

Worked Problems in Short-Term (Processor) Scheduling

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PROBLEM:

Several processes enter the ready queue in the order shown. Each I/O takes 20 msec, and I/Os are executed on a separate, dedicated device for each process, so that the I/Os for different processes can run simultaneously. Context switching takes less than 100 μ sec, and can therefore be ignored. **Lower** priority numbers correspond to **higher** process priority.

Time of Arrival	Process ID	CPU Burst Time (msec)	Process Priority (useful <u>only</u> with regard to Priority Scheduling)
0.0 msec	P1	6	3
1.0 msec	P2	14	7
2.0 msec	P3	22	2
3.0 msec	P4	73	3
4.0 msec	P5	29	1

For each indicated algorithm, indicate the order in which the various processes run, and the start time for each process,. Note that in the mid-term exam, for each algorithm you were asked to determine the first four processes to run on the CPU. However, for the final exam you will be given a smaller number of algorithms to work out, but you will have to determine for each algorithm a larger number of scheduling choices. Therefore, in these worked examples the number of scheduling decisions worked for each algorithm is more than four.

Algorithm	Process	Start Time
First-Come First-Served (FCFS)		0 msec
Shortest Job First (SJF) - Preemptive version		0 msec
Shortest Job First (SJF) - NON-preemptive version		0 msec

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Round Robin (time quantum = 4 msec)		0 msec
Round Robin (time quantum = 10 msec)		0 msec
Non-preemptive Priority Scheduling (simple priority: NO aging, NO adjustments of any kind in process priority)		0 msec

The following set of tables is provided for your assistance in figuring out the answers to the Short-Term Scheduling problem.

ABBREVIATIONS:

PID: “Process Identifier”

RBT: “Remaining [CPU] Burst Time”

trrq: “time of return to ready queue”

First-Come-First-Served (FCFS):

Time: 0 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P1	6	First:		
Second:			Second:		
Third:			Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 6 msec. P2 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P1	26
Second:	P3	22	Second:		
Third:	P4	73	Third:		
Fourth:	P5	29	Fourth:		
Fifth:			Fifth:		

Time: 20 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P3	22	First:	P1	26
Second:	P4	73	Second:	P2	40
Third:	P5	29	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 42 msec. P4 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P3	62
Second:	P5	29	Second:		
Third:	P1	6	Third:		
Fourth:	P2	14	Fourth:		
Fifth:			Fifth:		

Worked Problems on Short-Term (Processor) Scheduling

Time: 115 msec. P5 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P5	29	First:	P4	135
Second:	P1	6	Second:		
Third:	P2	14	Third:		
Fourth:	P3	22	Fourth:		
Fifth:			Fifth:		

Time: 144 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P1	6	First:	P5	164
Second:	P2	14	Second:		
Third:	P3	22	Third:		
Fourth:	P4	73	Fourth:		
Fifth:			Fifth:		

Time: 150 msec. P2 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P5	164
Second:	P3	22	Second:	P1	170
Third:	P4	73	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 164 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P3	22	First:	P1	170
Second:	P4	73	Second:	P2	184
Third:	P5	29	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

PID	Start Time
P1	0
P2	6
P3	20
P4	42
P5	115
P1	144
P2	150
P3	164

PREEMPTIVE Shortest Job First (SJF)

Time: 0 msec. P1 runs					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P1	6	First:		
Second:			Second:		
Third:			Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 1 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:		
Second:	P1	5	Second:		
Third:			Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Worked Problems on Short-Term (Processor) Scheduling

Time: 2 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:		
Second:	P3	22	Second:		
Third:	P1	4	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 3 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:		
Second:	P3	22	Second:		
Third:	P4	73	Third:		
Fourth:	P1	3	Fourth:		
Fifth:			Fifth:		

Time: 4 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:		
Second:	P3	22	Second:		
Third:	P4	73	Third:		
Fourth:	P5	29	Fourth:		
Fifth:	P1	2	Fifth:		

Time: 6 msec. P2 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P1	26
Second:	P3	22	Second:		
Third:	P4	73	Third:		
Fourth:	P5	29	Fourth:		
Fifth:			Fifth:		

Time: 20 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P3	22	First:	P1	26
Second:	P4	73	Second:	P2	40
Third:	P5	29	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 26 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P2	40
Second:	P5	29	Second:		
Third:	P1	6	Third:		
Fourth:	P3	16	Fourth:		
Fifth:			Fifth:		

Time: 32 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P2	40
Second:	P5	29	Second:	P1	52
Third:	P3	16	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 40 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P1	52
Second:	P5	29	Second:		
Third:	P2	14	Third:		
Fourth:	P3	8	Fourth:		
Fifth:			Fifth:		

