1 Process Management-I

(Introduction, Process, Threads & CPU Scheduling)

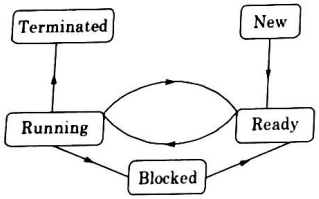
1.1 Which scheduling policy is most suitable for a time-shared operating systems?
(a) Shortest Job First
(b) Round Robin
(c) First come first serve
(d) Elevator **[1995 : 1 M]**

1.2 The sequence ..... is an optimal non-preemptive scheduling sequence for the following jobs which leaves the CPU idle for ..... unit(s) of time.

Job	Arrival time	Burst time
1	0.0	9
2	0.6	5
3	1.0	1

(a) {3, 2, 1}, 1 (b) {2, 1, 3}, 0
(c) {3, 2, 1}, 0 (d) {1, 2, 3}, 5
[1995 : 2 M]

1.3 The process state transition diagram in figure is representative of



(a) a batch operating system
(b) an operating system with a preemptive scheduler
(c) an operating system with a non-preemptive scheduler
(d) a uni-programmed operating system
[1996 : 1 M]

1.4 Which of the following is an example of spooled device?
(a) A line printer used to print the output of a number of jobs
(b) A terminal used to enter input data to a running program
(c) A secondary storage device in a virtual memory system
(d) A graphic display device **[1996 : 1 M]**

1.5 Four jobs to be executed on a single processor system arrive at time 0^+ in the order A, B, C, D. Their burst CPU time requirements are 4, 1, 8, 1 time units respectively. The completion time of A under round robin scheduling with time slice of one time unit is
(a) 10 (b) 4
(c) 8 (d) 9 **[1996 : 2 M]**

1.6 Which of the following is an example of a spooled device?
(a) The terminal used to enter the input data for the C program being executed
(b) An output device used to print the output of a number of jobs.
(c) The secondary memory device in a virtual storage system
(d) The swapping area on a disk used by the swapper. **[1998 : 1 M]**

1.7 Consider n processes sharing the CPU in a round-robin fashion. Assuming that each process switch takes s seconds, what must be the quantum size q such that the overhead resulting from process switching is minimized but at the same time each process is guaranteed to get its turn at the CPU at least every t seconds?
(a) $q \le \frac{t - ns}{n-1}$ (b) $q \ge \frac{t - ns}{n-1}$
(c) $q \le \frac{t - ns}{n+1}$ (d) $q \ge \frac{t - ns}{n+1}$
[1998 : 1 M]

1.8 Four jobs are waiting to be run. Their expected run times are 6, 3, 5 and x in what order should they be run to minimize the average response time? **[1998 : 2 M]**

1.9 System calls are usually invoked by using
(a) a software interrupt
(b) polling
(c) an indirect jump
(d) a privileged instruction **[1999 : 1 M]**

1.10 A multi-user, multi-processing operating system cannot be implemented on hardware that does not support
(a) Address translation
(b) DMA for disk transfer
(c) At least two modes of CPU execution (privileged and non-privileged)
(d) Demand paging **[1999 : 2 M]**

1.11 Which of the following actions is/are typically not performed by the operating system when switching context from process A to process B?
(a) Saving current register values and restoring saved register values for process B.
(b) Changing address translation tables.
(c) Swapping out the memory image of process A to the disk.
(d) Invalidating the translation look-aside buffer. **[1999 : 2 M]**

1.12 A processor needs software interrupt to
(a) Test the interrupt system of the processor
(b) Implement co-routines
(c) Obtain system services which need execution of privileged instructions
(d) Return from subroutine **[2001 : 1 M]**

1.13 A CPU has two modes-privileged and non-privileged. In order to change the mode from privileged to non-privileged
(a) a hardware interrupt is needed
(b) a software interrupt is needed
(c) a privileged instruction (which does not generate an interrupt) is needed
(d) a non-privileged instruction (which does not generate an interrupt) is needed **[2001 : 1 M]**

1.14 Consider a set of n tasks with known runtimes $r_1, r_2, ..., r_n$ to be run on a uniprocessor machine. Which of the following processor scheduling algorithms will result in the maximum throughput?
(a) Round-Robin
(b) Shortest-Job-First
(c) Highest-Response-Ratio-Next
(d) First-Come-First-Served **[2001 : 1 M]**

1.15 Which of the following scheduling algorithms is non-preemptive?
(a) Round Robin
(b) First-in-First-out
(c) Multilevel Queue Scheduling
(d) Multilevel Queue Scheduling with Feedback **[2001 : 1 M]**

1.16 Which of the following does not interrupt a running process?
(a) A device (b) Timer
(c) Scheduler process (d) Power failure **[2001 : 2 M]**

1.17 Which combination of the following features will suffice to characterize an OS as a multi-programmed OS? (i) more than one program may be loaded into main memory at the same time for execution. (ii) If a program waits for certain events such as I/O, another program is immediately scheduled for execution. (iii) If the execution of a program terminates, another program is immediately scheduled for execution
(a) (i) (b) (i) and (ii)
(c) (i) and (iii) (d) (i), (ii) and (iii) **[2002 : 2 M]**

1.18 Draw the process state transition diagram of an OS in which (i) each process is in one of the five states: created, ready, running, blocked (i.e. sleep or wait), or terminated, and (ii) only non-preemptive scheduling is used by the OS. Label the transitions appropriately. **[2002 : 2 M]**

1.19 A uni-processor computer system only has two processes, both of which alternate 10 ms CPU bursts with 90 ms I/O bursts. Both the processes were created at nearly the same time. The I/O of both processes can proceed in parallel. Which of the following scheduling strategies will result in the least CPU utilization (over a long period of time) for this system?
(a) First come first served scheduling
(b) Shortest remaining time first scheduling
(c) Static priority scheduling with different priorities for the two processes
(d) Round robin scheduling with a time quantum of 5 ms. **[2003 : 2 M]**

1.20 Consider the following statements with respect to user-level threads and kernel-supported threads
(i) Context switch 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) and (iv) only
(b) (ii) and (iii) only
(c) (i), and (iii) only
(d) (i) and (ii) only **[2004 : 1 M]**

Process	Arrival Time	Burst Time
P1	0	12
P2	2	4
P3	3	6
P4	8	5

The average waiting time (in milliseconds) of the processes is _____. **[2014 (Set-3) : 2 M]**

1.51 Consider a uniprocessor system executing three tasks T_1, T_2 and T_3, each of which is composed of an infinite sequence of jobs (or instances) which arrive periodically at intervals of 3, 7 and 20 milliseconds, respectively. The priority of each task is the inverse of its period, and the available tasks are scheduled in order of priority, with the highest priority task scheduled first. Each instance of T_1, T_2 and T_3 requires an execution time of 1, 2 and 4 milliseconds, respectively. Given that all tasks initially arrive at the beginning of the 1st millisecond and task preemptions are allowed, the first instance of T_3 completes its execution at the end of _____ milliseconds. **[2015 (Set-1) : 2 M]**

1.52 The maximum number of processes that can be in Ready state for a computer system with n CPUs is

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

[2015 (Set-3) : 1 M]

1.53 For the processes listed in the following table, which of the following scheduling schemes will give the lowest average turnaround time?

Process	Arrival Time	Processing Time
A	0	3
B	1	6
C	4	4
D	6	2

(a) First Come First Serve
(b) Non-preemptive Shortest Job First
(c) Shortest Remaining Time
(d) Round-Robin with Quantum value two

[2015 (Set-3) : 2 M]

1.54 Consider an arbitrary set of CPU-bound processes with unequal CPU burst lengths submitted at the same time to a computer system. Which one of the following process scheduling algorithms would minimize the average waiting time in the ready queue?

(a) Shortest remaining time first
(b) Round-robin with time quantum less than the shortest CPU burst
(c) Uniform random
(d) Highest priority first with priority proportional to CPU burst length

[2016 (Set-1) : 1 M]

1.55 Consider the following processes, with the arrival time and the length of the CPU burst given in milliseconds. The scheduling algorithm used is preemptive shortest remaining-time first.

Process	Arrival Time	Burst Time
P_1	0	10
P_2	3	6
P_3	7	1
P_4	8	3

The average turn around time of these processes is _____ milliseconds.

[2016 (Set-2) : 2 M]

1.56 Threads of a process share

(a) global variables but not heap
(b) heap but not global variables
(c) neither global variables nor heap
(d) both heap and global variables

[2017 (Set-1) : 1 M]

1.57 Consider the following CPU processes with arrival times (in milliseconds) and length of CPU bursts (in milliseconds) as given below:

Process	Arrival time	Burst time
P_1	0	7
P_2	3	3
P_3	5	5
P_4	6	2

If the pre-emptive shortest remaining time first scheduling algorithm is used to schedule the processes, then the average waiting time across all processes is _____ milliseconds.

[2017 (Set-1) : 1 M]

1.58 Which of the following is/are shared by all the threads in a process?

I. Program counter II. Stack
III. Address space IV. Registers

(a) I and II only (b) III only
(c) IV only (d) III and IV only

[2017 (Set-2) : 1 M]

1.59 Consider the set of processes with arrival time (in milliseconds), CPU burst time (in milliseconds), and priority (0 is the highest priority) shown below. None of the processes have I/O burst time.

Process	Arrival Time	Burst Time	Priority
P_1	0	11	2
P_2	5	28	0
P_3	12	2	3
P_4	2	10	1
P_5	9	16	4

The average waiting time (in milliseconds) of all the processes using preemptive priority scheduling algorithm is _____.

[2017 (Set-2) : 2 M]

1.60 Consider the following C program is executed on a Unix/Linux system:

```
#include<unistd.h>
int main()
{
    int i;
    for (i = 0; i < 10; i++)
        if (i % 2 == 0) fork( );
    return 0;
}
```

The total number of child processes created is _____.

[2019 : 1 M]

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

Process	P_1	P_2	P_3	P_4
Arrival time	0	1	3	4
CPU time	3	1	3	Z

These processes are run on a single processor using preemptive Shortest Remaining Time First scheduling algorithm. If the average waiting time of the processes is 1 millisecond, then the value of Z is _____.

[2019 : 2 M]

1.62 Consider the following statements about process state transitions for a system using preemptive scheduling.

I. A running process can move to ready state.
II. A ready process can move to running state.
III. A blocked process can move to running state.
IV. A blocked process can move to ready state.

Which of the above statements are TRUE?

(a) I, II, III and IV
(b) II and III only
(c) I, II and III only
(d) I, II and IV only

[2020 : 1 M]

1.63 Consider the following set of processes, assumed to have arrived at time 0. Consider the CPU scheduling algorithms Shortest Job First (SJF) and Round Robin (RR). For RR, assume that the processes are scheduled in the order P_1, P_2, P_3, P_4.

Processes	P_1	P_2	P_3	P_4
Burst time (in ms)	8	7	2	4

If the time quantum for RR is 4 ms, then the absolute value of the difference between the average turnaround times (in ms) of SJF and RR (round off to 2 decimal places) is _____.

[2020 : 2 M]

1.64 Three processes arrive at time zero with CPU bursts of 16, 20 and 10 milliseconds. If the scheduler has prior knowledge about the length of the CPU bursts, the minimum achievable average waiting time for these three processes in a non-preemptive scheduler (round to nearest integer) is _____ milliseconds.

[2021 (Set-1) : 1 M]

1.65 Which of the following standard C library functions will always invoke a system call when executed from a single-threaded process in a UNIX/Linux operating system?

