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Problem 6.1: *safe states* (2 points)

A system has $n = 5$ processes, $m = 5$ resource types, and the number of resources for each resource type is given by $t = (6, 17, 9, 9, 7)$. The system is in the following state:

$$M = \begin{bmatrix} 2 & 5 & 3 & 3 & 2 \\ 3 & 5 & 8 & 9 & 1 \\ 4 & 9 & 4 & 9 & 2 \\ 6 & 1 & 4 & 5 & 5 \\ 1 & 2 & 3 & 4 & 5 \end{bmatrix} \quad A = \begin{bmatrix} 1 & 5 & 3 & 1 & 1 \\ 0 & 2 & 1 & 1 & 1 \\ 0 & 7 & 1 & 2 & 1 \\ 3 & 1 & 1 & 1 & 0 \\ 1 & 2 & 3 & 2 & 1 \end{bmatrix}$$

Is the system in a safe state? Provide a calculation to justify your answer.

$$N = M - A = \begin{bmatrix} 1 & 0 & 0 & 2 & 1 \\ 3 & 3 & 7 & 8 & 0 \\ 4 & 2 & 3 & 7 & 1 \\ 3 & 0 & 3 & 4 & 5 \\ 0 & 0 & 0 & 2 & 4 \end{bmatrix}$$

avail = t − colsum(A)

avail = (1, 0, 0, 2, 3) R = {1} Process 1 terminates

avail = (2, 5, 3, 3, 4) R = {5} Process 5 terminates

avail = (2, 5, 3, 5, 8) no other process can terminate

State is unsafe

Problem 6.2: *deadlock detection* (1+1 = 2 points)

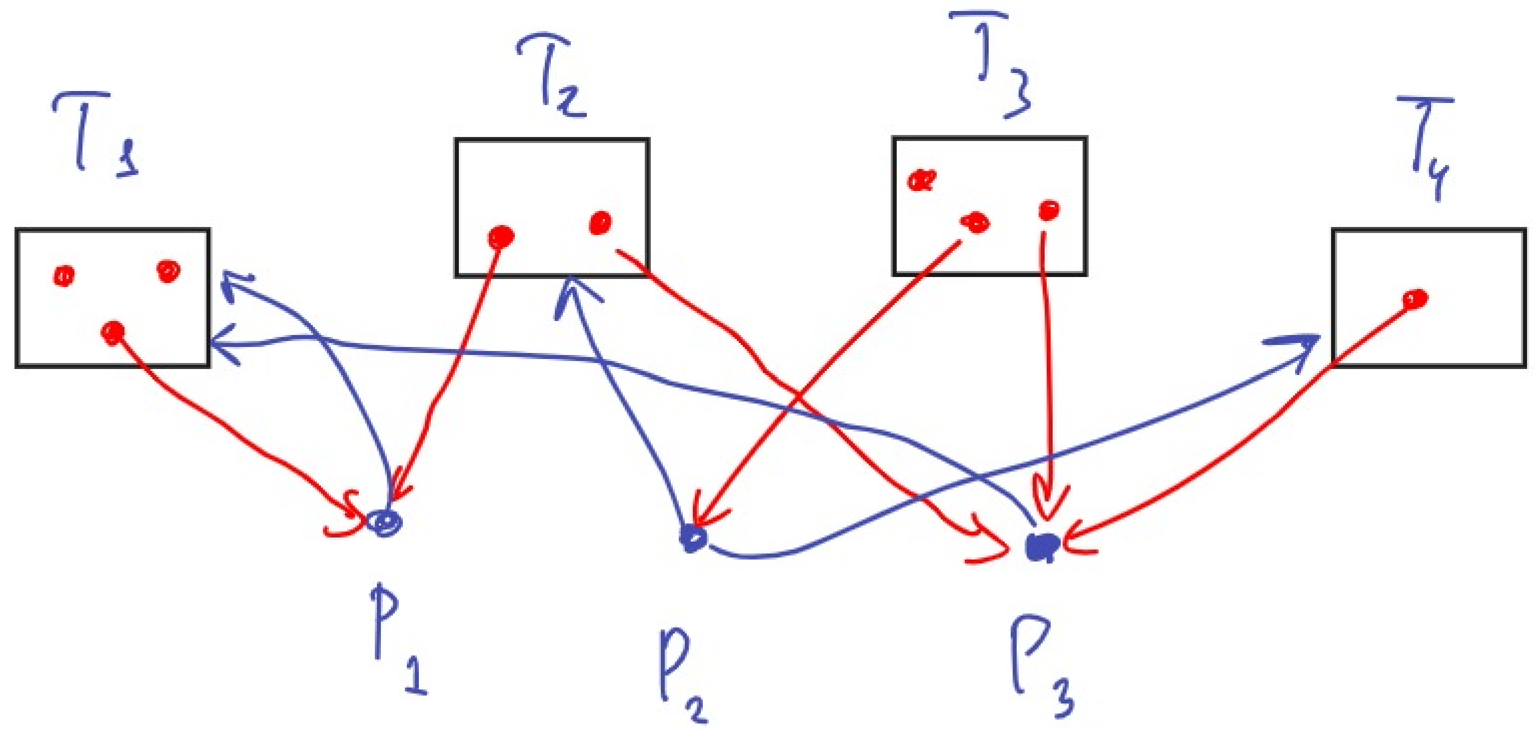
A system has $n = 3$ processes, $m = 4$ resource types, and the number of resources for each resource type is given by $t = (3, 2, 3, 1)$. The system is in the following state:

$$A = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 \end{bmatrix} \qquad N = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

a) Draw the corresponding resource allocation graph.

