CPU SCHEDULING

who will use CPU scheduling to selecting one of the process from ready state — **Short Term Scheduler**

where we apply CPU scheduling — **Ready state**
Scheduler

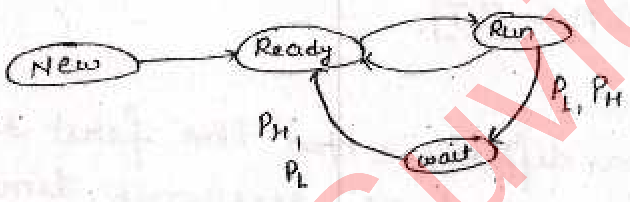
When (a) 1. Run → terminate
(running state) (termination state)

2. Run → wait
(running state) (wait state)

3. Run → ready
(running state) (ready state)

In all three cases when process leaving the running state & go to another state, then cpu scheduling is needed to bring out or to select one process from those available in ready state.

(b) wait → ready



→ When P_L (low priority) process is in running state & another P_H (high priority) process is go from wait state to ready state, then CPU scheduling is applied to select the appropriate process for execution.

Q. Consider a system with the n CPU processors

→ if P_H (high priority) process is being executed in running state & P_L is goes from wait to ready after I/o completion then also CPU scheduling is applied, but we will carry on with P_H execution.

(c) New → ready

Everytime a new process is created & go into ready state, then CPU scheduling is needed to select high priority process execution.

Goal

→ Maximize the CPU utilization, and.
→ minimize avg TAT and WT of the process.

CPU Scheduling Algorithm

1) FCFS (First Come First Serve)

Criteria: Arrival Time

Mode: Non-preemptive

Ex:

P.No	AT	BT
1	0	3
2	1	1
3	2	2
4	3	5
5	4	4

avg TAT = ?

avg WT = ?

Gantt Chart

P1	P2	P3	P4	P5

0, 3, 4, 6, 11, 15

At 3: (P_2, P_3, P_4)

At 4: (P_3, P_4, P_5)

P.No	CT	TAT	WT
1	3	3	0
2	4	3	2
3	6	4	2
4	11	8	3
5	15	11	7

$$\text{avg TAT} = \frac{3+3+4+8+11}{5} = \frac{29}{5} = 5.8$$

$$\text{avg WT} = \frac{14}{5} = 2.8$$

Ex:

P.No	AT	BT
1	6	4
2	2	5
3	3	3
4	1	1
5	4	2
6	5	6

Sol:

	P4	P2	P3	P5	P6	P1
0–1	1–2	2–7	7–10	10–12	12–18	18–22

0 1 2 7 10 12 18 22

(P_1, P_3, P_5, P_6)

P.No	WT	TAT	CT	AT	BT
1	12	16	22	6	4
2	0	5	7	2	5
3	4	7	10	3	3
4	0	1	2	1	1
5	6	8	12	4	2
6	7	13	18	5	6

$$\text{avg TAT} = \frac{16+5+7+1+8+13}{6} = \frac{50}{6} = 8.33$$

$$\text{avg WT} = \frac{12+4+6+7}{6} = \frac{29}{6} = 4.8$$

If the arrival times of the processes are matching then which has the lowest process id schedule the process

Ex:

P.No	AT	BT	CT	TAT	WT
1	8	4	17	9	5
2	3	2	5	2	0
3	7	6	13	6	0
4	10	3	20	10	7
5	2	1	3	1	0
6	3	1	6	3	2

$$\text{avg TAT} = \frac{31}{6} = 5.1$$

$$\text{avg WT} = \frac{14}{6} = 2.33$$

//////	//////	P5	P2	P6	//////	P3	P1	P4
0–1	1–2	2–3	3–5	5–6	6–7	7–13	13–17	17–20

0 1 2 3 5 6 7 13 17 20

Q.

P.No	AT	BT	CT	TAT	WT
1	0	20	20	20	0
2	1	2	22	21	19
3	2	2	24	22	20

P_1	P_2	P_3
0 – 20	20 – 22	22 – 24

avg WT = $\frac{20+19}{3} = \frac{39}{3} = 13$ → Convoy effect

Q.

P.No	AT	BT	CT	TAT	WT
1	0	2	2	2	0
2	1	2	4	3	1
3	2	20	24	22	2

avg WT = $\frac{1+2}{3} = \frac{3}{3} = 1$

P_1	P_2	P_3
0 – 2	2 – 4	4 – 24

Convoy effect:

In the FCFS, if the first process having large Burst time (CPU Bound process) then it will have the huge impact on the avg waiting time of the remaining process. This effect is called as Convoy effect.

