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CONTENTS

COMPUTER SCIENCE & IT

Objective Practice Sets

Operating System

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1 CHAPTER
Basic Concepts of Operating System

Multiple Choice Questions & NAT Questions

Q.1 Consider the following code:

```
int n = 5;
while (n > 0)
{
    fork( );
    n--;
}
```

The total number of child processes created is equal to _____.

Q.2 Consider the following program:

```
main( )
{
    for(int i = 0; i < 4; i++)
    {
        fork0;
        fork0;
    }
}
```

The number of child processes created, is equal to _____.

Q.3 The following C program is executed on a Unix/Linux system.

```
# include <unistd.h>
int main( ) {
    int i;
    for (i = 1; i <= 50; i++)
        if (i % 2 == 0 || i % 3 == 0) fork( );
    return 0;
}
```

Then the number of child processes created is equal to _____.

Q.4 Consider the following code:

```
#include <unistd.h>
int main( )
{
    fork( );
    for (i = 1; i <= 5; i++)
    {
        fork( );
        printf("*");
    }
    return 0;
}
```

Then the number of times * is printed, is equal to _____.

Q.5 Which of the following need not necessarily be saved on a context switch between the processes?

(a) Program counter
(b) Stack pointer
(c) Translation lookaside buffer
(d) General purpose registers

Q.6 Which of the following should be allowed only in Kernel mode?

1. Changing mapping from virtual to physical address.
2. Mask and unmask interrupts.
3. Disabling all interrupts.
4. Reading status of processor.
5. Reading time of day.

(a) 1, 2 and 3
(b) 1, 2, 4 and 5
(c) 2, 3 and 5
(d) All of these

Q.7 An interrupt handler is a

(a) location in memory that keeps track of recently generated interrupts
(b) peripheral device
(c) utility program
(d) special numeric code that indicates the priority of a request

Q.8 Executing more than one program concurrently by one user on one computer is known as
(a) multiprogramming (b) time-sharing
(c) multitasking (d) multiprocessing

Q.9 The simultaneous processing of two or more programs by multiple processors is
(a) multitasking (b) multiprogramming
(c) time-sharing (d) multiprocessing

Q.10 Which of the following does not interrupt a running process?
(a) timer interrupts (b) device
(c) power failure (d) scheduling process

Q.11 System call is used to access
(a) I/O functionality
(b) operating system functionality
(c) application functionality
(d) None of the above

Q.12 Swapping is performed by
(a) long term scheduler
(b) mid term scheduler
(c) short term scheduler
(d) dispatcher

Q.13 Choose the false statement
(a) static linking requires no support of OS
(b) dynamic linking requires no support of OS
(c) dynamic loading requires no support of OS
(d) none of the above

Q.14 Assume that the Kernel mode is non-preemptive. What happens when an I/O interrupt comes while a process 'P_1' is running in the Kernel mode on the CPU?
(a) CPU is given to the process for which the I/O has completed
(b) CPU is given to some other process based on the scheduling policy
(c) P_1 continues to execute on the CPU
(d) None of the above

Q.15 Overlay is
(a) a part of an operating system
(b) a specific memory location
(c) a single contiguous memory that was used in the olden days for running large programs by swapping
(d) overloading the system with many user files

Q.16 When an interrupt occurs, an operating system
(a) ignores the interrupt
(b) always changes the stage of the interrupted process after processing the interrupt
(c) always resumes execution of the interrupted process after processing the interrupt
(d) may change the state of the interrupted process to "blocked" and schedule another process

Q.17 Consider the following statements:
S_1: The OS is designed to maximize the resource utilization.
S_2: The control program manages the system programs.
Which of the above statements is/are true?
(a) S_1 is true S_2 is false
(b) S_2 is true and S_1 is false
(c) Both S_1 and S_2 are true
(d) Both S_1 and S_2 are false

Q.18 Bootstrap loader is always stored in
(a) Cache (b) ROM
(c) RAM (d) Disk

Q.19 Which of the following is true?
(a) Overlays are used to increase the size of physical memory.
(b) Overlays are used to increase the logical address space.
(c) When overlays are used, the size of a process is not limited to the size of physical memory.
(d) Overlays are used whenever the physical address space is smaller than the logical address space.