Worked Problems on Short-Term (Processor) Scheduling

Time: 48 msec. P2 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P1	52
Second:	P5	29	Second:	P3	68
Third:	P2	14	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 52 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P3	68
Second:	P5	29	Second:		
Third:	P2	10	Third:		
Fourth:	P1	6	Fourth:		
Fifth:			Fifth:		

Time: 58 msec. P2 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P3	68
Second:	P5	29	Second:	P1	78
Third:	P2	10	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 68 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P1	78
Second:	P5	29	Second:	P2	88
Third:	P3	22	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

PID	Start Time
P1	0
P2	6
P3	20
P1	26
P3	32
P2	48
P1	52
P2	58
P3	68

NON-Preemptive Shortest Job First (SJF)

Time: 0 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P1	6	First:		
Second:			Second:		
Third:			Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 6 msec. P2 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P1	26
Second:	P3	22	Second:		
Third:	P4	73	Third:		
Fourth:	P5	29	Fourth:		
Fifth:			Fifth:		

Worked Problems on Short-Term (Processor) Scheduling

Time: 20 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P3	22	First:	P1	26
Second:	P4	73	Second:	P2	40
Third:	P5	29	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 42 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P3	62
Second:	P5	29	Second:		
Third:	P1	6	Third:		
Fourth:	P2	14	Fourth:		
Fifth:			Fifth:		

Time: 48 msec. P2 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P3	62
Second:	P5	29	Second:	P1	70
Third:	P2	14	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 62 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P1	70
Second:	P5	29	Second:	P2	82
Third:	P3	22	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 84 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P3	104
Second:	P5	29	Second:		
Third:	P3	22	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 90 msec. P2 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P3	104
Second:	P5	29	Second:	P1	110
Third:	P2	14	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 104 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P1	110
Second:	P5	29	Second:	P2	124
Third:	P3	22	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 126 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:	P3	146
Second:	P5	29	Second:		
Third:	P1	6	Third:		
Fourth:	P2	14	Fourth:		
Fifth:			Fifth:		

Worked Problems on Short-Term (Processor) Scheduling

PID	Start Time
P1	0
P2	6
P3	20
P1	42
P2	48
P3	62
P1	84
P2	90
P3	104
P1	126

Round Robin (Time Quantum = 4 msec)

Time: 0 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P1	6	First:		
Second:			Second:		
Third:			Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 4 msec. P2 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:		
Second:	P3	22	Second:		
Third:	P4	73	Third:		
Fourth:	P5	29	Fourth:		
Fifth:	P1	2	Fifth:		

Time: 8 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P3	22	First:		
Second:	P4	73	Second:		
Third:	P5	29	Third:		
Fourth:	P1	2	Fourth:		
Fifth:	P2	10	Fifth:		

Time: 12 msec. P4 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:		
Second:	P5	29	Second:		
Third:	P1	2	Third:		
Fourth:	P2	10	Fourth:		
Fifth:	P3	18	Fifth:		

Time: 16 msec. P5 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P5	29	First:		
Second:	P1	2	Second:		
Third:	P2	10	Third:		
Fourth:	P3	18	Fourth:		
Fifth:	P4	69	Fifth:		
Time: 22 msec. P2 runs.					

Time: 20 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P1	2	First:		
Second:	P2	10	Second:		
Third:	P3	18	Third:		
Fourth:	P3	P4	69	Fourth:	
Fifth:	18	P5	25	Fifth:	
Time: 26 msec. P3 runs.					

Worked Problems on Short-Term (Processor) Scheduling

READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	10	First:	P1	42
Second:	P3	18	Second:		
Third:	P4	69	Third:		
Fourth:	P5	25	Fourth:		
Fifth:			Fifth:		

READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P3	18	First:	P1	42
Second:	P4	69	Second:		
Third:	P5	25	Third:		
Fourth:	P2	6	Fourth:		
Fifth:			Fifth:		

Time: 30 msec. P4 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	69	First:	P1	42
Second:	P5	25	Second:		
Third:	P2	6	Third:		
Fourth:	P3	14	Fourth:		
Fifth:			Fifth:		

Time: 34 msec. P5 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P5	25	First:	P1	42
Second:	P2	6	Second:		
Third:	P3	14	Third:		
Fourth:	P4	65	Fourth:		
Fifth:			Fifth:		

Time: 38 msec. P2 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	6	First:	P1	42
Second:	P3	14	Second:		
Third:	P4	65	Third:		
Fourth:	P5	21	Fourth:		
Fifth:			Fifth:		

