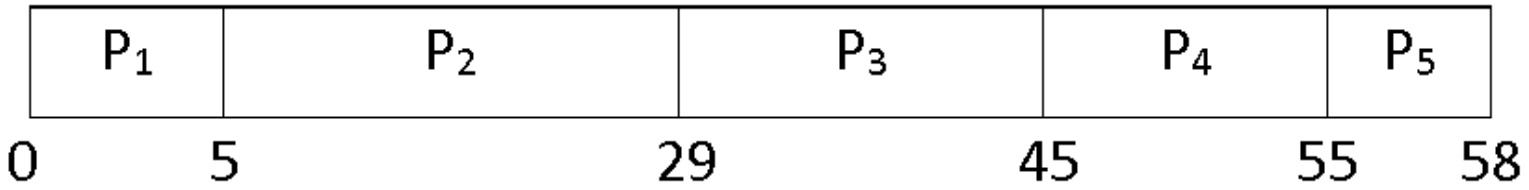
CPU Scheduling Problem Solving

Q: FCFS

- Consider the above set of processes that arrive at time zero. The length of the CPU **burst time** given in millisecond.
- Now calculate the average waiting time, average turnaround time and throughput.

Process	Burst Time(ms)
P_1	5
P_2	24
P_3	16
P_4	10
P_5	3



Solution: FCFS

- **Average Waiting Time**
- First of all, we have to calculate the waiting time of each process.
  Waiting Time = Starting Time - Arrival Time
  Waiting time of
  P1 = 0
  P2 = 5 - 0 = 5 ms
  P3 = 29 - 0 = 29 ms
  P4 = 45 - 0 = 45 ms
  P5 = 55 - 0 = 55 ms
- *Average Waiting Time = Waiting Time of all Processes / Total Number of Process*
  Therefore, average waiting time = (0 + 5 + 29 + 45 + 55) / 5 = 25 ms

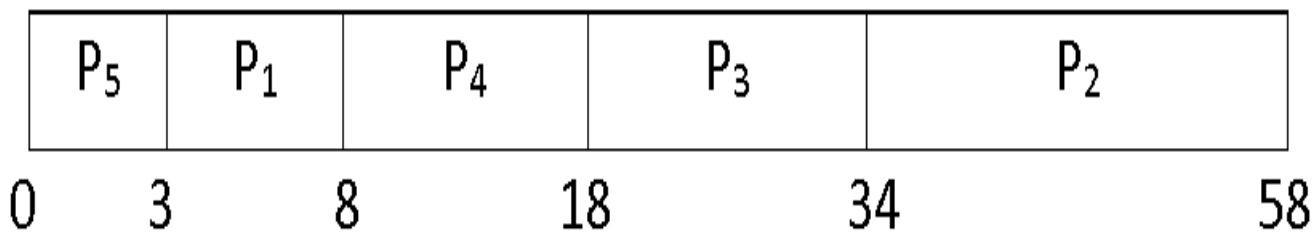
- **Average Turnaround Time**
- *Turnaround Time = Waiting time in the ready queue + executing time + waiting time in waiting-queue for I/O*
  Turnaround time of
  P1 = 0 + 5 + 0 = 5ms
  P2 = 5 + 24 + 0 = 29ms
  P3 = 29 + 16 + 0 = 45ms
  P4 = 45 + 10 + 0 = 55ms
  P5 = 55 + 3 + 0 = 58ms
- Total Turnaround Time = (5 + 29 + 45 + 55 + 58)ms = 192ms
- Average Turnaround Time = (Total Turnaround Time / Total Number of Process) = (192 / 5)ms = 38.4ms

Solution: FCFS

- **Throughput**
- Here, we have a total of five processes. Process P1, P2, P3, P4, and P5 takes 5ms, 24ms, 16ms, 10ms, and 3ms to execute respectively.
  Throughput = (5 + 24 +16 + 10 +3) / 5 = 11.6ms
  It means one process executes in every 11.6 ms.

