Exercise 1.1.a. The ready queue receives processes A, B, C and D with the following characteristics:

Process	Arrival time	CPU time	Priority
A	0	8	4(-)
B	2	4	3
C	5	9	2
D	12	3	1 (+)

a) Obtain the processing time line and the mean waiting time for the SRTF scheduling.

t	Ready	CPU	Comment
0			A arrives
1			
2			B arrives
3			
4			
5			C arrives
6			
7			
8			
9			
10			
11			
12			
13			
14			
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Exercise 1.1.b. The ready queue receives processes A, B, C and D with the following characteristics:

Process	Arrival time	CPU time	Priority
A	0	8	4(-)
B	2	4	3
C	5	9	2
D	12	3	1 (+)

b) Obtain the processing time line and the mean waiting time for the Preemptive Priorities scheduling.

t	Ready	CPU	Comment
0			A arrives
1			
2			B arrives
3			
4			
5			C arrives
6			
7			
8			
9			
10			
11			
12			
13			
14			
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Exercise 1.1.c. The ready queue receives processes A, B, C and D with the following characteristics:

Process	Arrival time	CPU time	Priority
A	0	8	4(-)
B	2	4	3
C	5	9	2
D	12	3	1 (+)

c) Obtain the processing time line and the mean waiting time for the Round Robin scheduling with q = 2.

t	Ready	CPU	Comment
0			A arrives
1			
2			B arrives
3			
4			
5			C arrives
6			
7			
8			
9			
10			
11			
12			
13			
14			
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Exercise 1.2.a. In a multiprogrammed system there is a single I/O device that is managed with FCFS. To this system arrive 3 processes A, B and C, which CPU and I/O burst scheme is as follows:

Process	Arrival time	Execution profile
A (+)	0 (first)	1CPU+1I/O+1CPU+1I/O+1CPU+1I/O+4CPU+1I/O+2CPU
B	0	2CPU+2I/O+3CPU+1I/O++3CPU+1I/O+1CPU
C (-)	0 (last)	1CPU+5I/O+1CPU+5I/O+1CPU

Obtain the time line representing the CPU and I/O busy time, as well as the ready and I/O queues state. Also, calculate the average turnaround time and the CPU utilization for the following CPU scheduling algorithms:

a) Round Robin with q = 1

t	Ready	CPU	I/O queue	I/O	Comment
0					A, B, C arrive
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
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Exercise 1.2.b. In a multiprogrammed system there is a single I/O device that is managed with FCFS. To this system arrive 3 processes A, B and C, which CPU and I/O burst scheme is as follows:

Process	Arrival time	Execution profile
A (+)	0 (first)	1CPU+1I/O+1CPU+1I/O+1CPU+1I/O+4CPU+1I/O+2CPU
B	0	2CPU+2I/O+3CPU+1I/O++3CPU+1I/O+1CPU
C (-)	0 (last)	1CPU+5I/O+1CPU+5I/O+1CPU

Obtain the time line representing the CPU and I/O busy time, as well as the ready and I/O queues state. Also, calculate the average turnaround time and the CPU utilization for the following CPU scheduling algorithms:

b) SJF

t	Ready	CPU	I/O queue	I/O	Comment
0					A, B, C arrive
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
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Exercise 1.3.a. In a multiprogrammed system there are two processes, A and B, with the following execution profiles:

Process	Arrival time	Execution profile
A (-)	0	3 CPU + 4 DISK + 6 CPU + 4 PRINTER + 3 CPU
B (+)	2	2 CPU + 5 DISK + 3 CPU + 3 PRINTER + 2 CPU

There is only one disk and one printer. Peripherals use a FCFS scheduling algorithm. Draw the execution time line and calculate the average waiting time and the average turnaround time in the following CPU scheduling cases:

a) Round robin with q = 1

t	Ready	CPU	DISK queu	DISK	Print queue	Print	Comment
0							A arrives
1							
2							B arrives
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
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Exercise 1.3.b. In a multiprogrammed system there are two processes, A and B, with the following execution profiles:

Process	Arrival time	Execution profile
A (-)	0	3 CPU + 4 DISK + 6 CPU + 4 PRINTER + 3 CPU
B (+)	2	2 CPU + 5 DISK + 3 CPU + 3 PRINTER + 2 CPU

