[Problemas de Sistemas Operativos: de la base al diseño]
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Exercise 1.

Given the next set of processes:

Process	Arrival	CPU Time	Priority
P1	0	10	3
P2	1	1	1
P3	3	4	3
P4	4	2	4
P5	5	5	2

a) Write a diagram that illustrates the execution of these processes using:

1. FIFO.

2. Scheduling with preemptive (or expulsive) priorities

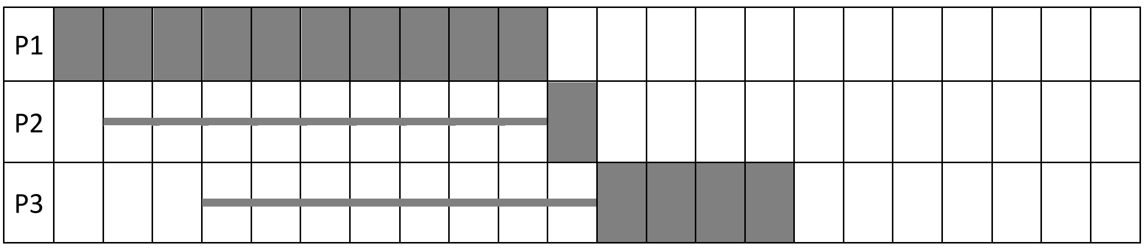
3. Scheduling with preemptive priorities and with Round Robin (q = 2) for the processes of the same priority. (If the execution slice of a process ends at the same instant that a new process arrives on the system, then the new process is placed in the ready-to-run queue before the process that expires the slice.)

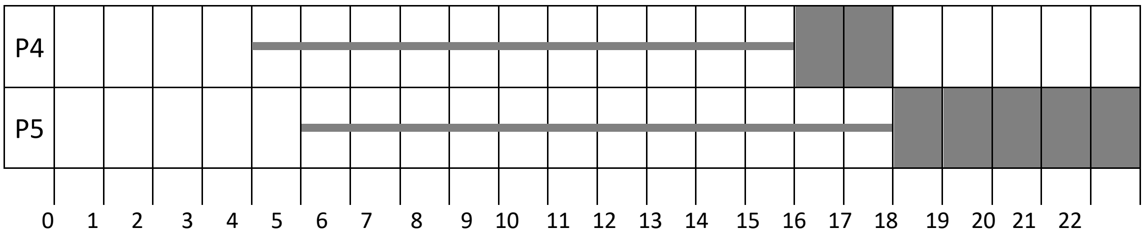
b) Calculate the waiting time for each scheduling process and algorithm.

SOLUTION

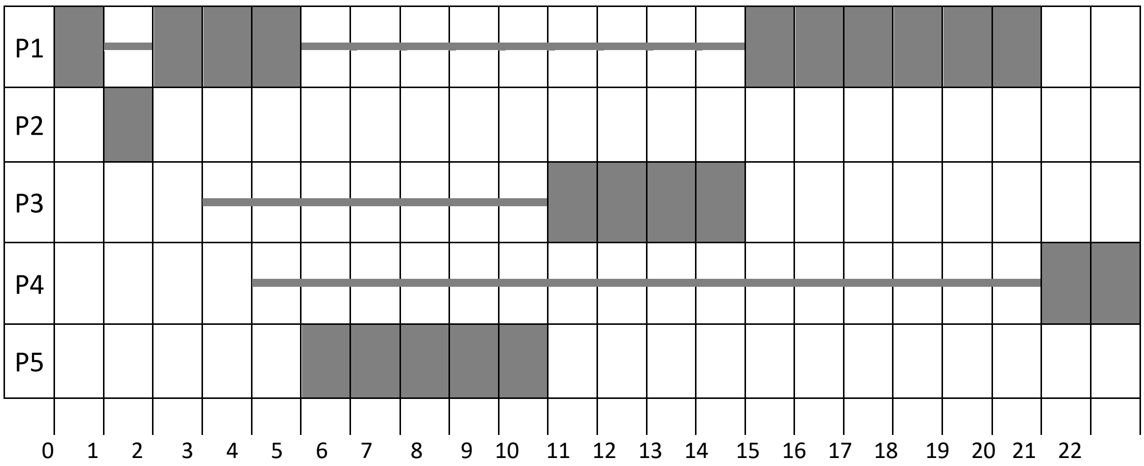
a)

