Fall 2019

1. What are the necessary characteristics of ~~dead lo~~ deadlock? Explain deadlock prevention and avoidance methods.

→ The necessary characteristics of deadlock are:-

a. Mutual exclusion

→ At least one resource must be held in a non-shareable mode, meaning only one process can use it at a time.

b. Hold and wait

→ A process must be holding at least one resource and waiting to acquire additional resources held by other processes.

c NO preemption

→ Resources cannot be forcibly taken away from a process they can only be released voluntarily.

d circular wait

→ There must exist a circular chain of two or more processes, each waiting for a resource held by the next process in the chain.

- Dealock prevention

a. Mutual Exclusion

02/02/2024 15:29

Page :
Date : / /

→ Ensure that resources that can lead to deadlock, especially those susceptible to mutual exclusion, are designed to allow multiple processes to share them.

b Hold and Wait
→ A process ~~must~~ must request and be allocated all it's resources before it begins execution or release all resources if it cannot be allocated all at once. This ensures a process does not hold resources while waiting for others

c No preemption
→ If a process cannot get all it's requested resources at once, it releases all the resources it currently holds, preventing the ~~scenario~~ scenario where a resource cannot be ~~forcily~~ forcibly taken from a process.

d. Circular wait:
→ Impose a total ordering of resource types and require that each process requests resources in an increasing order. This way, a circular wait is not possible.

• Deadlock Avoidance.

02/02/2024 15:29

Page :
Date : / /

a. Banker's Algorithm
→ The system keeps track of the maximum and currently allocated resources and calulates the remaining available resourcer. A process can only request resources if the system is left in a safe state after the allocation.

b. Resource Allocation Graph
→ Dynamically analyze the resource allocation state to determine if granting a resource request will result in a cycle in the Resource allocation Graph. If no cycle is present, allocate the resource, otherwise, the request is delayed.

c. Timeouts and killing Processes
→ Set timeouts for resource requests. If a process cannot acquire resources within a ~~s~~specified times it gets terminated or rolled back to safe state.

2. Draw a Gantt chart and find average turnaround time and waiting time of the following process applying FCFS, SJRF and round robin (with quantum = 3) ~~the~~ scheduling algorithm.

Process	A	B	C	D	E
Arrival time (sec)	0	3	4	6	10
Burst time	6	3	6	4	2

02/02/2024 15:29

- For FCFS

Gantt chart

A	B	C	D	E

0 (B,C,D) 6 9 (E) 15 19 21

Process	TAT = ET - AT	WT = TAT - BT
A	6	0
B	6	3
C	11	5
D	13	9
E	11	9
	$\Sigma TAT = 47$	$\Sigma WT = 26$

Average turnaround time $= \frac{47}{5} = \cancel{8.2}\ 9.4$

Average waiting time $= \frac{26}{5} = \cancel{4 sec}\ 5.2$ sec

- For SRTF

Gantt chart

A	B	D	E	D	C

0 (B,C,D) 6 9 (E) 10 12 15 21

Process	TAT = ET - AT	WT = TAT - BT
A	6	0
B	6	3
C	17	11
D	9	5
E	2	0
n = 5	$\Sigma TAT = 40$	$\Sigma WT = 19$

Average turnaround time $= \frac{40}{5} = 8$ sec

Average waiting time $= \frac{19}{5} = 3.3$ sec.

- Round Robin
  quantum = 3

Gantt chart :-

A	B	C	D	E	A	C	D

0 (B) 3 (C,D) 6 9 (E) 12 14 17 20 21

Process	TAT = ET - AT	WT = TAT - BT
A	17	11
B	3	0
C	16	10
D	15	11
E	4	2
n = 5	$\Sigma TAT = 55$	$\Sigma WT = 34$

02/02/2024 15:29

- Average turn around time $= \frac{55}{5} = 11$ sec

- Average waiting time $= \frac{34}{5} = 6.8$ sec

2019
Spring

1. ~~Why is deadlock state more critical than starvation?~~ Describe resource allocation graph with a deadlock, with a cycle but no deadlock.

