CMPUT 379 Lab

ETLC E1003: Tuesday, 5:00 – 7:50 PM.

Tianyu Zhang, Peiran Yao

CAB 311: Thursday, 2:00 – 4:50 PM.

Max Ellis, Aidan Bush

Today’s Lab

- Exercises on process scheduling and page replacement
- Questions for Assignment 3 and the final exam

Clarification

- Ex.1 - Q2 new jobs arrive after scheduling

Scheduling evaluation

- Turnaround time: `termination time - arrival time`
- Waiting time: time spent in the ready queue
  - `Waiting time = turnaround time - burst time`

SRTF scheduling

- Schedule the job that has the least (expected) **remaining** amount of work to do.
- **Preemptive** version of SJF (i.e. a working job may be moved back to the ready queue)

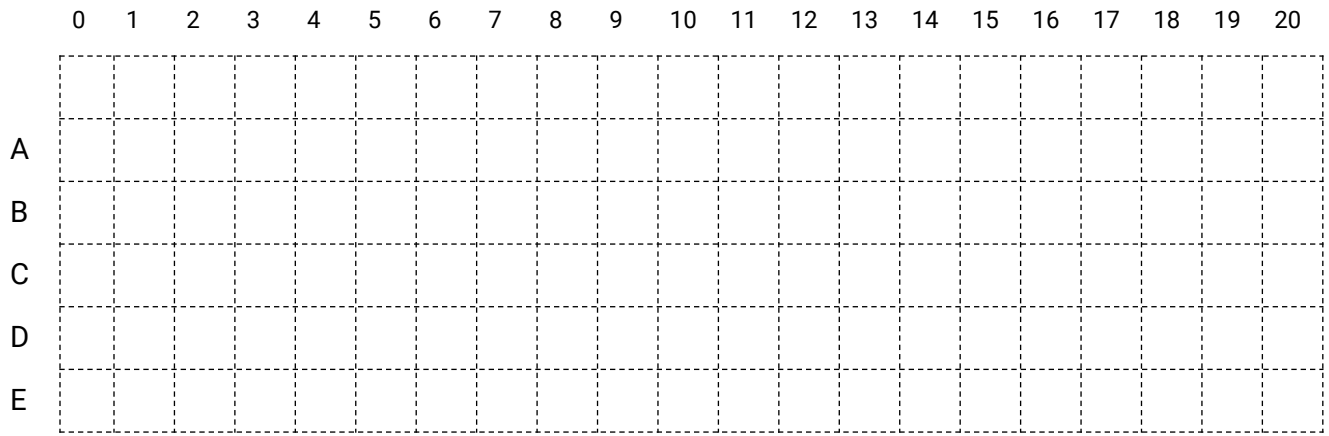
Exercise 1 - Q1

- If we use a SRTF scheduler, what will be the turnaround time for each process? And what will be the waiting time?
- Break tie by preferring the earlier job

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

Exercise 1 - Q1

T = 0, **A** arrives

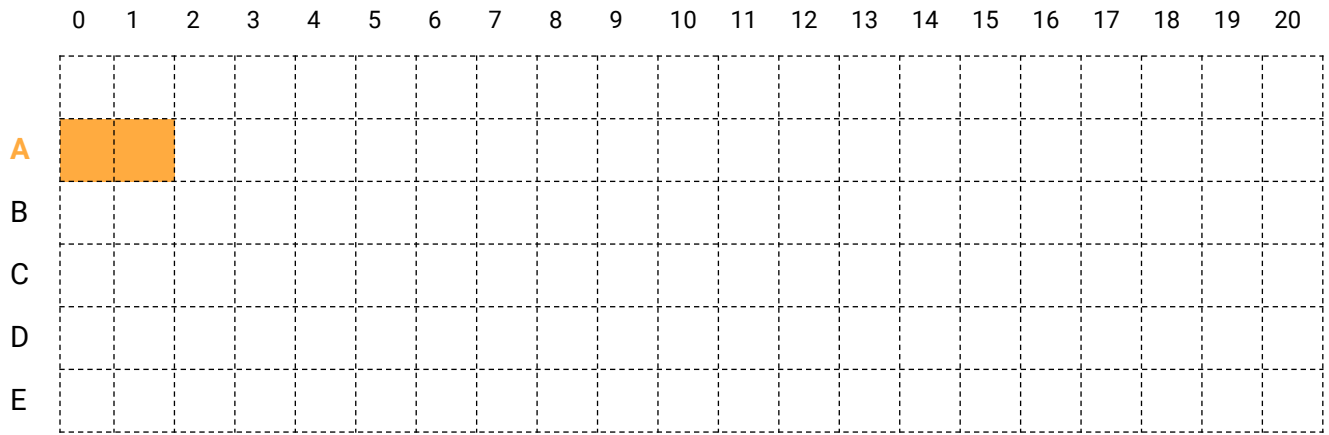


Process	Remaining time
A	3

Exercise 1 - Q1

T = 2, **B** arrives

A has the SRT

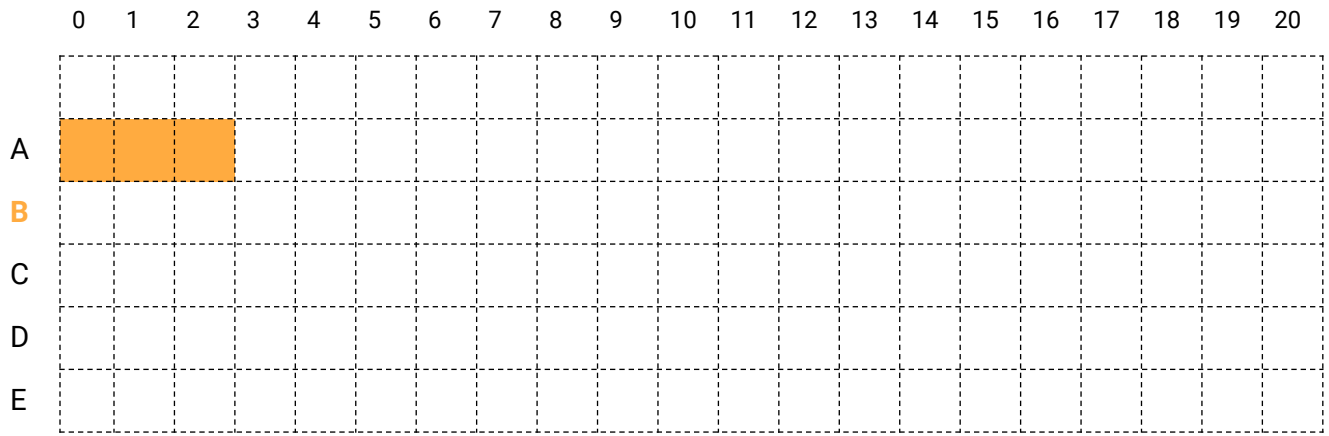


Process	Remaining time
A	1
B	6

Exercise 1 - Q1

T = 3, **A** terminates

B has the SRT

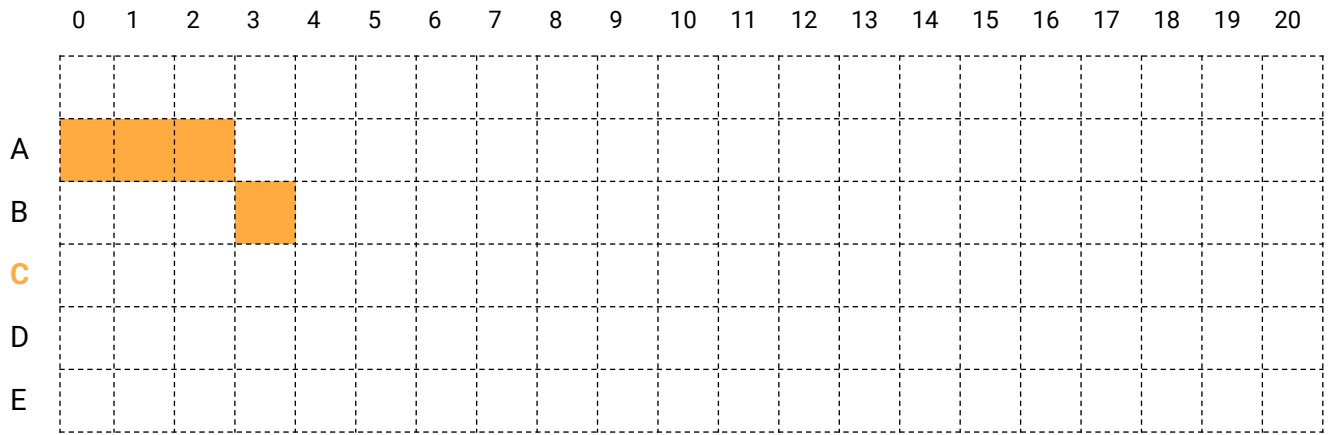


Process	Remaining time
B	6

Exercise 1 - Q1

T = 4, **C** arrives

C has the SRT

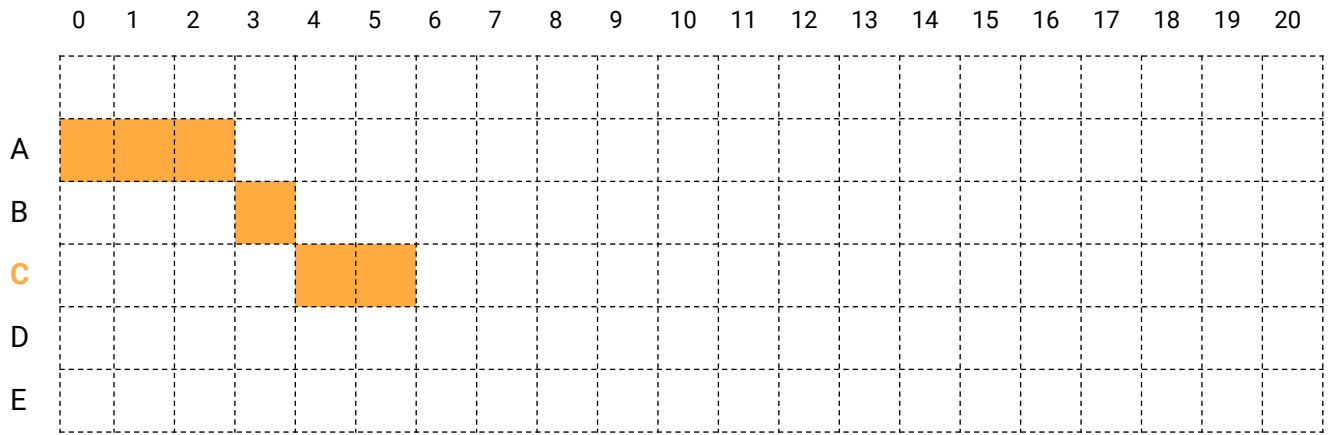


Process	Remaining time
B	5
C	4

Exercise 1 - Q1

T = 6, **D** arrives

C has the SRT

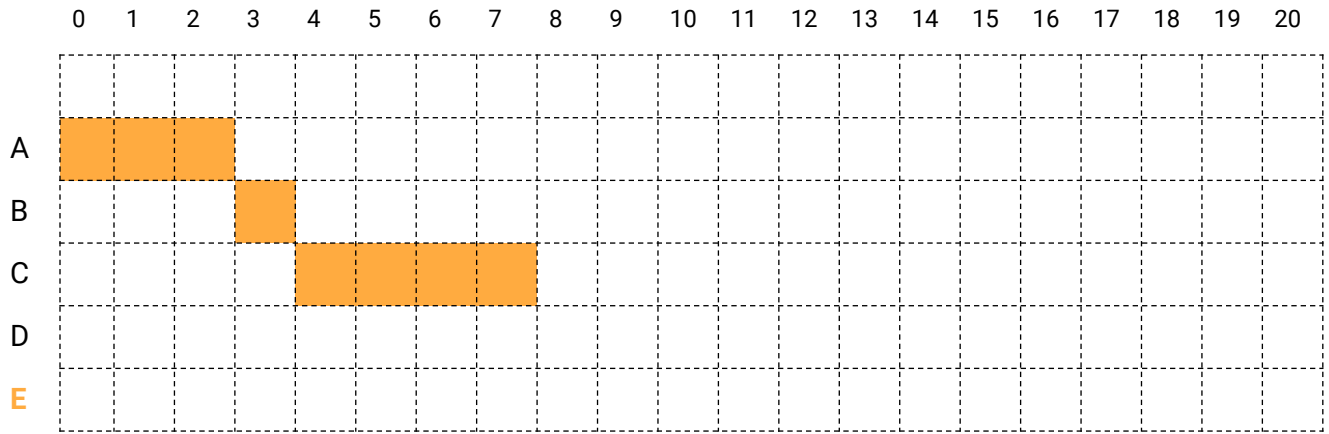


Process	Remaining time
B	5
C	2
D	5

Exercise 1 - Q1

T = 8, **C** terminates and **E** arrives

E has the SRT

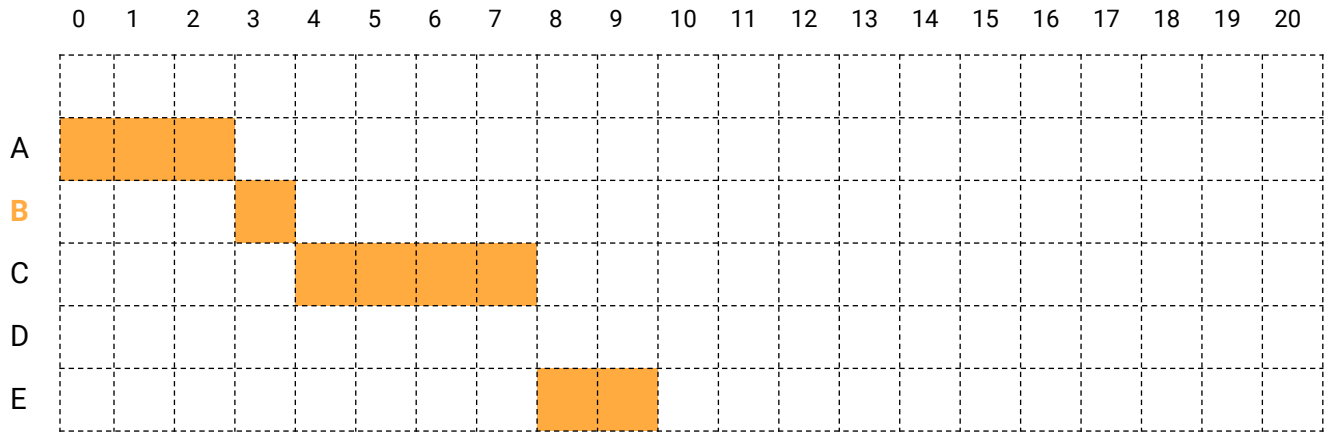


Process	Remaining time
B	5
D	5
E	2

Exercise 1 - Q1

T = 10, **E** terminates

B has the SRT (break tie by choosing the earlier job)

