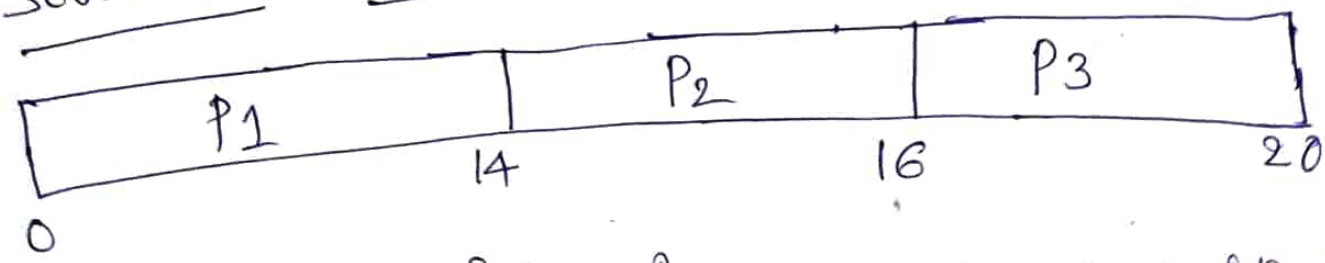
Numerical Problems on Scheduling Algorithms.

1. FCFS [Also called as FIFO] First come First Served]. ⇒ Non-preemptive Algorithm.

Problem (1) Consider the following set of process that Arrives at time 0 milliseconds with the length of the CPU Burst Time given in millI seconds. Calculate the Average waiting Time.

Process	Burst Time
P1	14
P2	2
P3	4

Solution :- Step 1. GANTT Chart.



Step 2: Waiting Time

Process	Waiting Time
P1	0-0
P2	14
P3	16

Average Waiting Time

$\Rightarrow \frac{0+14+16}{3} = \frac{30}{3} = 10$

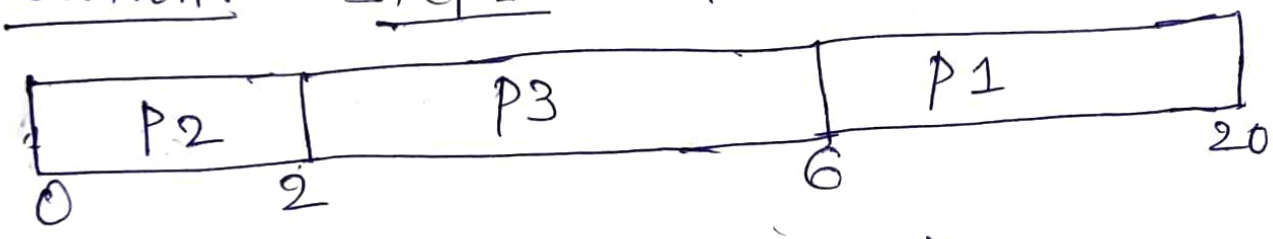
Problem (2) FCFS

If the processes changes their Order of Arrive i.e. P_2, P_3, P_1 Then the Results will be different

Process	Burst Time
P2	2
P3	4
P1	14

Calculate Waiting Time and Average waiting Time.

Solution:- Step 1. GANTT chart



Step 2 Waiting Time (WT)

Process	Waiting Time
P1	6
P2	0
P3	2

Step 3 Average Waiting Time (AWT)

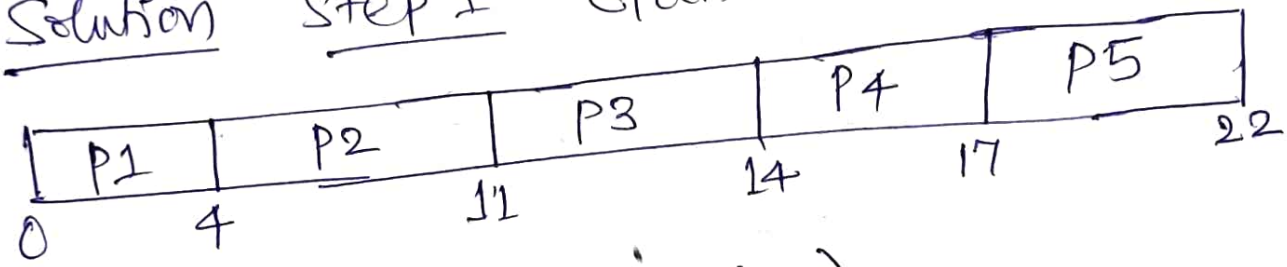
$$AWT = \frac{\text{Sum of } P1\ P2\ P3 \text{ waiting Time}}{3}$$

$$= \frac{6+0+2}{3} = 2.666 \text{ milliseconds.}$$

Problem (3) FCFS

Consider the following set of processes that arrive at time 0, with the length of CPU Burst Time given in milli seconds. Calculate the Average Waiting Time when the processes arrive in the following order - P1, P2, P3, P4, P5. Provide Gantt chart.