2) Shortest Job First (SJF)

Criteria: Burst time

Mode: Non-preemptive

Ex:

P.No	AT	BT
1	1	7
2	2	5
3	3	1
4	4	2
5	5	8

(idle)	P_1	P_3	P_4	P_2	P_5
0 – 1	1 – 8	8 – 9	9 – 11	11 – 16	16 – 24

8 ↓ (P_2, P_3, P_4, P_5)
5 1 2 8

Sol:

P.No	AT	BT	CT	TAT	WT
1	1	7	8	7	0
2	2	5	16	14	9
3	3	1	9	6	5
4	4	2	11	7	5
5	5	8	24	19	11

$$\text{avg TAT} = \frac{7+14+6+7+19}{5}$$

$$= 10.6$$

$$\text{avg WT} = \frac{0+9+5+5+11}{5}$$

$$= \frac{30}{5}$$

$$= 6$$

If the Burst times of the processes are matching, then schedule the process based on arrival time (having lowest arrival time)

Que. 2

P.No	AT	BT
1	6	1
2	3	3
3	4	6
4	1	5
5	2	2
6	5	1

	P_4	P_6	P_1	P_5	P_2	P_3
0 1	6	7	8	10	13	19

6 ↓
$(P_1, P_2, P_3, P_5, P_6)$
1 3 6 2 1

P. NO	AT	BT	CT	TAT	WT
1	6	1	8	2	1
2	3	3	13	10	7
3	4	6	19	15	9
4	1	5	6	5	0
5	2	2	10	8	6
6	5	1	7	2	1

avg TAT $= \frac{42}{6} = 7$

avg WT $= \frac{24}{6} = 4$

3) Shortest Remaining Time First (SRTF)

Criteria: Burst time

Mode: pre-emptive

(also called as pre-emptive Shortest Job first)

Ex:

P.No	AT	BT	CT
1	0	7	19
2	1	5	13
3	2	3	6
4	3	1	4
5	4	2	9
6	5	1	7

P.No	AT	BT
1	0	7 6
2	1	8 4
3	2	3 2 1 0
4	3	1 0
5	4	2
6	5	1 0

P1	P2	P3	P4	P3	P3	P6	P5	P2	P1

0 1 2 3 4 5 6 7 9 13 19

avg TAT = 7.16

avg WT = 4

Q)

P.No	AT	BT	CT	TAT	WT
1	3	4	13	10	6
2	4	2	9	5	3
3	5	1	7	2	1
4	2	6	19	17	11
5	1	8	26	25	17
6	2	4	6	4	0

P.No	AT	BT
1	3	4
2	4	2
3	5	1 0
4	2	6
5	1	8 7
6	2	4 3 2 1 0

(idle)	P5	P6	P6	P6	P6	P3	P2	P1	P4	P5

0 1 2 3 4 5 6 7 9 13 19 26

avg TAT = $\frac{63}{6}$ = 10.5

avg WT = $\frac{38}{6}$ = 6.33

Q)

P.No	AT	BT	CT	TAT	WT
1	2	8	25	23	15
2	7	1	9	2	1
3	6	2	8	2	0
4	3	6	18	15	9
5	5	4	12	7	3
6	3	2	5	2	0

P.No	AT	BT
✓ 1	2	~~8~~ 7
✗ 2	7	~~1~~ 0
✗ 3	6	~~2~~ ~~1~~ 0
✓ 4	3	6
✓ 5	5	~~4~~ 3
✗ 6	3	~~2~~ ~~1~~ 0

(idle)	P_1	P_6	P_6	P_5	P_3	P_3	P_2	P_5	P_4	P_1
0–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–12	12–18	18–25

avg TAT = $\frac{51}{6} = 8.5$

avg WT = $\frac{28}{6} = \frac{14}{3} = 4.66$

Gate 2011

Q.)

P.No	AT	BT	CT	TAT	WT
1	0	9	13	13	4
2	1	4	5	4	0
3	2	9	22	20	11

P.No	AT	BT
✓ 1	0	~~9~~ 8
✗ 2	1	~~4~~ 3
✓ 3	2	9

P_1	P_2	P_2	P_1	P_3
0–1	1–2	2–5	5–13	13–22

avg TAT = $\frac{37}{3} = 12.33$

avg WT = $\frac{15}{3} = 5$

2004

Q.

P.No	AT	BT	CT	TAT	WT
1	0	5	12	12	7
2	1	3	4	3	0
3	2	3	8	6	3
4	4	1	5	1	0

P.No	AT	BT
1	0	~~5~~ 4
2	1	~~3~~ ~~2~~ ~~1~~ 0
3	2	3
4	4	~~1~~ 0

P1	P2	P2	P2	P4	P3	P1

0 1 2 3 4 5 8 12

avg TAT = $\frac{22}{4}$ 5.50

avg WT = $\frac{10}{4}$ = 2.5

Gate 2007

Q.

P.No	AT	BT	CT	TAT	WT
1	0	20			
2	15	25			
3	30	10			
4	45	15			

P.No	AT	BT
1	0	~~20~~ ~~19~~ 5
2	15	~~25~~ ~~15~~ 10
3	30	~~10~~ 0
4	45	15

What is the WT of process 'P2' using SRTF?

