GATE and GATE Type Question

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1 Virtual Memory and Paging

Q1. GATE 2008: Multi-level Paging Table Address Bits

A processor uses **36-bit physical addresses** and **32-bit virtual addresses**, with a page frame size of **4 KB**. Each page table entry is of size **4 bytes**. A **three-level page table** is used for virtual to physical address translation, where the virtual address is used as follows:

- Bits **30–31** index the **first level** page table.
- Bits **21–29** index the **second level** page table.
- Bits **12–20** index the **third level** page table.
- Bits **0–11** are the **page offset**.

The number of bits required for addressing the next level page table (or page frame) in the page table entries of the **first, second, and third level** page tables are respectively:

(a) 20, 20, 20

(b) 24, 24, 24

(c) 24, 24, 20

(d) 25, 25, 24

Q2. Multi-level Virtual Address Structure

A system uses **40-bit virtual addresses** and **36-bit physical addresses**. The page size is **8 KB**,and each page table entry is **4 bytes**. The virtual address is broken down as follows for a **2-level page table**:

- Bits **29–39** for the **first level** index
- Bits **16–28** for the **second level** index
- Bits **0–15** for the **page offset**

What is the size (in bits) of the physical page number stored in each page table entry?

(a) 36

(b) 23

(c) 24

(d) 28

Q3. Number of Entries per Table

A processor has a **48-bit virtual address**, and page size is **4 KB**. A **three-level page table** is used with the following split:

- Level 1: 12 bits
- Level 2: 12 bits
- Level 3: 12 bits
- Offset: 12 bits

How many entries are there in each level of the page table?

(a) $2^{12}, 2^{12}, 2^{12}$

(b) $2^{16}, 2^{16}, 2^{4}$

(c) $2^{10}, 2^{12}, 2^{14}$

(d) $2^{16}, 2^{12}, 2^{8}$

Q4. Page Table Size Estimation

A 32-bit machine uses a **2-level paging** scheme with **4 KB pages**. Virtual address is split as:

- Level 1 index: 10 bits
- Level 2 index: 10 bits
- Offset: 12 bits

Assume:

- Each page table entry is **4 bytes**
- Only **1 process is running**

What is the **maximum size** (in bytes) of the total page tables needed for a process?

(a) 8 KB

(b) 16 KB

(c) 4 MB

(d) 4 KB

2 Operating Systems: Synchronization

Q1. [MCQ]

Which of the following is not a necessary condition for a deadlock to occur?

(a) Mutual Exclusion

(b) Hold and Wait

(c) No Preemption

(d) Context Switching

Q2. [MCQ]

Consider two processes accessing a shared variable using busy-wait locks. Which scenario can lead to starvation?

(a) Mutual exclusion is violated

(b) No process yields the CPU

(c) Both use priority inheritance

(d) Critical section is empty

Q3. [MSQ]

Which of the following techniques can help avoid deadlock?

(a) Resource allocation graph with a single instance per resource

(b) Banker's algorithm

(c) Wait-for graph cycle detection

(d) Allowing all requests at once

Q4. [MCQ]

The Peterson's algorithm ensures:

(a) Deadlock freedom

(b) Starvation freedom

(c) Mutual exclusion

(d) All of the above

Q5. [MCQ]

Which of the following is true for the Bakery Algorithm?

(a) It requires hardware support

(b) It prevents mutual exclusion

(c) It works for more than two processes

(d) It allows priority scheduling

Q6. [MCQ]

In a system using semaphores, a process executes **wait(S)** and is put to sleep. When **signal(S)** is called by another process:

(a) S is incremented, but the sleeping process continues to sleep

(b) Sleeping process is immediately awakened

(c) **signal()** fails silently

(d) S is reset to 0

Q7. [MCQ]

In which scenario does the use of spinlocks become inefficient?

(a) Multiprocessor systems

(b) Critical section is very short

(c) Process holds CPU for long durations in CS

(d) Atomic instructions are expensive

Q8. [MSQ]

Consider a system with preemptive scheduling and semaphores. Which conditions must be met for bounded waiting?

(a) FIFO ordering of blocked processes

(b) Starvation prevention

(c) Mutual exclusion

(d) Strict priority scheduling

Q9. [MCQ]

Which of the following mechanisms is non-blocking and busy-waiting?