Solution Step 1 Gantt chart.



Step 2 Waiting Time (WT)

Process	Waiting Time
P1	0
P2	4
P3	11
P4	14
P5	17

Step 3 Average Waiting Time (AWT)

$$AWT = \frac{0+4+11+14+17}{5} = \frac{46}{5} = 9.2 \text{ ms}.$$

Problems (3) Continued... FCFS... Solution

Step 4 FCFS

Turn Around Time (TAT) = WT + BT

Process	Turn Around Time Waiting Time + Burst Time
P1	0 + 4 = 4
P2	4 + 7 = 11
P3	11 + 3 = 14
P4	14 + 3 = 17
P5	17 + 5 = 22

Average Turn Around Time (ATAT)

$$ATAT = \frac{4 + 11 + 14 + 17 + 22}{5} = \frac{68}{5} = 13.60$$

$$= \frac{\text{Sum of All Turn Around Time}}{\text{Total number of Processes}}$$

$$= 13.60 \text{ milliseconds}$$

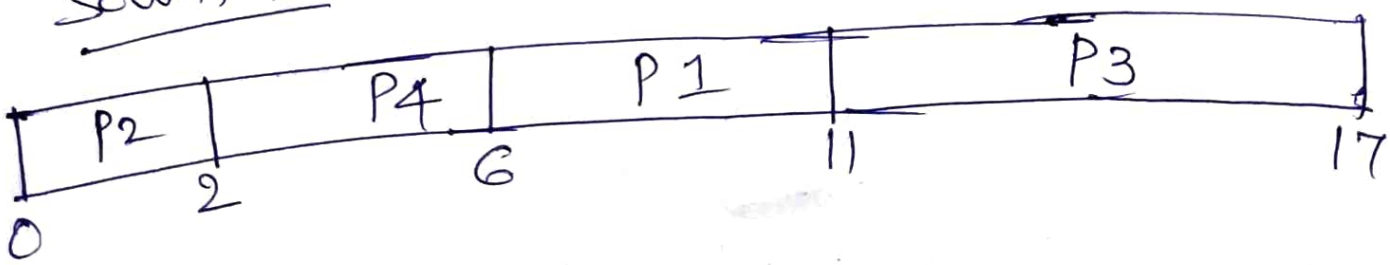
Numerical Problems on Shortest Job First Scheduling (SJFS) Algorithm (SJF)

It is a Non Preemptive CPU Scheduling Algorithm. Preemptive version of (SJF) is SRTN (Shortest Remaining Time Next)

Problem (1) Calculate the Average Waiting Time and Average Turn Around Time. Provide the Gantt chart.

Process	Burst Time (BT)
P1	5
P2	2
P3	6
P4	4

Solution:- Step 1. Gantt chart



Problem on SJF Continued...

Solution Step 2 Waiting Time (WT)

Process	Waiting Time
P1	6
P2	0
P3	11
P4	2

Average Waiting Time = $\frac{6+0+11+2}{4} = \frac{19}{4}$

Step 3 Average WT = 4.75 milliseconds

Turn Around Time = Waiting Time + Burst Time

Process	Turn Around Time Waiting Time + Burst Time
P1	6+5 = 11
P2	0+2 = 2
P3	11+6 = 17
P4	2+4 = 6

Step 4. Average Turn Around Time = $\frac{11+2+17+6}{4}$

$= \frac{36}{4} = 9$ ms.