Q: SJF (Shortest Job First) Scheduling

Process	Burst Time(ms)
P_1	5
P_2	24
P_3	16
P_4	10
P_5	3



Solution: SJF

- **Average Waiting Time**
- To find average waiting time in this problem. Here arrival time is common to all processes(i.e., zero).
  Waiting Time for
  P1 = 3 - 0 = 3ms
  P2 = 34 - 0 = 34ms
  P3 = 18 - 0 = 18ms
  P4 = 8 - 0 = 8ms
  P5 = 0ms
  Now, Average Waiting Time = (3 + 34 + 18 + 8 + 0) / 5 = 12.6ms

- **Average Turnaround Time**
- According to the SJF Gantt chart and the turnaround time formulae,
  Turnaround Time of
  P1 = 3 + 5 = 8ms
  P2 = 34 + 24 = 58ms
  P3 = 18 + 16 = 34ms
  P4 = 8 + 10 = 18ms
  P5 = 0 + 3 = 3ms
  Therefore, Average Turnaround Time = (8 + 58 + 34 + 18 + 3) / 5 = 24.2ms

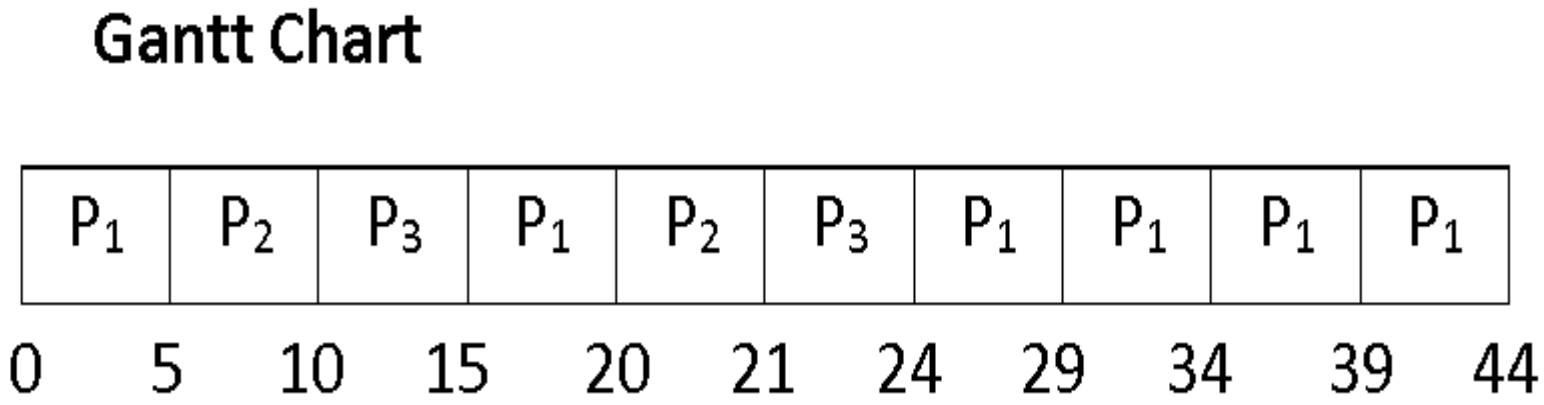
Solution: SJF

- **Throughput**
- Here, we have a total of five processes. Process P1, P2, P3, P4, and P5 takes 5ms, 24ms, 16ms, 10ms, and 3ms to execute respectively.
  Therefore, Throughput will be same as above problem i.e., 11.6ms for each process.

Q: **Round Robin Scheduling**

- Here is the Round Robin scheduling example with gantt chart. Time Quantum is **5ms**.

