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Sheet 5

5.1) ✱ We find the needed amount of resource for each process (N = M - A)

$$\begin{pmatrix} 3 & 5 & 8 & 10 & 1 \\ 2 & 5 & 3 & 3 & 2 \\ 4 & 12 & 4 & 9 & 2 \\ 6 & 1 & 4 & 5 & 5 \end{pmatrix} - \begin{pmatrix} 0 & 2 & 1 & 1 & 1 \\ 0 & 5 & 3 & 1 & 1 \\ 0 & 7 & 1 & 2 & 1 \\ 3 & 1 & 1 & 1 & 0 \end{pmatrix}$$

$$N = \begin{matrix} R_1 & R_2 & R_3 & R_4 & R_5 \end{matrix}$$
$$\begin{pmatrix} 3 & 3 & 7 & 9 & 0 \\ 2 & 0 & 0 & 2 & 1 \\ 4 & 5 & 3 & 7 & 1 \\ 3 & 0 & 3 & 4 & 5 \end{pmatrix} \begin{matrix} \cdots P1 \\ \cdots P2 \\ \cdots P3 \\ \cdots P4 \end{matrix}$$

✱ Calculating the available resource (non allocated resource):

- Allocated resource for each resource type, A = (3, 15, 6, 5, 3)
- Available = t - A = (3, 0, 2, 5, 6)

✱ Checking if it is in Safe state.

→ trying to allocate resource for P1
(3, 3, 7, 9, 0) > (3, 0, 2, 5, 6) = fails
✱ R_2, R_3, R_4 not sufficient
→ trying to allocate for P2 (2, 0, 0, 2, 1) < (3, 0, 2, 5, 6)
= good!

Available = (3, 0, 2, 5, 6) + (0, 5, 3, 1, 1)
= (3, 5, 5, 6, 7)

→ trying to allocate resource for P_3 — Fails

$(4,5,3,7,1) > (3,5,5,6,7)$

R_1 & R_4 not sufficient

→ trying to allocate for P_4

$(3,0,3,4,5) < (3,5,5,6,7)$ — Good!

Available = $(3,5,5,6,7) + (3,1,1,1,0) = (6,6,6,7,7)$

→ trying to allocate for P_1 again — Fails

$(3,3,7,9,0) > (6,6,6,7,7)$

R_3 and R_4 not sufficient

→ trying to allocate for P_3 — Good!

$(4,5,3,7,1) < (6,6,6,7,7)$

Available = $(6,6,6,7,7) + (0,7,1,2,1) = (6,13,7,9,8)$

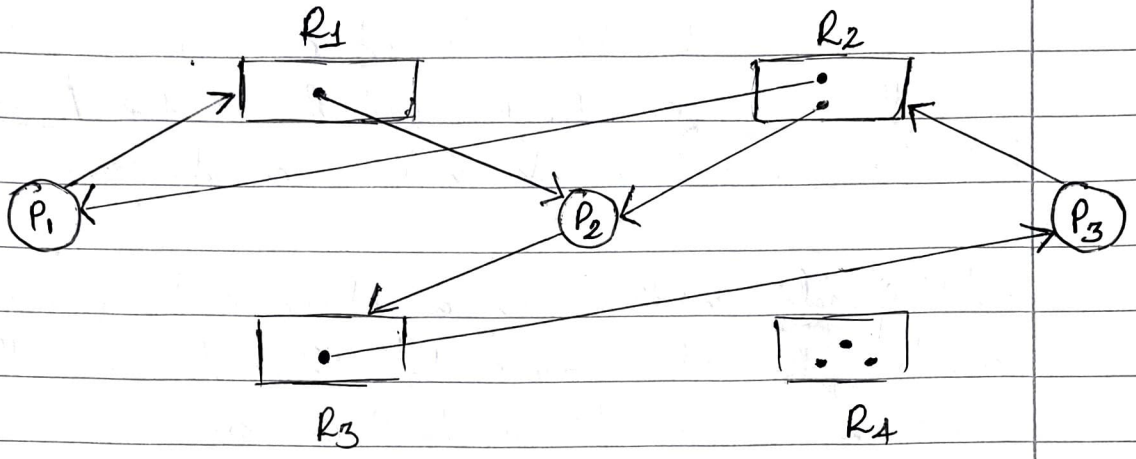
→ trying to allocate for P_1 — Good!

$(3,3,7,9,0) < (6,13,7,9,8)$

Available = $(6,13,7,9,8) + (0,2,1,1,1) = t$

From the above calculations, we can see that the system is in a Safe state and all processes can be executed ($P_2 \rightarrow P_4 \rightarrow P_3 \rightarrow P_1$)

5.2)



Available resource = (1,2,1,3) − (1, 2, 1, 0)
= (0, 0, 0, 3)

Note: in the above step, I calculated the free non allocated resources by substracting the allocated resources from the total amount of resources (t).

B) The system is Deadlocked

$$N = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \begin{matrix} -P_1 \\ -P_2 \\ -P_3 \end{matrix} \qquad \text{Available} = (0, 0, 0, 3)$$

- As we can see, P_1 needs R_1 to finish executing and releasing R_2. But R_1 isn't available.
- P_2 needs R_3 which is held by P_3. R_3 doesn't have another instance hence not on the Available list.
- P_3 needs R_2 to be released from either P_1 or P_2 and its holding R_3.

