SUBJECT:- Designing Principles of Operating System

ASSIGNMENT=1

Q1

1. Suppose the hypothetical machine contain instructions and data are 16-bits long, and memory is organized as a sequence of 16-bit words. Partial list of opcode has given below:

   0001=Load AC from memory

   0010=Store AC to memory

   0110=Subtract the value of AC from memory

   In these cases, The instructions format provide 4 bit for the opcode and remaining 12-bit of instruction format is word of memory can be directly addressed. Assumed that the program counter is set to location 300. It will fetch instructions from location 301 and 302. Show the program execution using the fetch stage and Execute stage for the following program:

   a. Load AC from memory 940.
   b. Subtract from AC to content of memory location 941.
   c. Store AC to memory location 941.

   Assume that the memory location 940 and 941 contain value of 10 and 5.

Ans Given,

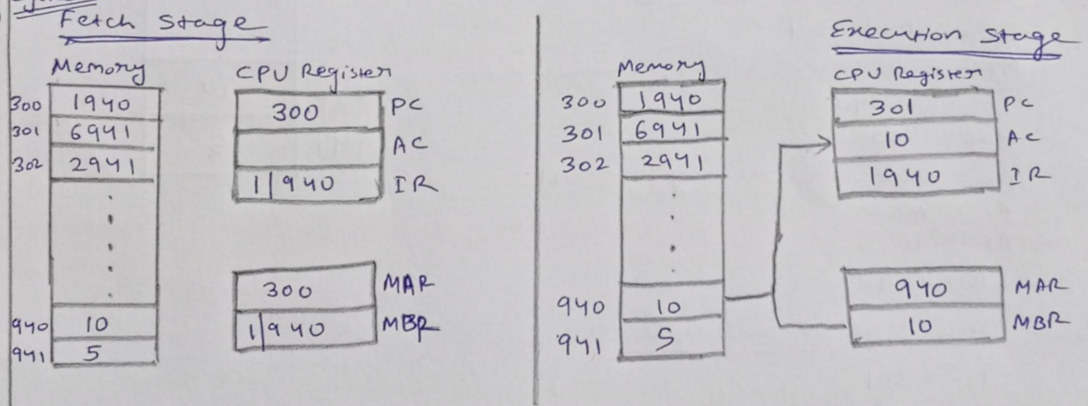
Opcodes size = 4 bit ; Memory Address size = 12 Bits

0001 = Load AC from Memory

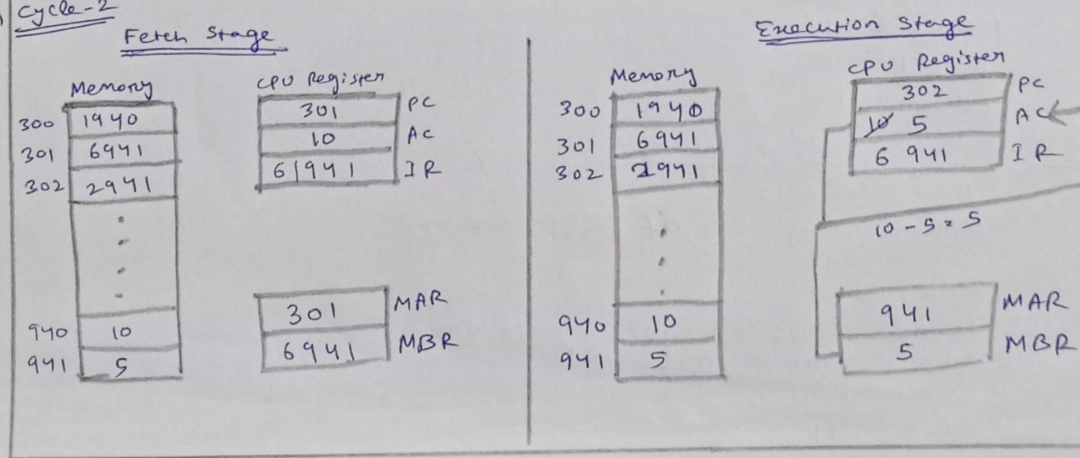
0010 = Store AC to Memory

0110 = Substract the value of AC from memory

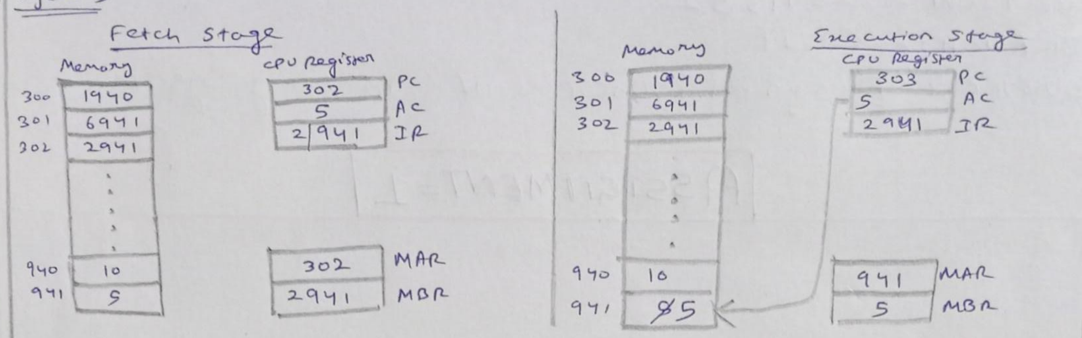
(a) Cycle-1



(b) Cycle-2



(c) Cycle-3



Q2 2. The program execution of above question (1) is described in the text using six steps. Expand this description to show the use of the memory address register (MAR) and memory buffer register (MBR).