Process	CPU Burst Time
P_1	30
P_2	6
P_3	8



Solution: SJF

- **Average Waiting Time**
- For finding Average Waiting Time, we have to find out the waiting time of each process.
  Waiting Time of
  P1 = 0 + (15 - 5) + (24 - 20) = 14ms
  P2 = 5 + (20 - 10) = 15ms
  P3 = 10 + (21 - 15) = 16ms
  Therefore, Average Waiting Time = (14 + 15 + 16) / 3 = 15ms

- **Average Turnaround Time**
- Same concept for finding the Turnaround Time.
  Turnaround Time of
  P1 = 14 + 30 = 44ms
  P2 = 15 + 6 = 21ms
  P3 = 16 + 8 = 24ms
  Therefore, Average Turnaround Time = (44 + 21 + 24) / 3 = 29.66ms

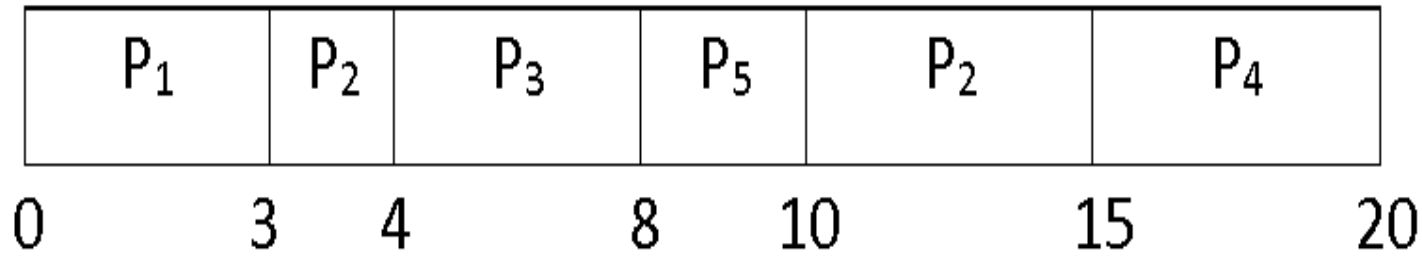
Throughput

Throughput = (30 + 6 + 8) / 3 = 14.66ms

In 14.66ms, one process executes.

Q: **Shortest Remaining Time First(SRTF)**

Process	Burst Time(CPU)	Arrival Time(ms)
P_1	3	0
P_2	6	2
P_3	4	4
P_4	5	6
P_5	2	8



Solution: SRTF

- **Average Waiting Time**
- First of all, we have to find the waiting time for each process.
  Waiting Time of process
  P1 = 0ms
  P2 = (3 - 2) + (10 - 4) = 7ms
  P3 = (4 - 4) = 0ms
  P4 = (15 - 6) = 9ms
  P5 = (8 - 8) = 0ms
  Therefore, Average Waiting Time = (0 + 7 + 0 + 9 + 0) / 5 = 3.2ms

- **Average Turnaround Time**
- First of all, we have to find the turnaround time of each process.
  Turnaround Time of process
  P1 = (0 + 3) = 3ms
  P2 = (7 + 6) = 13ms
  P3 = (0 + 4) = 4ms
  P4 = (9 + 5) = 14ms
  P5 = (0 + 2) = 2ms
  Therefore, Average Turnaround Time = (3 + 13 + 4 + 14 + 2) / 5 = 7.2ms

Throughput

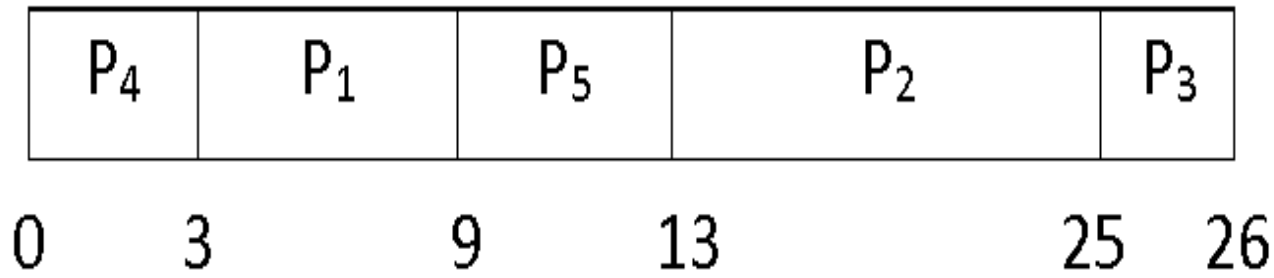
Throughput = (3 + 6 + 4 + 5 + 2) / 5 = 4ms

Therefore, each process takes 4ms to execute.

