CENTRAL PROCESSING UNIT

WHAT IS A CENTRAL PROCESSING UNIT?

- A Central Processing Unit (CPU) is the electronic component responsible for executing instructions and carrying out operations within a computer system.
- It is the 'brain' of the computer that interprets and executes instructions from the operating system and applications.

COMPONENTS OF A CPU

- A typical CPU consists of three main components: the Arithmetic Logic Unit (ALU), the Control Unit (CU) and the Registers.
- The ALU performs calculations, the CU controls the flow of data, and the Registers store data and instructions.

CPU PERFORMANCE

- The performance of a CPU is determined by its clock speed, the number of cores, and the amount of cache memory.
- A higher clock speed means the CPU can process more instructions per second, while more cores and cache memory can help improve performance when running multiple programs simultaneously.

TYPES OF CPUS

- There are two main types of CPUs: desktop CPUs and mobile CPUs. Desktop CPUs are more powerful and have more features, while mobile CPUs are designed to be more power-efficient and have lower power consumption.
- The type of CPU used in a computer will depend on the specific needs and requirements of the user.

CPU SCHEDULING

CPU SCHEDULING

- CPU Scheduling may be classified as:
  - Non-preemptive scheduling
    - If once the CPU has been assigned to a process and starts executing, the CPU cannot be taken away from that process
  - Preemptive scheduling
    - Even though the CPU has been assigned to a process and the process is already executing, the CPU scheduler may decide to assign the CPU to another process in the ready queue.

- A good scheduler should optimize the following performance criteria
  - CPU Utilization
  - Throughput
  - Turnaround time
  - Response time
  - Waiting time
- Different CPU scheduling algorithms:
  - First-Come, First-Served algorithm
  - Shortest Process First algorithm
  - Shortest Remaining Time First algorithm
  - Round Robin algorithm

CPU SCHEDULING

- A good scheduler should optimize the following performance criteria:
  - CPU utilization
  - Throughput
  - Turnaround time
  - Response time
  - Waiting time

DIFFERENT CPU SCHEDULING ALGORITHMS

- First-Come, First-Served algorithm
- Shortest Process First algorithm
- Shortest Remaining Time First algorithm
- Round Robin algorithm
- Priority scheduling
- Multilevel feedback queues

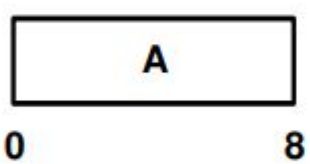
FIRST-COME, FIRST-SERVED ALGORITHM (FCFS)

- The one that enters the Ready queue first gets to execute at the CPU first.

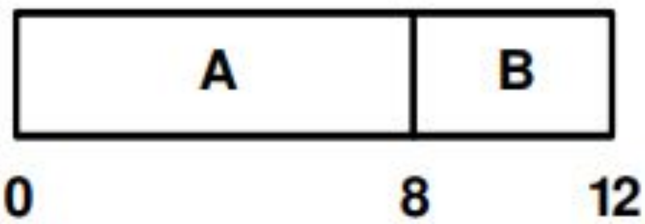
Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

Solution:

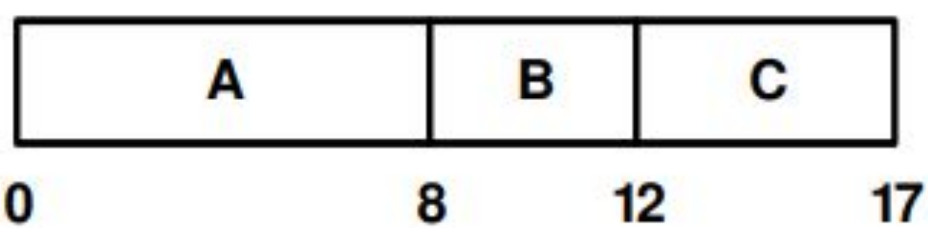
a. Process A arrives at the ready queue at $t = 0$ and will start executing at $t = 0$. It has a CPU burst of 8 so it will end at $t = 8$.