⇒

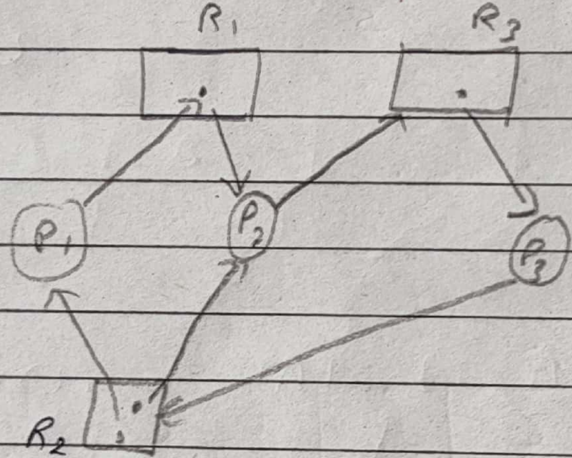


fig: Resource allocation graph with deadlock.

Here cycle is created between R_2, P_2, R_3, P_3 and R_2 where R denote resources and P denote processes.

In this figure, Resource (R_2) is allocated to process (P_2) and P_2 requests resource (R_3), also R_3 is allocated to P_3 and P_3 requests resource

Page :
Date : / /

R_2. At this condition cycle is created and all the processes hold their resources until completion and hence deadlock occurs.

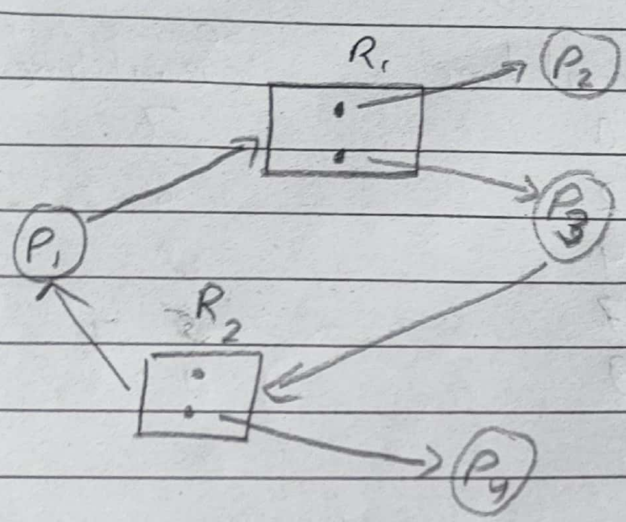


fig:- Resource allocation graph with cycle but no deadlock.

Here cycle is created between process (P_1, P_3) and Resources (R_2, R_1)

Here, Resources (R_2) is allocated to process (P_1) and P_1 requests for Resource (R_1). But, R_1 can be freed by process P_2 and Process P_1 can be executed.

Now Process P_1 frees resources (R_1, R_2).
Process (P_3) ~~wants~~ requests for resource R_2 and Resource (R_1) is allocated to P_3. So, P_3 can be executed either released by P_1 or P_4 after completion. In this way, deadlock doesnot occurs.

2. From the following set of information. Find the average waiting time and average ~~tur~~ turnaround time using FCFS, SJF, RR (Quantum = 3) and HRRN.

Process	Arrival time	Service time (Burst time)
A	0	7
B	2	6
C	4	8
D	7	5
E	9	4

- FCFS

A	B	C	D	E

0 7 13 21 26 30

Process	TAT = ET - AT	WT = TAT - BT
A	7	0
B	11	5
C	17	9
D	19	14
E	21	17
n = 5	Σ TAT = 75	Σ WT = 45

- Average turnaround time $= \frac{75}{5} = 15$

- Average waiting time $= \frac{45}{5} = 9$

02/02/2024 15:29

- SJF

A	D	E	B	C

0 (B, C, D) 7 (E) 12 16 22 30

Process	TAT = ET - AT	WT = TAT - BT
A	7	0
B	~~10~~ 20	14
C	26	18
D	5	0
E	7	3
n = 5	ΣTAT = 65	ΣWT = 35

- ~~Tot~~ Average Turnaround time $= \frac{\Sigma TAT}{n} = \frac{65}{5} = 13$

- Average waiting time $= \frac{\Sigma WT}{5} = \frac{35}{5} = 7$.