P1		P2	P2	P3	P2	P2	P4

0 L 15 20 30 40 45 55 70

CT = 55

AT = 15

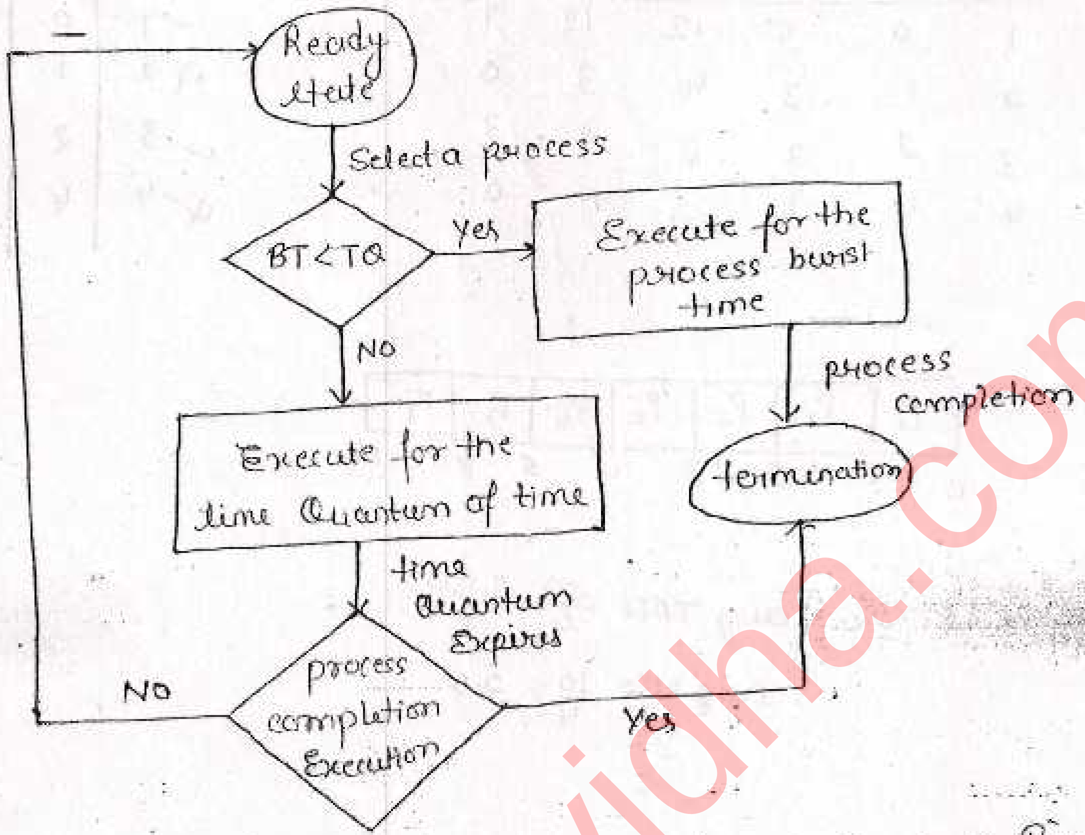
TAT = 55 - 15 = 40

WT = TAT - BT

= 40 - 25

= 15 Ans.

4) Round Robin Scheduling :-



Criteria: time quantum / time slice, Arrival Time

Mode: pre-emptive

Time Quantum means when a process is being scheduled for execution, the max^n execution time of the process will be equal to time Quantum (say = 3sec).

Ex:-

P.No	AT	BT	CT	TAT	WT	RT
1	0	4	8	8	4	0-0=0
2	1	5	18	17	12	2-1=1
3	2	2	6	4	2	4-2=2
4	3	1	9	6	5	8-3=5
5	4	6	21	17	11	9-4=5
6	6	3	19	13	10	13-6=7

T.Q = 2

P.No	A.T.	BT
1	0	~~4~~ 2 0
2	1	~~5~~ ~~3~~ ~~1~~ 0
3	2	~~2~~ 0
4	3	~~1~~ 0
5	4	~~6~~ ~~4~~ ~~2~~ 0
6	6	~~3~~ ~~1~~ 0

Ready Queue - P1, P2, P3, P1, P4, P5, P2, P6, P5, P2, P6, P5

P1	P2	P3	P1	P4	P5	P2	P6	P5	P2	P6	P5
0–2	2–4	4–6	6–8	8–9	9–11	11–13	13–15	15–17	17–18	18–19	19–21

avg TAT = 65/6 = 10.8

avg WT = 44/6 = 7.3

avg RT = 20/6 = 3.3

Ques? TQ=3

PNo	AT	BT	CT	TAT	WT	RT
1	5	5	32	27	22	10
2	4	6	27	23	17	5
3	3	7	33	30	23	3
4	1	9	30	29	20	0
5	2	2	6	4	2	2
6	6	3	21	15	12	12

P.No	AT	BT
~~1~~	5	~~5~~ ~~2~~ 0
~~2~~	4	~~6~~ ~~3~~ 0
~~3~~	3	~~7~~ ~~4~~ ~~1~~ 0
~~4~~	1	~~9~~ ~~6~~ ~~3~~ 0
~~5~~	2	~~2~~ 0
~~6~~	6	~~3~~ 0

Ready Queue - P4, P5, P3, P2, P4, P1, P6, P3, P2, P4, P1, P3

idle	P4	P5	P3	P2	P4	P1	P6	P3	P2	P4	P1	P3
0–1	1–4	4–6	6–9	9–12	12–15	15–18	18–21	21–24	24–27	27–30	30–32	32–33