Q.20 Process is
(a) A program in high level language kept on disk
(b) Contents of main memory
(c) A program in execution
(d) A job in secondary memory

Q.21 The state of a process after it encounters an I/O instruction is?
(a) Ready
(b) Blocked
(c) Idle
(d) Running

Q.22 Which of the following statements is true?

(a) Hard real time OS has less jitter than soft real time OS

(b) Hard real time OS has more jitter than soft real time OS

(c) Hard real time OS has equal jitter as soft real time OS

(d) None of the above

Multiple Select Questions (MSQ)

Q.23 Consider a demand-paging system with the following time-measured utilizations:

CPU utilization	20%
Paging disk	97.7%
Order I/O devices	5%

Which (if any) of the following will not (probably) improve CPU utilization?

(a) Install a faster CPU.

(b) Install a bigger paging disk.

(c) Increase the degree of multiprogramming.

(d) Decrease the degree of multiprogramming.

Q.24 Consider a demand-paging system with the following time-measured utilizations:

CPU utilization	20%
Paging disk	97.7%
Order I/O devices	5%

Which (if any) of the following will (probably) improve CPU utilization?

(a) Install more main memory.

(b) Install a faster hard disk or multiple controllers with multiple hard disks.

(c) Add prepaging to the page fetch algorithms.

(d) Increase the page size.

Q.25 Which one of the following is/are true?

(a) Kernel is the program that constitutes the central core of the operating system.

(b) Kernel is the first part of operating system to load into memory during booting.

(c) Kernel is made of various modules which can not be loaded in running operating system.

(d) Kernel remains in the memory during the entire computer session.

Q.26 Which one of the following error will be handle by the operating system?

(a) Power failure

(b) Lack of paper in printer

(c) Connection failure in the network

(d) Disk failure

Q.27 Which of the following statement(s) is/are correct for unix system calls?

(a) exec is used to invokes another program overlaying memory space with a copy.

(b) brk( ) A process synchronizes with termination of child process.

(c) wait is used to increase or decrease the size of data region.

(d) fork is used to creates a new process.

■■■■

Answers Basic Concepts of Operating System

1. (31)	**2.** (255)	**3.** (65535)	**4.** (12)	**5.** (c)	**6.** (a)	**7.** **(c)**	**8.** (c)	**9.** (d)
10. (b)	**11.** (b)	**12.** (b)	**13.** (b)	**14.** (c)	**15.** (c)	**16.** **(d)**	**17.** (a)	**18.** (b)
19. (c)	**20.** **(a)**	**21.** (b)	**22.** (a)	**23.** (a, b, c)	**24.** (a, b, c)	**25.** (a, b, d)	**26.** (a, b, c)	
27. (a, d)								

Explanations Basic Concepts of Operating System

1. (31)

There will be totally 5 fork calls after unrolling the loop, and 5 fork calls lead to $2^5-1 = 31$ child processes. Hence 31 will be the answer.

2. (255)

Unrolling the loop, we have totally 2*4 = 8 fork calls. So with 8 fork calls, we can have $2^8 - 1$, that is, 255 child processes. Hence answer is 255.

3. (65535)

If k is the total number of fork calls, then number of child processes created = $2^k - 1$

Total number of fork calls

= Number of integers between 1 and 50 which are divisible by either 5 or 7

= n(divisible by 5) + n(div by 7) – n(div by 35)

= 10 + 7 – 1 = 16

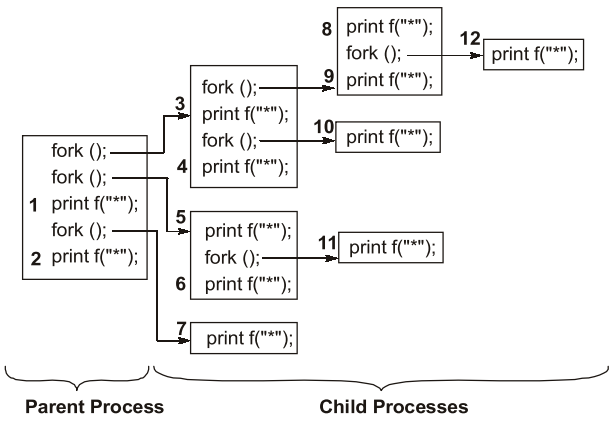
So, number of child processes = $2^{16} - 1 = 65535$.

4. (12)

The code can be reduced to:

```
fork( )
fork( );
printf("*");
fork( );
printf("*");
```

Let's start the trace



Number of times * printed = 12
Therefore (12) is the answer.