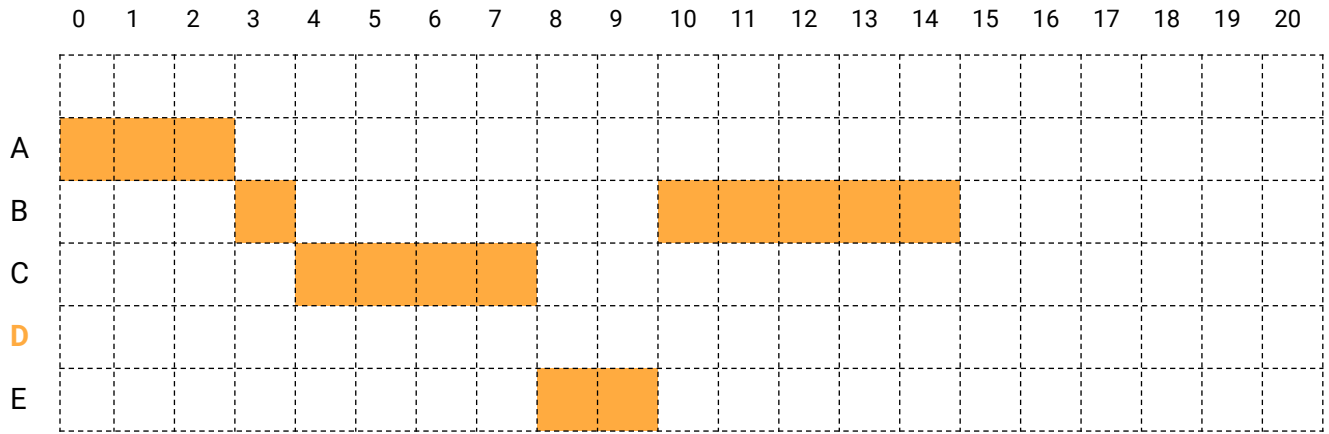


Process	Remaining time
B	5
D	5

Exercise 1 - Q1

T = 15, **B** terminates

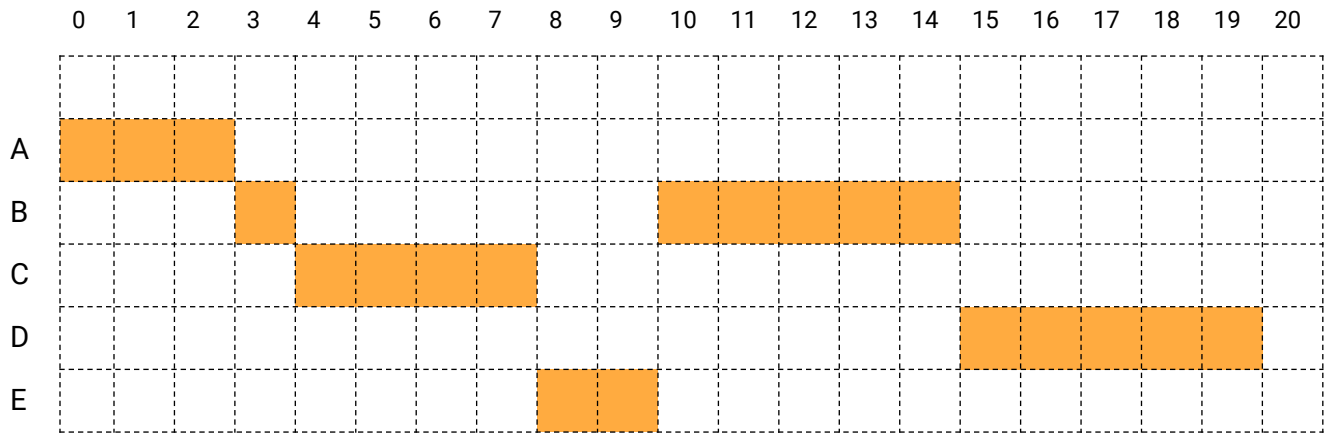
D has the SRT (break tie by choosing the earlier job)