- RR

quantum = 3

A	B	C	D	E	A	B	C	D	E

0 3 6 9 12 15 18 21 24 26 2

A	C

27 28 30

Page :
Date : / /

Process	TAT = ET - AT	WT = TAT - BT
A	28	21
B	19	13
C	26	18
D	19	14
E	18	14
$n = 5$	$\Sigma TAT = 110$	$\Sigma WT = 80$

- Average turn around time $= \frac{110}{5} = 22$

- Average waiting time $= \frac{80}{5} = 16$

3. Consider the following page reference string s: 1, 2, 3, 4, 2, 1, 5, 6, 2, 1, 2, 3, 7, 6, 3, 2, 1, 2, 3, 6. How many page faults would occur for each of the following page replacement algorithms assuming 3 pages a frame? In each case calculate fault ratio.

i) ~~Sech~~ Second chance page replacement
ii) LRU page replacement
iii) FIFO page replacement.

(i) Second chance page replacement

02/02/2024 15:30

1	2	3	4	2	1	5
3	3	3	3	3	1	1
2	2	2	2	1 2 1	2 1	2 0
1	1	1	4	4	4	5
Miss	Miss	Miss	Miss	Hit	Miss	Miss

6	2	1	2	3	7	6	3
1	2	2	2 1	2 1	2 0	6	6
6	6	6	6	3	3	3	3
5	5	1	1	1	7	7	7
Miss	Miss	Miss	Hit	Miss	Miss	Miss	Hit

2	1	2	3	6
6	1	1	1	6
3 1	3 0	3	3 1	3 0
2	2	2 1	2 1	2 0
Miss	Miss	Hit	Hit	Miss

Total No. of page fault = 15

(ii) LRU page replacement

1	2	3	4	2	1	5	6
		3	3	3	1	1	1
	2	2	2	2	2	2	6
1	1	1	4	4	4	5	~~5~~ 5
Miss	Miss	Miss	Miss	Hit	Miss	Miss	Miss

2	1	2	3	7	6	3	2
2	2	2	2	2	6	6	6
6	6	6	3	3	3	3	3
5	1	1	1	7	7	7	2
Miss	Miss	Hit	Miss	Miss	Miss	Hit	Miss

02/02/2024 15:30

1	2	3	6
6	6	3	3
1	1	1	6
2	2	2	2
Miss	Hit	Miss	Miss

Total no. of page fault = 16

iii) FIFO page replacement

1	2	3	4	2	1	5	6	2	1
		3	3	3	3	5	5	5	1
	2	2	2	2	1	1	1	2	2
1	1	1	4	4	4	4	6	6	6
Miss	Miss	Miss	Miss	Hit	Miss	Miss	Miss	Miss	Miss

2	3	7	6	3	2	1	3	2	6
1	1	1	6	6	6	6	3	3	3
2	2	7	7	7	7	1	1	1	1
6	3	3	3	3	2	2	2	2	6
Hit	Miss	Miss	Miss	Hit	Miss	Miss	Miss	Hit	Miss

Total no. of page faults = 16

02/02/2024 15:30

2020
Fall

1 Given the following set of information, what is the average waiting time and average turn-around time using SJF Preemptive, FCFS, RR (Quantum = 3) and HRRN.

Process	Arrival Time	~~Serive~~ Service Time (Burst Time)
A	0	8
B	2	6
C	4	9
D	7	5
E	9	4

- SJF preemptive

A A	D	E	B	C

0 (B,C,D) 8 (E) 13 17 23 32

Process	TAT = ET − AT	WT = TAT − B.T.
A	8	0
B	21	15
C	28	19
D	6	1
E	8	4

- Average Turnaround time $= \frac{71}{5} = 14.2$

- ~~Ave~~ Average waiting time $= \frac{39}{5} = 7.8$

02/02/2024 15:30

→ FCFS

A	B	C	D	E

0 8 14 23 28 32

Process	TAT = ET - AT	WT = TAT - BT
A	8	0
B	12	6
C	19	10
D	21	16
E	23	19
n = 5	ΣTAT = 83	ΣWT = 51