avg TAT = 128/6 = 21.3

avg WT = 96/6 = 16

avg RT = 32/6 = 5.3

TQ = 2

Ques

P.NO	AT	BT	CT	TAT	WT	RT
1	3	2	6	3	1	1
2	2	4	10	8	4	0
3	6	3	19	13	10	6
4	8	1	15	7	6	6
5	4	3	16	12	9	2
6	5	4	18	13	9	5

PNO	AT	BT
1	3	~~2~~ 0
2	2	~~4~~ ~~2~~ 0
3	6	~~3~~ ~~1~~ 0
4	8	~~1~~ 0
5	4	~~3~~ ~~1~~ 0
6	5	~~4~~ ~~2~~ 0

Ready Queue-
$P_2, P_1, P_5, P_2, P_6, P_3, P_4, P_5, P_6, P_3$

idle	P_2	P_1	P_5	P_2	P_6	P_3	P_4	P_5	P_6	P_3

0 2 4 6 8 10 12 14 15 16 18 19

avg TAT = 56/6 = 9.3

avg WT = $\frac{39}{6}$ = 6.5

avg RT = $\frac{20}{6}$ = 3.3

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Ques. 39

TQ=2

P.NO	AT	BT
1	0	~~5~~ ~~3~~ ~~1~~ 0
2	1	~~7~~ ~~5~~ ~~3~~ 1
3	3	~~4~~ ~~2~~ 0

Ready Queue -
$P_1, P_2, P_1, P_3, P_2, P_1, P_3, P_2, P_2$

P_1	P_2	P_1	P_3	P_2	P_1	P_3	P_2	P_2

0 2 4 6 8 10 11 13 15 16

R.R. P_1, P_3, P_2

FCFS

P_1	P_2	P_3

0 5 12 16

FCFS $P_1 P_2 P_3$

Note

⇒ In Round Robin, if the time quantum is less, than the no. of context switches will increase & their response time will be less.

⇒ If TQ is large than the no. of CS will decrease & the response time will be more.

⇒ In the round robin, if the time quantum is very very large, than the algorithm degenerates to FCFS Scheduling algorithm.

Q. Consider a system with four process P_1, P_2, P_3 & P_4 arriving in the ready queue in the same order at the time 0 (zero). The burst time required by these Jobs are 4, 1, 8 & 1 respectively then what is the completion time of process P_1. Assuming RR scheduling at the time quantum of 1.

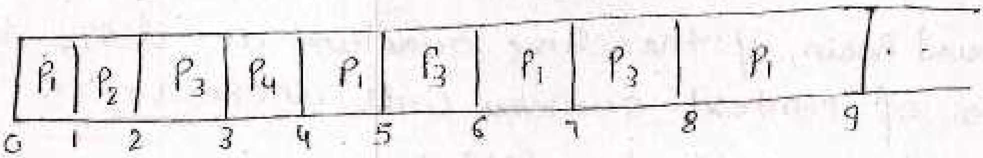
(a) 7
(b) 8
(c) 9 ✓
(d) 10
(e) None

Sol:

P.No	AT	BT
P_1	0	~~4~~ ~~3~~ ~~2~~ ~~1~~ 0
P_2	0	1
P_3	0	8
P_4	0	1

P_2	P_4	P_1	P_3	P_1	P_3	P_1	P_3	P_1

0 1 2 3 4 5 6 7 8 9



Q. Consider the system with 'n' process sharing the CPU in Round Robin fashion. The context switching time is 'S' units, then what must be the time quantum "q" such that the no. of context switches are reduced, but at the same time each process is guaranteed to get its turn/job at the CPU for every 't' seconds of time?

a) $q = \frac{t-ns}{n+1}$

b) $q = \frac{t+ns}{n-1}$

✓c) $\boxed{q = \frac{t-ns}{n-1}}$

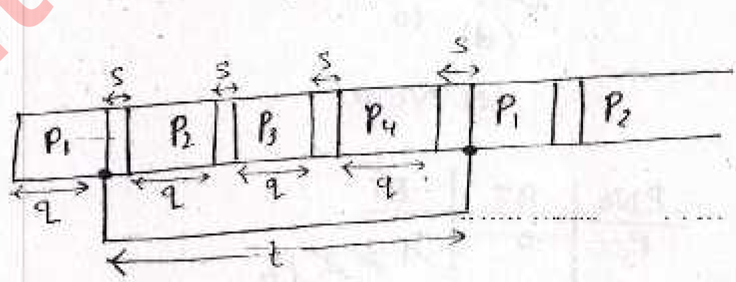
d) $q = \frac{t+ns}{n+1}$

Sol:-

P.No	AT	BT
1	0	
2	0	
3	0	
4	0	

Let $n=4$ (P_1, P_2, P_3, P_4)

TQ = q



$$t = ns + (n-1)q$$

$$t - ns = (n-1)q$$

$$\boxed{q = \frac{t-ns}{n-1}}$$

Now we consider: **Burst time = CPU time + I/O time**

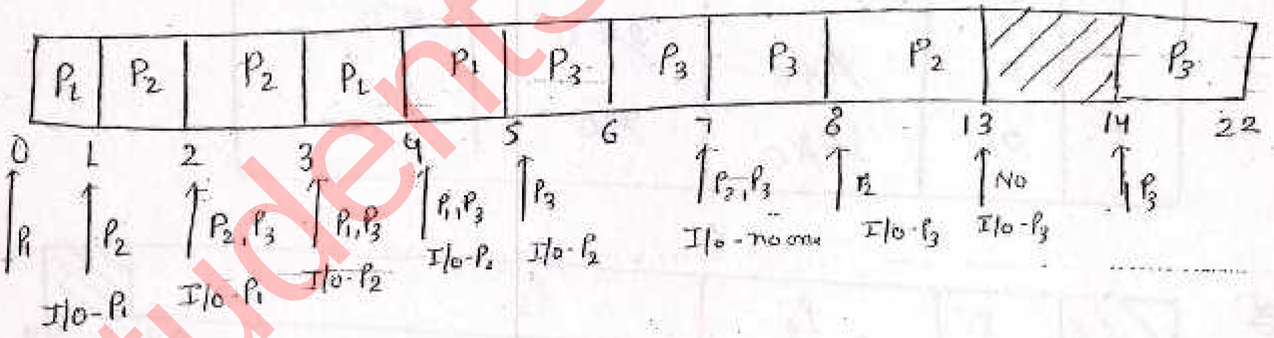
Que? –

		Execution Time		
P.No	AT	CPU time	I/O time	CPU time
1	0	~~1~~ 0	~~2~~ ~~1~~ 0	~~2~~ ~~1~~ 0
2	1	~~2~~ ~~1~~ 0	~~4~~ ~~3~~ ~~2~~ ~~1~~ 0	5/6
3	2	~~3~~ ~~2~~ ~~1~~ 0	~~6~~ 1	8