(a) Counting semaphore

(b) Binary semaphore

(c) Spinlock

(d) Mutex

Q10. [MCQ]

Which of the following issues is most likely to occur if semaphores are misused?

(a) Deadlock

(b) Thrashing

(c) Paging

(d) Fragmentation

Q11. [MCQ]

Which of the following statements is true regarding priority inversion?

(a) It is solved using Banker's algorithm

(b) It occurs when a low-priority process holds a lock needed by a high-priority one

(c) It is always prevented in spinlocks

(d) Round-robin scheduling prevents it

Q12. [MCQ]

The use of monitors provides:

(a) Mutual exclusion only

(b) Synchronization without requiring condition variables

(c) Encapsulation of shared data and synchronization

(d) Only inter-process communication

Q13. [MCQ]

In a classic producer-consumer problem, using bounded buffer and semaphores, which semaphore combination is incorrect?

(a) Empty initialized to N

(b) Full initialized to 0

(c) Mutex initialized to 0

(d) Mutex initialized to 1

Q14. [MSQ]

A correct solution to the Dining Philosophers problem must ensure:

(a) No deadlock

(b) No starvation

(c) Maximum concurrency

(d) No preemption

Q15. [MCQ]

A process enters its critical section. Suddenly, it is preempted. What is the main concern in such a system?

(a) Starvation

(b) Race condition

(c) Deadlock

(d) Context switching overhead

Q16. [MCQ]

Busy waiting in critical section management is:

(a) Always preferable on single-core systems

(b) Efficient when CS time is small and context-switching is expensive

(c) Prevented by semaphores

(d) Never used in modern OS

Q17. [MCQ]

Which of the following statements is false?

(a) Semaphore **wait()** operation is also called **P()**

(b) A monitor can have condition variables

(c) Spinlock wastes CPU cycles

(d) Peterson's algorithm works with preemption

Q18. [MSQ]

Which of the following mechanisms support process synchronization?

(a) Monitors

(b) Semaphores

(c) Message passing

(d) File I/O operations

Q19. [MCQ]

A deadlock can occur if:

(a) All four Coffman conditions hold

(b) At least three Coffman conditions hold

(c) Only circular wait holds

(d) Mutual exclusion is violated

Q20. [MCQ]

Two threads simultaneously execute **wait(mutex)** and get stuck. What likely happened?

(a) Mutual exclusion was violated

(b) **signal(mutex)** was never called

(c) Deadlock occurred due to wrong semaphore initialization

(d) Mutex had a race condition

3 Operating Systems: Synchronization - Numerical Problems

Q1. [NAT]

A system has 4 resources of the same type. P1, P2, P3 processes are competing for them. - P1 holds 2 resources - P2 holds 1 resource - P3 holds 1 resource

No process is releasing a resource. What is the minimum number of additional resources that must be added to avoid deadlock?

Q2. [NAT]

A system has 5 processes $\{P_0, P_1, P_2, P_3, P_4\}$ and 3 resource types A, B, C. - Total instances: A = 10, B = 5, C = 7 - Allocation matrix:

$$\begin{bmatrix} 0 & 1 & 0 \\ 2 & 0 & 0 \\ 3 & 0 & 2 \\ 2 & 1 & 1 \\ 0 & 0 & 2 \end{bmatrix}$$

- Maximum matrix:

$$\begin{bmatrix} 7 & 5 & 3 \\ 3 & 2 & 2 \\ 9 & 0 & 2 \\ 2 & 2 & 2 \\ 4 & 3 & 3 \end{bmatrix}$$

What is the number of safe sequences possible?

Q3. [NAT]

A counting semaphore is initialized to 3. Ten processes simultaneously perform ‘wait()‘ on it. How many processes get blocked?

Q4. [MCQ]

In a bounded buffer producer-consumer problem: - Buffer size = 7 - ‘empty‘ semaphore initialized to 7 - ‘full‘ semaphore initialized to 0 - 10 producers perform ‘wait(empty)‘ - 4 consumers perform ‘wait(full)‘

What is the value of the ‘empty‘ semaphore after these operations?

(a) 3 (b) 7 (c) 10 (d) 1

Q5. [NAT]

Suppose 5 resources of a single type are available. There are 3 processes. Each process may request up to 3 resources. What is the maximum number of resources that can be allocated to prevent deadlock?

Q6. [MCQ]

In a Peterson's algorithm-based system, two processes are executing concurrently and take 3 cycles in the critical section and 2 cycles in the remainder section. What is the maximum number of times a process can enter its critical section in 20 cycles?

