Memory Management: Binding and Relocation

1. **When does binding occur at load time?**
   A) When the program is compiled
   B) When the program is loaded into memory
   C) When the program is executed
   D) When the program terminates

   <u>Correct answer:</u> B)
   <u>Explanation:</u> Load-time binding occurs when the program is loaded into RAM and the base address becomes known only at that moment.

2. **A program is loaded at base address 5000. An instruction uses logical address 1200. What is the corresponding physical address?**
   A) 3800
   B) 5000
   C) 6200
   D) 1200

   <u>Correct answer:</u> C)
   <u>Explanation:</u> Physical address = base address + logical address = 5000 + 1200 = 6200.

Memory Management: Contiguous Allocation

3. **Which technique tends to produce more external fragmentation in the long run?**
   A) First-fit
   B) Worst-fit
   C) Best-fit
   D) External fragmentation does not exist with contiguous allocation

   <u>Correct answer:</u> A)
   <u>Explanation:</u> First-fit leaves small holes at the beginning of memory, increasing external fragmentation.

4. **A 200 KB memory area allocates processes of 60 KB, 80 KB, and 40 KB. How much free space remains?**
   A) 20 KB
   B) 40 KB
   C) 60 KB
   D) 0 KB

   <u>Correct answer:</u> A)

Explanation: 60 + 80 + 40 = 180 KB → 200 − 180 = 20 KB.

5. **Assume the following list of free contiguous memory blocks: 15 KB, 35 KB, 60 KB, 90 KB. Which block will be allocated to a 50 KB process assuming the best-fit allocation strategy?**
   A) 15 KB
   B) 35 KB
   C) 60 KB
   D) 90 KB

   Correct answer: C)
   Explanation: Best-fit selects the smallest block that can accommodate the process, which is 60 KB.

Memory Management: Paging

6. **Which problem does paging eliminate?**
   A) Internal fragmentation
   B) External fragmentation
   C) Thrashing
   D) Page faults

   Correct answer: B)
   Explanation: Paging eliminates external fragmentation by dividing memory into fixed-size blocks, but it may cause internal fragmentation.

7. **A process has a logical memory of 48 KiB and a page size of 4 KiB. How many logical pages are required?**
   A) 4
   B) 8
   C) 10
   D) 12

   Correct answer: D)
   Explanation: 48 / 4 = 12 pages.

8. **In a virtual memory system, a process generates a reference to logical address 9876. The page size is 1024 bytes. What are the virtual page number (VPN) and the offset?**
   A) VPN 9, offset 660
   B) VPN 8, offset 676
   C) VPN 9, offset 548
   D) VPN 10, offset 452

Correct answer: A)
Explanation:
VPN = 9876 ÷ 1024 = 9
Offset = 9876 mod 1024 = 660

9. **A system uses pages of size 512 B. Knowing that logical page 3 is mapped to physical frame 5 and that the offset is 200, what is the corresponding physical address?**
A) 2760
B) 2762
C) 2660
D) 2560

Correct answer: A)
Explanation: Frame 5 starts at 5 × 512 = 2560 → 2560 + 200 = 2760.

10. **A system has a virtual memory of 128 KiB and a page size of 2 KiB. How many page table entries (PTEs) are required in the page table?**
A) 32
B) 64
C) 128
D) 256

Correct answer: B)
Explanation: 2^17 B / 2^11 B = 2^7 = 64 pages → 64 PTEs.

11. **A system has a logical memory of 1 GiB divided into pages of 4 KiB. Knowing that each page table entry (PTE) occupies 8 bytes, how much space is required for a single page table per process, assuming it is organized as a simple linear array?**
A) 256 KiB
B) 768 KiB
C) 1 MiB
D) 2 MiB

Correct answer: D)
Explanation:
Total number of PTEs: $2^{30} / 2^{12} = 2^{18}$
Page table size = $2^{18} \times 2^{3}$ B = 2^{21} B = 2 MiB.

12. **A system uses 48-bit logical addresses and a logical memory divided into pages of 4 KiB. Knowing that each page table/directory entry (PTE/PDE) occupies 8 bytes, how many levels are required to store each process's page table using a hierarchical (*multi-level paging*) structure, assuming that each page directory must fit within a single page?**
    A) 2
    B) 3
    C) 4
    D) 9

    Correct answer: C)
    Explanation:
    Entries per page: $2^{12} / 2^3 = 2^9 = 512$ PTEs/PDEs per page → each level indexes 512 entries using 9 bits.
    Offset = $\log_2(2^{12}) = 12$ bits.
    The remaining bits for the VPN are $48 - 12 = 36$ bits.
    Number of levels = $36 / 9 = 4$.

