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# Memory

## Course: Systems Architecture

Lecturer: Gleb Lobanov

**February 25, 2024**

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# Contents

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01

# Memory

In this section, we will discuss what virtual memory and real memory are and what is the relationship between them.

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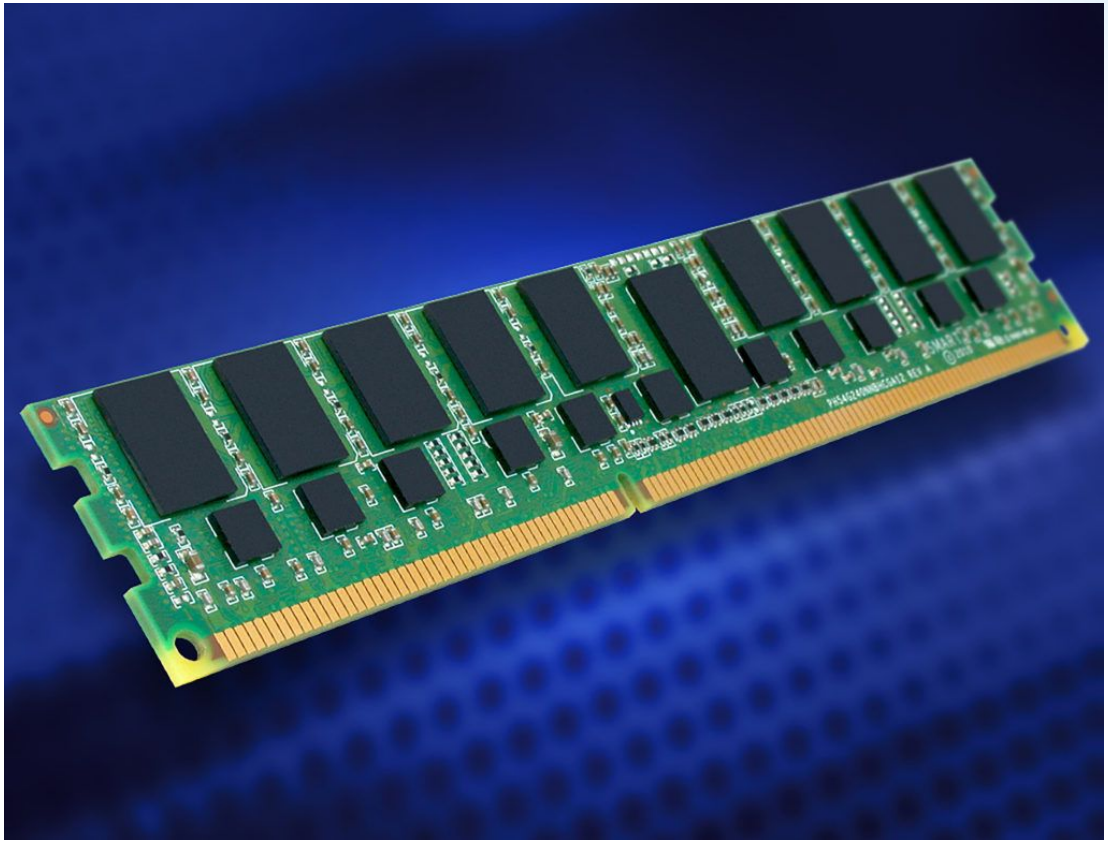
# Memory



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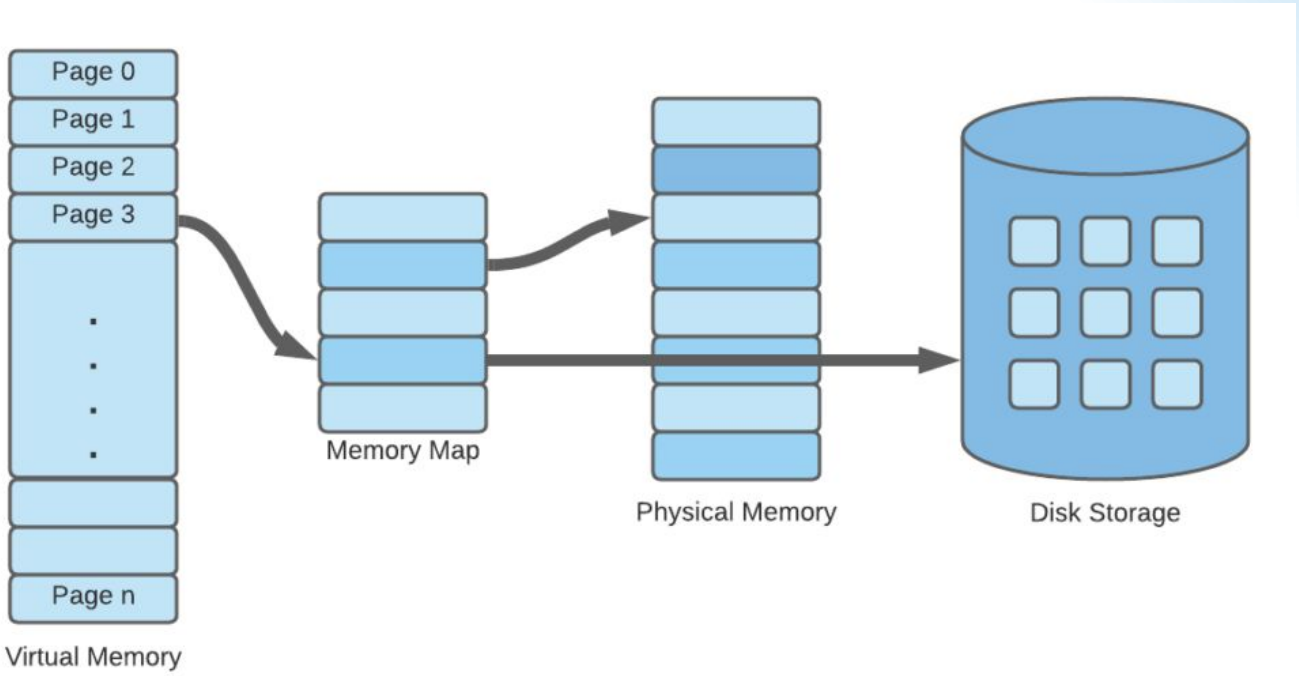
# Also memory