(a) 3 (b) 4 (c) 5 (d) 6

Q7. [NAT]

In a round-robin scheduling system with semaphore synchronization: - Semaphore S is initialized to 1 - Each process needs 3 critical section entries - Each entry takes 4 cycles - There are 4 processes

Assuming context switching is zero-cost, how many cycles are needed in total?

Q8. [MCQ]

In the Dining Philosopher problem with 5 philosophers using semaphores: - Each philosopher takes 1 unit time to eat and 2 units to think - Two philosophers are allowed to eat concurrently What is the minimum total time required for all 5 to eat once?

(a) 3 (b) 5 (c) 7 (d) 9

Q9. [NAT]

In a critical section problem with 'n' processes using a binary semaphore, each critical section takes 5 ms, and non-critical section takes 15 ms. What is the maximum throughput (in processes/second)?

Q10. [MCQ]

A system using monitors has 6 threads accessing a shared resource. The monitor allows at most 2 threads to be inside at a time. If all threads request access simultaneously and one entry takes 10ms, what is the total time for all threads to execute?

(a) 20ms (b) 30ms (c) 40ms (d) 60ms

4 Operating Systems: Hard Synchronization Problems

Q1. [GATE 2022 - Rephrased]

Consider the following threads T_1, T_2, T_3 with 3 semaphores S_1, S_2, S_3. The code for each thread is:

$\mathbf{T_1}$	$\mathbf{T_2}$	$\mathbf{T_3}$
while(true){ `wait(S3);` `print("C");` `signal(S2);` }	*while(true)*{ `wait(S1);` `print("B");` `signal(S3);` }	*while(true)*{ `wait(S2);` `print("A");` `signal(S1);` }

Which semaphore initialization gives 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) $S_1 = 0, S_2 = 1, S_3 = 1$

Q2. [GATE 2018 - Rephrased]

In a classical synchronization producer-consumer problem has following variables:

1. Buffer size = N
2. Semaphores: $empty = 0$, $full = N$, $mutex = 1$

Determine the correct values of P, Q, R, S in the following code:

Producer	**Consumer**
do{ `wait(P);` `wait(mutex);` `/* Add/Consume item */` `signal(mutex);` `signal(Q);` } `while(1);`	*do*{ `wait(R);` `wait(mutex);` `/* Add/Consume item */` `signal(mutex);` `signal(S);` } `while(1);`

(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) $P = empty, Q = full, R = full, S = empty$

Q3. [GATE 2010 - Rephrased]

Three processes P_0, P_1, P_2 and semaphores initialized as: $S_0 = 1, S_1 = 0, S_2 = 0$

P_0	P_1	P_2
`while(true)` `  wait(S0);` `  print("0");` `  signal(S1);` `  signal(S2);`	`wait(S1);` `  signal(S0);`	`wait(S2);` `  signal(S0);`

How many times can P_0 print "0"?
(a) Exactly once (b) Exactly twice (c) At least twice (d) Exactly thrice

Q4. [Semaphore Sequence]

Three semaphores $S1 = 0$, $S2 = 1$, $S3 = 0$. Processes:

- P1: `wait(S1); print("X"); signal(S2);`
- P2: `wait(S2); print("Y"); signal(S3);`
- P3: `wait(S3); print("Z"); signal(S1);`

What is the sequence printed by the processes?
(a) XYZXYZ... (b) ZYXZYX... (c) YZX... (d) Deadlock

Q5. [Critical Section Throughput]

A semaphore is used for mutual exclusion between $n = 3$ threads. Each thread executes:

```
while(true){
    wait(S);
    critical_section();
    signal(S);
}
```

If the critical section takes 10 ms and the remainder section takes 5 ms, what is the maximum possible throughput?

(a) 1 thread/sec

(b) 100 threads/sec

(c) 66.67 threads/sec

(d) 200 threads/sec

Q6. [Deadlock Detection]

There are 3 processes and 3 identical resources. Each process holds one resource and requests one more. Are we guaranteed to have deadlock?

(a) Yes

(b) No

(c) Only if request order is circular

(d) Depends on scheduling

Q7. [Producer-Consumer Semaphore Values]

In a bounded-buffer system:

- Buffer size = 5
- Initial values: `empty = 5, full = 0, mutex = 1`
- Producer uses: `wait(empty); wait(mutex); signal(mutex); signal(full);`
- Consumer uses: `wait(full); wait(mutex); signal(mutex); signal(empty);`

If 5 producer and 5 consumer operations are performed, what is the value of `empty`?

