COMP 2432 Operating Systems

Tutorial 7 Solution

1. CPU Scheduling.

1. CI	U Scheu	unng	•								
FCFS						SJF					
11111	11112 2	2223	34445 5	5555		11111	11113 3	4442	22225 5	5555	
	^	^	^ ^	4	decisions		^	^ ^	^	4	decisions
Pid	Burst	Arr	Prior	Wait	TR	Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	0	9	1	9	0	4	0	9
2	5	1	7	8	13	2	5	1	7	13	18
3	2	2	2	12	14	3	2	2	2	7	9
4	3	3	7	13	16	4	3	3	7	8	11
5	6	4	4	15	21	5	6	4	4	15	21
_	0	4	4	_			6	4	4	_	
Avg.				9.6	14.6	Avg.				8.6	13.6
SRT							(Unix/I				
	44222 2			1111		11111	11113 3				
^^^^	^	^	^	7	decisions			^	^	^ 4	decisions
Pid	Burst	Arr	Prior	Wait	TR	Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	16	25	1	9	0	4	0	9
2	5	1	7	5	10	2	5	1	7	16	21
3	2	2	2	0	2	3	2	2	2	7	9
4	3	3	7	1	4	4	3	3	7	19	22
5	6	4	4	7	13	5	6	4	4	7	13
	U	**	**	-	10.8		U	**	*		14.8
Avg.	/==· -			٥.8	10.0	Avg.		/ -	/ - ·		14.0
	(Window	-					Preempt				
11111	11112 2						11111 1				
	^	^	^	^ 4	decisions	^^^^		^	^	^ 7	decisions
Pid	Burst	Arr	Prior	Wait	TR	Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	0	9	1	9	0	4	2	11
2	5	1	7	8	13	2	5	1	7	16	21
3	2	2	2	21	23	3	2	2	2	0	2
4	3	3	7	11	14	4	3	3	7	19	22
	6	_	4			_		4		_	
5	6	4	4	13	19	5	6	4	4	7	13
Avg.				10.6	15.6	Avg.				8.8	13.8
Prior	Preempt	(Win	idows)			RR, w	ith quan	tum 5	i		
	24441 1	1111	11555 5	5533		11111	22222 3	3444	55555 1	.1115	
^^^^	^ ^		^	^ 8	decisions	^	. ^	^ ^	^	^ 6	decisions
Pid	Burst	Arr	Prior	Wait	TR	Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	8	17	1	9	0	4	15	24
2	5	1	7	0	5	2	5	1	7	4	9
3	2	2	2	21	23	3	2	2	2	8	10
	3	3	7	3	_	4		3	7		12
4	_		· -		6	_	3		=	9	
5	6	4	4	13	19	5	6	4	4	15	21
Avg.				9.0	14.0	Avg.				10.2	15.2
	ith quan						ith quan				
11112	22233 4	4411	11555 5	2155		11122	23311 1	4445	55221 1	.1555	
^	^ ^	^	^	^^^	decisions	^	^ ^	^ ^	^ ^	^ 8	decisions
Pid	Burst	Arr	Prior		TR	Pid	Burst	Arr	Prior	Wait	TR
1	9	0	4	14	23	1	9	0	4	13	22
2	5	1	7	16	21	2	5	1	7	13	18
	_										
3	2	2	2	6	8	3	2	2	2	4	6
4	3	3	7	7	10	4	3	3	7	8	11
5	6	4	4	15	21	5	6	4	4	15	21
Avg.				11.6	16.6	Avg.				10.6	15.6
RR, w	ith quan	tum 2	2								
	13344 2			1551							
^ ^	^ ^ ^	^ ^			3 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						
				11.4	16.4						
Avg.											