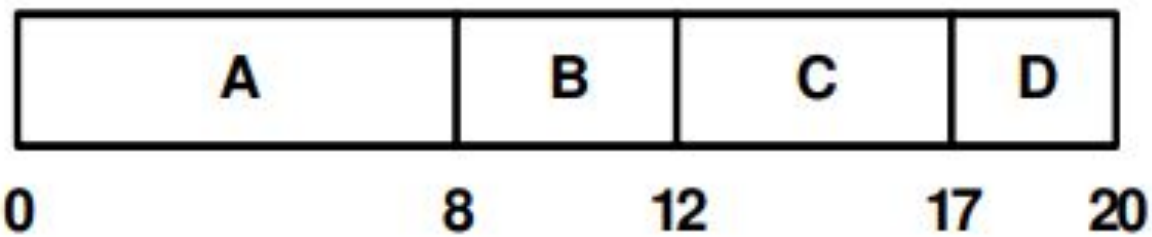
b. Processes B, C, and D are inside the ready queue (in that order) by the time process A finishes executing at t = 8. The CPU scheduler will select process B to execute next. It will start executing at t = 8. It has a CPU burst of 4 so it will end at t = 12.



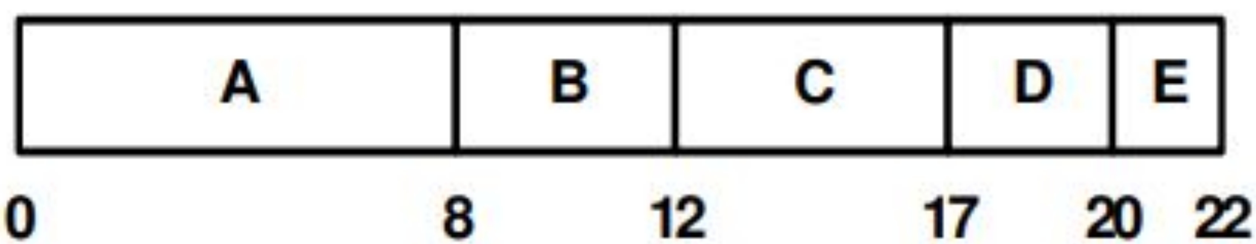
c. Processes C, D, and E are inside the ready queue (in that order) by the time process B finishes executing at t = 12. The CPU scheduler will select process C to execute next. It will start executing at t = 12. It has a CPU burst of 5 so it will end at t = 17.

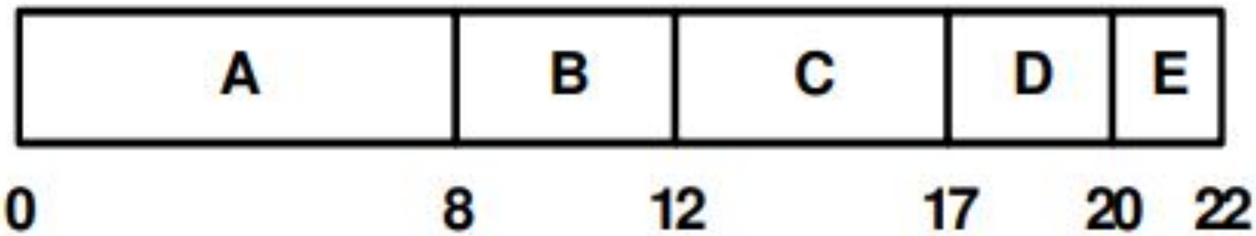


d. Processes D and E remain inside the ready queue (in that order) at $t = 17$. The CPU scheduler will select process D to execute next. It will start executing at $t = 17$. It has a CPU burst of 3 so it will end at $t = 20$.



e. Process E is the only process remaining inside the ready queue at $t = 20$. The CPU scheduler will select process E to execute next. It will start executing at $t = 20$. It has a CPU burst of 2 so it will end at $t = 22$.