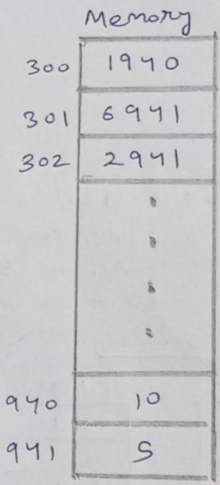
Ans Given,

Opcode size: 4 bits ; Memory Address size: 12 bits

0001 = Load AC from Memory

0010 = Store AC to Memory

0110 = subtract the value of AC from memory



Step-1 : Fetch stage of 1st cycle :-

PC = 300

MAR = ~~300~~ PC = 300

MBR = 1940

AC = 0

IR = 1940

Step-2 Execution stage of 1st cycle

PC = 300 + 1 = 301

MAR = IR from Fetch stage; Addressable part

= 940

MBR = 10

AC = Loaded from Memory (1 → 0001)

=> AC = MBR

=> AC = 10

IR = 1940

Step-3 Fetch Stage of 2nd cycle :

PC = 301

MAR = PC = 301

MBR = 6941

AC = 10

IR = 6941

Step 4 Execution stage of 2nd cycle

PC = 301 + 1 = 302

MAR = Addressable part of IR from fetch stage

= 941

MBR = 5

AC = (6 → 0110) : subtract AC from Memory

=> AC = AC − MBR

=> AC = 10 − 5 = 5

IR = 6941

Step-5 : Fetch stage of 3rd Cycle

PC = 302

MAR = PC = 302

MBR = 2941

AC = 5

IR = 2941

Step 6 : Execution stage of 3rd cycle

PC = 302 + 1 = 303

MAR = ~~303~~ Addressable Part of IR from fetch stage

= 941

~~MBR = 5~~ IR = 2941

AC = 5

MBR = 5

(2 ⇒ 0010) : Store AC to Memory

∴ M [941] = AC = 5 , where

M [941] = Memory Address of 941.

∴ After six steps,

PC = 303

~~MAR = 941~~ M [940] = 10

M [941] = 5

AC = 5

IR = 2941

(Ans)

Q3 3. Suppose that a large file is being accessed by a computer memory system comprising of a cache and a main memory. The cache access time is 50 ns. Time to access main memory (including cache access) is 550 ns. The file can be opened either in read or in write mode. A write operation involves accessing both main memory and the cache (write-through cache). A read operation accesses either only the cache or both the cache and main memory depending upon whether the access word is found in the cache or not. It is estimated that read operations comprise of 80% of all operations. If the cache hit ratio for read operations is 0.9, what is the average access time of this system?

Ans Given,

Cache Access Time = 50 ns

Time to Access both Main memory & cache = 550 ns

Write operation : Accessing both main memory & cache

∴ Write operation requires 550 ns

Read operation : If access word is found in cache = 50 ns

If access word is not found in cache = 550 ns

∴ Read-hit requires = 50 ns

Read-Miss requires = 550 ns

Read operations = 80% = 0.8

Write operations = 20% = 0.2

Cache hit ratio for read operation = 0.9

Cache Miss ratio for read operation = 0.1

~~Avg. Access time for read~~

~~Cache hit ratio for 80% of all opera~~

For read operation of 0.8,

Cache hit ratio = $0.9 \times 0.8 = 0.72$

Cache Miss ratio = $0.8 - 0.72 = 0.08$

$\therefore$ Avg. Access Time for read operation = $0.72 \times 50 + 0.08 \times 550$
$= 36 + 44$
$= \underline{80 \text{ ns}}$

Avg. Access Time for write operation = $((0 \times 0.2) \times 50) + (1 \times 0.2) \times 550$
$= 0 + 110$
$= \underline{110 \text{ ns}}$

$\therefore$ Avg. Access Time of this system = $110 + 80 = \underline{190 \text{ ns}}$ (Ans)

Q4

4. Consider a computer with 400Mbytes of available memory (not used by os). Three program, JOB1, JOB2 and JOB3 are submitted for execution at the same time with attribute listed below.

	JOB1	JOB2	JOB3
Type of job	Heavy compute (70% CPU used)	Heavy I/O (10% CPU used)	Heavy I/O (10% CPU used)
Duration	10 min	20 min	15 min
Memory required	150M	100M	125M

For simple Batch environment, these job are executed in sequence JOB1, JOB2 then JOB3. Find out CPU utilization, memory utilization and Throughput in case of uniprogramming and multiprogramming system.

Ans

Uniprogramming

(*) CPU Utilization = $\dfrac{0.7 \times 10 + 0.1 \times 20 + 0.1 \times 15}{(10 + 20 + 15)} = \dfrac{7 + 2 + 1.5}{45} = \dfrac{10.5}{45}$

CPU Utilization % = $\dfrac{10.5}{45} \times 100 = \underline{23.33\%}$ (Ans)

(*) Memory Utilization = $\dfrac{150 \times 10 + 100 \times 20 + 125 \times 15}{(10 + 20 + 15) \times 400} = \dfrac{1500 + 2000 + 1875}{18000} = \dfrac{5375}{18000}$

Memory Utilization % = $\dfrac{5375}{18000} \times 100 = \underline{29.86\%}$ (Ans)

(*) Throughput = 3 jobs / 45 minutes

$\Rightarrow \dfrac{\cancel{3}\,1}{\cancel{45}\,15}$ jobs/min $= \dfrac{1}{15}$ jobs/min