b) Is the system deadlocked? Provide a calculation to justify your answer.

a)



b) avail $= (2, 0, 1, 0)$ $R = \{P_1, P_3\}$ P_1, P_3 terminate

avail $= (3, 2, 2, 1)$ $R = \{P_2\}$ P_2 terminates

avail $= (3, 2, 3, 1)$ $A = \emptyset$ no deadlock

Problem 6.3: *scheduling strategies* (4+2 = 6 points)

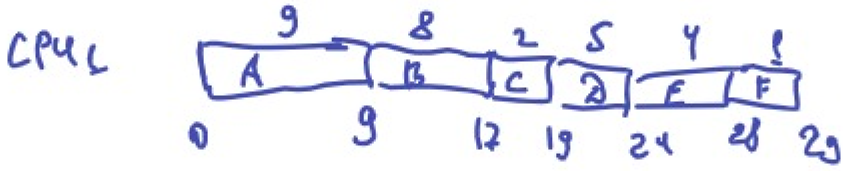
A computer system with a single CPU has to execute six processes $A, \dots, F$. The arrival times and the execution times of the processes are given by the following table.

process	arrival time	execution time
A	0	9
B	4	8
C	6	2
D	8	5
E	13	4
F	15	1

a) Draw the schedule for the scheduling strategies first-come first-served (FCFS), shortest processing time first (SPTF), longest processing time first (LPTF), and round robin (RR) with a time slice of 1 time unit. Assume that arrivals happen before a scheduling point and that new processes are added at the end of the run queue.

b) For each schedule, calculate the average turnaround time $\bar{t}$ and the average waiting time $\bar{w}$.

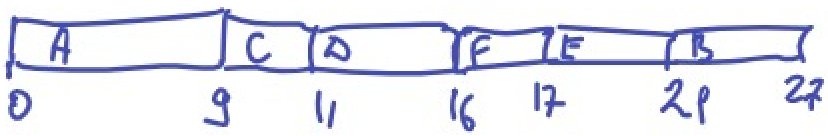
1) FCFS:



$$\bar{t} = \frac{1}{6}(9+13+13+16+15+14) = \frac{80}{6} = \frac{40}{3}$$

$$\bar{w} = \frac{1}{6}(0+5+11+11+11+13) = \frac{51}{6}$$

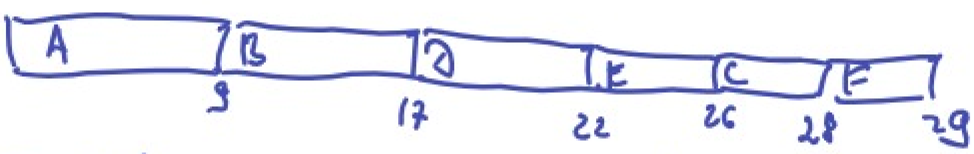
2) SPTF:



$$\bar{t} = \frac{1}{6}(9+23+5+8+8+2) = \frac{55}{6}$$

$$\bar{w} = \frac{1}{6}(0+15+3+3+4+1) = \frac{26}{6} = \frac{13}{2}$$

3) LPTF:



$$\bar{t} = \frac{1}{6}(9+13+22+14+13+14) = \frac{85}{6}$$

$$\bar{w} = \frac{1}{6}(0+5+20+9+9+13) = \frac{56}{6}$$

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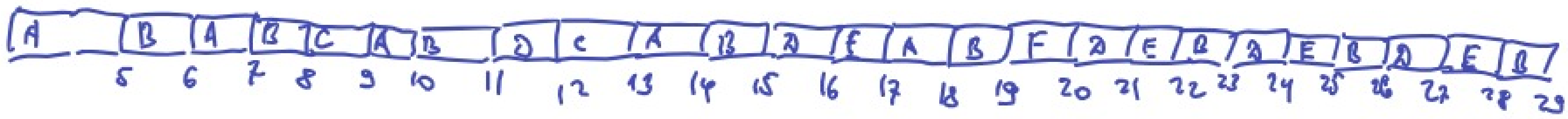
4) RR:



$$\bar{t} = \frac{1}{6}\left(18 + 25 + 7 + 19 + 15 + 5\right) = \frac{89}{6}$$

$$\bar{w} = \frac{1}{6}\left(9 + 17 + 5 + 14 + 11 + 4\right) = \frac{60}{6}$$