Numerical Example on Priority scheduling Algorithm

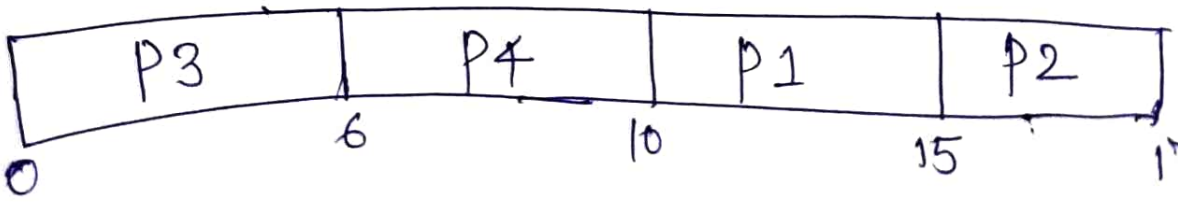
It is both preemptive and non preemptive.
Each process is assigned on priority number.

Problem (1) Calculate the Average Time for Waiting Time, Turn Around Time, provide Gantt chart for the given process that Arrive at time 0.

Process	Burst Time	priority
P1	5	3
P2	2	4
P3	6	1
P4	4	2

Solution Step 1 Gantt chart

For Non-preemptive priority scheduling.



Solution on Priority scheduling continued...

Step 2 Waiting Time (WT)

Process	Waiting Time
P1	10
P2	15
P3	0
P4	6

Average Waiting Time $= \frac{10+15+0+6}{4} = \frac{31}{4} = 7.75$

Step 3 Turn Around Time = Waiting Time + Burst Time.

Process	Turn Around Time
P1	10 + 5 = 15
P2	15 + 2 = 17
P3	0 + 6 = 6
P4	6 + 4 = 10

Average Turn Around Time $= \frac{15+17+6+10}{4}$

$= \frac{48}{4} = 12$ milliseconds

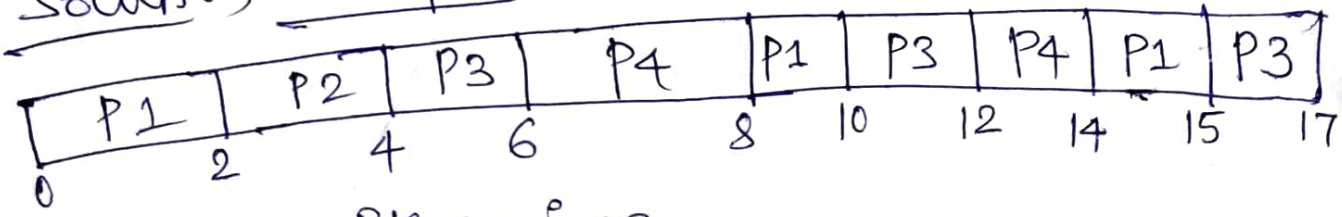
Problems on Round Robin Scheduling Algorithm

It is a preemptive cpu scheduling Algorithm.
Process are given a limited Amount of time of processor called Time Slice (or) Time Quantum.

Example (1) Consider the following set of process that arrive at a time 0, with the length of CPU Burst Time given in milliseconds. Calculate the Average Waiting Time and Average Turn Around Time. Provide Gantt chart for the same (Time Slice = 2).

Process	Burst Time (BT)
P1	5
P2	2
P3	6
P4	4

Solution **Step 1** Gantt chart



Step 2 Waiting Time

Process	Waiting Time
P1	10
P2	2

Solution on Round Robin scheduling continued --

Step 2 Waiting Time.

Process	Waiting Time
P3	11
P4	10

Average waiting Time = $\frac{10+2+11+10}{4} = \frac{33}{4} = 8.25$ milliseconds

Step 3 Turn Around Time

Turn Around Time = Waiting Time + Burst Time

Process	Turn Around Time TAT = WT + BT
P1	10 + 5 = 15
P2	2 + 2 = 4
P3	11 + 6 = 17
P4	10 + 4 = 14

Step 4 Average Turn Around Time

$ATAT = \frac{15+4+17+14}{4} = \frac{50}{4} = 12.5$ milliseconds

Problems on Shortest Remaining Time First CPU scheduling Algorithm (SRTF)

It is a Preemptive SJF. In this Algorithm the CPU Scheduler selects the process with the smallest estimated run time to completion.

When new process is admitted the SRTF only needs to compare the currently executing process with the new process, ignoring all other processes currently waiting to execute.