Q: **Priority Scheduling**

Process	CPU Burst Time	Priority
P_1	6	2
P_2	12	4
P_3	1	5
P_4	3	1
P_5	4	3

Gantt Chart



Solution: Priority

- **Average Waiting Time**
- First of all, we have to find out the waiting time of each process.
  Waiting Time of process
  P1 = 3ms
  P2 = 13ms
  P3 = 25ms
  P4 = 0ms
  P5 = 9ms
  Therefore, Average Waiting Time = (3 + 13 + 25 + 0 + 9) / 5 = 10ms

- **Average Turnaround Time**
- First finding Turnaround Time of each process.
  Turnaround Time of process
  P1 = (3 + 6) = 9ms
  P2 = (13 + 12) = 25ms
  P3 = (25 + 1) = 26ms
  P4 = (0 + 3) = 3ms
  P5 = (9 + 4) = 13ms
  Therefore, Average Turnaround Time = (9 + 25 + 26 + 3 + 13) / 5 = 15.2ms

Throughput

Throughput = (6 + 12 + 1 + 3 + 4) / 5 = 5.2ms
Therefore, each process takes 5.2ms to execute.

Q: Shortest remaining time first scheduling

- Consider three CPU-intensive processes, which require 10, 20 and 30 time units and arrive at times 0, 2 and 6, respectively.
- How many context switches are needed if the operating system implements a shortest remaining time first scheduling algorithm?
- Do not count the context switches at time zero and at the end.

(A) 1
(B) 2 
(C) 3
(D) 4

Explanation:

- Let three process be P0, P1 and P2 with arrival times 0, 2 and 6 respectively and CPU burst times 10, 20 and 30 respectively.
- At time 0, P0 is the only available process so it runs.
- At time 2, P1 arrives, but P0 has the shortest remaining time, so it continues.
- At time 6, P2 arrives, but P0 has the shortest remaining time, so it continues.
- At time 10, P1 is scheduled as it is the shortest remaining time process.
- At time 30, P2 is scheduled.
- Only two context switches are needed. P0 to P1 and P1 to P2.