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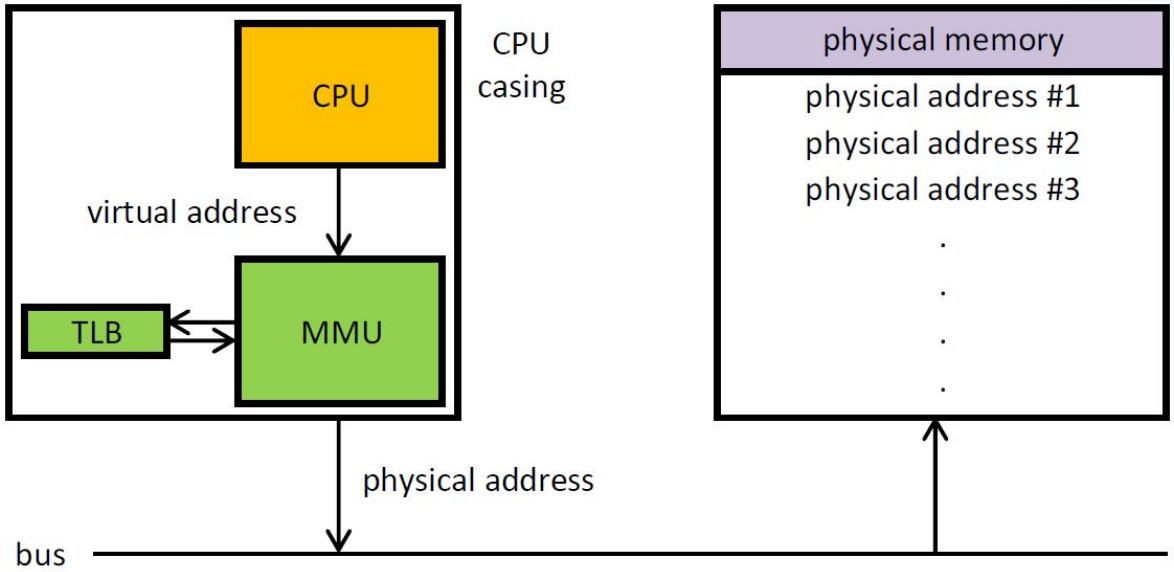
# Memory management unit




CPU: Central Processing Unit
MMU: Memory Management Unit
TLB: Translation lookaside buffer

source

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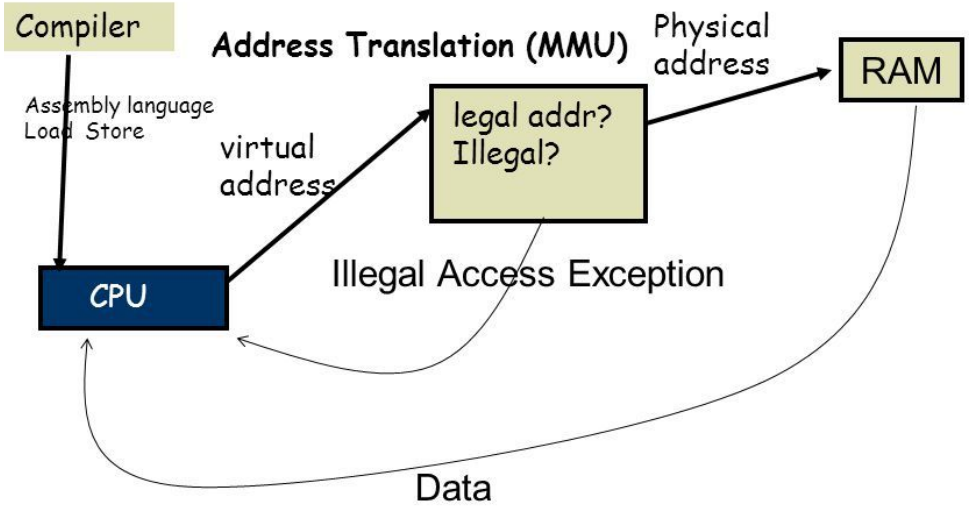
# Memory management unit



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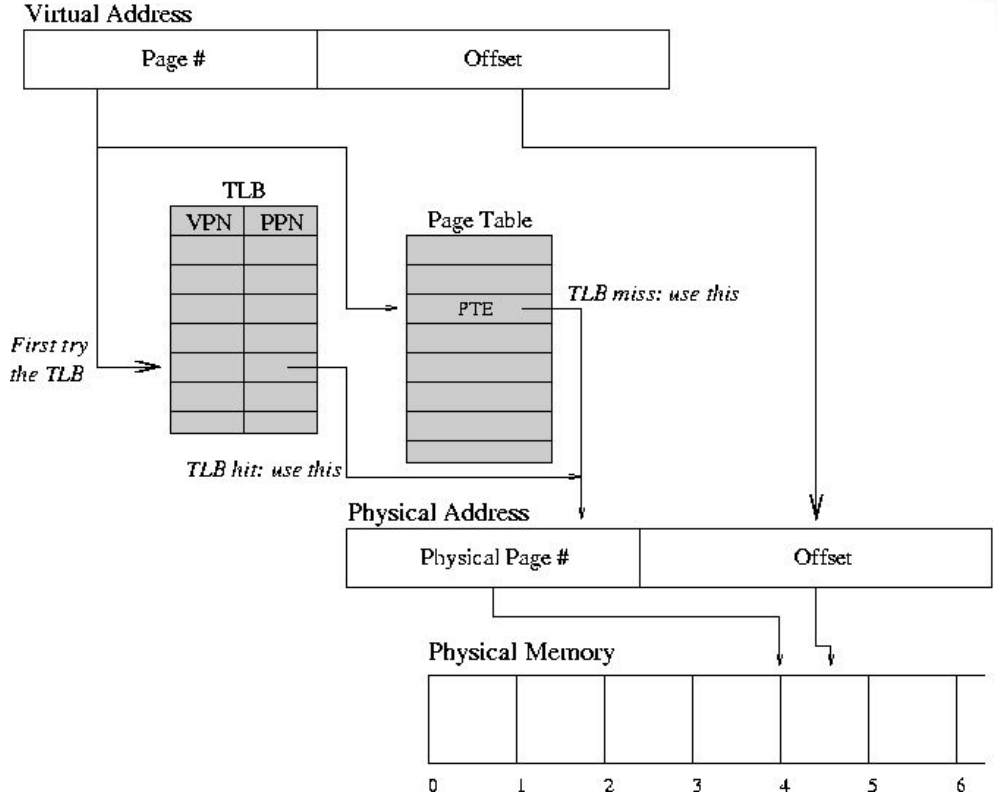
# Translation Lookaside Buffer (TLB)




