1. FCFS

$P_1 = 19ms$, $P_2 = 7ms$, $P_3 = 5ms$

Wait time (P1) = 0

Wait time (P2) = 19

Wait time (P3) = 19 + 7 = 26

Average wait time = (0 + 19 + 26) / 3

= 15 ms

FCFS scheduling with I/O

P1 : (10 ms CPU, 4ms I/O, 3ms CPU)

P2 : (3ms CPU, 4ms I/O, 3ms CPU, 4ms I/O, 2ms CPU)

P3 : (5ms CPU, 5ms I/O, 8ms CPU)

Ready Q before Scheduling	$P_1(10)$ $P_2(3)$ $P_3(5)$	$P_2(3)$ $P_3(5)$	$P_3(5)$ $P_1(3)$	$P_1(3)$ $P_2(3)$	$P_2(3)$ $P_3(8)$	$P_3(8)$ $P_2(2)$	$P_2(2)$
Scheduled Process	$P_1(10)$	$P_2(3)$	$P_3(5)$	$P_1(3)$	$P_2(3)$	$P_3(8)$	$P_2(2)$
Waiting process after scheduling		$P_1(4)$	$P_2(4)$	$P_3(5)$		$P_2(4)$	

Average waiting time

2. Shortest Job first (SJF) - Non preemptive scheduling

P1 = 19 ms, P2 = 7 ms, P3 = 5 ms

Wait time (P1) = 5 + 7 = 12

wait time (P2) = 5

wait time (P3) = 0

Average waiting time = (12 + 5 + 0)/3 = 17/3 ms

SJF scheduling with I/O

P_1: (10 ms CPU, 4 ms I/O, 3 ms CPU)

P2: (3 ms CPU, 4 ms I/O, 3 ms CPU, 4 ms I/O, 2 ms CPU)

P3: (5 ms CPU, 5 ms I/O, 8 ms CPU)

Read Q before scheduling	$P_1(10)$ $P_2(3)$ $P_3(5)$	$P_1(10)$ $P_3(5)$	$P_1(10)$ $P_2(3)$	$P_1(10)$	$P_3(8)$ $P_2(2)$	$P_3(8)$	$P_1(3)$
Scheduled Process	$P_2(3)$	$P_3(5)$	$P_2(3)$	$P_1(10)$	$P_2(2)$	$P_3(8)$	$P_1(3)$
Waiting processes after scheduling		$P_2(4)$	$P_3(3)$	$P_3(2)$ $P_2(4)$	$P_1(2)$	$P_1(2)$	

Average waiting time =

STF with scheduling I/O

P1 : CPU (10ms) , IO (2ms) , CPU (5 ms)

P2 : CPU (2ms) , IO (7ms) , CPU (2ms) , IO (4ms) , CPU (2ms)

P3 : CPU (4ms) , IO (3ms) , CPU (8ms)

Ready Q before scheduling	P1(10) P2(2) P3(4)	P1(10) P3(4)	P1(10)	P2(2) P3(8)	P3(8) P1(5)	P3(8) P2(2)	P3(8)
Scheduled Process	P2(2)	P3(4)	P1(10)	P2(2)	P1(5)	P2(2)	P3(8)
waiting processes after scheduling		P2(4)	P2(3) P3(3)	P1(2)	P2(4)		

Average waiting time = 32/3 = 10.66

P1 = (2+4) + 0 = 6

P2 = 0 + (10-3) + 1 = 8

P3 = 2 + (10-3+2+5+2) = 18

Pre-emptive scheduling

1. Round robin (RR) scheduling
2. Multilevel queue scheduling
3. Multilevel feedback queue scheduling

Round robin waiting time example (5ms)

P1 = 7 ms, P2 = 19 ms, P3 = 5 ms

7	19	5	2	14	10	0	5	5	4
P1	P2	P3	P1	P2	~~P3~~	~~P1~~	P2	P2	P2

waiting time (P1) : 0 + 10 = 10

waiting time (P2) : 5 + 7 = 12

waiting time (P3) : 10

Average waiting time = (10 + 12 + 10)/3 = 32/3 ms

Round robin waiting time example (10 ms)