13. **A 36-bit logical address is used in a system with a page size of 4 KiB. How many bits are required to identify the virtual page number (VPN)?**
    A) 10
    B) 12
    C) 16
    D) 24

    Correct answer: D)
    Explanation: 4 KiB = 2^{12} → offset = 12 bits. VPN = $36 - 12 = 24$ bits.

14. **A system with a virtual memory of 2 GiB uses pages of size 16 KiB. How many bits are required to represent a logical address, and how are they divided between page number and offset?**
    A) 30 total bits: 16 for the page number, 14 for the offset
    B) 30 total bits: 14 for the page number, 16 for the offset
    C) 31 total bits: 17 for the page number, 14 for the offset
    D) 32 total bits: 18 for the page number, 14 for the offset

    Correct answer: C)
    Explanation:
    $\log_2(2 \text{ GiB}) = \log_2(2^{31}) = 31$
    Offset = $\log_2(2^{14}) = 14$ bits; VPN = $31 - 14 = 17$ bits.

Memory Access Time

15. **A system uses a TLB (Translation Lookaside Buffer) with an access time of 10 ns and a main memory access time of 100 ns. If the TLB hit rate is 90%, what is the effective average memory access time?**
    A) 110 ns
    B) 120 ns
    C) 130 ns
    D) 210 ns

    Correct answer: B)
    Explanation:
    T_{TLB} = 10 ns; T_M = 100 ns; P_{hit} = 0.9
    Expected memory access time =
    $P_{hit} \times (T_{TLB} + T_M) + (1 - P_{hit}) \times (T_{TLB} + 2T_M)$
    $= 0.9 \times 110 + 0.1 \times 210 = 120$ ns.

16. **In a paged system, the memory access time is 200 ns and each page fault requires 10 ms to handle. If the page fault rate is 1 out of 4000 accesses, what is the effective average memory access time?**
    A) ~270 ns
    B) ~2.7 μs
    C) ~4 μs
    D) ~27 ms

    Correct answer: B)
    Explanation:
    $T_M = 200 \text{ ns} = 2 \times 10^{-7}$ s
    $T_{fault} = 10 \text{ ms} = 10^{-2}$ s
    $P_{fault} = 1 / 4000 = 2.5 \times 10^{-4}$
    Expected memory access time = $P_{fault} \times T_{fault} + (1 - P_{fault}) \times T_M$
    = 2.5*10^-4 * 10^-2 + (1-2.5*10^-4) * 2*10^-7 ~ 2.7 * 10^-6 s = 2.7 μs.

Virtual Memory

17. **Which page replacement algorithm can suffer from Belady's anomaly?**
    A) LRU
    B) OPT
    C) FIFO
    D) Second Chance

    Correct answer: C)

Explanation: FIFO can increase the number of page faults when more frames are added.

18. **A system uses the LRU page replacement algorithm. The reference string is: A, B, C, A, D, B, E, C, C, D, E. With 3 frames, how many page faults occur, assuming that initially no frames are loaded (*pure demand paging*)?**
A) 7
B) 8
C) 9
D) 10

Correct answer: B)
Explanation:

Step	Page	Frame 1	Frame 2	Frame 3	Page Fault	Explanation (LRU)
1	**A**	A	–	–	❌	Empty frame
2	**B**	A	B	–	❌	Empty frame
3	**C**	A	B	C	❌	Empty frame
4	**A**	A	B	C	✅	A is already loaded
5	**D**	A	D	C	❌	LRU = **B**
6	**B**	A	D	B	❌	LRU = **C**
7	**E**	E	D	B	❌	LRU = **A**

8	**C**	E	C	B	❌	LRU = **D**
9	**C**	E	C	B	✅	C is already loaded
10	**D**	E	C	D	❌	LRU = **B**
11	**E**	E	C	D	✅	E is already loaded

19. **A system uses the FIFO page replacement algorithm. The reference string is: A, B, B, A, C, D, C, E, A, B, E. With 3 frames, how many page faults occur assuming that initially no frame is loaded (*pure demand paging*)?**
    A) 7
    B) 8
    C) 9
    D) 10