1. FIFO.



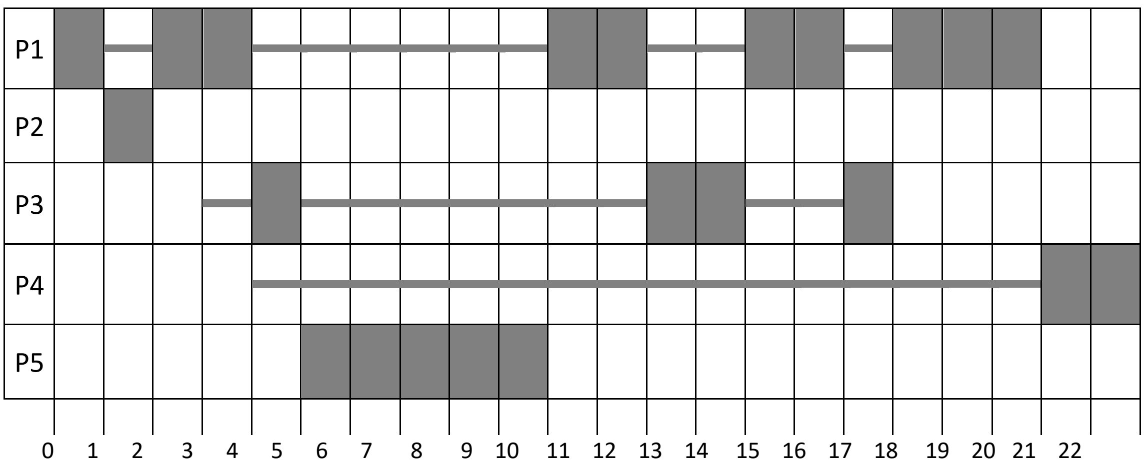


2. Scheduling with preemptive priorities.



- En el instante t=10, se pone a ejecutar P3 porque estaba a la cola de listos antes que P1.

3. Scheduling with preemptive priorities and Round Robin (q=2) for equal priority processes.



- In time t=10, P1 is run as it was in the ready queue before P3.

b) .

	P1	**P2**	**P3**	**P4**	**P5**

Fifo	0	9	8	11	12
Priorities	10	0	7	16	0
Priorities and Round Robin	10	0	10	16	0

Exercise 2

In a given operating system, process scheduling is carried out according to priority. The system has three priority levels (1, 2 and 3), with 1 being the highest priority level and 3 the least priority. Within each priority level, round-robin scheduling is performed with a 200 ms time slice.

Furthermore, an aging algorithm is used to avoid starvation of the less priority processes. If a process remains 600 ms. in a queue of a certain priority level without executing, it is passed to the next higher queue. When that process is kicked out of the CPU, it returns to its original priority queue. If applied to a process that is in the highest priority queue, the aging algorithm is admitted that its priority can be even higher (negative number of priority is allowed).

The following table specifies a set of processes with their priority, their arrival time and the total time required for their execution.

Process	Priority	Arrival T.	Execution T.
P1	3	100	600
P2	2	200	500
P3	1	300	200
P4	1	400	300
P5	2	500	700

Calculate:

a) The time that each process remains on hold from its arrival in the system until it ends.

b) The return time of each process (time elapsed since the process arrives until its execution ends).

c) Average waiting time and average return time.

Repeat the calculations in case the policy used in each priority queue is FIFO.

Repeat the calculations in case the policy used in each priority queue is FIFO.

SOLUTION

The following table expresses the evolution of the processes in the CPU and in the queues. Each process is expressed by 4 values (pe, pr, tr, te), where pe represents the effective priority, pr the actual priority, tr the remaining time and te the aging time.

T	CPU	Q1	Q2	Q3
100	P1(3,3,600,0)			
200	P2(2,2,500,0)			P1(3,3,500,0)
300	P3(1,1,200,0)		P2(2,2,400,0)	P1(3,3,500,100)
400	P3(1,1,100,0)	P4(1,1,300,0)	P2(2,2,400,100)	P1(3,3,500,200)
500	P3->FIN P4(1,1,300,0)		P2(2,2,400,200) P5(2,2,700,0)	P1(3,3,500,300)
800	P4->FIN P2(2,2,400,0)		P5(2,2,700,300) P1(2,3,500,0)	
1000	P5(2,2,700,0)		P1(2,3,500,200) P2(2,2,200,0)	
1200	P1(2,3,500,0)		P2(2,2,200,200) P5(2,2,500,0)	
1400	P2(2,2,200,0)		P5(2,2,500,0)	P1(3,3,300,0)
1600	P2->FIN P5(2,2,500,0)			P1(3,3,300,200)
1800	P5(2,2,300,0)			P1(3,3,300,400)
2000	P5(2,2,100,0)		P1(3,3,300,0)	
2100	P5-> FIN P1(3,3,300,0)			
2400	P1-> FIN			