$= \dfrac{1 \times 4}{15 \times 4} = \dfrac{4}{60}$ Jobs/min

$= \underline{4 \text{ Jobs/hr}}$ (Ans)

Multiprogramming

(*) CPU utilization $= \dfrac{0.7\times 10 + 0.1\times 20 + 0.1\times 15}{20} = \dfrac{7+2+1.5}{20} = \dfrac{10.5}{20}$

CPU utilization % $= \dfrac{10.5}{20}\times 100 = \underline{52.5\%}$ (Ans)

(*) Memory utilization $= \dfrac{150\times 10 + 100\times 20 + 125\times 15}{20\times 400} = \dfrac{1500+2000+1875}{8000} = \dfrac{5375}{8000}$

Memory utilization % $= \dfrac{5375}{8000}\times 100 = \underline{67.19\%}$ (Ans)

(*) Throughput = 3 jobs in 20 minutes

$\Rightarrow \dfrac{3}{20}$ Jobs/min $= \dfrac{3\times 3}{20\times 3}$ Jobs/min

$= \dfrac{9}{60}$ jobs/min

$= 9$ jobs/hr (Ans)

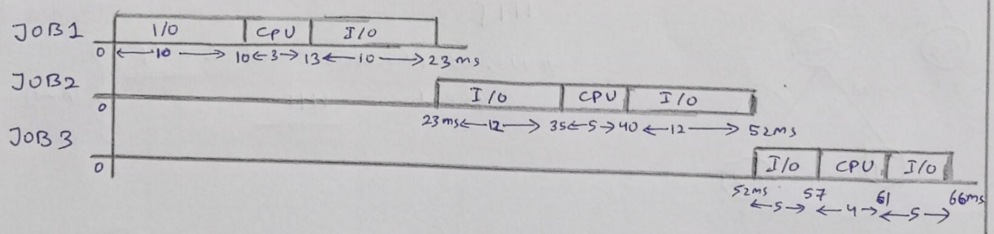
Qs

5. In a batch operating system, three jobs are submitted for execution. Each job involves an I/O activity, CPU time and another I/O activity of the same time span as the first. Job JOB1 requires a total of 23 ms, with 3 ms CPU time; JOB2 requires a total time of 29 ms with 5 ms CPU time; JOB3 requires a total time of 14 ms with 4 ms CPU time. Illustrate their execution and find CPU utilization for uniprogramming and multiprogramming systems.

Ans

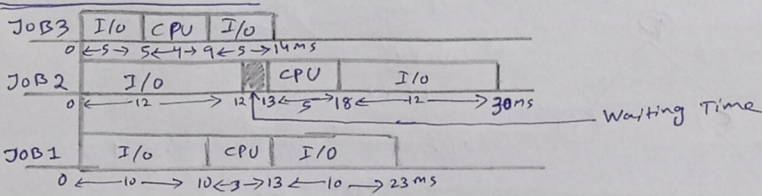
	JOB1	JOB2	JOB3
I/O	10 ms	12 ms	5 ms
CPU	3 ms	5 ms	4 ms
I/O	10 ms	12 ms	5 ms
Total Time	23 ms	29 ms	14 ms

Uniprogramming



CPU Utilization $= \dfrac{3+5+4}{23+29+14}\times 100 = \dfrac{12}{66}\times 100 = \underline{18.18\%}$

MULTIPROGRAMMING



CPU utilization $= \dfrac{3+5+4}{30}\times 100 = \dfrac{12}{30}\times 100 = \underline{40\%}$

Q6

6. Trace the following program segment and determine how many processes are created. Draw a graph that shows how the processes are related.

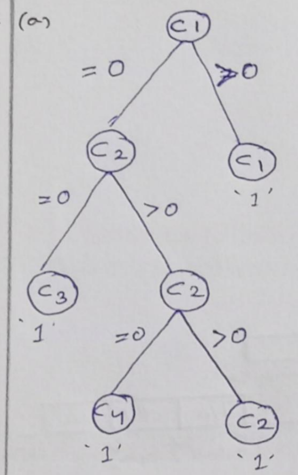
a.
```
int main( )
{
   pid_t c1,c2;
  c2=0;
  c1 = fork();
  if (c1 == 0)
      c2 = fork();
  if (c2 > 0)
      fork();
  printf(" 1");
  return 0;
}
```

b.
```
int main( )
{
  pid_t c1=1,c2=1;
  c1 = fork();
  if (c1 != 0)
      c2 = fork();
  if (c2== 0)
      fork();
  printf(" 1");
  return 0;
}
```

c.
```
int main( )
 {
  if (fork() || fork())
     fork();
  printf(" 1 ");
  return 0;
}
```

d.
```
int main( )
 {
  if (fork() && (!fork()))
     if (fork() || fork())
        fork();
  printf("2 ");
  return 0;
}
```

Ans (a)



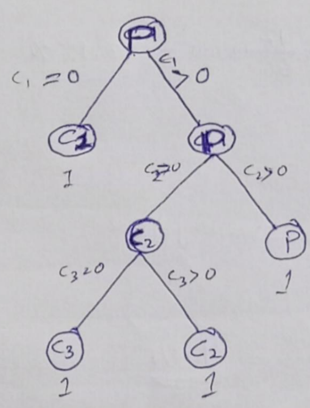
(*) This tree shows that No. of processes created is C1, C2, C3, C4, thus 4 no. of processes.