Process	Remaining time
D	5

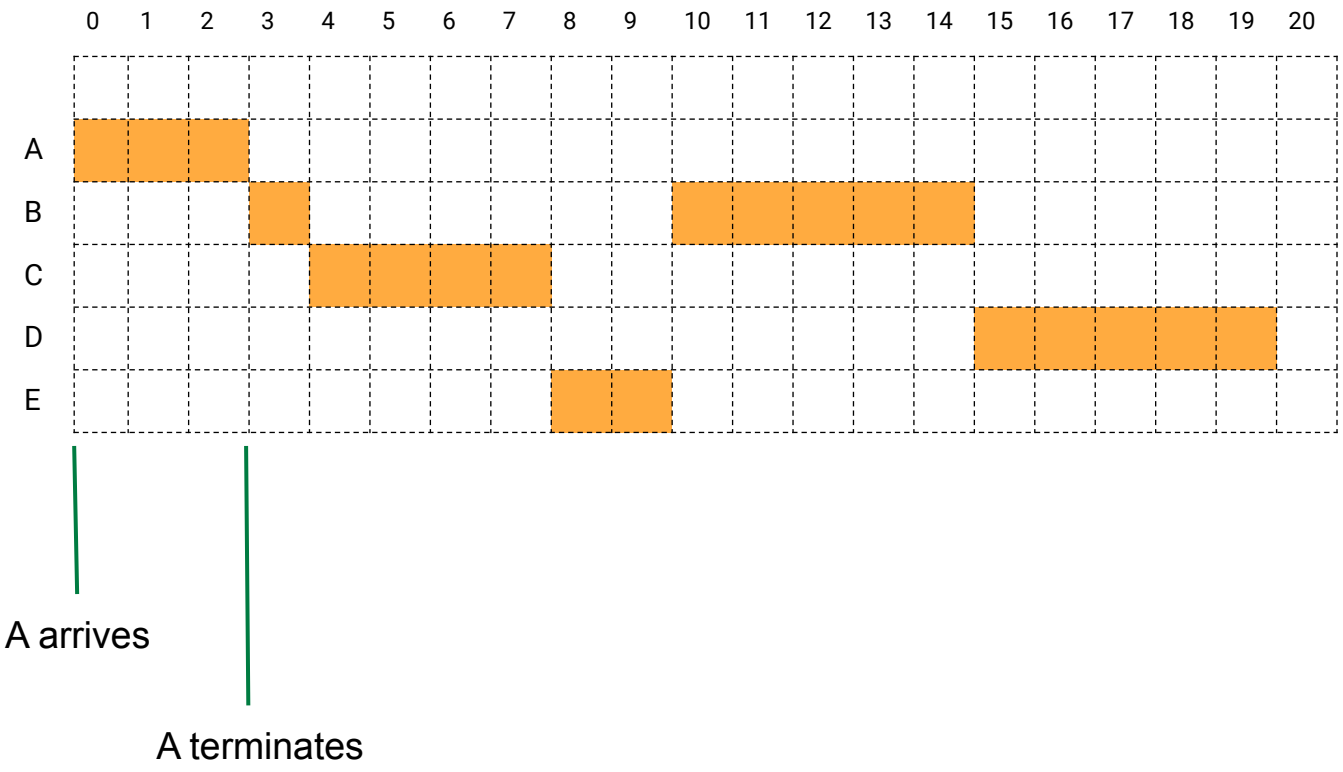
Exercise 1 - Q1

T = 20, **D** terminates



Process	Remaining time

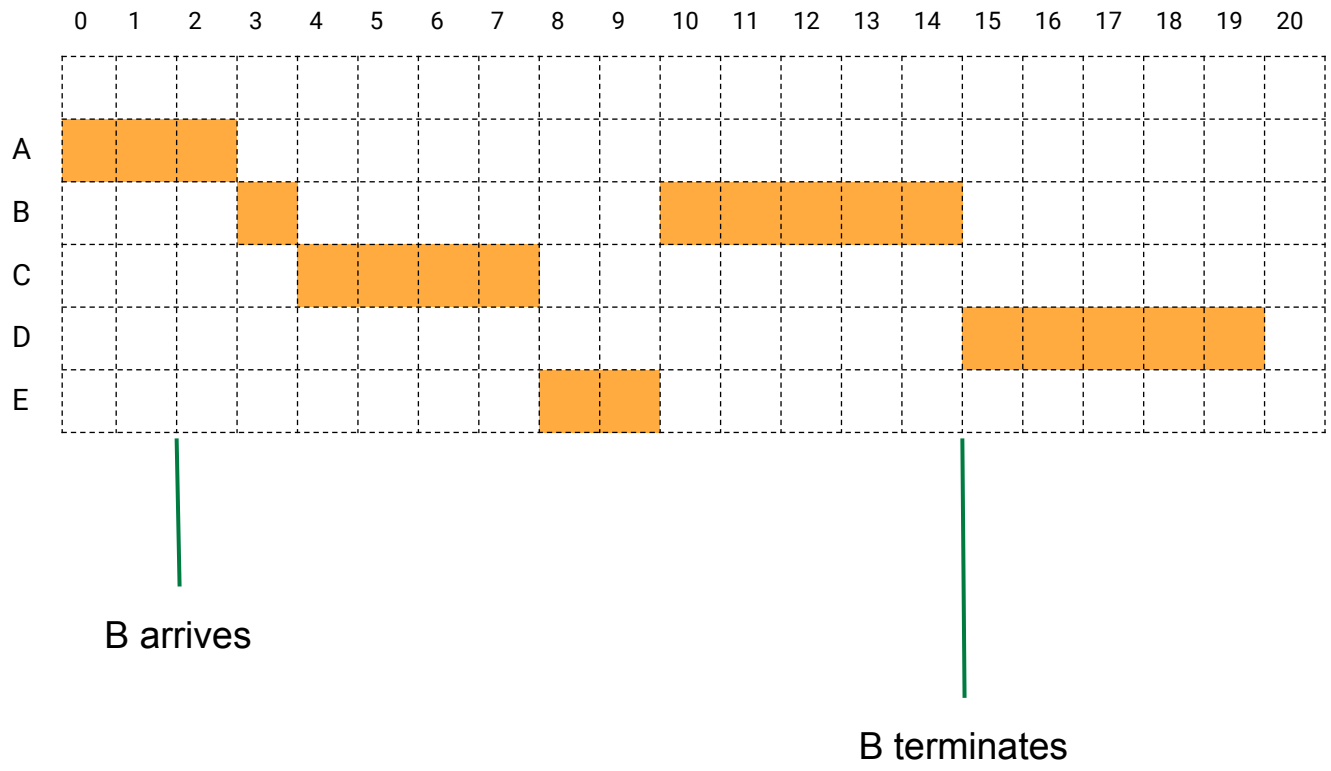
Exercise 1 - Q1



Process	Turnaround time
A	3 - 0 = 3

turnaround time = termination time - arrival time

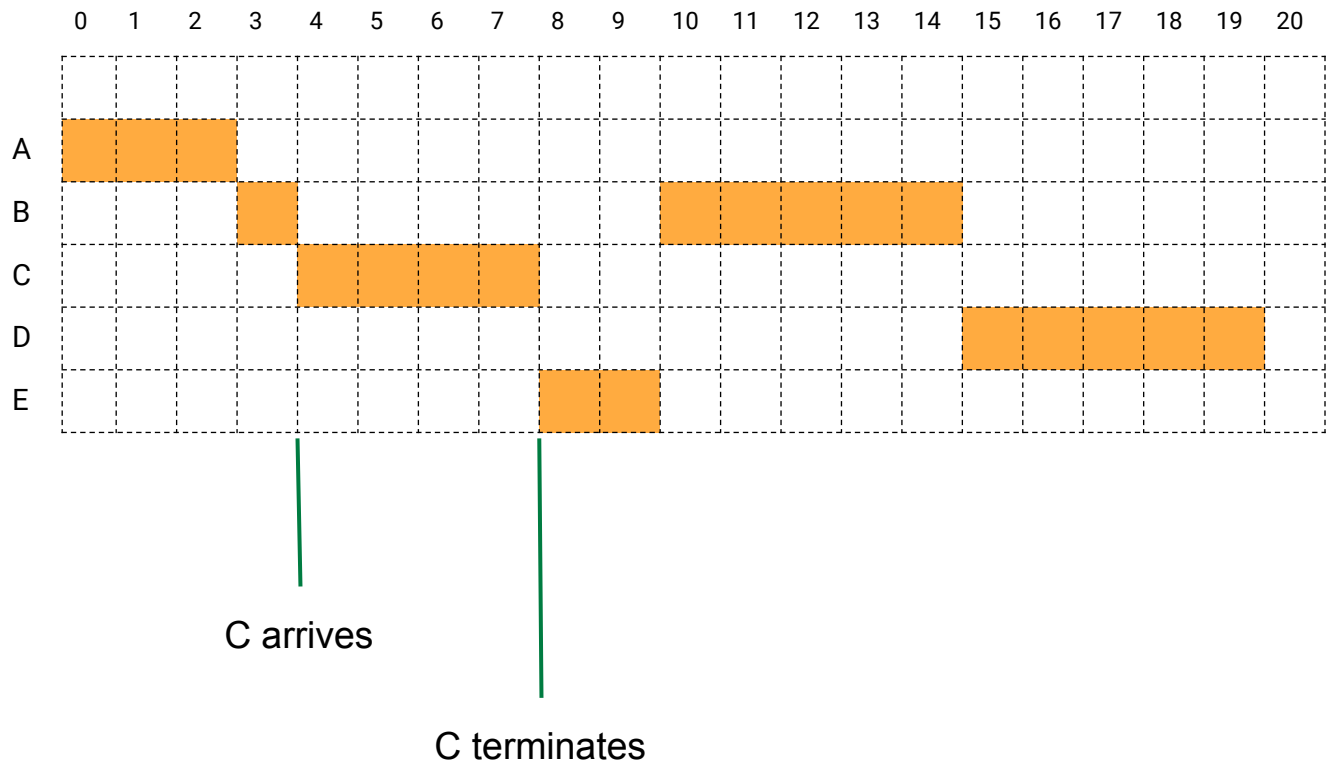
Exercise 1 - Q1



Process	Turnaround time
A	3 - 0 = 3
B	15 - 2 = 13

turnaround time = termination time - arrival time

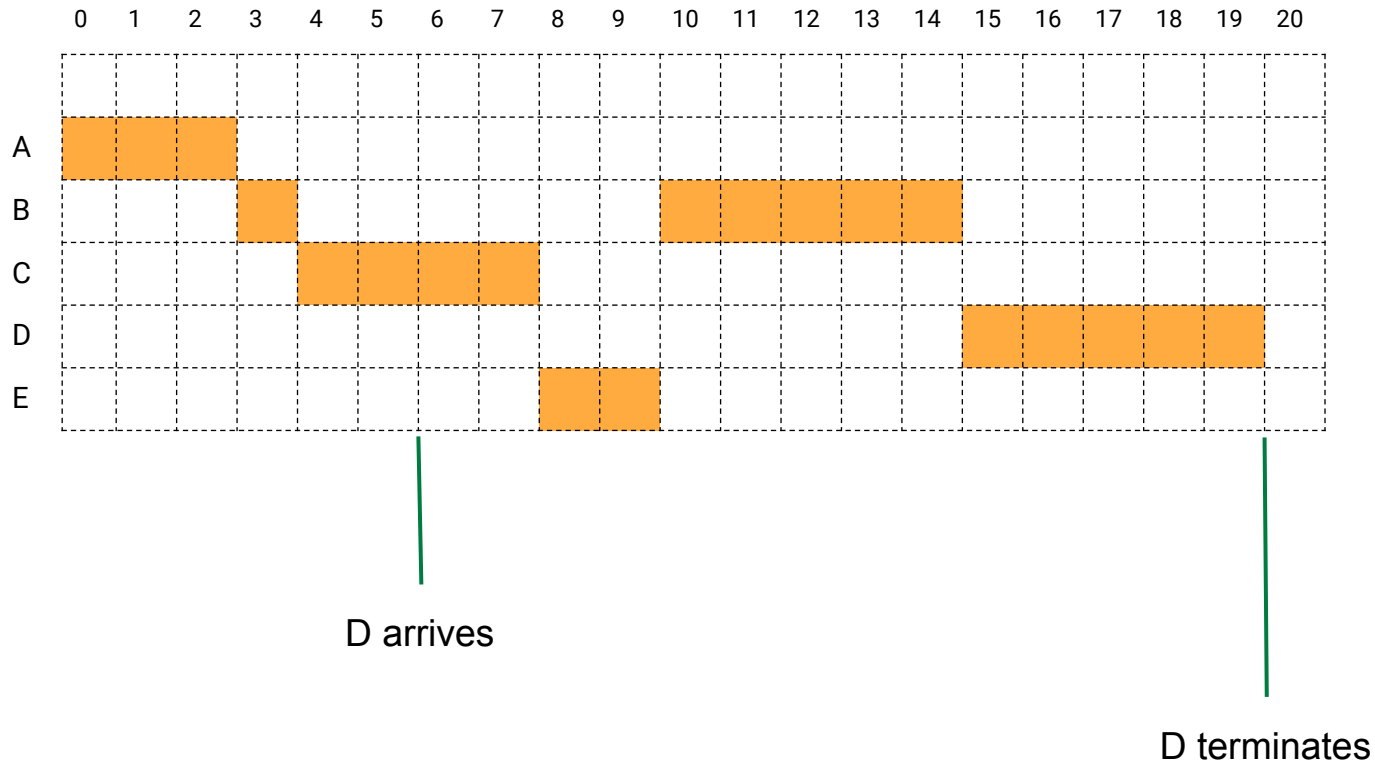
Exercise 1 - Q1



Process	Turnaround time
A	3 - 0 = 3
B	15 - 2 = 13
C	8 - 4 = 4

turnaround time = termination time - arrival time

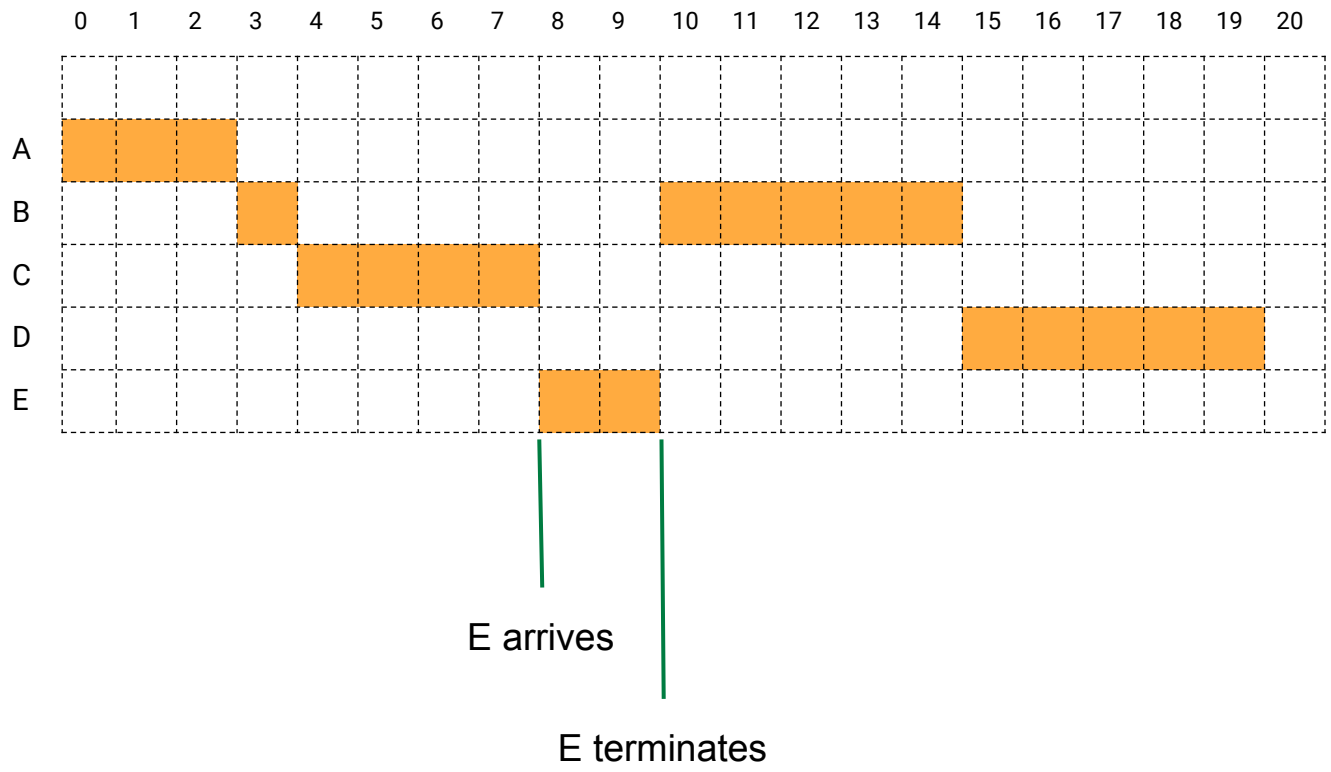
Exercise 1 - Q1



Process	Turnaround time
A	3 - 0 = 3
B	15 - 2 = 13
C	8 - 4 = 4
D	20 - 6 = 14

turnaround time = termination time - arrival time

Exercise 1 - Q1



Process	Turnaround time
A	3 - 0 = 3
B	15 - 2 = 13
C	8 - 4 = 4
D	20 - 6 = 14
E	10 - 8 = 2

turnaround time = termination time - arrival time

Exercise 1 - Q1

Process	Turnaround time
A	3 - 0 = 3
B	15 - 2 = 13
C	8 - 4 = 4
D	20 - 6 = 14
E	10 - 8 = 2

Process	Waiting time
A	3 - 3 = 0
B	13 - 6 = 7
C	4 - 4 = 0
D	14 - 5 = 9
E	2 - 2 = 0

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Waiting time =
turnaround time -
burst time
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Exercise 1 - Q1

Process	Turnaround time
A	3 - 0 = 3
B	15 - 2 = 13
C	8 - 4 = 4
D	20 - 6 = 14
E	10 - 8 = 2
Avg.	7.2

Process	Waiting time
A	3 - 3 = 0
B	13 - 6 = 7
C	4 - 4 = 0
D	14 - 5 = 9
E	2 - 2 = 0
Ave.	3.2

Exercise 1 - Q1 Thinking questions

- What are the advantages of SRTF scheduling?
- What issue have you observed in the example?
- Is SRTF suitable for PC operating systems? Why?

- Impossible to predict the amount of CPU time a job needs
- Long running CPU bound jobs can starve (process B and D)
- Provably optimal wrt. Minimizing the average waiting time (good for interactive jobs)

Round Robin scheduling

- After each time quantum, switch to the next job in the ready queue
- If a process finishes before exhausting a whole quantum, switch to the next job immediately

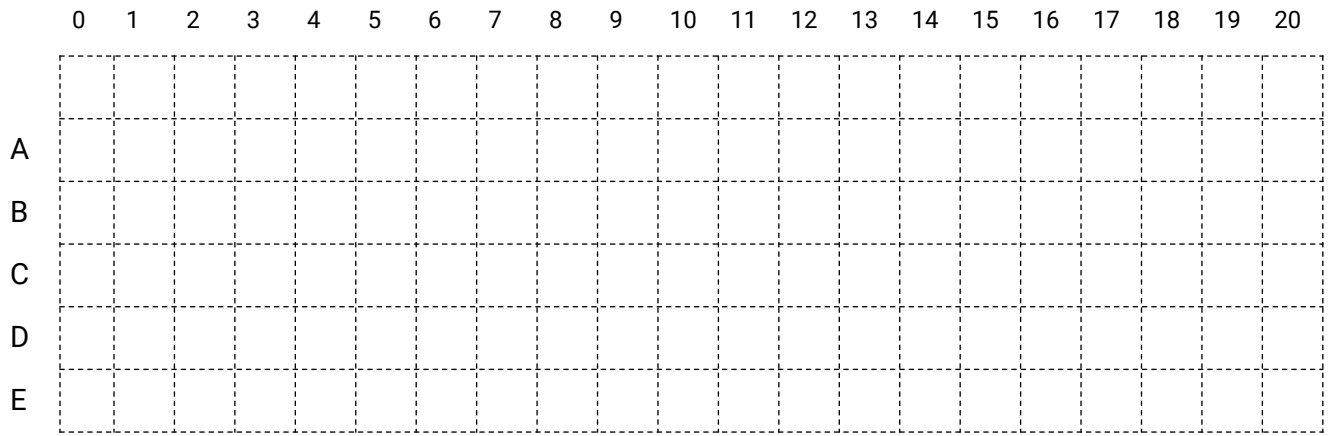
Exercise 1 - Q2

- If we use a Round Robin scheduler with time quantum 1, what will be the turnaround time for each process? And what will be the waiting time?
- Break tie by preferring the earlier job