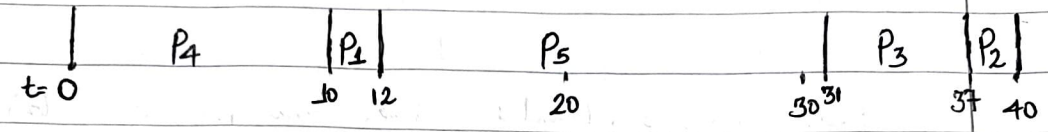
As we can see, the three processes are waiting for resources to be released from one another as there is no R_1, R_2 and R_3 in the Available list (0,0,0,3) which results in deadlock.

- Additionaly there is a closed cycle formed through $R_3 \rightarrow P_3 \rightarrow R_2 \rightarrow P_2 \rightarrow R_3$. Although this doesn't always indicate a deadlock, we can use it as a sign of deadlock in this situation.

FCFS:

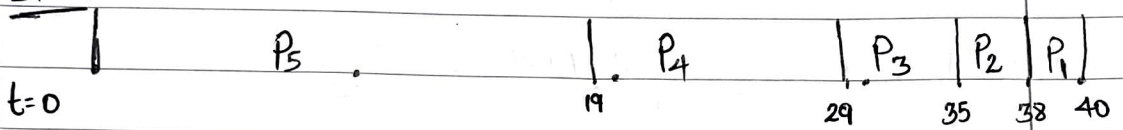
5.3)

a)



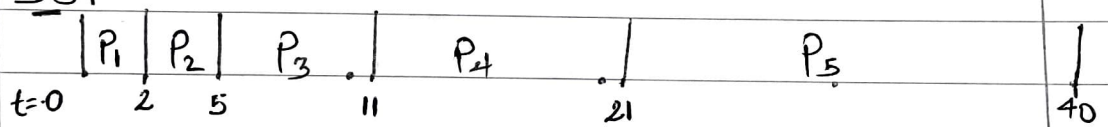
- $P_4 \Rightarrow t=0 \rightarrow t=10$ $P_5 \Rightarrow t=12 \rightarrow t=31$ $P_2 \Rightarrow t=37 \rightarrow t=40$
  $P_1 \Rightarrow t=10 \rightarrow t=12$ $P_3 \Rightarrow t=31 \rightarrow t=37$

LPTF



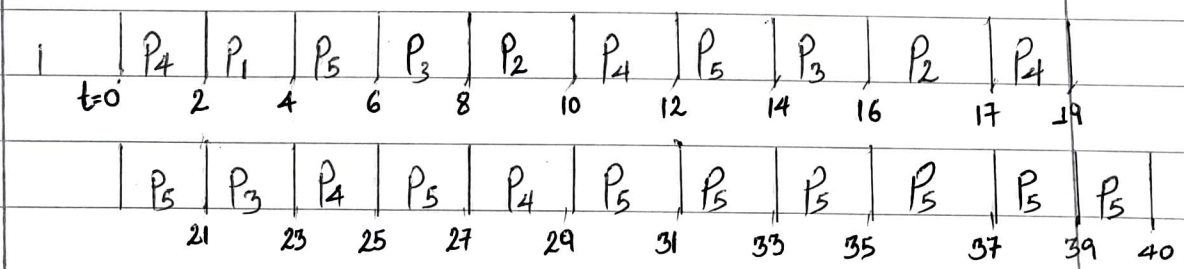
- $P_5 \Rightarrow t=0 \rightarrow t=19$ $P_3 \Rightarrow t=29 \rightarrow t=35$ $P_1 \Rightarrow t=38 \rightarrow t=40$
  $P_4 \Rightarrow t=19 \rightarrow t=29$ $P_2 \Rightarrow t=35 \rightarrow t=38$

SJF



- $P_1 \Rightarrow t=0 \rightarrow t=2$ $P_3 \Rightarrow t=5 \rightarrow t=11$ $P_5 \Rightarrow t=21 \rightarrow t=40$
  $P_2 \Rightarrow t=2 \rightarrow t=5$ $P_4 \Rightarrow t=11 \rightarrow t=21$

RR



P_1 ends at $t=4$ P_4 ends at $t=29$

P_2 ends at $t=17$ P_5 ends at $t=40$

P_3 ends at $t=23$

b) FCFS: To calculate the average completion time, we calculate the finishing times of the processes and find their average. (completion times taken from part (a))

$$t = \frac{10+12+31+37+40}{5} = \underline{\underline{26}}$$

LPTF: $\frac{19+29+35+38+40}{5} = \underline{\underline{32.2}}$

SJF: $\frac{2+5+11+21+40}{5} = \underline{\underline{15.8}}$

RR: $\frac{4+17+23+29+40}{5} = \underline{\underline{22.6}}$

5.4)

File	symbol	internal	external	weak	strong
a.c	x		✓		
a.c	y			✓	
a.c	f	✓			
a.c	g				✓
b.c	x				✓
b.c	y	✓			
b.c	f				✓
b.c	g		✓		

- The output is

b)

```
b.c : f()
a.c : g()
a.c : f()
```