(a) 5

(b) 0

(c) 1

(d) 2

Q8. [Thread Interleaving with Semaphore]

Two threads T_1 and T_2 run concurrently:

```
T1: wait(S); print("A"); signal(S);
T2: wait(S); print("B"); signal(S);
```

If $S = 1$ initially, which sequences are possible?

(a) AB

(b) BA

(c) AABB

(d) ABAB

Q9. [Semaphore Starvation]

A semaphore is initialized to 1 and accessed by multiple threads. If a few threads wait indefinitely due to scheduler behavior, what phenomenon is observed?

(a) Deadlock

(b) Starvation

(c) Race Condition

(d) Livelock

Q10. [Gate-style Synchronization Loop]

Consider 3 processes synchronized as follows:

- P1: `wait(S1); signal(S2);`
- P2: `wait(S2); signal(S3);`
- P3: `wait(S3); signal(S1);`

With initial values: $S1 = 1$, $S2 = 0$, $S3 = 0$

What type of execution order is enforced?

(a) Arbitrary

(b) P1 $\rightarrow$ P2 $\rightarrow$ P3 cyclically

(c) P3 always runs first

(d) Deadlock

5 Verbal Reasoning – Analogy, Grammar, Coherence, Inference

Q1. Analogy (Vocabulary)

walk : jog : sprint :: bothered : __________ : daunted

(a) phased

(b) phrased

(c) fazed

(d) fused

Correct Answer: (c) fazed *Explanation:* Walk, jog, sprint represent increasing intensity. Similarly, bothered → fazed → daunted shows increasing psychological intensity.

Q2. Fill in the Blank (Preposition Usage)

She looked ________ the list of names to find hers, but it wasn't there.

(a) on

(b) down

(c) for

(d) on

Correct Answer: (b) down *Explanation:* "Looked down the list" is the correct phrasal usage.

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Q3. Sentence Arrangement (Coherent Sequence)

Arrange the following four sentences in a logical order:

I. She picked up the phone and dialed a number.

II. A few moments later, she smiled and hung up.

III. The phone rang three times before someone answered.

IV. Her eyes were anxious as she searched for the contact.

Which of the following sequences forms a coherent narrative?

(a) IV, I, III, II

(b) I, III, IV, II

(c) IV, III, I, II

(d) I, IV, II, III

Correct Answer: (a) IV, I, III, II *Explanation:* Starts with her searching, then dialing, then ringing, then ending with a smile.

—

Q4. Paragraph Inference

Paragraph: Climate change models predict that rising sea levels and increased temperature variations will lead to changes in the distribution of many marine species. Fish that are normally found in tropical waters may migrate to temperate zones in search of optimal conditions. This could have major consequences for global fisheries and local ecosystems.

Which of the following can be inferred with certainty?

(a) Marine biodiversity will increase in temperate zones.

(b) Fish migration patterns are affected by water temperature.

(c) All tropical fish will migrate to cooler waters.

(d) Global fisheries will collapse due to climate change.

Correct Answer: (b) *Explanation:* Only option (b) is directly supported and certain based on the paragraph.

6 Answers to Conceptual Questions

Answers: Multi-Level Paging

Answers: Q1: (c), Q2: (b), Q3: (a), Q4: (c)

Answers: Synchronization

Q1: (d), Q2: (b), Q3: (a)(b)(c)(d), Q4: (d), Q5: (c)
Q6: (b), Q7: (c), Q8: (a)(b)(c), Q9: (c), Q10: (a)
Q11: (b), Q12: (c), Q13: (c), Q14: (a)(b)(c), Q15: (b)
Q16: (b), Q17: (d), Q18: (a)(b)(c), Q19: (a), Q20: (c)

Answers: Synchronization - Numerical

Q1: 1, Q2: 1, Q3: 7, Q4: (a), Q5: 4,
Q6: (b), Q7: 48, Q8: (c), Q9: 50, Q10: (c)

Answers: Synchronization - Hard Set

Q1: (c), Q2: (d), Q3: (a), Q4: (a), Q5: (c), Q6: (a), Q7: (a), Q8: (a), (b), Q9: (b), Q10: (b)