Exercise 1 - Q2

T = 0, **A** arrives

Next to schedule: A

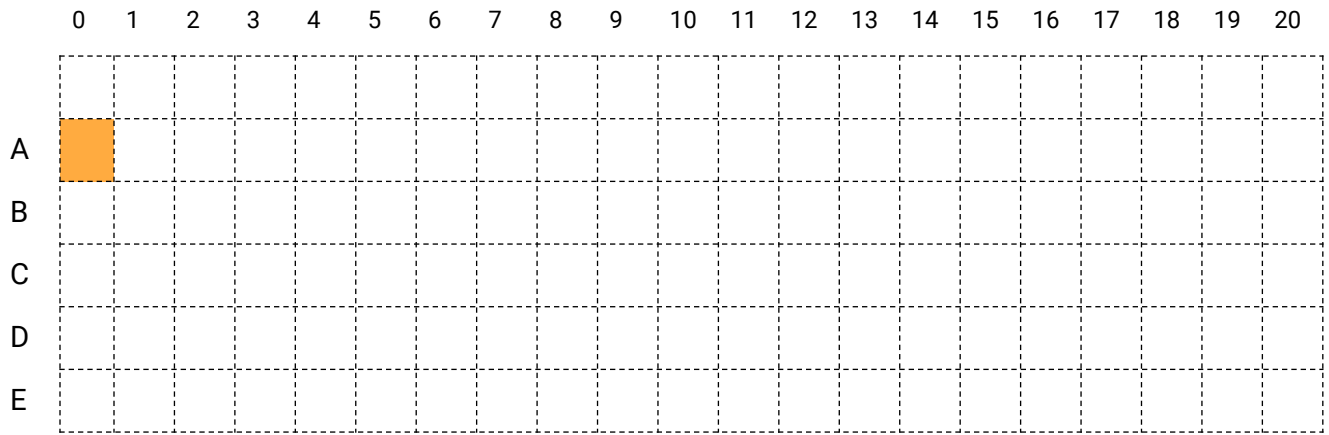


Process	Remaining time
A	3

Exercise 1 - Q2

T = 1

Next to schedule: A

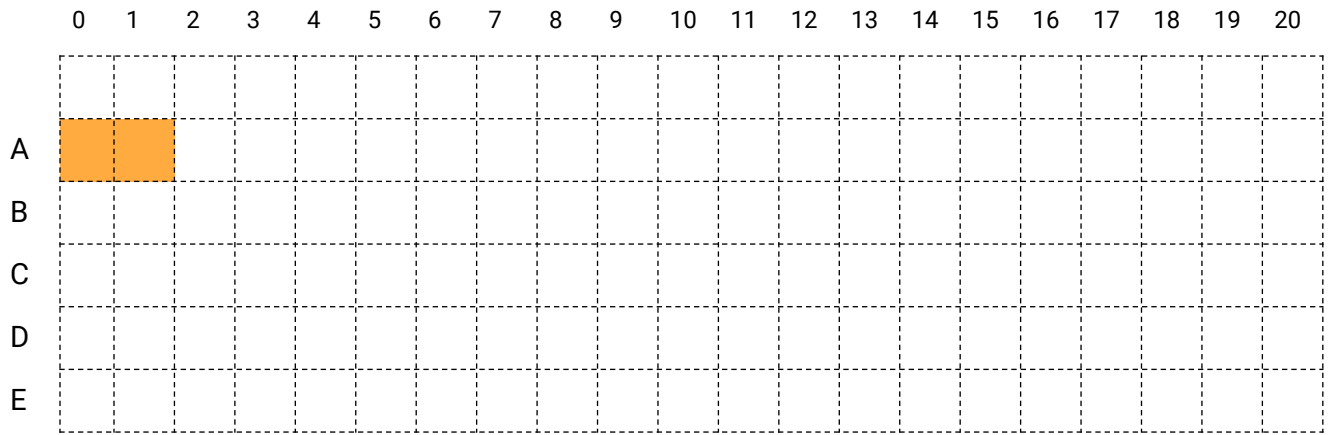


Process	Remaining time
A	2

Exercise 1 - Q2

T = 2

Next to schedule: A

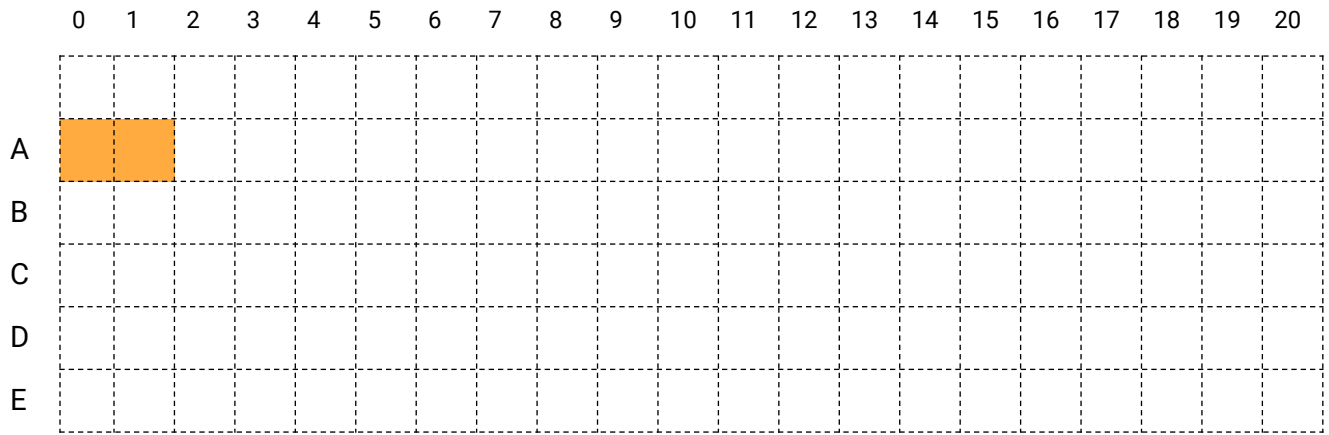


Process	Remaining time
A	1

Exercise 1 - Q2

T = 2, B arrives

Next to schedule: A

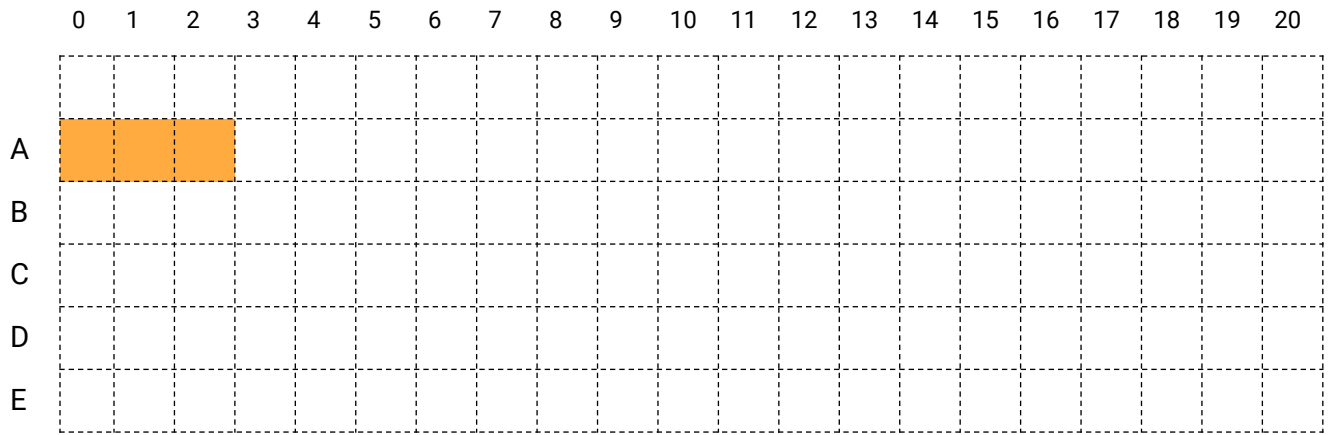


Process	Remaining time
A	1
B	6

Exercise 1 - Q2

T = 3, A terminates

Next to schedule: B

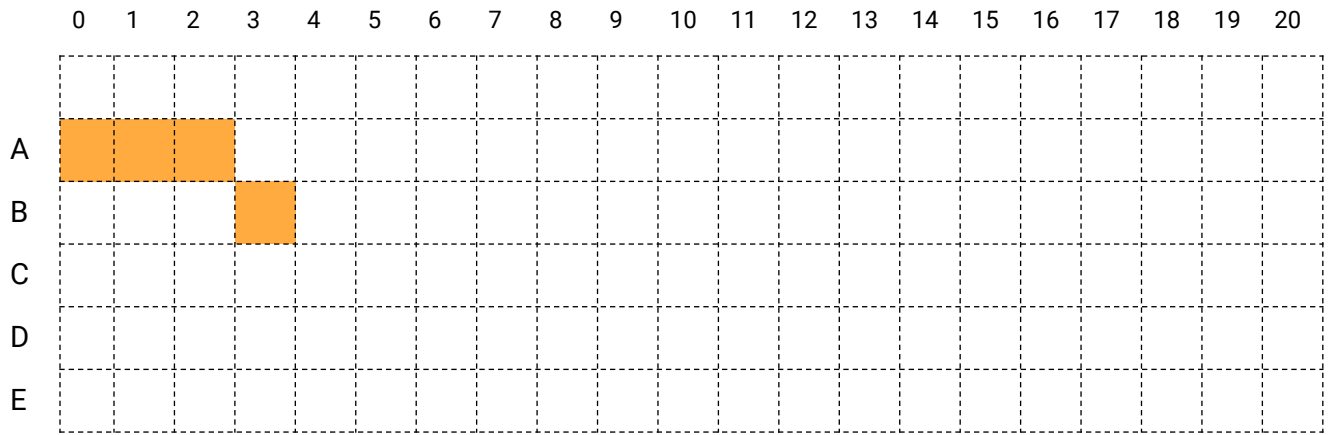


Process	Remaining time
B	6

Exercise 1 - Q2

T = 4

Next to schedule: B

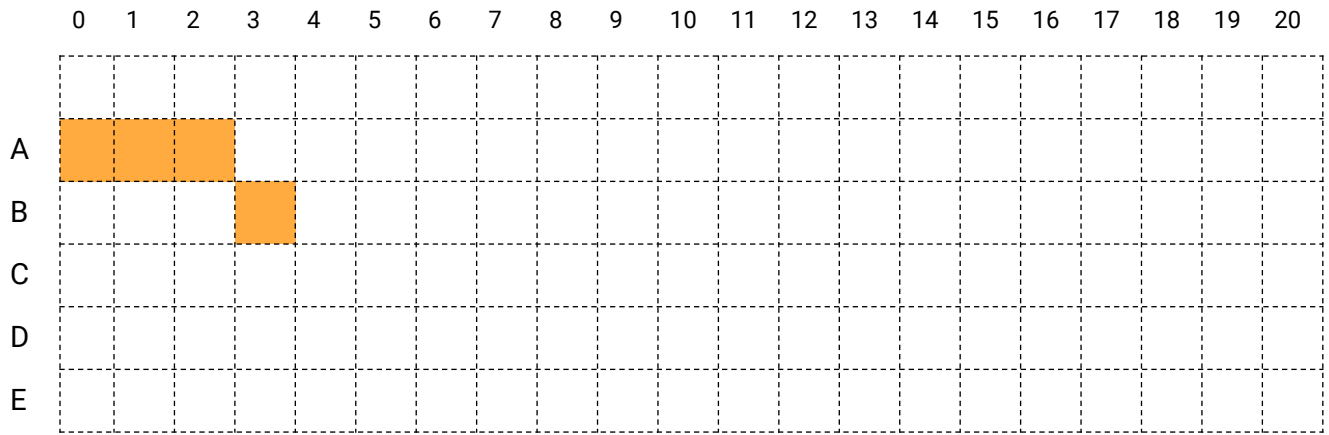


Process	Remaining time
B	5

Exercise 1 - Q2

T = 4, C arrives

Next to schedule: B

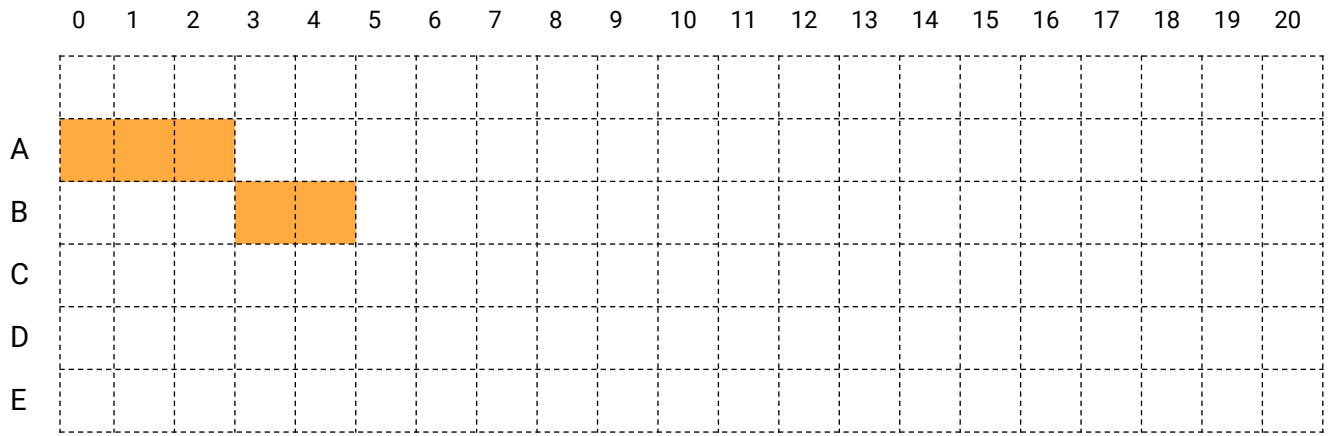


Process	Remaining time
B	5
C	4

Exercise 1 - Q2

T = 5

Next to schedule: C

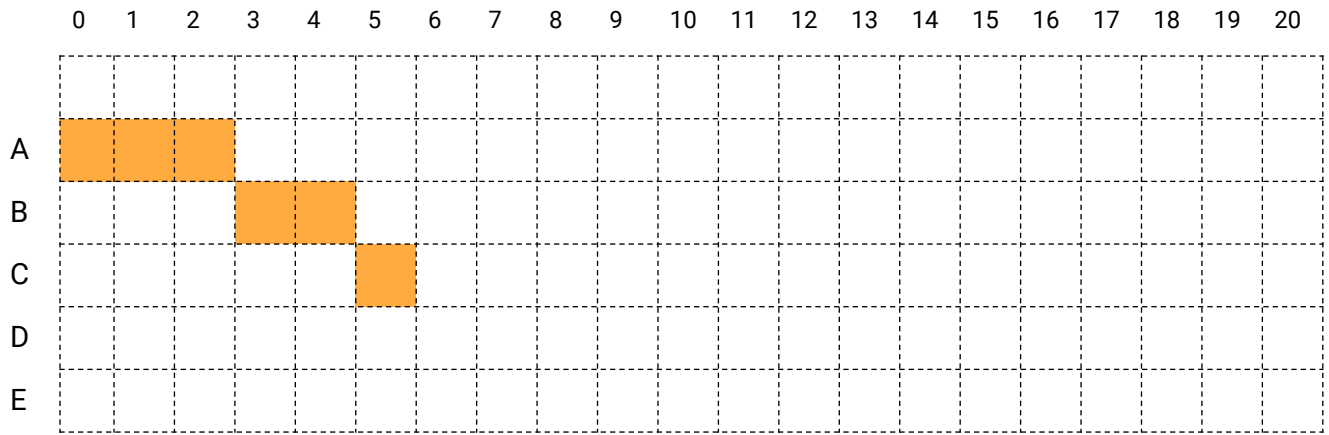


Process	Remaining time
B	4
C	4

Exercise 1 - Q2

T = 6