2. More CPU Scheduling.

FCFS 11111111	11111111	112222	2222233		1555555! ^	555555	SJF 1111111	111111111	14444	33333222	222222	5555555	555555
4 dec	4 decisions												
Pid	Burst	Arr	Prior	Wait	TR	Resp	Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	0	17	8.5	P1	17	0	4	0	17	8.5
P2	10	1	7	16	26	21.0	P2	10	1	7	25	35	30.0
P3	5	2	2	25	30	27.5	P3	5	2	2	19	24	21.5
P4	4	3	7	29	33	31.0	P4	4	3	7	14	18	16.0
P5	13	4	4	32	45	38.5	P5	13	4	4	32	45	38.5
Avg.	13	-	•	20.4	30.2	25.3	Avg.	13	•	•	18.0	27.8	22.9
SRT				20.4	30.2	23.3	_	/TTm i == /T i	n)		10.0	27.0	22.5
	44442222	Prior (Unix/Linux) 111111111111111113333555555555555522222222											
8 ded	cisions						4 dec	cisions					
Pid	Burst	Arr	Prior	Wait	TR	Resp	Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	32	49	40.5	P1	17	0	4	0	17	8.5
P2	10	1	7	9	19	14.0	P2	10	1	7	34	44	39.0
Р3	5	2	2	0	5	2.5	Р3	5	2	2	15	20	17.5
P4	4	3	7	4	8	6.0	P4	4	3	7	42	46	44.0
P5	13	4	4	16	29	22.5	P5	13	4	4	18	31	24.5
Avg.				12.2	22.0	17.1	Avg.				21.8	31.6	26.7
	(Windows	:)					_	Preempt	(Unix	/Linux)			
	111111111	•	2222244	4455555	5555555	5533333		111111111	-		5555552		2224444
4 dec	cisions						8 de	cisions					
Pid	Burst	Arr	Prior	Wait	TR	Resp	Pid	Burst	Arr	Prior	Wait	TR	Resp
P1	17	0	4	0	17	8.5	P1	17	0	4	5	22	13.5
P2	10	1	7	16	26	21.0	P2	10	1	7	34	44	39.0
P3	5	2	2	42	47	44.5	P3	5	2	2	0	5	2.5
P4	4	3	7	24	28	26.0	P4	4	3	7	42	46	44.0
P5	13	4	4	27	40	33.5	P5	13	4	4	18	31	24.5
_	13	4	4	21.8	31.6	26.7	_	13	4	4	19.8	29.6	24.5
Avg.													
		·· ·			31.0	20.7	Avg.				19.8	29.0	
Prior I	Preempt	-	-				RR, wi	th quant					-
Prior I 1222222	22224444	111111	-				RR, wit	222333334	44455	55511111			-
Prior I 12222222 ^^^^	22224444: ^ /	111111	11111111	1155555	5555555	5533333	RR, with 1111122	222333334 ^ ^ ecisions	44455 ^	^ /	2222255	55551111	1155511
Prior I 1222222 ^^^^ 8 dec Pid	22224444 ^ cisions Burst	111111 Arr	11111111 Prior	1155555 ^ Wait	5555555 TR	5533333 ^ Resp	RR, with 1111122.	2223333334 ^ ^ ecisions Burst	Arr	Prior	2222255 ^ ^ Wait	55551111 ^ TR	1155511 ^ ^ Resp
Prior I 12222222 ^^^^ 8 dec Pid P1	222244441 ^ cisions Burst 17	Arr 0	11111111 Prior 4	1155555 ^ Wait 14	5555555 TR 31	Resp 22.5	RR, with 1111122 10 de Pid P1	222333334 ^ ^ ecisions Burst 17	Arr 0	Prior	2222255 ` ^ Wait 32	55551111 ^ TR 49	Resp 27.5
Prior I 1222222 ^^^ 8 dec Pid P1 P2	222244443 cisions Burst 17 10	Arr 0 1	Prior 4 7	1155555 ^ Wait 14 0	TR 31	Resp 22.5 5.0	RR, with 1111122 10 de Pid P1 P2	2223333334 ^ ^ ecisions Burst 17 10	Arr 0 1	Prior 4 7	2222255 Wait 32 23	TR 49 33	Resp 27.5 9.0
Prior I 12222222 ^^^^ 8 dec Pid P1	222244441 ^ cisions Burst 17	Arr 0 1 2	Prior 4 7 2	1155555 Wait 14 0 42	5555555 TR 31	Resp 22.5	RR, with 1111122 10 de Pid P1	222333334 ^ ^ ecisions Burst 17	Arr 0	Prior 4 7 2	2222255 Wait 32 23 8	55551111 ^ TR 49	Resp 27.5 9.0 10.5
Prior I 1222222 ^^^ 8 dec Pid P1 P2	222244443 cisions Burst 17 10	Arr 0 1	Prior 4 7	1155555 ^ Wait 14 0	TR 31	Resp 22.5 5.0	RR, with 1111122 10 de Pid P1 P2	2223333334 ^ ^ ecisions Burst 17 10	Arr 0 1	Prior 4 7	2222255 Wait 32 23	TR 49 33	Resp 27.5 9.0
