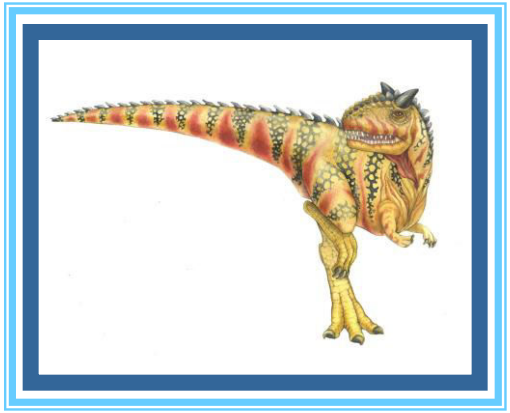
Memory Management



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Contents

- *Background*
- *Logical versus Physical Address Space*
- *Swapping*
- *Contiguous Allocation*
- *Paging*
- *Segmentation*
- *Segmentation with Paging*

Memory Management

- *Efficient utilization of main memory* ***(Goal)***.
- *Method of managing* ***primary memory***.
- *Each approach has its own advantages and disadvantages.*

Memory Management

- ***Main memory*** *and the* ***registers*** *built into the processor itself are the only general-purpose storage that the* ***CPU can access directly****.*
- *CPU access to primary memory is many times slower than access to registers, but* ***caches*** *help speed things up.*
- *Any instructions in execution, and any data being used by the instructions, must be in one of these direct-access storage devices*
- *We are not only concerned with the relative speed of accessing physical memory, we must ensure correct operation.*

Memory Management

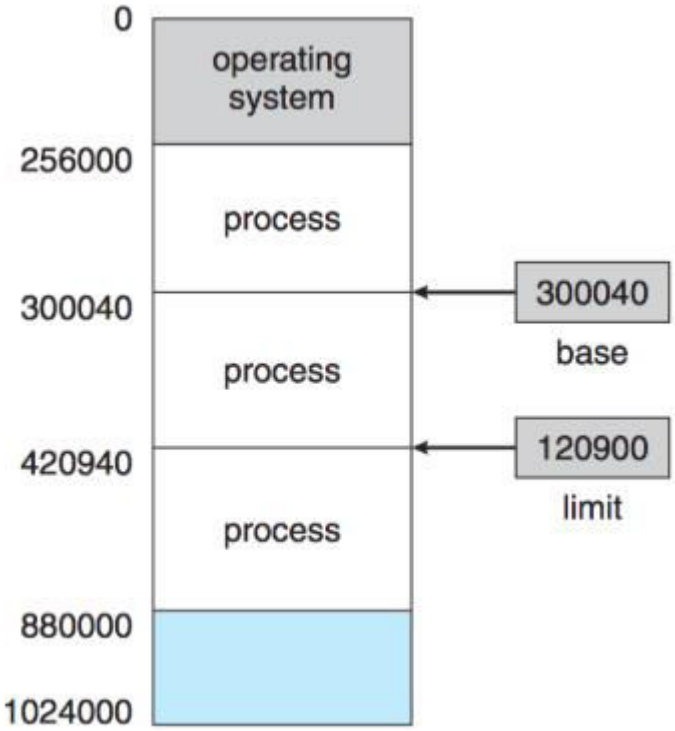
- *For proper system operation we must protect the operating system from access by user processes and should protect user processes from one another.*
- ***Hardware*** *must* ***protect user processes*** *from one another (because OS doesn't intervene between CPU and its memory access).*
- *The* ***performance penalty*** *would be very extreme if designers assigned this task to the operating system - it would simply not be practical.*

Memory Management

- *Each process must have a separate memory space which protects the processes from each other*
- *We can provide this protection by using two registers, usually a* ***base*** *and a* ***limit****.*

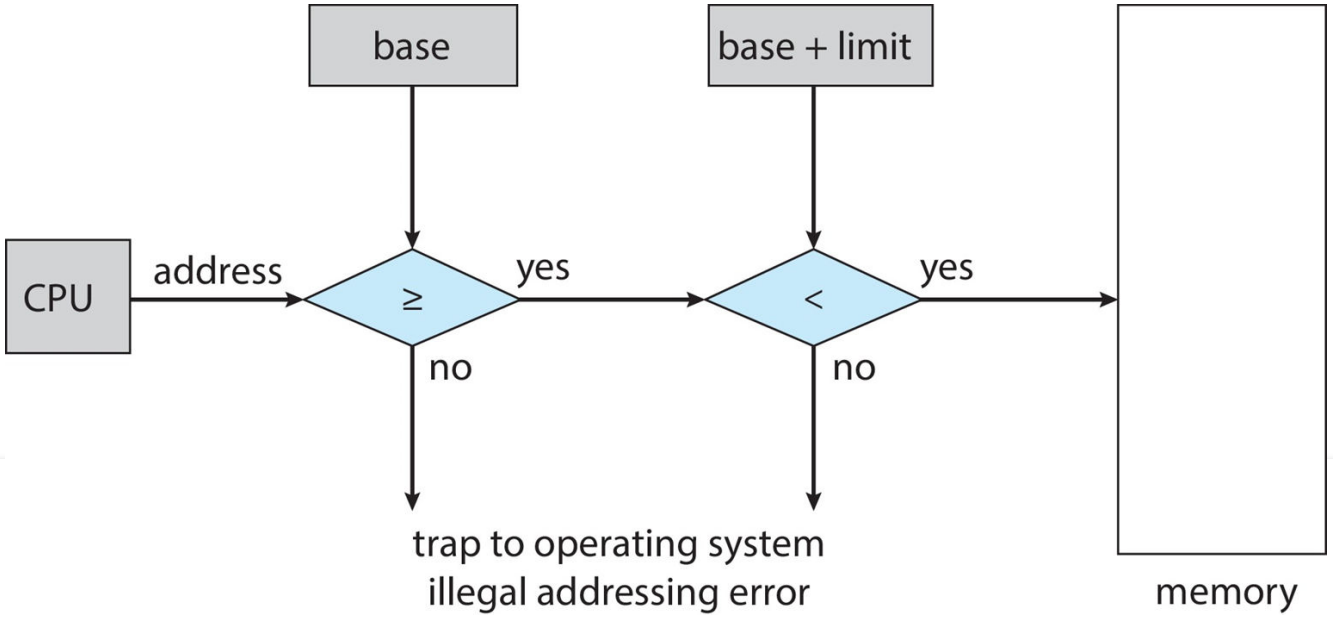
Basic Hardware

- *The OS allocates one **contiguous span** of primary memory to a process P.*
- *The **base register** contains the **lowest address** allocated to P.*
- *The **limit register** contains the number of bytes **(size)** in the allocation.*
- *Using the values in the base and limit registers, hardware checks every address generated in user mode.*