(a) exit (b) strlen
(c) sleep (d) malloc

[2021 (Set-1) : 1 M]

1.66 Which of the following statement(s) is/are correct in the context of CPU scheduling?

(a) The goal is to only maximize CPU utilization and minimize throughput.
(b) Turnaround time includes waiting time.
(c) Round-robin policy can be used even when the CPU time required by each of the processes is not known apriori.
(d) Implementing preemptive scheduling needs hardware support.

[2021 (Set-2) : 1 M]

1.67 Consider four processes P, Q, R, and S scheduled on a CPU as per round robin algorithm with a time quantum of 4 units. The processes arrive in the order P, Q, R, S, all at time $t = 0$. There is exactly one context switch from S to Q, exactly one context switch from R to Q, and exactly two context switches from Q to R. There is no context switch from S to P. Switching to a ready process after the termination of another process is also

considered a context switch. Which one of the following is NOT possible as CPU burst time (in time units) of these processes?

(a) P = 4, Q = 10, R = 6, S = 2
(b) P = 2, Q = 9, R = 5, S = 1
(c) P = 4, Q = 12, R = 5, S = 4
(d) P = 3, Q = 7, R = 7, S = 3

[2022 : 2 M]

1.68 Which one or more of the following need to be saved on a context switch from one thread (T1) of a process to another thread (T2) of the same process?

(a) Page table base register
(b) Stack pointer
(c) Program counter
(d) General purpose registers

[2023 : 1 M]

1.69 Which one or more of the following options guarantee that a computer system will transition from user mode to Kernel mode?

(a) Function call
(b) Malloc call
(c) Page fault
(d) System call

[2023 : 1 M]

1.70 Which one or more of the following CPU scheduling algorithms can potentially cause starvation?

(a) First-in First-Out
(b) Round Robin
(c) Priority Scheduling
(d) Shortest Job First

[2023 : 1 M]

1.71 Which of the following statements about threads is/are TRUE?

(a) Threads can only be implemented in Kernel space
(b) Each thread has its own file descriptor table for open files
(c) Threads belonging to a process are by default not protected from each other
(d) All the threads belonging to a process share a common stack

[2024 (Set-1) : 1 M]

1.72 Which of the following process state transitions is/are NOT possible?

(a) Waiting to Running
(b) Ready to Waiting
(c) Running to Terminated
(d) Running to Ready

[2024 (Set-1) : 1 M]

1.73 Consider the following two threads T1 and T2 that update two shared variables a and b. Assume that initially $a = b = 1$. Though context switching between threads can happen at any time, each statement of T1 or T2 is executed atomically without interruption.

T1	T2
$a = a + 1;$	$b = 2 * b;$
$b = b + 1;$	$a = 2 * a;$

Which one of the following options lists all the possible combinations of values of a and b after both T1 and T2 finish execution?

(a) $(a = 3, b = 4)$; $(a = 4, b = 3)$; $(a = 3, b = 3)$
(b) $(a = 4, b = 4)$; $(a = 4, b = 3)$; $(a = 3, b = 4)$
(c) $(a = 2, b = 2)$; $(a = 2, b = 3)$; $(a = 3, b = 4)$
(d) $(a = 4, b = 4)$; $(a = 3, b = 3)$; $(a = 4, b = 3)$

[2024 (Set-1) : 2 M]

1.74 Consider a process P running on a CPU. Which one or more of the following events will always trigger a context switch by the OS that results in process P moving to a non-running state (e.g., ready, blocked)?

(a) A timer interrupt is raised by the hardware.
(b) P tries to access a page that is in the swap space, triggering a page fault.
(c) An interrupt is raised by the disk to deliver data requested by some other process.
(d) P makes a blocking system call to read a block of data from the disk.

[2024 (Set-2) : 1 M]

1.75 Consider a multi-threaded program with two threads T1 and T2. The threads share two semaphores: s1 (initialized to 1) and s2 (initialized to 0). The threads also share a global variable x (initialized to 0). The threads execute the code shown below.

```
// code of T1          // code of T2
wait (s1);             wait (s1);
x = x + 1;             x = x + 1;
print(x);              print(x);
wait(s2);              signal(s2);
signal(s1);            signal(s1);
```

Which of the following outcomes is/are possible when threads T1 and T2 execute concurrently?

(a) T2 runs first and prints 1, T1 runs next and prints 2
(b) T2 runs first and prints 1, T1 does not print anything (deadlock)
(c) T1 runs first and prints 1, T2 runs next and prints 2
(d) T1 runs first and prints 1, T2 does not print anything (deadlock)

[2024 (Set-2) : 2 M]

1.76 Consider a single processor system with four processes A, B, C, and D, represented as given below, where for each process the first value is its arrival time, and the second value is its CPU burst time.

A(0, 10), B(2, 6), C(4, 3) and D(6, 7)

Which one of the following options gives the average waiting times when preemptive Shortest Remaining Time First (SRTF) and Non-Preemptive Shortest Job First (NP-SJF) CPU scheduling algorithms are applied to the processes?

(a) SRTF = 6, NP-SJF = 7
(b) SRTF = 7, NP-SJF = 7.5
(c) SRTF = 7, NP-SJF = 8.5
(d) SRTF = 6, NP-SJF = 7.5

[2024 (Set-2) : 2 M]

Answers Process Management-I

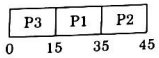
1.1	(b)	1.2	(a)	1.3	(b)	1.4	(a)	1.5	(d)	1.6	(b)	1.7	(a)	1.8	Sol.	1.9	(a)		
1.10	(c)	1.11	(c)	1.12	(c)	1.13	(d)	1.14	(b)	1.15	(b)	1.16	(a)	1.17	(d)	1.18	Sol.		
1.19	(d)	1.20	(a)	1.21	(a)	1.22	(c)	1.23	(a)	1.24	(d)	1.25	(c)	1.26	(d)	1.27	(b)		
1.28	(b)	1.29	(b)	1.30	(b)	1.31	(a)	1.32	(a)	1.33	(d)	1.34	(b)	1.35	(c)	1.36	(b)		
1.37	(b)	1.38	(c)	1.39	(d)	1.40	(c)	1.41	(d)	1.42	(c)	1.43	(a)	1.44	(c)	1.45	(c)		
1.46	(b)	1.47	(d)	1.48	(7.2)	1.49	(1000)	1.50	(5.5)	1.51	(12)	1.52	(d)	1.53	(c)	1.54	(a)		
1.55	(8.25)	1.56	(d)	1.57	(3)	1.58	(b)	1.59	(29)	1.60	(31)	1.61	(2)	1.62	(d)	1.63	(5.25)		
1.64	(12)	1.65	(a, c)	1.66	(b, c, d)	1.67	(d)	1.68	(b, c, d)	1.69	(c, d)	1.70	(c, d)	1.71	(c)	1.72	(a, b)		
1.73	(d)	1.74	(b, d)	1.75	(a, d)	1.76	(d)												

Process	Priority	CPU Time	Arrival Time	TAT
P1	10	20 sec	00.00.05	20
P2	9	10 sec	00.00.03	30
P3	8	15 sec	00.00.00	45

So, Turn Around Time of P2 is 30.

Using non-preemptive priority scheduling.

Gantt chart:



Process	Priority	CPU Time	Arrival Time	TAT
P1	10	20 sec	00.00.05	30
P2	9	10 sec	00.00.03	42
P3	8	15 sec	00.00.00	15

So, Turn Around Time of P2 is 42.

1.25 (c)

By following I and II conditions the process P_1 will get both the resouces R_1 and R_2.

If R_1 and R_2 are allocated to the Process P_1, then it will complete it's job and release it. After that process P_2 will get both the resources and complete it's Job.

1.26 (d)

Fork( ) returns 0 is child process and process ID of child process is parent process.

In child(x), a = a + 5

In paraent(u), a = a – 5. Therefore, x = u + 10

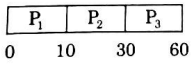
The physical addresses of parent and child processes will be different, v ≠ y.

1.27 (b)

Let three processes are P_1, P_2 and P_3

Process	Arrival Time	Burst Time
P_1	0	10
P_2	2	20
P_3	6	30

The Gantt chart for SRTF scheduling algorithm is



So there is only two context switches, at time unit 10 context switch from P_1 to P_2 and at time unit 30 context switch from P_2 to P_3.

1.28 (b)

If it were a preemptive scheduling then there would have been a transition from Running state to Ready state. So it is non-preemptive scheduling.

1.29 (b)

At t = 0 only P1 is present so execute it for 1 unit (**remaining CPU time of P1 = 0, now it will perform I/O**).

At t = 1 no process is available for CPU so CPU will remain idle and P1 will perform I/O (**remaining I/O time of P1 = 4**)

At t = 2 P2 arrives and is available for CPU so execute it for 1 unit and simultaneously P_1 will do I/O (**remaining CPU time of P_2 = 2 & remaining I/O time of P1 = 3**).

At t = 3 P3 also arrives and it is having highest priority among all processes available for CPU so we can execute P3 for its complete CPU burst (i.e 2 unit) as all processes has arrived and simultaneously P1 will do I/O(**remaining CPU time of P3 = 0, now P3 will perform I/O & remaining I/O time of P1 = 1**).

At t = 5 only P2 is available for CPU so it will execute for 1 unit and P1 and P3 will perform I/O(**remaining CPU time of P2 = 1, remaining I/O time of P3 = 2, remaining I/O time of P1 = 0, now P1 will perform CPU**).

At t = 6 P2 and P1 are available for CPU but P1 will be selected because it is having highest priority then P2 so execute P1 for 1 unit (**remaining CPU time of P1 = 2 & remaining I/O time of P3 is 1**)

At t = 7 again P1 will be executed for 1 unit (**remaining CPU time of P1 = 1 & remaining I/O time of P3 = 0, now P3 will perform CPU**).

At t = 8 now P1, P2 & P3 are available for CPU so P3 will be selected based on highest priority and will be executed for 1 unit (**remaining CPU time of P3 = 0, so P3 completed at t = 9**).

At t = 9 P1 will be executed on CPU for 1 unit (**remaining CPU time of P1 = 0, so P1 completed at t = 10**).

At t = 10 only P2 is available for CPU so it will execute its remaining CPU burst (i.e 1 unit) (**remaining CPU time of P2 = 0, now P2 will perform I/O.**)

At t = 11 P2 will perform I/O for 3 units and CPU will remain IDLE.

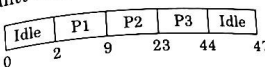
At t = 14 P2 will perform CPU again and P2 **is completed at t = 15**

P1	IDLE	P2	P3	P2	P1	P1	P3	P1	P2	IDLE	P2
0	1	2	3	5	6	7	8	9	10	11	14 15

1.30 (b)

Process	Total burst time	I/O time	CPU time	I/O time
P1	10	2	7	1
P2	20	4	14	2
P3	30	6	21	3

The Gantt chart is



Total time spent = 47

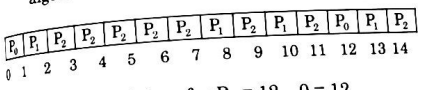
Idle time = 2 + 3 = 5

$$\% \text{ of idle time} = \frac{5}{47} \times 100 = 10.6\%$$

1.31 (a)

Process id	Arrival Time	CPU burst
P_0	0	2
P_1	0	4
P_2	0	8

The Gantt chart for LRTF CPU scheduling algorithm.