Prior I 1222222 ^^^ 8 dec Pid P1 P2 P3	222244443 Cisions Burst 17 10 5	Arr 0 1 2	Prior 4 7 2	1155555 Wait 14 0 42	TR 31 10 47	Resp 22.5 5.0 44.5	RR, with 1111122. 10 de Pid Pid P1 P2 P3	2223333334 ^ ecisions Burst 17 10 5	Arr 0 1	Prior 4 7 2	2222255 Wait 32 23 8	TR 49 33 13	Resp 27.5 9.0 10.5
Prior I 1222222: ^^^ 8 dec Pid P1 P2 P3 P4 P5	222244443 ^ /cisions Burst 17 10 5 4	Arr 0 1 2 3	Prior 4 7 2 7	1155555 Wait 14 0 42 8	TR 31 10 47 12	Resp 22.5 5.0 44.5 10.0	RR, with 1111122	2223333334 ^ ^ ecisions Burst 17 10 5 4	Arr 0 1 2 3	Prior 4 7 2 7	2222255 Wait 32 23 8	TR 49 33 13	Resp 27.5 9.0 10.5 14.0
Prior I 1222222: ^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg.	222244442 cisions Burst 17 10 5 4 13	Arr 0 1 2 3 4	Prior 4 7 2 7	1155555 Wait 14 0 42 8 27	TR 31 10 47 12 40	Resp 22.5 5.0 44.5 10.0 33.5	RR, with 1111122. A 10 de Pid P1 P2 P3 P4 P5 Avg.	2223333334 ecisions Burst 17 10 5 4 13	Arr 0 1 2 3	Prior 4 7 2 7	2222255 Wait 32 23 8 12	TR 49 33 13 16 43	Resp 27.5 9.0 10.5 14.0 31.5
Prior I 12222223 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg.	22224444 cisions Burst 17 10 5 4 13 th quant 233334444	Arr 0 1 2 3 4 cum 4	Prior 4 7 2 7 4 555522223	1155555 Wait 14 0 42 8 27 18.2	TR 31 10 47 12 40 28.0	Resp 22.5 5.0 44.5 10.0 33.5 23.1	RR, with 1111122 Arg. 10 do Pid P1 P2 P3 P4 P5 Avg. RR, with 1112223	2223333334 ^ ^ ecisions Burst 17 10 5 4	Arr 0 1 2 3 4	Prior 4 7 2 7 4 33111455	2222255 Wait 32 23 8 12 30 21.0	TR 49 33 13 16 43 30.8	Resp 27.5 9.0 10.5 14.0 31.5 18.5
Prior I 12222222 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 1111222	22224444 cisions Burst 17 10 5 4 13 th quant 233334444	Arr 0 1 2 3 4 4411115.	Prior 4 7 2 7 4 555522223	1155555 Wait 14 0 42 8 27 18.2	TR 31 10 47 12 40 28.0	Resp 22.5 5.0 44.5 10.0 33.5 23.1	RR, with 1111122 Arg. P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg.	2223333334 ^ ecisions Burst 17 10 5 4 13 th quant 331114445	Arr 0 1 2 3 4 um 3	Prior 4 7 2 7 4 33111455	2222255 Wait 32 23 8 12 30 21.0	TR 49 33 13 16 43 30.8	Resp 27.5 9.0 10.5 14.0 31.5 18.5
Prior I 12222222 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 1111222	22224444 cisions Burst 17 10 5 4 13 th quant 2333334444 ^ ecisions	Arr 0 1 2 3 4 411115.	Prior 4 7 2 7 4 555522223	1155555 Wait 14 0 42 8 27 18.2	TR 31 10 47 12 40 28.0	Resp 22.5 5.0 44.5 10.0 33.5 23.1	RR, with 1111122 Arg. P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg.	2223333334 ^	Arr 0 1 2 3 4 um 3	Prior 4 7 2 7 4 33111455	2222255 Wait 32 23 8 12 30 21.0	TR 49 33 13 16 43 30.8	Resp 27.5 9.0 10.5 14.0 31.5 18.5
Prior I 12222223 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 11112223	22224444 cisions Burst 17 10 5 4 13 th quant 2333334444 ^ ecisions	Arr 0 1 2 3 4 411115.	Prior 4 7 2 7 4 555522223	1155555 Wait 14 0 42 8 27 18.2	TR 31 10 47 12 40 28.0	Resp 22.5 5.0 44.5 10.0 33.5 23.1	RR, wit 1111122 10 de Pid P1 P2 P3 P4 P5 Avg. RR, wit 1112223 ^ 18 de	2223333334 ^	Arr 0 1 2 3 4 um 3	Prior 4 7 2 7 4 33111455	2222255 Wait 32 23 8 12 30 21.0	TR 49 33 13 16 43 30.8	Resp 27.5 9.0 10.5 14.0 31.5 18.5