5. (c)

PCB doesn't need to save TLB entries during a context switch, as once a CS occurs, the TLB entries may become invalid as the virtual to physical mappings may be irrelevant to the newly scheduled process, so the TLB is generally flushed in this case. Hence (c) is the answer.

6. (a)

Only critical services must reside in the Kernel. All services mentioned except reading status of processors and reading time of the day are critical. Hence option (a) is correct.

14. (c)

When the Kernel is non-preemptive and any process is running in a Kernel mode, then process continues to run until either it completes or it waits for some input/output.

16. (d)

When a interrupt occurs operating system decides the request on the fact that the interrupt has higher priority or less priority. If less, the interrupted process is resumed and only after the execution of process, the interrupt is handled. However if interrupt has higher priority the process is blocked and interrupt is entertained. Hence an operating system may or may not change the state of the interrupted process to "blocked" and schedule another process.

19. (c)

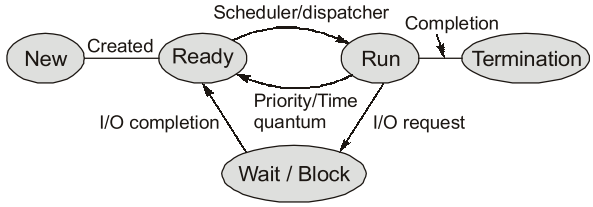
By using the overlays we can execute much greater processes simultaneously which cannot be execute and reside in the memory at the same time. In this the process to be executed process brought to memory only when it is needed at the time of execution.

20. (a)

The program under execution is called process.

21. (b)

The process state diagram is:



2 CHAPTER
Process and Threads

Multiple Choice Questions

Q.1 Consider n threads T_1, T_2, T_3, ..., T_n of a process P_i. Which of the following cannot be shared between them?
(a) Code (b) Data
(c) Files (d) Stack

Q.2 Consider the following statements:
I. For user level threads, a blocking system call blocks the entire process.
II. For Kernel level threads, a blocking system call blocks the entire process.
III. User level threads are transparent to the Kernel.
Which of the above statement(s) are true?
(a) Only I, III (b) Only II, III
(c) Only I, II (d) All of the above

Q.3 Which of the following instructions is not privileged?
(a) Clearing Memory Map
(b) Reading time of clock
(c) Disabling Interrupts
(d) Changing memory map

Q.4 Which of the following statements comparing the context of a thread with that of a process is true?
(a) two processes will not share any context; two threads of a same process will only share the data and the code (text) areas of the context
(b) two processes will not share any context; two threads of a same process will share the data, code (text) and the stack areas of the context
(c) two processes will share the data and the code (text) areas of the user context; two threads of a same process will only share the register context
(d) the overhead involved in context switching for threads is much higher than that for processes

Q.5 Which of the following information is not part of process control block
1. Process state 2. List of open files
3. Process page table 4. Stack pointer
(a) Only 3 (b) 3 and 4
(c) 2 and 4 (d) None of these

Q.6 Convoy effect is a result of
(a) one long CPU bound process and many other CPU bound processes are waiting
(b) many CPU bound processes and less I/O bound processes
(c) many CPU and I/O bound processes
(d) proper mix of CPU and I/O bound processes

Q.7 In a time-sharing operating system, when the time slot given to a process is completed, the process goes from the RUNNING state to the
(a) BLOCKED state
(b) READY state
(c) SUSPENDED state
(d) TERMINATED state

Q.8 In a multiprogramming environment
(a) the processor executes more than one process at a time
(b) the programs are developed by more than one person
(c) more than one process resides in the memory
(d) a single user can execute many programs at the same time

Q.9 If a system contains n processors and n processes then what will be maximum and minimum processes in running state respectively.
(a) n, n (b) n, 0
(c) n^2, 0 (d) n^2, n^2

Q.10 Match **List-I** with **List-II** select the correct answer using the codes given below the lists:
List-I
A. Run → ready
B. Run → blocked
C. Blocked → run
D. Run → terminated

List-II

1. Not possible
2. When a process terminates itself
3. When a process time quantum expires
4. When a process issues an input/output request

Codes:

	A	B	C	D
(a)	1	4	3	2
(b)	2	1	3	4
(c)	3	4	1	2
(d)	1	4	2	3

Q.11 While designing a Kernel, an operating system designer must decide whether to support Kernel-level or user-level threading. Which of the following statements is/are true?