Turn around time for P_0 = 12 – 0 = 12

Turn around time for P_1 = 13 – 0 = 13

Turn around time for P_2 = 14 – 0 = 14

$$\text{Average Turn around Time} = \frac{39}{3} = 13$$

1.32 (a)

List-I

A. Gang Scheduling

B. Rate Monotonic Scheduling

C. Fair Show Scheduling

List-II

3. Thread Scheduling
2. Real-time Scheduling
1. Guaranteed Scheduling

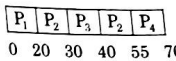
1.33 (d)

In Kernel level threads, the blocking system call causes, the Kernel can schedule another thread in the application for execution. So statement (d) is false about Kernel level threads.

1.34 (b)

Process	Execution Time	Arrival Time
P_1	20	0
P_2	25	15
P_3	10	30
P_4	15	45

The Gantt chart for SRT Scheduling algorithm is



So the waiting time for

$P_2 = (20 - 15) + (40 - 30) = 5 + 10 = 15$

1.35 (c)

When time quantum used in round robin scheduling is more than maximum time required to execute any process then its behave like First Come First serve.

1.36 (b)

Statement (b) is not true because an ISR (Interrupt Service Routine) is invoked after completion of I/O in synchronous but not in asynchronous I/O.

1.37 (b)

fork( ) system call creates the child process initially number of processes is 0. After first fork( ), it creates a single process. After second fork( ), it creates one parent and two child processes. After n + 1 fork( ), the total number of processes is 2^n but we subtract the main process then total number of child processes is $2^n - 1$.

1.38 (c)

Transition C indicates that OS uses preemptive scheduling. II is also true.

1.39 (d)

In the shortest remaining time first scheduling, process will not get a chance if that one has the high remaining time so due to this, starvation take place.

Shortest remaining time first scheduling will cause starvation, is true because if a large CPU brust required process is there and if consider that all the processes which are coming have less CPU-brust then the former have to wait untill all finish execution gives starvation.

In preemptive scheduling, always one process preempt due to low priority then due to this starvation take place.
Response time = first response - process submission time
In the round robin every process first response gets after certain time quantum so due to this it give more better than FCFS in term of response time.

1.40 **(c)**

Process switching includes mode switching.
Context switching can occur only in Kernal mode.

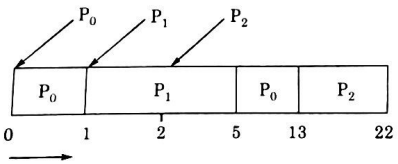
1.41 **(d)**

Interrupt from CPU temperature sensor is given top priority to protect system resources. When CPU temperature is too high, the BIOS initiate an interrupt and informs the Operating System. OS gives top priority to this interrupt and immediately shuts down the system.

1.42 **(c)**

(a) **False:** On per thread basics, OS maintains both CPU register state and stack. Hence option (a) is false, because only CPU register state mentioned.
(b) **False:** OS maintains a separate stack for each thread.
(c) **True:** OS does not maintain virtual memory state.
(d) **False:** OS does not maintain scheduling and accounting information.

1.43 **(a)**

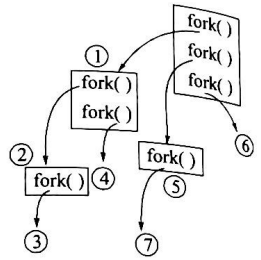


Average waiting time

$$= \frac{w_1 + w_2 + w_3}{3}$$

$$= \frac{(5-1)+0+(13-2)}{3} = 5.0 \text{ ms}$$

1.44 **(c)**



The number of child process created
$= 2^n - 1 = 2^3 - 1 = 7$
(where n is number of fork( ) statements)

1.45 **(c)**

RR Queue:

P1	P2	P1	P3	P2	P1	P3	P2
0	1	2	3	4	6	8	10

P1	P2	P1	P3	P2	P1	P3	P2
0	2	4	6	8	10	11	13	16

$\Rightarrow$ P1, P3, P2

FCFS: P1, P2, P3
Therefore option (c) is correct.
FCFS : P1, P2, P3
RR2 : P1, P3, P2

1.46 **(b)**

Lets take an example:

Process	Execution time	Arrival time
1	10	0
2	8	1
3	7	2
4	6	3

Consider scheduler schedule processes priority after S times units so order of execution will be $P_1\ P_2\ P_3\ P_4\ P_1\ P_2\ P_3\ P_4$ (S < execution time of any process) which is exactly same as round robin so answer is (b).

1.47 **(d)**

Kernel level threads shares the code segment.

1.48 **(7.2)**

	A.T	E.T
A	0	6
B	3	2
C	5	4
D	7	6
E	10	3

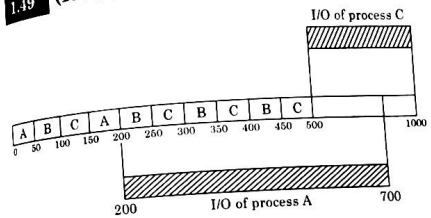
Using SRTF:

A	B	A	C	E	D
0	3	5	8	12	15	21

T.A.T (A) = 8 – 0 = 8
T.A.T (B) = 5 – 3 = 2
T.A.T (C) = 12 – 5 = 7
T.A.T (D) = 21 – 7 = 14
T.A.T (E) = 15 – 10 = 5

Average T.A.T $= \frac{8+2+7+14+5}{5} = 7.2$

1.49 **(1000)**



$\therefore$ At 1000 time units C completes its I/O.

1.50 **(5.5)**

SRTF:

P1	P2	P3	P4	P1
0	2	6	12	17	27

Waiting time of P1 = 17 – 2 = 15
Waiting time of P2 = 2 – 2 = 0
Waiting time of P3 = 6 – 3 = 3
Waiting time of P4 = 12 – 8 = 4

Average waiting time $= \frac{15+0+3+4}{4} = 5.5$

1.51 **(12)**

Periodic arrival times of T1: 0, 3, 6, 9, 12, 15, 18, 21,...

Priority of T1 $= \frac{1}{3}$, service time of $T_1 = 1$.

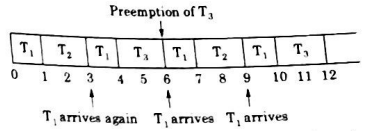
Periodic arrival times of T_2: 0, 7, 14, 21,...

Priority of $T_2 = \frac{1}{7}$, service time of $T_2 = 2$.

Periodic arrival times of T_3: 0, 20, 40,...

Priority of $T_3 = \frac{1}{20}$, service time of $T_3 = 4$.

T_1 has highest priority and T3 has lowest priority.



First instance of T_3 (4 units) completed at the end of 12 ms.

1.52 **(d)**

Maximum number of processes that can be in ready state is independent of number of processes (n).

1.53 **(c)**

Process	Arrival Time	B.T
A	0	3
B	1	6
C	4	4
D	6	2

(i) **FCFS:**

A	B	C	D
0	3	9	13	15

Avg TAT $= \frac{3+8+9+9}{4} = \frac{29}{4} = 7.25$

(ii) **Non-peemptive SJF:**

A	B	D	C
0	3	9	11	15

Avg TAT $= \frac{3+8+5+11}{4} = 6.75$

(iii) **SRTF:**

A	B	D	C	B
0	3	4	8	10	15

Avg TAT $= \frac{3+14+4+4}{4} = \frac{25}{4} = 6.25$

(iv) **RR:**

A	B	A	C	B	D	C	B
0	2	4	5	7	9	11	13	15

Avg TAT $= \frac{5+14+9+5}{4} = \frac{33}{4} = 8.25$

$\therefore$ SRTF has lowest turn around time.

1.54 **(a)**

To minimize the average waiting time, we need to select the shortest remaining time process first, because all are arriving at the same time, and they have unequal CPU burst times.

All other options will not minimize the waiting time. So, the answer is SRTF algorithm.

1.55 **(8.25)**

Gantt chart

P_1	P_2	P_3	P_2	P_4	P_1
0	3	7	8	10	13	20

Process Number	Arrival time	Burst time	Completion time	TAT
1	0	10	20	20
2	3	6	10	7
3	7	1	8	1
4	8	3	13	5
Average turn around time : 33/4 = 8.25				

Average turn around time is 8.25.

1.56 **(d)**

Generally every thread of a process have their own PC and stack. Both heap and global variables are shared by every thread of a process.

1.57 **(3)**

Using premptive SRTF algorithm Gantt chart will be,

P_1	P_2	P_4	P_1	P_3
0	3	6	8	12	17

P_2 P_4 P_1 P_3

Turnaround time	Waiting time
$P_1 \rightarrow 12 - 0 = 12$	$P_1 \rightarrow 12 - 7 = 5$
$P_2 \rightarrow 6 - 3 = 3$	$P_2 \rightarrow 3 - 3 = 0$
$P_3 \rightarrow 17 - 5 = 12$	$P_3 \rightarrow 12 - 5 = 7$
$P_4 \rightarrow 8 - 6 = 2$	$P_4 \rightarrow 2 - 2 = 0$

Average Waiting Time $= \frac{5+0+7+0}{4} = 3.0$

1.58 **(b)**

All the threads share address space but other entities like, stack, PC, resisters are not shared and every thread will have its own.

1.59 **(29)**

Process	Arrival Time	Burst Time	Priority	C.T.	T.A.T.	W.T.
P_1	0	11	2	49	49	38
P_2	5	28	0 (high)	33	28	0
P_3	12	2	3	51	39	37
P_4	2	10	1	40	38	28
P_5	9	16	4	67	58	42
					Total	145

P_1	P_4	P_2	P_4	P_1	P_3	P_5
0	2	5	33	40	49	51	67

Average waiting time $= \frac{145}{5} = 29$

1.60 **(31)**

Number of child process created using n fork() calls $= 2^n - 1$

- fork(); statement inside the loop is executed when $i = 0, 2, 4, 6, 8$. So $n = 5$ times fork() is executed.

So, number of child processes created $= 2^5 - 1 = 31$

1.61 **(2)**

Assume, $Z = 2$

P_1	P_2	P_1	P_1	P_4	P_3
0	1	2	3	4	6	9

	Arrival time	CPU time	Completion time	Waiting time
P_1	0	3	4	1
P_2	1	1	2	0
P_3	3	3	9	3
P_4	4	$Z = 2$	6	0

Average waiting time (WT) $= \frac{1+0+3+0}{4} = 1$ ms

Hence, $Z = 2$

1.62 **(d)**

Statement I, II and IV are correct.

1.63 **(5.25)**

SJF:

P_3	P_4	P_2	P_1
0	2	6	13	21

Turn Around Time (TAT) $= (21 - 0) + (13 - 0) + (2 - 0) + (6 - 0)$

Average TAT $= \frac{42}{4} = 10.5$

RR:

P_1	P_2	P_3	P_4	P_1	P_2
0	4	8	10	14	18	21

Turn Around Time (TAT) $= (18 - 0) + (21 - 0) + (10 - 0) + (14 - 0)$

$= 18 + 21 + 10 + 14$

Average TAT $= \frac{63}{4} = 15.75$

Hence, $|\text{SJF (TAT)} - \text{RR(TAT)}|$

$= |10.5 - 15.75| = 5.25$

1.64 **(12)**

WT	CT	P. No.	AT	BT
0	10	A	0	16
26	46	B	0	20
10	26	C	0	10

C	A	B
0	10	26	46

Average writing time $= \frac{0+26+10}{3} = \frac{36}{3} = 12$

1.66 **(b, c, d)**

- Goal is to maximize CPU utilization and maximize the throughput. So, statement (a) is false.
- Statement (b) is true, because turnaround time = completion time – arrival time and waiting time is included in this.
- Statement (c) is true because using time quantum, we can run the processes even if burst time is not known initially in round-robin.
- True for example, round robin scheduling requires hardware support which is timer.