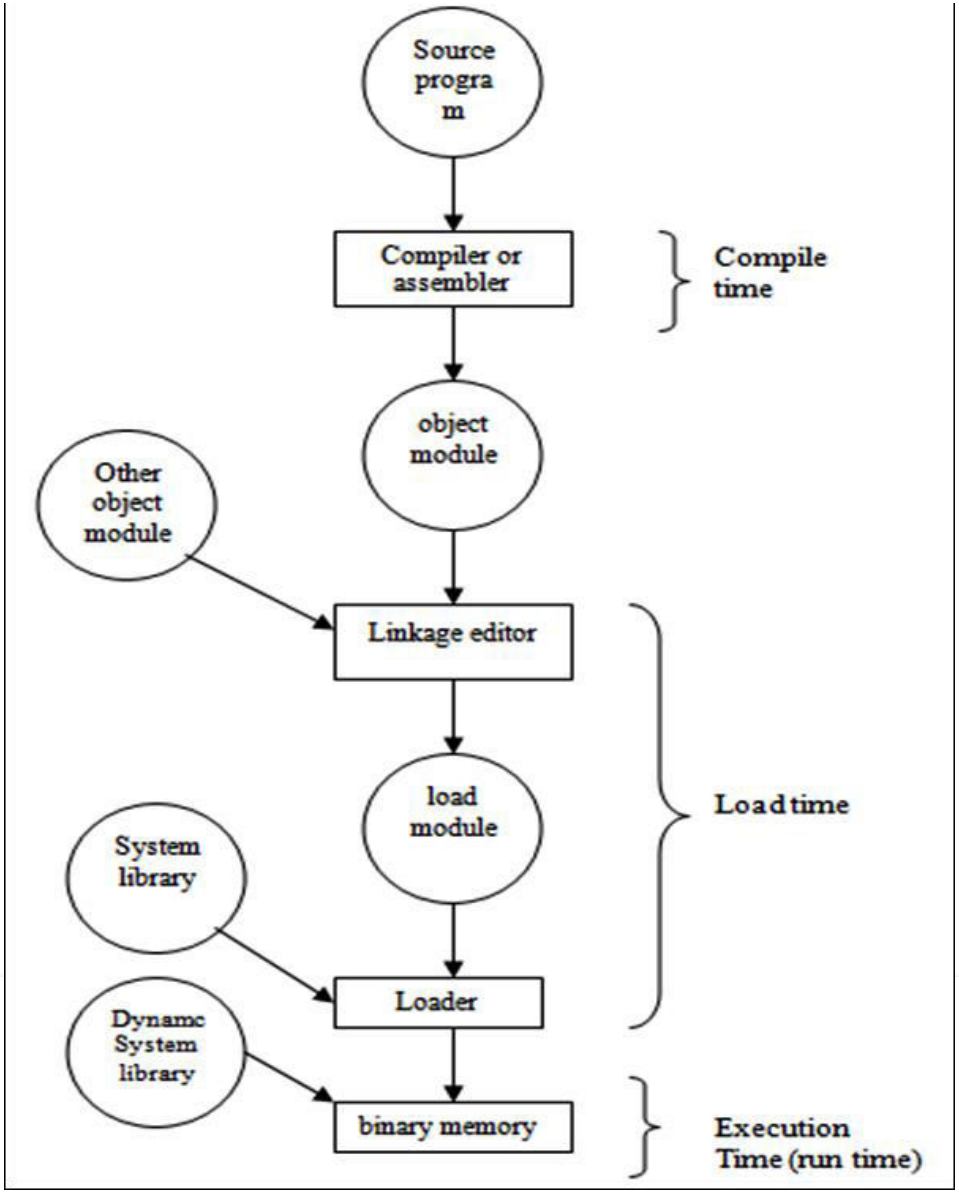


Basic Hardware

- *Any attempt by a program executing in user mode to access operating-system memory or other users' memory results in a **trap** to the operating system, which treats the attempt as a fatal error*
- *This scheme prevents a user program from **(accidentally or deliberately)** modifying the code of either the operating system or other users*
- *The base and limit registers can be loaded only by the operating system **(privileged instruction).***



Program Execution Steps

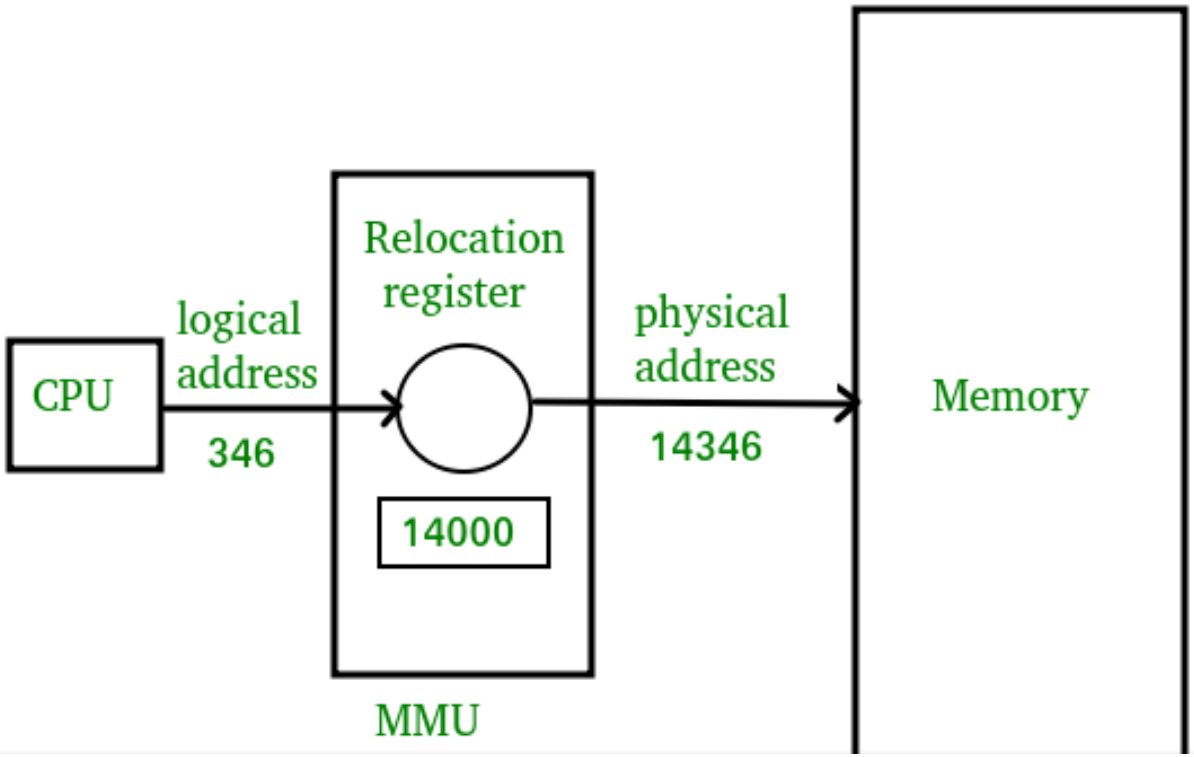


Memory-Management Unit (MMU)

- ***Hardware device*** *that maps virtual address to physical address.*
- *In* ***MMU*** *scheme, the value in the relocation register is added to every address generated by a user process at the time it is sent to memory.*
- *The user program deals with logical addresses; it never sees the real physical addresses.*

Memory Management Unit

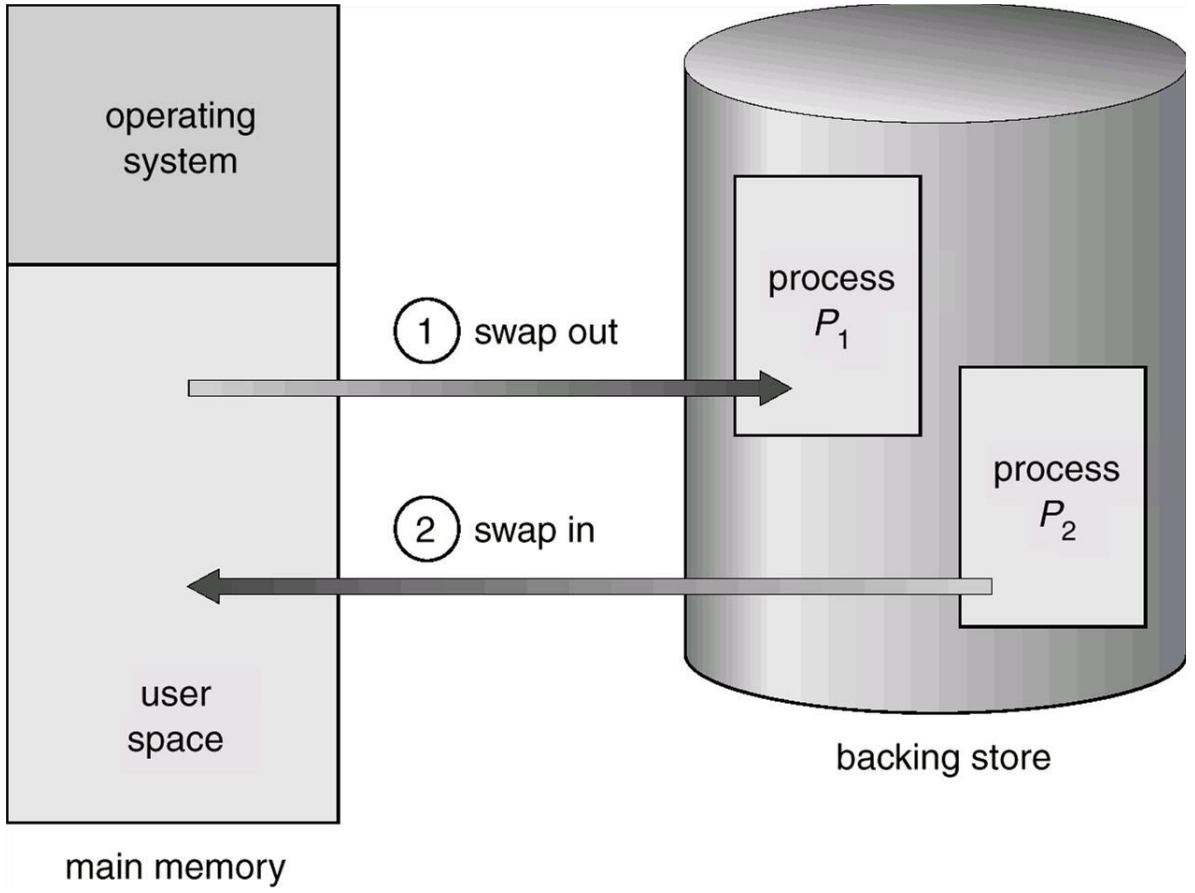
A ***hardware component*** referred to as the ***Memory Management Unit (MMU)*** is responsible for ***translating*** a *virtual address to a physical address*.



BASIS FOR COMPARISON	LOGICAL ADDRESS	PHYSICAL ADDRESS
Basic	It is the virtual address generated by CPU	The physical address is a location in a memory unit.
Address Space	Set of all logical addresses generated by CPU in reference to a program is referred as Logical Address Space.	Set of all physical addresses mapped to the corresponding logical addresses is referred as Physical Address.
Visibility	The user can view the logical address of a program.	The user can never view physical address of program
Access	The user uses the logical address to access the physical address.	The user can not directly access physical address.
Generation	The Logical Address is generated by the CPU	Physical Address is Computed by MMU
Rebooting	Logic address is erased when the system is rebooted.	Physical address is not affected when the system is rebooted.