Time: 42 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P3	14	First:		
Second:	P4	65	Second:		
Third:	P5	21	Third:		
Fourth:	P1	6	Fourth:		
Fifth:	P2	6	Fifth:		

PID	Start Time
P1	0
P2	4
P3	8
P4	12
P5	16
P1	20
P2	22
P3	26
P4	30
P5	34
P2	38
P3	42

Worked Problems on Short-Term (Processor) Scheduling

Round Robin (Time Quantum = 10 msec)

Time: 0 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P1	6	First:		
Second:			Second:		
Third:			Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 6 msec. P2 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P1	26
Second:	P3	22	Second:		
Third:	P4	73	Third:		
Fourth:	P5	29	Fourth:		
Fifth:			Fifth:		

Time: 16 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P3	22	First:	P1	26
Second:	P4	73	Second:		
Third:	P5	29	Third:		
Fourth:	P2	4	Fourth:		
Fifth:			Fifth:		

Time: 26 msec. P4 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	73	First:		
Second:	P5	29	Second:		
Third:	P2	4	Third:		
Fourth:	P1	6	Fourth:		
Fifth:	P3	12	Fifth:		

Time: 36 msec. P5 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P5	29	First:		
Second:	P2	4	Second:		
Third:	P1	6	Third:		
Fourth:	P3	12	Fourth:		
Fifth:	P4	63	Fifth:		

Time: 46 msec. P2 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	4	First:		
Second:	P1	6	Second:		
Third:	P3	12	Third:		
Fourth:	P4	63	Fourth:		
Fifth:	P5	19	Fifth:		

Time: 50 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P1	6	First:	P2	70
Second:	P3	12	Second:		
Third:	P4	63	Third:		
Fourth:	P5	19	Fourth:		
Fifth:			Fifth:		

Time: 56 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P3	12	First:	P2	70
Second:	P4	63	Second:	P1	76
Third:	P5	19	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Worked Problems on Short-Term (Processor) Scheduling

Time: 66 msec. P4 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P4	63	First:	P2	70
Second:	P5	19	Second:	P1	76
Third:	P3	2	Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 76 msec. P5 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P5	2	First:		
Second:	P2	14	Second:		
Third:	P3	2	Third:		
Fourth:	P4	53	Fourth:		
Fifth:	P1	6	Fifth:		

PID	Start Time
P1	0
P2	6
P3	16
P4	26
P5	36
P2	46
P1	50
P3	56
P4	66
P5	76

NON-Preemptive Priority

Time: 0 msec. P1 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P1	6	First:		
Second:			Second:		
Third:			Third:		
Fourth:			Fourth:		
Fifth:			Fifth:		

Time: 6 msec. P5 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P1	26
Second:	P3	22	Second:		
Third:	P4	73	Third:		
Fourth:	P5	29	Fourth:		
Fifth:			Fifth:		

Time: 35 msec. P3 runs					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P5	55
Second:	P3	22	Second:		
Third:	P4	73	Third:		
Fourth:	P1	6	Fourth:		
Fifth:			Fifth:		

Time: 57 msec. P5 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P3	77
Second:	P4	73	Second:		
Third:	P1	6	Third:		
Fourth:	P5	29	Fourth:		
Fifth:			Fifth:		

Worked Problems on Short-Term (Processor) Scheduling

Time: 86 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P5	106
Second:	P4	73	Second:		
Third:	P1	6	Third:		
Fourth:	P3	22	Fourth:		
Fifth:			Fifth:		

Time: 108 msec. P5 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P3	128
Second:	P4	73	Second:		
Third:	P1	6	Third:		
Fourth:	P5	29	Fourth:		
Fifth:			Fifth:		

Time: 137 msec. P3 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P5	157
Second:	P4	73	Second:		
Third:	P1	6	Third:		
Fourth:	P3	22	Fourth:		
Fifth:			Fifth:		

Time: 159 msec. P5 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P3	179
Second:	P4	73	Second:		
Third:	P1	6	Third:		
Fourth:	P5	29	Fourth:		
Fifth:			Fifth:		

Time: 188 msec. P3 runs					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P5	208
Second:	P4	73	Second:		
Third:	P1	6	Third:		
Fourth:	P3	22	Fourth:		
Fifth:			Fifth:		

Time: 210 msec. P5 runs.					
READY Queue			WAIT Queue		
Element	PID	RBT	Element	PID	trrq
First:	P2	14	First:	P3	230
Second:	P4	73	Second:		
Third:	P1	6	Third:		
Fourth:	P5	29	Fourth:		
Fifth:			Fifth:		

PID	Start Time
P1	0
P5	6
P3	35
P5	57
P3	86
P5	57
P3	86
P5	108
P3	137
P5	159
P3	188
P5	210