1.67 **(d)**

P	Q	R	S	Q	R	Q

The above gantt chart satisfies all conditions given in the question the option (a), (b), (c) but not option (d). So, answer is option (d).

1.68 **(b, c, d)**

The status of a process or thread is saved via context switching. This makes it possible for the procedure to continue running later. During context switches, the registers (integer and floating-point), programme counter, condition registers (status register or flag register), and any other thread execution state must be stored. Registers, the stack pointer, and the programme counter must all be reloaded from the TCB of the new thread.

When the threads are from different processes, it is necessary to load the pointer for the top-level page table of the new address space in addition to saving and restoring the information mentioned above. (Notice that the process control block (PCB) already contains this top-level page table pointer from the previous process, so it is not necessary to preserve it.)

1.69 **(c, d)**

Page fault and system call required to change mode but others may not required.

1.70 **(c, d)**

In First Come First Serve (FCFS), if a process with a very large burst time comes before other processes, the other processes will have to wait for a very long time, but it is obvious that other processes will definitely get their chance to execute, so it is not likely that it will suffer from starvation.

There is no starvation in Round Robin because there is a defined time duration and every process will have a chance to run.

If higher priority processes keep coming in priority-based scheduling, low priority processes will starve.

If processes with short process times continue to arrive in Shortest Job First (SJF), processes with longer burst times will have to wait and starve.

■■■■

2 Process Management-II
(IPC, Synchronization and Concurrency)

2.1 A critical section is a program segment.
(a) Which should run in certain specified amount of time
(b) Which avoids deadlocks
(c) Where shared resources are accessed
(d) Which must be enclosed by a pair of semaphore operations, P and V
[1996 : 1 M]

2.2 A solution to the Dining Philosophers Problem which avoids deadlock is
(a) ensure that all philosophers pick up the left fork before the right fork
(b) ensure that all philosophers pick up the right fork before the left fork
(c) ensure that one particular philosophers picks up the left fork before the right fork, and that all other philosophers pick up the right fork before the left fork
(d) None of the above
[1996 : 2 M]

2.3 Each process Pi, i = 1 ... 9 is coded as follows
repeat
P(mutex)
{critical section}
V(mutex)
forever
The code for P_{10} is identical except that it uses V(mutex) in place of P(mutex). What is the largest number of processes that can be inside the critical section at any moment?
(a) 1 (b) 2
(c) 3 (d) None of these
[1997 : 2 M]

2.4 When the result of a computation depends on the speed of the processes involved there is said to be
(a) cycle stealing (b) race condition
(c) a time lock (d) a deadlock
[1998 : 1 M]

2.5 A counting semaphore was initialized to 10. Then 6 P (wait) operations and 4V (signal) operations were completed on this semaphore. The resulting value of the semaphore is
(a) 0 (b) 8
(c) 10 (d) 12 **[1998 : 1 M]**

2.6 Let m[0]...m[4] be mutexes (binary semaphores) and P[0]...P[4] be processes. Suppose each process P[i] executes the following:
wait (m[i]);wait (m[(i+1) mode 4]);
.....
release (m[i]); release (m[(i+1)mod 4]);
This could cause
(a) Thrashing
(b) Deadlock
(c) Starvation, but not deadlock
(d) None of the above
[2000 : 1 M]

2.7 Suppose a processor does not have any stack pointer register. Which of the following statement is true?
(a) It cannot have subroutine call instruction
(b) It can have subroutine call instruction, but no nested subroutine calls
(c) Nested subroutine calls are possible, but interrupts are not
(d) All sequences of subroutine calls and also interrupts are possible **[2001 : 1 M]**

2.8 Where does the swap space reside?
(a) RAM (b) Disk
(c) ROM (d) On-chip cache
[2001 : 1 M]

2.9 Consider Peterson's algorithm for mutual exclusion between two concurrent processes i and j. The program executed by process is shown below:
repeat
flag[i]=true;
turn=j;
while (P) do no-op;
Enter critical section, perform actions, then exit critical section
flag[i]=false;
Perform other non-critical section actions.
Until false;
For the program to guarantee mutual exclusion, the predicate P in the while loop should be
(a) flag[j] = true and turn = i
(b) flag [j] = true and turn = j
(c) flag [i] = true and turn = j
(d) flag [i] = true and turn = i **[2001 : 2 M]**

Common Data for Q. 2.10 & 2.11:
Suppose we want to synchronize two concurrent processes P and Q using binary semaphores S and T. The code for the processes P and Q is shown below.

Process P:	**Process Q:**
while (1) {	while (1) {
W:	Y:
print '0';	print '1' ;
print '0';	print '1' ;
X:	Z:
}	}

Synchronization statements can be inserted only at points W, X, Y and Z.

2.10 Which of the following will always lead to an output string with '001100110011'?
(a) P(S) at W, V(S) at X, P(T) at Y, V(T) at Z, S and T initially 1
(b) P(S) at W, V(T) at X, P(T) at Y, V(S) at Z, S initially 1, and T initially 0
(c) P(S) at W, V(T) at X, P(T) at Y, V(S) at Z, S and T initially 1
(d) P(S) at W, V(T) at X, P(T) at Y, V(T) at Z, S initially 1, and T initially 0 **[2003 : 2 M]**

2.11 Which of the following will ensure that the output string never contains a substring of the form 01^n0 or 10^n1 where n is odd?
(a) P(S) at W, V(S) at X, P(T) at Y, V(T) at Z, S and T initially 1
(b) P(S) at W, V(T) at X, P(T) at Y, V(S) at Z, S and T initially 1
(c) P(S) at W, V(S) at X, P(S) at Y, V(S) at Z, S initially 1
(d) V(S) at W, V(T) at X, P(S) at Y, P(T) at Z, S and T initially 1 **[2003 : 2 M]**

2.12 Consider two processes P_1 and P_2 accessing the shared variables X and Y protected by two binary semaphores S_X and S_Y respectively, both initialized to 1. P and V denote the usual semaphore operators, where P decrements the semaphore value, and V increments the semaphore value. The pseudocode of P_1 and P_2 is as follows:

P_1:	P_2:
while true do {	while true do{
L_1 :	L_3 : .....
L_2 :	L_4 : .....
X = X + 1;	Y = Y + 1;
Y = Y – 1;	X = X – 1;
V(S_X);	V(S_Y);
V(S_Y); }	V(S_X); }

In order to avoid deadlock, the correct operators at L_1, L_2, L_3 and L_4 are respectively
(a) P(S_Y), P(S_X), P(S_X), P(S_Y)
(b) P(S_X), P(S_Y), P(S_Y), P(S_X)
(c) P(S_X), P(S_X), P(S_Y), P(S_Y)
(d) P(S_X), P(S_Y), P(S_X), P(S_Y)
[2004 : 2 M]

2.13 The semaphore variables full, empty and mutex are initialized to 0, n and 1, respectively. Process P_1 repeatedly adds one item at a time to a buffer of size n, and process P_2 repeatedly removes one item at a time from the same buffer using the programs given below. In the programs, K, L, M and N are unspecified statements.

```
P1 : while (1)
{
    K;
    P(mutex);
    Add an item to the buffer;
    V(mutex);
    L;
}
P2 :  while (1)
{
    M;
    P(mutex);
    Remove an item from the buffer;
    V(mutex);
    N;
}
```

The statements K, L, M and N are respectively
(a) P(full), V(empty), P(full), V(empty)
(b) P(full), V(empty), P(empty), V(full)
(c) P(empty), V(full), P(empty), V(full)
(d) P(empty), V(full), P(full), V(empty)
[2004 : 2 M]

2.14 Given below is a program which when executed spawns two concurrent processes:

```
semaphore X : = 0 ;
/* Process now forks into concurrent processes
P1 & P2 */
P1: repeat forever      P2: repeat forever
V(X);                       P(X);
Compute;                    Compute;
P(X);                       V(X);
```

Consider the following statements about processes P1 and P2:
I. It is possible for process P1 to starve.
II. It is possible for process P2 to starve.
Which of the following holds?

(a) Both I and II are true.
(b) I is true but II is false.
(c) II is true but I is false
(d) Both I and II are false. **[2005 : 2 M]**

2.15 Two concurrent processes P1 and P2 use four shared resources R1, R2, R3 and R4, as shown below:

P1:	P2:
Compute:	Compute;
Use R1;	Use R1;
Use R2;	Use R2;
Use R3;	Use R3;
Use R4;	Use R4;

Both processes are started at the same time, and each resource can be accessed by only one process at a time. The following scheduling constraints exist between the access of resources by the processes:

- P2 must complete use of R1 before P1 gets access to R1.
- P1 must complete use of R2 before P2 gets access to R2.
- P2 must complete use of R3 before P1 gets access to R3.
- P1 must complete use of R4 before P2 gets access to R4.

There are no other scheduling constraints between the processes. If only binary semaphores are used to enforce the above scheduling constraints, what is the minimum number of binary semaphores needed?

(a) 1 (b) 2
(c) 3 (d) 4 **[2005 : 2 M]**

2.16 The atomic *fetch-and-set x, y* instruction unconditionally sets the memory location x to 1 and fetches the old value of x in y without allowing any intervening access to the memory location x. Consider the following implementation of P and V functions on a binary semaphore S.

```
void P(binary_semaphore *S) {
    unsigned y;
unsigned *x = & (S → value);
    do {
        fetch-and-set x, y;
    } while (y);
}
void V (binary_semphore *S) {
    S → value = 0;
}
```

Which one of the following is true?

(a) The implementation may not work if context switching is disabled in P
(b) Instead of using fetch-and-set, a pair of normal load/store can be used
(c) The implementation of V is wrong
(d) The code does not implement a binary semaphore **[2006 : 2 M]**

Common Data for Q. 2.17 & 2.18:

Barrier is a synchronization construct where a set of processes synchronizes globally i.e. each process in the set arrives at the barrier and waits for all others to arrive and then all processes leave the barrier. Let the number of processes in the set be three and S be a binary semaphore with the usual P and V functions. Consider the following C implementation of a barrier with line numbers shown on the left.

```
void barrier (void) {
 1 :  P (S) ;
 2 :  process_arrived + +;
 3 :  V (S) ;
 4 :  while (process_arrived ! = 3) ;
 5 :  P (S) ;
 6 :  process_left + + ;
 7 :  if (process_left = = 3){
 8 :        process_arrived = 0;
 9 :        process_left = 0;
10 :  }
11 :  V (S) ;
12 :  }
```

The variables process_arrived and process_left are shared among all processes and are initialized to zero. In a concurrent program all the three processes call the barrier function when they need to synchronize globally.

2.17 The above implementation of barrier is incorrect. Which one of the following is true?

(a) The barrier implementation is wrong due to the use of binary semaphore S
(b) The barrier implementation may lead to a deadlock if two barrier invocations are used in immediate succession
(c) Lines 6 to 10 need not be inside a critical section
(d) The barrier implementation is correct if there are only two processes instead of three **[2006 : 2 M]**

2.18 Which one of the following rectifies the problem in the implementation?

(a) Lines 6 to 10 are simply replaced by process_arrived

(b) At the beginning of the barrier the first process to enter the barrier waits until process_arrived becomes zero before proceeding to execute P(S)
(c) Context switch is disabled at the beginning of the barrier and re-enabled at the end
(d) The variable process_left is made private instead of shared **[2006 : 2 M]**

2.19 Processes P1 and P2 use critical_flag in the following routine to achieve mutual exclusion. Assume that critical_flag is initialized to FALSE in the main program.

```
get_exclusive_access ( )
{
  if (critical _flag = = FALSE)
  {
    critical_flag = TRUE ;
    critical_region ( ) ;
    critical_flag = FALSE;
  }
}
```

Consider the following statements.
(i) It is possible for both P1 and P2 to access critical_region concurrently.
(ii) This may lead to a deadlock.
Which of the following holds?
(a) (i) is false and (ii) is true
(b) Both (i) and (ii) are false
(c) (i) is true and (ii) is false
(d) Both (i) and (ii) are true **[2007 : 1 M]**

2.20 Two processes, P1 and P2, need to access a critical section of code. Consider the following synchronization construct used by the processes:

```
/* P1 */
while (true) {
 wants1 = true;
 while (wants2 = = true);
 /*    Critical
       Section */
 wants 1 = false;
}
/* Remainder section */
```

```
/* P2 */
while (true) {
 wants2 = true;
 while (wants1 = = true);
 /*    Critical
       Section */
 wants 2 = false;
}
/* Remainder section */
```

Here, wants1 and wants2 are shared variables, which are initialized to false. Which one of the following statements is TRUE about the above construct?