- Average Turn around time $= \frac{83}{5} = 16.6$
- Average waiting time $= \frac{51}{5} = 10.2$

→ RR
Quantum = 3

A	B	C	D	E	A	B	C	D	E	A	C

0 3 6 9 12 15 18 21 24 26 27 29 32

Process	TAT = ET - AT	WT = TAT - BT
A	29	21
B	19	13
C	28	19
D	19	14
E	18	14
	ΣTAT = 113	ΣWT = 81

Page :

Date : / /

- Average ~~waiting time~~ TAT $= \frac{\Sigma TAT}{n} = \frac{113}{5}$

- Average waiting time $= \frac{\Sigma WT}{n} = \frac{81}{5} = 16.2$

2. Consider the following page reference strings:-
2, 3, 4, 5, 3, 2, 6, 7, 3, 2, 3, 4, 8, 7, 4, 3, 2, 3, 4, 7.
How many page faults wolud occur for each of the following page replacement algorithms assuming 3 pages a frame? In each case calculate fault ratio.

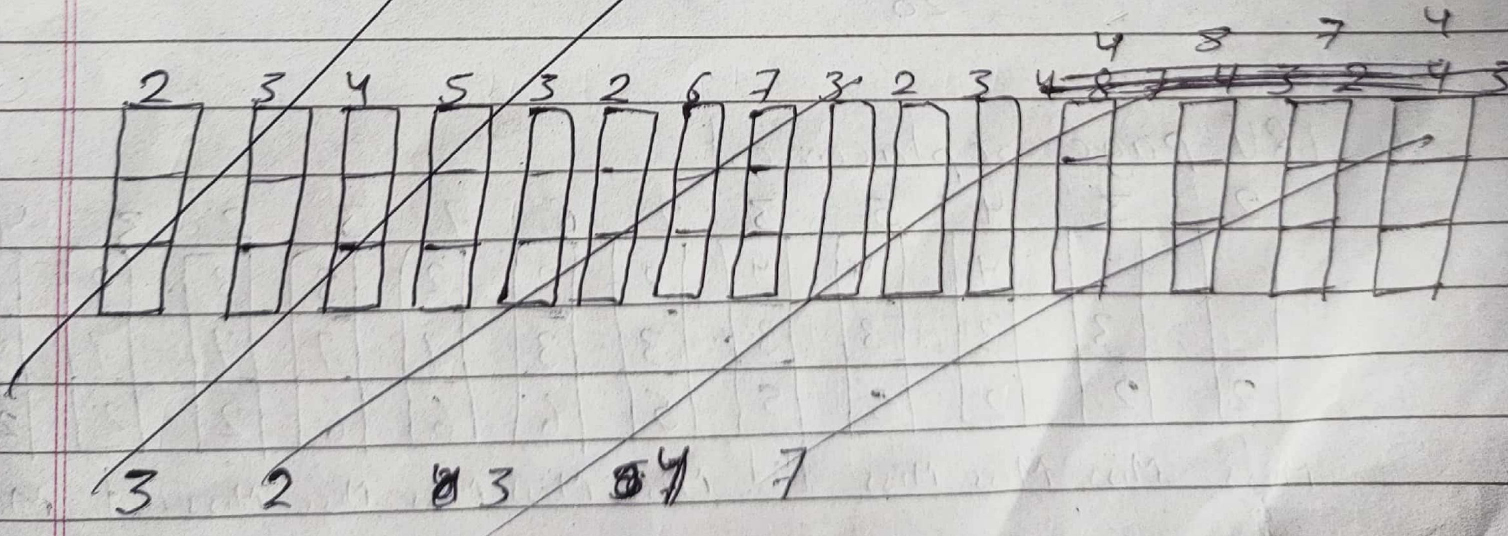
(i) Optimal Page replacement [Not used for longest period of time)

(ii) LRU page replacement

(iii) FIFO page replacement

=)

(i) Optimal page Replacement :



(i) ~~Optimal page replacement~~

2	3	4	5	3	2	6	7	3	2	3	4
		4	4	4	2	2	2	3	3	3	3
	3	3	3	3	3	3	7	7	7	7	4
2	2	2	5	5	5	6	6	6	2	2	2
Miss	Miss	Miss	Miss	Hit	Miss	Miss	Miss	Miss	Miss	Hit	Miss