Schematic View of Swapping

Swapping makes it possible for the total physical address space of all processes to exceed the real physical memory of the system. Increase Degree of multiprogramming.



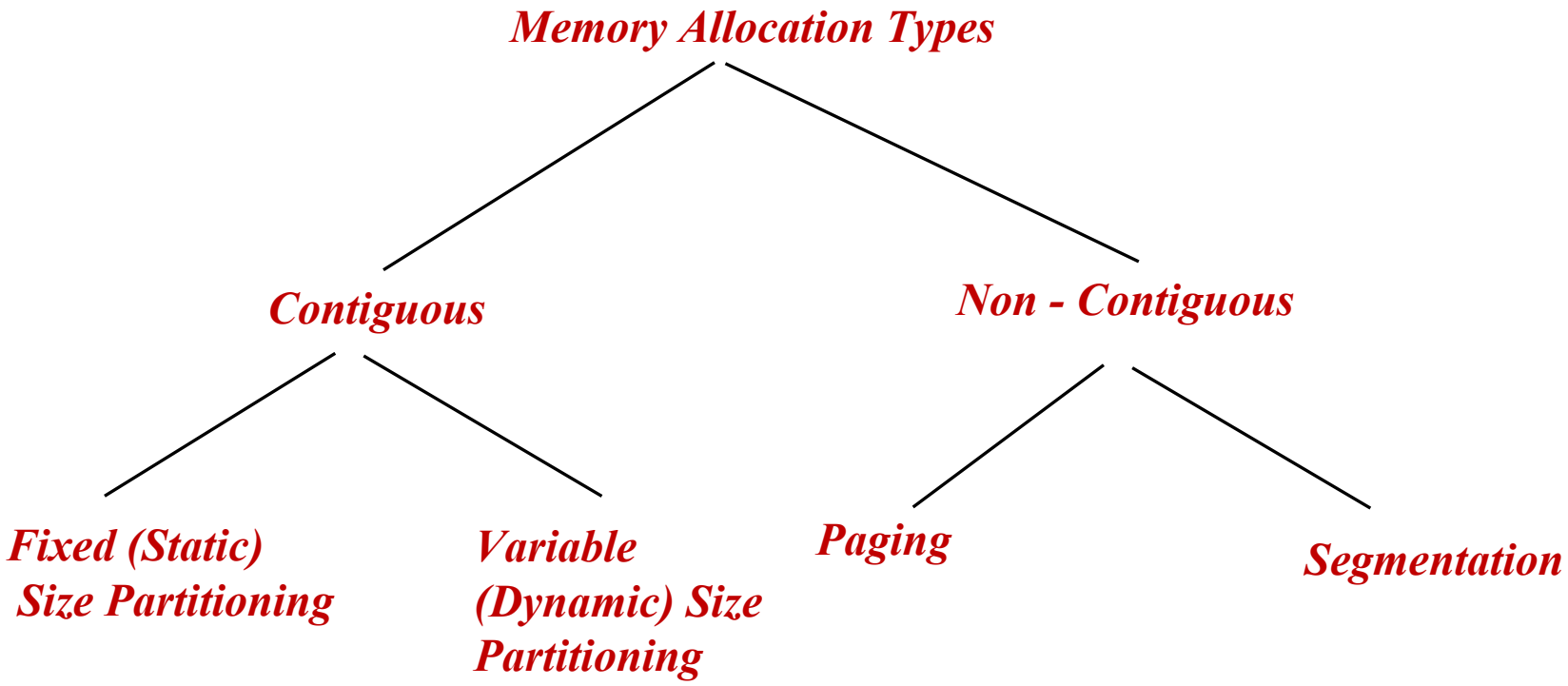
Swapping

- *A process can be **swapped** temporarily out of memory to a **backing store**, and then **brought back** into memory for continued execution.*
- ***Backing store** – fast disk large enough to accommodate copies of all memory images for all users; must provide direct access to these memory images.*
- ***Roll out, roll in** – swapping variant used for priority-based scheduling algorithms; lower-priority process is swapped out so higher-priority process can be loaded and executed.*
- *Major part of swap time is transfer time; total transfer time is directly proportional to the amount of memory swapped.*

Swapping

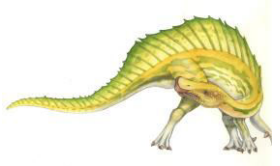
- *Before swapping a process we must ensure it is idle not waiting for I/O. If we swapped out a process p1 waiting for I/O and swap in process p2 then I/O operation will try to access memory that now belongs to p2. Solution to this problem is either do* ***double buffering*** ***(use two buffers to speed up a computer that can overlap I/O with processing),*** *execute I/O operations in OS buffer only, Transfer between operating system buffer and process memory will occur only when p1 swapped in or never swap a process with pending I/O*

Types of Memory Allocation



Contiguous Allocation

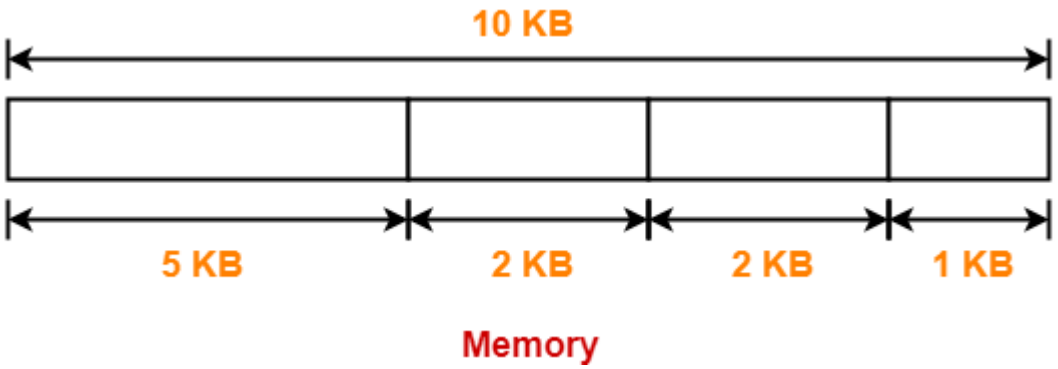
- ***Contiguous memory allocation:*** *Each process is contained in* ***single section of memory*** *that is contiguous.*
- ***Non contiguous memory allocation:*** *a process will acquire the memory space but it is not at one place it is at the different locations according to the process requirement.*



Contiguous Allocation (Cont.)

- ***Fixed (Static) Size Partitioning:***
  - *In this technique, main memory is pre-divided into fixed size partitions,* ***size of partitions could be different****.*
  - *The size of each partition is fixed and can not be changed.*
  - *Each partition is allowed to store* ***exactly one process****.*
  - *Degree of multiprogramming depends on number of partitions.*
  - *Internal Fragmentation.*

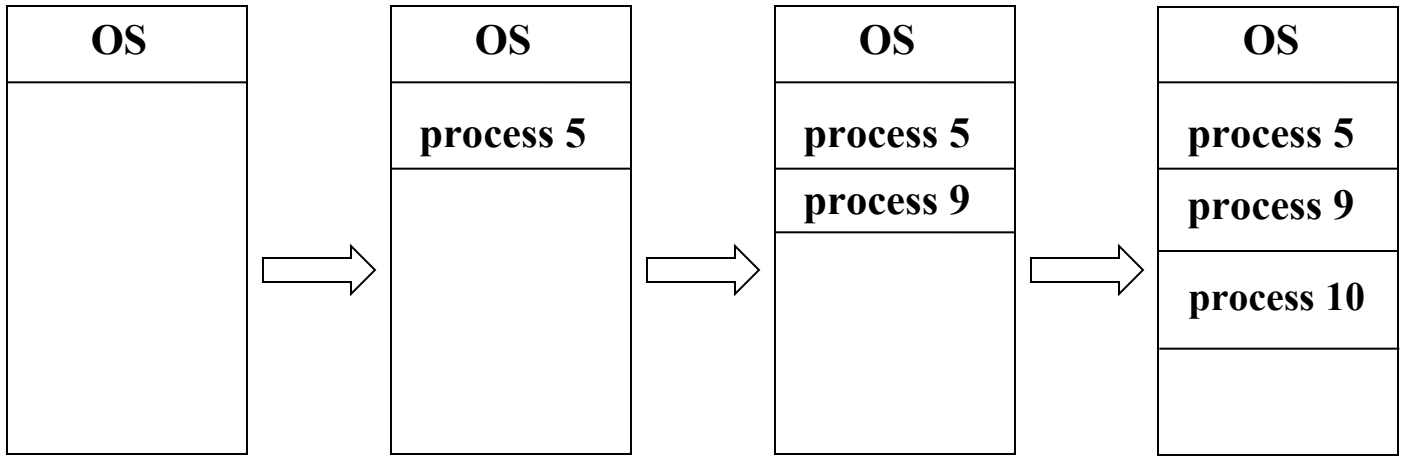
Contiguous Allocation (Cont.)