1. Kernel-level threading may be preferable to user-level threading because storing information about user-level threads in the process control block would create a security risk.
2. User-level threading may be preferable to Kernel-level threading because in user-level threading, if one thread blocks on I/O, the process can continue.

(a) 1 only (b) 2 only
(c) 1 and 2 only (d) None of these

Q.12 Consider the following statements with respect to user-level threads and Kernel-supported threads

(i) Context switching is faster with Kernel-supported threads.
(ii) For user-level threads, a system call can block the entire process.
(iii) Kernel-supported threads can be scheduled independently.
(iv) User-level threads are transparent to the Kernel.

Which of the above statements are true?

(a) (*ii*), (*iii*), (*iv*) only (b) (*ii*) and (*iii*) only
(c) (*i*) and (*iii*) only (d) (*i*) and (*ii*) only

Q.13 Assume process A has 3 user level threads and process B has 4 Kernel-level threads. Consider while process A is running in CPU, process B is waiting in ready queue. If one of the thread in A is blocked then find status of A threads and B threads?

(a) All A threads are blocked and all B threads are blocked
(b) All A threads are blocked and B threads are not blocked
(c) All B threads are blocked and A threads are not blocked
(d) None of these

Q.14 Assume T_1 and T_2 are two threads of the same process. Consider the following information:

1. Data section
2. Stack section
3. Code section
4. I/O files

Find which of the above information can be shared by T_1 and T_2.

(a) 1, 2, 3 (b) 1, 2, 4
(c) 1, 3, 4 (d) 2, 3, 4

Q.15 In a system having a single processor, a new process arrives at the rate of six processes per minute and each such process requires seven seconds of service time. What is the CPU utilization?

(a) 70% (b) 30%
(c) 60% (d) 64%

Q.16 Which of the following is false?

(a) User level threads are not scheduled by the Kernel.
(b) Context switching between user level threads is faster than context switching between Kernel level threads.
(c) When a user thread is blocked all other threads of its processes are blocked.
(d) Kernel level threads cannot utilize multiprocessor systems by splitting threads on different processors or cores.

Q.17 Which of the following scheduling can be done by thread library?

(a) Process scheduling
(b) User thread scheduling
(c) Kernel thread scheduling
(d) None

Q.18 Match **List-I** and **List-II** and select the correct answer using the codes given below the lists as per the deadlock prevention scheme :

List-I

A. Fork
B. Context switch
C. Degree of multiprogramming
D. Message passing

List-II

1. Inter process communication
2. Process creation
3. Dispatcher
4. Long term scheduler

Answers Process and Threads

1. (d)	2. (a)	3. (c)	4. (a)	5. (d)	6. (a)	7. (b)	8. (c)	9. (b)
10. (c)	11. (a)	12. (b)	13. (b)	14. (c)	15. (a)	16. (d)	17. (b)	18. (d)
19. (b, c)	20. (a, b, d)	21. (a, b, d)	22. (a, b, c)	23. (b, c)	24. (a, b, c)	25. (b, d)		
26. (b, c, d)	27. (b, c, d)	28. (a, b, d)						

Explanations Process and Threads

1. (d)

Every threads has to have its own stack, and its own set of registers, and these can't be shared between any two threads. Rest can be shared. So (d) is the correct answer.

2. (a)

Since user level threads are transparent to the Kernel, a blocking system call blocks the entire process, and hence I and III are true. But Kernel level threads are not transparent to the Kernel, hence II is false.

3. (c)

Clearing Memory Map: Privileged Instruction.
Reading time of clock : Non privileged Instruction.
Disabling Interrupts : Privileged Instruction.
Changing Memory Map: Privileged Instruction.
Hence (c) is correct.

6. (a)

CPU bound processes requires lot of processor time, resulting in long wait for I/O bound processes for the processor. This effect is called convey effect. It results in lower CPU and I/O devices utilization.

9. (b)

When system contains '*n*' processor and '*n*' processes, then maximum number of processes in running state can be '*n*' with each processor containing maximum of one process in the running state. The minimum number is zero with no processor having a process in running state.
Hence correct option (b).

10. (c)

When a process issues an input/output request then it goes from running state to blocked state.
When a process terminates itself it goes from running state to terminate state.
A process cannot go to running state after completing its I/O, it most go to ready state.
Hence option (c) is correct.