Example (1) problem on (SRTF)

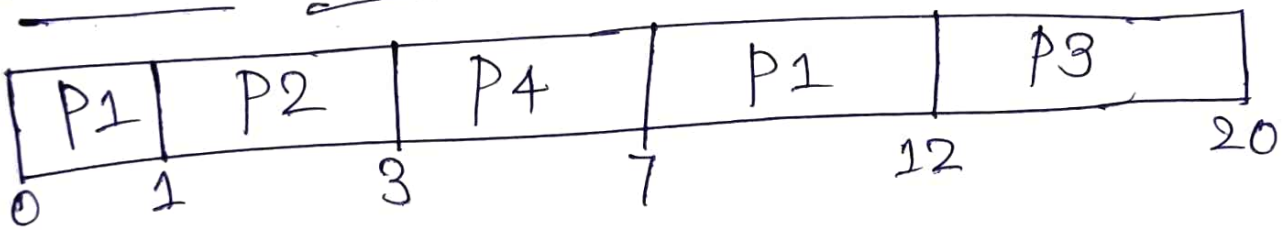
Consider the four process with their Arrival Time and Burst time, Calculate Average waiting Time, Turn Around time and Provide Gantt chart.

Process	Burst Time (BT)	Arrival Time (AT)
P_1	6	0
P_2	2	1
P_3	8	2
P_4	4	3

Problem on SRTF Continued....

Process	Burst time	Arrival Time
P1	6	0
P2	2	1
P3	8	2
P4	4	3

Solution Step 1 Gantt chart



Step 2 Waiting Time

Process	Waiting Time
P1	6
P2	0
P3	10
P4	0

Step 3 Average Waiting Time (AWT)

$\Rightarrow \frac{6+0+10+0}{4} = \frac{16}{4}$

$= 4$ milliseconds.

Step 4 Turn Around Time.

Process	Turn Around Time
P1	6+6=12
P2	2+0=2
P3	8+10=18
P4	4+0=4

Step 5 Average TAT

$= \frac{12+2+18+4}{4}$

$= \frac{36}{4} = 9$ milliseconds

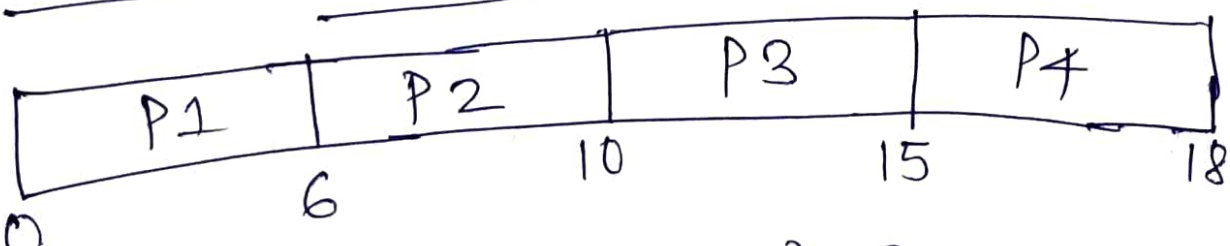
Problem on SJF (preemptive and Non preemptive) and FCFS. CPU Algorithms.

Example: (1) Consider the following set of processes with the lengths of CPU Burst Time given in milliseconds

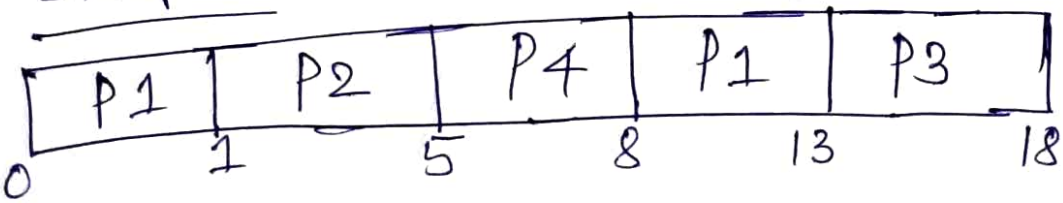
process	Arrival Time (AT)	Burst Time (BT)
P1	0	6
P2	1	4
P3	3	5
P4	5	3

Draw the Gantt chart, Illustrative the execution of these processes using SJF (preemptive and non preemptive) and FCFS. Calculate Average Turn Around Time Average waiting Time in each process.

