CSS225: Operating System
Final Mock Exam

curated by The Peanuts

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Conditions: Semi-Closed Book (A4 Both Sides)

Directions:

1. This exam has 29 pages (including this page).
2. No multitasking during taking the exam.
3. Write your username or process ID at the top.
4. Reading the problem is optional but highly recommended.
5. Solutions can be written in English or Thai.
6. Students may not escape through Windows or Linux.

~~*For solution, click here*~~

Part A: Multiple-Choice Questions (15 marks)

1. _____ is a situation where a set of processes are blocked because each process is holding a resource and waiting for another resource acquired by some other process.

a) Preemption

b) A deadlock

c) Page replacement

d) Swapping

2. Which one is INCORRECT about resource types and instances?

a) Consider a system with four different models of printers. Here, there are four resource types.

b) The resources may be partitioned into several types (or classes), each consisting of some number of identical instances.

c) Consider a system with three identical CPUs. Here, there are three instances of the resource type named CPU.

d) All answers are correct.

3. Which one is INCORRECT about the necessary conditions in a deadlock?

a) There are four necessary conditions.

b) One necessary condition for deadlock is no preemption, which states that at least one resource must be held in a non-sharable mode.

c) One necessary condition for deadlock is hold and wait, which states that a process must be holding one resource and waiting to acquire additional resources.

d) All answers are correct.

4. Which one is INCORRECT about a resource-allocation graph?

a) A resource-allocation graph consists of a set of vertices and a set of edges. ✓

b) The set of vertices is partitioned into two different types of nodes: processes and resource types. ✓

c) Each resource-type node has only one instance. ✗ (can be more)

d) A request edge is denoted by an arrow pointing from a process to a resource type. ✓

5. In a resource-allocation graph, an assignment edge is:

a) A directed edge from a process to a resource type

b) A directed edge from an instance in a resource type to a process

c) A directed edge from a process to an instance in a resource type

d) A directed edge from an instance in a resource type to a resource type

6. Most operating systems handle deadlocks by:

a) Ignoring the deadlock problem and pretending that deadlocks never occur in the system

b) Allowing the system to enter a deadlocked state, detecting it, and recovering

c) Using a protocol to prevent or avoid deadlocks, ensuring that the system will never enter a deadlocked state

d) No correct answer

7. Which one of the following actions could prevent a deadlock?

a) Allow the mutual exclusion condition

b) Allow the hold-and-wait condition

c) Allow the preemption condition

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d) Allow the circular-wait condition

8. There will be no _____ if all resources are sharable.

a) Mutual exclusion

b) Hold-and-wait

c) Preemption

d) Circular-wait

9. When should we apply the safety algorithm?

a) To find out whether resource assignments should be preempted

b) To find out whether a system is in a safe state

c) To find out whether a process should be terminated

d) To find out whether a system is in the circular-wait condition

10. If a system does NOT employ either a deadlock-prevention or a deadlock avoidance algorithm, then a deadlock situation may occur. In this environment, what may the system provide/do?

a) An algorithm to check whether the system is in a safe state

b) An algorithm to recover from the deadlock

c) An algorithm to grant resource requests

d) No correct answer

11. If deadlock is controlled by the banker's algorithms (safety algorithm and resource-request algorithm), which of the following actions (on the variables in these algorithms) can be done safely (without introducing the possibility of deadlock)?

a) Increase the variable Max and the number of processes

b) Increase the variable Max and decrease the variable Available

c) Decrease the variable Max and increase the number of processes

d) Decrease the variable Max and increase the variable Available

12. Which one is INCORRECT about the process termination as a deadlock recovery method?

a) It is a recovery method from a deadlock

b) We will preempt some resources from processes and give these resources to other processes

c) We will eliminate one process at a time and check whether a deadlock has been eliminated

d) All answers are correct

13. In the context of a wait-for graph, which statement is TRUE?

a) It's a simplified resource-allocation graph when all resource types have multiple instances

b) If the graph contains a cycle, there is a deadlock in the system

c) It shows resource nodes directly connected to process nodes

d) All of the above

14. Which is NOT a necessary condition for a deadlock to occur?

a) Mutual exclusion

b) Hold and wait

c) No preemption

d) Processes must be of same priority

*** **15. If the base register holds 4501 and the limit register is 5000, then the program can legally access all addresses from 4501 through:**