What is the completion time of processes P_1, P_2, P_3 using SRTF scheduling?

Note:- (i) process first spends the CPU time & followed by I/O time & followed by CPU time again.

(ii) I/O of the processes can be overlapped as much as possible.



P.No	CT
1	5
2	13
3	22

Que?

		Execution Time		
P.No	AT	I/O time	CPU time	I/O time
1	0	~~4~~ ~~2~~ 0	~~14~~ ~~6~~ ~~5~~ 0	~~2~~ ~~1~~ 0
2	0	~~8~~ 0	~~28~~ ~~27~~ ~~22~~	~~4~~ 0
3	0	~~12~~ ~~11~~ ~~6~~ 0	~~42~~ 28 ~~21~~ ~~20~~ ~~14~~ 0	6

findout completion time of processes P_1, P_2, P_3 using SRTF scheduling?

Sol:

/////	P_2	P_3	P_3	P_1	P_1	P_3	/////	P_2
0–4	4–12	12–13	13–18	18–19	19–20	20–26	26–40	40–44

- 0: P_1, P_2, P_3
- 4: P_2, P_3 ; CPU – P_1
- 12: P_3 ; CPU – P_1, P_2
- 13: P_3
- 18: P_1, P_3 ; CPU – P_2
- 19: P_1, P_3 ; CPU – P_2
- 20: P_3 ; CPU – P_2
- 26: CPU – P_2, P_3
- 40: P_2 ; CPU – P_3

Que?

P.NO	AT	I/O time	CPU time	I/O time
1	0	~~4~~ 0	~~14~~ 0	~~2~~ 0
2	0	~~8~~ ~~4~~ 0	~~28~~ 0	~~4~~ 0
3	0	~~12~~ ~~8~~ 0	~~42~~ 0	6

Sol:

/////	P_1	P_2	P_3	/////
0–4	4–18	18–46	46–88	88–94

- 0: No ; I/O P_1, P_2, P_3
- 4: P_1 ; I/O P_2, P_3
- 18: P_2, P_3 ; I/O P_1
- 46: P_3 ; I/O P_2
- 88: I/O P_3
- 94: No ; No

C.T.	P.No
18+2=20	1
46+4=50	2
88+6=94	3

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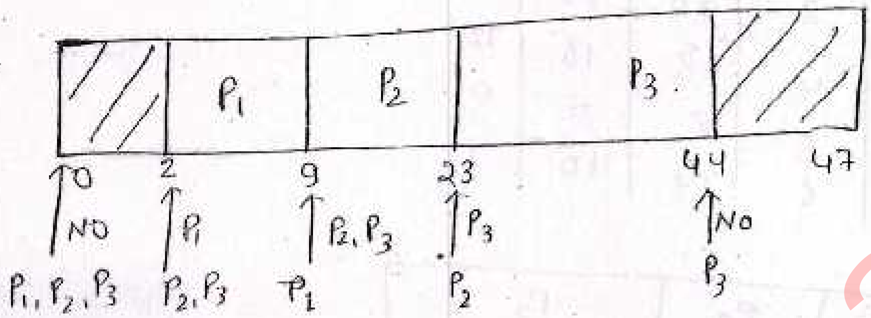
ET	P.NO	AI	I/O	CPU	I/O
10	1	0	2/10	7/10	1/10
20	2	0	4/20	14/20	2/20
30	3	0	6/30	21/30	3



CPU idle = (2-0) + (47-44) = 2+3 = 5

% = $\frac{5}{47} \times 100 = \frac{500}{47} = 10.6\%$

5) Longest Job First (LJF)

Creteria: Burst time

Mode: Non pre-emptive

Q)

PNO	AT	BT	CT	TAT	WT
1	0	3	3	3	0
2	1	2	20	19	17
3	2	4	18	16	12
4	3	5	8	5	0
5	4	6	14	10	4

P1	P4	P5	P3	P2
0 – 3	3 – 8	8 – 14	14 – 18	18 – 20

avg TAT = 53/5 = 10.6

avg WT = $\frac{33}{5}$ = 6.6

Note

If the burst time of the process are matching then schedule the process which has lowest arrival time.