source

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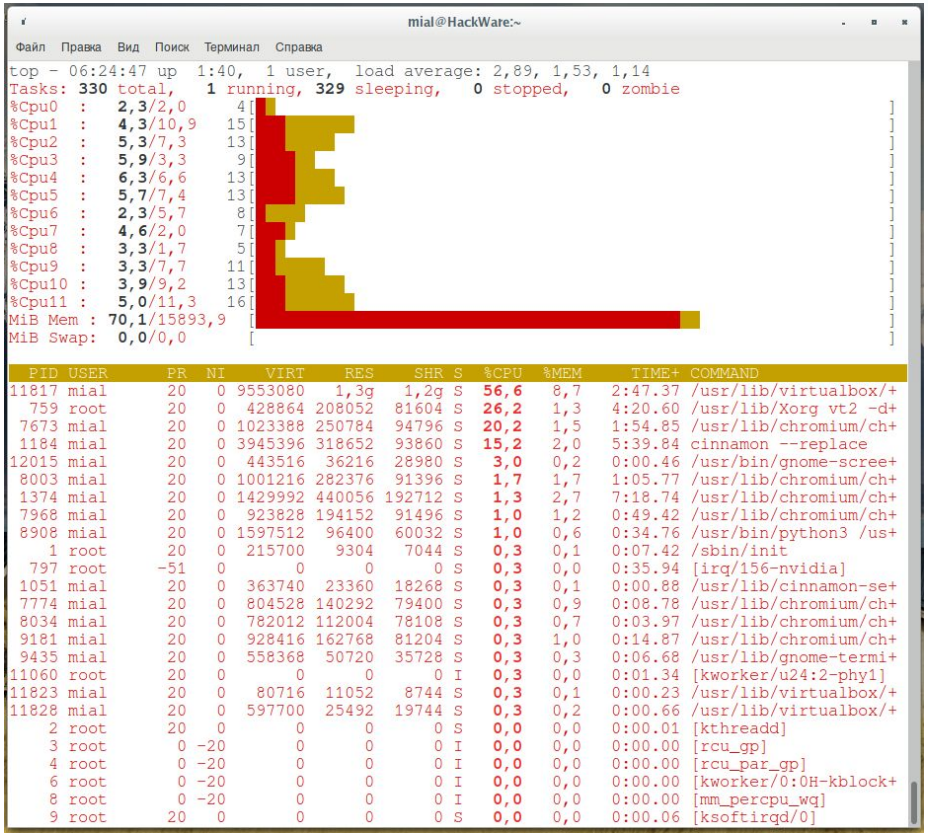
# Memory



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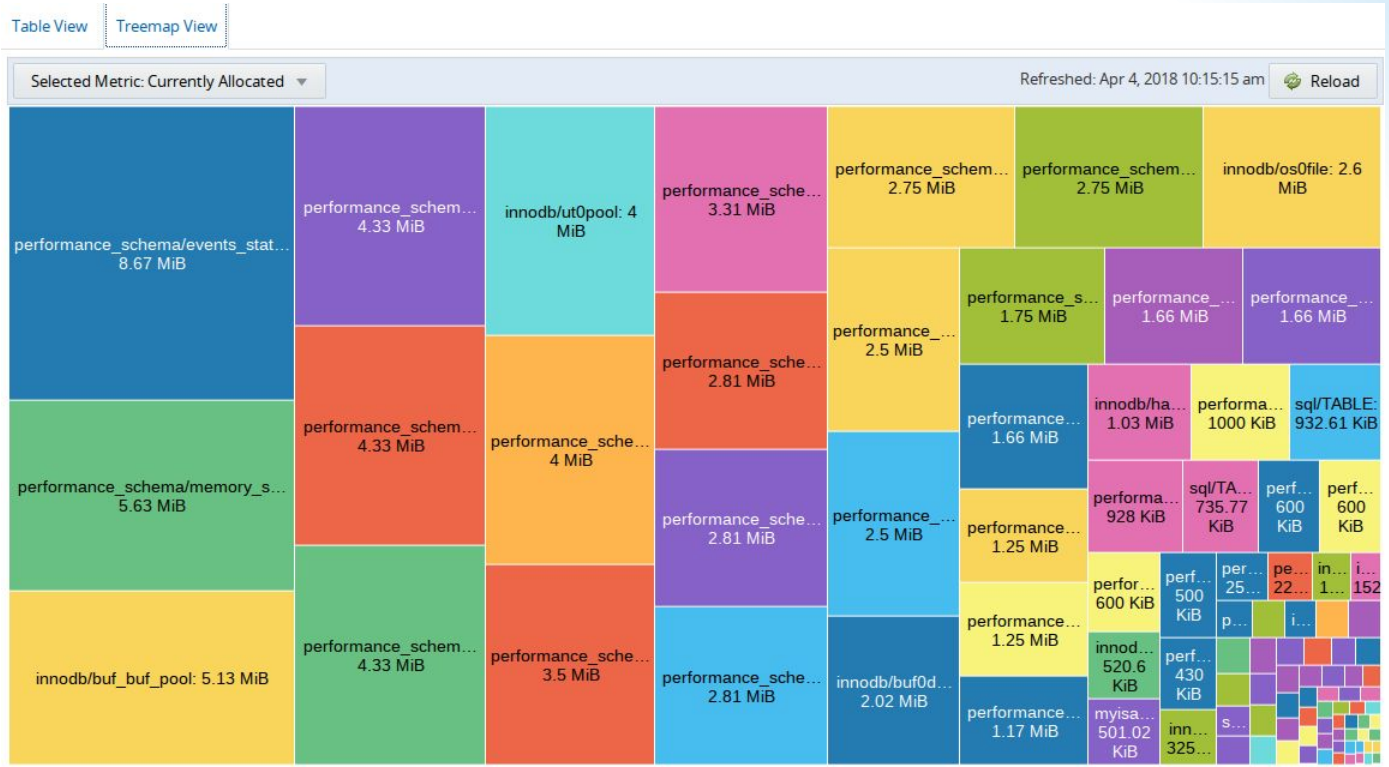
# Memory