Proces	**Tfin**	**Tret**	**Tesp**
P1	2400	2400-100=2300	2300-600=1700
P2	1600	1600-200=1400	1400-500=900
P3	500	500-300=200	200-200=0
P4	800	800-400=400	400-300=100
P5	2100	2100-500=1600	1600-700=900
Promedio		**1180**	**720**

En el caso de FIFO, se tiene:

T	CPU	Q1	Q2	Q3
100	P1(3,3,600,0)			
200	P2(2,2,500,0)			P1(3,3,500,0)

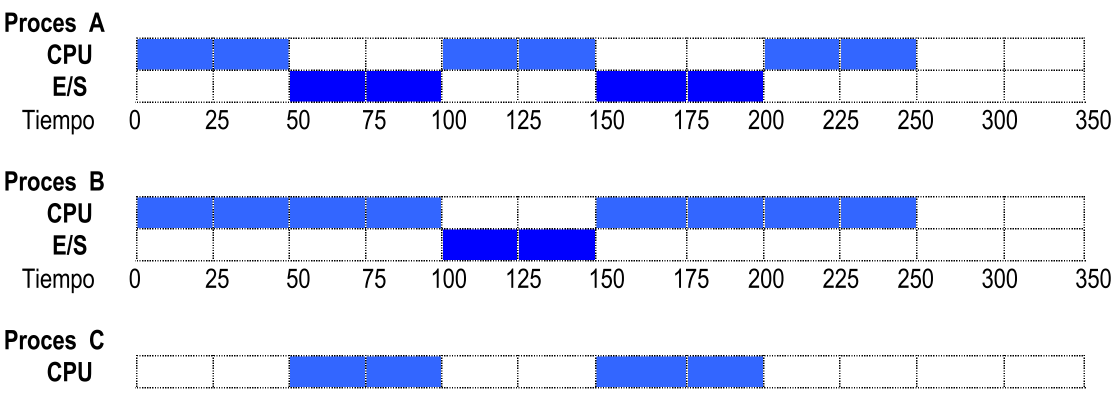
300	P3(1,1,200,0)		P2(2,2,400,0)	P1(3,3,500,100)
400	P3(1,1,100,0)	P4(1,1,300,0)	P2(2,2,400,100)	P1(3,3,500,200)
500	P3->FIN P4(1,1,300,0)		P2(2,2,400,200) P5(2,2,700,0)	P1(3,3,500,300)
800	P4->FIN P2(2,2,400,0)		P5(2,2,700,300) P1(2,3,500,0)	
1100	P5(1,2,700,0)		P1(2,3,500,300) P2(2,2,100,0)	
1400	P5(1,2,400,0)	P1(1,3,500,0)	P2(2,2,100,300)	
1700	P5(1,2,100,0)	P1(1,3,500,300) P2(1,2,100,0)		
1800	P5->FIN P1(1,3,500,0)	P2(1,2,100,100)		
2300	P1->FIN P2(1,2,100,0)			
2400	P2->FIN			

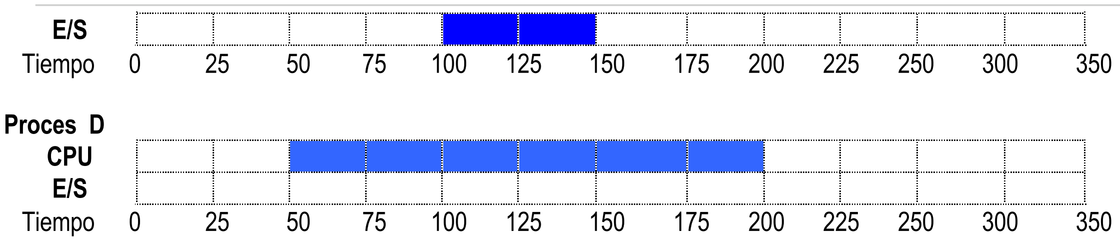
Proces	**Tfin**	**Tret**	**Tesp**
P1	2300	2300-100=2200	2200-600=1600
P2	2400	2400-200=2200	2200-500=1700
P3	500	500-300=200	200-200=0
P4	800	800-400=400	400-300=100
P5	1800	1800-500=1300	1300-700=600
Promedio		**1260**	**800**

Exercise 3.

Consider a multithreaded operating system in which 4 processes are running concurrently, whose separate theoretical execution traces are as follows.