(*) OUTPUT

1111

# No. of processes created = 4
output = 1111
} (Ans)

(b)



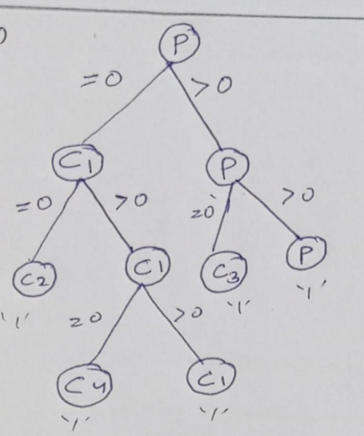
(*) This tree shows that No. of processes created is C_1, C_2, C_3, P, thus 4 no. of processes.

(*) OUTPUT

1111

# No. of processes created = 4
output = 1111
} (Ans)

(c)



(+) No. of Process created

= P, C1, C2, C3, C4

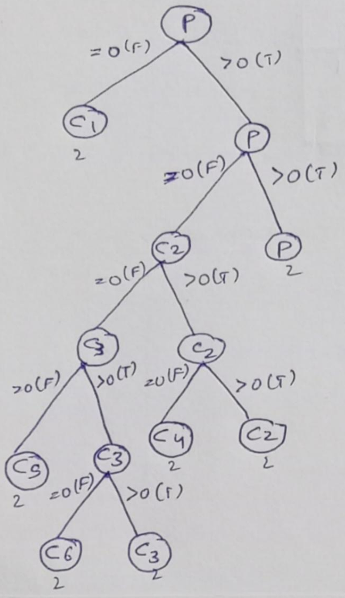
∴ No. of process = 5

(+) OUTPUT

1 1 1 1 1

\# No. of process = 5
Output = 11111 } (Ans)

(d)



(+) No. of processes created

= P, C1, C2, C3, C4, C5, C6

∴ No. of process = 7

(+) Output.

2 2 2 2 2 2 2

\# No. of process = 7
Output = 2222222 } (Ans)

Q7

7. Consider the following four processes with arrival times (in milliseconds) and their length of CPU bursts (in milliseconds) as shown below:

Process	Arrival time	Burst Time
P1	0	3.
P2	1	1
P3	3	3
P4	4	x

Find the value of x, such that the average waiting time of the processes is 1 millisecond, if the processes execute on a single processor using SRTF scheduling.

Ans Given,
Avg. Waiting Time = 1 ms

For SRTF,

Process	Arrival Time	Burst Time
P1	0	~~3~~ ~~2~~ ~~1~~ 0
P2	1	~~1~~ 0
P3	3	3
P4	4	x

Completion Time Turn Around Time Waiting Time

Gantt Chart

Case A : x<3

P1	P2	P1	P1	P4	P3

0 1 2 3 4 4+x 7+x

Case B : x>3

P1	P2	P1	P1	P3	P4

0 1 2 3 4 7 7+x

For process P1, P2,

Process	A.T	BT	TAT	WT
P_1	0	3	$4-0=4$	$4-3=1$
P_2	1	1	$2-1=1$	$1-1=0$

For process P3, P4,

Case A $x < 3$

Process	AT	BT	TAT	WT
P_3	3	3	$7+x-3=4+x$	$4+x-3=1+x$
P_4	4	x	$4+x-4=x$	$x-x=0$

Case B $x>3$

Process	AT	BT	TAT	WT
P_3	3	3	$7-3=4$	$4-3=1$
P_4	4	x	$7+x-4=3+x$	$3+x-x=3$

In case A, $x<3$,

$\therefore$ Avg waiting Time $= \frac{1+0+(1+x)+0}{4}$

$\Rightarrow 1 = \frac{2+x}{4} \Rightarrow 4 = 2+x$

$\Rightarrow x = 2$ ms

In case B, $x>3$

$\therefore$ Avg waiting Time $= \frac{1+0+1+3}{4}$

$\Rightarrow 1 = \frac{5}{4}$

$\Rightarrow 1 \neq 1.25$

$\therefore x = 2$ ms (Ans)

Q8 8. Consider the set of processes with arrival time (in milliseconds), CPU burst time (in milliseconds), and priority (**high number implies high priority**) as shown below.

Process	Arrival time	Burst Time	Priority
P1	0	11	1
P2	0	8	0
P3	12	2	3
P4	2	6	2
P5	9	16	4

Find the average turnaround time, average waiting time and average response time for each of the following scheduling algorithm along with their Gantt chart illustrating the execution of these processes:

- FCFS (Consider the order specified in the table),
- SJF (Non preemptive),
- SRTF,
- Non preemptive Priority based scheduling,
- Preemptive Priority based scheduling,
- Highest Response Ratio Next (Consider the order specified in the table),
- Round robin scheduling (quantum =2ms)

Which of the algorithms results in the minimum average waiting time over all processes?