The waiting time of each process is computer as

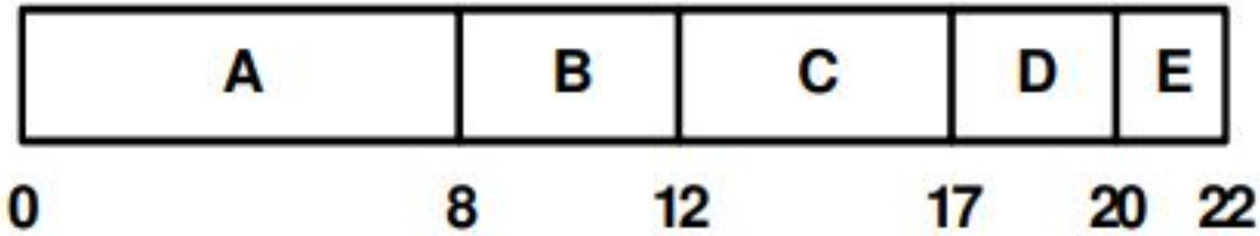
WT = time left queue – time entered queue

The waiting times for each of the five processes are:

$WT_A = 0 - 0 = 0$ ms
$WT_B = 8 - 3 = 5$ ms
$WT_C = 12 - 4 = 8$ ms
$WT_D = 17 - 6 = 11$ ms
$WT_E = 20 - 10 = 10$ ms

Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

average waiting time
$= (0 + 5 + 8 + 11 + 10)/5 = 34/5 = 6.8$ ms



The turnaround time for each process is computed as

TA = time of completion - arrival time

The turnaround times for each of the five processes are:

$TA_A = 8 - 0 = 8$ ms
$TA_B = 12 - 3 = 9$ ms
$TA_C = 17 - 4 = 13$ ms
$TA_D = 20 - 6 = 14$ ms
$TA_E = 22 - 10 = 12$ ms

average turnaround time
$= (8 + 9 + 13 + 14 + 12)/5 = 56/5 = 11.2$ ms

SHORTEST PROCESS FIRST ALGORITHM (SPF)

- The process with the shortest CPU burst time is the one that will be excecuted first

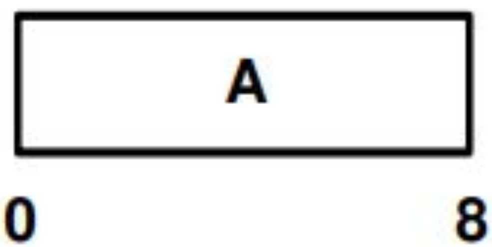
Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

SPF

All values are in milliseconds.

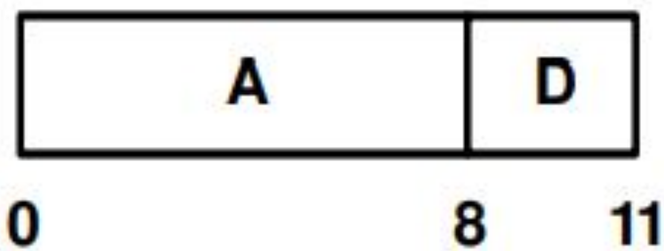
Solution:

a. Process A arrives at the ready queue at $t = 0$ and will start executing at $t = 0$. It has a CPU burst of 8 so it will end at $t = 8$.



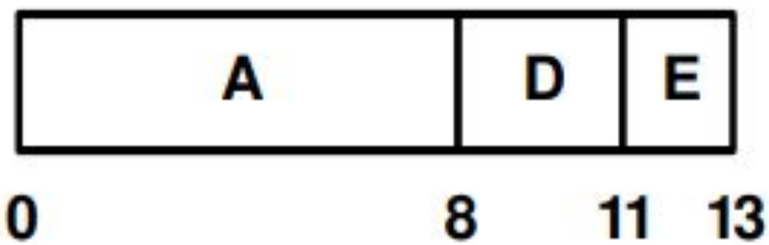
SPF

b. Processes B, C, and D are inside the ready queue (in that order) by the time process A finishes executing at t = 8. The CPU scheduler will select process D to execute next. It will start executing at t = 8. It has a CPU burst of 3 so it will end at t = 11.