    Correct answer: A)
    Explanation:

Step	Page	Frame 1	Frame 2	Frame 3	Page Fault	Explanation (FIFO)
1	**A**	A	–	–	❌	Empty frame
2	**B**	A	B	–	❌	Empty frame
3	**B**	A	B	–	✅	B is already loaded
4	**A**	A	B	–	✅	A is already loaded

5	**C**	A	B	C	❌	Empty frame
6	**D**	D	B	C	❌	FIFO → replaces A
7	**C**	D	B	C	✅	C is already loaded
8	**E**	D	E	C	❌	FIFO → replaces B
9	**A**	D	E	A	❌	FIFO → replaces C
10	**B**	B	E	A	❌	FIFO → replaces D
11	**E**	B	E	A	✅	E is already loaded

Secondary Storage Devices

20. **Which component is NOT part of disk access time?**
    A) Seek time
    B) Rotational delay
    C) Transfer time
    D) Page fault time

    Correct answer: D)
    Explanation: A page fault concerns virtual memory, not the physical disk.

Disk Scheduling Algorithms

21. **Which disk scheduling algorithm guarantees the greatest fairness?**
    A) SSTF
    B) FCFS
    C) SCAN
    D) LOOK (optimized SCAN)

    Correct answer: B)
    Explanation: FCFS does not discriminate against requests that are far from the current head position.

22. **In a magnetic disk using the SCAN scheduling algorithm, the requests arrive in the following order: 50, 20, 30, 90, 60. Assuming the disk head is at cylinder 40 and is moving toward the outer cylinders (toward lower-numbered cylinders), what is the order in which the requests are serviced?**
    A) 30, 20, 50, 60, 90
    B) 50, 60, 90, 30, 20
    C) 50, 20, 30, 90, 60
    D) 30, 20, 90, 60, 50

    Correct answer: A)
    Explanation: SCAN services requests in one direction until the end is reached, then reverses direction.

23. **In a magnetic disk using the FCFS scheduling algorithm, the requests arrive in the following order: 70, 20, 10, 50, 45. Assuming the disk head is initially at track 30, what is the total distance traveled (measured as the number of track movements)?**
    A) 105
    B) 115
    C) 145
    D) 155

    Correct answer: C)
    Explanation:
    30 → 70 = 40
    70 → 20 = 50
    20 → 10 = 10
    10 → 50 = 40
    50 → 45 = 5
    Total = 145

24. **In a magnetic disk with 100 cylinders (numbered from 0 to 99) using the C-SCAN scheduling algorithm, the requests arrive in the following order: 60, 25, 45, 10, 90, 75. Assuming the disk head is at cylinder 35 and is moving toward the outer cylinders (toward lower-numbered cylinders), what is the total distance traveled (measured as the number of track movements)?**
A) 88
B) 168
C) 178
D) 188

<u>**Correct answer:**</u> D)
<u>**Explanation:**</u>
10 + 15 + 10 + 99 + 9 + 15 + 15 + 15 = 188

Movement	**From**	**To**	**Distance (n. track hops)**
1	35	25	$\lvert 35 - 25 \rvert = 10$
2	25	10	$\lvert 25 - 10 \rvert = 15$
3	10	0	$\lvert 10 - 0 \rvert = 10$
4	0	99	$\lvert 99 - 0 \rvert = 99$
5	99	90	$\lvert 99 - 90 \rvert = 9$
6	90	75	$\lvert 90 - 75 \rvert = 15$
7	75	60	$\lvert 75 - 60 \rvert = 15$
8	60	45	$\lvert 60 - 45 \rvert = 15$

25. In a magnetic disk, the average seek time is 10 ms, and the rotational delay is 5 ms. Knowing that 5 MiB of data are transferred in 50 ms, what is the disk transfer rate?

A) ~124 MiB/s
B) ~137 MiB/s
C) ~143 MiB/s
D) ~150 MiB/s

Correct answer: C)
Explanation:
T_seek = 10 ms; T_rot = 5 ms
T_tot = T_seek + T_rot + T_transf → 50 ms = 10 ms + 5 ms + T_transf
T_transf = 50 ms - 15 ms = 35 ms = 3.5 * 10^-2 s
Data = 5 MiB = 5 * 2^20 B
Transfer Rate = Data / T_transf = (5 * 2^20) / (3.5 * 10^-2) ~ 149,796,571 byte/s ~ 143 MiB/s