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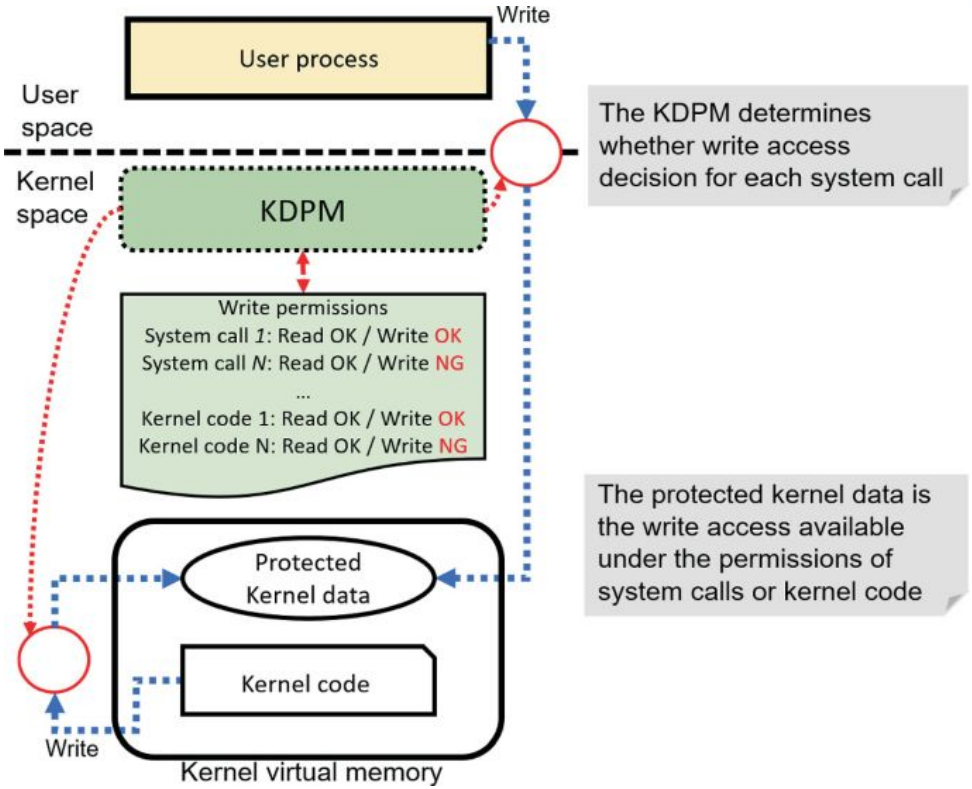
# Kernel DMA Protection



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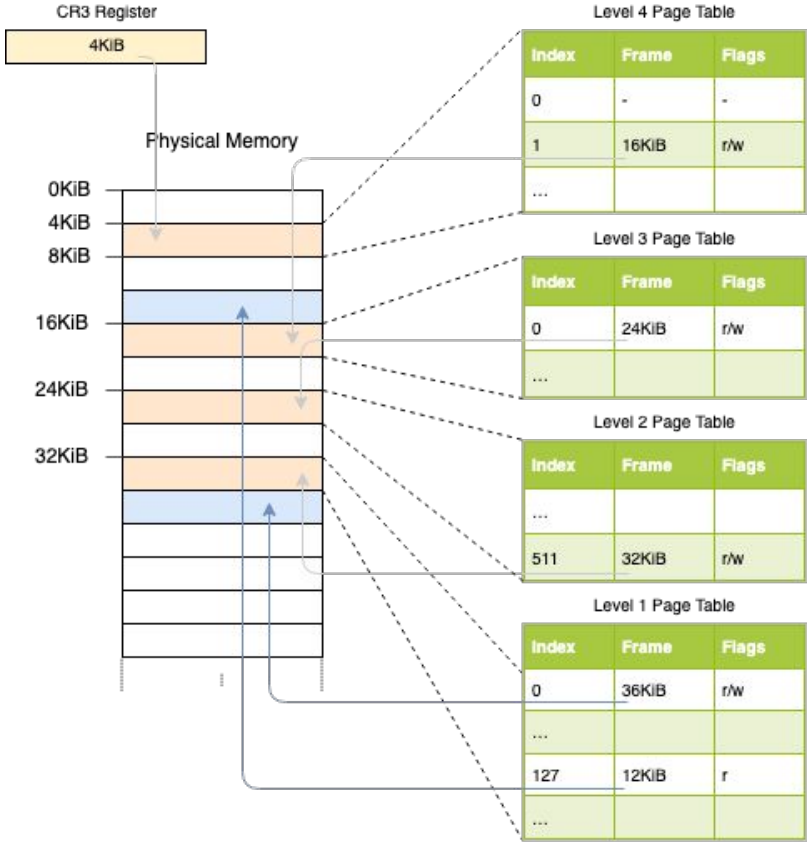
# Pages