12. (b)

Kernel level threads can be scheduled independently. For user level threads a system call can block the entire process and are not transparent to Kernel.

13. (b)

Process A has user-level threads. Whole process has single control block instead of maintaining control block for each thread. So blocking one thread cause all processes to block. Here process *A* and process *B* are independent, hence no relation between *A* and *B*.
$\therefore$ Option (b) is correct.

14. (c)

Each thread needs a program counter and stack section to keep the local variables of procedures. So stack section can not be shared by threads.
$\therefore$ option (c) is correct.

15. (a)

Number of processes = 6
Time required by each process = 7 sec

$$\text{CPU utilization} = \frac{\text{Useful time}}{\text{Total time}} = \frac{42}{60} \times 100 = 70\%$$

16. (d)

Kernel level threads can utilize multiprocessor systems by splitting threads on different processors or cores. Since they are independent of each other.

3 CHAPTER

CPU Scheduling

Multiple Choice Questions & NAT Questions

Q.1 Jobs keep arriving at a processor. A job can have an associated time length as well as a priority tag. New jobs may arrive while some earlier jobs are running. Some jobs may keep running indefinitely for service. Which of the following job-scheduling policies is starvation free?

(a) Round – robin (b) Shortest job first
(c) Priority queuing (d) Latest job first

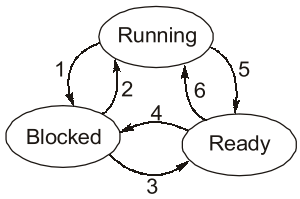
Q.2 Consider 4 processes, P_1, P_2, P_3 and P_4, whose arrival and burst times are given below:

	AT	BT
P_1	1	6
P_2	2	8
P_3	3	7
P_4	4	3

If SJF (non preemptive) algorithm is used, then the value of throughput, is

(a) 0.16 (b) 0.26
(c) 0.17 (d) None of these

Q.3 In the given figure, 3 process states are shown:



The transitions are numbered 1 to 6. Then which of the transitions are not possible on a uniprocessor system which uses preemptive CPU scheduling algorithm?

(a) 2 and 4 (b) 1 and 3
(c) 2 and 5 (d) All are possible

Q.4 The maximum number of processes that can be in ready state for a computer system with n CPUs is:

(a) 1 (b) n
(c) n^2 (d) Independent of n

Q.5 Consider 4 processes P_1, P_2, P_3, P_4 to be scheduled on a uniprocessor system. All the given processes arrive at time zero, and have burst times equal to 5, 2, 4 and 1 nanoseconds respectively, and Round-Robin Scheduling Algorithm is used. Let X be the process which finishes last when the time quantum is set to 2 ns, and Y be the process finishing last when the time quantum is set to 4 ns. Then X and Y are:

(a) P_1, P_2 (b) P_2, P_4
(c) P_2, P_4 (d) P_1, P_1

Q.6 Consider the following CPU scheduling Algorithms:

(a) First In First Out (FIFO)
(b) Shortest Job First (SJF)
(c) Round Robin (RR)
(d) Longest Remaining Time First (LRTF)

Which of the above algorithms suffer from starvation?

Q.7 Consider 6 processes, numbered 1 to 6 whose arrival and burst times are as shown.

PNO	AT	BT
1	0	4
2	1	5
3	2	2
4	3	1
5	4	6
6	6	3

If the system uses round robin scheduler, then the average turnaround time, if time quantum equals 2 units, is equal to _____.

Q.8 If the above question, the average response time is equal to _____.

Q.9 Consider four processes P_1, P_2, P_3, P_4 all arriving at time zero as follows.

Process ID	Burst Time
P_1	6
P_2	8
P_3	7
P_4	3

If the system uses non-preemptive SJF algorithm, then the throughput of the system is equal to

(a) 0.16 (b) 0.26
(c) 0.18 (d) None of these

Q.10 Consider the following 5 processes whose arrival and burst times are given below:

PNO	AT	BT
0	0	3
1	2	6
2	4	4
3	6	5
4	8	2

The Average Turn Around Time of a process if highest Response Ratio Next Scheduler is used, is equal to _____.

Q.11 Consider three processes P_0, P_1 and P_2, each of them arriving at time zero, requiring burst times 2, 4 and 8 respectively. The system uses the Longest Time Remaining First (LRTF) algorithm to schedule the processes onto the CPU. If ties are broken by giving priority to the process with the lowest process id, then the average turn around time of a process is equal to _____.