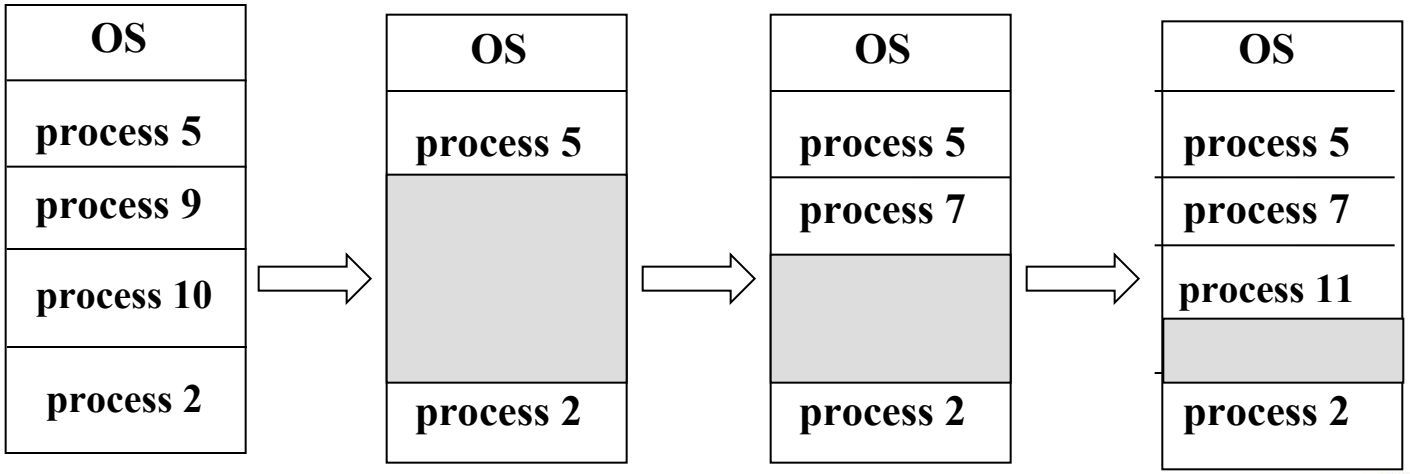


Contiguous Allocation (Cont.)

- ***Variable (dynamic) Size Partitioning:***
  - *It performs the allocation dynamically.*
  - *Initially all memory is available for the processes, it is considered as one large block of available memory, a* ***Hole****.*
  - *When a process arrives, a partition of size equal to the size of process is created, Then, that partition is allocated to the process.*
  - *Operating system maintains information about: a) allocated partitions b) free partitions (hole*

Contiguous Allocation (Cont.)



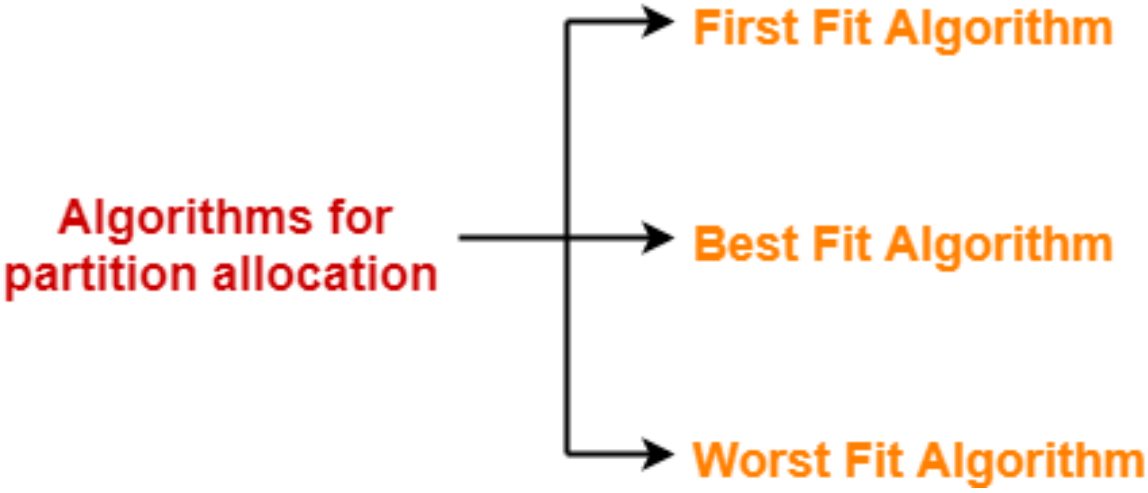


Contiguous Allocation (Cont.)

- *The processes arrive and leave the main memory.*
- *As a result, holes of different size are created in the main memory.*
- *These holes are allocated to the processes that arrive in future.*

Partition Allocation Algorithms

Partition allocation algorithms are used to decide which hole should be allocated to the arrived process..



Partition Allocation Algorithms

First-fit Algorithm:

- *This algorithm starts scanning the partitions serially from the starting.*
- *When an empty partition that is big enough to store the process is found, it is allocated to the process.*
- *Obviously, the partition size has to be greater than or at least equal to the process size.*

Partition Allocation Algorithms

Best-fit Algorithm:

- *This algorithm first scans all the empty partitions.*
- *It then allocates the smallest size partition to the process.*

Worst-fit Algorithm:

- *This algorithm first scans all the empty partitions.*

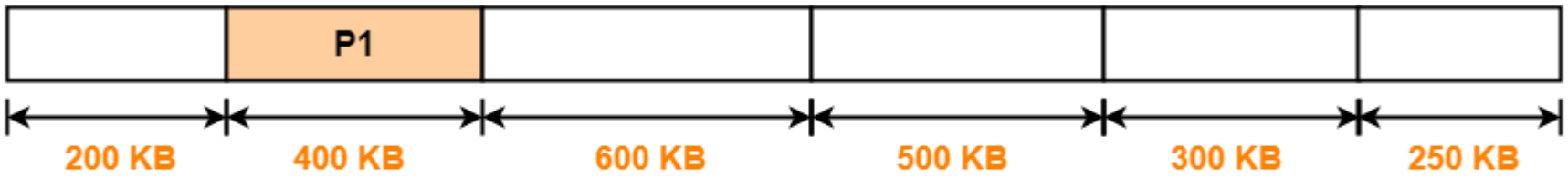
Static Size Partitioning Problem

Consider six memory partitions of size 200 KB, 400 KB, 600 KB, 500 KB, 300 KB and 250 KB. These partitions need to be allocated to four processes of sizes P1- 357 KB, P2- 210 KB, P3- 468 KB and P4-491 KB in that order.

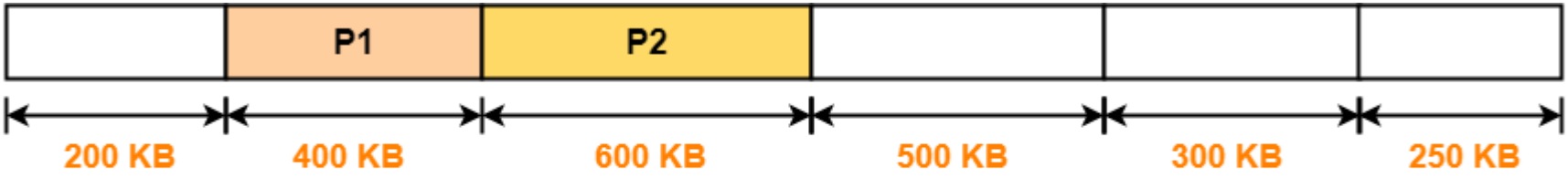
Perform the allocation of processes using-

1. *First Fit Algorithm*
2. *Best Fit Algorithm*
3. *Worst Fit Algorithm*

First Fit



Main Memory

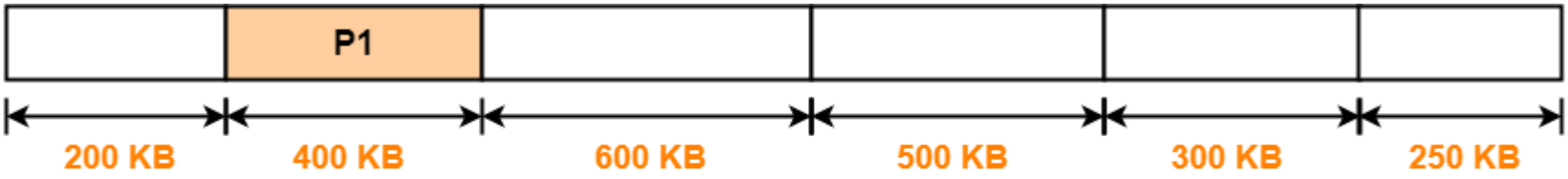


Main Memory

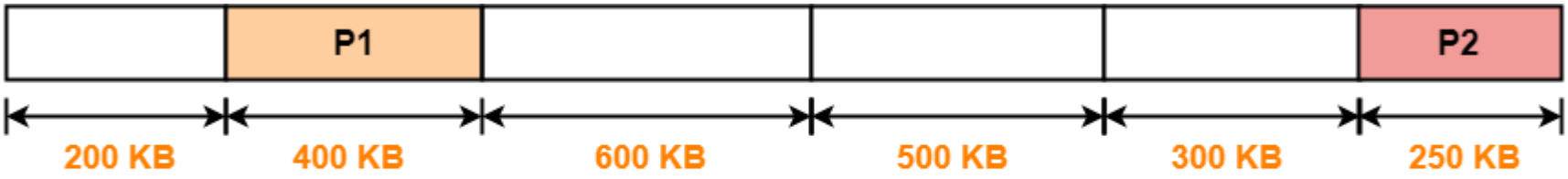
Main Memory

- *Process P4 can not be allocated the memory.*
- *This is because no partition of size greater than or equal to the size of process P4 is available.*