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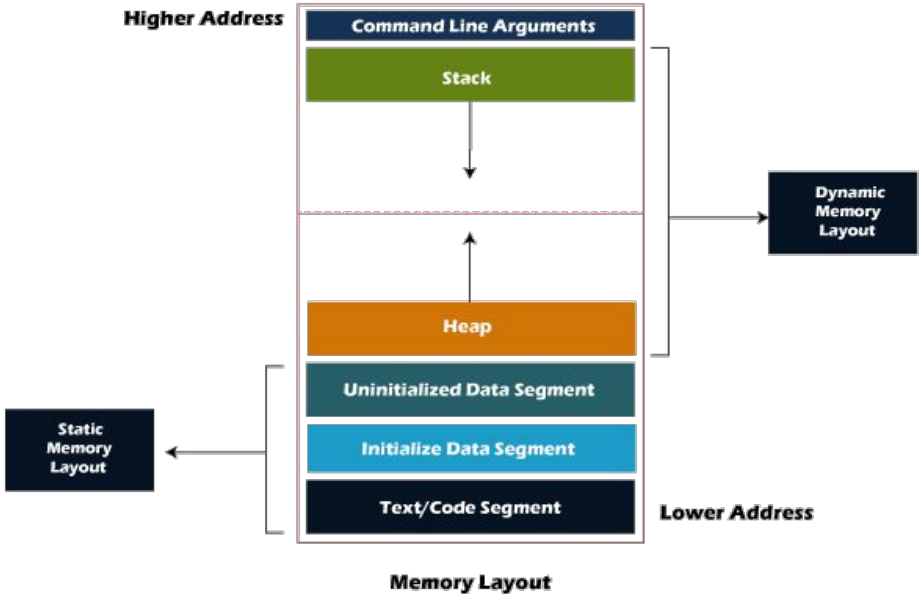
# Memory structure



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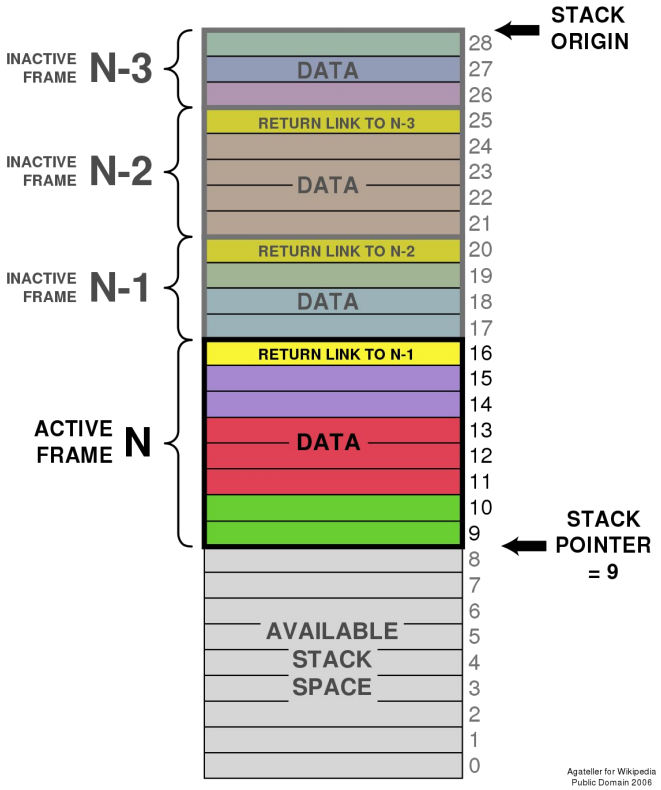
# Stack



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02

# Memory allocation

In this section, we will discuss what memory allocation is and what allocation algorithms exist.

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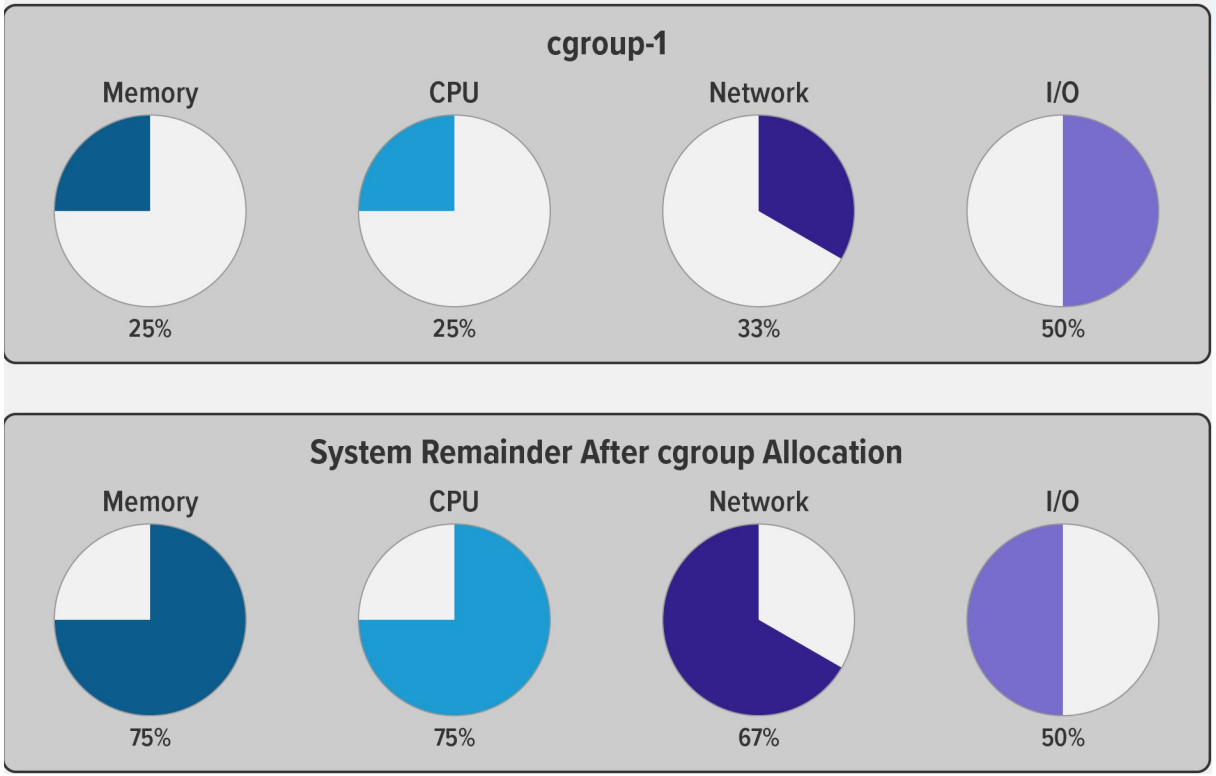
# Allocation



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# How to alloc memory?