Next to schedule: B

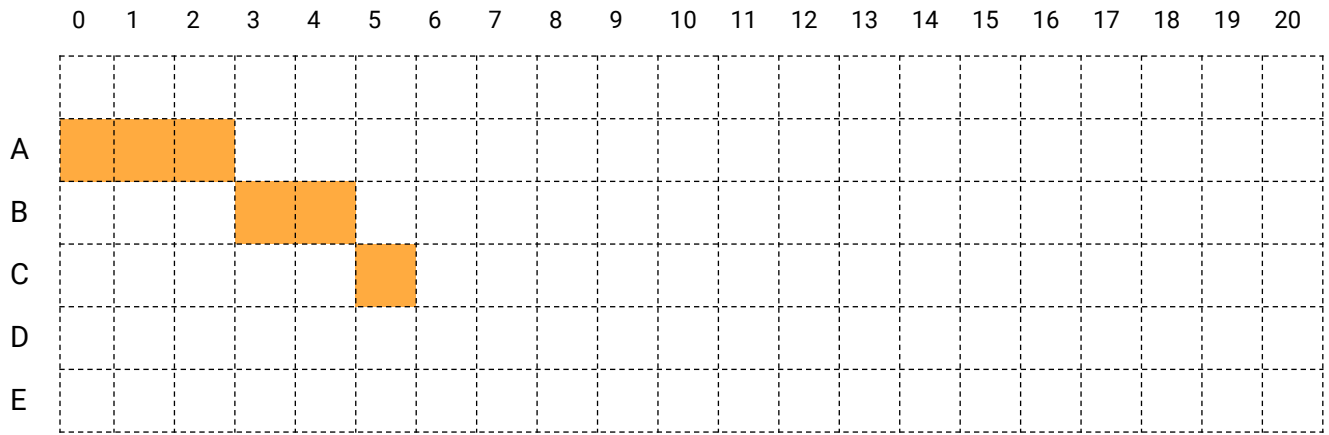


Process	Remaining time
B	4
C	3

Exercise 1 - Q2

T = 6, D arrives

Next to schedule: B

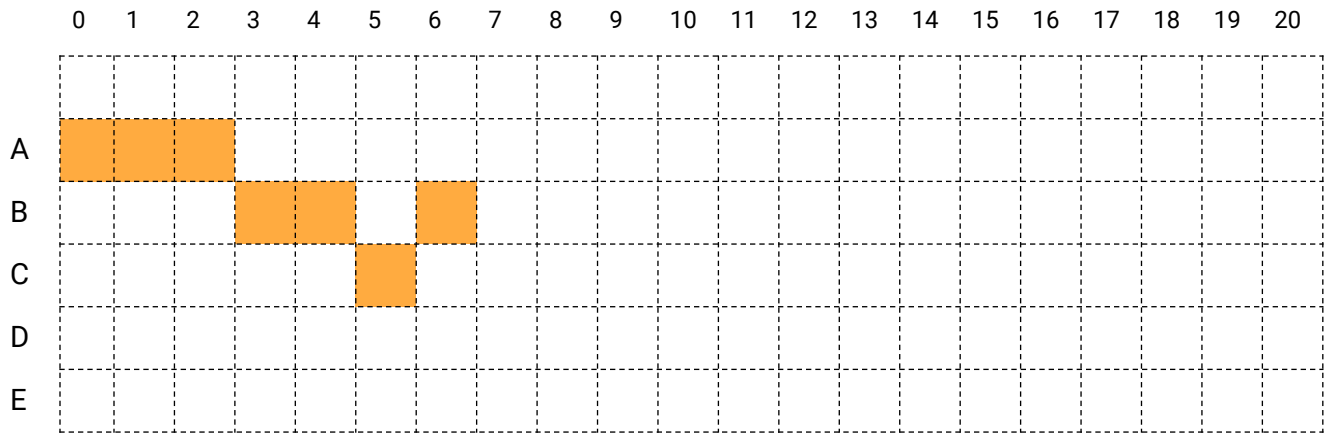


Process	Remaining time
B	4
C	3
D	5

Exercise 1 - Q2

T = 7

Next to schedule: C

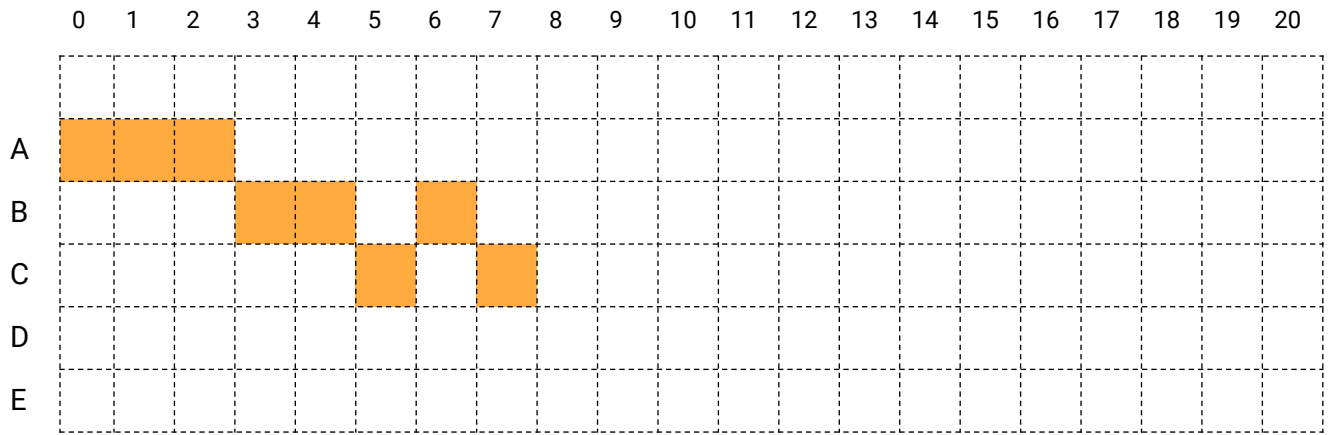


Process	Remaining time
B	3
C	3
D	5

Exercise 1 - Q2

T = 8

Next to schedule: D

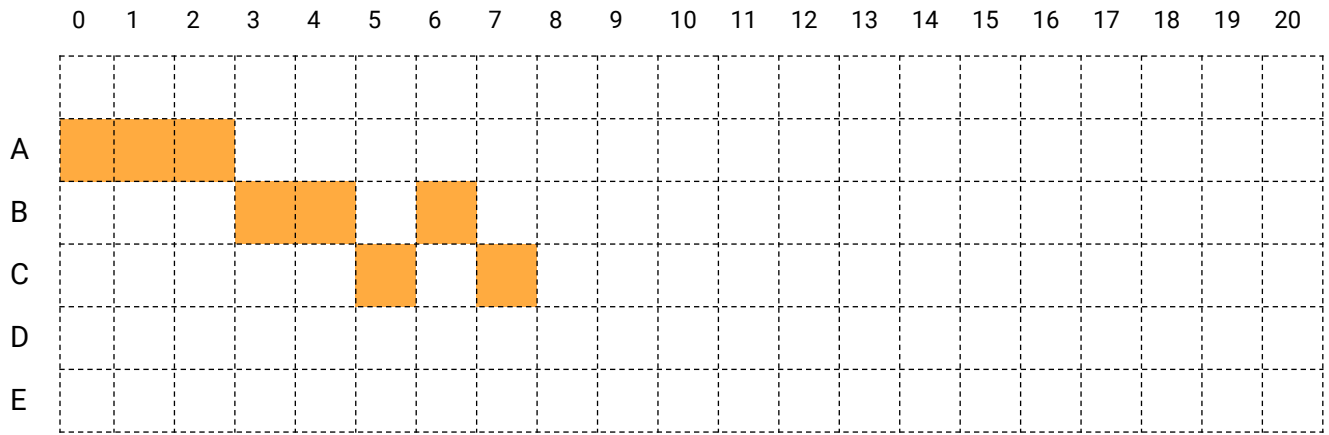


Process	Remaining time
B	3
C	2
D	5

Exercise 1 - Q2

T = 8, E arrives

Next to schedule: D

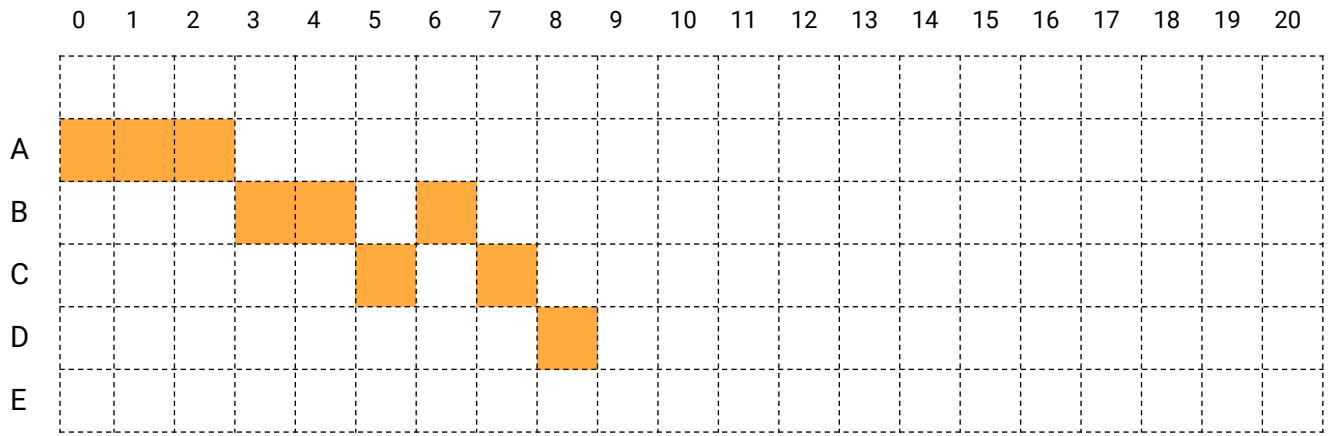


Process	Remaining time
B	3
C	2
D	5
E	2

Exercise 1 - Q2

T = 9

Next to schedule: E

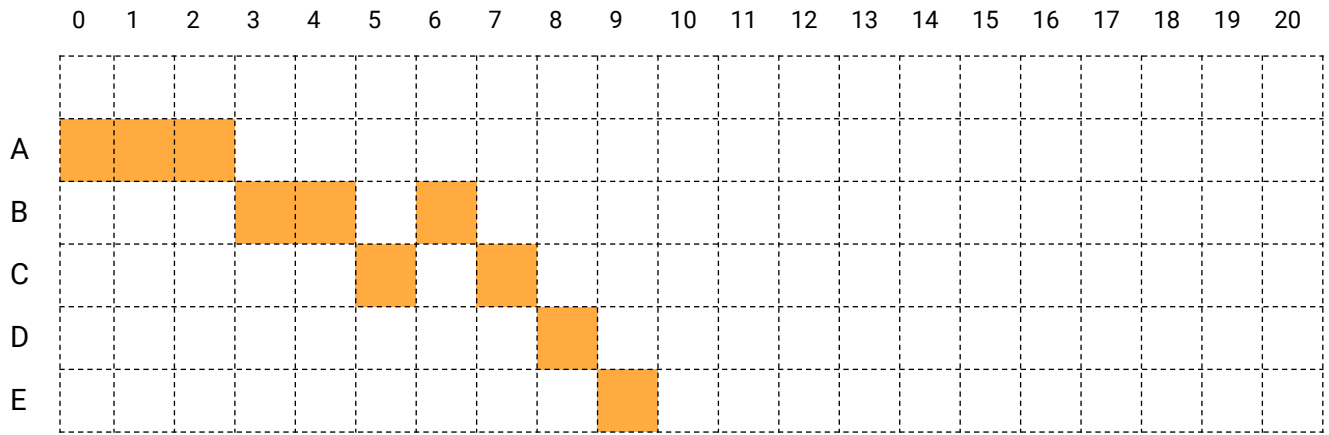


Process	Remaining time
B	3
C	2
D	4
E	2

Exercise 1 - Q2

T = 10

Next to schedule: B

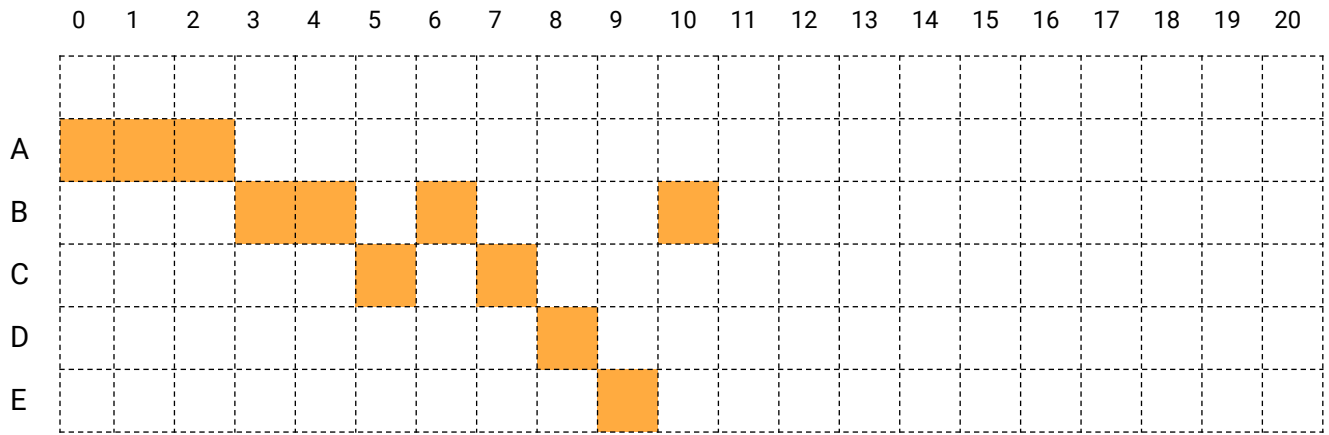


Process	Remaining time
B	3
C	2
D	4
E	1

Exercise 1 - Q2

T = 11

Next to schedule: C

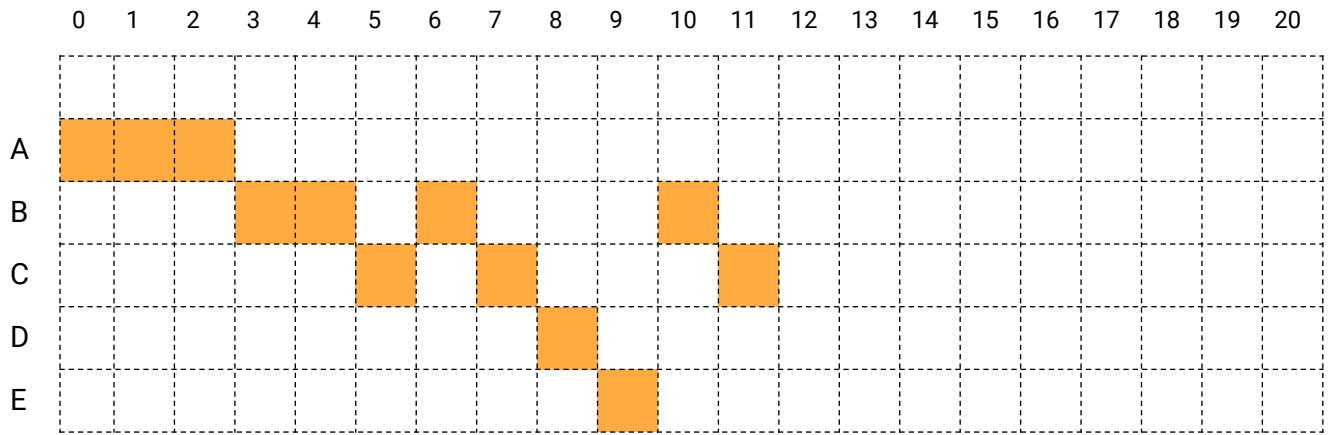


Process	Remaining time
B	2
C	2
D	4
E	1