a) 5000

b) 9500

c) 9501

d) 5001

16. Which one is CORRECT about standard swapping?

a) It moves only some pages of a process

b) It involves moving whole processes between main memory and a disk

c) It is popularly used in modern operating systems

d) No correct answer

17. Which one is CORRECT about memory-allocation techniques?

a) Contiguous memory allocation permits the physical address space of a process to be noncontiguous

b) In paging, each process is contained in a single section of memory that is contiguous to the section containing the next process

c) Segmentation is a memory-management scheme that supports the programmer view of memory

d) No correct answer

18. Given these five memory partitions of 150KB, 450KB, 75KB, 650KB, and 125KB (in order), how would the best-fit algorithm place a process of size 130KB?

a) In the 150KB partition ↙ perfectionist

b) In the 75KB partition

c) In the 650KB partition

d) In the 125KB partition

19. In segmentation, the physical address of logical address $< 1, 345 >$ with base 300 and length 1050 for segment 1 would be:

a) 2845 345 < 1050 ✓

b) 7745 ∴ 300 + 345 = 645

c) 645

d) No correct answer

20. Which one is INCORRECT about paging?

a) We break the logical memory (logical addresses) of a process into fixed-sized blocks called pages

b) The page size must be smaller than the frame size

c) We can avoid external fragmentation

d) All answers are correct

21. **Assuming a 2KB page size and one word equal to one byte, what are the page number and offset for the address reference 5500?**

a) Page 0, offset 904

b) Page 1, offset 1404

c) Page 2, offset 1404

d) Page 3, offset 904

$\left\lfloor \frac{5500}{2048} \right\rfloor = 2$

$5500 \% 2048 = 1401$

22. **Consider a logical address space of 16 pages with 1KB page size and one word equal to one byte, mapped onto a physical memory of 512 frames. How many bits are required in the logical address and the physical address?**

a) A logical address needs 13 bits and a physical address needs 15 bits

b) A logical address needs 13 bits and a physical address needs 19 bits

c) A logical address needs 14 bits and a physical address needs 15 bits

d) A logical address needs 14 bits and a physical address needs 19 bits

23. **In segmentation, if the segment table has Base = 2300 and Length = 1200 for segment 2, what would be the physical address of logical address $< 2, 53 >$?**

a) 2353

b) 4353

c) 1253

d) 2200

$53 < 1200$ ✓

$\therefore 2300 + 53 = 2353$

24. Consider a process of 10500 bytes being allocated into the main memory by paging whose page size is 2KB and one word is equal to one byte. How much is the size of internal fragmentation?

a) 192

b) 1500

c) 1788

d) 2000

$\lceil \frac{10500}{2048} \rceil = 6$

$\therefore$ Internal fragmentation $= (6 \times 2048) - 10500$

$= 1788$

25. Which one is INCORRECT about memory protection in a paged environment?

a) If a valid-invalid bit is set to valid, the associated page is in the main memory

b) If a valid-invalid bit is set to invalid, the associated page is not in the main memory

c) If a valid-invalid bit is set to invalid, the associated page might be in the backing store such as a disk

d) All answers are correct

26. When using the paging method for memory management, which of these is TRUE?

a) Page offset remains the same in both logical and physical addresses

b) Paging suffers from external fragmentation but not internal fragmentation

c) Each process must be stored in contiguous frames

d) Frame size can be different from page size

27. Which one is INCORRECT about the virtual-memory management?

a) It helps increasing the degree of multiprogramming

b) It does not allow that programs/processes can be larger than physical memory

c) It is a technique that allows the execution of processes that are not completely in memory

d) All answers are correct

28. What is demand paging?

a) It is a shared memory architecture used in multiprocessing (multiple CPUs) systems

b) It is an electronic component that can operate a port, a bus, or a device

c) It is a strategy to load pages from a disk into the main memory only as they are needed

d) No correct answer

29. Which one is INCORRECT about copy-on-write?

a) It is a technique allowing the parent and child processes initially to share the same pages

b) There is only one copy-on-write page per a process

c) A copy-on-write page means that, if either process writes to this shared page, a copy of the shared page is created

d) All answers are correct

30. Assume that there exists a process with three user-level threads and that the mapping of user threads to kernel threads is many to one. If one user thread incurs a page fault while accessing its stack, how would the other user threads belonging to the same process also be affected by the page fault?