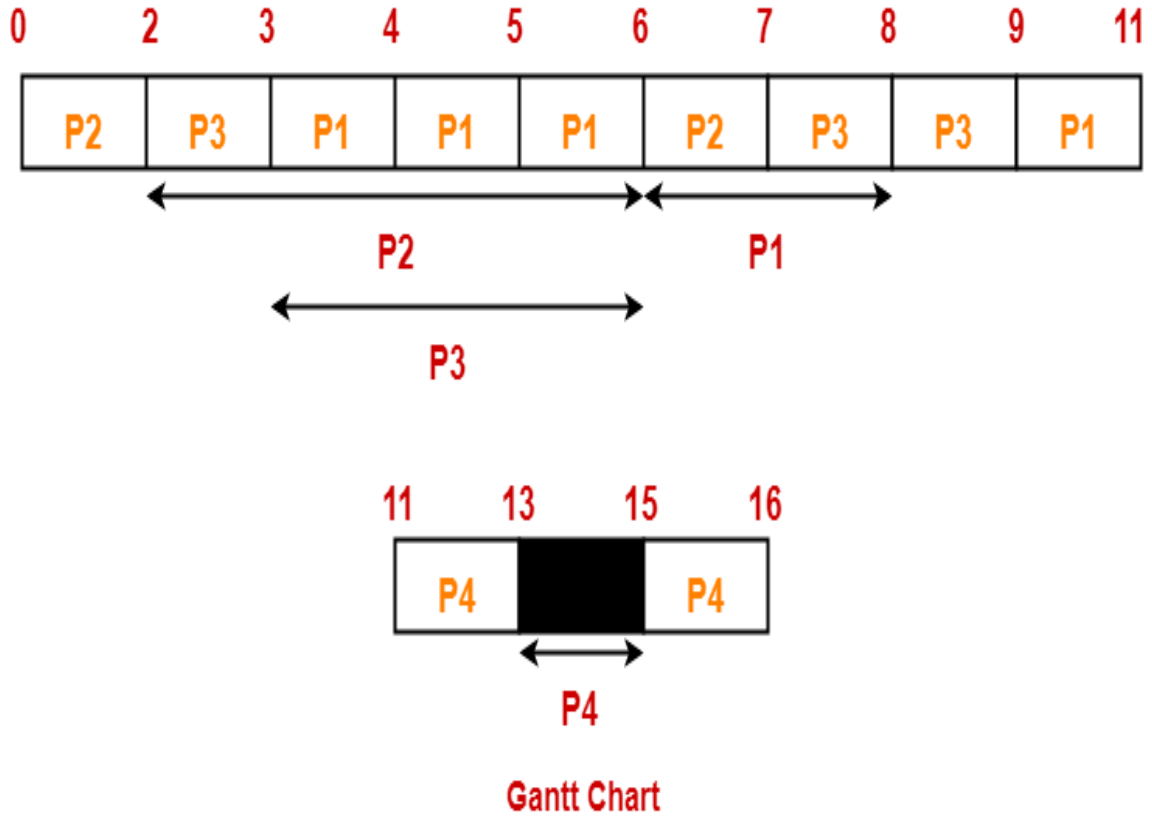
Q: Shortest Remaining Time First

- Consider the set of 4 processes whose arrival time and burst time are given below:-

Process	Arrival Time	CPU Burst	I/O Burst	CPU Burst
P1	0	3	2	2
P2	0	2	4	1
P3	2	1	3	2
P4	5	2	2	1

- CPU scheduling policy is Shortest Remaining Time First, calculate the average waiting time and average turn around time.

Solution:



Gantt Chart

- Now, we know-
  - Turn Around time = Exit time – Arrival time
  - Waiting time = Turn Around time – Burst time

Process Id	Exit Time	Turn Around Time	Waiting Time
P1	11	11 – 0 = 11	11 – (3+2) = 6
P2	7	7 – 0 = 7	7 – (2+1) = 4
P3	9	9 – 2 = 7	7 – (1+2) = 4
P4	16	16 – 5 = 11	11 – (2+1) = 8