Q)

P.NO	AT	BT	CT	TAT	WT
1	3	3	18	15	12
2	1	1	2	1	0
3	2	3	15	13	10
4	4	2	20	16	14
5	6	6	12	6	0
6	2	4	6	4	0
				55	36

avg TAT = 55/6 = 9.1

avg WT = 36/6 = 6

(idle)	P2	P6	P5	P3	P1	P4
0 – 1	1 – 2	2 – 6	6 – 12	12 – 15	15 – 18	18 – 20

6) **Longest Job First (LJF) or Longest Remaining Time First (LRTF)**

Criteria: Burst time

mode: pre-emptive

Q)

P.NO	AT	BT	CT	TAT	WT
1	1	2	~~21~~	~~20~~	~~18~~
2	2	4	~~20~~	~~18~~	~~14~~
3	3	6	~~17~~	~~14~~	~~8~~
4	4	8	~~12~~	~~8~~	~~0~~
				~~60~~	~~40~~

P.NO	AT	BT
✓ 1	1	~~2~~ 1
✓ 2	2	~~4~~ ~~3~~ ~~2~~ 1
✗ 3	3	~~6~~ ~~5~~ ~~4~~ ~~3~~ 2 1
✗ 4	4	~~8~~ ~~7~~ ~~6~~ ~~5~~ ~~4~~ ~~3~~ 2 1

////	P1	P2	P3	P4	P4	P3	P2	P1

0 1 2 3 4 5 12 17 20 21

↑ P1 (1), ↑ P1, P2 (2), ↑ P1, P2, P3 (3), ↑ P1, P2, P3, P4 (4), ↑ P1, P2, P3, P4 (5), ↑ P1, P2, P3 (12), ↑ P1, P2 (17)

~~avg TAT = 60/4 = 15~~

~~avg WT = 40/4 = 10~~

////	P1	P2	P3	P4	P4	P3	P4	P3	P4	P2	P3	P4	P2

0 1 2 3 4 5 7 8 9 10 11 12 13 14 15

P3	P4	P1	P2	P3	P4

16 17 18 19 20 21

AT	BT	CT	TAT	WT
1	2	18	17	15
2	4	19	17	13
3	6	20	17	11
4	8	21	17	9
			68	48

avg TAT = 68/4 = 17

avg WT = 48/4 = 12

6) Priority Based Scheduling

Criteria: priority

Mode: Non-preemptive.

Ex:

Priority	P.No	AT	BT	CT	TAT	WT
4	1	0	4	4	4	0
5	2	1	5	16	15	10
HP — 7	3	2	1	5	3	2
2	4	3	2	18	15	13
LP — 1	5	4	3	21	17	14
6	6	5	6	11	6	0
					60	39

P1	P3	P6	P2	P4	P5
0–4	4–5	5–11	11–16	16–18	18–21

0 4 5 11 16 18 21

avg TAT = 60/6 = 10

avg WT = 39/6 = 6.5

Note: If the priorities of the processes are matching then schedule the process which has the lowest arrival time

Que:

Priority	PNO	AT	BT	CT	TAT	WT
~~4~~ 4	1	4	6	17	13	7
~~x~~ 5	2	6	3	11	5	2
~~x~~ 6	3	3	4	8	5	1
~~x~~ 6	4	2	2	4	2	0
HP — ~~x7~~	5	1	1	2	1	0
LP — ~~x~~ 3	6	2	2	19	17	15
					43	25

avg TAT = 7.16

avg WT = 4.16

//////	P5	P4	P3	P2	P1	P6
0–1	1–2	2–4	4–8	8–11	11–17	17–19

0 1 2 4 8 11 17 19

7) ## Priority Based Scheduling (Preemptive PBS)

Criteria: Priority

Mode: Pre-emptive

Ex:

priority	P.No	AT	BT	CT	TAT	WT
LP — 4	1	1	~~4~~ 3	18	17	13
5	2	2	2	14	12	10
HP — 7	3	2	~~3~~ 2	10	8	5
8	4	3	~~5~~ 0	8	5	0
5	5	3	1 0	15	12	11
6	6	4	2 0	12	8	6
					62	45

(idle)	P1	P3	P4	P3	P6	P2	P5	P1
0–1	1–2	2–3	3–8	8–10	10–12	12–14	14–15	15–18

avg TAT = 62/6 = 10.3

avg WT = 45/6 = 7.5

Que:

priority	P.NO	AT	BT	CT	TAT	WT
5	1	1	~~4~~ ~~3~~ 2	16	15	11
2	2	2	5	21	19	14
6	3	3	~~6~~ 5	14	11	5
4	4	0	1	1	1	0
7	5	4	~~2~~ 1	9	5	3
8	6	5	3	8	3	0
					54	33

P4	P1	P1	P3	P5	P6	P5	P3	P1	P2
0–1	1–2	2–3	3–4	4–5	5–8	8–9	9–14	14–16	16–21

avg TAT = 9

avg WT = 5.5

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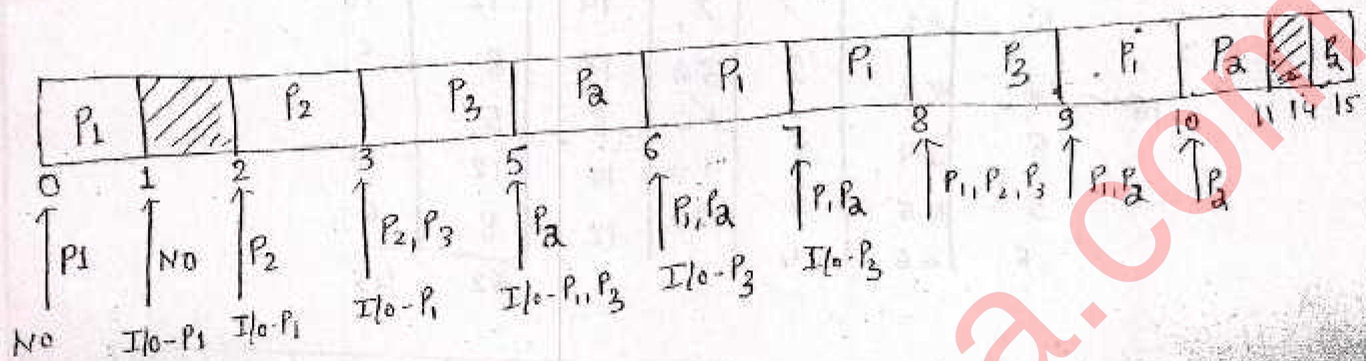
Q.38