(a) It does not ensure mutual exclusion.
(b) It does not ensure bounded waiting.
(c) It requires that processes enter the critical section in strict alternation.
(d) It does not prevent deadlocks, but ensures mutual exclusion. **[2007 : 2 M]**

2.21 Synchronization in the classical readers and writers problem can be achieved through use of semaphores. In the following incomplete code for readers-writers problem, two binary semaphores mutex and wrt are used to obtain synchronization

```
wait (wrt)
writing is performed
signal (wrt)
wait (mutex)
readcount = readcount + 1
if readcount = 1 then S1
S2
reading is performed
S3
readcount = readcount – 1
if readcount = 0 then S4
Signal (mutex)
```

The values of S1, S2, S3, S4, (in that order) are
(a) signal (mutex), wait (wrt), signal (wrt), wait (mutex)
(b) signal (wrt), signal (mutex), wait (mutex), wait (wrt)
(c) wait (wrt), signal (mutex), wait (mutex), signal (wrt)
(d) signal (mutex), wait (mutex), signal (mutex), wait (mutex) **[2007 : 2 M]**

2.22 The P and V operations on counting semaphores, where s is a counting semaphore, are defined as follows:

```
P(s): s = s – 1;
      if s < 0 then wait;
V(s): s = s + 1;
      if s ≤ 0 then wakeup a process waiting on s;
```

Assume that P_b and V_b, the wait and signal operations on binary semaphores are provided. Two binary semaphores X_b and Y_b are used to implement the semaphore operations P(s) and V(s) as follows:

```
P(s):   Pb(Xb);
        s = s – 1;
        if (s < 0) {
          Vb (Xb);
          Pb(Yb);
        }
        else Vb(Xb);
```

V(s): $P_b(X_b)$;
s = s + 1;
if (s ≤ 0) $V_b(Y_b)$;
$V_b(X_b)$;

The initial values of X_b and Y_b are respectively
(a) 0 and 0 (b) 0 and 1
(c) 1 and 0 (d) 1 and 1
[2008 : 2 M]

2.23 The enter_CS ( ) and leave_CS ( ) functions to implement critical section of a process are realized using test-and-set instruction as follows:

```
Void enter_CS (X)
{
    while (test-and-set (X));
}
Void leave_CS (X)
{
    X = 0 ;
}
```

In the above solution, X is a memory location associated with the CS and is initialized to 0.
Now consider the following statements
I. The above solution to CS problem is deadlock-free.
II. The solution is starvation free.
III. The processes enter CS in FIFO order.
IV. More than one process can enter CS at the same time.
Which of the above statements are TRUE?
(a) I only (b) I and II
(c) II and III (d) IV only
[2009 : 2 M]

2.24 Consider the methods used by processes P1 and P2 for accessing their critical sections whenever needed, as given below. The initial values of shared boolean variables S1 and S2 are randomly assigned.

Method used by P1	Method used by P2
while (S1==S2);	while (S1!=S2);
Critical Section	Critical Section
S1=S2;	S2=not (S1);

Which one of the following statements describes the properties achieved?
(a) Mutual exclusion but not progress
(b) Progress but not mutual exclusion
(c) Neither mutual exclusion nor progress
(d) Both mutual exclusion and progress
[2010 : 1 M]

2.25 The following program consists of 3 concurrent processes and 3 binary semaphores. The semaphores are initialized as S0 = 1, S1 = 0, S2 = 0.

Process P0	Process P1	Process P2
while (true) {	wait (S1);	wait (S2);
wait (S0);	release(S0);	release(S0);
print '0'		
release (S1);		
release (S2);		
}		

How many times will process P0 print '0'?
(a) At least twice
(b) Exactly twice
(c) Exactly thrice
(d) Exactly once
[2010 : 2 M]

2.26 Fetch_And_Add(X, i) is an atomic Read-Modify-Write instruction that reads the value of memory location X, increments it by the value i, and returns the old value of X, it is used in the pseudocode shown below to implement a busy-wait lock. L is unsigned integer shared variable initialized to 0. The value of 0 corresponds to lock being available, while any non-zero value corresponds to the lock being not available.

```
AcquireLock ( L ){
    while ( Fetch_And_Add( L, 1 ))
    L = 1;
}
ReleaseLock ( L ){
    L = 0;
}
```

This implementation
(a) fails as L can overflow
(b) fails as L can take on a non-zero value when the lock is actually available
(c) works correctly but may starve some processes
(d) works correctly without starvation
[2012 : 2 M]

2.27 Three concurrent processes X, Y and Z execute three different code segments that access and update ceratin shared variables. Process X execute the P operation (i.e., wait) on semaphores a, b and c; process Y executes the P operation on semaphores b, c and d; process Z executes the P operation on semaphores c, d and a before entering the respective code segments. After completing the execution of its code segments, each process invokes the V operation (i.e., signal) on its three semaphores. All semaphores are binary semaphores initialized to one. Which one of the following represents a deadlock-free order of invoking the P operations by the processes?
(a) X : P(a)P(b)P(c) (b) X : P(b)P(a)P(c)
Y : P(b)P(c)P(d) Y : P(b)P(c)P(d)
Z : P(c)P(d)P(a) Z : P(a)P(c)P(d)
(c) X : P(b)P(a)P(c) (d) X : P(a)P(b)P(c)
Y : P(c)P(b)P(d) Y : P(b)P(c)P(d)
Z : P(a)P(c)P(d) Z : P(c)P(d)P(a)
[2013 : 1 M]

2.28 A shared variable x, initialized to zero, is operated on by four concurrent process W, X, Y, Z as follows. Each of the processes W and X reads x from memory, increments by one, stores it to memory, and then terminates. Each of the processes Y and Z reads x from memory, decrements by two, stores it to memory and then terminates. Each process before reading x invokes the P operations (i.e., wait) on a counting semaphore S and invokes the V operation (i.e., signal) on the semaphore S after storing x to memory. Semaphore S is initialized to two. What is the maximum possible value of x after all processes complete execution?
(a) – 2 (b) – 1
(c) 1 (d) 2 **[2013 : 2 M]**

2.29 A certain computation generates two arrays a and b such that a[i] = f for 0 ≤ i ≤ n and b[i] = g(a[i]) for 0 ≤ i < n. Suppose this computation is decomposed into two concurrent processes X and Y such that X computes the array a and Y computes the array b. The processes employ two binary semaphores R and S, both initialized to zero. The array a is shared by the two processes. The structure of the processes are shown below:

Process X
```
private i;
for (i = 0; i < n; i++)
{
    a[i] = f(i);
    ExitsX (R, S);
}
```

Process Y
```
private i;
for (i = 0; i < n; i++)
{
    EntryY(R, S);
    b[i] = g(a[i]);
}
```

Which one of the following represents the **CORRECT** implementations of ExitsX and EntryY?

(a)
```
ExitsX (R, S) {
  P(R);
  V(S)
}
EntryY(R, S) {
  P(S);
  V(R);
}
```

(b)
```
ExitsX (R, S) {
  V(R);
  V(S);
}
EntryY(R, S) {
  P(R);
  P(S);
}
```

(c)
```
ExitsX (R, S) {
  P(S);
  V(R)
}
EntryY(R, S) {
  V(S);
  P(R);
}
```

(d)
```
ExitsX (R, S) {
  V(R);
  P(S);
}
EntryY(R, S) {
  V(S);
  P(R);
}
```

[2013 : 2 M]

2.30 Consider the procedure below for the Producer-Consumer problem which uses semaphores:

```
semaphore n = 0;
semaphore s = 1;
void producer()
{
  while(true)
  {
    produce();
    semWait(s);
    addToBuffer();
    semSignal(s);
    semSignal(n);
  }
}
void consumer()
{
  while (true)
  {
    semWait (s);
    semWait (n);
    removeFromBuffer ( );
    semSignal (s);
    consume( );
  }
}
```

Which one of the following is TRUE?
(a) The producer will be able to add an item to the buffer, but the consumer can never consume it.
(b) The consumer will remove no more than one item from the buffer.
(c) Deadlock occurs if the consumer succeeds in acquiring semaphore s when the buffer is empty.
(d) The starting value for the semaphore n must be 1 and not 0 for deadlock-free operation.
[2014 (Set-2) : 2 M]

2.31 The following two functions P1 and P2 that share a variable B with an initial value of 2 execute concurrently.

```
P1()
{
    C = B – 1;
    B = 2 * C;
}
```

```
P2()
{
    D = 2 * B;
    B = D – 1;
}
```

The number of distinct values that B can possibly take after the execution is _____.
[2015 (Set-1) : 1 M]

2.32 Two processes X and Y need to access a critical section. Consider the following synchronization construct used by both the processes

```
Process X
/* other code for process X */
while (true)
{   varP = true;
    while (varQ = = true)
    {  /* Critical Section */
       varP = false;
    }
}
/* other code for process X */
Process Y
/* other code for process Y */
while (true)
{   varQ = true;
    while (varP = = true)
    {  /* Critical Section */
       varQ = false;
    }
}
/* other code for process Y */
```

Here, varP and varQ are shared variables and both are initialized to false. Which one of the following statements is true?

(a) The proposed solution prevents deadlock but fails to guarantee mutual exclusion
(b) The proposed solution guarantees mutual exclusion but fails to prevent deadlock
(c) The proposed solution guarantees mutual exclusion and prevents deadlock
(d) The proposed solution fails to prevent deadlock and fails to guarantee mutual exclusion

[2015 (Set-3) : 1 M]

2.33 Consider the following proposed solution for the critical section problem. There are n processes: $P_0 \ldots P_{n-1}$. In the code, function $pmax$ returns an integer not smaller than any of its arguments. For all i, $t[i]$ is initialized to zero.

Code for P_i :

```
do
{
   c[i]=1; t[i] = pmax (t[0],..., t[n-1]) +1; c[i] = 0;
   for every j ≠ i in {0,..., n - 1}
   {  while (c[j]);
      while (t[j] != 0 && t[j] <= t[i]);
   }
   Critical Section; t[i] = 0;
   Remainder Section;
} while (true);
```

Which one of the following is TRUE about the above solution?

(a) At most one process can be in the critical section at any time
(b) The bounded wait condition is satisfied
(c) The progress condition is satisfied
(d) It cannot cause a deadlock

[2016 (Set-1) : 2 M]

2.34 Consider the following two-process synchronization solution:

```
Process 0
    Entry: loop while (turn == 1);
    (critical section)
    Exit: turn = 1;
Process 1
    Entry : loop while (turn == 0);
    (critical section)
    Exit: turn = 0;
```

The shared variable turn in initialized to zero. Which one of the following is **TRUE**?