Solution Step 1 FCFS Gantt chart

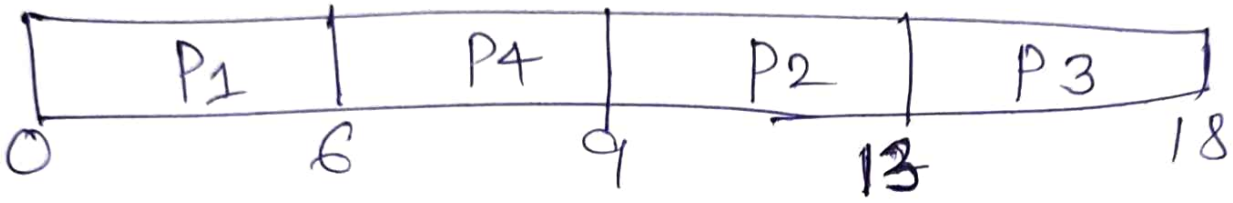


Step 2 SJF (preemptive) Gantt Chart



Solution of SJF (Preemptive and nonpreemptive) and FCFS Continued....

Step3 SJF (Non Preemptive) Gantt chatt



Step4 FCFS

Process	Waiting Time	Turn Around Time BT + WT
P_1	0	6
P_2	5	9
P_3	7	12
P_4	10	13

Average waiting Time $= \frac{0+5+7+10}{4} = \frac{22}{4} = 5.5$

Average Turn Around Time $= \frac{6+9+12+13}{4}$

$= \frac{40}{4} = 10$ milli seconds.

Solution Continued on SJF (preemptive, non preemptive) and FCFS.

Step 5 SJF (preemptive)

process	Waiting Time	Turn Around Time WT + BT
P1	7	7+6=13
P2	0	0+4=4
P3	10	5+10=15
P4	0	0+3=3

Average waiting Time $= \frac{7+0+10+0}{4} = \frac{17}{4} = 4.25$

Average Turn Around Time $= \frac{13+4+15+3}{4} = \frac{35}{4}$

$= 8.75$ milliseconds

Step 6 SJF (non-preemptive)

process	Waiting Time	Turn Around Time WT + BT
P1	0	0+6=6
P2	8	8+4=12
P3	10	9+5=14
P4	1	1+3=4

Average Waiting Time $= \frac{0+8+10+1}{4} = \frac{19}{4} = 4.75$

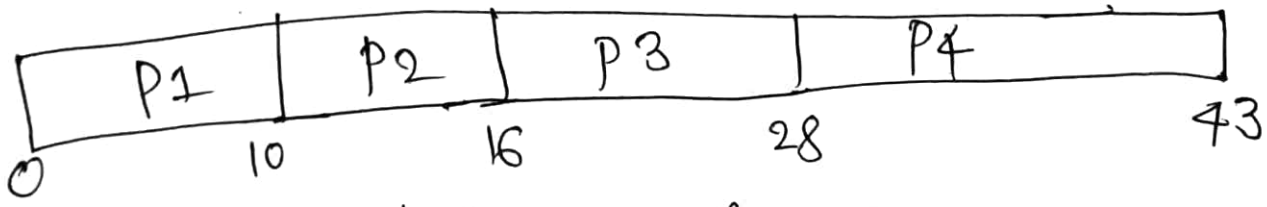
Average Turn Around Time $= \frac{6+12+14+4}{4} = \frac{36}{4} = 9$

Numerical Example on (A) FCFS, (B) Preemptive and (C) Non-preemptive Versions of Shortest Job First and (D) Round Robin (Time Slice = 2) schedule Algorithms with Gantt Chart for the processes given Below. Calculate their Average waiting Time and Turn Around Time.

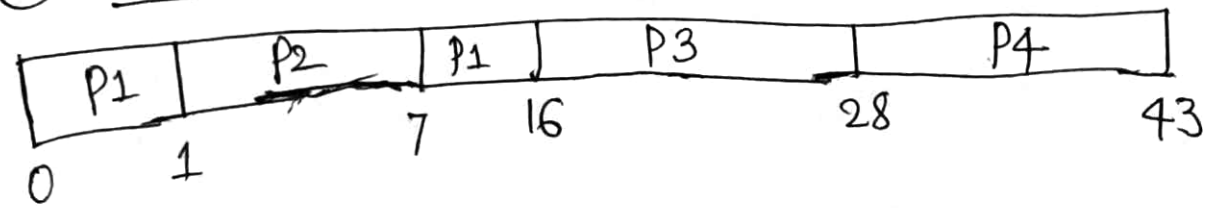
Problem (1)

