Assignment #6

Problem 6.1: *safe states* (3 points)

A system has $n = 5$ processes, $m = 5$ resource types, and the number of resources for each resource type is given by $t = (6, 17, 9, 10, 7)$. The system is in the following state:

$$M = \begin{bmatrix} 2 & 5 & 3 & 3 & 2 \\ 3 & 5 & 8 & 10 & 1 \\ 4 & 12 & 4 & 9 & 2 \\ 6 & 1 & 4 & 5 & 5 \\ 1 & 2 & 3 & 4 & 5 \end{bmatrix} \qquad A = \begin{bmatrix} 0 & 5 & 3 & 1 & 1 \\ 0 & 2 & 1 & 1 & 1 \\ 0 & 7 & 1 & 2 & 1 \\ 3 & 1 & 1 & 1 & 0 \\ 1 & 2 & 3 & 2 & 1 \end{bmatrix}$$

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

$N = M - A =$

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

$=$

$$\begin{bmatrix} 2 & 0 & 0 & 2 & 1 \\ 3 & 3 & 7 & 9 & 0 \\ 4 & 5 & 3 & 7 & 1 \\ 3 & 0 & 3 & 4 & 5 \\ 0 & 0 & 0 & 2 & 4 \end{bmatrix} \begin{matrix} \leftarrow P_1 \checkmark \\ \leftarrow P_2 \checkmark \\ \leftarrow P_3 \checkmark \\ \leftarrow P_4 \checkmark \\ \leftarrow P_5 \checkmark \end{matrix}$$

$a = t - \text{colsum}(A)$

$= (6, 17, 9, 10, 7) - (4, 17, 9, 7, 4)$

$= (2, 0, 0, 3, 3)$ ← safe state

$+A(P_1)$ $a = (2, 0, 0, 3, 3)$ $R = \{P_1\}$

$a = (2, 5, 3, 4, 4)$ $R = \{P_5\}$

$+A(P_5)$ $a = (3, 7, 6, 6, 5)$ $R = \{P_4\}$

$+A(P_4)$ $a = (6, 8, 7, 7, 5)$ $R = \{P_3\}$

+A(P3)

$a = (6, 15, 8, 9, 6)$ $R = \{P_2\}$

$a = (6, 17, 9, 10, 7)$ ← same as t

System is in a safe state!

Problem 6.2: *deadlock detection* (1+2 = 3 points)

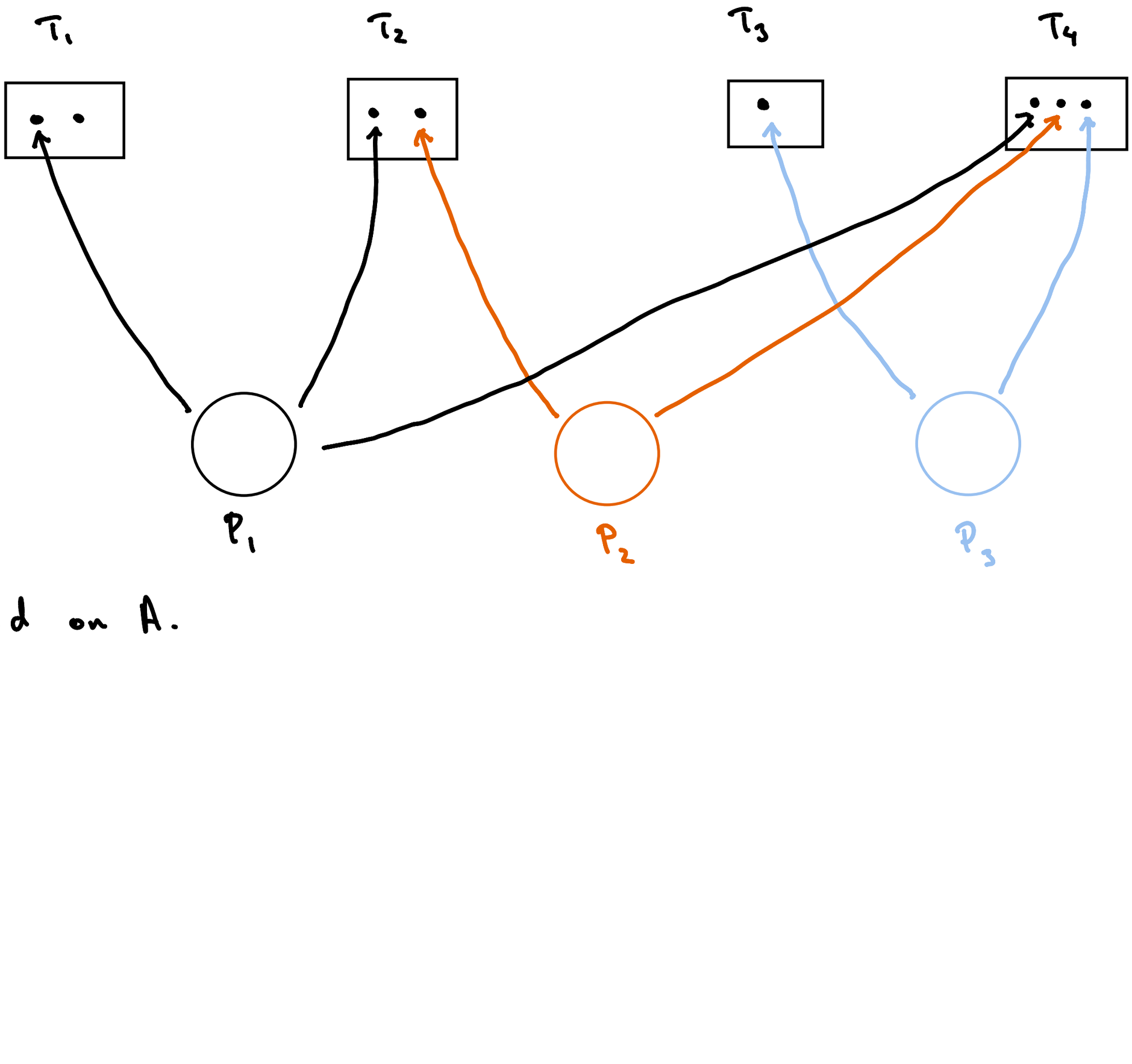
A system has $n = 3$ processes, $m = 4$ resource types, and the number of resources for each resource type is given by $t = (2, 2, 1, 3)$. The system is in the following state:

$$A = \begin{bmatrix} 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \end{bmatrix} \quad N = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix} \begin{matrix} P_1 \\ P_2 \\ P_3 \end{matrix}$$

a) Draw the corresponding resource allocation graph.

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

a)



Based on A.

b) $a = t - \text{colsum}(A)$

$= (2,2,1,3) - (1,2,1,3)$

$= (1,0,0,0)$

$a = (1,0,0,0)$ $\quad R = \{P_2\}$

$a = (1,1,0,1)$ $\quad R = \{P_3\}$

$a = (1,1,1,2)$ $\quad R = \{P_1\}$

$a = (2,2,1,3) = t \Rightarrow$ no deadlocks!

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

A computer system with a single CPU has to execute $n = 6$ processes $A, \ldots, F$. The arrival times and the execution times of the processes are given by the following table.

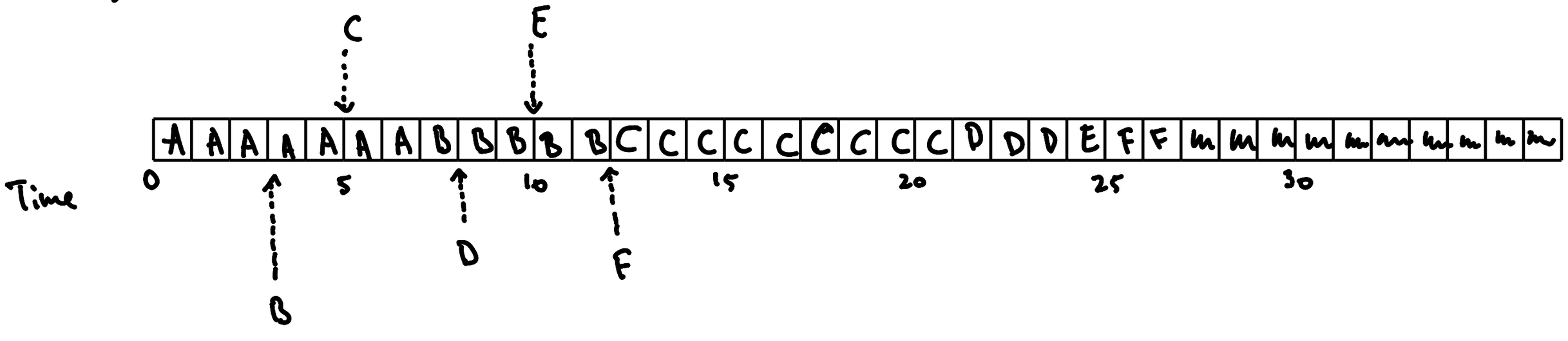
process	arrival time	execution time
A	0	7
B	3	5
C	5	9
D	8	3
E	10	1
F	12	2