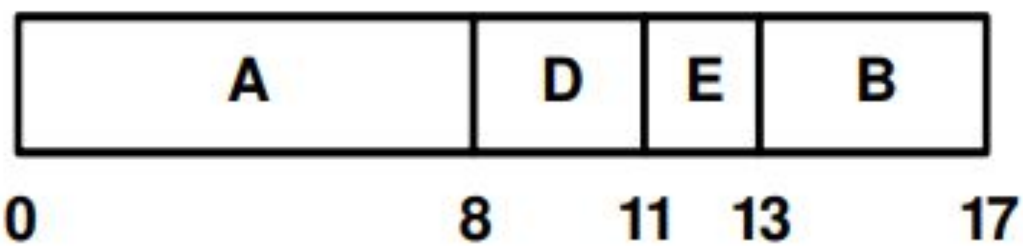
SPF

c. Processes B, C, and E are inside the ready queue (in that order) by the time process D finishes executing at $t = 11$. The CPU scheduler will select process E to execute next. It will start executing at $t = 11$. It has a CPU burst of 2 so it will end at $t = 13$.



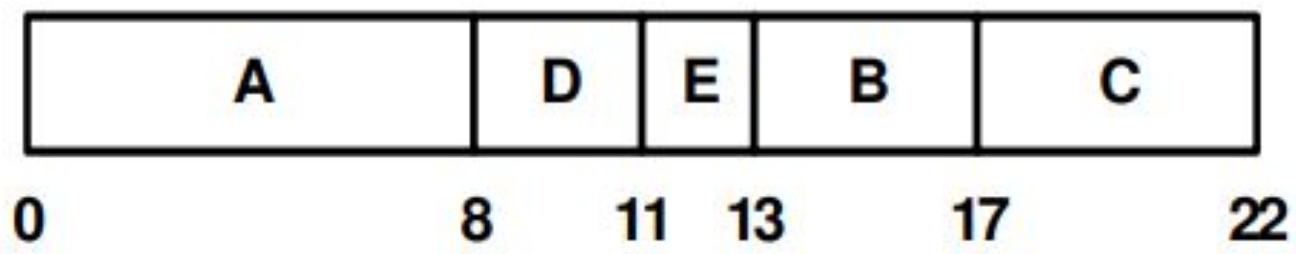
SPF

d. Processes B and C remain inside the ready queue (in that order) at $t = 13$. The CPU scheduler will select process B to execute next. It will start executing at $t = 13$. It has a CPU burst of 4 so it will end at $t = 17$.



SPF

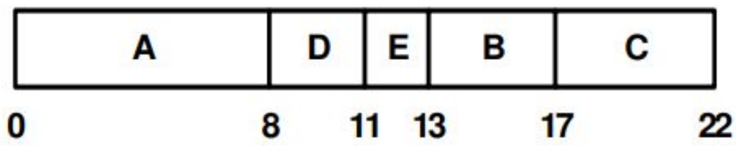
e. Process C is the only process remaining inside the ready queue at $t = 17$. The CPU scheduler will select process C to execute next. It will start executing at $t = 17$. It has a CPU burst of 5 so it will end at $t = 22$.



SPF

The waiting times for each of the five processes are:

Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2



$WT_A = 0 - 0 = 0$ ms
$WT_B = 13 - 3 = 10$ ms
$WT_C = 17 - 4 = 13$ ms
$WT_D = 8 - 6 = 2$ ms
$WT_E = 11 - 10 = 1$ ms

average waiting time
$= (0 + 10 + 13 + 2 + 1)/5 = 26/5 = 5.2$ ms

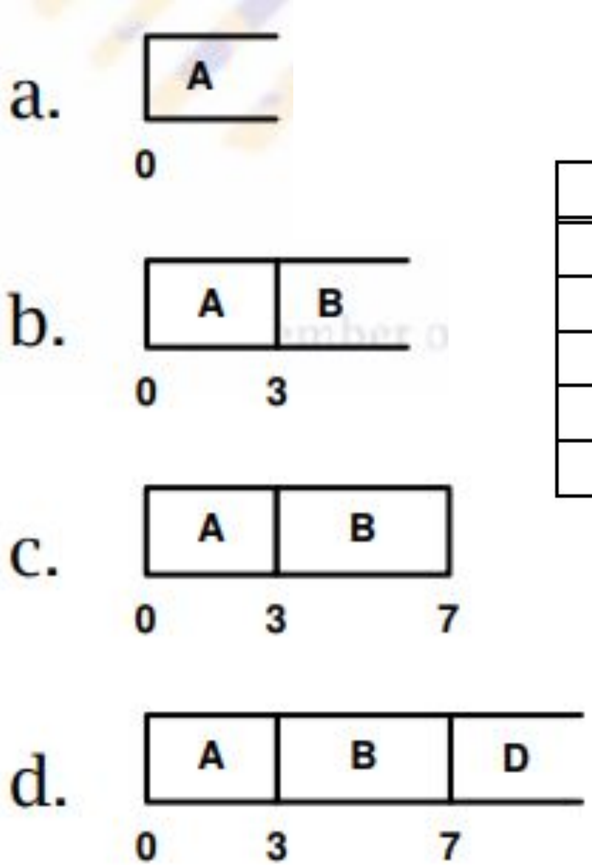
The turnaround times for each of the five processes are:

$TA_A = 8 - 0 = 8$ ms
$TA_B = 17 - 3 = 14$ ms
$TA_C = 22 - 4 = 18$ ms
$TA_D = 11 - 6 = 5$ ms
$TA_E = 13 - 10 = 3$ ms

average turnaround time
$= (8 + 14 + 18 + 5 + 3)/5 = 48/5 = 9.6$ ms

Shortest Remaining Time First algorithm (SRTF)

It is the preemptive version of SPF.



Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

Shortest Remaining Time First algorithm (SRTF)

It is the preemptive version of SPF.

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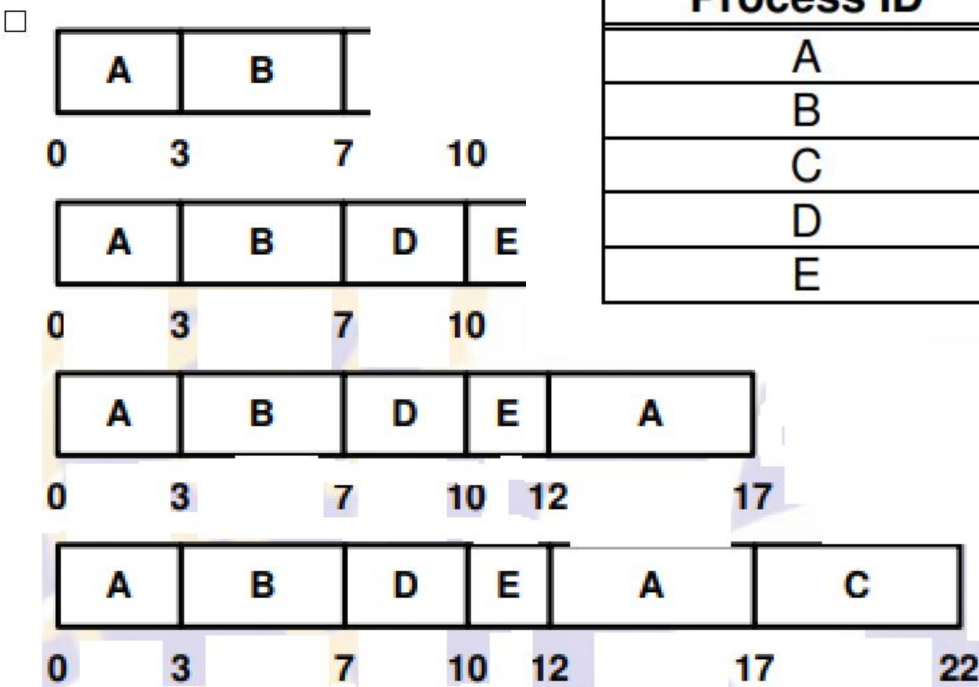
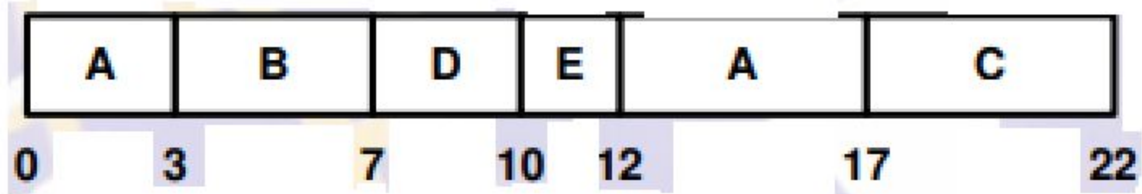


Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

SRTF

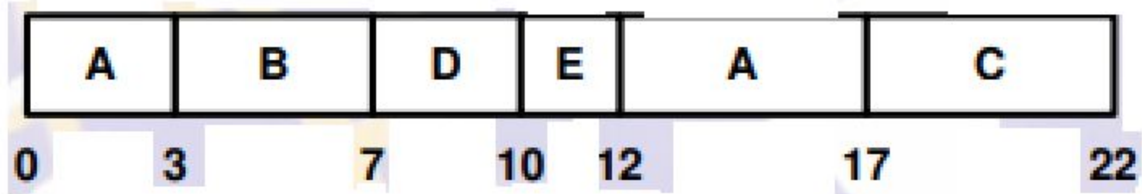


Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

WT_A = (0-0) + (12-3) = 9 ms
WT_B = 3-3 = 0 ms
WT_C = 17-4 = 13 ms
WT_D = 7-6 = 1 ms
WT_E = 10-10 = 0 ms

The average waiting time is
(9+0+13+1+0)/5 = 23/5 = 4.6 ms

SRTF



Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

TA_A = 17-0 = 17ms

TA_B = 7-3 = 4ms

TA_C = 22-4 = 18ms

TA_D = 10-6= 4ms

TA_E = 12-10 = 2 ms

The average turnaround time is

(17+4+18+4+2)/5 = 45/5 = 9.0 ms

4. ***Round Robin Algorithm (RR)***

It is a preemptive version of FCFS algorithm. The one that enters the Ready queue first gets to be executed by the CPU first but is given a time limit. This limit is called ***time quantum*** or ***time slice***. The process will enter the rear of the queue after its time slice expires.

Example:
A set of processes with their respective arrival times at the ready queue and the length of their next CPU burst are given below.

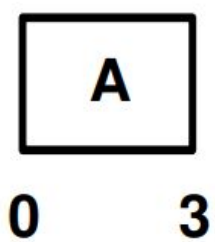
Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

Assume that the time slice is 3.

All values are in milliseconds.

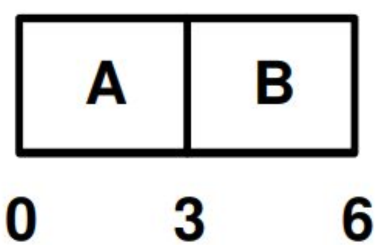
Solution:

a. Process A arrives at the ready queue at $t = 0$ and will start executing at $t = 0$. At t = 3, process B arrives and process A consumes its first time slice. Process A goes back to the ready queue.



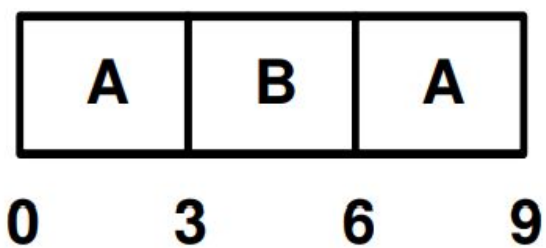
Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

b. Processes B (CPU burst of 4) and A (CPU burst of 5) are inside the ready queue (in that order) by the time process A finishes executing at t = 3. The CPU scheduler will select process B to execute next. Process B will start executing at t = 3. Process C arrives at the ready queue at t = 4. At t = 6, process D arrives and process B consumes its first time slice. Process B goes back to the ready queue.



Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

c. Processes A (CPU burst of 5), C (CPU burst of 5), D (CPU burst of 3), and B (CPU burst of 1) are inside the ready queue (in that order) by the time process B finishes executing at $t = 6$. The CPU scheduler will select process A to execute next. Process A will start executing at $t = 6$ and ends after its second time slice at $t = 9$. Process A goes back to the ready queue.



Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

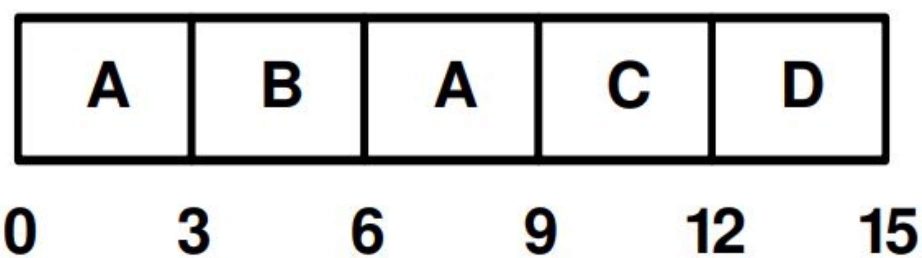
d. Processes C (CPU burst of 5), D (CPU burst of 3), B (CPU burst of 1), and A (CPU burst of 2) are inside the ready queue (in that order) by the time process A finishes executing at t = 9. The CPU scheduler will select process C to execute next. Process E arrives at the ready queue at t = 10. At t = 12, process C consumes its first time slice. Process C goes back to the ready queue.

A	B	A	C

0 3 6 9 12

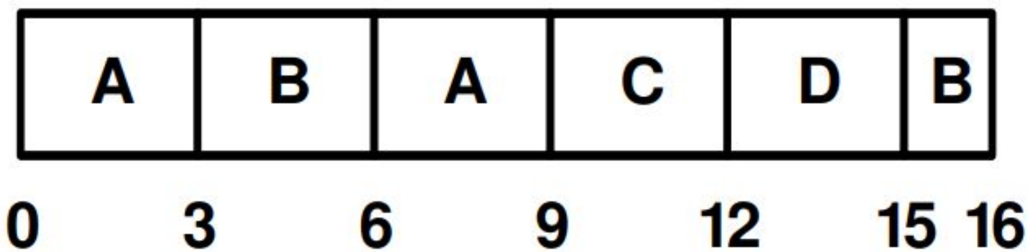
Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

e. Processes D (CPU burst of 3), B (CPU burst of 1), A (CPU burst of 2), E (CPU burst of 2), and C (CPU burst of 2) are inside the ready queue (in that order) by the time process C finishes executing at t = 12. The CPU scheduler will select process D to execute next. Process D will start executing at t = 12 and ends at t = 15.



Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

f. Processes B (CPU burst of 1), A (CPU burst of 2), E (CPU burst of 2), and C (CPU burst of 2) are inside the ready queue (in that order) by the time process C finishes executing at $t = 15$. The CPU scheduler will select process B to execute next. Process B will start executing at $t = 15$ and ends at $t = 16$.



Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

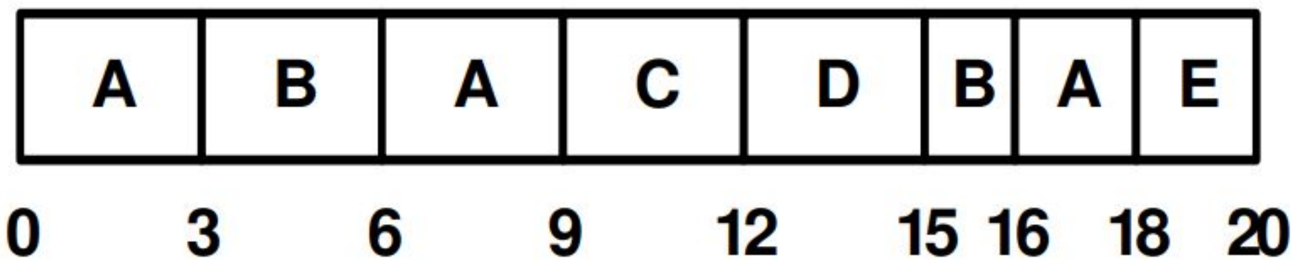
g. Processes A (CPU burst of 2), E (CPU burst of 2), and C (CPU burst of 2) are inside the ready queue (in that order) by the time process C finishes executing at t = 16. The CPU scheduler will select process A to execute next. Process A will start executing at t = 16 and ends at t = 18.