Process	Arrival Time	Burst Time
P1	0	10
P2	1	6
P3	2	12
P4	3	15

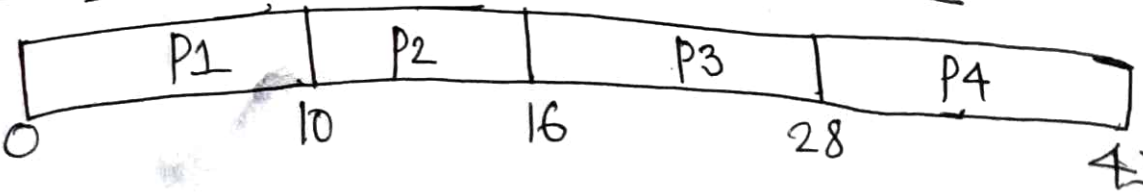
Solution Step 1 (A) Gantt chart FCFS.



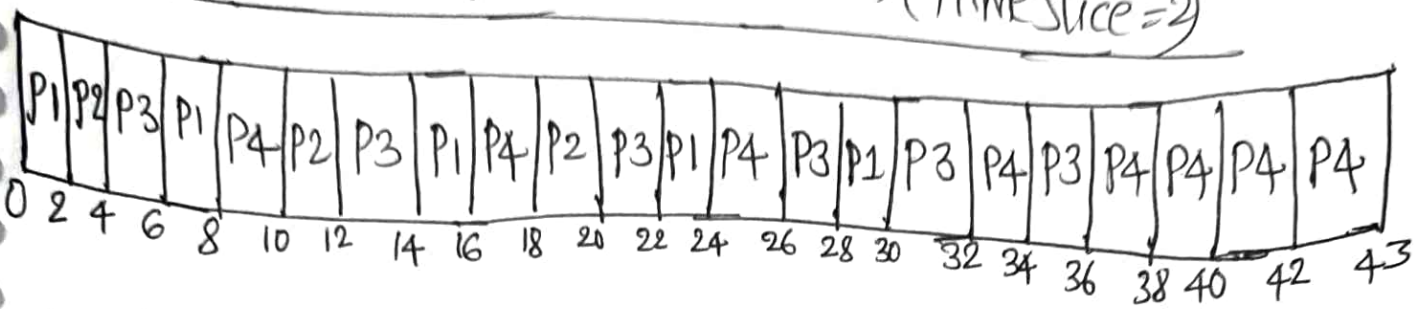
(B) Gantt chart for preemptive SJF



(C) Gantt chart for Non Preemptive SJF



Gantt chart for Round Robin (Time Slice = 2)



Waiting Time.

Process	FCFS	preemptive SJF	Non preemptive SJF	Round Robin
P1	0	6	0	20
P2	9	0	9	13
P3	14	14	14	22
P4	25	25	25	33

Average Waiting Time

$$FCFS = \frac{0+9+14+25}{4} = \frac{48}{4} = 12$$

$$\text{Preemptive SJF} = \frac{6+0+14+25}{4} = \frac{45}{4} = 11.25$$

$$\text{Non preemptive SJF} = \frac{0+9+14+25}{4} = \frac{48}{4} = 12$$

$$\text{Round Robin} = \frac{20+13+22+33}{4} = \frac{88}{4} = 22$$

Turn Around Time = Waiting Time + Burst Time

Process	FCFS	Preemptive SJF	Non preemptive SJF	Round Robin
P_1	10	16	10	30
P_2	15	6	15	19
P_3	26	26	26	34
P_4	40	40	40	48