Prior I 12222222 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 11112222	222244442 ^ cisions Burst 17 10 5 4 13 th quant 233334444 ^ ^ ecisions Burst	Arr 0 1 2 3 4 411115. ^ ^ 3 Arr	Prior 4 7 2 7 4 555522223	1155555 Wait 14 0 42 8 27 18.2 1111555	TR 31 10 47 12 40 28.0	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 ^ ^^ Resp 29.5	RR, with 1111122 Arg. P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg. 18 de Pid	2223333334 ^	Arr 0 1 2 3 4 um 3	Prior 4 7 2 7 4 33111455	2222255 Wait 32 23 8 12 30 21.0 5222111	TR 49 33 13 16 43 30.8	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5
Prior I 12222222 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 11112222 ^ 14 de Pid P1 P2	22224444: ^ cisions Burst 17 10 5 4 13 th quant 233334444 ^ ^ ecisions Burst 17 10	Arr 0 1 2 3 4 411115. ^ ^ 3 Arr 0 1	Prior 4 7 2 7 4 555522223 ^ ^/ Prior 4 7	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28	TR 31 10 47 12 40 28.0 55221112 TR 48 38	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 ^ A Resp 29.5 24.0	RR, with 1111122 Arg. P1 P2 P3 P4 P5 Avg. RR, with 111223 Arg. 18 de Pid P1 P2	2223333334	Arr 0 1 2 3 4 4 4 4 4 5 5 5 5 2 2 2 5	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7	2222255 Wait 32 23 8 12 30 21.0 5222111 ^ ^ Wait 31 29	TR 49 33 13 16 43 30.8 5552111 TR 48 39	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0
Prior I 12222222 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 11112222 ^ 14 de Pid P1 P2 P3	222244442 ^ cisions Burst 17 10 5 4 13 th quant 233334444 ^ ^ ecisions Burst 17 10 5	Arr 0 1 2 3 4 411115. ^ ^ 6 Arr 0 1 2	Prior 4 7 2 7 4 555522223 ^ ^/ Prior 4 7 2	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22	TR 31 10 47 12 40 28.0 55221112 TR 48 38 27	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 ^ A Resp 29.5 24.0 8.5	RR, with 1111122 Arg. P1 P2 P3 P4 P5 Avg. RR, with 111223 Arg. 18 de Pid P1 P2 P3	2223333334	Arr 0 1 2 3 4 4 4 4 4 5 5 5 5 2 2 2 5	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2	2222255 Wait 32 23 8 12 30 21.0 5222111 ^ ^ Wait 31 29 16	TR 49 33 13 16 43 30.8 5552111 TR 48 39 21	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5
Prior I 12222222 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 11112222 ^ 14 de Pid P1 P2 P3 P4	222244442 ^ cisions Burst 17 10 5 4 13 th quant 233334444 ^ ^ ecisions Burst 17 10 5 4	Arr 0 1 2 3 4 411115. ^ ^ 3 Arr 0 1 2 3	Prior 4 7 2 7 4 555522223 ^ ^/ Prior 4 7 2 7	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22 9	TR 31 10 47 12 40 28.0 55221112 TR 48 38 27 13	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 ^ ^^ Resp 29.5 24.0 8.5 11.0	RR, with 1111122 Arg. P1 P2 P3 P4 P5 Avg. RR, with 111223 Arg. Arg. P1 P2 P3 P4 P5 P3 P4 P5 P3 P4	2223333334	Arr 0 1 2 3 4 Arr 0 1 2 3 4 Arr 0 1 2 3 3 Arr 0 1 2 3	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2 7	2222255 Wait 32 23 8 12 30 21.0 5222111 ^ ^ Wait 31 29 16 20	TR 49 33 13 16 43 30.8 5552111 TR 48 39 21 24	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5 11.0