1) First-Fit
2) Best-Fit
3) Worst-Fit
4) Next-Fit
5) Quick-Fit
6) Slab Allocation*
7) Buddy Allocation*

maybe some others

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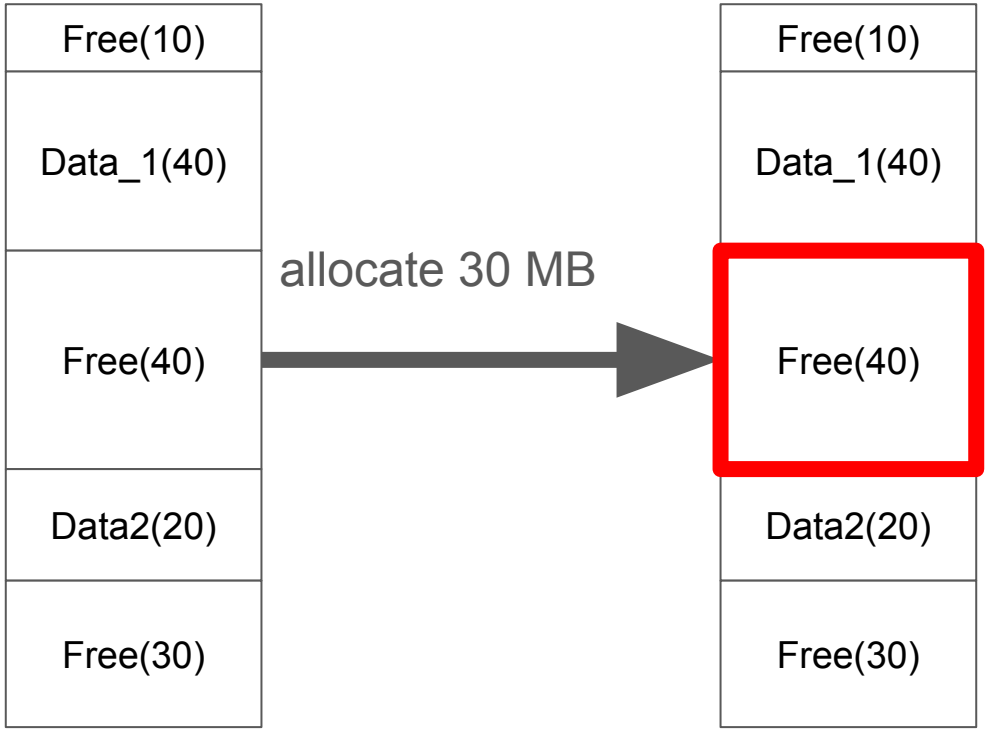
# First-Fit Allocation



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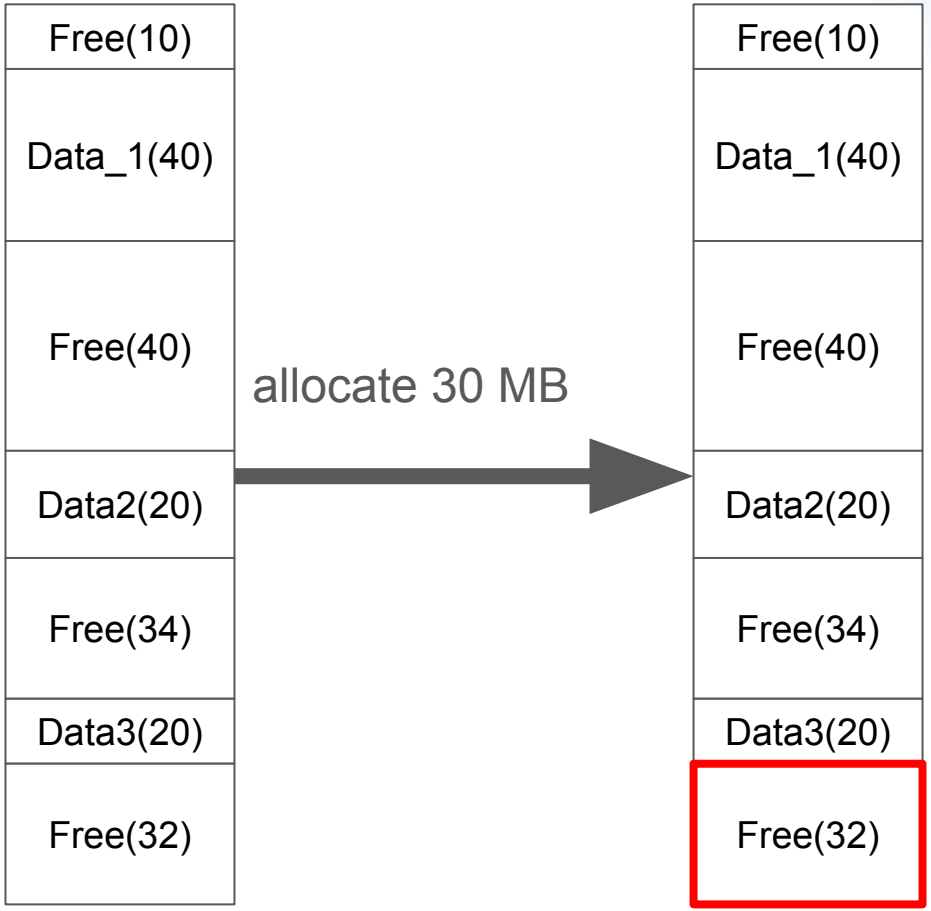
# Best-Fit Allocation