- Average Turn Around time =

(11 + 7 + 7 + 11) / 4 = 36 / 4 = 9 unit

- Average waiting time =

(6 + 4 + 4 + 8) / 4 = 22 / 4 = 5.5 units

Q: Priority Scheduling

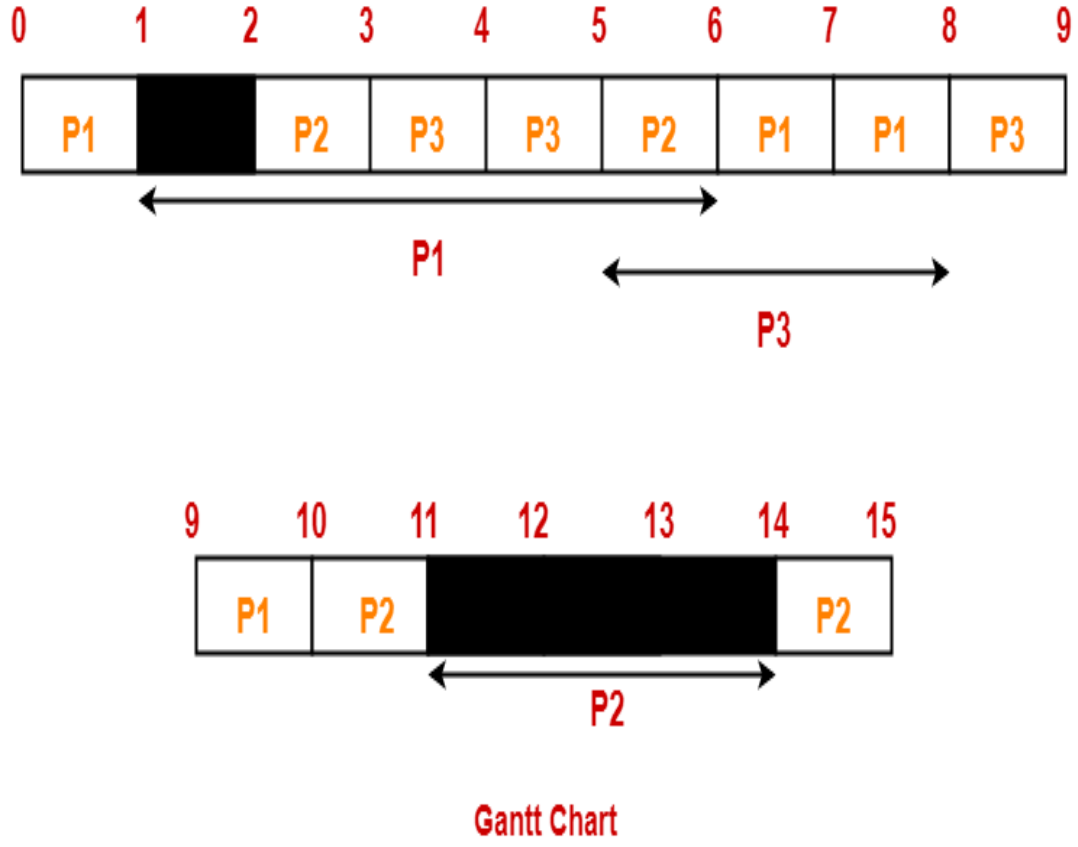
- If the CPU scheduling policy is Priority Scheduling, calculate the average waiting time and average turn around time.

Note:-(Lower number means higher priority).

- Consider the set of **3** processes whose arrival time and burst time are given below:-

Process No.	Arrival Time	Priority	CPU Burst	I/O Burst	CPU Burst
P1	0	2	1	5	3
P2	2	3	3	3	1
P3	3	1	2	3	1

Solution:



Gantt Chart

- Now, we know-
  - Turn Around time = Exit time – Arrival time
  - Waiting time = Turn Around time – Burst time

Process Id	Exit Time	Turn Around Time	Waiting Time
P1	10	10 – 0 = 10	10 – (1+3) = 6
P2	15	15 – 2 = 13	13 – (3+1) = 9
P3	9	9 – 3 = 6	6 – (2+1) = 3

- Average Turn Around time =
  (10 + 13 + 6) / 3 = 29 / 3 = 9.67 units
- Average waiting time =
  (6 + 9 + 3) / 3 = 18 / 3 = 6 units

Q:

Process No.	Arrival time	Priority	CPU	I/O	CPU	Completion time
P1	0	2	1	5	3	10
P2	2	3	3	3	1	15
P3	3	1	2	3	1	9
P4	3	4	2	4	1	18

Solution:

- Now, we know-
  - Turn Around time = Exit time – Arrival time
  - Waiting time = Turn Around time – Burst time

Process Id	Exit Time	Turn Around Time	Waiting Time
P1	10	10 – 0 = 10	10 – 1 = 9
P2	15	15 – 2 = 13	13 – 3 = 10
P3	9	9 – 3 = 6	6 – 2 = 4
P3	18	18 - 3= 15	15 - 2= 13

- Average Turn Around time =

  (10 + 13 + 6+15) / 4 = / 4 = units
- Average waiting time =

  (9 + 10 + 4+13) / 4 = / 4 = units

- Ratio of CPU idleness = 4/18
- Ratio of CPU usage = 14/18