Prior I 12222222	222244442 ^ cisions Burst 17 10 5 4 13 th quant 233334444 ^ ^ ecisions Burst 17 10 5	Arr 0 1 2 3 4 411115. ^ ^ 6 Arr 0 1 2	Prior 4 7 2 7 4 555522223 ^ ^/ Prior 4 7 2	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22 9 32	TR 31 10 47 12 40 28.0 55221112 TR 48 38 27 13 45	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 ^ ^^ Resp 29.5 24.0 8.5 11.0 31.5	RR, with 1111122 Arg. 10 de Pid P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg. 18 de Pid P1 P2 P3 P4 P5	2223333334	Arr 0 1 2 3 4 4 4 4 4 5 5 5 5 2 2 2 5	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2	2222255 Wait 32 23 8 12 30 21.0 5222111 Wait 31 29 16 20 32	TR 49 33 13 16 43 30.8 55552111 TR 48 39 21 24 45	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5 11.0 32.5
Prior I 1222222 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 1111222 ^ 14 de Pid P1 P2 P3 P4 P5 Avg. RR, wit	22224444: ^ cisions Burst 17 10 5 4 13 th quant 233334444 ^ ^ cisions Burst 17 10 5 4 13 th quant	Arr 0 1 2 3 4 411115. ^ ^ 3 Arr 0 1 2 3 4 4 2 2 3 4 2 3 4 2 3 4 2 3 4 2 3 4 2 3 4 2 3 4 2 3 4 2 3 4 2 3 4 2 3 4 2 3 4 2 3 4 3 4	Prior 4 7 2 7 4 555522223 ^ ^/ Prior 4 7 2 7 4	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22 9 32 24.4	TR 31 10 47 12 40 28.0 55221112 TR 48 38 27 13 45 34.2	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 ^ ^^ Resp 29.5 24.0 8.5 11.0 31.5 20.9	RR, with 1111122 Arg. P1 P2 P3 P4 P5 Avg. RR, with 111223 Arg. Arg. P1 P2 P3 P4 P5 P3 P4 P5 P3 P4	2223333334	Arr 0 1 2 3 4 Arr 0 1 2 3 4 Arr 0 1 2 3 3 Arr 0 1 2 3	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2 7	2222255 Wait 32 23 8 12 30 21.0 5222111 ^ ^ Wait 31 29 16 20	TR 49 33 13 16 43 30.8 5552111 TR 48 39 21 24	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5 11.0
Prior I 1222222 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 1111222 ^ 14 de Pid P1 P2 P3 P4 P5 Avg. RR, wit 1112213	222244442 ^cisions Burst 17 10 5 4 13 th quant 233334444 ^ ^ ecisions Burst 17 10 5 4 13	Arr 0 1 2 3 4 411115 ^ Arr 0 1 2 3 4 421115 4 cum 2 133442	Prior 4 7 2 7 4 555522223 ^ Prior 4 7 2 7 4 2 55511322	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22 9 32 24.4	TR 31 10 47 12 40 28.0 5522111: ^ ^ TR 48 38 27 13 45 34.2	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 ^ ^^ Resp 29.5 24.0 8.5 11.0 31.5 20.9	RR, with 1111122 Arg. 10 de Pid P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg. 18 de Pid P1 P2 P3 P4 P5	2223333334	Arr 0 1 2 3 4 Arr 0 1 2 3 4 Arr 0 1 2 3 3 Arr 0 1 2 3	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2 7	2222255 Wait 32 23 8 12 30 21.0 5222111 Wait 31 29 16 20 32	TR 49 33 13 16 43 30.8 55552111 TR 48 39 21 24 45	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5 11.0 32.5
Prior I 1222222 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 1111222 ^ 14 de Pid P1 P2 P3 P4 P5 Avg. RR, wit 111122133 ^ ^ ^	22224444: ^ cisions Burst 17 10 5 4 13 th quant 233334444 ^ cisions Burst 17 10 5 4 13 th quant 34422551:	Arr 0 1 2 3 4 411115 ^ Arr 0 1 2 3 4 411115 ^ Arr 0 1 2 3 4 cum 2 133442	Prior 4 7 2 7 4 555522223 ^ Prior 4 7 2 7 4 2 55511322	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22 9 32 24.4	TR 31 10 47 12 40 28.0 5522111: ^ ^ TR 48 38 27 13 45 34.2	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 ^ ^^ Resp 29.5 24.0 8.5 11.0 31.5 20.9	RR, with 1111122 Arg. 10 de Pid P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg. 18 de Pid P1 P2 P3 P4 P5	2223333334	Arr 0 1 2 3 4 Arr 0 1 2 3 4 Arr 0 1 2 3 3 Arr 0 1 2 3	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2 7	2222255 Wait 32 23 8 12 30 21.0 5222111 Wait 31 29 16 20 32	TR 49 33 13 16 43 30.8 55552111 TR 48 39 21 24 45	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5 11.0 32.5