Ans (*) FCFS

Process	AT	BT	Priority	TAT	WT	RT
P_1	0	11	1	11 − 0 = 11	11 − 11 = 0	0 − 0 = 0
P_2	0	8	0	19 − 0 = 19	19 − 8 = 11	11 − 0 = 11
P_3	12	2	3	43 − 12 = 31	31 − 2 = 29	41 − 12 = 29
P_4	2	6	2	25 − 2 = 23	23 − 6 = 17	19 − 2 = 17
P_5	9	16	4	41 − 9 = 32	32 − 16 = 16	25 − 9 = 16

Gantt chart,

P_1	P_2	P_4	P_5	P_3

0   11   19   25   41   43

Here,
TAT = Turn Around Time
WT = Waiting Time
RT = Response Time

$\therefore$ Avg TAT $= \frac{11+19+31+23+32}{5} = \underline{23.2 \text{ ms}}$

Avg. WT $= \frac{0+11+29+17+16}{5} = \underline{14.6 \text{ ms}}$

Avg. RT $= \frac{0+11+29+17+16}{5} = \underline{14.6 \text{ ms}}$

(Ans)

(*) SJF (Non-Preemptive)

Process	AT	BT	Priority	TAT	WT	RT
P_1	0	11	1	27 − 0 = 27	27 − 11 = 16	16 − 0 = 16
P_2	0	8	0	8 − 0 = 8	8 − 8 = 0	0 − 0 = 0
P_3	12	2	3	16 − 12 = 4	4 − 2 = 2	14 − 12 = 2
P_4	2	6	2	14 − 2 = 12	12 − 6 = 6	8 − 2 = 6
P_5	9	16	4	43 − 9 = 34	34 − 16 = 18	27 − 9 = 18

Gantt chart

P_2	P_4	P_3	P_1	P_5

0   8   14   16   27   43

$\therefore$ Avg. TAT $= \frac{27+8+4+12+34}{5} = \frac{85}{5} = \underline{17 \text{ ms}}$

Avg. WT $= \frac{16+0+2+6+18}{5} = \frac{42}{5} = \underline{8.4 \text{ ms}}$

Avg. RT $= \frac{16+0+2+6+18}{5} = \frac{42}{5} = \underline{8.4 \text{ ms}}$

(Ans)

(*) SRTF

Process	AT	BT	Priority	TAT	WT	RT
P_1	0	11	1	27 − 0 = 27	27 − 11 = 16	16 − 0 = 16
P_2	0	8	0	8 − 0 = 8	8 − 8 = 0	0 − 0 = 0
P_3	12	2	3	14 − 12 = 2	2 − 2 = 0	12 − 12 = 0
P_4	2	6	2	16 − 2 = 14	14 − 6 = 8	8 − 2 = 6
P_5	9	16	4	43 − 9 = 34	34 − 16 = 18	27 − 9 = 18

Gantt Chart

Gantt Chart

P2	P2	P4	P4	P3	P4	P1	P5

0 ↓ 2 ↓ 8 ↓ 9 ↓ 12 14 ↓ 16 27 43

P2=6 P2=0 P4=5 P4=2 P4=0

$$\text{Avg. TAT} = \frac{27+8+2+14+34}{5} = \frac{85}{5} = \underline{17\,ms}$$

$$\text{Avg. WT} = \frac{16+0+0+8+18}{5} = \frac{42}{5} = \underline{8.4\,ms}$$

$$\text{Avg. RT} = \frac{16+0+0+6+18}{5} = \frac{40}{5} = \underline{8\,ms}$$

(Ans)

(*) Non-Preemptive Priority Based Scheduling :-

Process	AT	BT	Priority	TAT	WT	RT
P1	0	11	1	11-0=11	11-11=0	0-0=0
P2	0	8	0	43-0=43	43-8=35	35-0=35
P3	12	2	3	29-12=17	17-2=15	27-12=15
P4	2	6	2	35-2=33	33-6=27	29-2=27
P5	9	16	4	27-9=18	18-16=2	11-9=2

Gantt Chart

P1	P5	P3	P4	P2

0 11 27 29 35 43

$$\text{Avg. TAT} = \frac{11+43+17+33+18}{5} = \underline{24.4\,ms}$$

$$\text{Avg. WT} = \frac{0+35+15+27+2}{5} = \underline{15.8\,ms}$$

$$\text{Avg. RT} = \frac{0+35+15+27+2}{5} = \underline{15.8\,ms}$$

(Ans)

(*) Preemptive Priority Based Scheduling :-

Process	AT	BT	Priority	TAT	WT	RT
P1	0	11	1	35-0=35	35-11=24	0-0=0
P2	0	8	0	43-0=43	43-8=35	35-0=35
P3	12	2	3	27-12=15	15-2=13	25-12=13
P4	2	6	2	8-2=6	6-6=0	2-2=0
P5	9	16	4	25-9=16	16-16=0	9-9=0

Gantt Chart

P1	P4	P1	P5	P5	P3	P1	P2

0 ↓ 2 ↓ 8 ↓ 9 ↓ 12 25 27 35 43

P1=9 P4=0 P1=8 P5=13

$$\text{Avg. TAT} = \frac{35+43+15+6+16}{5} = \underline{23\,ms}$$

$$\text{Avg. WT} = \frac{24+35+13+0+0}{5} = \underline{14.4\,ms}$$

$$\text{Avg. RT} = \frac{0+35+13+0+0}{5} = \underline{9.6\,ms}$$

(Ans)

(*) Highest Response Ratio Next

Process	AT	BT	Priority	TAT	WT	RT
P_1	0	11	1	11 − 0 = 11	11 − 11 = 0	0 − 0 = 0
P_2	0	8	0	27 − 0 = 27	27 − 8 = 19	19 − 0 = 19
P_3	12	2	3	19 − 12 = 7	7 − 2 = 5	17 − 12 = 5
P_4	2	6	2	17 − 2 = 15	15 − 6 = 9	11 − 2 = 9
P_5	9	16	4	43 − 9 = 34	34 − 16 = 18	27 − 9 = 18