Processes A and B are low priority, while processes C and D are high priority.





a) Represent the execution trace of the CPU (indicating which process is in the CPU at each moment), when a priority scheduling algorithm is used. Within each priority level, a Round Robin algorithm is used with a time slice of 40 units. Indicate the status of the scheduling queues at all times.

b) Determine the mean waiting time and the mean normalized return time.

SOLUTION:

Tiempo	En ejecución	Cola AP	Cola BP	Bloqueados
0	A (0 | 50)		B (0 | 100)	
40	B(0 | 100)		A (40 | 10)	
50	C (0 | 50)	D (0 | 150)	A (40 | 10), B (10 | 90)	
90	D (0 | 150)	C (40 | 10)	A (40 | 10), B (10 | 90)	
130	C (40 | 10)	D (40 | 110)	A (40 | 10), B (10 | 90)	
140	D (40 | 110)		A (40 | 10), B (10 | 90)	C (190)
180	D (80 | 70)		A (40 | 10), B (10 | 90)	C (190)
190	D (90 | 60)	C (50 | 50)	A (40 | 10), B (10 | 90)	
220	C (50 | 50)	D (120 | 30)	A (40 | 10), B (10 | 90)	
260	D (120 | 30)	C (90 | 10)	A (40 | 10), B (10 | 90)	
290 (Fin D)	C (90 | 10)		A (40 | 10), B (10 | 90)	
300 (Fin C)	A (40 | 10)		B (10 | 90)	
310	B (10 | 90)			A (360)
350	B (50 | 50)			A (360)
360	B (60 | 40)		A (50 | 50)	
390	A (50 | 50)		B (90 | 10)	
430	B (90 | 10)		A (90 | 10)	
440	A (90 | 10)			B (490)
450				B (490), A (500)
490	B (100 | 100)			A (500)
500	B (110 | 90)		A (100 | 50)	
530	A (100 | 50)		B (140 | 60)	
570	B (140 | 60)		A (140 | 10)	
610	A (140 | 10)		B (180 | 20)	
620 Fin A	B (180 | 20)			

Tiempo	En ejecución	Cola AP	Cola BP	Bloqueados
640 Fin B				

Proces	Llegada	Servicio	Inicio	Fin	Retorno	Espera	R Norm
A	0	250	0	620	620	620 – 250 = 370	620/250 = 2.48
B	0	250	40	640	600	600 – 250 = 350	600 / 250 = 2,4
C	50	150	50	300	300 – 50 = 250	250 – 150 = 100	250 / 150 = 1.667
D	50	150	90	290	290 -90 = 200	200 – 150 = 50	200 / 150 = 1,333

Normalized Turnaround time = 1,97

Exercise 4.

An operating system uses a cyclic (round-robin) scheduler. At any given moment there are no jobs running and you want to run four jobs whose arrival times to the system are as follows:

Process	Arrival Time
A	0
B	500
C	200
D	400

The execution traces of the processes indicate the following alternative sequences of execution in CPU and time required for I / O operations.

Proces A		Proces B		Proces C		Proces D	
CPU	E/S	CPU	E/S	CPU	E/S	CPU	E/S
200		20		500		1500	
	500		100		100		
100		40		1000			
			100				
		30					

			100				
		50					

When a context switch occurs, the operating system requires 10 TU to perform a full context switch. If the same process that was already running is selected, the context switch only requires 5 TUs.

On the other hand, when an I / O operation ends, a service treatment routine must be executed by the operating system for 5UT, after which the execution of the current process continues until its time slice is completely consumed. For simplicity, it is considered that each process performs input / output on a different device and there are no interactions between them. In the event of an I / O interrupt and a clock interrupt at the same time, the I / O interrupts are considered to have higher priority.

The cases with a time slice of 200 TU and 500 TU will be considered.

a) Service time (time spent on productive tasks: CPU / ES).

b) Waiting time (time that each process spends in waiting queues).

c) Average waiting time.

d) Return time (difference between arrival time and end time).

e) Normalized return time (ratio between return time and service time).

In addition, the student is asked to make a critical comment on the results.