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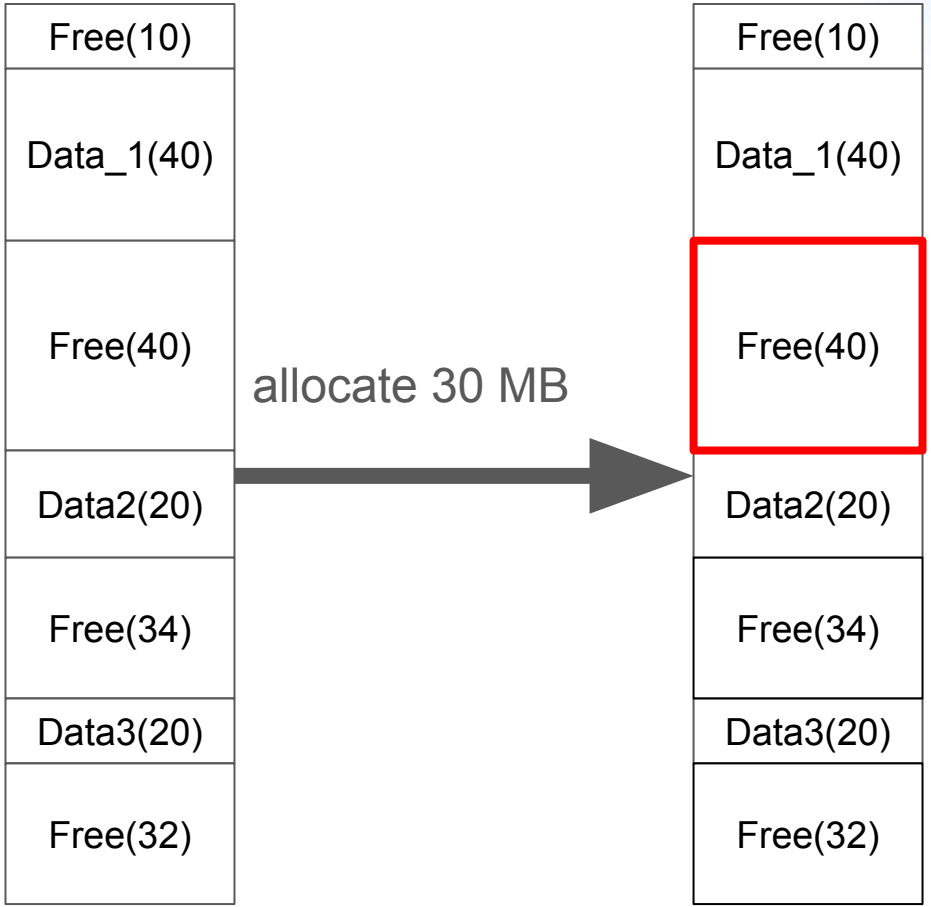
# Worst-Fit Allocation



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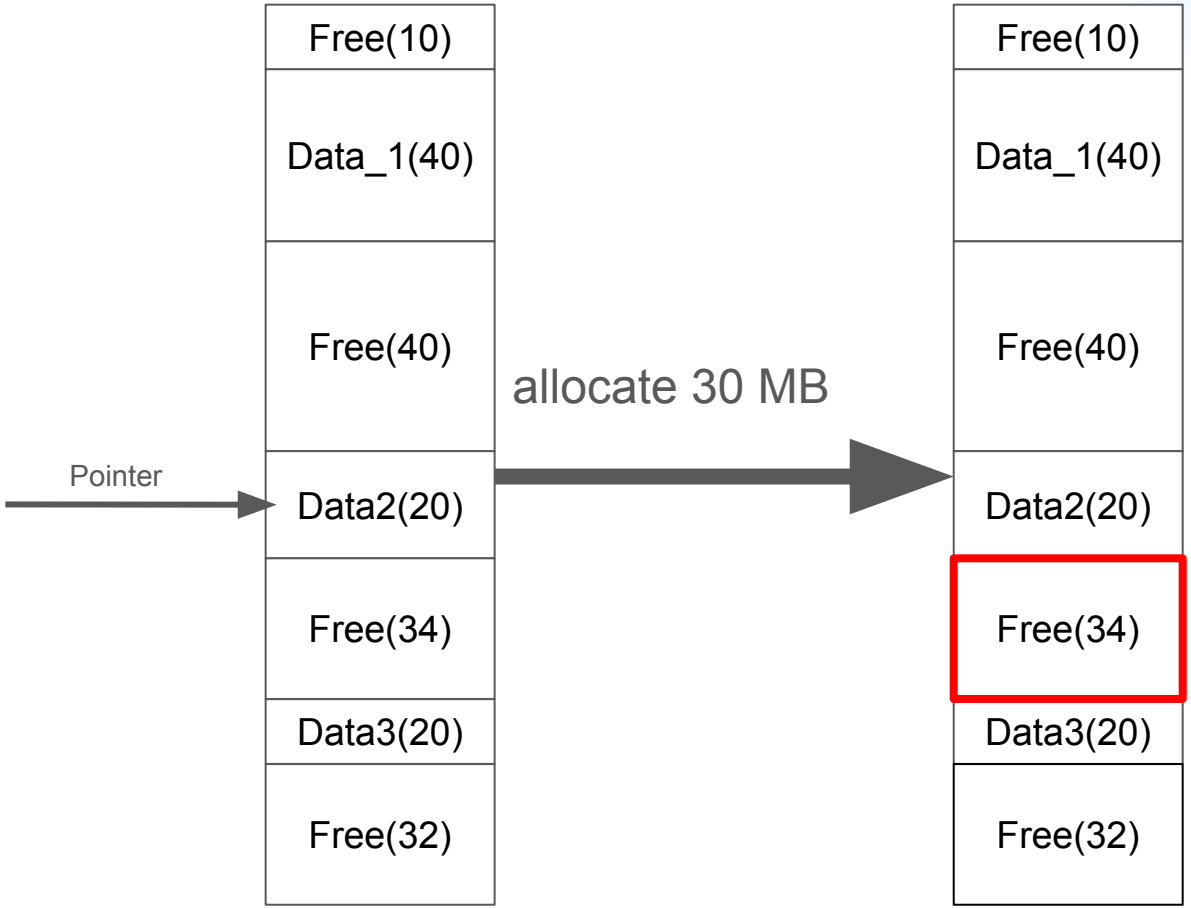
# Next-Fit Allocation



