " + p.priority);
        avgWaitTime = avgWaitTime + p.waitTime;
        avgTurnAroundTime = avgTurnAroundTime + p.turnAroundTime;
    }
    avgWaitTime = avgWaitTime/numProcess;
    avgTurnAroundTime = avgTurnAroundTime/numProcess;
    System.out.println("Average Waiting Time is: "+avgWaitTime);
    System.out.println("Average Turn Around Time is: "+avgTurnAroundTime);
}
public static void main(String args[])
{
    Priority p = new Priority();
    p.cal();
    p.display();
}
}

```

```
import java.util.*;
```

```

class Process
{
    int pNo=0;
    int arrivalTime=0;
    int burstTime=0;
    int turnAroundTime=0;
    int waitTime=0;
    int rburst=0;
}

```

```

class RR
{
    Queue<Process> arrivalQueue = new LinkedList<Process>();
    Queue<Process> readyQueue = new LinkedList<Process>();
    Queue<Process> finishQueue= new LinkedList<Process>();
    int numProcess;
    int elapsed=0;
    int quantum=0;
    Process p[];
    String seq = "";
    RR()
    {
        Scanner sc = new Scanner(System.in);
        System.out.println("Enter no. of processes:");
        numProcess = sc.nextInt();
        p = new Process[numProcess];

        System.out.println("Enter size of Quantum:");
    }
}

```



```

quantum = sc.nextInt();

for(int i=0;i<numProcess;i++)
{
    p[i] = new Process();
    p[i].pNo=i;
    System.out.println("Enter arrival Time for Process: "+i);
    p[i].arrivalTime = sc.nextInt();
    System.out.println("Enter Burst Time for Process: "+i);
    p[i].burstTime=sc.nextInt();
    p[i].rburst=p[i].burstTime;
}
}

void setArrival()
{
    Process temp;
    for(int i=0; i<numProcess-1 ;i++)
    {
        for(int j=i+1; j<numProcess ; j++)
        {
            if(p[j].arrivalTime < p[i].arrivalTime)
            {
                temp = p[j];
                p[j] = p[i];
                p[i] = temp;
            }
        }
    }

    for(int i=0;i<numProcess;i++)
    {
        arrivalQueue.add(p[i]);
    }
}

void setReadyQueue()
{
    int asize = arrivalQueue.size();
    for(int i=0;i<asize;i++)
    {
        Process p = arrivalQueue.remove();
        if(p.arrivalTime <= elapsed)
        {
            readyQueue.add(p);
        }
        else
        {
            arrivalQueue.add(p);
        }
    }
}

```

```

    }
}

void cal()
{
    setArrival();
    int rrflag=0;
    Process p1=p[0];
    while(!arrivalQueue.isEmpty() || !readyQueue.isEmpty())
    {
        if(!arrivalQueue.isEmpty())
        {
            setReadyQueue();
        }

        if(rrflag == 1)
        {
            readyQueue.add(p1);
            rrflag = 0;
        }

        if(!readyQueue.isEmpty())
        {
            p1 = readyQueue.remove();
            if(p1.rburst <= quantum)
            {
                elapsed = elapsed + p1.rburst;
                p1.turnAroundTime = elapsed - p1.arrivalTime;
                p1.waitTime = p1.turnAroundTime - p1.burstTime;
                finishQueue.add(p1);
                seq = seq + p1.pNo + " -> ";
            }
            else
            {
                elapsed = elapsed + quantum;
                p1.rburst = p1.rburst - quantum;
                if(!arrivalQueue.isEmpty())
                {
                    rrflag=1;
                }
                else
                {
                    readyQueue.add(p1);
                }
                seq = seq + p1.pNo + " -> ";
            }
        }
    }
    else

```

```

        {
            elapsed = elapsed + 1;
        }
    }
}

void display()
{
    double avgWaitingTime = 0, avgTurnAroundTime = 0;
    System.out.println("PN \t AT \t BT \t TAT \t WT");
    while(!finishQueue.isEmpty())
    {
        Process p = finishQueue.remove();
        System.out.println(p.pNo + " \t " + p.arrivalTime + " \t " + p.burstTime + " \t " +
p.turnAroundTime + " \t " + p.waitTime);
        avgWaitingTime = avgWaitingTime + p.waitTime;
        avgTurnAroundTime = avgTurnAroundTime + p.turnAroundTime;
    }
    avgWaitingTime = avgWaitingTime/numProcess;
    avgTurnAroundTime = avgTurnAroundTime/numProcess;
    System.out.println("Average Waiting Time is: "+avgWaitingTime);
    System.out.println("Average Turn Around Time is: "+avgTurnAroundTime);
    System.out.println(seq);
}

public static void main(String args[])
{
    RR r = new RR();
    r.cal();
    r.display();
}
}

```