<u>SOLUTION:</u>

200 UT slice:

Tiempo	En ejecución	Cola	E/S	Rodaja
0	A(200)			0
200	CC	C(500)	A(500)	200
210	C(500)		A(490)	0
400	C(310)	D(1500)	A(300)	190
410	CC	D(1500), C(300)	A(290)	200
420	D(1500)	C(300)	A(280)	0
500	D(1420)	C(300), B(20)	A(200)	80
620	CC	C(300), B(20), D(1300)	A(80)	200
630	C(300)	B(20), D(1300)	A(70)	0
700	E/S – A	C(230), B(20), D(1300)		70
705	C(230)	B(20), D(1300), A(100)		70
835	CC	B(20), D(1300), A(100), C(100)		200

Tiempo	En ejecución	Cola	E/S	Rodaja
845	B(20)	D(1300), A(100), C(100)		0
865	CC	D(1300), A(100), C(100)	B(100)	20
875	D(1300)	A(100), C(100)	B(90)	0
965	E/S – B	D(1210), A(100), C(100)		90
970	D(1210)	A(100), C(100), B(40)		90
1080	CC	A(100), C(100), B(40), D(1100)		200
1090	A(100)	C(100), B(40), D(1100)		0
1190	CC – Fin A	C(100), B(40), D(1100)		100
1200	C(100)	B(40), D(1100)		0
1300	CC	B(40), D(1100)	C(100)	100
1310	B(40)	D(1100)	C(90)	0
1350	CC	D(1100)	C(50)	40
1360	D(1100)		C(40), B(100)	0
1400	E/S – C	D(1060)	B(60)	40
1405	D(1060)	C(1000)	B(55)	40
1460	E/S – B	D(1005), C(1000)		95
1465	D(1005)	C(1000), B(30)		95
1570	CC	C(1000), B(30), D(900)		200
1580	C(1000)	B(30), D(900)		0
1780	CC	B(30), D(900), C(800)		200
1790	B(30)	D(900), C(800)		0
1820	CC – Fin B	D(900), C(800)		30
1830	D(900)	C(800)		0
2030	CC	C(800), D(700)		200
2040	C(800)	D(700)		0
2240	CC	D(700), C(600)		200
2250	D(700)	C(600)		0
2450	CC	C(600), D(500)		200
2460	C(600)	D(500)		0
2660	CC	D(500), C(400)		200
2670	D(500)	C(400)		0
2870	CC	C(400), D(300)		200
2880	C(400)	D(300)		0
3080	CC	D(300), C(200)		200
3090	D(300)	C(200)		0
3290	CC	C(200), D(100)		200
3300	C(200)	D(100)		0
3500	CC – Fin C	D(100)		200
3510	D(100)			0
3610	Fin D			

Proces	Llegada	Servicio	Fin	Retorno	Espera	Ret. N.
A	0	800	1190	1190	390	1.488
B	500	290	1820	1320	1030	4.551

C	200	1600	3500	3300	1700	2.063
D	400	1500	3610	3210	1710	2.14

Average waiting time 1207.05.
Average turnaround 2.561.

500 UT slice:

Tiempo	En ejecución	Cola	E/S	Rodaja
0	A(200)			0
200	CC	C(500)	A(500)	200
210	C(500)		A(490)	0
400	C(310)	D(1500)	A(300)	190
500	C(210)	D(1500), B(20)	A(200)	290
700	E/S – A	C(10), D(1500), B(20)		490
705	C(10)	D(1500), B(20), A(100)		490
715	CC	D(1500), B(20), A(100)	C(100)	500
725	D(1500)	B(20), A(100)	C(90)	0
815	E/S – C	D(1410), B(20), A(100)		90
820	D(1410)	B(20), A(100), C(1000)		90
1230	CC	B(20), A(100), C(1000), D(1000)		500
1240	B(20)	A(100), C(1000), D(1000)		0
1260	CC	A(100), C(1000), D(1000)	B(100)	20
1270	A(100)	C(1000), D(1000)	B(90)	0
1360	E/S – B	A(10), C(1000), D(1000)		90
1365	A(10)	C(1000), D(1000), B(40)		90
1375	CC – Fin A	C(1000), D(1000), B(40)		100
1385	C(1000)	D(1000), B(40)		0
1885	CC	D(1000), B(40), C(500)		500
1895	D(1000)	B(40), C(500)		0
2395	CC	B(40), C(500), D(500)		500
2405	B(40)	C(500), D(500)		0
2445	CC	C(500), D(500)	B(100)	40
2455	C(500)	D(500)	B(90)	0
2545	E/S – B	C(410), D(500)		90
2550	C(410)	D(500), B(30)		90
2960	CC – Fin C	D(500), B(30)		500
2970	D(500)	B(30)		0

Tiempo	En ejecución	Cola	E/S	Rodaja
3470	CC – Fin D	B(30)		500
3480	B(30)			0
3510	Fin B			

Proces	Llegada	Servicio	Fin	Retorno	Espera	Ret. N.
A	0	800	1375	1375	575	1.719
B	500	290	3510	3010	2720	10.379
C	200	1600	2960	2760	1160	1.725
D	400	1500	3470	2460	960	1.64

Average waiting time1353.75.
Average turnaround 3.866.