(a) This is a correct two-process synchronization solution
(b) This solution violates mutual exclusion requirement
(c) This solution violates progress requirement
(d) This solution violates bounded wait requirement **[2016 (Set-2) : 2 M]**

2.35 Consider a non-negative counting semaphore S. The operation P(S) decrements S, and V(S) increments S. During an execution, 20 P(S) operations and 12 V(S) operations are issued in some order. The largest initial value of S for which at lest one P(S) operation will remain blocked is _____. **[2016 (Set-2) : 2 M]**

2.36 A multithreaded program P executes with x number of threads and uses y number of locks for ensuring mutual exclusion while operating on shared memory locations. All locks in the program are non-reentrant, i.e., if a thread holds a lock l, then it cannot re-acquire lock l without releasing it. If a thread is unable to acquire a lock, it blocks until the lock becomes available. The minimum value of x and the minimum value of y together for which execution of P can result in a deadlock are:

(a) $x = 1, y = 2$ (b) $x = 2, y = 1$
(c) $x = 2, y = 2$ (d) $x = 1, y = 1$

[2017 (Set-1) : 2 M]

2.37 Consider the following solution to the producer-consumer synchronization problem. The shared buffer size is N. Three semaphores empty, full and mutex are defined with respective initial values of 0, N and 1. Semaphore empty denotes the number of available slots in the buffer, for the consumer to read from. Semaphore full denotes the number of available slots in the buffer, for the producer to write to. The placeholder variables, denoted by P, Q, R and S, in the code below can be assigned either empty or full. The valid semaphore operations are: wait ( ) and signal ( ).

Producer:	Consumer

do {
wait (P);
wait (mutex);
//Add item to buffer
signal (mutex);
signal (Q);
} while (1);
	do {
	wait (R);
	wait (mutex);
	//Consume item from buffer
	signal (mutex);
	signal (S);
	} while (1);

Which one of the following assignment to P, Q, R and S will yield the correct solution?

(a) P: full, Q: full, R: empty, S; empty
(b) P: empty, Q: empty, R: full, S: full
(c) P: full, Q: empty, R: empty, S: full
(d) P: empty, Q: full, R: full, S: empty

[2018 : 2 M]

2.38 Consider three concurrent processes P1, P2 and P3 as shown below, which access a shared variable D that has been initialized to 100.

P1	P2	P3
D = D + 20	D = D - 50	D = D + 10

The processes are executed on a uniprocessor system running a time-shared operating system. If the minimum and maximum possible values of D after the three processes have completed executed are X and Y respectively, then the value of Y – X is _____. **[2019 : 1 M]**

2.39 Consider the following snapshot of a system running n concurrent processes. Process i is holding X_i instances of a resource R, $1 \le i \le n$. Assume that all instances of R are currently in use. Further, for all i, process i can place a request for at most Y_i additional instances of R while holding the X_i instances it already has. Of the n processes, there are exactly two processes p and q such that $Y_p = Y_q = 0$. Which one of the following conditions guarantees that no other process apart from p and q can complete execution?

(a) $X_p + X_q < \text{Min}\{Y_k \mid 1 \le k \le n, k \ne p, k \ne q\}$
(b) $\text{Min}(X_p, X_q) \ge \text{Min}\{Y_k \mid 1 \le k \le n, k \ne p, k \ne q\}$
(c) $\text{Min}(X_p, X_q) \le \text{Max}\{Y_k \mid 1 \le k \le n, k \ne p, k \ne q\}$
(d) $X_p + X_q < \text{Max}\{Y_k \mid 1 \le k \le n, k \ne p, k \ne q\}$

[2019 : 2 M]

2.40 Each of a set of n processes executes the following code using two semaphores a and b initialized to 1 and 0, respectively. Assume that count is a shared variable initialized to 0 and not used in CODE SECTION P.

```
CODE SECTION P
wait(a); count = count + 1;
if (count = = n) signal(b);
signal(a); wait(b); signal(b);
CODE SECTION Q
```

What does the code achieve?

(a) It ensures that at most two processes are in CODE SECTION Q at any time.
(b) It ensures that all processes execute CODE SECTION P mutually exclusively.
(c) It ensures that no process executes CODE SECTION Q before every process has finished CODE SECTION P.
(d) It ensures that at most $n - 1$ processes are in CODE SECTION P at any time.

[2020 : 2 M]

2.41 Consider the following pseudocode, where S is a semaphore initialized to 5 in line#2 and counter is a shared variable initialized to 0 in line#1. Assume that the increment operation in linc#7 is not atomic.

```
1.  int counter = 0;
2.  Semaphore S = init(5);
3.  void parop(void)
4.  {
5.      wait(S);
6.      wait(S);
7.      counter++;
8.      signal(S);
9.      signal(S);
10. }
```

If five threads execute the function parop concurrently, which of the following program behavior(s) is/are possible?

(a) The value of counter is 1 after all the threads successfully complete the execution of parop.
(b) The value of counter is 0 after all the threads successfully complete the execution of parop.
(c) There is a deadlock involving all the threads.

(d) The value of counter is 5 after all the threads successfully complete the execution of parop.

[2021 (Set-1) : 2 M]

2.42 Consider a computer system with multiple shared resource types, with one instance per resource type. Each instance can be owned by only one process at a time. Owning and freeing of resources are done by holding a global lock (L). The following scheme is used to own a resource instance:

```
function OwnResource (Resource R)
    Acquire lock L // a global lock
    if R is available then
        Acquire R
        Release lock L
    else
        if R is owned by another process P then
        Terminate P, after releasing all
        resources owned by P
            Acquire R
            Restart P
            Release lock L
        end if
    end if
end function
```

Which of the following choice(s) about the above scheme is/are correct?

(a) The scheme violates the mutual exclusion property.
(b) The scheme ensures that deadlocks will not occur.
(c) The scheme may lead to live-lock.
(d) The scheme may lead to starvation.

[2021 (Set-2) : 2 M]

2.43 Consider the following multi-threaded code segment (in a mix of *C* and pseudo-code), invoked by two processes P_1 and P_2, and each of the processes spawns two threads T_1 and T_2:

```
int x = 0;          // global
Lock L1;            // global
main() {
  create a thread to execute foo();  // Thread T1
  create a thread to execute foo();  // Thread T2
  wait for the two threads to finish execution;
  print (x);}
foo() {
  int y = 0;
  Acquire L1;
  x = x + 1;
  y = y + 1;
  Release L1;
  print (y); }
```

Which of the following statement(s) is/are correct?

(a) At least one of P_1 and P_2 will print the value of x as 4,
(b) Both P_1 and P_2 will print the value of x as 2
(c) Both T_1 and T_2, in both the processes, will print the value of y as 1.
(d) At least one of the threads will print the value of y as 2.

[2021 (Set-2) : 2 M]

2.44 Consider the following threads, T_1, T_2 and T_3 executing on a single processor, synchronized using three binary semaphore variables, S_1, S_2 and S_3, operated upon using standard wait( ) and signal( ) operations. The threads can be context switched in any order and at any time.

T_1	T_2	T_3
while (true) { wait (S_3); print ("C"); signal (S_2); }	while (true) { wait (S_1); print ("B"); signal (S_3); }	while (true) { wait (S_2); print ("A"); signal (S_1); }

Which initialization of the semaphores would print the sequence BCABCABCA.....?

(a) $S_1 = 1; S_2 = 1; S_3 = 1$
(b) $S_1 = 1; S_2 = 1; S_3 = 0$
(c) $S_1 = 1; S_2 = 0; S_3 = 0$
(d) $S_1 = 0; S_2 = 1; S_3 = 1$

[2022 : 1 M]

2.45 Consider the two functions incr and decr shown below:

```
incr() {                    decr() {
    wait(s);                    wait(s);
    X = X + 1;                  X = X - 1;
    signal(s);                  signal(s);
}                           }
```

There are 5 threads each invoking incr once, and 3 threads each invoking decr once, on the same shared variable *X*. The initial value of *X* is 10. Suppose there are two implementations of the semaphore s, as follows:

I-1: *s* is a binary semaphore initialized to 1.
I-2: *s* is a counting semaphore initialized to 2.

Let V1, V2 be the values of *X* at the end of execution of all the threads with implementations I-1, I-2, respectively.

Which one of the following choices corresponds to the minimum possible values of V1, V2, respectively?

(a) 15, 7 (b) 7, 7
(c) 12, 7 (d) 12, 8

[2023 : 2 M]

2.46 Consider the following code snippet using the fork( ) and wait( ) system calls. Assume that the code compiles and runs correctly, and that the system calls run successfully without any errors.

```
int x = 3;
while (x > 0) {
    fork( );
    printf("hello");
    wait(NULL);
    x--;
}
```

The total number of times the printf statement is executed is _____.

[2024 (Set-1) : 2 M]

Answers Process Management-II

2.1	(c)	2.2	(c)	2.3	(d)	2.4	(b)	2.5	(b)	2.6	(b)	2.7	(a)	2.8	(b)	2.9	(b)
2.10	(b)	2.11	(c)	2.12	(d)	2.13	(d)	2.14	(d)	2.15	(b)	2.16	(a)	2.17	(b)	2.18	(b)
2.19	(c)	2.20	(d)	2.21	(c)	2.22	(c)	2.23	(a)	2.24	(a)	2.25	(a)	2.26	(b)	2.27	(b)
2.28	(d)	2.29	(c)	2.30	(c)	2.31	(3)	2.32	(a)	2.33	(a)	2.34	(c)	2.35	(7)	2.36	(d)
2.37	(c)	2.38	(80)	2.39	(a)	2.40	(c)	2.41	(a, c, d)	2.42	(b, c, d)	2.43	(b, c)	2.44	(c)		
2.45	(c)	2.46	(14)														

Explanations Process Management-II

2.1 (c)

Critical section is an area in a program where the resources can be accessed.

2.2 (c)

Ensure that one particular philosophers picks up the left fork before the right fork, and that all other philosophers pick up the right fork before the left fork.

2.3 (d)

Everytime when process P_{10} enters it performs the 'UP' operation so after that one more process can enter into it, so this phenomena continue till end. So 10 processes at a time can enter into critical section.

2.4 (b)

Race condition.

2.5 (b)

Initially semaphore is 10, then 6 down operations are performed means (10 – 6) and 4 up operation means (4 + 4) = 8.
So option (b) is correct.

2.6 (b)

All processes are in deadlock condition i.e., not a single one process can enter into critical section.

2.7 (a)

If stack pointer register is not available then activation records in the stack can not be created. So it cannot have subroutine call instruction.

2.8 (b)

Disk has swap space.

2.9 (b)

To ensure the mutual exclusion, we have to take care that 'turn' value which is 'j' so we should not allow that process in CS which is having flag [j] = true.
Hence option (b) is correct.

2.10 (b)

To get the expected output , The sequence of processes are P, Q, P, Q, P, Q and so on we must initialize S = 1 and T = 0.

2.11 (c)

If the output string never contains a substring of the form 01^n0 or 10^n1 where n is odd then the procedures becomes.

S = 1

Process P:	Process Q:
While(1){	While(1){
W : P(S)	Y : P(S)
print '0';	print '1';
print '0';	print '1';
X : V(S)	Z : V(S)
}	}

2.12 (d)

S_x and S_y are two binary semaphores if we assume P means wait and V means signal then for two process P_1 and P_2 we take alternate then there in no chance of dead lock.

2.13 (d)

Here full and empty are integer semaphore which denote number of full slots in buffer and number of empty slot in buffer at any time respectively. While mutex is binary semaphore to provide mutual exclusion.

Initially full = 0 empty = n and mutex = 1.