a) They are not affected

b) They are in a deadlock

c) They have to wait for the faulting page to be brought into memory

d) No correct answer

31. Which action could increase the page-fault rate?

a) Increase the degree of multiprogramming

b) Increase the size of the hard disk

c) Increase the size of the main memory

d) No correct answer

32. Assume that a page fault happens. If no frame is free, by using a _____, we find a frame that is not currently being used and free it.

a) Page-replacement algorithm

b) Victim frame (ตัวนี้ก็ผิดได้)

c) Demand paging

d) No correct answer

33. Which one is CORRECT about the optimal page-replacement algorithm?

a) The optimal page-replacement algorithm guarantees the lowest possible page fault rate for a fixed number of frames

b) The optimal page-replacement algorithm is difficult to implement

c) The optimal page-replacement algorithm requires future knowledge of the reference string

d) All answers are correct

34. The _____ page-replacement algorithm uses the time when a page was brought into the memory.

a) FIFO

b) LRU

c) Optimal

d) No correct answer

35. Which page-replacement algorithm suffers from Belady's anomaly?

a) FIFO page-replacement algorithm

b) Optimal page-replacement algorithm

c) LRU page-replacement algorithm

d) No correct answer

36. Which one is INCORRECT about frame allocation?

a) Managing which page frames are stored at which locations can significantly affect performance in NUMA systems

b) In local replacement, a process cannot take a frame occupied by another process

c) The minimum number of frames is a factor considered in the allocation of frames

d) All answers are correct

37. Consider that there are three processes: the process P0 with 15 pages, the process P1 with 30 pages, and the process P2 with 50 pages. If we would like to split 50 frames among these three processes, how many frames are given to each process by using the proportional allocation?

a) P0 (16 frames); P1 (16 frames); P2 (16 frames)

b) P0 (15 frames); P1 (30 frames); P2 (50 frames)

$\frac{15}{95}(50) \approx 7$

c) P0 (8 frames); P1 (16 frames); P2 (26 frames)

$\frac{30}{95}(50) \approx 15$

d) P0 (7 frames); P1 (15 frames); P2 (26 frames)

$\frac{50}{95}(50) \approx 26$

38. Which one is INCORRECT about thrashing?

a) The system can detect thrashing by evaluating the level of CPU utilization as compared to the level of multiprogramming

b) Thrashing is caused by under-allocation of the minimum number of frames required by a process, forcing it to continuously page fault

c) Thrashing can be eliminated by increasing the level of multiprogramming

d) All answers are correct

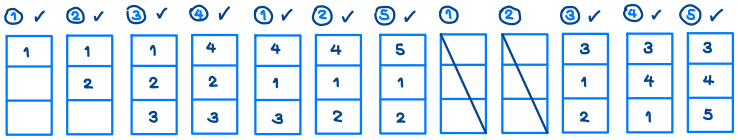
39. When using LRU page replacement with 3 frames, what would be the number of page faults for the reference string: 1, 2, 3, 4, 1, 2, 5, 1, 2, 3, 4, 5?

a) 8

b) 9

c) 10

d) 11



40. Which one is INCORRECT about files and file systems?

a) The file system consists of two distinct parts: a collection of files and a directory structure

b) File system management is a service provide by an application program

c) A file is a named collection of related information that is recorded on secondary storage

d) All answers are correct

41. _____ typically consist(s) of name, types, location, size, protection, and date.