Priority	P.No	AT	CPU	I/O	CPU
2 (highest)	P1	0	~~1~~ 0	~~5 4 3~~ 0	~~3 2 1~~ 0
3 (lowest)	P2	2	~~3 2 1~~ 0	~~3 2 1~~ 0	~~1~~ 0
1 (highest)	P3	3	~~2 1~~ 0	~~3 2 1~~ 0	1



$P_1 \rightarrow 10$

$P_3 \rightarrow 9$

$P_2 \rightarrow 15$

Ans (b)

3) Highest Response Ratio Next (HRRN):

Criteria - Response ratio

Mode - non pre-emptive

$$\text{Response Ratio} = \frac{\omega + S}{S}$$

where, ω - waiting time
S - service time (or) Burst time

The highest response ratio next favours the shorter jobs & also limits the waiting time of longer jobs

Ex:

P.No	AT	BT	CT	TAT	WT
1	0	3	3	3	0
2	2	6	9	7	1
3	4	4	13	9	5
4	6	5	20	14	9
5	8	2	15	7	5
				40	20

P_1	P_2	P_3	P_5	P_4
0–3	3–9	9–13	13–15	15–20

At 9: P_3, P_4, P_5 At 13: P_4, P_5

$R.R(P_3) = \frac{5+4}{4} = 9/4 = 2.25$

$R.R(P_4) = \frac{3+5}{5} = 8/5 = 1.6$

$R.R(P_5) = \frac{1+2}{2} = 3/2 = 1.5$

$R.R(P_4) = \frac{7+5}{5} = 12/5 = 2.4$

$R.R(P_5) = \frac{5+2}{2} = 7/2 = 3.5$

avg TAT = 40/5 = 8

avg WT = 20/5 = 4

Qun:

P.No	AT	BT	CT	TAT	WT
1	1	1	2	1	0
2	4	2	6	2	0
3	5	6	12	7	1
4	6	2	14	8	6
5	7	4	18	11	7
				29	14

avg TAT = 14/5 = 2.8

avg WT = 29/5 = 5.8

(idle)	P_1	(idle)	P_2	P_3	P_4	P_5
0–1	1–2	2–4	4–6	6–12	12–14	14–18

At 6: P_3, P_4

$R.R(P_3) = \frac{1+6}{6} = 7/6 = 1.1$

$R.R(P_4) = \frac{0+2}{2} = 2/2 = 1$

$RR(P_4) = \frac{6+2}{2} = \frac{8}{2} = 4$

$RR(P_5) = \frac{5+4}{4} = \frac{9}{4} = 2.25$

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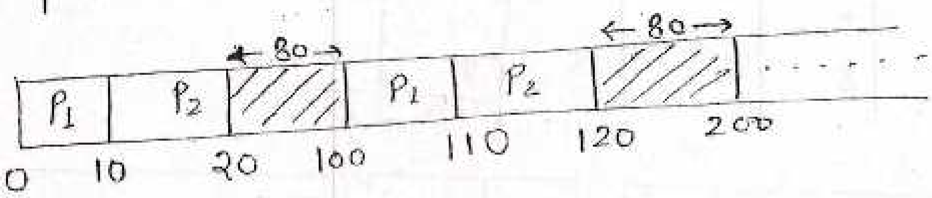
P.No	A.T	CPU	I/O	CPU	I/O	CPU	I/O
P1	0	10	90	10	90	10	90
P2	0	10	90	10	90	10	90