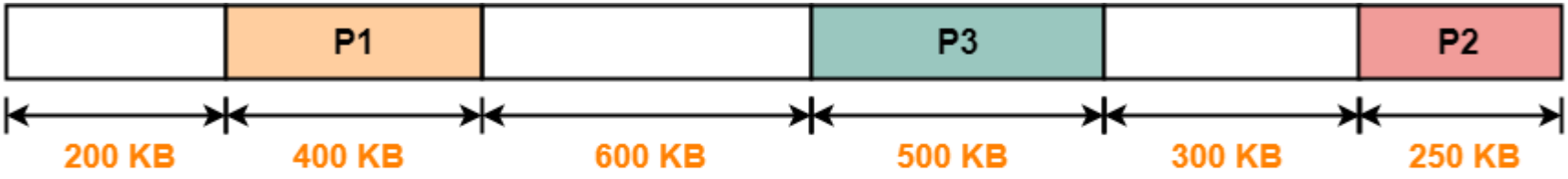
Best Fit



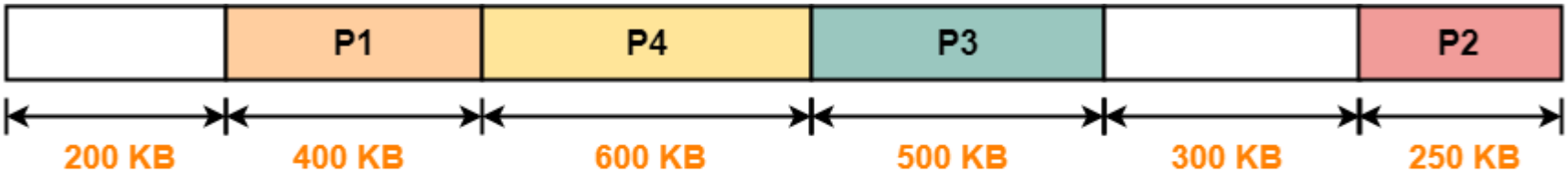
Main Memory



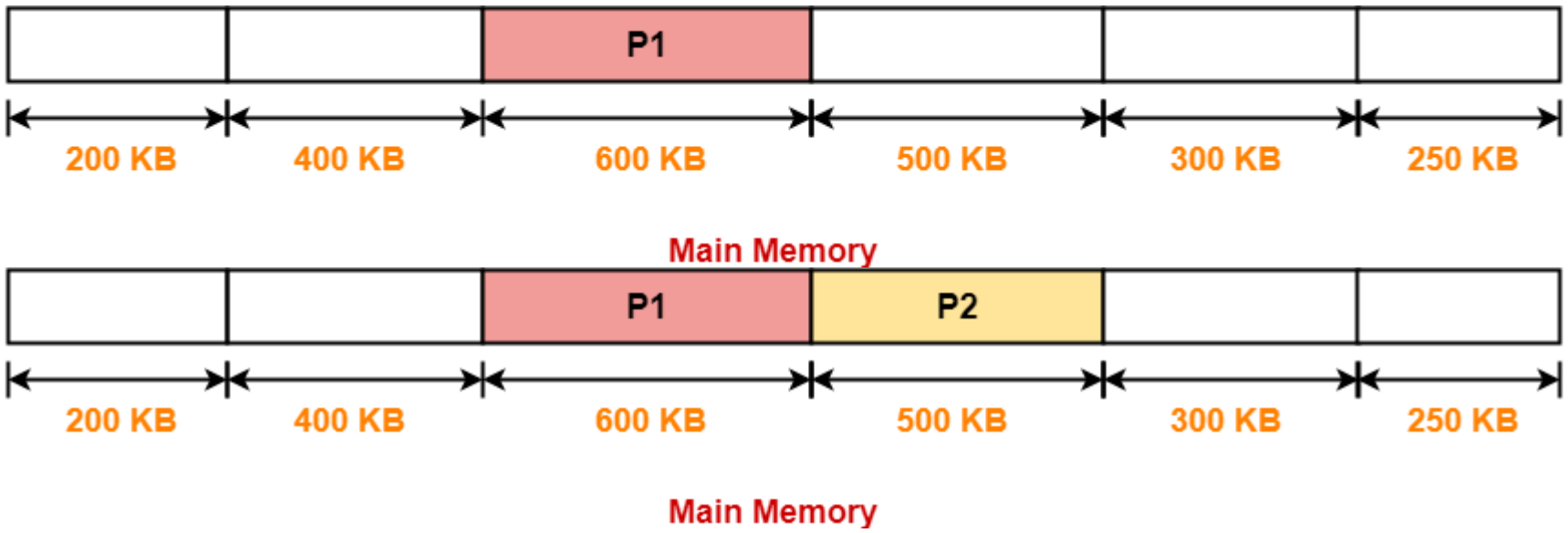
Main Memory



Main Memory



Worst Fit



- Process P3 and Process P4 can not be allocated the memory.
- This is because no partition of size greater than or equal to the size of process P3 and process P4 is available.

Important Points about static Partitioning

- *Best Fit Algorithm works best, because space left after the allocation inside the partition is of very small size. Thus, internal fragmentation is least.*

- *Worst Fit Algorithm works worst. This is because space left after the allocation inside the partition is of very large size. Thus, internal fragmentation is maximum.*

Advantages of Static Partitioning

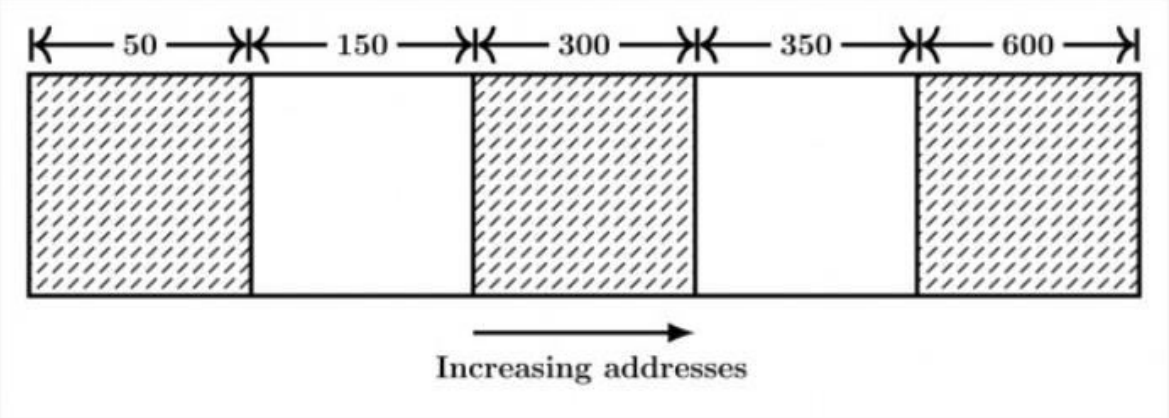
- *It is simple and easy to implement.*
- *It supports multiprogramming since multiple processes can be stored inside the main memory.*
- *Only one memory access is required which reduces the access time.*

Disadvantages of Static Partitioning

- *It suffers from both **internal fragmentation** and **external fragmentation**.*
- *It utilizes memory inefficiently.*
- *The degree of multiprogramming is **limited** equal to number of partitions.*
- *There is a **limitation on the size of process** since processes with size greater than the size of largest partition can't be stored and executed.*

Dynamic Storage - Allocation Problem

Consider the following heap (figure) in which blank regions are not in use and hatched region are in use.