Exercise 1 - Q2

T = 12

Next to schedule: D

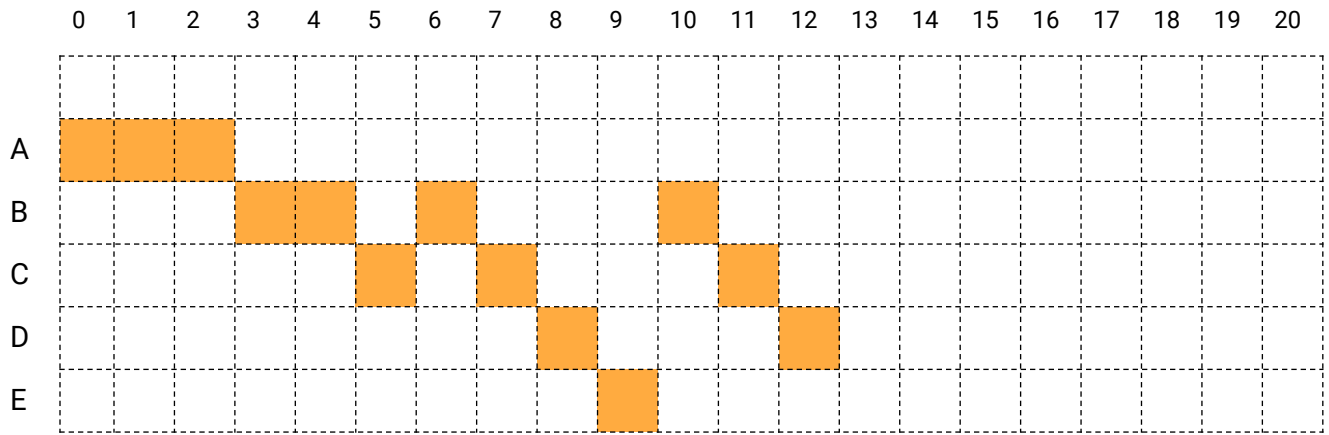


Process	Remaining time
B	2
C	1
D	4
E	1

Exercise 1 - Q2

T = 13

Next to schedule: E

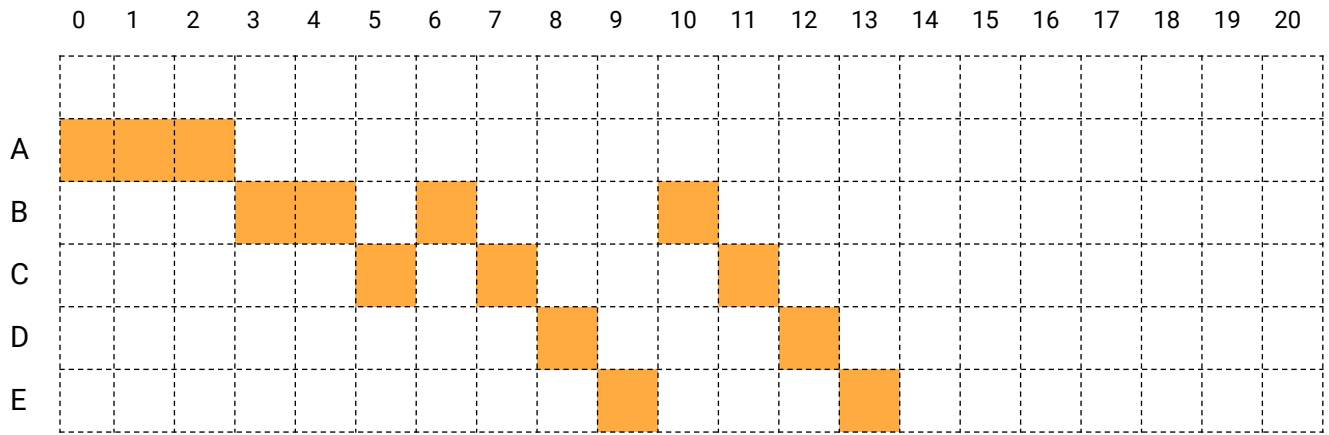


Process	Remaining time
B	2
C	1
D	3
E	1

Exercise 1 - Q2

T = 14, E terminates

Next to schedule: B

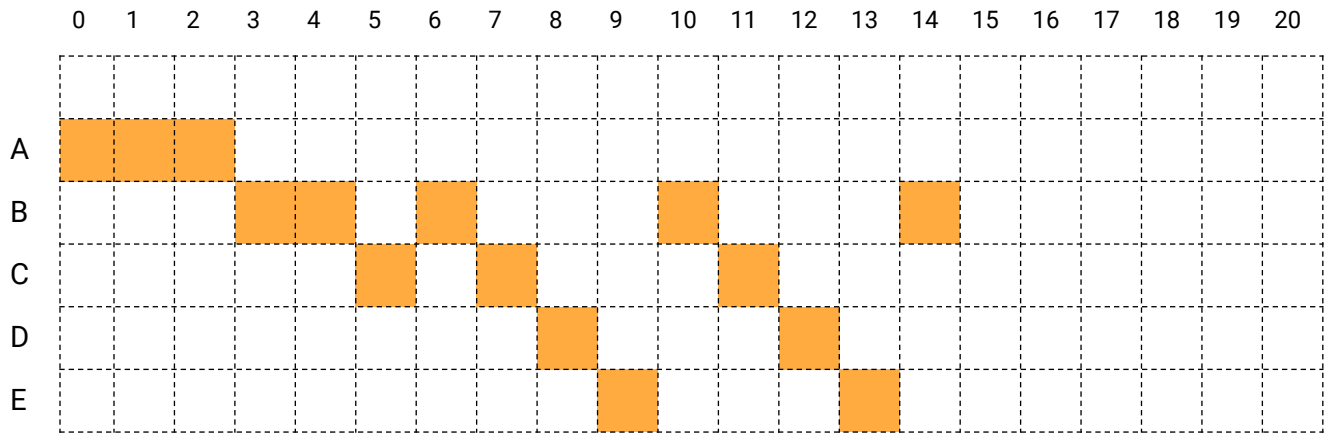


Process	Remaining time
B	2
C	1
D	3

Exercise 1 - Q2

T = 15

Next to schedule: C

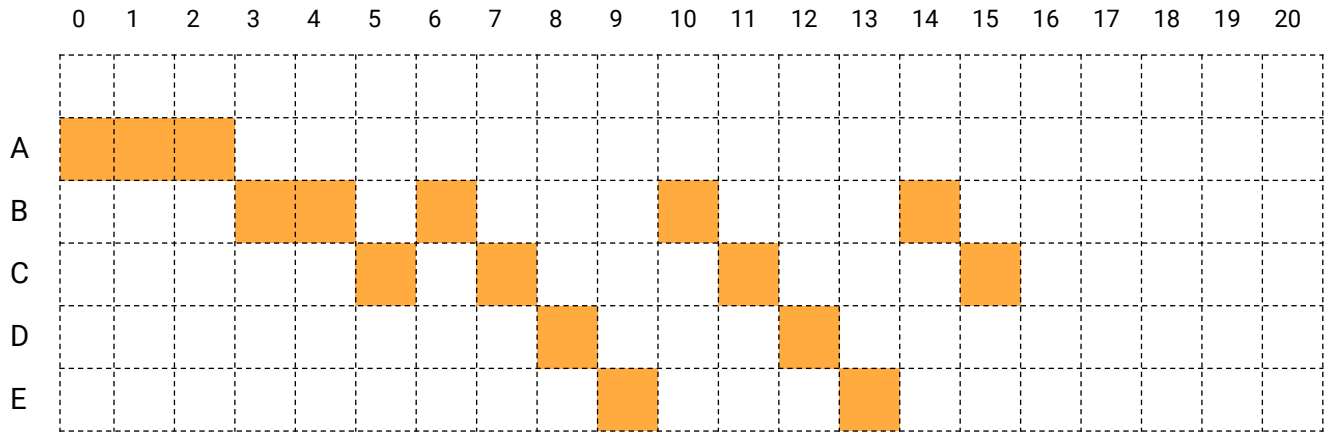


Process	Remaining time
B	1
C	1
D	3

Exercise 1 - Q2

T = 16, C terminates

Next to schedule: D

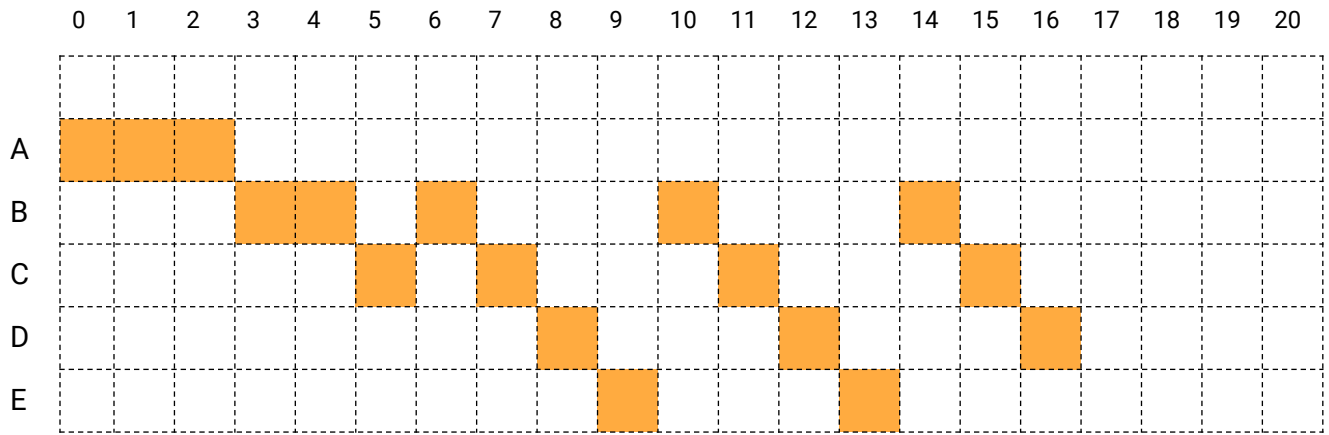


Process	Remaining time
B	1
D	3

Exercise 1 - Q2

T = 17

Next to schedule: B

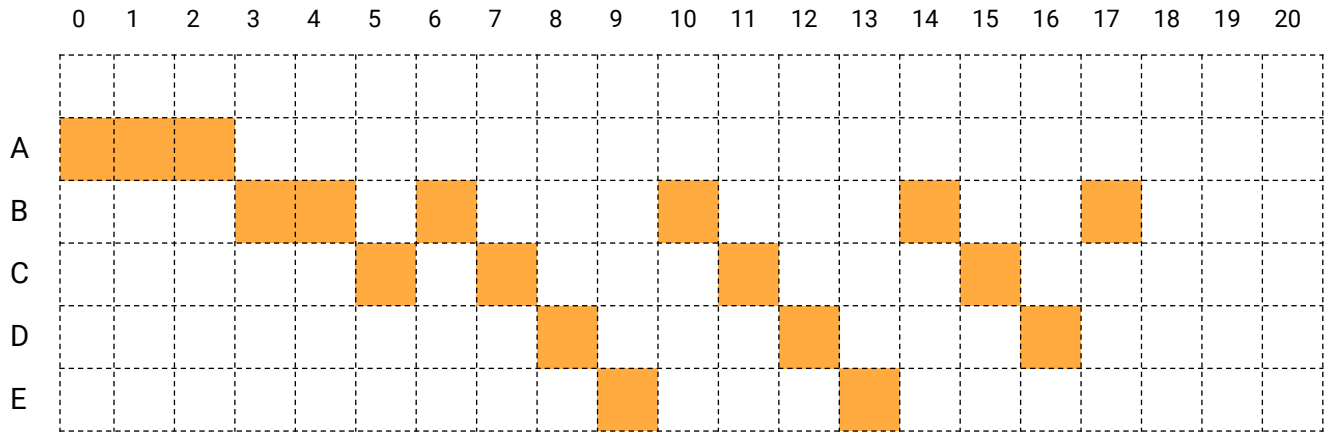


Process	Remaining time
B	1
D	2

Exercise 1 - Q2

T = 18, B terminates

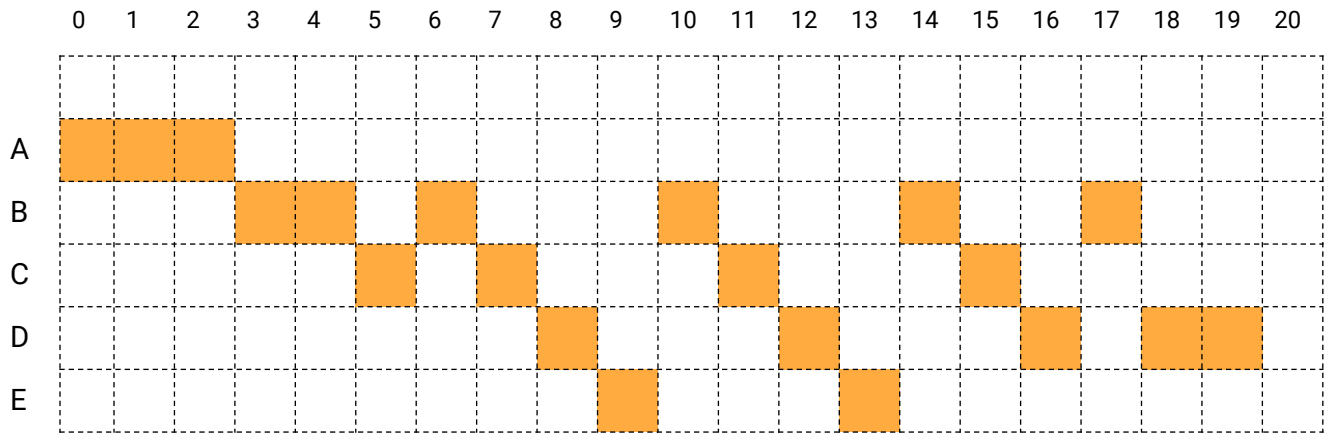
Next to schedule: D



Process	Remaining time
D	2

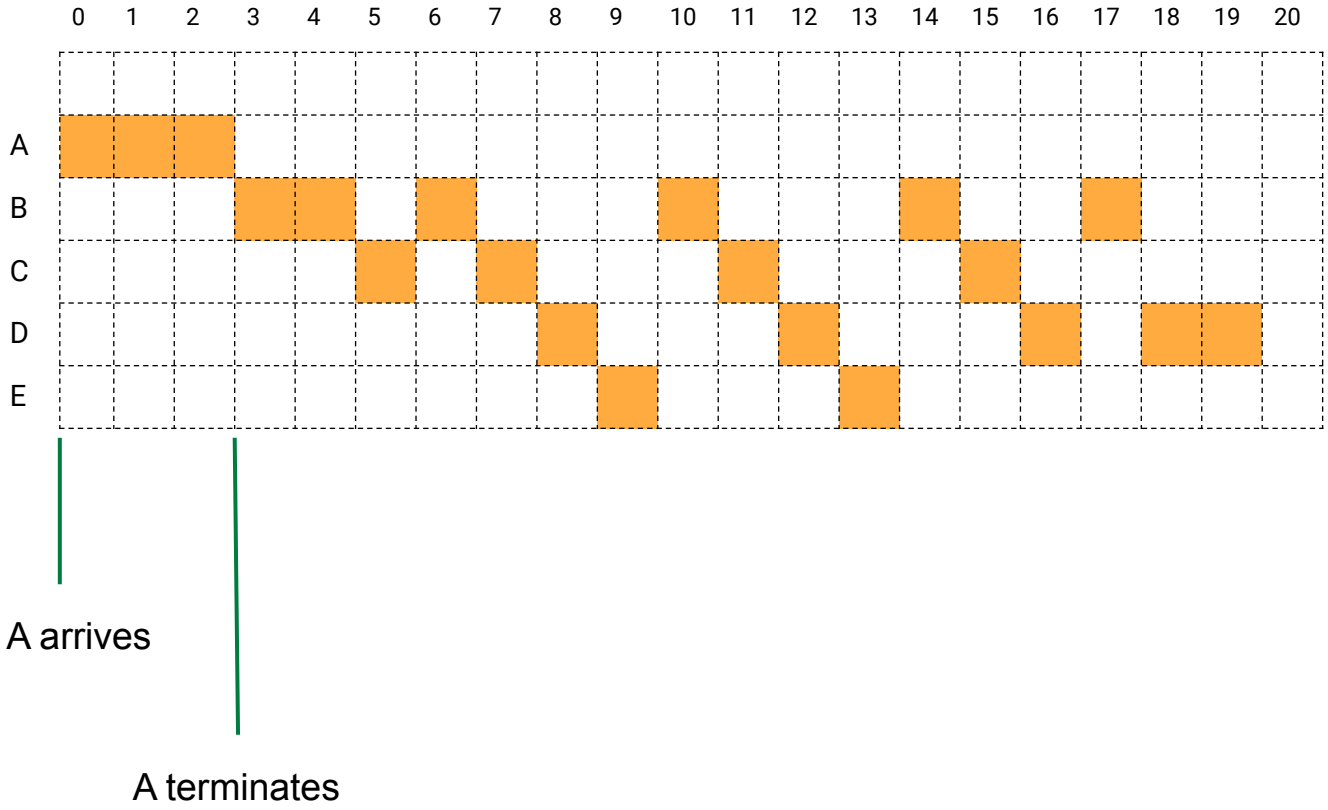
Exercise 1 - Q2

T = 20, D terminates



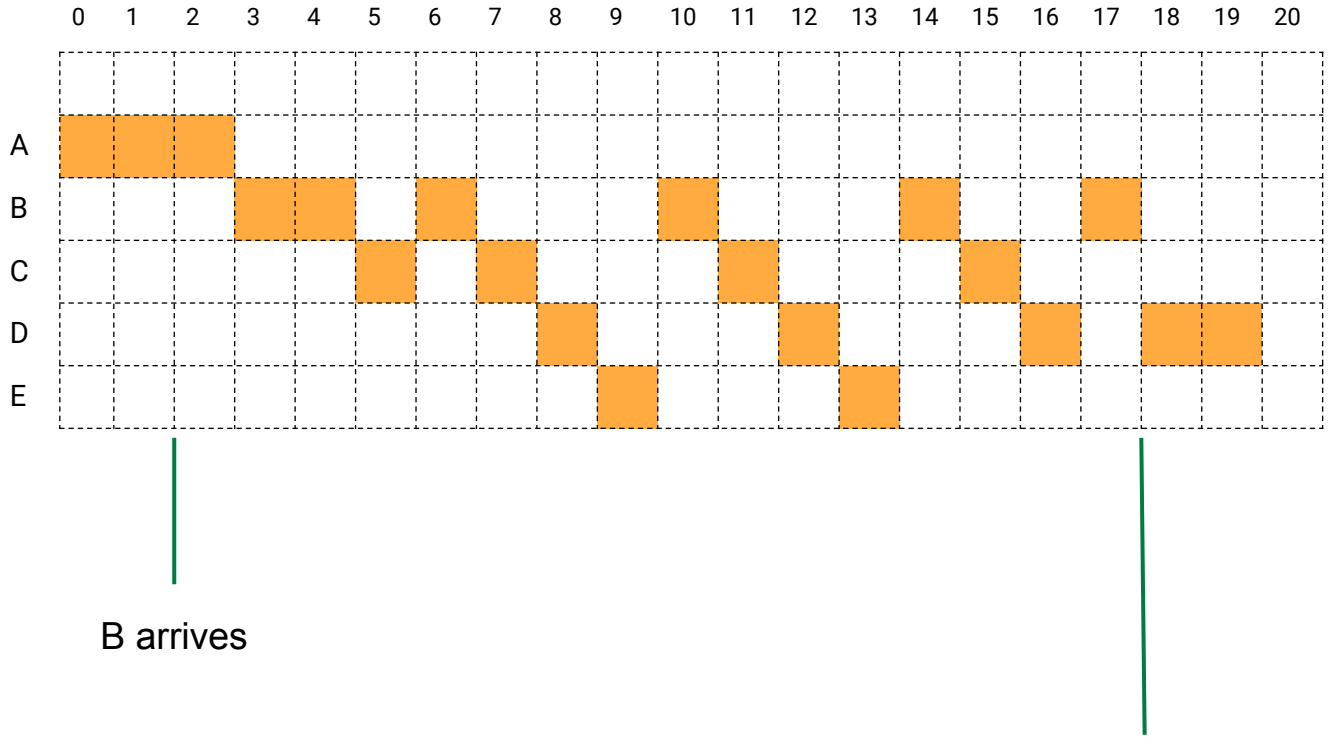