- When no item into buffer, since mutex = 1. So to restrict consumer to remove item P (full) must be there at M and when it leave the critical section made V (empty) at N i.e. one empty slot increase.
- When producer tries to add an item into buffer before entering to critical section, it must perform P (empty) i.e. one empty decrease and while leaving critical section make V (full) i.e. one new item added successfully.

So, correct order will be P (empty), V (full), P (full) and V (empty) to ensure consumer will be block until 1 item added into buffer.

2.14 (d)

None of the processes will ever starve. Starvation is said to be possible if in ALL the possible ways that a process want to enter CS, it is DENIED the access. But that can't happens here.

P1 is never starved because this is INFACT the first process that can enter. V(X) by P1 is always successful and hence it always enter the CS. So 1 is FALSE.

When P1 is in CS, X = 1. At this time P_2 can make a successful DOWN operation P(X) and enter CS. So 2 is also FALSE.

But P2 must exit the CS before P_1.

2.15 (b)

With one semaphore it is not possible, since binary semaphore is used.

So, try with 2 binary semaphore a and b assume initialize to 0.

P1:	P2:
P(a)	
R1	
	R1
	V(a)
	P(b)
	R2
R2	
V(b)	
P(a)	
R3	
	R3
	V(a)
	P(b)
	R4
R4	
V(b)	

So, minimum 2 semaphore needed.

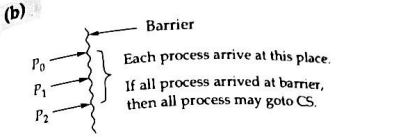
2.16 (a)

The P and V function is as follows:

```
1.  void P (binary-semaphore * S){
2.      unsigned y;
3.      unsigned * x = & (S → value);
4.      do {
5.          fetch-and-set x, y;
6.      } while (y);
7.  }
8.  void V (binary-semaphore * S){
9.      S → value = 0;
10. }
```

fetch-and-set instruction always sets the memory location x = 1 and fetches the old value of x into y. The binary semphore * S takes only two values either 0 and 1. When we initiliaze S = 0 then in statement 3 this value will be start at location x and fetch-and-set instruction changes the value of x = 0 to x = 1 and y becomes 0. If there are more than two processes and context switching between processes is disabled in P then this implementation doesn't work properly and can't synchronize the processes.

2.17 (b)

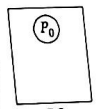


Given code:

```
1.  P(S);
2.  process_arrived++;
3.  V(S);
4.  while (process_arrived != 3);   → This time act as barrier
5.  P(S);
6.  process_left++;
7.  if (process_left == 3)
8.  {  process_arrived = 0;
9.     process_left = 0;            → These code work like critical section
10. }
11. V(S);
```

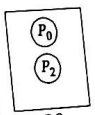
Each process in the set arrive at barrier. We need to provide synchronization to process to enter barrier and wait for all other processes to arrive. Once they arrive, they start leaving the barrier and same thing goes on.

Process	Code
P_0	1. S = 0 2. P_A = 1 3. S = 1 4. (1! = 3); → condition true



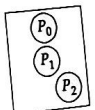
So, P_0 arrive at barrier and waiting for other process to arrive.

Process	Code
P_1	1. S = 0 2. P_A = 2 3. S = 1 4. (2! = 3); True



So, P_1 stop and waiting for other process.

Process	Code
P_2	1. S = 0 2. P_A = 3 3. S = 1 4. (3! = 3); False



Now all 3-process arrived barrier, so while condition become false, to now the processes start leaving the barrier one by one.

Now suppose P_0 leaves the barrier, and not waiting for other processes (P_1 and P_2) to leave the barrier and immediately P_1 entering to barrier.

i.e.

Process	Code
P_0	5. S = 0 6. P_L = 1 7. (1 == 3) : false (so, 8 and 9 do not execute) 11. S = 1

Now S = 1

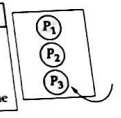
P_1 and P_2 still in loop.

So, we have two choices:

Choice 1: P_1 can leave the barrier

Choice 2: P_0 can enter into the barrier (Case for deadlock)

Process	Code
1.	S = 0
2.	P_A = 4
3.	S = 1
4.	(4! = 3); True



So, P_0 also enters the barrier and the while loop now, will be true forever because, we have 3 processes and all three processes stuck up at barrier.

Hence, no possibility of while loop to become false. Hence, deadlock will occur.

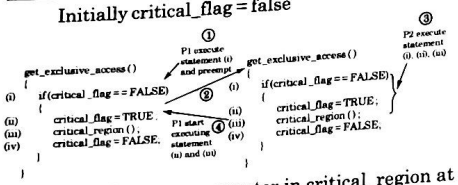
Hence we conclude that, as soon as all the 3 processes arrive at barrier and until and unless, all the process leave the barrier, we will not call barrier again. So, two invocations if used in immediate succession, may lead to deadlock.

2.18 (b)

```
void barrier (void)
{
    while (process_left != 0);   ← Correction in implementation of code
    P(S);
    P_A++;
    V(S);
    while
    (P_A != 3);
    P(S);
    P_L++;
    if (P_L == 3)
    {
        P_A = 0;
        P_L = 0;
    }
        V(S);
}
```

2.19 (c)

Initially critical_flag = false



So, both process can enter in critical_region at same time.

So, no mutual exclusion.

We know that Dead lock → Mutual exclusion.

So, no Mutual exclusion → No deadlock. Here no deadlock possible.

Note: Here arrow shows order of execution and preemption is temporary, any process can preempt at any time.

2.20 (d)

In process P_1 if wants1 is true then wants2 entered in critical section and in process P_2 if wants2 is true then wants1 entered in critical section but in both cases a deadlock can occur but it ensures the mutual exclusion.

2.21 (c)

Writers code

wait (wrt)
writing is performed
signal (wrt)

- If read count = = 1 then it must perform wait (wrt)
  So, at same time reader and writer cannot access critical section.
- Since more than one reader an access the critical section simultaneously
  So, at S2 signal (mutex) must be done.

Readers code

wait (mutex)
read count = read count + 1
if (read count = =1)
then wait (wrt) S1
signal (mutex) S2
reading is performed
wait (mutex) S3
read count = read count = 1
If (read count = = 0)
then signal (wrt) S4
Signal (mutex)

Since by seeing S1 and S2 option (c) matches. Hence it is correct answer.

2.22 (c)

In given code, P(S) decrements the value of semaphore and V(S) increment the value of semaphore. P_b and V_b are wait and signal operations on binary semaphore. X_b and Y_b are binary semaphore. To avoid the mutual exclusion condition if the value of X_b is 1 and the value of $Y_b = 0$ then P(S) and V(S) works properly.

2.23 (a)

II. False let $P_1, P_2, \ldots P_n$ are processes let P_1 is currently holding lock and P_2 is waiting to enter CS after P_1 it is not definite that P_2 will surely enter critical section and it may happen that each time P_2 try to enter CS it is blocked by some other process which may lead P_2 to starvation.

III. False as there is not fixed order whichever process get lock access can enter so not necessary to follow FIFO.

IV. Given code of test and set instruction satisfy mutual exclusion so atmost one process can enter CS

∴ By elimination only option (a) is true.

2.24 (a)

P1	P2
While (S1 == S2);	While (S1! = S2);
Critical section	Critical section
S1 = S2;	S2 = Not(S1);

We initially take $S_1 = 1$, and $S_2 = 1$.

When P1 execute S1 = S2 then it do nothing and process P1 go into critical section after executing it make the value of S1 = S2 and when P1 execute then P2 not execute because that checks different condition in while so both show mutual exclusion. But progress is not shown by these two because in this one process can be delayed infinitely.

Because again both P1 make its own condition true (S1 = S2 and S2 = not (S1);).

2.25 (a)

When $S_0 = 1$, $S_1 = 0$

So firstly the value of S_1 and $S_2 = 0$, P_1 and P_2 Not execute. The value of $S_0 = 1$, So it execute, process P_0 Now value of $S_0 = 0$

And it print zero one time when it release (S_1) call then value of S_1, S_2 increase by 1. So P_1 execute. It makes value of S_1 again zero and $S_0 = 1$, after it release (S_2) make value of $S_2 = 0$ by applying wait and $S_0 = 2$. So again P_0 process execute and wait (S_0) means it decrease by one so it print zero and this process continue. So P_0 print zero at least twice.

2.26 (b)

Assume P_1 executes until while condition and preempts before executing L = 1. Now P_2 executes all statements, hence L = 0. Then P_1 without checking L it makes L = 1 by executing the statement where it was preempted.

∴ It takes a non-zero value (L = 1) when the lock is actually available (L = 0)

2.27 (b)

Trick: To check deadlock in the given code proceed parallely i.e. first executed the first line of all the processes then executed the second line of all processes and so on.

(a)

X	Y	Z
1. P(a)	1. P(b)	1. P(c)
2. P(b)	2. P(c)	2. P(d)
3. P(c)	3. P(d)	3. P(a)

Value of a, b, c are 1 initially.

Execute first line of all processes i.e. $X_1 \rightarrow Y_1 \rightarrow Z_1$ after the executive of $X_1 \rightarrow Y_1 \rightarrow Z_1$ value of {a,b,c} = 0. Now no process is allowed to enter into the critical section. So deadlock.

(b)

X	Y	Z
1.P(b)	1.P(b)	1.P(a)
2.P(a)	2.P(c)	2.P(c)
3.P(c)	3.P(d)	3.P(d)

1. Execute X_1 so value of b gets 0.
2. As value of b = 0 when we execute Y_1 it get blocked (Y is blocked).
3. Now execute Z_1 so value of a get 0.
4. Now try to execute the second line of unblocked processes as value of a = 0 when we try to execute X_2 it get blocked (X is blocked)
5. Now execute Z_2, value of c gets 0.
6. As process X and Y are blocked so we can easily execute Z_3.

So no deadlock, like wise we can check option c and d, so option (b) is correct.

2.28 (d)

	X	W	Y	Z
1.	P(s)	P(s)	P(s)	P(s)
2.	R(x)	R(x)	R(x)	R(x)
3.	x = x +1	x = x + 1	x = x + 2	x = x + 2
4.	Store to MM	Store to MM	Store to MM	Store to MM
5.	V(s)	V(s)	V(s)	V(s)

1. Start with X. P(s) ⇒ s = 1 read x = 0, x = x+1
   Now before store into the memory process X preempt to process Y.
2. Y will perform P(s) ⇒ s = 0, read x = 0
   x = x – 2 then store x = – 2 and V(s) ⇒ s = 1
3. Z will perform P(s) ⇒ s = 0, read x = – 2
   x = x – 2
   then store x = – 4 and V(s) ⇒ s = 1
4. Now process x will store value of variable x into the MM so x = 1 and V(s) ⇒ s = 2
5. Now process W perform P(s) ⇒ s = 1 read x = 1
   x = x + 1, store x = 2, V(s) ⇒ s = 2,
   Option (d) is correct

2.29 (c)

The solution is using a binary semaphore. X and Y are two different processes whatever the values inserted by the processes in the array that will be used by process Y afterwards.

Option (a): It is wrong, because there exists a deadlock.

Option (b): It is wrong, because process X can insert multiple values in an array and terminate but process Y can consume only one value.

Option (c): It is correct, because each and every value inserted by the process X in the array will be immediately consumed by process Y.

Option (d): It is wrong, because process X can insert two values in the array but the process Y can consume only one value if the preemption occurs after V(S) operation in the entry seciton of process Y.