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 $\bar{w}$.

a) FCFS:

b)



$Q_3 = \{B\}$

$Q_5 = \{B, C\}$

$Q_8 = \{C, D\}$

$Q_{10} = \{C, D, E\}$

$Q_{12} = \{C, D, E, F\}$

$a_A = 0$, $e_A = 7$, $t_A = 7 - 0 = 7$, $w_A = 7 - 7 = 0$

$a_B = 3$, $e_B = 12$, $t_B = 12 - 3 = 9$, $w_B = 9 - 5 = 4$

$a_C = 5$, $e_C = 21$, $t_C = 21 - 5 = 16$, $w_C = 16 - 9 = 7$

$a_D = 8$, $e_D = 24$, $t_D = 24 - 8 = 16$, $w_D = 16 - 3 = 13$

$a_E = 10$, $e_E = 25$, $t_E = 25 - 10 = 15$, $w_E = 15 - 1 = 14$

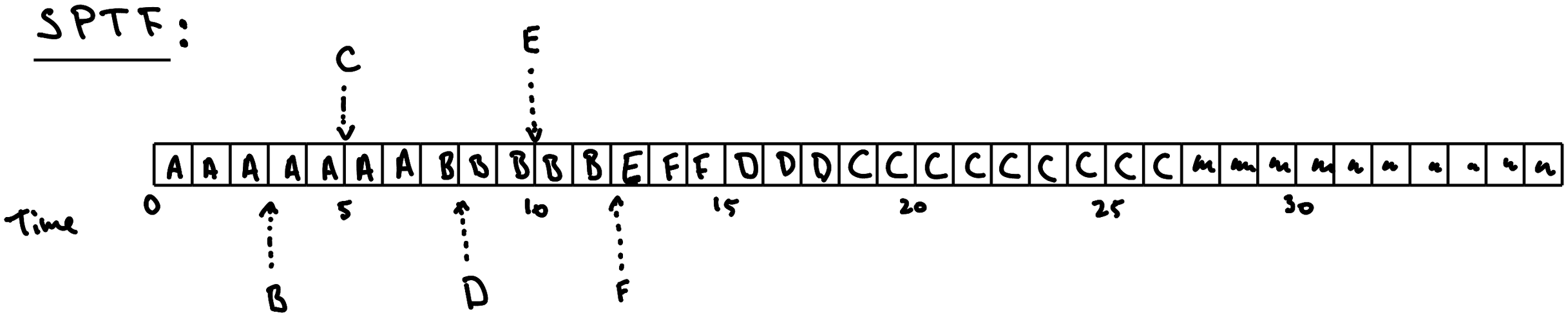
$a_F = 12$, $e_F = 27$, $t_F = 27 - 12 = 15$, $w_F = 15 - 2 = 13$

$$\bar{t} = \frac{1}{6}(7 + 9 + 16 + 16 + 15 + 15)$$

$$= \underline{\underline{13}} \text{ time units}$$

$$\bar{w} = \frac{1}{6}(0 + 4 + 7 + 13 + 14 + 13) = \underline{\underline{8.5}} \text{ time units}$$

SPTF:



min-heap

↳ $Q_3 = \{B\}$

$Q_5 = \{B, C\}$

$Q_8 = \{D, C\}$

$Q_{10} = \{E, D, C\}$

$Q_{12} = \{E, F, D, C\}$

$a_A = 0$, $e_A = 7$, $t_A = 7 - 0 = 7$, $w_A = 7 - 7 = 0$

$a_B = 3$, $e_B = 12$, $t_B = 12 - 3 = 9$, $w_B = 9 - 5 = 4$

$a_E = 10$, $e_E = 13$, $t_E = 13 - 10 = 3$, $w_E = 3 - 1 = 2$

$a_F = 12$, $e_F = 15$, $t_F = 15 - 12 = 3$, $w_F = 3 - 2 = 1$

$a_D = 8$, $e_D = 18$, $t_D = 18 - 8 = 10$, $w_D = 10 - 3 = 7$

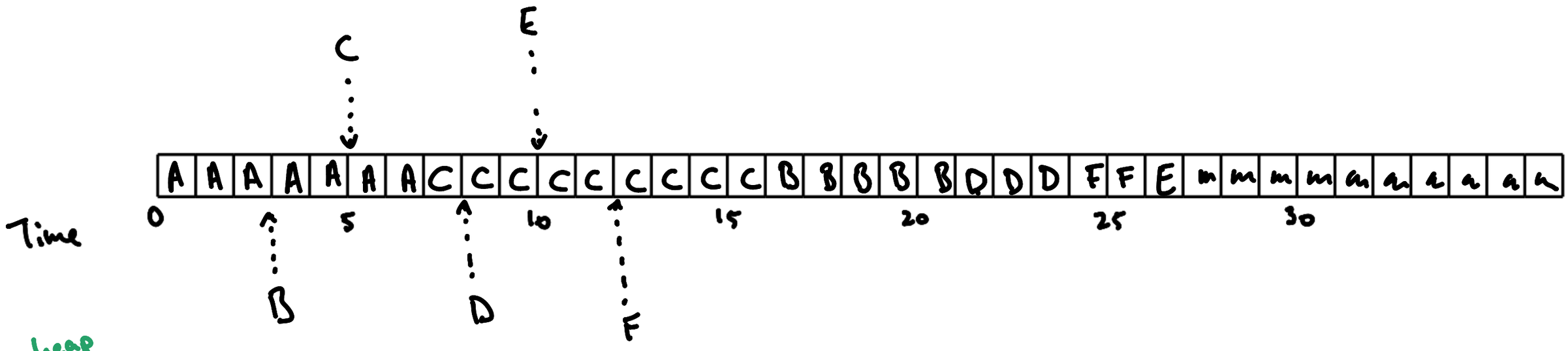
$a_C = 5$, $e_C = 27$, $t_C = 27 - 5 = 22$, $w_C = 22 - 9 = 13$

$$\overline{t} = \frac{1}{6}(7 + 9 + 3 + 3 + 10 + 22)$$

$$= \underline{\underline{8.83}} \text{ time units (2dp)}$$

$$\overline{w} = \frac{1}{6}(0 + 4 + 2 + 1 + 7 + 13) = \underline{\underline{4.5}} \text{ time units}$$

LPT F:



max-heap

$Q_3 = \{B\}$ $Q_8 = \{B, D\}$ $Q_{12} = \{B, D, F, E\}$

$Q_5 = \{C, B\}$ $Q_{10} = \{B, D, E\}$

$a_A = 0$, $e_A = 7$, $t_A = 7 - 0 = 7$, $w_A = 7 - 7 = 0$

$a_C = 5$, $e_C = 16$, $t_C = 16 - 5 = 11$, $w_C = 11 - 9 = 2$

$a_B = 3$, $e_B = 21$, $t_B = 21 - 3 = 18$, $w_B = 18 - 5 = 13$

$a_D = 8$, $e_D = 24$, $t_D = 24 - 8 = 16$, $w_D = 16 - 3 = 13$

$a_F = 12$, $e_F = 26$, $t_F = 26 - 12 = 14$, $w_F = 14 - 2 = 12$

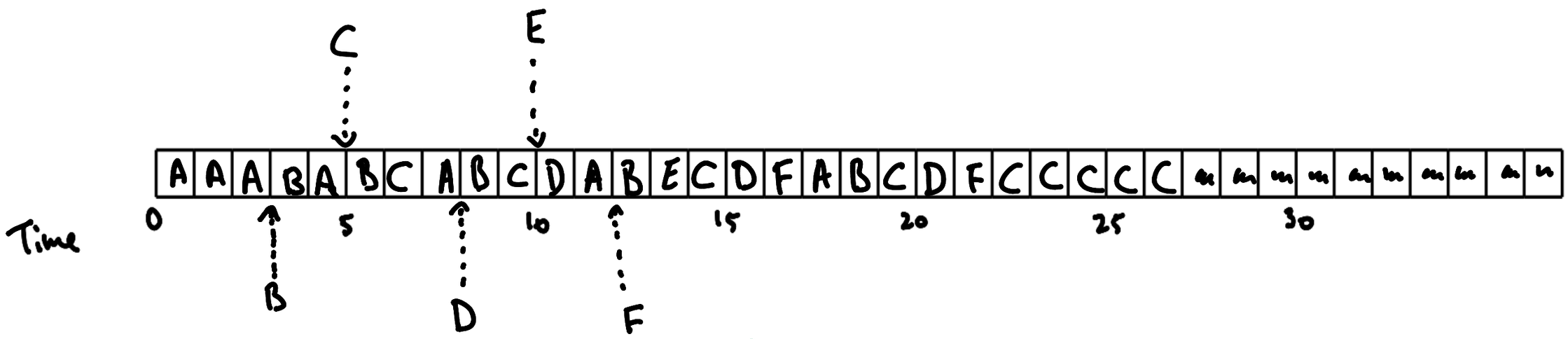
$a_E = 10$, $e_E = 27$, $t_E = 27 - 10 = 17$, $w_E = 17 - 1 = 16$