8	7	4	3	2	3	4	7
3	7	7	7	2	2	2	7
4	4	4	4	4	4	4	4
8	8	8	3	3	3	3	3
Miss	Miss	Hit	Miss	Miss	Hit	Hit	Miss

- Total No. of page faults = 15
- Fault ratio = $\frac{15}{20}$ = 3:4

ii LRU page replacement

2	3	4	5	3	2	6	7	3	2	3	4
		4	4	4	2	2	2	3	3	3	3
	3	3	3	3	3	3	7	7	7	7	4
2	2	2	5	5	5	6	6	6	2	2	2
Miss	Miss	Miss	Miss	Hit	Miss	Miss	Miss	Miss	Miss	Hit	Miss

8

8	7	4	3	2	3	4	7
3	7	7	~~7~~	2	2	2	7
4	4	4	4	4	4	4	4
8	8	8	3	3	3	3	3
Miss	Miss	Hit	Miss	Miss	Hit	Hit	Miss

- Total no. of page fault = 15
- Page fault ratio = $\frac{15}{20}$ = 3 : 4

iii FIFO page replacement.

2	3	4	5	3	2	6	7	3	2	3	4
		4	4	4	4	6	6	6	2	2	2
	3	3	2	3	2	2	2	3	3	3	3
2	2	2	5	5	5	5	7	7	7	7	4
Miss	Miss	Miss	Miss	Hit	Miss	Miss	Miss	Miss	Miss	Hit	Miss

8	7	4	3	2	3	4	7
2	7	7	7	7	7	4	4
8	8	8	8	2	2	2	2
4	4	4	3	3	3	3	7
Miss	Miss	Hit	Miss	Miss	Hit	Miss	Miss

Total no of page fault = 16

Page Fault ratio = $\frac{16}{20}$ = 4 : 5

02/02/2024 15:31

CamScanner

3 Five processes and 3 resource types A, B, C and D (Below is the snapshot of the ~~stak~~ state as:

Process	Max	Allocation	Available
	A, B, C, D	A, B, C, D	A, B, C, D
P0	6 0 1 2	4 0 0 1	3 2 1 1
P1	2 7 5 0	1 1 0 0	
P2	2 3 5 6	1 2 5 4	
P3	1 6 5 3	0 6 3 3	
P4	1 6 5 6	0 2 1 2	

Is this a safe state? If yes, what is safe sequence?

2021
Fall

1 Consider the deadlock situation that could occur in the dining philosopher's problem when the philosopher obtain the chopstick one at a time. Discuss how the four necessary conditions for deadlock indeed hold in this setting. Discuss how deadlock could be avoided by eliminating any one of the four conditions.

⇒ In the dining philosophers problem, a deadlock can occur when each philosophers picks up ~~one~~ one chopstick and waits for the other, resulting in a circular waiting scenario. The four necessary condition for deadlock in this situation are:-

a. Mutual Exclusion:- Philosophers must hold a chopstick exclusively to themselves, creating mutual exclusion.

b. Hold and wait:- A philosopher can hold one chopstick while waiting for another, ~~contributing~~ contributing to the hold and wait condition.

c. NO preemption:- Once a philosopher holds a chopstick, it cannot be taken away forcibly, adhering to the no preemption condition.

d. Circular wait:- Philosophers from a circular dependency while waiting for a chopstick, satisfying the circular wait condition.

To avoid deadlock, one of the four conditions must be eliminated. Here are potential solutions:-

1. Mutual Exclusion:- Allow philosophers to share chopsticks. This eliminates the need for exclusive acess and break the mutual exclusion condition.

2. Hold and wait :- Require philosophers to acquire all necessary resources (both chopsticks) simultaneously or release the ~~aa~~ acquired resources if unable to get the second chopstick. This way the hold and wait condition is eliminated.

3 No preemption:- Allow a philosopher to ~~be~~ be interrupted and force to release their chopsticks if another philosopher requests them urgently. ~~However this~~

4. Circular wait:- Assign a unique identifier to each chopstick and require philosophers to always pick up chopsticks in a specific order. This breaks the circular dependency.