Gantt Chart

P_1	P_4	P_3	P_2	P_5

0 11 17 19 27 43

$T_{11} = R_{P_2} = ((11-0)+8)/8 = 19/8 = 2.375$

$R_{P_4} = ((11-2)+6)/6 = 15/6 = 2.5$ → choosen

$R_{P_5} = ((11-9)+16)/16 = 18/16 = 1.125$

$T_{17} = R_{P_2} = ((17-0)+8)/8 = 25/8 = 3.125$

$R_{P_3} = ((17-12)+2)/2 = 7/2 = 3.5$ → choosen

$R_{P_5} = ((17-9)+16)/16 = 24/16 = 1.5$

$T_{19} = R_{P_2} = ((19-0)+8)/8 = 27/8 = 3.375$ → choosen

$R_{P_5} = ((19-9)+16)/16 = 26/16 = 1.625$

$$\text{Avg. TAT} = \frac{11+27+7+15+34}{5} = \frac{94}{5} = \underline{\underline{18.8\text{ms}}}$$

$$\text{Avg. WT} = \frac{0+19+5+9+18}{5} = \frac{51}{5} = \underline{\underline{10.2\text{ms}}}$$

$$\text{Avg. RT} = \frac{0+19+5+9+18}{5} = \frac{51}{5} = \underline{\underline{10.2\text{ms}}}$$

(Ans)

(*) Round Robin Scheduling (Quantum = 2ms):

Process	AT	BT	Priority	TAT	WT	RT
P_1	0	11	1	33 − 0 = 33	33 − 11 = 22	0 − 0 = 0
P_2	0	8	0	28 − 0 = 28	28 − 8 = 20	2 − 0 = 2
P_3	12	2	3	20 − 12 = 8	8 − 2 = 6	18 − 12 = 6
P_4	2	6	2	22 − 2 = 20	20 − 6 = 14	4 − 2 = 2
P_5	9	16	4	43 − 9 = 34	34 − 16 = 18	14 − 9 = 5

Gantt chart

P_1	P_2	P_4	P_1	P_2	P_4	P_1	P_5	P_2	P_3	P_4	P_1	P_5	P_2	P_1	P_5	P_1	P_5

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 33 35

P_5	P_5	P_5	P_5

35 37 39 41 43

t	arrived process	Scheduled process	Running Time (TQ | BT)	Back in Queue?	Remaining BT
0	$P_1 P_2$	P_1	$2 < 11$	yes	9
2	$P_2 P_4 P_1$	P_2	$2 < 8$	yes	6
4	$P_4 P_1 P_2$	P_4	$2 < 6$	yes	4
6	$P_1 P_2 P_4$	P_1	$2 < 9$	yes	7
8	$P_2 P_4 P_1$	P_2	$2 < 6$	yes	4
10	$P_4 P_1 P_5 P_2$	P_4	$2 < 4$	yes	2
12	$P_1 P_5 P_2 P_3 P_4$	P_1	$2 < 7$	yes	5
14	$P_5 P_2 P_3 P_4 P_1$	P_5	$2 < 16$	yes	14
16	$P_2 P_3 P_4 P_1 P_5$	P_2	$2 < 4$	yes	2
18	$\cancel{P_3} P_4 P_1 P_5 P_2$	P_3	$2 = 2$	No	0
20	$\cancel{P_4} P_1 P_5 P_2$	P_4	$2 = 2$	No	0
22	$P_1 P_5 P_2$	P_1	$2 < 5$	yes	3
24	$P_5 P_2 P_1$	P_5	$2 < 14$	yes	12
26	$\cancel{P_2} P_1 P_5$	P_2	$2 = 2$	No	0
28	$P_1 P_5$	P_1	$2 < 3$	yes	1
30	$P_5 P_1$	P_5	$2 < 12$	yes	10
32	$\cancel{P_1} P_5$	P_1	$2 > 1$	No	0
33	P_5	P_5	$2 < 10$	yes	8
43	—	—	—	—	—

$$\text{Avg. TAT} = \frac{33+28+8+20+34}{5} = \frac{123}{5} = 24.6 \text{ ms}$$

$$\text{Avg. WT} = \frac{22+20+6+14+18}{5} = \frac{80}{5} = 16 \text{ ms}$$

$$\text{Avg. RT} = \frac{0+2+6+2+5}{5} = \frac{15}{5} = 3 \text{ ms}$$

(Ans)

The algorithms SJF(Non-Preemptive) & SRTF has the shortest avg. waiting Time of 8.4ms.

Q9

9. Consider the set of processes with arrival time (in milliseconds), CPU burst time (in milliseconds), and priority (**lowest number implies high priority**) as shown below.

Process	Arrival time	Burst Time	Priority
P1	0	4	3
P2	0	2	1
P3	1	3	2
P4	2	2	4

Find the average turnaround time, average waiting time and average response time for each of the following scheduling algorithm along with their Gantt chart illustrating the execution of these processes:

- FCFS (Consider the order specified in the table),
- SJF (Non preemptive),
- SRTF,
- Non preemptive Priority based scheduling,
- Preemptive Priority based scheduling,
- Highest Response Ratio Next (Consider the order specified in the table),
- Round robin scheduling (quantum =2ms)

Which of the algorithms results in the minimum average waiting time over all processes?