Average Turn Around Time

$$FCFS = \frac{10+15+26+40}{4} = \frac{91}{4} = 22.75$$

$$\text{preemptive SJF} = \frac{16+6+26+40}{4} = \frac{88}{4} = 22$$

$$\text{Non preemptive SJF} = \frac{10+15+26+40}{4} = \frac{91}{4} = 22.75$$

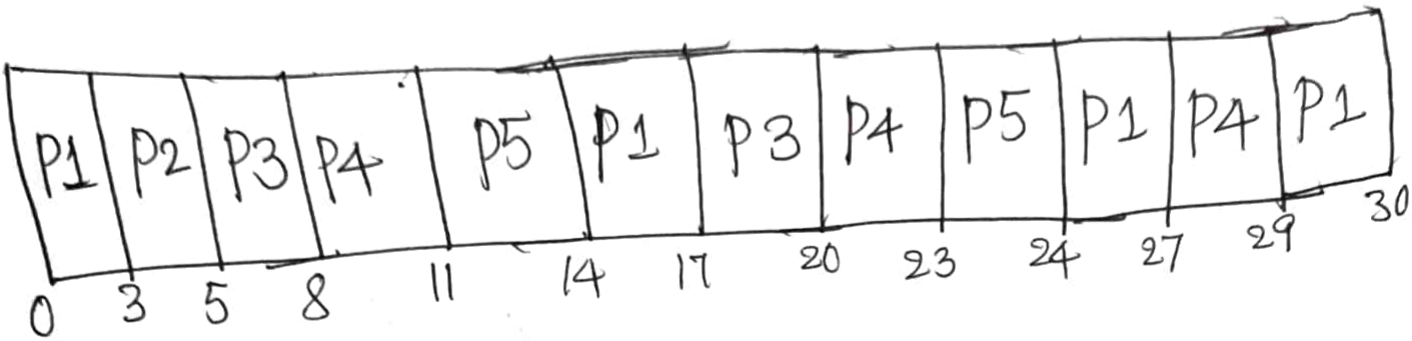
$$\text{Round Robin RR} = \frac{30+19+34+48}{4} = \frac{131}{4} = 35.22$$

Numerical Example on Priority Algorithm and Round Robin Algorithm

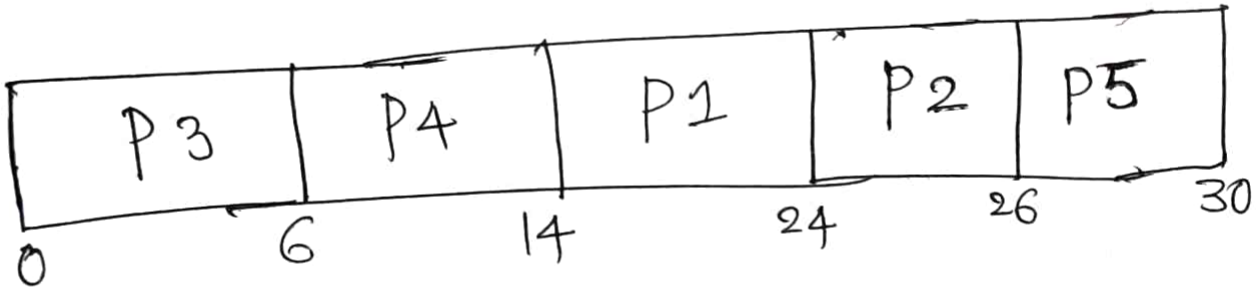
Problem 1 Consider Five processes P1 To P5 arrived at the same time. They have estimated Running time 10, 2, 6, 8 and 4 seconds respectively Their priorities are 3, 2, 5, 4 and 1 respectively with 5 being highest priority. Find the average waiting Time, Average Turn around time for Round Robin (Time Slice q=3) and priority Scheduling Algorithm.

Process	Estimated Running Time (BT)	priority
P1	10	3
P2	2	2
P3	6	5
P4	8	4
P5	4	1

Solution Step 1 Gantt chart for Round Robin (Time Slice q=3)



Step 2 Gantt chart for Priority.