Process	Remaining time

Exercise 1 - Q2



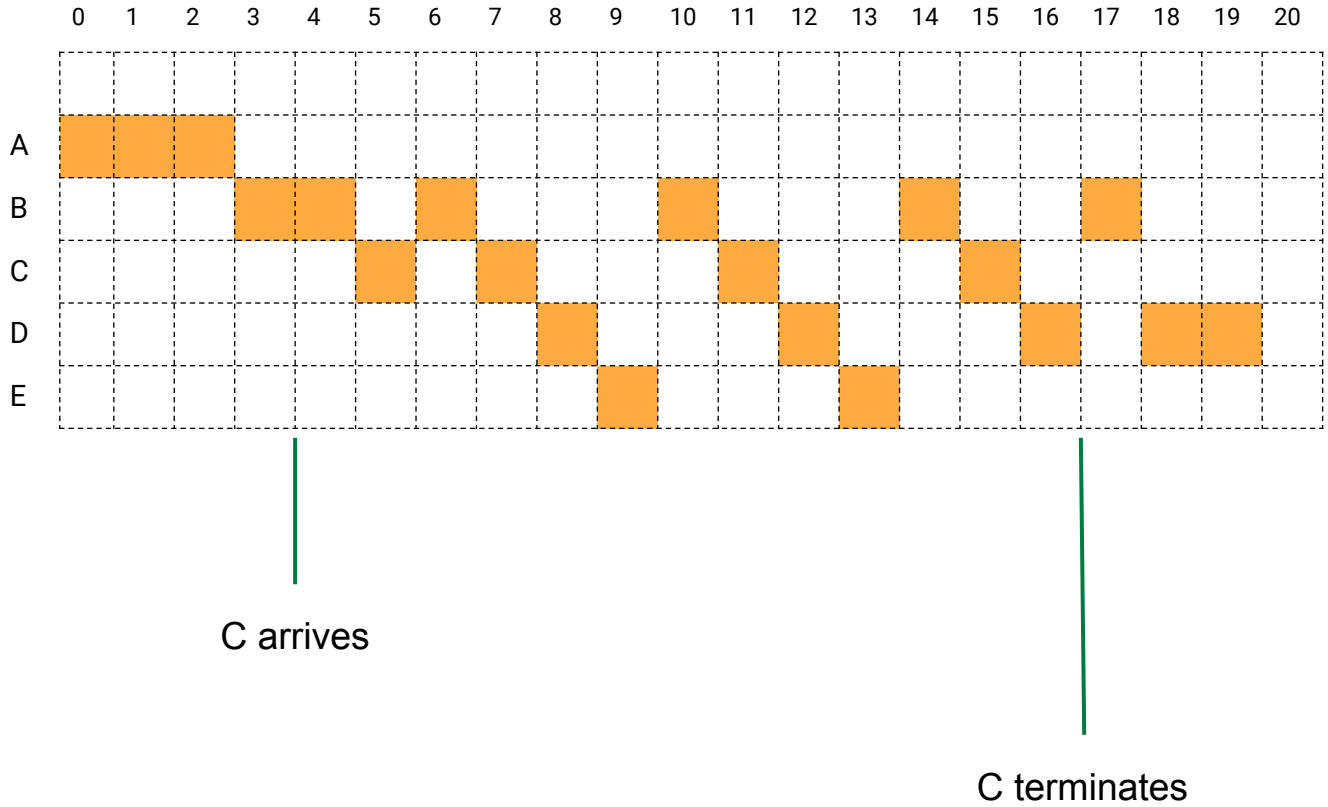
Process	Turnaround time
A	3 - 0 = 3

Exercise 1 - Q2



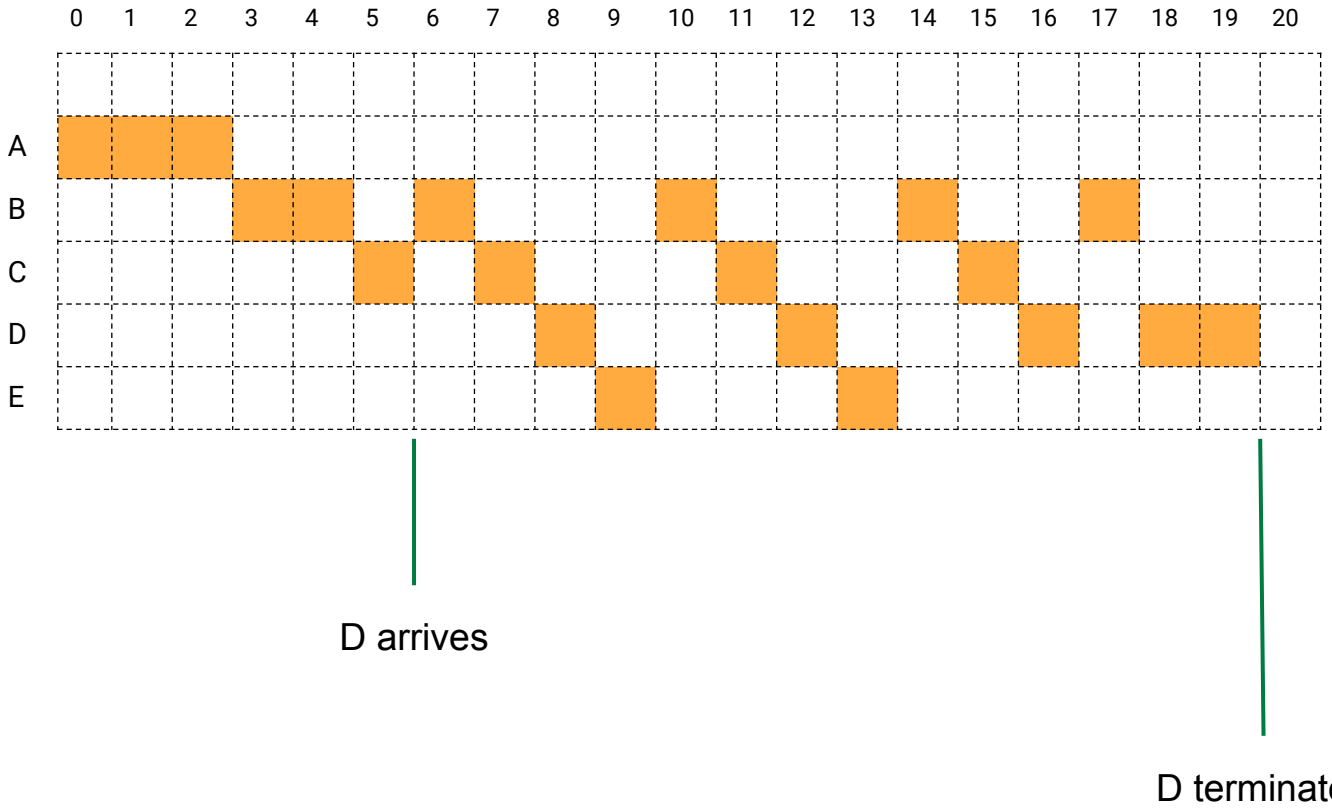
Process	Turnaround time
A	3 - 0 = 3
B	18 - 2 = 16

Exercise 1 - Q2



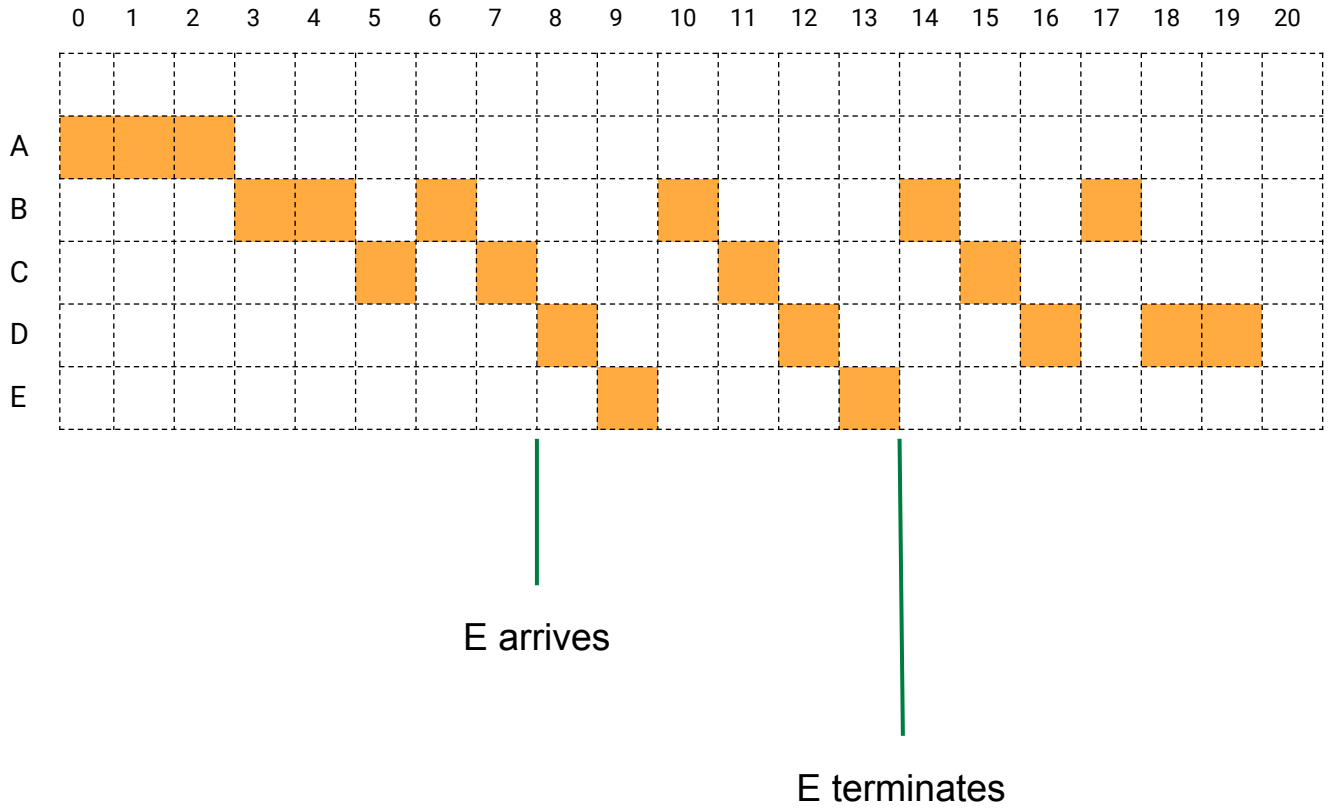
Process	Turnaround time
A	3 - 0 = 3
B	18 - 2 = 16
C	17 - 4 = 13

Exercise 1 - Q2



Process	Turnaround time
A	3 - 0 = 3
B	18 - 2 = 16
C	17 - 4 = 13
D	20 - 6 = 14

Exercise 1 - Q2



Process	Turnaround time
A	3 - 0 = 3
B	18 - 2 = 16
C	17 - 4 = 13
D	20 - 6 = 14
E	14 - 8 = 6

Exercise 1 - Q2

Process	Turnaround time
A	3 - 0 = 3
B	18 - 2 = 16
C	17 - 4 = 13
D	20 - 6 = 14
E	14 - 8 = 6
Avg.	10.4

Process	Waiting time
A	3 - 3 = 0
B	16 - 6 = 10
C	13 - 4 = 9
D	14 - 5 = 9
E	6 - 2 = 4
Avg.	6.4

Exercise 1 - Q2 Thinking questions

- What are the advantages of RR scheduling?
- What are the disadvantages of RR scheduling?
- How will different time quantum size influence average turnaround time and average wait time?