```
import java.util.*;
```

```

class Process
{
    int pNo=0;
    int arrivalTime=0;
    int burstTime=0;
    int turnAroundTime=0;
    int waitTime=0;
    int rburst=0;
}

class SJF
{
    Queue<Process> arrivalQueue = new LinkedList<Process>();
    Queue<Process> readyQueue = new LinkedList<Process>();
}

```



```

Queue<Process> finishQueue= new LinkedList<Process>();
int numProcess;
int elapsed=0;
int quantum=0;
Process p[];

```

```

SJF()

```

```

{
    Scanner sc = new Scanner(System.in);
    System.out.print("Enter no. of Processes : ");
    numProcess = sc.nextInt();
    p = new Process[numProcess];

    System.out.print("Enter size of Quantum : ");
    quantum = sc.nextInt();

    for(int i=0;i<numProcess;i++)
    {
        p[i] = new Process();
        p[i].pNo=i;
        System.out.println("Enter arrival Time for Process: "+i);
        p[i].arrivalTime = sc.nextInt();
        System.out.println("Enter Burst Time for Process: "+i);
        p[i].burstTime=sc.nextInt();
        p[i].rburst=p[i].burstTime;
    }
}

```

```

void setArrival()

```

```

{
    Process temp;
    for(int i=0; i<numProcess-1 ;i++)           //Sorting it in ascending order according to
burst time
    {
        for(int j=i+1; j<numProcess ; j++)
        {
            if(p[j].burstTime < p[i].burstTime)
            {
                temp = p[j];
                p[j] = p[i];
                p[i] = temp;
            }
        }
    }

    for(int i=0;i<numProcess;i++)
    {
        arrivalQueue.add(p[i]);
    }
}

```

```

}

void setReadyQueue()
{
    for(int i=0;i<arrivalQueue.size();i++)
    {
        Process p = arrivalQueue.remove();
        if(p.arrivalTime <= elapsed)
        {
            readyQueue.add(p);
        }
        else
        {
            arrivalQueue.add(p);
        }
    }
}

void sortReadyQueue()
{
    Process p1[] = new Process[numProcess]; //Temporary array used for sorting
    int queueSize = readyQueue.size();

    for(int i=0;i<queueSize;i++)
    {
        p1[i] = readyQueue.remove();
    }

    Process temp;
    for(int i=0; i<queueSize-1 ;i++)
    {
        for(int j=i+1; j<queueSize ; j++)
        {
            if(p1[j].rburst < p1[i].rburst)
            {
                temp = p1[j];
                p1[j] = p1[i];
                p1[i] = temp;
            }
        }
    }
    for(int i=0;i<queueSize;i++)
    {
        readyQueue.add(p1[i]);
    }
}

void cal()
{

```

```

setArrival();

while(!arrivalQueue.isEmpty() || !readyQueue.isEmpty())
{
    if(!arrivalQueue.isEmpty())
    {
        setReadyQueue();
    }

    if(!readyQueue.isEmpty())
    {
        if(readyQueue.size() > 1)
        {
            sortReadyQueue();
        }
        Process p = readyQueue.remove();
        if(p.rburst <= quantum)
        {
            elapsed = elapsed + p.rburst;
            p.turnAroundTime = elapsed - p.arrivalTime;
            p.waitTime = p.turnAroundTime - p.burstTime;
            finishQueue.add(p);
        }
        else
        {
            elapsed = elapsed + quantum;
            p.rburst = p.rburst - quantum;
            readyQueue.add(p);
        }
    }
    else
    {
        elapsed = elapsed + 1;
    }
}

void display()
{
    double avgWaitingTime=0,avgTurnAroundTime=0;
    System.out.println("PN \t AT \t BT \t TAT \t WT");
    while(!finishQueue.isEmpty())
    {
        Process p = finishQueue.remove();
        System.out.println(p.pNo + " \t " + p.arrivalTime + " \t " + p.burstTime + " \t " +
p.turnAroundTime + " \t " + p.waitTime);
        avgWaitingTime = avgWaitingTime + p.waitTime;
        avgTurnAroundTime = avgTurnAroundTime + p.turnAroundTime;
    }
}