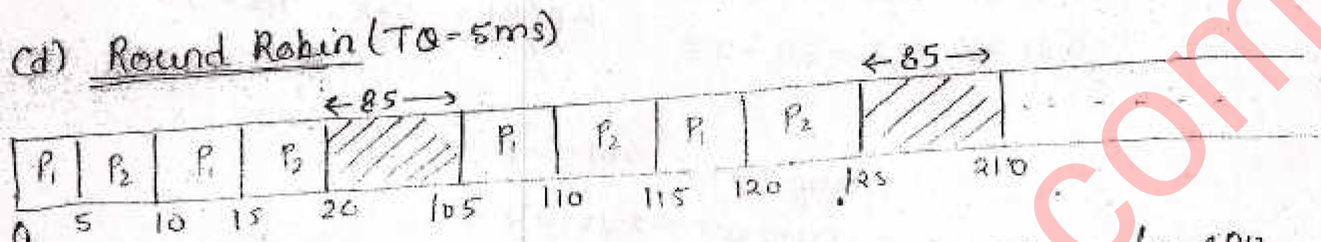
(a) FCFS



(b) SRTF will look same as like as FCFS

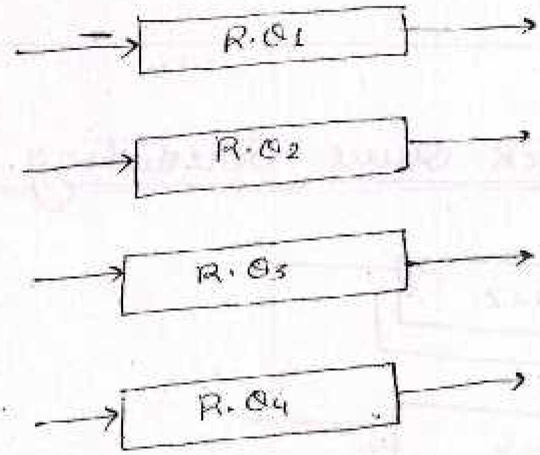
(c) Priority also same

(d) Round Robin (TQ = 5ms)



Ans. (d) in this ques, RR algo takes 85 ms for CPU being idle. more than other three algo which will take 80 ms for CPU being idle.

9) Multi level Queue Scheduling :-



1) Depending on the priority of the process in which particular ready queue the process has to be placed will be decided.

2) Generally the high priority process will be placed in the top-level Ready Queue & the low priority process will be placed in the bottom-level ready queue.

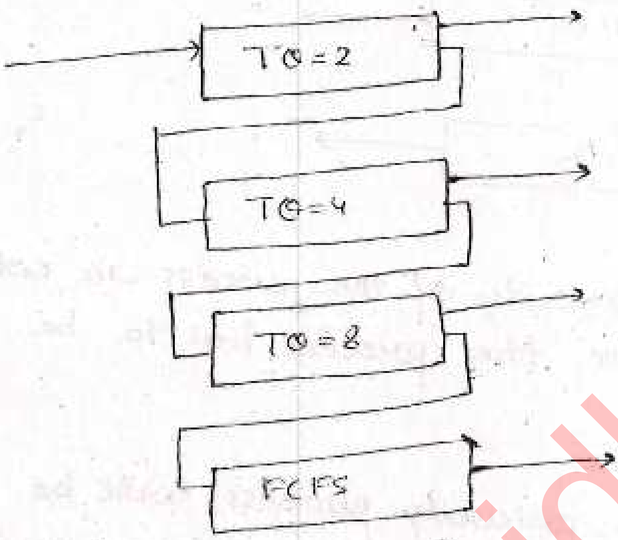
3) It is also possible to use different scheduling algorithm in the different ready queue.

4) Only after completion of the all the processes from the top level ready queue, the further level ready queue process will be scheduled.

5) If this is the strategy followed then the process which are placed in the bottom level ready queue will suffer from starvation.

Starvation - The indefinite waiting of a process is called as starvation.

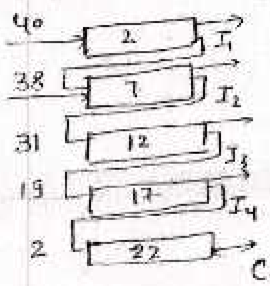
10) **Multilevel Feedback Queue Scheduling**



⇒ In the Multilevel Feedback Queue Scheduling algorithm, the starvation problem is avoided under the same time the preference will be given to high priority processes.

Prob: Consider a system which has a CPU bound process which requires the burst time of 40 time units. The multilevel feedback queue scheduling algorithm is used & if the queue time quantum of '2' & at each level it will be incremented by '5' time units then how many times the process will be interrupted & on what queue the process will terminate the execution?

Sol



Interrupt (4 times)

Completion at level 5

Algorithm	Starvation
1) FCFS	NO
2) NP (SJF)	yes
3) SRTF	yes
4) R.R	NO
5) NP→LJF	yes
6) LRTF	yes
7) NP→Priority	yes
8) P→Priority	yes
9) HRRN	NO
10) MLQ	yes
11) MLFQ	NO

– if shorter processes are keep on coming then process having large BT arrive at 0 is indefinite waiting time

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In the SJF scheduling algorithm, the burst time of the processes will be predicted or expected by using the below formula –

$$\tau_{n+1} = \alpha . T_n + (1-\alpha) \tau_n$$

where τ_{n+1} → Next Expected burst time

T_n → previous actual burst time

τ_n → previous Expected burst time

α → parameter which controls the relative weight of the recent and past history

$0 \le \alpha \le 1$

Given: $\alpha = 0.5$ $\quad T_1 = 10$

P No	BT
P1	5
P2	8
P3	3
P4	5

$T_2 = \alpha T_1 + (1-\alpha)T_1$
$= 0.5(5) + (1-0.5)10$
$= 2.5 + 5 = 7.5$

$T_3 = \alpha T_2 + (1-\alpha)T_2$
$= 0.5(8) + (0.5)7.5$
$= 4 + 3.75 = 7.75$

Correct option: (a)

$T_4 = \alpha T_3 + (1-\alpha)T_3$
$= 0.5(3) + (0.5)7.75$
$= 1.5 + 3.875$
$= 5.375$

$T_5 = \alpha T_4 + (1-\alpha)T_4$
$= 0.5(5) + (0.5)5.375$
$= 2.5 + 2.6875 = \boxed{5.1875}$ Ans.

Sol. 41 Ans $\boxed{5}$ option (c)

$T_5 = \alpha T_4 + (1-\alpha)T_4$
$= 1(5) + (1-1)T_4$
$= 5 + 0$
$= 5$