2. Given the following information, draw a GANTT charts for procesor scheduling Preemptive shortest job first and RR (Quantum = 2). Also, find average waiting time, average turnaround time and average

Page :
Date : / /

response time for all cases.

Process	Arrival time	Burst time
P1	0.0	7
P2	3.0	4
P3	5.0	2
P4	6.0	4

- Preemptive shortest job first

GANTT chart

P1	P1	P1	P3	P2	P4

0 (P2) 3 (P3) 5 (P4) 7 9 13 17

Start time of Execu

Process	TAT = ET - AT	WT = TAT - BT	R.T = S.T.E - A.T.
P1	7	0	0
P2	10	6	~~2~~ 6
P3	4	2	2
P4	11	7	7
	$\Sigma TAT = 32$	$\Sigma WT = 15$	$\Sigma RT = 15$

- Average turn around time $= \frac{\Sigma TAT}{n} = \frac{32}{4} = 8$
- Average waiting time $= \frac{\Sigma WT}{4} = \frac{15}{4} = 3.75$
- Average response time $= \frac{\Sigma RT}{4} = \frac{15}{4} = 3.75$

Page :
Date : / /

- Round Robin
(Quantum = 2)

- GANTT CHART

P1	P1	P2	P3	P4	P1	P2	P4	P1

0 2 (P2) 4 (P3,P4) 6 8 10 12 14 16 17

Process	TAT = ET − AT	WT = TAT − BT	R.T. = ST − AT
P_1	17	10	0
P_2	11	7	1
P_3	3	1	1
P_4	10	6	2
	$\Sigma TAT = 41$	$\Sigma WT = 24$	$\Sigma RT = 4$

- Average Turnaround time $= \frac{\Sigma TAT}{4} = \frac{41}{4} = 10.25$

- Average waiting time $= \frac{\Sigma WT}{4} = \frac{24}{4} = 6$

- Average Response time $= \frac{\Sigma RT}{n} = \frac{4}{4} = 1$

3 Consider the following page reference strings: 2, 3, 3, 4, 5, 6, 5, 7, 1, 2, 5, 8, 6, 4, 1. How many page faults ~~on~~ would occur for each of the following page replacement algorithms assuming 3 pages frames?

(i) LRU page replacement
(ii) FIFO page "
(iii) Optimal page "

• LRU page replacement

2	3	3	4	5	6	5	7	1	2	5	8
			4	4	4	4	7	7	7	5	5
	3	3	3	3	6	6	6	6	2	2	2
2	2	2	2	5	5	5	5	1	1	1	8
Miss	Miss	Hit	Miss	Miss	Miss	Hit	Miss	Miss	Miss	Miss	Miss

6	4	1
5	4	4
6	6	6
8	8	1
Miss	Miss	Miss

Total no. of page faults = 13

02/02/2024 15:32

(ii) FIFO

2	3	3	4	5	6	5	7	1	2	5	8	6	4	1
			4	4	4	4	7	7	7	5	5	5	4	4
	3	3	3	3	6	6	6	6	2	2	2	6	6	6
2	2	2	2	5	5	5	5	1	1	1	8	8	8	1
Miss	Miss	Hit	Miss	Miss	Miss	Hit	Miss	Miss	Miss	Miss	Miss	Miss	Miss	Miss

Total no. of page faults = 15

(iii) Optimal page replacement

2	3	3	4	5	6	5	7	1	2
			4	4	4	4	7	1	1
	3	3	3	5	5	5	5	5	2
2	2	2	2	2	6	6	6	6	6
Miss	Miss	Hit	Miss	Miss	Miss	Hit	Miss	Miss	Miss

5	8	6	4	1
1	1	1	1	1
5	8	8	8	8
6	6	6	4	4
Miss	Miss	Hit	Miss	Hit

Total no. of page fault = 13

02/02/2024 15:32

2023
Spring

Page :
Date : / /

1 Consider the following set of processes with the length of the CPU burst given in miliseconds. Construct the Gantt chart and calculate average waiting time and turnaround time. Also explain which one is the best algorithm.