Process Y : _ _ _ _ _ _ _
_ _ _ _ _ _ _
Entry Y(R, S) { R = 0;
V(S); S = ∅ 1;
→ Preemption

Process X : _ _ _ _ _ _ _
_ _ _ _ _ _ _
Exists (R, S) { R = ∅ ✗ 1;
V(R); S = ✗ 0;
P(S);
_ _ _ _ _ _ _
Exists (R, S) {
V(R);
→ Preemption

Process Y : _ _ _ _ _ _ _ R = ✗ 0;
P(R); S = ∅ 1;
_ _ _ _ _ _ _
_ _ _ _ _ _ _
Entry Y(R, S) {
V(S);
→ Preemption

Process X : P(S); R = 0;
S = ✗ 0;

2.30 (c)

Option (a): If producer want to produce an item, it will first perform wait(s); then add to buffer( ); then signal semaphore s, n

∴ Value of semaphore become

n = ∅ 1;

s = ✗ ∅ 1;

If we now run consumer code, we have to perform wait option on semaphore s, n

∴ n = ∅ ✗ 0;

s = ✗ ∅ ✗ 0;

after removing from buffer( ); it will signal(s) and consume( )

∴ Consumer can consume item produced by producer so option (a) is false.

Option (b): It is also false as after removing one item from buffer we can repeat above process any number of times.

Option (c): If consumer run before producer has produced i.e. if buffer is empty, it will perform wait option on 's' which is successful after that it perform an unsuccessful wait option on semaphore 'n'

So, s = ✗ 0;

n = 0 (wait will lead to suspension)

Now if producer try to run and perform wait(s); it will also get suspended as both process are suspended and no other process to signal them so deadlock occurs.

∴ Option (c) is true.

Option (d): False, if we consume item in the buffer using consumer code, followed by producer in option (c), deadlock will occur.

2.31 (3)

B = 2

C = B – 1 B = 2 × C D = 2 × B B = D – 1 ⇓ B = 3	D = 2 × B B = D – 1 C = B – 1 B = 2 × C ⇓ B = 4	C = B – 1 D = 2 × B B = 2 × C B = D – 1 ⇓ B = 3	C = B – 1 D = 2 × B B = D – 1 B = 2 × C ⇓ B = 2	D = 2 × B C = B – 1 B = D – 1 B = 2 × C ⇓ B = 2	D = 2 × B C = B – 1 B = 2 × C B = D – 1 ⇓ B = 1

⇒ B = 2, 3 or 4

∴ Three distinct values are possible.

2.32 (a)

(i) Mutual exclusion fail in the given program. First, process X executes all statements till var$P$ = true. Second, process Y executes all statements till var$Q$ = true; Now, both process X and process Y both can execute while condition as true and then enters critical section simultaneously. Therefore mutual exclusion fails.

(ii) Deadlock is prevented by the given code.

2.33 (a)

Since *p*max returns as integer not smaller than any of its argument there may be a case when $t[\,j\,] == t[i]$ and $t[\,j\,]$ is not equal 0 for it.

∴ while ($t[\,j\,]$!= 0 && $t[\,j\,]$ <= $t[i]$);

will be true and process may get stuck in infinite loop which lead to deadlock and hence progress is also not satisfied.

As there is not proper definite waiting for process

∴ Among process P_0 ..... P_{n-1} some process may not get chance to execute and may starve.

∴ Bounded wait is not satisfied.

2.34 (c)

Given problem is strict alteration problem it violates progress. As if initially when turn is initialized to zero and process 1 try to enter into critical section it will be stuck in while loop as a result condition for progress is violates because a process outside the critical section should not block another process from entering to critical section if it is free. Bounded wait is satisfied as after process 0 has executed process 1 will definitely get a chance to execute so there is bounded wait with respect to number of processes.

2.35 (7)

S – 20 + 12 = –1

S – 8 = –1

S = – 1 + 8 = + 7

So, the initial values of the semaphore should be '7'.

2.37 (c)

Full = N, empty = 0, mutex = 1

- Initially buffer will be empty, so consumer should not start first, so option b, D are eliminated.
- With option A consumer will never consume the item, so it is wrong.
- Option 'c' is correct answer which proper functionality of produce and consumer.

2.38 (80)

Initial value of D = 100

Minimum value occur when P1, P2, P3 read and P1, P3 update the value

P1 update D = 110

P3 update D = 120

and last P2 will update the D = 100 – 50 = 50 = X

Maximum value will occur when P2 and P3 read the initial value of D and update, first run P2 and update D = 50. P3 will run and update

D = 100 + 10 = 110

Now P1 will read the value of D = 110 and update

D = D + 20 = 110 + 20

D = 130 = Y

Y – X = 130 – 50 = 80

2.39 (a)

- Process 'p' is holding X_p resources and does not request any new resources. So 'p' can complete it's execution and releases X_p resources.
- Process 'q' is holding X_q resources and does not request any new resources. So 'q' can complete it's execution and release X_q resources.

  Now available resources = $X_p + X_q$
- Other than 'p' and 'q' no other processes completes it execution, means available resources ($X_p + X_q$) is less than the resources demanded or requested by all other processes.

  So, $X_p + X_q < \text{Min}\{Y_k \mid 1 \le k \le n, k \ne p, k \ne q\}$ holds true.

2.40 (c)

All the processes running the given code will remain block due to wait(b) until the value of count becomes n.

When the value of count will become equals to n, value of b changes to 1 which will subsequently allow a process to go into section Q.

Hence, no process can go to section Q until all the process executes code section P.

2.41 (a, c, d)

(a) True: (P_1) first process came executed wait(S); wait(S)

counter++; was partially executed and the process preempted. Other process came updated counter to 4.

Now P_1 came and wrote counter to 1. So (a) is correct.

(b) Not possible at least counter will be 1.

(c) True: All 5 processes executed first wait(S) and are blocked.

(d) True: Each process executed the code sequentially and counter was finally updated to 5.

Option (a), (c) and (d) are correct.

2.42 (b, c, d)

- Mutual exclusion is not violated.
- Also, there will be no deadlock because of forceful preemption of resources.
- This may lead to starvation if the process is keeps on coming and preempting each other like P_1 is preempted by P_2 and P_2 is preempted by P_3.
- Live-lock is also possible due to continuous preemption of resources.

For option (c) consider two processes P_1 and P_2 now P_1 enter the code acquires lock and resource.

Now P_2 enters the else part kills P_1 and acquire R and restart P_1.

Now P_1 again acquire lock and kills the process P_2 this continues creating a live lock scenario but there is ambiguity in the code since "Release R" is not written any where so ambiguity is regarding how the process will release Resource R. According to the code, the only way to release the resource is by getting killed.

2.43 **(b, c)**

P_1 and P_2 can spawn two threads T_1 and T_2.

```
int x = 0; //global
Lock L1; //global
main( ) {
    foo( ); //Thread T1
    foo( ); //Thread T2
    print(x);
}
foo( ) {
a.  int y = 0;
b.  Acquire L1;
c.  x = x + 1;
d.  y = y + 1;
    Release L1;
    print(y);
}
```

- Let P_1 executed T_1 and in foo( ).

(a) $P_1 - T_1$ $\overset{X}{\boxed{\not{0}}}1$

(b) $P_1 - T_1$

(c) $x = x + 1$ $(P_1 - T_1)$
.... Preempt T_1 of P_1.

Similarly, perform thread T_2 of P_1 then $x = 2$.

Now, if we similarly perform both threads of P_2 then x will be maximum 2.

Note: It is not mentioned about IPC or concurrent mechanism so the process will not shared the global variable. Each process will have its on own address space so the maximum value of x by each process can be 2 only.

Note: But as we know every foo call will have its own copy of variable y so y can not be more than 1 in any case.

2.44 **(c)**

Inorder to get the required output only semaphore S_1 should be initialized to 1, other semaphore should be initialized to 0.

So, $S_1 = 1$; $S_2 = 0$; $S_3 = 0$

Answer is option (c).

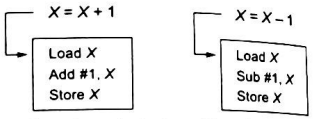
2.45 **(c)**

I-1: s is a binary semaphore initialized to 1. With binary semaphore, there can't be two threads that can simultaneously access the critical section, Thus, each thread with run incr( ) or decr( ) one by one.

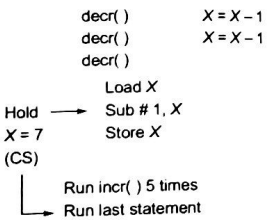
Hence, only possible value of X at the end is 12.

I-2: With counting semaphore of value 2. Two processes at a time can access critical section.

Note:



In order to minimize X value, we need to maximize the impact of decr( ) and minimize the impact of incr( ).



Thus, finally $\boxed{X = 7}$ will get stored.

■■■■

3 Deadlock

3.1 An operating system contains 3 user processes each requiring 2 units of resource R. the minimum number of units of r such that no deadlocks will ever arise is

(a) 3 (b) 5

(c) 4 (d) 6 **[1997 : 2 M]**

3.2 A computer has six tape drives, with n processes competing for them. Each process may need two drives. What is the maximum value of n for the system to be deadlock free?

(a) 6 (b) 5

(c) 4 (d) 3 **[1998 : 1 M]**

3.3 Which of the following is NOT a valid deadlock prevention scheme?

(a) Release all resources before requesting a new resource.

(b) Number the resources uniquely and never request a lower numbered resource than the last one requested.

(c) Never request a resource after releasing any resource

(d) Request and all required resources be allocated before execution. **[2000 : 2 M]**

3.4 In a certain operating system, deadlock prevention is attemped using the following scheme. Each process is assigned a unique timestamp, and is restarted with the same timestamp if killed. Let P_h be the process holding a resource R, P_r be a process requesting for the same resource R, and $T(P_h)$ and $T(P_r)$ be their timestamps respectively. The decision to wait or preempt one of the processes is based on the following algorithm.

```
if T(Pr) < T(Ph) then
kill Pr
else
wait
```

Which one of the following is TRUE?

(a) The scheme is deadlock-free, but not starvation-free

(b) The scheme is not deadlock-free, but starvation-free

(c) The scheme is neither deadlock-free nor starvation-free

(d) The scheme is both deadlock-free and starvation-free **[2004 : 2 M]**

3.5 Suppose n processes, $P_1, ..., P_n$ share m identical resource units, which can be reserved and released one at a time. The maximum resource requirement of process P_i is s_i where $s_i > 0$. Which one of the following is a sufficient condition for ensuring that deadlock does not occur?

(a) $\forall i, s_i < m$ (b) $\forall i, s_i < n$

(c) $\sum_{i=1}^{n} s_i < (m + n)$ (d) $\sum_{i=1}^{n} s_i < (m * n)$

[2005 : 2 M]

3.6 Consider the solution to the bounded buffer producer/consumer problem by using general semaphores S, F, and E. The semaphore S is the mutual exclusion semaphore initialized to 1. The semaphore F corresponds to the number of free slots in the buffer and is initialized to N. The semaphore E corresponds to the number of elements in the buffer and is initialized to 0.

Producer Process	Consumer Process
Produce an item;	Wait (E);
Wait (F);	Wait (S);
Wait (S);	Remove an item from the buffer;
Append the item to the buffer;	Signal (S);
Signal (S);	Signal (F);
Signal (E);	Consumer the item;

Which of the following interchange operations may result in a deadlock?

I. Interchanging Wait (F) and Wait (S) in the Producer process.

II. Interchanging Signal (S) and Signal (F) in the Consumer process.

(a) I only (b) II only

(c) Neither I nor II (d) Both I and II **[2006 : 2 M]**

3.7 Consider the following snapshot of a system running n processes. Process i is holding x_i instances of a resource R, for $1 \le i \le n$. Currently, all instances of R are occupied. Further, for all i,