Prior I 1222222 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 1111222 ^ 14 de Pid P1 P2 P3 P4 P5 Avg. RR, wit 1112213 ^ ^ ^ ^	22224444: ^ cisions Burst 17 10 5 4 13 th quant 233334444 ^ cisions Burst 17 10 5 4 13 th quant 34422551: ^ ^ ^ ^	Arr 0 1 2 3 4 411115. ^ ^ 6 Arr 0 1 2 3 4 4 411115. ^ ^ 6 4 411115. ^ ^ 6 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	Prior 4 7 2 7 4 555522223 ^ Prior 4 7 2 7 4 25511322	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22 9 32 24.4	TR 31 10 47 12 40 28.0 5522111: ^ ^ TR 48 38 27 13 45 34.2	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 A AAAAAAAAAAAAAAAAAAAAAAAAAAAA	RR, with 1111122 Arg. 10 de Pid P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg. 18 de Pid P1 P2 P3 P4 P5	2223333334	Arr 0 1 2 3 4 Arr 0 1 2 3 4 Arr 0 1 2 3 3 Arr 0 1 2 3	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2 7	2222255 Wait 32 23 8 12 30 21.0 5222111 Wait 31 29 16 20 32	TR 49 33 13 16 43 30.8 55552111 TR 48 39 21 24 45	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5 11.0 32.5
Prior I 1222222 ^^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 1111222 ^ 14 de Pid P1 P2 P3 P4 P5 Avg. RR, wit 1112213 ^ ^ ^ ^ 25 de Pid	22224444 cisions Burst 17 10 5 4 13 th quant 233334444 cisions Burst 17 10 5 4 13 th quant 34422551: ^ ^ ^ ecisions Burst Burst 17	Arr 0 1 2 3 4 411115 ^ Arr 0 1 2 3 4 411115 ^ Arr 0 1 2 3 4 cum 2 133442 ^ Arr	Prior 4 7 2 7 4 555522223 ^ Prior 4 7 2 7 4 Prior 4 Prior	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22 9 32 24.4	TR 31 10 47 12 40 28.0 5522111 7 TR 48 38 27 13 45 34.2	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 A AAAAAAAAAAAAAAAAAAAAAAAAAAAA	RR, with 1111122 Arg. 10 de Pid P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg. 18 de Pid P1 P2 P3 P4 P5	2223333334	Arr 0 1 2 3 4 Arr 0 1 2 3 4 Arr 0 1 2 3 3 Arr 0 1 2 3	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2 7	2222255 Wait 32 23 8 12 30 21.0 5222111 Wait 31 29 16 20 32	TR 49 33 13 16 43 30.8 55552111 TR 48 39 21 24 45	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5 11.0 32.5
Prior I 1222222: ^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 1111222: ^ 14 de Pid P1 P2 P3 P4 P5 Avg. RR, wit 11122113: ^ ^ ^ ^ 25 de Pid P1	22224444 cisions Burst 17 10 5 4 13 th quant 233334444 cisions Burst 17 10 5 4 13 th quant 34422551: ^ ^ ^ ecisions Burst 17 10 13	Arr 0 1 2 3 4 4 4 1 1 1 1 5 6 Arr 0 1 2 3 4 4 4 1 1 1 1 5 6 Arr 0 1 2 3 4 4 4 1 1 1 5 6 Arr 0 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	Prior 4 7 2 7 4 555522223 ^ Prior 4 7 2 7 4 Prior 4 Prior 4	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22 9 32 24.4 5511225	TR 31 10 47 12 40 28.0 5522111 7 7 TR 48 38 27 