The sequence of requests for blocks of sizes 300, 25, 125, 50 can be satisfied if we use

A. either first fit or best fit policy (any one)

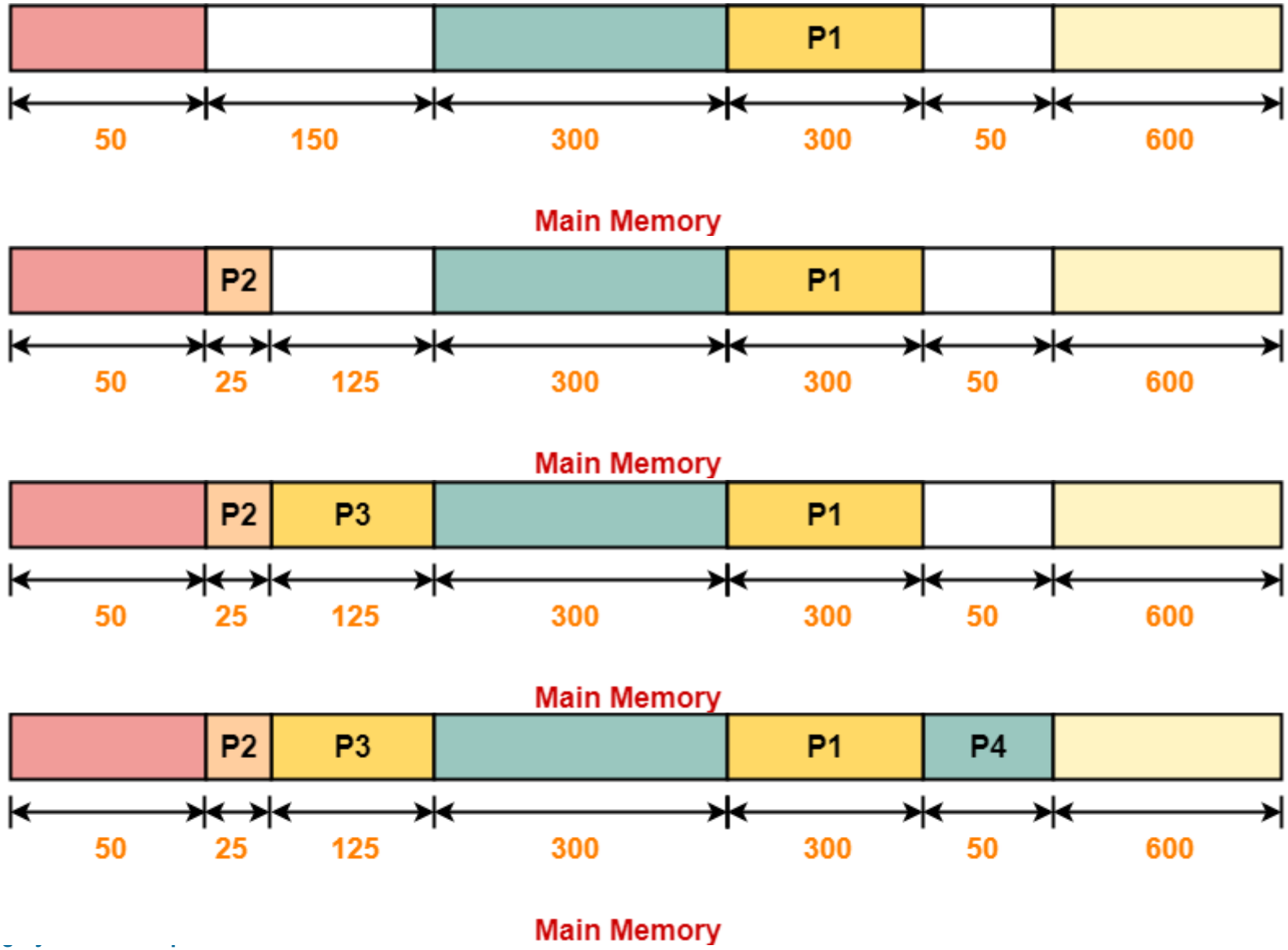
B. first fit but not best fit policy

C. best fit but not first fit policy

D. None of the above

Dynamic Storage-Allocation Problem

Allocation Using First Fit Algorithm

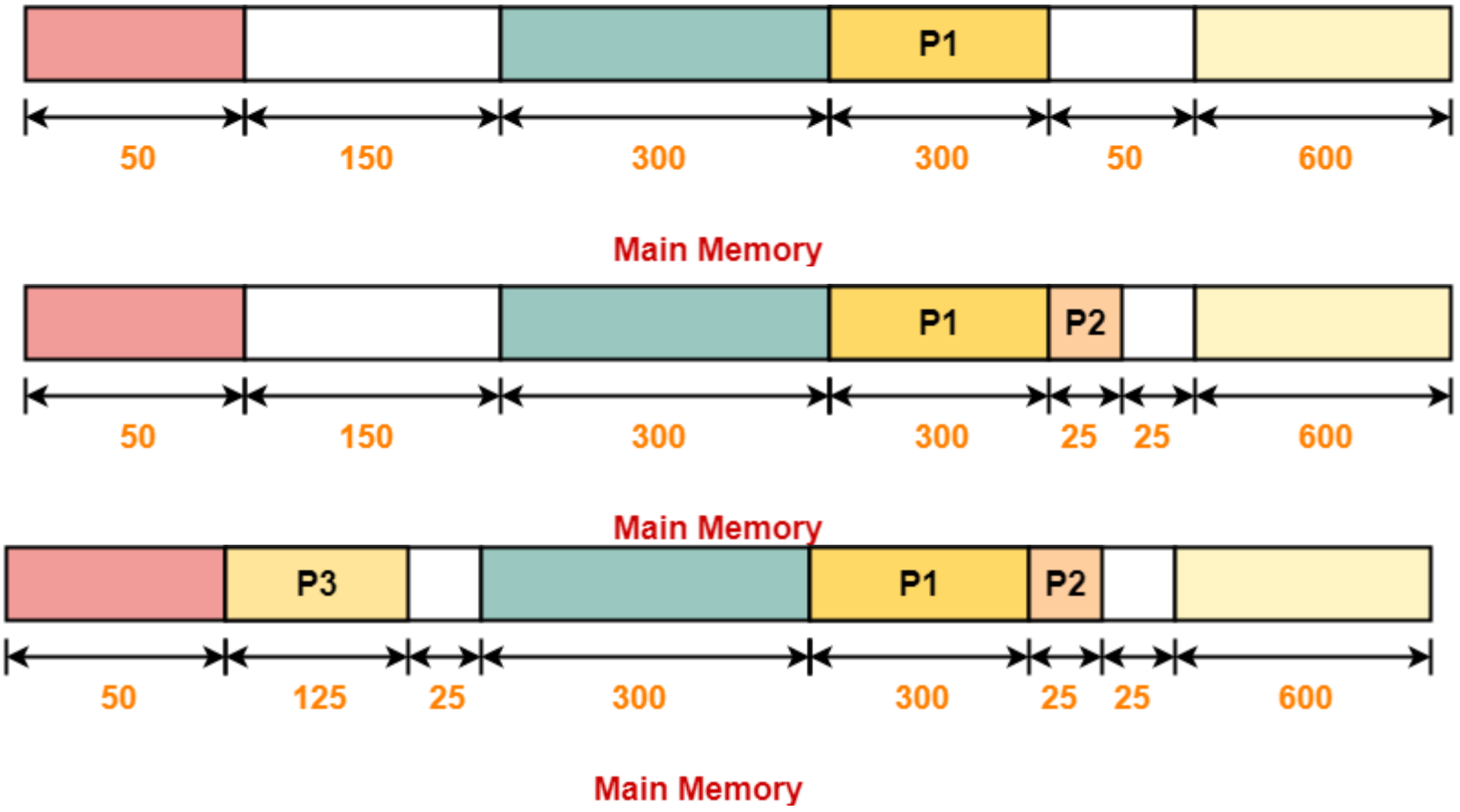


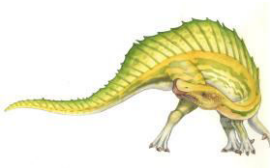
Important Points about Dynamic Size Partitioning

- *Worst Fit Algorithm works best, This is because space left after allocation inside the partition is of large size, There is a high probability that this space might suit the requirement of arriving processes.*
- *Best Fit Algorithm works worst. This is because space left after allocation inside the partition is of very small size and there is a low probability that this space might suit the requirement of arriving processes.*

Dynamic Storage-Allocation Problem

Allocation Using Best Fit Algorithm-





Advantages of Dynamic Size Partitioning

- *It does not suffer from internal fragmentation.*
- *Degree of multiprogramming is dynamic.*
- *There is no limitation on the size of processes.*

Disadvantages of Dynamic Size Partitioning

- *It suffers from external fragmentation.*
- *Allocation and deallocation of memory is complex.*

Problem-4

In a computer system where the 'best fit' algorithm is used for allocating 'jobs' to 'memory partition', the following situation was encountered.

Partition size in KB	4 KB		8 KB		20 KB		2 KB
Jobs	2 K	14 K	3 K	6 K	10 K	20 K	2 K
Times for execution	4	10	2	1	1	8	6

When will the 20 K job complete?