a) A file system

b) File attributes

c) Permissions

d) Path names

42. In general, files are stored in _____, so the contents are persistent between system reboots.

a) Volatile storage devices

b) Nonvolatile storage devices

c) RAM

d) Registers

43. Which one is INCORRECT about a partition and a volume in the file system?

a) Partitioning is useful for limiting the sizes of individual file systems, putting multiple file-system types on the same device, or leaving part of the device available for other uses

b) A volume is a partition that has been formatted into a filesystem

c) A partition consists of files and a volume table of contents (also known as a device directory or directory)

d) All answers are correct

44. Any entity containing a file system is generally known as a _____.

a) Partition

b) Directory

c) Volume

d) Track

45. Which type of directories suffers from the naming problem?

a) Single-level directory

b) Two-level directory

c) Tree-structured directory

d) Acyclic-graph directory

46. Which one is INCORRECT about the path name?

a) A path name is used to identify the location of a file in a computer

b) An absolute path name defines a path to the file from the current directory

c) /University/SIIT/StudentList.docx is an example of the Unix path name

d) All answers are correct

47. In the Linux OS, the file owner has set the following file permissions (excluding the letter to specify a directory or a file): r-xrw-r-x. Which one is CORRECT?

a) The file owner can read, write, and execute this file

b) A user in the same group with the file owner can read and write this file

c) The other users (not the file owner and a member in the same group with the file owner) can write and execute this file

d) No correct answer

48. In the hard disk (magnetic disk), where are the data stored?

a) Disk platters

b) Read-write head

c) Disk arm

d) No correct answer

49. Which one is NOT a file-implementation approach?

a) Linked-List Allocation

b) I-nodes

c) Paging

d) Linked-List Allocation Using a Table in Memory

50. Where is the file allocation table (FAT) stored?

a) Main memory

b) Hard disk

c) Flash/USB drive

d) CPU

51. Assume that there are 100 files in the computer system, how many I-node tables do we have (excluding the directories)?

a) 1

b) 2

c) 100

d) 200

1 - free
0 - not free

52. Consider the following free-space bit vector: 00110011001100110.... Which statement is CORRECT?

4 6 7 10

a) The physical-block number 4 is free

b) The physical-block number 6 is free

c) The physical-block number 7 is not free

d) The physical-block number 10 is not free

53. Since there are a lot of new devices produced, how could a computer system recognize and use these devices?

a) By using the kernel I/O subsystem

b) By using application programs

c) By using interrupt handlers

d) By using device drivers

54. A _____ is an asynchronous and character-stream device.

a) Keyboard

b) CD-ROM

c) Hard disk

d) No correct answer

55. Which file allocation method allows a file's data blocks to be stored anywhere on disk with pointers embedded in each block?

a) Contiguous allocation

b) Indexed allocation (i-nodes)

c) FAT (File Allocation Table)