Critical comment: As the time slice increases, tasks with low interactivity and long execution periods (C and D) are favored. In addition, the total execution time of the job set is reduced.

Exercise 5

On a given operating system that schedules using priority queues, processes run based on their priority (1 being the highest). It is assumed that the processes enter the system in its priority queue and do not move from it.

When several processes have the same priority, a round robin scheduling policy is used, with a 100 ms slice. When the slice of a process is finished, it is put at the end of its priority queue.

The following table specifies for each process, its priority, its arrival time and the time it takes to execute, distinguishing CPU and blocking I / O.

Note: With blocking input / output the process frees the CPU and it is ready for the next process. When the I / O data is ready, the process moves to the ready-to-run queue, but at the end of its priority queue.

PROCESSES	PRIORITY	ARRIVAL	EXECUTION TIME
P1	3	0	250 CPU + 100 E/S + 200 CPU
P2	2	200	300 CPU
P3	1	400	100 CPU + 250 E/S + 50 CPU
P4	1	500	400 CPU
P5	2	400	100 CPU + 100 E/S + 100 CPU

For the following two situations:

a) Scheduling without expulsion. The preparation with the highest priority is chosen but the one who is there is not expelled.

b) Scheduling with expulsion. The one who is executing is expelled if one of higher priority arrives or his time slice expires.

It is requested

1. Make a cronogram of the execution of the processes.

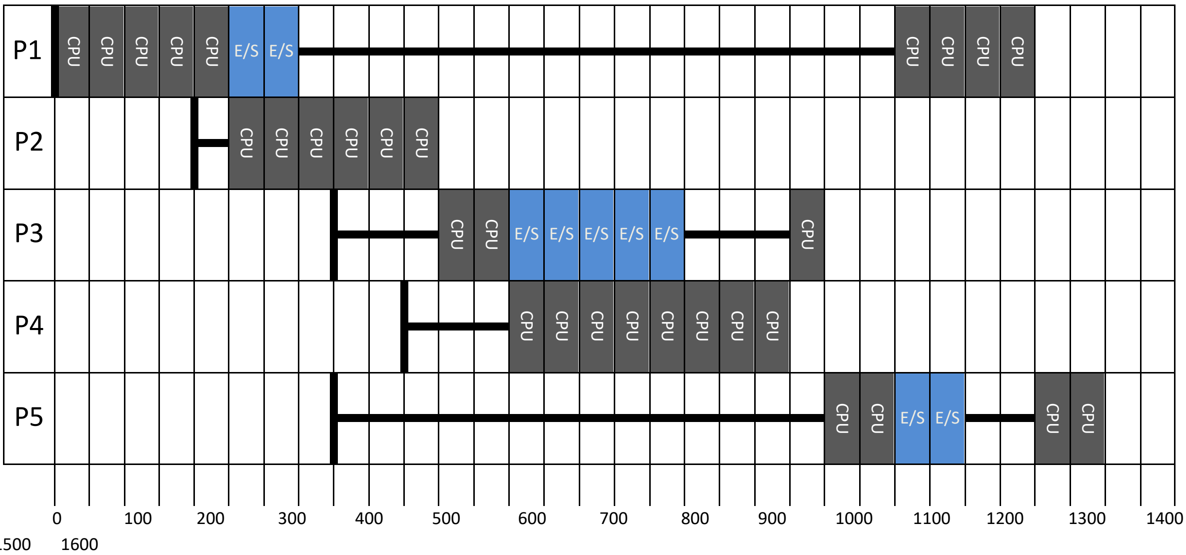
2. Calculate the time that each process is kept on hold from its arrival in the system until it ends.

3. Calculate the return time of each process (time elapsed since the process arrives until the end of its execution).

4. Average waiting time and average return time.

SOLUCIÓN Exercise 3: (Octubre. Examen Parcial 1. Leganés. Curso 2010-2011)