13 45 34.2 5511551	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 A Resp 29.5 24.0 8.5 11.0 31.5 20.9	RR, with 1111122 Arg. 10 de Pid P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg. 18 de Pid P1 P2 P3 P4 P5	2223333334	Arr 0 1 2 3 4 Arr 0 1 2 3 4 Arr 0 1 2 3 3 Arr 0 1 2 3	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2 7	2222255 Wait 32 23 8 12 30 21.0 5222111 Wait 31 29 16 20 32	TR 49 33 13 16 43 30.8 55552111 TR 48 39 21 24 45	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5 11.0 32.5
Prior I 1222222: ^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 1111222: ^ 14 de Pid P1 P2 P3 P4 P5 Avg. RR, wit 11122113: ^ ^ ^ ^ 25 de Pid P1 P2	22224444 cisions Burst 17 10 5 4 13 th quant 233334444 cisions Burst 17 10 5 4 13 th quant 34422551: ^ ^ ^ ecisions Burst 17 10 13	Arr 0 1 2 3 4 411115 ^	Prior 4 7 2 7 4 555522223 ^ Prior 4 7 2 7 4 25511322 ^ Prior 4 7	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22 9 32 24.4 5511225 Wait 32 24	TR 31 10 47 12 40 28.0 5522111 7 TR 48 38 27 13 45 34.2 55115511 7 TR 49 34	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 ^ ^^ Resp 29.5 24.0 8.5 11.0 31.5 20.9	RR, with 1111122 Arg. 10 de Pid P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg. 18 de Pid P1 P2 P3 P4 P5	2223333334	Arr 0 1 2 3 4 Arr 0 1 2 3 4 Arr 0 1 2 3 3 Arr 0 1 2 3	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2 7	2222255 Wait 32 23 8 12 30 21.0 5222111 Wait 31 29 16 20 32	TR 49 33 13 16 43 30.8 55552111 TR 48 39 21 24 45	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5 11.0 32.5
Prior I 1222222: ^^^	22224444 cisions Burst 17 10 5 4 13 th quant 233334444 cisions Burst 17 10 5 4 13 th quant 34422551: ^ ^ ^ ^ ecisions Burst 17 10 5 4 13	Arr 0 1 2 3 4 411115 ^	Prior 4 7 2 7 4 555522223 ^ Prior 4 7 2 7 4 Prior 4 7 2 7 4 Prior 4 7 2 7 4	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22 9 32 24.4 5511225 Wait 32 24 20	TR 31 10 47 12 40 28.0 5522111 7 TR 48 38 27 13 45 34.2 55115511 7 TR 49 34 25	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 A Resp 29.5 24.0 8.5 11.0 31.5 20.9	RR, with 1111122 Arg. 10 de Pid P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg. 18 de Pid P1 P2 P3 P4 P5	2223333334	Arr 0 1 2 3 4 Arr 0 1 2 3 4 Arr 0 1 2 3 3 Arr 0 1 2 3	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2 7	2222255 Wait 32 23 8 12 30 21.0 5222111 Wait 31 29 16 20 32	TR 49 33 13 16 43 30.8 55552111 TR 48 39 21 24 45	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5 11.0 32.5
Prior I 1222222: ^^^ 8 dec Pid P1 P2 P3 P4 P5 Avg. RR, wit 1111222: ^ 14 de Pid P1 P2 P3 P4 P5 Avg. RR, wit 1122113: ^ 25 de Pid P1 P2 P3 P4 P5	22224444 cisions Burst 17 10 5 4 13 th quant 23333444 cisions Burst 17 10 5 4 13 th quant 34422551: ^^^^ ecisions Burst 17 10 5 4 13	Arr 0 1 2 3 4 411115 ^	Prior 4 7 2 7 4 555522223 ^ Prior 4 7 2 7 4 Prior 4 7 2 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22 24.4 5511225 Wait 32 24 20 13	TR 31 10 47 12 40 28.0 5522111: ^ ^ TR 48 38 27 13 45 34.2 5511551: ^ ^ ^ TR 49 34 25 17	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 A Resp 29.5 24.0 8.5 11.0 31.5 20.9	RR, with 1111122 Arg. 10 de Pid P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg. 18 de Pid P1 P2 P3 P4 P5	2223333334	Arr 0 1 2 3 4 Arr 0 1 2 3 4 Arr 0 1 2 3 3 Arr 0 1 2 3	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2 7	2222255 Wait 32 23 8 12 30 21.0 5222111 Wait 31 29 16 20 32	TR 49 33 13 16 43 30.8 55552111 TR 48 39 21 24 45	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5 11.0 32.5