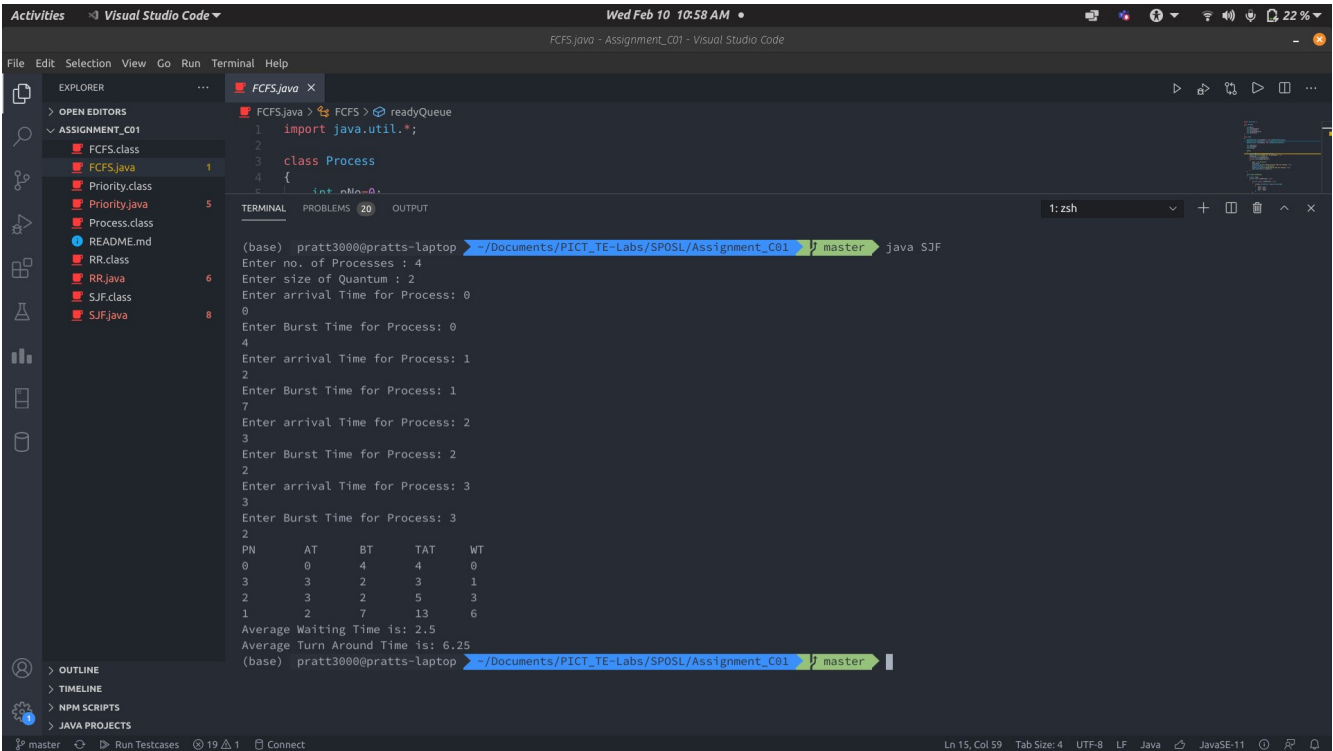
```



```

        avgWaitingTime = avgWaitingTime/numProcess;
        avgTurnAroundTime = avgTurnAroundTime/numProcess;
        System.out.println("Average Waiting Time is: "+avgWaitingTime);
        System.out.println("Average Turn Around Time is: "+avgTurnAroundTime);
    }
    public static void main(String args[])
    {
        SJF s = new SJF();
        s.cal();
        s.display();
    }
}

```



The screenshot shows the Visual Studio Code interface with a Java file named `FCFS.java` open. The terminal window displays the output of running the program `java SJF`. The program prompts for the number of processes (4), the size of the quantum (2), and then the arrival and burst times for each process. The output includes a Gantt chart, the average waiting time (2.5), and the average turn around time (6.25).