d) Linked-list allocation

56. What problem does the "bit vector" solve in file systems?

a) Memory fragmentation

b) Free space management

c) File protection

d) Directory organization

57. When allocating space for a file using linked-list allocation, what marks the end of the file?

a) A null pointer

b) A value of -1 ⟶ ระวังสับสนกับ FAT

c) A value of 0

d) A special end-of-file block

58. In the context of I/O devices, which one best describes an operation that follows a predictable response pattern?

a) Asynchronous

b) Synchronous

c) Random access

d) Interrupt-driven

59. What are the primary advantages of interrupt-driven I/O over polling?

a) Lower CPU overhead

b) Higher I/O speeds

c) Simpler implementation

d) Lower device costs

60. Which page replacement algorithm would be most efficient for a process that sequentially accesses memory in a loop?

a) FIFO

b) LRU

look ahead

c) Optimal

d) Random replacement

61. What is the purpose of the control register in a device controller?

a) To show the current status of the device

b) To hold data coming from the CPU

c) To hold data coming from the device

d) To receive commands from the CPU

62. A victim frame is:

a) A frame selected for replacement during a page fault

b) A frame with invalid data

c) A frame shared between processes

d) A frame reserved for high-priority processes

63. What happens when a system is thrashing?

a) The CPU is idle most of the time

b) The system spends most time executing processes

c) The system spends most time swapping pages

d) The file system becomes corrupted

64. In the copy-on-write mechanism, when does the system actually create a copy of a shared page?

a) When a process reads from the page

b) When a process tries to modify the page

c) When the page is initially loaded into memory

d) When the parent process terminates

65. Which of the following is an advantage of segmentation over paging?

a) Eliminates internal fragmentation

b) Segments correspond to logical divisions of a program

c) Simplifies memory allocation

d) Requires less overhead in the page table

67. If a system uses local page replacement, which statement is TRUE?

a) A process can only replace pages belonging to itself

b) Any process can replace any page in the system

c) Only high-priority processes can replace pages

d) Pages cannot be replaced at all

68. Which of the following is TRUE about the acyclic-graph directory structure?

a) It allows only one path to any file

b) It prevents sharing of files or directories

c) It allows multiple paths to the same file

d) It requires that directories form cycles

69. What is the primary function of the Memory Management Unit (MMU)?

a) To manage process scheduling

b) To translate logical addresses to physical addresses

c) To control I/O operations

d) To implement process synchronization

70. If a file's permissions in a Unix-based system are set to "r–r—–", which of the following is TRUE?

a) The owner can read but not write or execute the file r--|r--|---

b) Group members can read, write, and execute the file

c) All users can read the file

d) Both the owner and group members have the same permissions

Part B: Short Answer Questions (60 marks)

1. Consider the following resource-allocation state, where P0, P1, P2, and P3 are processes and A, B, C, and D are resource types:

	Allocation				Max				Need = Max - Allocation			
	A	B	C	D	A	B	C	D	A	B	C	D
Process P0	1	0	1	1	3	2	1	1	2	2	0	0
Process P1	2	0	0	1	4	2	1	2	2	2	1	1
Process P2	1	1	0	0	2	2	1	0	1	1	1	0
Process P3	0	0	3	0	1	1	4	0	1	1	1	0

Work = **Available**
A = 2, B = 1, C = 0, D = 1

Is the system in a safe state? If yes, identify a safe sequence. If no, explain why not.

Work = [2 1 0 1]
Finish = [F F F F]

Check P_0
Finish[0] = F ✓
$Need_0 \leq Work$
[2 2 0 0] ≤ [2 1 0 1] ✗

Check P_1
Finish[1] = F ✓
$Need_1 \leq Work$
[2 2 1 1] ≤ [2 1 0 1] ✗

Check P_2
Finish[2] = F ✓
$Need_2 \leq Work$
[1 1 1 0] ≤ [2 1 0 1] ✗

Check P_3
Finish[3] = F ✓
$Need_3 \leq Work$
[1 1 1 0] ≤ [2 1 0 1] ✗

∴ The system is not in the safe state, no process can finish with the currently available resources #

2. Consider a system using segmentation for memory management with the following segment table:

Segment	Base	Limit
0	1400	500
1	6300	300
2	4200	800
3	3500	600

a) What is the physical address for the logical address $< 2, 350 >$?

350 < 800 ✓

∴ 4200 + 350 = 4550 #

b) What is the physical address for the logical address $< 1, 280 >$?

280 < 300 ✓

∴ 6300 + 280 = 6580 #

c) What is the physical address for the logical address $< 3, 600 >$?

600 < 600 ✗ กรุณาระบุ

∴ Error #

Given the page table shown below. What is the physical address (in the binary-number format) according to this logical address (paging format): $< 2, 23 >$?

Page	Frame	Flag
0	15	v
1	8	v
2	21	v
3	42	v

6 bits to represent frame number

$\langle f, d \rangle = \langle 21, 23 \rangle$

6 bit to represent offset number

$= \langle 010101, 010111 \rangle$

Physical Address = 010101010111 # (binary-number format)

Page size = 4 KB = 4×1024 bytes = 2^{12}

Logical address size = 32 bits

Physical memory size = 1 GB = 2^{30} bytes

3. Consider a system with page size of 4KB. The system uses a 32-bit logical address and has 1GB of physical memory.

a) How many bits are needed for the page number and for the page offset in the logical address?

Page offset (n) : $n = 12$ bits #

Page number (m-n) : $m - n = 32 - 12$

$= 20$ bits #

b) How many entries are in the page table?

$2^{20} = 1{,}048{,}576$ #

c) How many frames are in the physical memory?

$\frac{2^{30}}{2^{12}} = 2^{18} = 262{,}144$ frames #

d) For the logical address 0x3D2CE ($250{,}574$ Typo again in decimal), what are the page number and offset?