Q.12 Consider 6 processes whose arrival and burst times are given below:

PNO	AT	BT	Priority
1	0	4	4
2	1	5	5
3	2	1	7
4	3	2	1
5	4	3	2
6	5	6	6

The system uses non preemptive priority scheduling algorithm such that higher priority numbers indicate higher priority, and lower indicate lower priority, then the average waiting time of a process is equal to_____. (Upto one decimal place)

Q.13 Consider 3 processes whose arrival and burst times are given below:

Process	Arrival Time	Burst Time	Priority
P_1	0	4	3(Lowest)
P_2	2	7	1(Highest)
P_3	3	10	2

If the system uses the preemptive priority scheduler. Then the average waiting time of a process is equal to ..... (Numerically type)

Q.14 The aging algorithm with $a = 0.5$ is used to predict run times. The previous four runs from oldest to most recent are 40,20,20, and 15 msec, with $E_1 = 10$. The prediction for the next time will be:

(a) 15 msec (b) 28.75 msec
(c) 39 msec (d) 40 msec

Q.15 Consider 4 processes whose arrival and burst times are given below:

PNO	AT	BT
P_1	0	5
P_2	1	3
P_3	2	4
P_4	3	3

If Round Robin Scheduling is used with time slice of 3 units, and there is a context switching overhead of 1 unit and (assuming no context scheduling overhead) then the percentage of time for which the CPU remains idle, is equal to:

(a) 25 (b) 35
(c) 50 (d) 60

Q.16 Consider 3 processes P_1, P_2 and P_3 arriving at $t = 0$ and having process times 20, 30 and 10 respectively. Each process uses the first 30% of its process time in CPU, then 50% in IO and the last 20% in CPU. Then the average response time, if FCFS scheduling is used, is equal to _____.

Q.17 Consider 3 processes P_1, P_2 and P_3 whose burst requirements are given below:

PNO	AT	IO	CPU	IO	Priority Label
1	0	2	7	1	2
2	1	4	14	2	1 (H)
3	2	6	21	3	3 (L)

Answers CPU Scheduling

1. (a)	2. (a)	3. (a)	4. (d)	5. (d)	6. (a)	7. (10.83)	8. (3.33)	9. (a)
10. (8)	11. (13)	12. (6.5)	13. (7.66)	14. (b)	15. (a)	16. (7)	17. (30.67)	18. (27.33)
19. (5.3)	20. (a)	21. (c)	22. (b)	23. (c)	24. (d)	25. (d)	26. (b)	27. (88.67)
28. (b)	29. (b)	30. (d)	31. (94)	32. (68)	33. (11)	34. (0)	35. (c)	36. (63)
37. (a)	38. (b)	39. (b)	40. (c)	41. (d)	42. (a)	43. (b)	44. (c)	45. (c)
46. (c)	47. (c)	48. (b)	49. (b)	50. (d)	51. (d)	52. (d)	53. (d)	54. (c)
55. (a)	56. (b)	57. (b)	58. (c)	59. (6.5)	60. (24.5)	61. (6.67)	62. (a)	63. (b)
64. (c)	65. (12)	66. (c)	67. (c)	68. (d)	69. (a)	70. (d)	71. (c)	72. (a, b)
73. (a, c)	74. (b, d)	75. (a, b)	76. (a, b, c)	77. (a, d)	78. (b, c)	79. (a, c, d)		80. (a, b, c)

Explanations CPU Scheduling

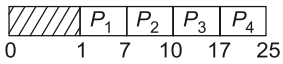
1. (a)

Round-Robin ensures no starvation.

So option (a) is the correct answer.

2. (a)

Gantt Chart:



$$\text{Throughput} = \frac{\text{Number of processes}}{\text{MAX(CT)} - \text{MIN(AT)}}$$

$$\text{Throughput} = \frac{4}{(25-1)} = \frac{1}{6} = 0.16$$

3. (a)

CPU cannot directly move from blocked state to running state. It will first move to ready state, and then the scheduling algorithm will decide when to place it in running state. So the transition (2) is not possible.

Similarly transition (4) is not possible, as a process will only enter ready state if it is in need of CPU.