There is only one disk and one printer. Peripherals use a FCFS scheduling algorithm. Draw the execution time line and calculate the average waiting time and the average turnaround time in the following CPU scheduling cases:

b) Preemptive priorities with p(B) > p(A)

t	Ready	CPU	DISK queu	DISK	Print queue	Print	Comment
0							A arrives
1							
2							B arrives
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
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Exercise 2. Suppose an operating system where there are four priority classes numbered from 0 to 3. The scheduling algorithm is **Round Robin for classes 0, 1 and 2**, and is **FCFS for class 3**. The **highest priority class is 0**. Time quanta, **qi for classes 0, 1 and 2** are given by the following formula: **qi = i + 1**. The scheduling algorithm is **multilevel queue preemptive**.
Processes that enter the system are initially admitted into the highest priority class (0). There is a mechanism of priority degradation obeying the following rule: "**a process remains in its class until it has consumed two time quanta, thereafter it is degraded to the next lower priority class**". Processes that reach Class 3 remain there until they end execution.
Obtain the **turnaround time** and the **ending class** of every of the following three processes:

Process	Arrival time	Execution profile	Ending class	Turnaround time
A	0	4 CPU		
B	0	8 CPU		
C	0	12 CPU		

t	Ready				CPU	Comment
	Queue 3 FCFS	Queue 2 RR q=3	Queue 1 RR q=2	Queue 0 RR q=1		
0						P1, P2, P3 arrive
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
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Exercise 3. An operating system uses scheduling algorithm based on "**priority classes**" with two levels, and **the scheduling policy for each level is FCFS**. **Planning between the two levels is preemptive priorities**, being the highest priority level 1. **When a process is ejected, it goes to the head of its queue**. Processes share a single disk with FCFS scheduling. The operating system assigns processes to one of two levels depending on their processor and disk consumption. **If a process has consumed more CPU time than disk, it is assigned to level 2, otherwise it is assigned to level 1**. Initially the processes are in level 1. The system determines the level for each process every unit of time. Three processes arrive simultaneously to the system, but in the order A, B and C. The execution profiles are shown in the following table. Obtain the processing time line, the mean turnaround time and the mean waiting time.

Process	Execution profile
A	2 CPU + 1 DISK + 7CPU
B	1CPU + 3 DISK + 1 CPU + 2 DISK + 1 CPU + 2 DISK + 1 CPU
C	2CPU + 1 DISK + 1CPU + 2 DISK + 1 CPU + 2 DISK + 1 CPU

	Ready					
	Class 1	Class 2				
0						A, B, C arrive
1						
2						
3						
4						
5						
6						
7						
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Criteria to apply in scheduling exercises

GENERAL ADVICE: Usually the exercise enunciates are not rigorously complete, and it is left in the student hands to consider the alternatives and to explain which one is the most convenient or less bad. In order to get a correct resolution of scheduling exercise, it is advisable to perform a trace as complete as possible, that will include the status of each process and the events that produce changes in its state.

NOTE ABOUT THE REPRESENTATION OF SOLUTIONS: The solutions of scheduling exercises are developed in tables with as many columns as resources and associated queues that the proposed system has, and rows that describe the system state at a certain time instant.

- **In relation to COLUMNS**
  - The READY column refers to the queue of processes that are waiting to the CPU being assigned to them.
  - The CPU column refers to the process that has got the CPU at that time instant and therefore it is the running process.
  - In addition it appears a column that indicates the timeline.
  - The last column on the right allow to write comments explaining events and actions relevant at any time instant.
- **In relation to ROWS**
  - The row i-th represents the time instant "i".
  - The events listed in the row i-th occur at instant "I". Therefore, the status of processes represented in the row i-th is a consequence of the events listed in that row.
  - It is possible that several events happen simultaneously at a certain time instant. Because there can be significant variations in the further evolution of the processing trace depending on the sequence considered to such events, it will be assumed the following ordering (which is reasonable though not necessarily the only one possible):
    1. New process arrival.
    2. Process ending.
    3. Getting out of suspension state (I/O access end, getting out of an event waiting, etc).
    4. End of CPU quantum (Round Robin policies).