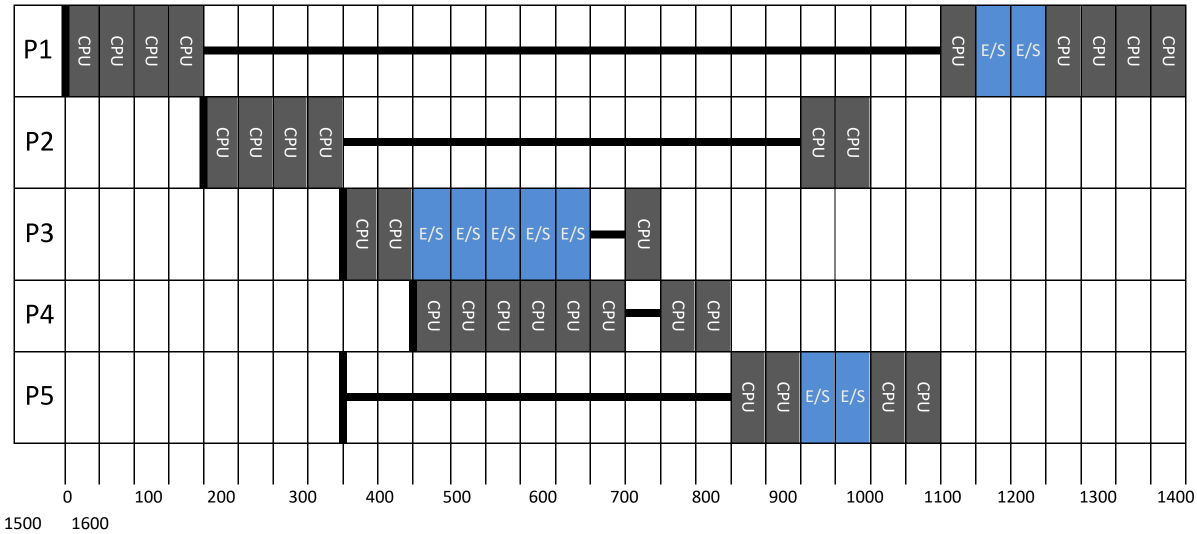
a) Non-preemptive scheduling:



	P1	P2	P3	P4	P5	Avg
Wait time (ms)	850	50	300	150	800	430
Turnaround time (ms)	1400	350	700	550	1100	820

b) Preemptive scheduling:

- Entra primero en la cola de listos el Proces nuevo que entra, no el expulsado → *implica que a los 950 ms el que ejecuta es P5, antes que P2*.

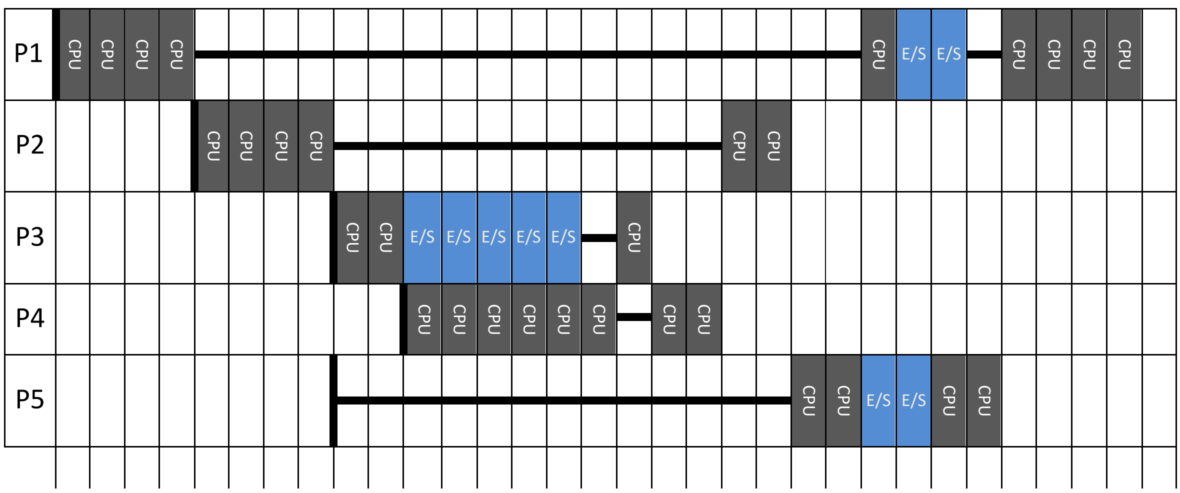


	P1	P2	P3	P4	P5	Avg
Wait time (ms)	1050	650	50	50	550	470
Turnaround time(ms)	1600	950	450	450	850	860

In addition to this solution, there is another possibility that has also been considered valid:

POSSIBILITY B: (Scheduling with expulsion)

• The process expulsed enters the ready queue first, not the new one that enters ◊ implies that at 950 ms the one that executes is P2, before P5.