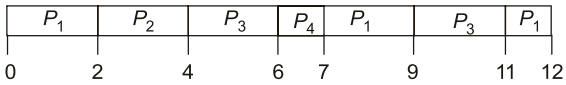
So (a) is the right choice.

4. (d)

Any number of processes can enter the ready queue, irrespective of the number of CPUs available in the system. So (d) is the answer.

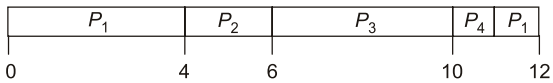
5. (d)

Here's the Gantt Chart for the first case.



Clearly P_1 finishes last.

And for the second case when time quantum is set to 4 units,



P_1 happens to finish last here as well. So in both cases, P_1 is the one to finish last. So (d) is the answer.

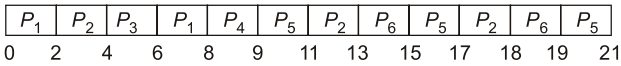
6. (a)

Only SJF suffers from starvation, and the rest don't. So (a) is the answer.

7. (10.83)

PNO	AT	BT	CT	TAT
1	0	4	8	8
2	1	5	18	17
3	2	2	6	4
4	3	1	9	6
5	4	6	21	17
6	6	3	19	13

Gantt Chart:



Therefore average TAT

$$= \frac{(8+17+4+6+17+3)}{6} = 10.83$$

8. (3.33)

(Response time P_i) = (Time at which P_i is scheduled for the first time) – (Arrival time of P_i)

Response Time (P_1) = 0 – 0 = 0

Response Time (P_2) = 2 – 1 = 1

Response Time (P_3) = 4 – 2 = 2

Response Time (P_4) = 8 – 3 = 5

Response Time (P_5) = 9 – 4 = 5

Response Time (P_6) = 13 – 6 = 7

Average response time

$$= \frac{\sum_{i=1}^{6}(RT(P_i))}{6} = \frac{(0+1+2+5+5+7)}{6}$$

Solve to get 3.33 as the answer.

9. (a)

$$\text{Throughput} = \frac{\text{Number of processes}}{\text{Max(CT)} - \text{Min(AT)}}$$

Where, Max(CT) refers to the completion time of a process finishing last; and Min(AT) refers to the arrival time of the process which is the first to arrive amongst all the processes.

Gantt chart:

P_4	P_1	P_3	P_2
0	3	9	16	24

Number of processes completed = 4

Max (CT) = 24, Min (AT) = 0

Therefore throughput = $\left(\frac{4}{24}\right) = 0.16$

10. (8)

Gantt Chart:

P_0	P_1	P_2	P_4	P_3
0	3	9	13	18	22

Upon calculating, average TAT = $\frac{40}{5} = 8$

Hence 8 is the answer.

11. (13)

Gantt Chart:

P_2	P_1	P_2	P_1	P_2	P_0	P_1	P_2	P_0	P_1	P_2
0	4	5	6	7	8	9	10	11	12	13	14

Process	AT	BT	CT	TAT
P_0	0	2	12	12
P_1	0	4	13	13
P_2	0	8	14	14

Average TAT = $\frac{(12+13+14)}{3} = 13$

12. (6.5)

Gantt Chart:

P_1	P_3	P_6	P_2	P_4	P_5
0	4	5	11	16	18	21

PNO	CT	TAT	WT
1	4	4	0
2	16	15	10
3	5	3	2
4	18	15	13
5	21	17	14
6	11	6	0

Average WT = $\frac{39}{6} = 6.5$

Note: If priorities of process match, schedule the process which has lowest arrival time.

13. (7.66)

Gantt Chart:

P_1	P_2	P_3	P_1
0	2	9	19	21

Waiting time of P_1 = (19 – 2) = 17 units

Waiting time of P_2 = 0 units

Waiting time of P_3 = (9 – 3) = 6 units

∴ Average Waiting Time

$$= \frac{(17+0+6)}{3} = \frac{23}{3} = 7.66 \text{ units}$$

14. (b)

We need to find E_5.

$E_5 = 0.5(15) + 0.5\ E_4$

$E_4 = 0.5(15) + 0.5\ E_3$

$E_3 = 0.5(15) + 0.5\ E_2$

$E_2 = 0.5(15) + 0.5\ E_1$

Putting $E_1 = 10$, we get $E_2 = 25$, $E_3 = 22.5$, $E_4 = 21.25$, and finally $E_5 = 28.75$.

Hence (b) is the answer.