Process	Arrival time	Burst time	Priority
P1	0	9	2
P2	4	4	1
P3	10	3	3
P4	0	6	4

(i) RR (Quantum = 1ms)
(ii) Priority scheduling (1 higher priority)
(iii) Shortest job first (preemptive)

(i) RR
Quantum = 1ms
GANTT chart

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

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

P1	P2	P3	P4	P1	P3	P1	P1

14 15 16 17 18 19 20 21 22

Page :
Date : / /

Process	TAT = ET - AT	WT = TAT - BT
P1	22	13
P2	12	8
P3	10	7
P4	18	12
	$\Sigma TAT = 62$	$\Sigma WT = 40$

- Average turnaround time $= \frac{\Sigma TAT}{4} = \frac{62}{4} = 15.5$
- Average waiting time $= \frac{\Sigma WT}{4} = \frac{40}{4} = 10$

(ii) Priority scheduling (1 higher priority)

P1	P2	P1	P3	P4

0 4 8 13 16 22

Process	TAT = ET - AT	WT = TAT - BT
P1	13	4
P2	4	0
P3	6	3
P4	22	16
	$\Sigma TAT = 45$	$\Sigma WT = 23$

- Average Turnaround time $= \frac{45}{4} = 11.25$
- Average waiting time $= \frac{23}{4} = 5.75$

02/02/2024 15:32

(iii) Shortest job first (preemptive)

P4	P2	P3	P1

0 6 10 13 22

P2, P2 P4

Process	TAT = E.T. - AT	WT = TAT - BT
P1	~~22~~ 22	~~13~~ 13
P2	6	2
P3	~~6~~ 3	0
P4	6	0
	$\Sigma TAT = 37$	$\Sigma WT = 15$

- Average Turnaround time $= \frac{\Sigma TAT}{n} = \frac{37}{4} = 9.25$
- Average waiting time $= \frac{15}{4} = 3.75$.

2. Consider the following page reference strings 9, 3, 4, 5, 3, 9, 6, 7, 3, 9, 3, 4, 8, 7, 4, 3, 9, 3, 4, 7. How many page faults would occur for each of the following page replacement algorithms assuming 3 pages a frame? In each case calculate fault ratio.

i) Second chance page replacement

ii LRU page replacement
iii FIFO page replacement

(i) Second chance page replacement

9	3	4	5	3	9	6	7	3	9	3	4	8
		4	4	4	9	9	9	3	3	3	1 3	1 3 0
	3	3	3	3	1 3	3	7	7	7	7	4	4
9	9	9	5	5	5	6	6	6	9	9	9	8
M	M	M	M	M	M	M	M	M	M	H	M	M

7	4	3	9	3	4	7
7	7	7	7	7	4	7
4	4 1	4 0	9	9	9	9
8	8	3	3	3 1	3	3
M	H	M	M	H	M	M

Total no. of page fault = 17

ii LRU page replacement

9	3	4	5	3	9	6	7	3	9	3	4
		4	4	4	9	9	9	3	3	3	3
	3	3	3	3	3	3	7	7	7	7	4
9	9	9	5	5	5	6	6	6	9	9	9
M	M	M	M	H	M	M	M	M	M	H	M

02/02/2024 15:32

8	7	4	3	9	3	4	7
3	7	7	7	9	9	9	7
4	7	4	4	4	4	4	4
8	8	8	3	3	3	3	3
M	M	H	M	M	H	H	M

Total no of page faults = 15

iii. FIFO page replacement

9	3	4	5	3	9	6	7	3	9	3
		4	4	4	4	6	6	6	9	9
	3	3	3	3	9	9	9	3	3	3
9	9	9	5	5	5	5	7	7	7	7
M	M	M	M	H	M	M	M	M	M	H

4	8	7	4	3	9	3	4	7
9	9	7	7	7	7	7	4	7
3	8	8	8	8	9	9	9	9
~~7~~4	4	4	4	3	3	3	3	3
M	M	M	H	M	M	H	M	M

Total no. of page fault = 16

Page fault ratio = $\frac{16}{20}$ = 4 : 5