$\overline{t} = \frac{1}{6}(7 + 11 + 18 + 16 + 14 + 17)$

$= \underline{\underline{13.83}}$ time units (2dp)

$\overline{w} = \frac{1}{6}(0 + 2 + 13 + 13 + 12 + 16) = \underline{\underline{9.33}}$ time units (2dp)

RR:



remaining

$Q_3 = \{B\} \rightarrow \{A\}$ $\quad R = \{A=4, B=5\}$

$Q_4 = \{A\} \rightarrow \{B\}$ $\quad R = \{A=4, B=4\}$

$Q_5 = \{B, C\} \rightarrow \{C, A\}$ $\quad R = \{A=3, B=4, C=9\}$

$Q_6 = \{C, A\} \rightarrow \{A, B\}$ $\quad R = \{A=3, B=3, C=9\}$

$Q_7 = \{A, B\} \rightarrow \{B, C\}$ $\quad R = \{A=3, B=3, C=8\}$

$Q_8 = \{B, C, D\} \rightarrow \{C, D, A\}$ $\quad R = \{A=2, B=3, C=8, D=3\}$

$Q_9 = \{C, D, A\} \rightarrow \{D, A, B\}$ $\quad R = \{A=2, B=2, C=8, D=3\}$

$Q_{10} = \{D, A, B, E\} \rightarrow \{A, B, E, C\}$ $\quad R = \{A=2, B=2, C=7, D=3, E=1\}$

$Q_{11} = \{A, B, E, C\} \rightarrow \{B, E, C, D\}$ $\quad R = \{A=2, B=2, C=7, D=2, E=1\}$

$Q_{12} = \{B, E, C, D, F\} \rightarrow \{E, C, D, F, A\}$ $\quad R = \{A=1, B=2, C=7, D=2, E=1, F=2\}$

$Q_{13} = \{E, C, D, F, A\} \rightarrow \{C, D, F, A, B\}$ $\quad R = \{A=1, B=1, C=7, D=2, E=1, F=2\}$

$Q_{14} = \{C, D, F, A, B\} \rightarrow \{D, F, A, B\}$ $\quad R = \{A=1, B=1, C=7, D=2, E=0, F=2\}$

$Q_{15} = \{D, F, A, B\} \rightarrow \{F, A, B, C\}$ $\quad R = \{A=1, B=1, C=6, D=2, F=2\}$

$Q_{16} = \{F, A, B, C\} \rightarrow \{A, B, C, D\}$ $\quad R = \{A=1, B=1, C=6, D=1, F=2\}$

$Q_{17} = \{A, B, C, D\} \rightarrow \{B, C, D, F\}$ $\quad R = \{A=1, B=1, C=6, D=1, F=1\}$

$Q_{18} = \{B, C, D, F\} \rightarrow \{C, D, F\}$ $\quad R = \{A=0, B=1, C=6, D=1, F=1\}$

$Q_{19} = \{C, D, F\} \rightarrow \{D, F\}$ $\quad R = \{B=0, C=6, D=1, F=1\}$

$Q_{20} = \{D, F\} \rightarrow \{F, C\}$ $R = \{C = 5, D = 1, F = 1\}$

$Q_{21} = \{F, C\} \rightarrow \{C\}$ $R = \{C = 5, D = 0, F = 1\}$

$Q_{22} = \{C\} \rightarrow \{\}$ $R = \{C = 5, F = 0\}$

$a_A = 0$, $e_A = 18$, $t_A = 18 - 0 = 18$, $w_A = 18 - 7 = 11$

$a_B = 3$, $e_B = 19$, $t_B = 19 - 3 = 16$, $w_B = 16 - 5 = 11$

$a_C = 5$, $e_C = 27$, $t_C = 27 - 5 = 22$, $w_C = 22 - 9 = 13$

$a_D = 8$, $e_D = 21$, $t_D = 21 - 8 = 13$, $w_D = 13 - 3 = 10$

$a_E = 10$, $e_E = 14$, $t_E = 14 - 10 = 4$, $w_E = 4 - 1 = 3$

$a_F = 12$, $e_F = 22$, $t_F = 22 - 12 = 10$, $w_F = 10 - 2 = 8$

$\bar{t} = \frac{1}{6}(18 + 16 + 22 + 13 + 4 + 10) = \underline{\underline{13.83}}$ time units (2dp)

$\bar{w} = \frac{1}{6}(11 + 11 + 13 + 10 + 3 + 8) = \underline{\underline{9.33}}$ time units (2dp)