A	B	A	C	D	B	A

0 3 6 9 12 15 16 18

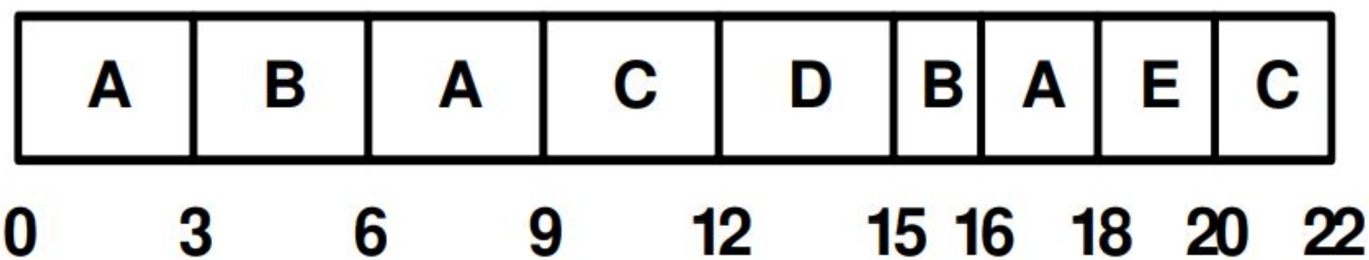
Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

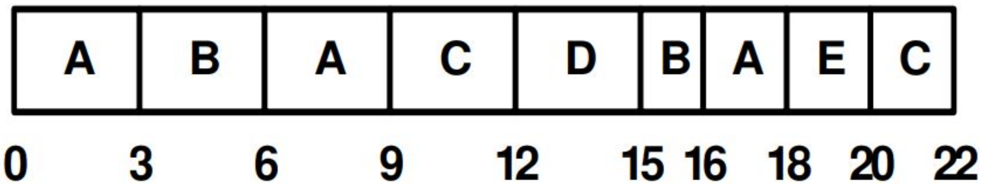
h. Processes E (CPU burst of 2) and C (CPU burst of 2) are inside the ready queue (in that order) by the time process A finishes executing at t = 18. The CPU scheduler will select process E to execute next. Process E will start executing at t = 18 and ends at t = 20.



Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

i. Process C (CPU burst of 2) is the only process remaining inside the ready queue at $t = 20$. The CPU scheduler will select process C to execute next. Process C will start executing at $t = 20$ and ends at $t = 22$.





Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

The waiting times for each of the five processes are:

$WT_A = (0 - 0) + (6 - 3) + (16 - 9) = 10$ ms
$WT_B = (3 - 3) + (15 - 6) = 9$ ms
$WT_C = (9 - 4) + (20 - 12) = 13$ ms
$WT_D = 12 - 6 = 6$ ms
$WT_E = 18 - 10 = 8$ ms

average waiting time
$= (10 + 9 + 13 + 6 + 8)/5 = 46/5 = 9.2$ ms

A	B	A	C	D	B	A	E	C

0 3 6 9 12 15 16 18 20 22

Process ID	Arrival Time	CPU Burst
A	0	8
B	3	4
C	4	5
D	6	3
E	10	2

The turnaround time for each of the five processes are:

$TA_A = 18 - 0 = 18$ ms
$TA_B = 16 - 3 = 13$ ms
$TA_C = 22 - 4 = 18$ ms
$TA_D = 15 - 6 = 9$ ms
$TA_E = 20 - 10 = 10$ ms

average turnaround time
$= (18 + 13 + 18 + 9 + 10)/5 = 68/5 = 13.6$ ms

ASSIGNMENT #1

QUIZ #1

Determine the average waiting time and average turnaround time of the processes in the table below using:

a. First-Come, First-Served Algorithm
b. Shortest Process First Algorithm

Process ID	Arrival Time	CPU Burst	Priority
A	0	4	3
B	3	7	2
C	8	3	1
D	10	3	4

Show your solutions.

ASSIGNMENT #2

Determine the average waiting time and the average turn-around time of the processes below using SRTF.

Process ID	Arrival Time	CPU Burst	Priority
A	0	4	3
B	3	7	2
C	8	3	1
D	10	3	4

Show your solutions.

ASSIGNMENT #3

Determine the average waiting time and the average turn-around time of the processes below using SRTF.

Process ID	Arrival Time	CPU Burst	Priority
A	0	4	3
B	3	7	2
C	8	3	1
D	10	3	4

Show your solutions.