```

(base) pratt3000@pratts-laptop ~/Documents/PICT_TE-Labs/SPOSIL/Assignment_C01 master$ java SJF
Enter no. of Processes : 4
Enter size of Quantum : 2
Enter arrival Time for Process: 0
0
Enter Burst Time for Process: 0
4
Enter arrival Time for Process: 1
2
Enter Burst Time for Process: 1
7
Enter arrival Time for Process: 2
3
Enter Burst Time for Process: 2
2
Enter arrival Time for Process: 3
3
Enter Burst Time for Process: 3
2
PN   AT   BT   TAT  WT
0    0    4    4    0
3    3    2    3    1
2    3    2    5    3
1    2    7    13   6
Average Waiting Time is: 2.5
Average Turn Around Time is: 6.25
(base) pratt3000@pratts-laptop ~/Documents/PICT_TE-Labs/SPOSIL/Assignment_C01 master$

```

Visual Studio Code interface showing the execution of the RR.java program. The Explorer pane on the left lists files in the ASSIGNMENT\_C01 directory, including FCFS.class, FCFS.java, Priority.class, Priority.java, Process.class, README.md, RR.class, RR.java, SJF.class, and SJF.java. The main editor displays the code for RR.java, which implements a Round Robin scheduling algorithm. The terminal window shows the execution of the program, where the user enters the number of processes (3) and the quantum size (2). The program then prompts for arrival and burst times for each process. The output displays a table with columns PN, AT, BT, TAT, and WT, showing the scheduling results for the three processes. The average waiting time is 2.6666666666666665 and the average turn around time is 6.333333333333333.

```
String seq = "";
RR()
{
    Scanner sc = new Scanner(System.in);
    System.out.println("Enter no. of processes:");
    numProcess = sc.nextInt();
    p = new Process[numProcess];

    System.out.println("Enter size of Quantum:");
    quantum = sc.nextInt();

    (base) pratt3000@pratts-laptop ~/Documents/PICT_TE-Labs/SPOSL/Assignment_C01 master java RR
Enter no. of processes:
3
Enter size of Quantum:
2
Enter arrival Time for Process: 0
1
Enter Burst Time for Process: 0
5
Enter arrival Time for Process: 1
0
Enter Burst Time for Process: 1
4
Enter arrival Time for Process: 2
7
Enter Burst Time for Process: 2
2
PN    AT    BT    TAT    WT
1     0     4     6     2
2     7     2     3     1
0     1     5    10     5
Average Waiting Time is: 2.6666666666666665
Average Turn Around Time is: 6.333333333333333
1 -> 0 -> 1 -> 0 -> 2 -> 0 ->
(base) pratt3000@pratts-laptop ~/Documents/PICT_TE-Labs/SPOSL/Assignment_C01 master
```

Visual Studio Code interface showing the execution of the Priority.java program. The Explorer pane on the left lists files in the ASSIGNMENT\_C01 directory, including FCFS.class, FCFS.java, Priority.class, Priority.java, Process.class, README.md, RR.class, RR.java, SJF.class, and SJF.java. The main editor displays the code for Priority.java, which implements a Priority scheduling algorithm. The terminal window shows the execution of the program, where the user enters the arrival times and priorities for six processes. The output displays a table with columns PN, AT, BT, TAT, WT, and PT, showing the scheduling results for the six processes. The average waiting time is 8.285714285714286 and the average turn around time is 13.871428571428571.

```
Priority
Enter arrival Time for Process: 3
4
Enter Burst Time for Process: 3
2
Enter Priority for Process: 3
5
Enter arrival Time for Process: 4
6
Enter Burst Time for Process: 4
9
Enter Priority for Process: 4
7
Enter arrival Time for Process: 5
5
Enter Burst Time for Process: 5
4
Enter Priority for Process: 5
4
Enter arrival Time for Process: 6
7
Enter Burst Time for Process: 6
10
Enter Priority for Process: 6
10
PN    AT    BT    TAT    WT    PT
0     0     3     3     0     2
2     1     4     6     2     3
1     2     5    10     5     6
5     5     4    11     7     4
3     4     2    14    12     5
4     6     9    21    12     7
6     7    10    30    20    10
Average Waiting Time is: 8.285714285714286
Average Turn Around Time is: 13.871428571428571
(base) pratt3000@pratts-laptop ~/Documents/PICT_TE-Labs/SPOSL/Assignment_C01 master
```

Activities Visual Studio Code Wed Feb 10 10:57 AM FCFS.java - Assignment\_C01 - Visual Studio Code

File Edit Selection View Go Run Terminal Help

EXPLORER

FCFS.java X

FCFS.java > FCFS > readyQueue

1 import java.util.\*;

2

3 class Process

4 {

5 int nNo=0;

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