0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600

	P1	P2	P3	P4	P5	Avg
Wait time (ms)	1000	550	50	50	650	460
Turnaround time (ms)	1550	850	450	450	950	850

Exercise 6.

In a given operating system, processes are executed based on multilevel queues with the following characteristics:

- The system has 3 queues:

  o The first one follows a Round-Robin scheduling algorithm with a quantum of 2ms.

  o The second follows a Round-Robin algorithm with a quantum of 4 ms.

  o The third follows a FIFO scheduling.

- The processes enter the system through the first queue.

- Processes are downgraded if the system expulses them from the processor due to quantum expiration.

- Scheduling between queues is based on priorities, with the first being the highest priority, then the second and then the third.

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Answer:

a) Draw a cronogram for the following set of processes:

PROCESSES	ARRIVAL	EXECUTION
P1	0	1ms CPU + 6ms E/S + 1ms CPU
P2	1	3 ms CPU
P3	3	5ms CPU + 3ms E/S + 1ms CPU
P4	3	3 ms CPU

Draw the solution in the following table:

Proces	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
P1																
P2																
P3																
P4																

b) Indicate for each process their time of stay in the system and the penalty time suffered by each one of them.

c) What is the worst treated process?

SOLUCIÓN Exercise 3: (Octubre. Examen Parcial 2. Leganés. Curso 2010-2011)

a)

Proces	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
P1	CPU	E/S	E/S	E/S	E/S	E/S	E/S	CPU								
P2		CPU	CPU						CPU							
P3				CPU	CPU					CPU	CPU	CPU	E/S	E/S	E/S	CPU
P4						CPU	CPU						CPU			

b)

Process	Stay	Penalty
P1	8	0
P2	8	5
P3	13	4
P4	10	7

c) The worst treated process is process 4 since it takes 10 periods to finish its execution, when it only has 3 execution periods, it suffers 7 penalty periods.

Exercise 7.

An operating system uses a cyclic (round-robin) scheduler. At a given moment there are no jobs running and you want to run jobs whose arrival times to the system are as follows:

Priorities are inverse of their value. Thus, a process with priority 1 is prioritized over another with priority 2 or 3.

You are asked to fill in the following tables in the following cases:

a) Round-robin scheduling policy with slice of 1

b) Round-robin scheduling policy with slice of 4

c) SJF (Shortest Job First) scheduling Policy (Non-Expulsive)

NOTE: If the execution slice of a process ends at the same instant that a new process arrives on the system, then the new process is placed in the ready-to-run queue before the process that expires the slice.

SOLUCIÓN Exercise 2: (Octubre. Examen Parcial 1. Colmenarejo. Curso 2010-2011)

a) *round-robin*, slice 1

A	5														4		3		2		1			
B		7														6		5		4		3	2	1
C			5	4		3						2		1										
D					3						2		1											
E							4	3	2	1														
Tiempo	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

Process	End time	Turnaround	Execution time	Wait time	Turnaround normalized
A	21	21-0=21	5	21-5=16	21/5=4,2
B	23	24-1=23	7	23-7=16	23/7=3,3

C	14	14-2=12	5	12-5=7	12/5=2,4
D	13	13-4=9	3	9-3=6	9/3=3
E	10	10-6=4	4	4-4=0	6/6=1
Average		13,8	4,8	9	2,78

b) *round-robin* slice = 4

A	5	4																3	2	1				
B															7	6	5				4	3	2	1
C			5	4	3						2	1												
D						3							2	1										
E							4	3	2	1														
Tiempo	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

Process	End time	Turnaround	Execution time	Wait time	Turnaround normalizado
A	20	20-0=20	5	20-5=15	20/5=4
B	24	24-1=23	7	23-7=16	23/7=3,3
C	12	12-2=10	5	10-5=5	10/5=2
D	14	14-4=10	3	10-3=7	10/3=3,3
E	10	10-6=4	4	4-4=0	4/4=1
Valores medios		13,4	4,8	8,6	2,72

c) SJF (*Shortest Job First*)

A	5	4	3	2	1																			
B																		7	6	5	4	3	2	1
C													5	4	3	2	1							
D						3	2	1																
E									4	3	2	1												
Tiempo	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

Process	End time	Turnaround	Execution time	Wait time	Turnaround normalizado
A	5	5-0=5	5	5-5=0	5/5=1
B	24	24-1=23	7	23-7=16	23/7=3,3
C	17	17-2=15	5	15-5=10	15/5=3
D	8	8-4=6	3	6-3=3	6/3=2
E	12	12-6=6	4	6-4=2	6/4=1,5
Valores medios		11	4,8	6,2	2,16