COMP 2432 Operating Systems

Tutorial 7 Solution

1. CPU Scheduling.

FCFS

```
11111 11112 22223 34445 55555
          ^     ^  ^  ^       4 decisions
```

Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	0	9
2	5	1	7	8	13
3	2	2	2	12	14
4	3	3	7	13	16
5	6	4	4	15	21
Avg.				9.6	14.6

SJF

```
11111 11113 34442 22225 55555
          ^  ^  ^     ^       4 decisions
```

Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	0	9
2	5	1	7	13	18
3	2	2	2	7	9
4	3	3	7	8	11
5	6	4	4	15	21
Avg.				8.6	13.6

SRT

```
12334 44222 25555 55111 11111
 ^^^^   ^    ^      ^         7 decisions
```

Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	16	25
2	5	1	7	5	10
3	2	2	2	0	2
4	3	3	7	1	4
5	6	4	4	7	13
Avg.				5.8	10.8

Prior (Unix/Linux)

```
11111 11113 35555 55222 22444
          ^  ^      ^     ^   4 decisions
```

Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	0	9
2	5	1	7	16	21
3	2	2	2	7	9
4	3	3	7	19	22
5	6	4	4	7	13
Avg.				9.8	14.8

Prior (Windows)

```
11111 11112 22224 44555 55533
          ^     ^   ^      ^  4 decisions
```

Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	0	9
2	5	1	7	8	13
3	2	2	2	21	23
4	3	3	7	11	14
5	6	4	4	13	19
Avg.				10.6	15.6

Prior Preempt (Unix/Linux)

```
11331 11111 15555 55222 22444
 ^^^^        ^      ^     ^   7 decisions
```

Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	2	11
2	5	1	7	16	21
3	2	2	2	0	2
4	3	3	7	19	22
5	6	4	4	7	13
Avg.				8.8	13.8

Prior Preempt (Windows)

```
12222 24441 11111 11555 55533
 ^^^^  ^  ^         ^      ^  8 decisions
```

Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	8	17
2	5	1	7	0	5
3	2	2	2	21	23
4	3	3	7	3	6
5	6	4	4	13	19
Avg.				9.0	14.0

RR, with quantum 5

```
11111 22222 33444 55555 11115
     ^     ^  ^  ^     ^    ^ 6 decisions
```

Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	15	24
2	5	1	7	4	9
3	2	2	2	8	10
4	3	3	7	9	12
5	6	4	4	15	21
Avg.				10.2	15.2

RR, with quantum 4

```
11112 22233 44411 11555 52155
   ^    ^ ^   ^    ^    ^^^  8 decisions
```

Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	14	23
2	5	1	7	16	21
3	2	2	2	6	8
4	3	3	7	7	10
5	6	4	4	15	21
Avg.				11.6	16.6

RR, with quantum 3

```
11122 23311 14445 55221 11555
  ^   ^ ^   ^  ^   ^ ^   ^   8 decisions
```

Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	13	22
2	5	1	7	13	18
3	2	2	2	4	6
4	3	3	7	8	11
5	6	4	4	15	21
Avg.				10.6	15.6

RR, with quantum 2

```
11221 13344 22551 14255 11551
  ^ ^  ^ ^ ^  ^ ^  ^^^  ^ ^ ^ 13 decisions
```

Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	16	25
2	5	1	7	12	17
3	2	2	2	4	6
4	3	3	7	11	14
5	6	4	4	14	20
Avg.				11.4	16.4

2. More CPU Scheduling.

FCFS

```
1111111111111111122222222223333344445555555555555
              ^         ^    ^   ^
```

4 decisions

Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	0	17	8.5
P2	10	1	7	16	26	21.0
P3	5	2	2	25	30	27.5
P4	4	3	7	29	33	31.0
P5	13	4	4	32	45	38.5
Avg.				20.4	30.2	25.3

SJF

```
1111111111111111144443333322222222225555555555555
                ^   ^    ^         ^
```

4 decisions

Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	0	17	8.5
P2	10	1	7	25	35	30.0
P3	5	2	2	19	24	21.5
P4	4	3	7	14	18	16.0
P5	13	4	4	32	45	38.5
Avg.				18.0	27.8	22.9

SRT

```
1233333444422222222255555555555551111111111111111
 ^^^^  ^   ^        ^           ^
```

8 decisions

Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	32	49	40.5
P2	10	1	7	9	19	14.0
P3	5	2	2	0	5	2.5
P4	4	3	7	4	8	6.0
P5	13	4	4	16	29	22.5
Avg.				12.2	22.0	17.1

Prior (Unix/Linux)

```
1111111111111111133333555555555555522222222224444
                ^    ^           ^         ^
```

4 decisions

Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	0	17	8.5
P2	10	1	7	34	44	39.0
P3	5	2	2	15	20	17.5
P4	4	3	7	42	46	44.0
P5	13	4	4	18	31	24.5
Avg.				21.8	31.6	26.7

Prior (Windows)

```
1111111111111111122222222224444555555555555533333
              ^         ^   ^           ^
```

4 decisions

Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	0	17	8.5
P2	10	1	7	16	26	21.0
P3	5	2	2	42	47	44.5
P4	4	3	7	24	28	26.0
P5	13	4	4	27	40	33.5
Avg.				21.8	31.6	26.7

Prior Preempt (Unix/Linux)

```
1133333111111111111111555555555555522222222224444
 ^^^^  ^             ^           ^         ^
```

8 decisions

Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	5	22	13.5
P2	10	1	7	34	44	39.0
P3	5	2	2	0	5	2.5
P4	4	3	7	42	46	44.0
P5	13	4	4	18	31	24.5
Avg.				19.8	29.6	24.7