Prior I 1222222: ^^^	22224444 cisions Burst 17 10 5 4 13 th quant 233334444 cisions Burst 17 10 5 4 13 th quant 34422551: ^ ^ ^ ^ ecisions Burst 17 10 5 4 13	Arr 0 1 2 3 4 411115 ^	Prior 4 7 2 7 4 555522223 ^ Prior 4 7 2 7 4 Prior 4 7 2 7 4 Prior 4 7 2 7 4	1155555 Wait 14 0 42 8 27 18.2 1111555 Wait 31 28 22 9 32 24.4 5511225 Wait 32 24 20	TR 31 10 47 12 40 28.0 5522111 7 TR 48 38 27 13 45 34.2 55115511 7 TR 49 34 25	Resp 22.5 5.0 44.5 10.0 33.5 23.1 1555515 A Resp 29.5 24.0 8.5 11.0 31.5 20.9	RR, with 1111122 Arg. 10 de Pid P1 P2 P3 P4 P5 Avg. RR, with 1112223 Arg. 18 de Pid P1 P2 P3 P4 P5	2223333334	Arr 0 1 2 3 4 Arr 0 1 2 3 4 Arr 0 1 2 3 3 Arr 0 1 2 3	Prior 4 7 2 7 4 33111455 ^ ^ ^^ Prior 4 7 2 7	2222255 Wait 32 23 8 12 30 21.0 5222111 Wait 31 29 16 20 32	TR 49 33 13 16 43 30.8 55552111 TR 48 39 21 24 45	Resp 27.5 9.0 10.5 14.0 31.5 18.5 Resp 25.5 19.0 6.5 11.0 32.5

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
                            11122 23334 44555 22233 3445
02:
Q3:
                                                         2 2333
  Pid
        Burst
               Arr
                    Prior
                           Wait
                                 TR
         7
    1
                0
                           16
                                 23
         12
                           33
                                 45
    2
                1
    3
         13
                           34
                                 47
    4
         9
                3
                           31
                                 40
    5
          8
                4
                           32
                                 40
                           29.2 39.0
  Avg.
```

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
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
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
Queue 3 becomes empty at time 49
Summarizing
                       55 33445 5
Q1: 11221 13344 22
02:
                 111 222
                                  2223 33 4 44555 33344 5
Q3:
                                          22
 Pid
       Burst Arr Prior Wait TR
                                 15
        7
               0
                           8
    1
        12
    2
                1
                          21
                                 33
    3
        13
               2
                          34
                                 47
         9
                          33
                                 42
    4
               3
    5
         8
                           34
                                 42
                          26.0 35.8
  Avg.
```