Page offset (n) : $n = 12$ bits #

Page number (m-n) : $m - n = 32 - 12$

$= 20$ bits #

page number: $\left\lfloor \frac{250574}{4096} \right\rfloor = 61$

offset $250574 - (61 \times 4096) = 718$

0x3D2CE = 0000 0000 0000 0011 1101 0010 1100 1110

page number ⇓ 61 | offset ⇓ 718

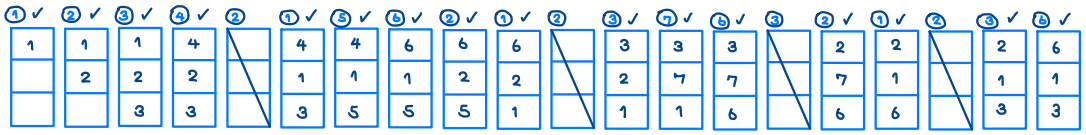
∴ Page number = 61 , Offset = 718 #

4. Consider a system using demand paging with a reference string:

$$1, 2, 3, 4, 2, 1, 5, 6, 2, 1, 2, 3, 7, 6, 3, 2, 1, 2, 3, 6$$

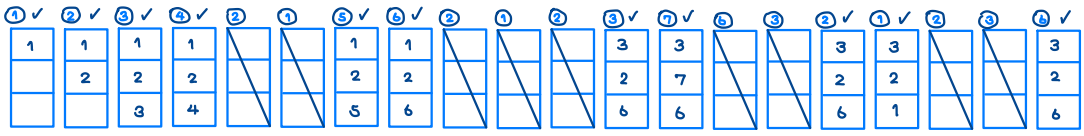
Assuming 3 frames that are initially empty, calculate the number of page faults for each of the following page replacement algorithms. Draw the frame content after each page access and clearly indicate when page faults occur:

a) FIFO



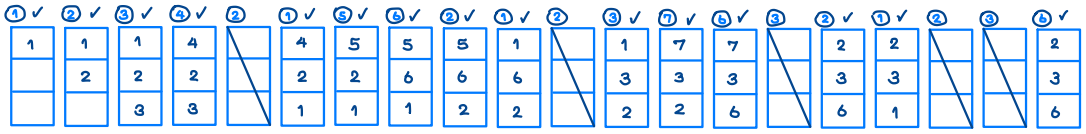
∴ Page faults = 16 #

b) LRU



∴ Page faults = 11 #

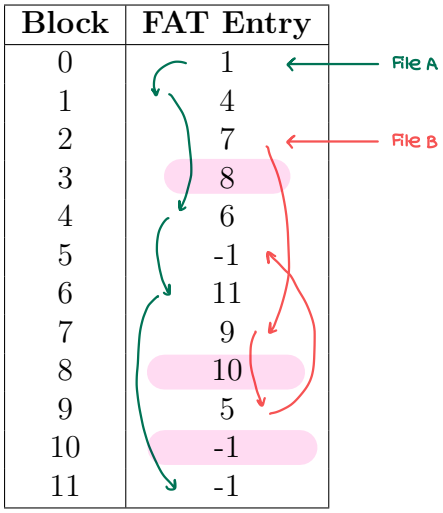
c) Optimal



∴ Page faults = 15 #

5. Consider the following File Allocation Table (FAT):

Block	FAT Entry
0	1
1	4
2	7
3	8
4	6
5	-1
6	11
7	9
8	10
9	5
10	-1
11	-1



File A starts at block 0 and File B starts at block 2.

a) What are the physical-block numbers that store the data (file)-blocks of File A? List them in order.

0→1→4→6→11 #

b) What are the physical-block numbers that store the data (file)-blocks of File B? List them in order.

2→7→9→5 #

c) According to this FAT, which currently free physical-block numbers would be allocated if a new File C is to be created requiring 3 blocks? Explain your answer.

3→8→10
8→3→10
} ใช้ได้ order ไหนก็ได้ system #

eight ← typo (should be fixed on your version)

6. Given [redacted] memory partitions of 10KB, 4KB, 20KB, 18KB, 7KB, 9KB, 12KB, and 15KB (in order), how would each of the following allocation algorithms place processes of size 12KB, 10KB, 7KB, and 9KB (in order)? For each algorithm, show the resulting memory state after all placements and indicate if any process cannot be placed.