Structure of Page Table

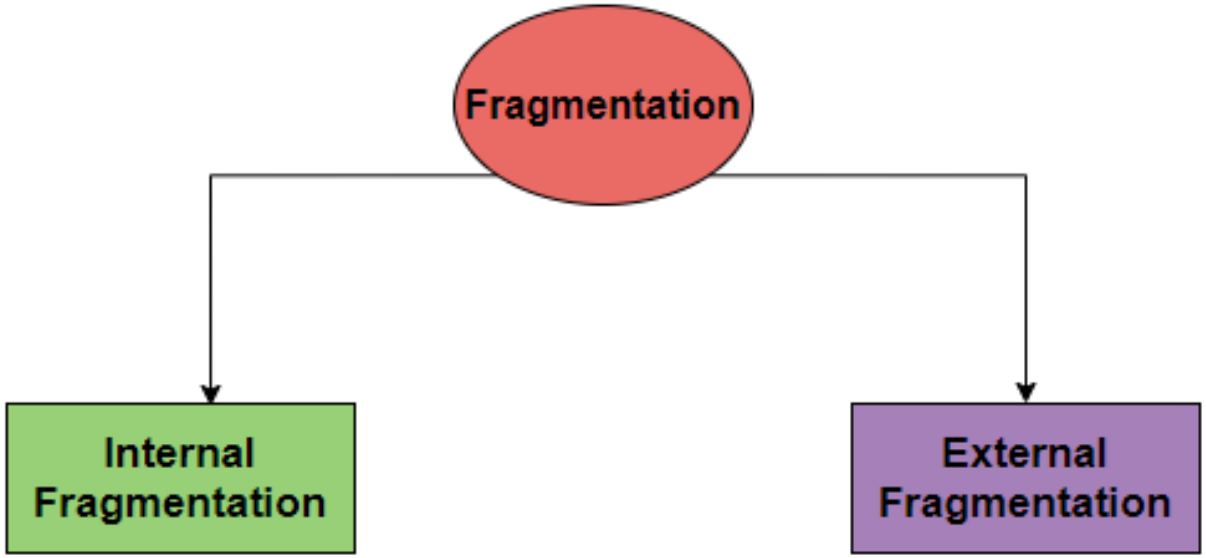
Jobs	Job size	Ex. Time
1	2k	4
2	14k	10
3	3k	2
4	6k	1
5	6k	4
6	10k	1
7	20k	8
8	2k	6

Structure of Page Table

Jobs	Job size	Ex. Time
1	2k	4
2	14k	10
3	3k	2
4	6k	1
5	6k	4
6	10k	1
7	20k	8
8	2k	6

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
4k	3	3	8	8	8	8	8	8											
8k	4	5	5	5	5														
20k	2	2	2	2	2	2	2	2	2	2	6	7	7	7	7	7	7	7	7
2k	1	1	1	1															

Fragmentation



Internal Fragmentation

- *It occurs when the space is left inside the partition after allocating the partition to a process.*
- *This space is called as internally fragmented space.*
- *This space can not be allocated to any other process. This is because only static partitioning allows to store only one process in each partition.*
- *Internal Fragmentation occurs only in static partitioning.*

External Fragmentation

- *It occurs when the total amount of empty space required to store the process is available in the main memory.*
- *But because the space is not contiguous, so the process can not be stored.*

Fragmentation

- ***External fragmentation*** *– total memory space exists to satisfy a request, but it is not contiguous.*
- ***Internal fragmentation*** *– allocated memory may be slightly larger than requested memory; this size difference is memory internal to a partition, but not being used.*

.

Solution for External Fragmentation

- *Reduce external fragmentation by compaction*
  - *Shuffle memory contents to place all free memory together in one large block.*
- *Permit the logical address space to be noncontiguous, allow process to allocate physical memory wherever it is available: Paging and segmentation.*

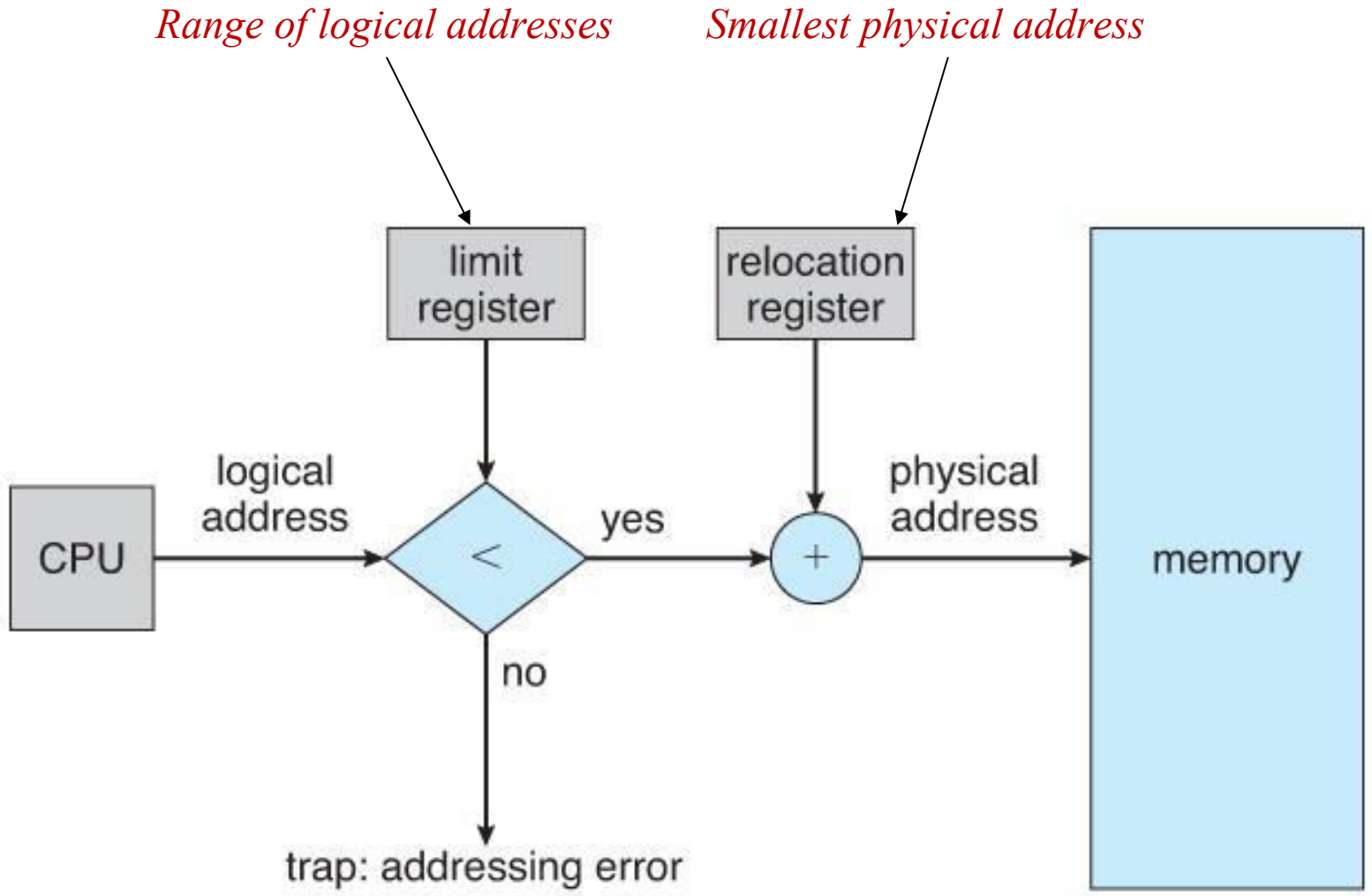
Translating Logical to Physical Address

- *CPU always **generates** a logical address.*
- *A **physical address is needed to access the main memory**.*
- *During **context switching**, the values corresponding to the process being loaded are set in the registers **(Relocation Register, Limit Register).***
- *Relocation register contains value of **smallest physical address**; limit register contains **range of logical addresses** – each logical address must be less than the limit register.*
- *Relocation-register scheme used to protect user processes from each other, and from changing operating-system code and data.*

Translating Logical to Physical Address

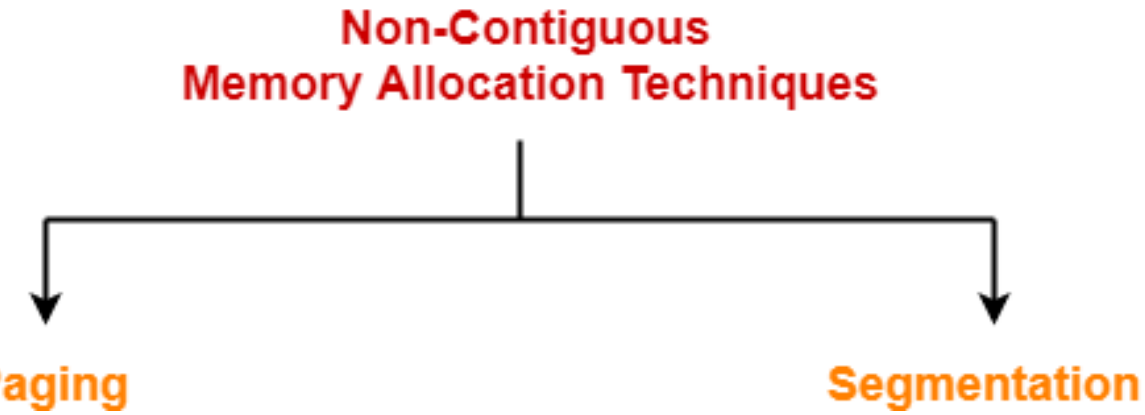
- *CPU generates a **logical address containing** the address of the instruction that it wants to read.*
- *The address must always lie in the range [0, limit-1]. If address is found to be smaller than the limit, then the request is treated as a valid request. Then, generated address is added with the base address of the process.*
- *The result obtained after addition is the address of the memory location storing the required word.*