Step 3 Waiting Time

Process	Round Robin	Priority
P1	20	14
P2	3	24
P3	14	0
P4	21	6
P5	20	26

Average Waiting Time = $\frac{20+3+14+21+20}{5} = \frac{78}{5}$

Round Robin = 15.60 milliseconds

Step 4 Turn Around Time

Process	Round Robin	priority
P1	30	24
P2	5	26
P3	20	6
P4	29	14
P5	24	30

Average Turn Around Time = $\frac{30+5+20+29+24}{5}$

Round Robin $= \frac{108}{5} = 21.6$ milliseconds

Average Turn Around Time = $\frac{24+26+6+14+30}{5}$

priority $= \frac{100}{5} = 20$ milliseconds

Average Waiting Time = $\frac{14+24+0+6+26}{5}$

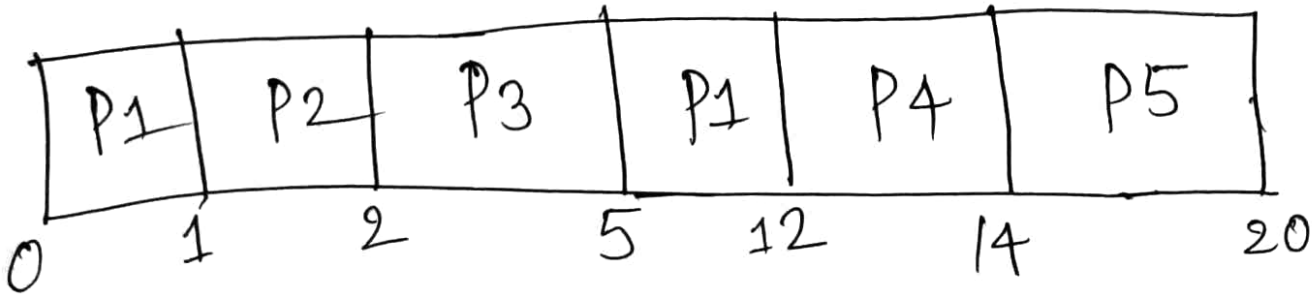
priority $= \frac{70}{5} = 14$ milliseconds

Numerical Example on CPU scheduling Algorithms Priority - preemptive mode -

Example (1) Consider the following processes Find Average Waiting Time, Average Turn Around time and provide Gantt chart.

Process	Arrival Time (AT)	Burst Time (BT)	priority
P1	0	8	3
P2	1	1	1
P3	2	3	2
P4	3	2	3
P5	4	6	4

Solution:- Step 1 Gantt chart



Waiting Time (WT)

Process	Waiting Time
P1	5-1 = 4
P2	1-1 = 0
P3	2-2 = 0
P4	12-3 = 9
P5	14-4 = 10

Average waiting time = $\frac{4+0+0+9+10}{5}$

$= \frac{23}{5}$

Avg Waiting Time = 4.6 milliseconds

Turn Around Time (TAT) = WT + BT

Process	Waiting Time + Burst Time (TAT)
P1	4 + 8 = 12
P2	0 + 1 = 1
P3	0 + 3 = 3
P4	9 + 2 = 11
P5	10 + 6 = 16

Average Turn Around Time

$$= \frac{12 + 1 + 3 + 11 + 16}{5}$$

$\Rightarrow$ ATAT $= \frac{43}{5} = 8.6$ milliseconds

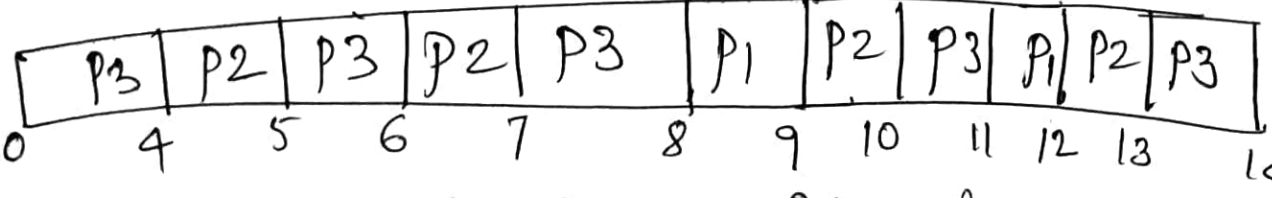
Example on CPU Scheduling Algorithm (LRTF)

Longest Remaining Time first

Problem: Find Average waiting Time, Turn Around Time, provide Gantt chart:

process	Arrival Time	Burst Time
P1	0	2
P2	0	4
P3	0	8

Solution Step 1 Gantt chart



Step 2 completion Time, waiting Time, TAT.

Turn Around Time = Completion Time − Arrival Time

Step 3

Process	AT	BT	CT Completion Time	TAT (CT-AT)
P1	0	2	12	CT-AT 12-0=12
P2	0	4	13	13-0=13
P3	0	8	14	14-0=14

Step 4: Average Turn Around Time = $\frac{12+13+14}{3}$

$= \frac{39}{3} = 13$ milli seconds

CpuAlgorithms Numerical Examples in this material.

1. FCFS (First Come First Served)
2. Round Robin scheduling
3. Shortest Remaining Time First (SRTF)
4. priority scheduling (Preemptive and non Preemptive)
5. Shortest Job First (SJF)
6. Longest Time Remaining First (LRTF).