a) First-fit algorithm

10 KB → 0 KB
4 KB
20 KB → 8 KB → 1 KB
18 KB → 9 KB
7 KB
9 KB
12 KB
15 KB

P_1 12 KB 20 → 8 KB
P_2 10 KB 10 → 0 KB
P_3 7 KB 8 → 1 KB
P_4 9 KB 18 → 9 KB

b) Best-fit algorithm

10 KB → 0 KB
4 KB
20 KB
18 KB
7 KB → 0 KB
9 KB → 0 KB
12 KB → 0 KB
15 KB

P_1 12 KB 12 → 0 KB
P_2 10 KB 10 → 0 KB
P_3 7 KB 7 → 0 KB
P_4 9 KB 9 → 0 KB

c) Worst-fit algorithm

10 KB
4 KB
20 KB → 8 KB
18 KB → 8 KB
7 KB
9 KB
12 KB → 3 KB
15 KB → 8 KB

P_1 12 KB 20 → 8 KB
P_2 10 KB 18 → 8 KB
P_3 7 KB 15 → 8 KB
P_4 9 KB 12 → 3 KB

From Baitong

7. **Consider a system with five processes P0 through P4 and three resource types A, B, and C. Resource type A has 10 instances, resource type B has 5 instances, and resource type C has 7 instances. The following snapshot describes the current state:**

Max - Alloc

Alloc + Avail

for check Ans : A B C → 10 5 7

	Allocation			Max			Need		
	A	B	C	A	B	C	A	B	C
Process P0	0	1	0	7	5	3	7	4	3
Process P1	2	0	0	3	2	2	1	2	2
Process P2	3	0	2	9	0	2	6	0	0
Process P3	2	1	1	2	2	2	0	1	1
Process P4	0	0	2	4	3	3	4	3	1

work = **Available**

A = 3, B = 3, C = 2

a) Is the system in a safe state? If yes, provide a safe sequence.

need ≤ work → work = w + Alloc

P_0 : 7 4 3 ≤ 3 3 2 ✗

P_1 : 1 2 2 ≤ 3 3 2 ✓ → 332 + 200 = 532

P_2 : 6 0 0 ≤ 5 3 2 ✗

P_3 : 0 1 1 ≤ 5 3 2 ✓ → 532 + 211 = 743

P_4 : 4 3 1 ≤ 7 4 3 ✓ → 743 + 002 = 745

P_0 : 7 4 3 ≤ 7 4 5 ✓ → 745 + 010 = 755

P_2 : 6 0 0 ≤ 7 5 5 ✓ → 755 + 302 = 10 5 7

Safe state #

Safe Sequence :

$< P_1, P_3, P_4, P_0, P_2 >$

b) Suppose process P1 requests (1, 0, 2). Can this request be granted immediately? Explain your answer.

$P_1 \rightarrow (1,0,2)$

1) Request ≤ need

102 ≤ 122 ✓

2) Request ≤ Available

102 ≤ 332 ✓

3) Available = Available - Request

= 332 - 102

= 230

Alloc = Alloc + Request

= 200 + 102

= 302

Need = Need - Request

= 122 - 102

= 020

	Allocation			Max			Need		
	A	B	C	A	B	C	A	B	C
Process P0	0	1	0	7	5	3	7	4	3
Process P1	~~2~~ 3	~~0~~ 0	~~0~~ 2	3	2	2	~~1~~	~~2~~	~~2~~ 0 2 0
Process P2	3	0	2	9	0	2	6	0	0
Process P3	2	1	1	2	2	2	0	1	1
Process P4	0	0	2	4	3	3	4	3	1

Ava = 230 = work

Can grant Request from P_1, it is safe.

Safe Sequence :

$< P_1, P_3, P_4, P_0, P_2 >$

need ≤ work → work = w + Alloc

P_0 : 7 4 3 ≤ 2 3 0 ✗

P_1 : 0 2 0 ≤ 2 3 0 ✓ → 230 + 302 = 532

P_2 : 6 0 0 ≤ 5 3 2 ✗

P_3 : 0 1 1 ≤ 5 3 2 ✓ → 532 + 211 = 743

P_4 : 4 3 1 ≤ 7 4 3 ✓ → 743 + 002 = 745

P_0 : 7 4 3 ≤ 7 4 5 ✓ → 745 + 010 = 755

P_2 : 6 0 0 ≤ 7 5 5 ✓ → 755 + 302 = 10 5 7