Ans (*) FCFS

Process	AT	BT	Priority	TAT	WT	RT
P_1	0	4	3	4-0=4	4-4=0	0-0=0
P_2	0	2	1	6-0=6	6-2=4	4-0=4
P_3	1	3	2	9-1=8	8-3=5	6-1= 5
P_4	2	2	4	11-2=9	9-2=7	9-2=7

Gantt Chart

P_1	P_2	P_3	P_4

0 4 6 9 11

$$\text{Avg. TAT} = \frac{4+6+8+9}{4} = \frac{27}{4} = 6.75\text{ms}$$
$$\text{Avg. WT} = \frac{0+4+5+7}{4} = \frac{16}{4} = 4\text{ms}$$
$$\text{Avg. RT} = \frac{0+4+5+7}{4} = \frac{16}{4} = 4\text{ms}$$
(Ans)

(*) SJF (~~Pre~~ Non preemptive)

Process	AT	BT	Priority	TAT	WT	RT
P_1	0	4	3	11-0=11	11-4=7	7-0=7
× P_2	0	2	1	2-0=2	2-2=0	0-0=0
P_3	1	3	2	7-1=6	6-3=3	4-1=3
× P_4	2	2	4	4-2=2	2-2=0	2-2=0

Gantt Chart

P_2	P_4	P_3	P_1

0 2 4 7 11

$$\text{Avg. TAT} = \frac{11+2+6+2}{4} = \frac{21}{4} = 5.25\text{ ms}$$
$$\text{Avg. WT} = \frac{7+0+3+0}{4} = \frac{10}{4} = 2.5\text{ms}$$
$$\text{Avg. RT} = \frac{7+0+3+0}{4} = \frac{10}{4} = 2.5\text{ms}$$
(Ans)

(*) SRTF

Process	AT	BT	Priority	TAT	WT	RT
P_1	0	4	3	11-0 = 11	11-4 = 7	7-0 = 7
P_2	0	2	1	2-0 = 2	2-2 = 0	0-0 = 0
P_3	1	3	2	7-1 = 6	6-3 = 3	4-1 = 3
P_4	2	2	4	4-2 = 2	2-2 = 0	2-2 = 0

Gantt chart

P_2	P_2	P_4	P_3	P_1
0 – 1	1 – 2	2 – 4	4 – 7	7 – 11

$P_2 = 1$ (at 0), $P_2 = 0$ (at 1)

$$\text{Avg TAT} = \frac{11+2+6+2}{4} = \frac{21}{4} = 5.25\text{ms}$$

$$\text{Avg. WT} = \frac{7+0+3+0}{4} = \frac{10}{4} = 2.5\text{ms}$$

$$\text{Avg. RT} = \frac{7+0+3+0}{4} = \frac{10}{4} = 2.5\text{ms}$$

(Ans)

(*) Non Preemptive Priority Based scheduling :-

Process	AT	BT	Priority	TAT	WT	RT
P_1	0	4	3	9-0 = 9	9-4 = 5	5-0 = 5
P_2	0	2	1	2-0 = 2	2-2 = 0	0-0 = 0
P_3	1	3	2	5-1 = 4	4-3 = 1	2-1 = 1
P_4	2	2	4	11-2 = 9	9-2 = 7	9-2 = 7

Gantt chart

P_2	P_3	P_1	P_4
0 – 2	2 – 5	5 – 9	9 – 11

$$\text{Avg. TAT} = \frac{9+2+4+9}{4} = \frac{24}{4} = 6\text{ms}$$

$$\text{Avg. WT} = \frac{5+0+1+7}{4} = \frac{13}{4} = 3.25\text{ms}$$

$$\text{Avg RT} = \frac{5+0+1+7}{4} = \frac{13}{4} = 3.25\text{ms}$$

(Ans)

(*) Preemptive Priority Based Scheduling

Process	AT	BT	Priority	TAT	WT	RT
P_1	0	4	3	9-0 = 9	9-4 = 5	5-0 = 5
P_2	0	2	1	2-0 = 2	2-2 = 0	0-0 = 0
P_3	1	3	2	5-1 = 4	4-3 = 1	2-1 = 1
P_4	2	2	4	11-2 = 9	9-2 = 7	9-2 = 7

Gantt chart

P_2	P_2	P_3	P_1	P_4
0 – 1	1 – 2	2 – 5	5 – 9	9 – 11

$P_2 = 1$ (at 0), $P_2 = 0$ (at 1)

$$\text{Avg. TAT} = \frac{9+2+4+9}{4} = \frac{24}{4} = 6\text{ms}$$

$$\text{Avg. WT} = \frac{5+0+1+7}{4} = \frac{13}{4} = 3.25\text{ms}$$

$$\text{Avg. RT} = \frac{5+0+1+7}{4} = \frac{13}{4} = 3.25\text{ms}$$

(Ans)

(*) Highest Response Ratio Next:

Process	AT	BT	Priority	TAT	WT	RT
P_1	0	4	3	4-0=4	4-4=0	0-0=0
P_2	0	2	1	6-0=6	6-2=4	4-0=4
P_3	1	3	2	11-1=10	10-3=7	8-1=7
P_4	2	2	4	8-2=6	6-2=4	6-2=4

Gantt chart

P_1	P_2	P_4	P_3
0 – 4	4 – 6	6 – 8	8 – 11

T_4 : $R_{P_2} = ((4-0)+2)/2 = 6/2 = 3$ → choosen
$R_{P_3} = ((4-1)+3)/3 = 6/3 = 2$
$R_{P_4} = ((4-2)+2)/2 = 4/2 = 2$

T_6 : $R_{P_3} = ((6-1)+3)/3 = 8/3 = 2.67$
$R_{P_4} = ((6-2)+2)/2 = 6/2 = 3$ → choosen

$$\text{Avg. TAT} = \frac{4+6+10+6}{4} = \frac{26}{4} = 4.5\text{ms}$$
$$\text{Avg. WT} = \frac{0+4+7+4}{4} = \frac{15}{4} = 3.75\text{ms}$$
$$\text{Avg. RT} = \frac{0+4+7+4}{4} = \frac{15}{4} = 3.75\text{ms}$$
(Ans)