P1 = 7ms , P2 = 19 ms , P3 = 5 ms

7	19	5	~~0~~	9	~~0~~	0
P1	P2	P3	~~P1~~	P2	~~P3~~	P2

Waiting time (P1) : 0
Waiting time (P2) : 7 + 5 = 12
Waiting time (P3) : (7+10) = 17

Average waiting time : (0 + 12 + 17) / 3 = 29/3 ms

Round Robin scheduling with I/O (5ms slices)

P1 (10ms CPU , 4ms I/O , 3ms CPU)
P2 (3ms CPU , 4ms I/O , 3 ms CPU , 4ms I/O , 2ms CPU)
P3 (5 ms CPU , 5ms I/O , 8ms CPU)

P1 (10 ms)	P2 (3ms)	P3 (5ms)	P1 (5ms)	P2 (3ms)	P3 (8ms)	P1 (3ms)	P2 (2ms)	P3 (3ms)
P2 (3ms)	P3 (5ms)	P1 (5ms)	P2 (3ms)	P3 (8ms)	P1 (3ms)	P2 (2ms)	P3 (3ms)	
P3 (5ms)	P1 (5ms)					P3 (3ms)		
P1 (5ms)	P2 (3ms)	P3 (5ms)	P1 (5ms)	P2 (3ms)	P3 (5ms)	P1 (3 ms)	P2 (2ms)	P3 (3ms)
		P2 (4ms)	P3 (5ms)	P1 (4ms)	P2 (4ms)			

FIFO page replacement

F#	A	B	C	B	A	D	A	B	C	D	A	B	A	C	B	D
1	A	A	A	A	A	D	D	D	C	C	C	B	B	B	B	B
2		B	B	B	B	B	A	A	A	D	D	D	D	C	C	C
3			C	C	C	C	C	B	B	B	A	A	A	A	A	D
PF	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y

Number of page fault : 12

Least recently Used (LRU) page replacement

F#	A	B	C	B	A	D	A	B	C	D	A	B	A	C	B	D
1	A(0)	A(0)	A(0)	A(0)	A(4)	A(4)	A(6)	A(6)	A(6)	D(9)	D(9)	D(9)	D(9)	C(13)	C(13)	C(13)
2		B(1)	B(1)	B(3)	B(3)	B(3)	B(3)	B(7)	B(7)	B(7)	A(10)	A(10)	A(12)	A(12)	A(12)	D(15)
3			C(2)	C(2)	C(2)	D(5)	D(5)	D(5)	C(8)	C(8)	C(8)	B(11)	B(11)	B(11)	B(14)	B(14)
PF	Y	Y	Y	N	N	Y	N	N	Y	Y	Y	Y	N	Y	N	Y

Number of page fault : 10

Second-chance (clock) page replacement algorithm

F#	A	B	C	B	A	D	A	B	C	D	A	B	A	C	B	D
1	A+	A+	*A+	*A+	*A+	D+	D+	*D+	C+	C+	*C+	B+	B+	B+	B+	*B-
2		B+	B+	B+	B+	*B-	A+	A+	*A-	D+	D+	*D-	*D-	C+	C+	C-
3			C+	C+	C+	C-	*C-	B+	B-	*B-	A+	A-	A-	*A+	*A+	D+
PF	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y

Number of page faults : 12

F#	1	0	7	1	0	2	1	2	3	0
1	*1+	*1+	*1+	*1+	*1+	2+	2+	2+	*2+	0+
2		0+	0+	0+	0+	*0-	1+	1+	1+	*1-
3			7+	7+	7+	7-	*7-	*7-	3+	3-
PF	Y	Y	Y	N	N	Y	Y	N	Y	Y

Number of page faults : 7

Optimal page replacement

F#	1	0	7	1	0	2	1	2	3	0	3	2	4	0	3	0	2	1
1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3		
2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
3			7	7	7	2	2	2	2	2	2	2	4	4	4	4		
PF	Y	Y	Y	N	N	Y	N	N	Y	N	N	N	Y	N	N	N		