Prior Preempt (Windows)

```
1222222222244441111111111111111555555555555533333
 ^^^^     ^   ^              ^           ^
```

8 decisions

Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	14	31	22.5
P2	10	1	7	0	10	5.0
P3	5	2	2	42	47	44.5
P4	4	3	7	8	12	10.0
P5	13	4	4	27	40	33.5
Avg.				18.2	28.0	23.1

RR, with quantum 5

```
1111122222333333444455555111112222255555111115551 1
    ^    ^   ^   ^    ^    ^    ^    ^    ^  ^
```

10 decisions

Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	32	49	27.5
P2	10	1	7	23	33	9.0
P3	5	2	2	8	13	10.5
P4	4	3	7	12	16	14.0
P5	13	4	4	30	43	31.5
Avg.				21.0	30.8	18.5

RR, with quantum 4

```
1111222233334444111155552222311115555221111555515
   ^   ^   ^   ^   ^   ^   ^^   ^  ^ ^   ^   ^^
```

14 decisions

Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	31	48	29.5
P2	10	1	7	28	38	24.0
P3	5	2	2	22	27	8.5
P4	4	3	7	9	13	11.0
P5	13	4	4	32	45	31.5
Avg.				24.4	34.2	20.9

RR, with quantum 3

```
1112223331114445552223311145552221115552111555115
  ^  ^  ^  ^  ^  ^  ^ ^  ^^  ^  ^  ^  ^^  ^  ^ ^
```

18 decisions

Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	31	48	25.5
P2	10	1	7	29	39	19.0
P3	5	2	2	16	21	6.5
P4	4	3	7	20	24	11.0
P5	13	4	4	32	45	32.5
Avg.				25.6	35.4	18.9

RR, with quantum 2

```
1122113344225511334422551132255112255115511551151
 ^ ^ ^ ^ ^ ^ ^ ^ ^ ^ ^ ^^ ^ ^ ^ ^ ^ ^ ^ ^ ^ ^^
```

25 decisions

Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	32	49	31.5
P2	10	1	7	24	34	20.0
P3	5	2	2	20	25	14.5
P4	4	3	7	13	17	7.0
P5	13	4	4	31	44	31.5
Avg.				24.0	33.8	20.9

It can be observed that the number of context switching decisions is higher in preemptive scheduling when compared with non-preeptive scheduling. This should have been quite expected as each process may take more rounds to execute. The number of context switching decisions is higher in round-robin scheduling since processes are taking turn to use the CPU. Under robin-robin scheduling, the number of context switching decisions also goes up rapidly when the time quantum is reduced, especially when the burst time of processes becomes higher. This is again a natural expectation that it takes more CPU rounds for the processes to finish execution.

Optimal turnaround time is observed for SRT and SJF, as expected. The turnaround time would in general increase with smaller time quantum in round-robin as we probably would expect, but the trend actually would reverse when larger time quantum is used in this particular question. However, more cases should be studied before a conclusion could be drawn, e.g. by means of simulation of many varying cases. The waiting time is highly related to turnaround time and will show similar trend and behavior as turnaround time.

With respect to the response time, it can be seen that for most cases, the response time is about the average of waiting time and turnaround time, since it occurs right at the middle of the process execution. However, for round-robin, the response time is in general lower. This is also the rationale behind adopting round-robin in order to enhance response by giving the CPU to each process in turn.

3. Multi-level Scheduling.

Fixed Priority Scheduling.

```
Multi-level Feedback Queue: fixed priority
11221 13344 22553 34455
Queue 1 becomes empty at time 20
Processes on queue 2 can now begin
                        11122 23334 44555 22233 3445
Queue 2 becomes empty at time 44
Processes on queue 3 can now begin
                                                    2 2333
Queue 2 becomes empty at time 49
```

```
Summarizing
Q1: 11221 13344 22553 34455
Q2:                         11122 23334 44555 22233 3445
Q3:                                                   2 2333
```

Pid	Burst	Arr	Prior	Wait	TR
1	7	0	-	16	23
2	12	1	-	33	45
3	13	2	-	34	47
4	9	3	-	31	40
5	8	4	-	32	40
Avg.				29.2	39.0

Time Slicing Scheduling.

```
Multi-level Feedback Queue: time slicing
Pay attention to when each queue uses up its time slice
11221 13344 22
Queue 1 uses up its time slice at time 12
Processes on queue 2 can now begin, P1, P2 are there in that order
              111 222
Queue 2 uses up its time slice at time 18
Queue 3 is empty at time 18
Queue 1 continues to use its next time slice
                      55 33445 5
Queue 1 becomes empty at time 26
Processes on queue 2 can now begin, P2, P3, P4, P5 are there in that order
                                 2223 33
Queue 2 uses up its time slice at time 32
Processes on queue 3 can now begin, P2 is there
                                       22
Queue 3 becomes empty at time 34
Queue 2 continues to use its next time slice
                                         4 44555
Queue 2 uses up its time slice at time 40, but queue 1 and 3 are empty
Queue 2 continues to use its next time slice
                                                  33344 5
Queue 2 becomes empty at time 46
Processes on queue 3 can now begin, P3 is there
                                                        33
Queue 3 uses up its time slice at time 48, but queue 1 and 2 are empty
Queue 3 continues to use its next time slice
                                                          3
Queue 3 becomes empty at time 49
```

```
Summarizing
Q1: 11221 13344 22       55 33445 5
Q2:               111 222          2223 33  4 44555 33344 5
Q3:                                     22               333
```

Pid	Burst	Arr	Prior	Wait	TR
1	7	0	-	8	15
2	12	1	-	21	33
3	13	2	-	34	47
4	9	3	-	33	42
5	8	4	-	34	42
Avg.				26.0	35.8