(*) Round Robin Scheduling (Quantum = 2 ms)

Process	AT	BT	Priority	TAT	WT	RT
P_1	0	4	3	10-0=10	10-4=6	0-0=0
P_2	0	2	1	4-0=4	4-2=2	2-0=2
P_3	1	3	2	11-1=10	10-3=7	4-1=3
P_4	2	2	4	8-2=6	6-2=4	6-2=4

Gantt chart

P_1	P_2	P_3	P_4	P_1	P_3
0 – 2	2 – 4	4 – 6	6 – 8	8 – 10	10 – 11

t	Arrival Process	Scheduled process	Running Time (TQ | BT)	Back in Queue	Remaining BT
0	P1 P2	P_1	$2 < 4$	Yes	2
2	~~P_2~~ $P_3 P_4 P_1$	P_2	$2 = 2$	NO	0
4	$P_3 P_4 P_1$	P_3	$2 < 3$	Yes	1
6	~~P_4~~ P_1 P_3	P_4	$2 = 2$	No	0
8	~~P_1~~ P_3	P_1	$2 = 2$	No	0
10	P_3	P_3	$2 > 1$	No	0
11	–	–	–	–	–

$$\text{Avg. TAT} = \frac{10+4+10+6}{4} = \frac{30}{4} = \underline{7.5ms}$$

$$\text{Avg. WT} = \frac{6+2+7+4}{4} = \frac{19}{4} = \underline{4.75ms}$$

$$\text{Avg. RT} = \frac{0+2+3+4}{4} = \frac{9}{4} = \underline{2.25ms}$$

(Ans)

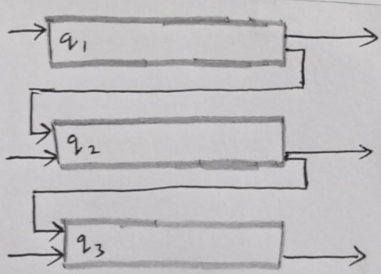
The algorithms. SJF & SRTF results in minimum avg. waiting time of 2.5ms.

Q10

10. Consider a multilevel feedback queue scheduling (MLFBQ) with three queues q1, q2 and q3, where q1 has the highest priority and q3 has the lowest priority. q1 and q2 use round robin algorithm with time quantum equal to 3 and 5 milliseconds respectively. q3 uses first-come first-serve algorithm. Assume the arrival time of all processes as 0. A process entering the ready queue will put in queue 0. Processes in queue q1, q2 will be demoted to lower priority queue, if not completed on specified time quantum. Find the average waiting time (A.W.T) and average turnaround time (A.T.A.T) for executing the following process?

process	Burst time
P1	8
P2	22
P3	4
P4	12

Ans

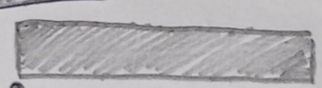


(Highest priority) [Round Robin ; Time Quantum = 3ms]

[Round Robin ; Time Quantum : 5ms]

(Lowest priority) [FCFS]

Gantt Chart



Process	Arrival Time	Burst Time	TAT	WT
P_1	0	8	17-0 = 17	17-8 = 9
P_2	0	22	42-0 = 42	42-22 = 20
P_3	0	4	23-0 = 23	23-4 = 19
P_4	0	12	46-0 = 46	46-12 = 34

At q1, (TQ = 3ms)

t	Arrival process	Scheduled process	Remaining Time (TQ BT)	Back in Queue	Remaining BT
0	$P_1 P_2 P_3 P_4$	P_1	3 < 8	yes	5
3	$P_2 P_3 P_4 P_1$	P_2	3 < 22	yes	19
6	$P_3 P_4 P_1 P_2$	P_3	3 < 4	yes	1
9	$P_4 P_1 P_2 P_3$	P_4	3 < 12	yes	9

At q2 (TQ = 5ms)

t	Arrival process	Scheduled process	Remaining Time (TQ BT)	Back in Queue	Remaining BT
12	$\cancel{P_1} P_2 P_3 P_4$	P_1	5 ≤ 5	No	0
17	$P_2 P_3 P_4$	P_2	5 < 19	Yes	14
22	$\cancel{P_3} P_4 P_2$	P_3	5 > 1	NO	0
23	$P_4 P_2$	P_4	5 < 9	Yes	4

At q3 (FCFS) (No Time Quantum)

t	Arrival process	Scheduled process	Remaining Time	Back in Queue	Remaining BT
28	$P_2 P_4$	P_2	14	NO	0
42	P_4	P_4	4	NO	0
46	—	—	—	—	—

Gantt chart

P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4	P_2	P_4
0–3	3–6	6–9	9–12	12–17	17–22	22–23	23–28	28–42	42–46

$$\underbrace{0 \;\; 3 \;\; 6 \;\; 9 \;\; 12}_{q_1} \quad \underbrace{12 \;\; 17 \;\; 22 \;\; 23 \;\; 28}_{q_2} \quad \underbrace{28 \;\; 42 \;\; 46}_{q_3}$$

$$\text{Avg. WT} = \frac{9+20+19+34}{4} = \frac{82}{4} = 20.5\text{ms}$$

$$\text{Avg TAT} = \frac{17+42+23+46}{4} = \frac{128}{4} = 32\text{ms}$$

(Ans)