Contiguous Allocation: Memory Protection



Non-Contiguous Memory Allocation

- *It allows to store parts of a single process in a non-contiguous fashion.*
- *Thus, **different parts** of the same process can be stored at **different places** in the **main memory**.*



Segmentation

- *Divide process in logically related partition.*
- *The process is divided into **modules** for better visualization.*
- *Segmentation is a **variable size** partitioning scheme.*
- *In segmentation, secondary memory and main memory are divided into partitions of unequal size.*
- *The size of partitions depend on the length of modules.*
- *The partitions of secondary memory are called as **segments**.*

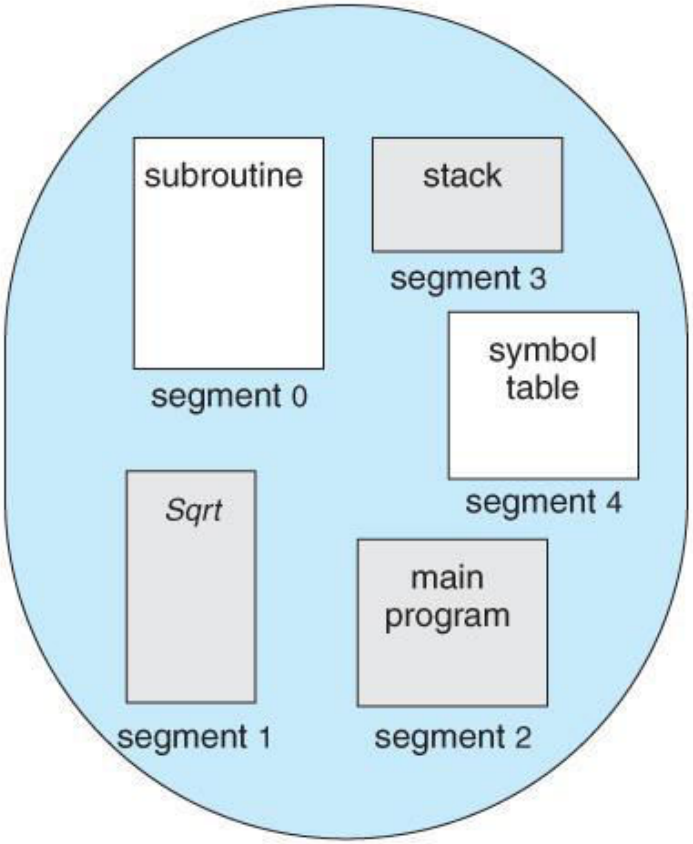
Segmentation

- *Thus, a logical address consists of a two tuple:*

  <segment-number, offset>.

- *This mapping is effected by a segment table. Each entry in the segment table has a* ***segment base and a segment limit****.*
- ***Segment base****: Contains the starting physical address where the segment resides in memory.*
- ***Segment limit:*** *specifies the length of the segment.*
- *Segment table is kept in memory: Segment table base register, segment table length register.*

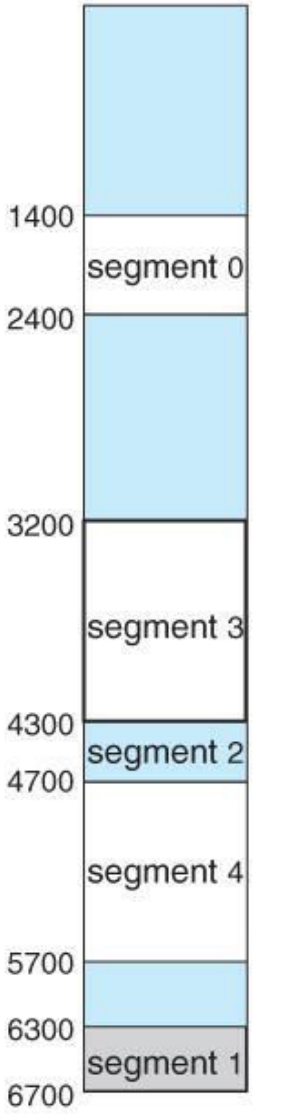
Segmentation hardware



logical address space

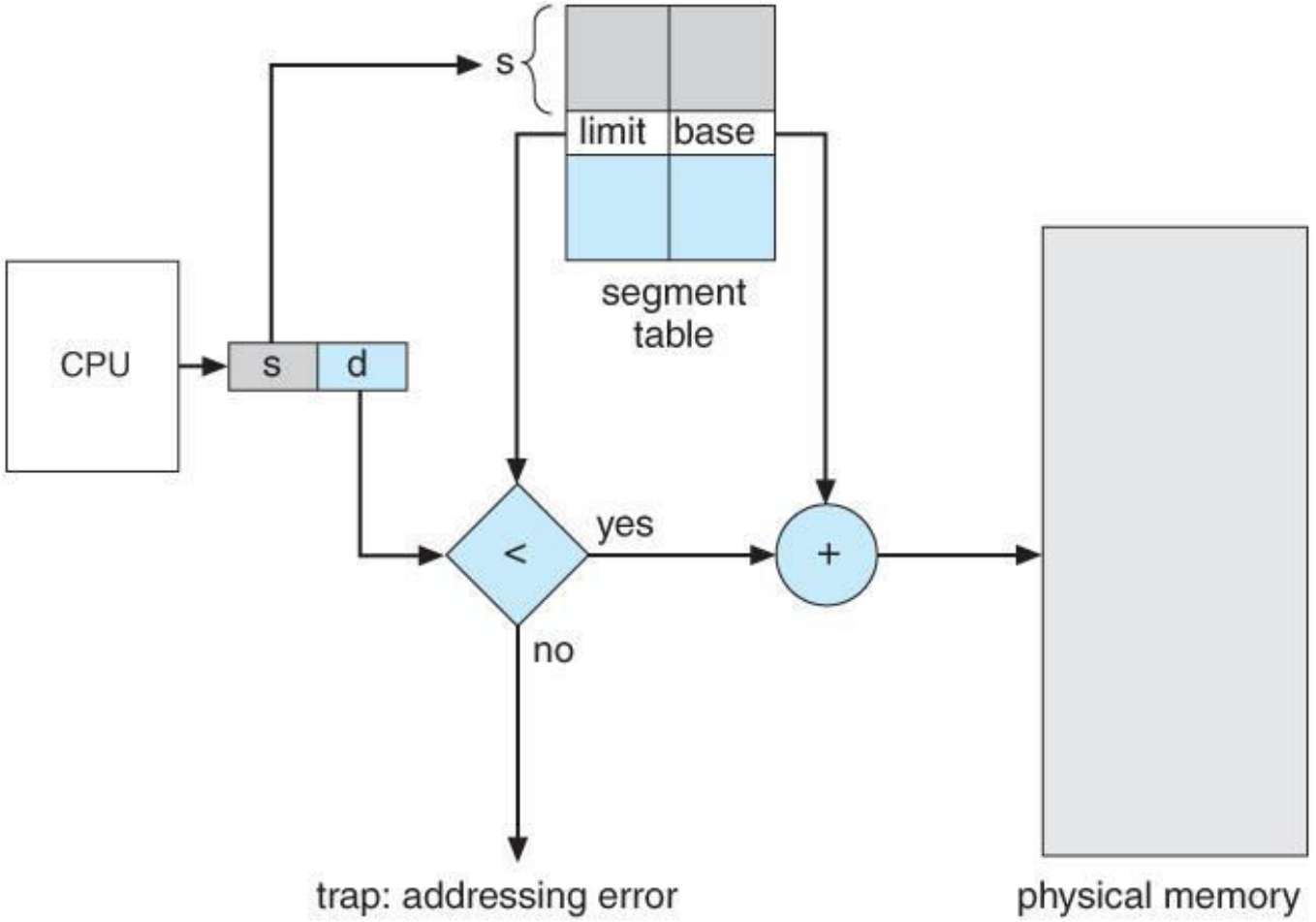
	limit	base
0	1000	1400
1	400	6300
2	400	4300
3	1100	3200
4	1000	4700

segment table



physical memory

Segmentation Hardware



Segmentation Advantages

- *It allows to divide the program into modules which* ***provides better visualization***.
- *It solves the problem of* ***internal fragmentation***.

Segmentation Disadvantages

- *Segments of unequal size are not suited for swapping.*
- *It **suffers from external fragmentation** as the free space gets broken down into smaller pieces with the processes being loaded and removed from the main memory.*

Segmentation

Consider the segment table given below:

Segment No.	Base	Limit
0	1219	700
1	2300	14
2	90	100
3	1327	580
4	1952	96

Which of the following logical address will produce trap addressing error?

1. ***0, 430***
2. ***1, 11***
3. ***2, 100***
4. ***3, 425***
5. ***4, 95***

Calculate the physical address if no trap is produced.