- Omitted
- Long averaging waiting time if tasks are equal in size. Hard to choose time quantum size.
- Fair & guaranteed wait time between being scheduled.

Exercise 2 - Q1

- How many times will page fault occur under LRU policy?
- Suppose 4 page frames are available and all the frames are initially empty.
- To break ties, replace the oldest page.

```
12, 8, 3, 7, 8, 3, 9, 10, 3, 5, 7, 10, 3, 7, 5, 7, 12, 10, 7, 5, 12
```

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	-																					
Frame #2	-																					
Frame #3	-																					
Frame #4	-																					
Page faults																						

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	-																					
Frame #2	-																					
Frame #3	-																					
Frame #4	-																					
Page faults																						

Exercise 2 - Q1

- LRU

Access	12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1 -																					
Frame #2 -																					
Frame #3 -																					
Frame #4 -																					
Page faults																					

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**																					
Frame #2	**-**																					
Frame #3	**-**																					
Frame #4	**-**																					
Page faults		1																				

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**																					
Frame #2	**-**																					
Frame #3	**-**																					
Frame #4	**-**																					
Page faults		1																				

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**																					
Frame #2	**-**																					
Frame #3	**-**																					
Frame #4	**-**																					
Page faults		1																				

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**																					
Frame #2	**8**																					
Frame #3	**-**																					
Frame #4	**-**																					
Page faults		1	2																			

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**																					
Frame #2	**8**																					
Frame #3	**3**																					
Frame #4	**7**																					
Page faults		1	2	3	4																	

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**																					
Frame #2	**8**																					
Frame #3	**3**																					
Frame #4	**7**																					
Page faults		1	2	3	4																	

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**																					
Frame #2	**8**																					
Frame #3	**3**																					
Frame #4	**7**																					
Page faults		1	2	3	4																	

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**																					
Frame #2	**8**																					
Frame #3	**3**																					
Frame #4	**7**																					
Page faults		1	2	3	4																	

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**																					
Frame #2	**8**																					
Frame #3	**3**																					
Frame #4	**7**																					
Page faults		1	2	3	4																	

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**																					
Frame #2	**8**																					
Frame #3	**3**																					
Frame #4	**7**																					
Page faults		1	2	3	4																	

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**																					
Frame #2	**8**																					
Frame #3	**3**																					
Frame #4	**7**																					
Page faults		1	2	3	4																	

Exercise 2 - Q1

- **LRU - Least Recently Used**

  Frame 1 at time 1, 2 at time 5, 3 at time 6, 4 at time 4

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**																					
Frame #2	**8**																					
Frame #3	**3**																					
Frame #4	**7**																					
Page faults		1	2	3	4																	

Exercise 2 - Q1

- **LRU - Least Recently Used**

  Frame 1 at time 1, 2 at time 5, 3 at time 6, 4 at time 4

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**9**																					
Frame #2	**8**																					
Frame #3	**3**																					
Frame #4	**7**																					
Page faults		1	2	3	4			5														

Exercise 2 - Q1

- **LRU - Least Recently Used**

  Frame 1 at time 9, 2 at time 5, 3 at time 6, **4 at time 4**

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**9**																					
Frame #2	**8**																					
Frame #3	**3**																					
Frame #4	**7**																					
Page faults		1	2	3	4			5														

Exercise 2 - Q1

- **LRU - Least Recently Used**

  Frame 1 at time 9, 2 at time 5, 3 at time 6, **4 at time 4**

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**9**																					
Frame #2	**8**																					
Frame #3	**3**																					
Frame #4	**10**																					
Page faults		1	2	3	4			5	6													

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**9**																					
Frame #2	**8**																					
Frame #3	**3**																					
Frame #4	**10**																					
Page faults		1	2	3	4			5	6													

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**9**																					
Frame #2	**5**																					
Frame #3	**3**																					
Frame #4	**10**																					
Page faults		1	2	3	4			5	6		7											

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**7**																					
Frame #2	**5**																					
Frame #3	**3**																					
Frame #4	**10**																					
Page faults		1	2	3	4			5	6		7	8										

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**7**																					
Frame #2	**5**																					
Frame #3	**3**																					
Frame #4	**10**																					
Page faults		1	2	3	4			5	6		7	8										

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**7**																					
Frame #2	**5**																					
Frame #3	**3**																					
Frame #4	**10**																					
Page faults		1	2	3	4			5	6		7	8										

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**7**																					
Frame #2	**5**																					
Frame #3	**3**																					
Frame #4	**10**																					
Page faults		1	2	3	4			5	6		7	8										

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**7**																					
Frame #2	**5**																					
Frame #3	**3**																					
Frame #4	**10**																					
Page faults		1	2	3	4			5	6		7	8										

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**7**																					
Frame #2	**5**																					
Frame #3	**3**																					
Frame #4	**10**																					
Page faults		1	2	3	4			5	6		7	8										

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**7**																					
Frame #2	**5**																					
Frame #3	**3**																					
Frame #4	**12**																					
Page faults		1	2	3	4			5	6		7	8						9				

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**7**																					
Frame #2	**5**																					
Frame #3	**10**																					
Frame #4	**12**																					
Page faults		1	2	3	4			5	6		7	8						9	10			

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**7**																					
Frame #2	**5**																					
Frame #3	**10**																					
Frame #4	**12**																					
Page faults		1	2	3	4			5	6		7	8						9	10			

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**7**																					
Frame #2	**5**																					
Frame #3	**10**																					
Frame #4	**12**																					
Page faults		1	2	3	4			5	6		7	8						9	10			

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**7**																					
Frame #2	**5**																					
Frame #3	**10**																					
Frame #4	**12**																					
Page faults		1	2	3	4			5	6		7	8						9	10			

Exercise 2 - Q1

- LRU

Access		12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**7**	12	12	12	12	12	12	9	9	9	9	7	7	7	7	7	7	7	7	7	7	7
Frame #2	**5**	0	8	8	8	8	8	8	8	8	5	5	5	5	5	5	5	5	5	5	5	5
Frame #3	**10**	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	10	10	10	10
Frame #4	**12**	0	0	0	7	7	7	7	10	10	10	10	10	10	10	10	10	12	12	12	12	12
Page faults		1	2	3	4			5	6		7	8						9	10			

Exercise 2 - Q1

- How many times will page fault occur under LRU policy?
- Suppose 4 page frames are available and all the frames are initially empty.
- To break ties, replace the oldest page.

```
12, 8, 3, 7, 8, 3, 9, 10, 3, 5, 7, 10, 3, 7, 5, 7, 12, 10, 7, 5, 12
```

- Answer: 10

Exercise 2 - Q2

- How many times will page fault occur under clock policy?
- Suppose 4 page frames are available and all the frames are initially empty.
- To break ties, replace the oldest page.

```
12, 8, 3, 7, 8, 3, 9, 10, 3, 5, 7, 10, 3, 7, 5, 7, 12, 10, 7, 5, 12
```

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**-**	**0**																					
Frame #2	**-**	**0**																					
Frame #3	**-**	**0**																					
Frame #4	**-**	**0**																					
Page faults																							

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**	**0**																					
Frame #2	**8**	**0**																					
Frame #3	**3**	**0**																					
Frame #4	**7**	**0**																					
Page faults			1	2	3	4																	

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**	**0**																					
Frame #2	**8**	**1**																					
Frame #3	**3**	**0**																					
Frame #4	**7**	**0**																					
Page faults			1	2	3	4																	

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**12**	**0**																					
Frame #2	**8**	**1**																					
Frame #3	**3**	**1**																					
Frame #4	**7**	**0**																					
Page faults			1	2	3	4																	

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**9**	**0**																					
Frame #2	**8**	**1**																					
Frame #3	**3**	**1**																					
Frame #4	**7**	**0**																					
Page faults			1	2	3	4			5														

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**9**	**0**																					
Frame #2	**8**	**1**																					
Frame #3	**3**	**1**																					
Frame #4	**7**	**0**																					
Page faults			1	2	3	4			5														

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**9**	**0**																					
Frame #2	**8**	**0**																					
Frame #3	**3**	**1**																					
Frame #4	**7**	**0**																					
Page faults			1	2	3	4			5														

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**9**	**0**																					
Frame #2	**8**	**0**																					
Frame #3	**3**	**1**																					
Frame #4	**7**	**0**																					
Page faults			1	2	3	4			5														

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**9**	**0**																					
Frame #2	**8**	**0**																					
Frame #3	**3**	**0**																					
Frame #4	**7**	**0**																					
Page faults			1	2	3	4			5														

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**9**	**0**																					
Frame #2	**8**	**0**																					
Frame #3	**3**	**0**																					
Frame #4	**10**	**0**																					
Page faults			1	2	3	4			5	6													

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**9**	**0**																					
Frame #2	**8**	**0**																					
Frame #3	**3**	**1**																					
Frame #4	**10**	**0**																					
Page faults			1	2	3	4			5	6													

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**0**																					
Frame #2	**8**	**0**																					
Frame #3	**3**	**1**																					
Frame #4	**10**	**0**																					
Page faults			1	2	3	4			5	6		7											

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**0**																					
Frame #2	**7**	**0**																					
Frame #3	**3**	**1**																					
Frame #4	**10**	**0**																					
Page faults			1	2	3	4			5	6		7	8										

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**0**																					
Frame #2	**7**	**0**																					
Frame #3	**3**	**1**																					
Frame #4	**10**	**1**																					
Page faults			1	2	3	4			5	6		7	8										

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**0**																					
Frame #2	**7**	**0**																					
Frame #3	**3**	**1**																					
Frame #4	**10**	**1**																					
Page faults			1	2	3	4			5	6		7	8										

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**0**																					
Frame #2	**7**	**1**																					
Frame #3	**3**	**1**																					
Frame #4	**10**	**1**																					
Page faults			1	2	3	4			5	6		7	8										

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**1**																					
Frame #2	**7**	**1**																					
Frame #3	**3**	**1**																					
Frame #4	**10**	**1**																					
Page faults			1	2	3	4			5	6		7	8										

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**1**																					
Frame #2	**7**	**1**																					
Frame #3	**3**	**1**																					
Frame #4	**10**	**1**																					
Page faults			1	2	3	4			5	6		7	8										

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**1**																					
Frame #2	**7**	**1**																					
Frame #3	**3**	**0**																					
Frame #4	**10**	**1**																					
Page faults			1	2	3	4			5	6		7	8										

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**1**																					
Frame #2	**7**	**1**																					
Frame #3	**3**	**0**																					
Frame #4	**10**	**0**																					
Page faults			1	2	3	4			5	6		7	8										

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**0**																					
Frame #2	**7**	**1**																					
Frame #3	**3**	**0**																					
Frame #4	**10**	**0**																					
Page faults			1	2	3	4			5	6		7	8										

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**0**																					
Frame #2	**7**	**0**																					
Frame #3	**3**	**0**																					
Frame #4	**10**	**0**																					
Page faults			1	2	3	4			5	6		7	8										

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**0**																					
Frame #2	**7**	**0**																					
Frame #3	**12**	**0**																					
Frame #4	**10**	**0**																					
Page faults			1	2	3	4			5	6		7	8						9				

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**0**																					
Frame #2	**7**	**0**																					
Frame #3	**12**	**0**																					
Frame #4	**10**	**1**																					
Page faults			1	2	3	4			5	6		7	8						9				

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**0**																					
Frame #2	**7**	**1**																					
Frame #3	**12**	**0**																					
Frame #4	**10**	**1**																					
Page faults			1	2	3	4			5	6		7	8						9				

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**1**																					
Frame #2	**7**	**1**																					
Frame #3	**12**	**0**																					
Frame #4	**10**	**1**																					
Page faults			1	2	3	4			5	6		7	8						9				

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**1**																					
Frame #2	**7**	**1**																					
Frame #3	**12**	**1**																					
Frame #4	**10**	**1**																					
Page faults			1	2	3	4			5	6		7	8						9				

Exercise 2 - Q2

- Clock

Access			12	8	3	7	8	3	9	10	3	5	7	10	3	7	5	7	12	10	7	5	12
Frame #1	**5**	**1**	12	12	12	12	12	12	9	9	9	5	5	5	5	5	5	5	5	5	5	5	5
Frame #2	**7**	**1**	0	8	8	8	8	8	8	8	8	8	7	7	7	7	7	7	7	7	7	7	7
Frame #3	**12**	**1**	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	12	12	12	12	12
Frame #4	**10**	**1**	0	0	0	7	7	7	7	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Page faults			1	2	3	4			5	6		7	8						9				

Exercise 2 - Q2

- How many times will page fault occur under clock policy?
- Suppose 4 page frames are available and all the frames are initially empty.
- To break ties, replace the oldest page.

```
12, 8, 3, 7, 8, 3, 9, 10, 3, 5, 7, 10, 3, 7, 5, 7, 12, 10, 7, 5, 12
```

- Answer: 9

Questions for Assignment 3 and the final exam

- Consistency test sample input:
  - 1-1: some bits in free_block_list marked as 1 but not allocated by any file (not in the range of [start_block, start_block + size - 1] for all inodes).
  - 1-2: some bits in free_block_list marked as 0 but allocated by some files
  - 1-3: some blocks are allocated by more than one file
  - 2-1: duplicate names in root
  - 2-2: duplicate names in the same folder
  - 3-1: inode is marked as free but some bits are not zero
  - 3-2: inode is marked as in use but the name is empty
  - 6-1: parent is 126
  - 6-2: parent inode is a file