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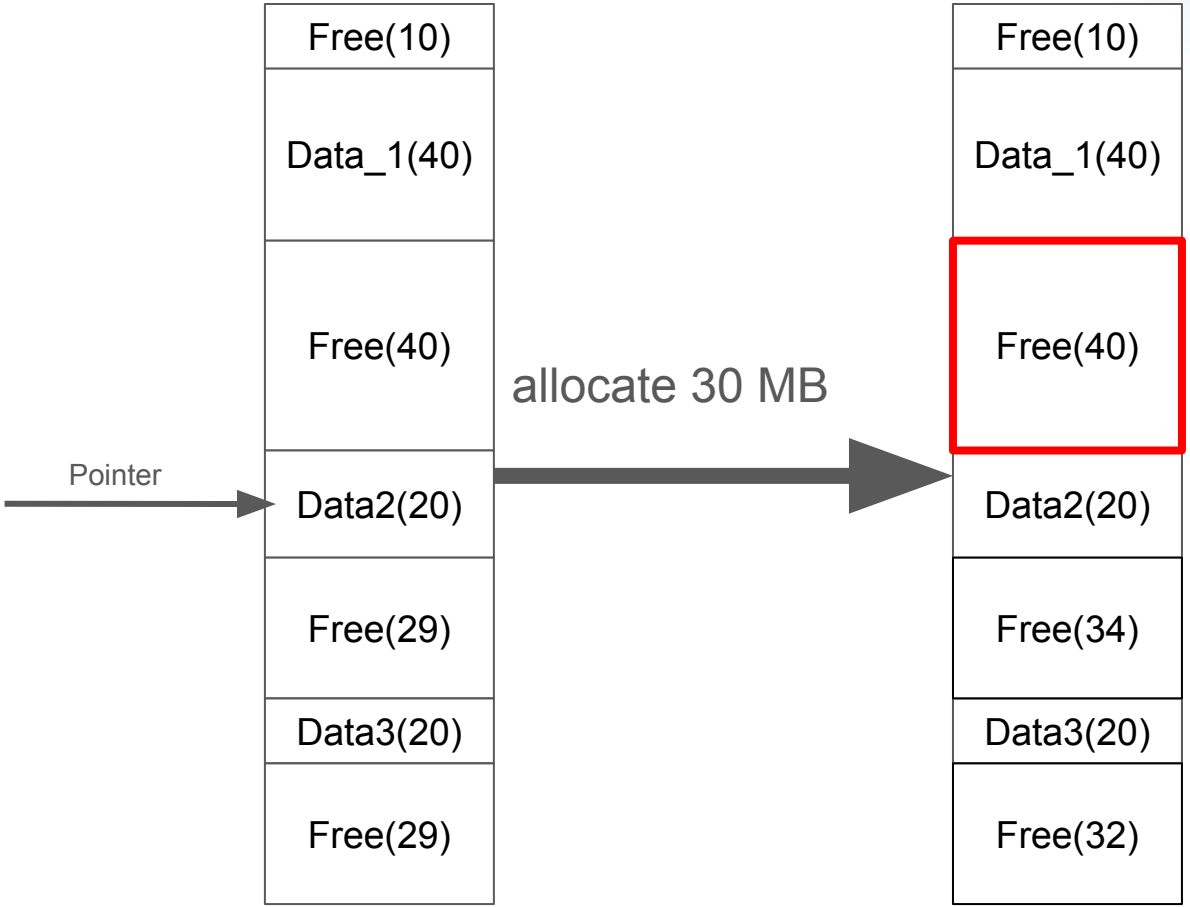
# Important!!!



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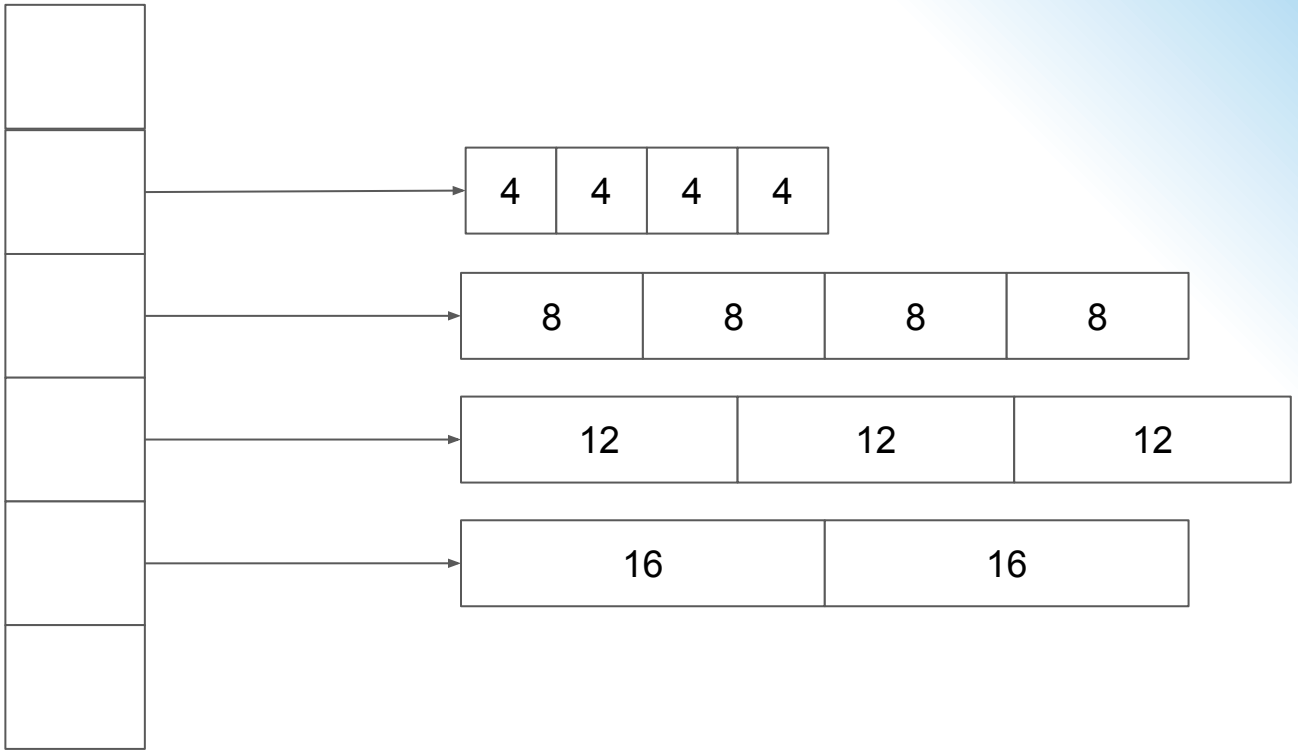
# Quick-Fit Allocation



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# Why none of them?

All these algorithms involve dynamic memory allocation, and this is bad because of the 50% Memory Loss Rule

*- Jason Statham*

link

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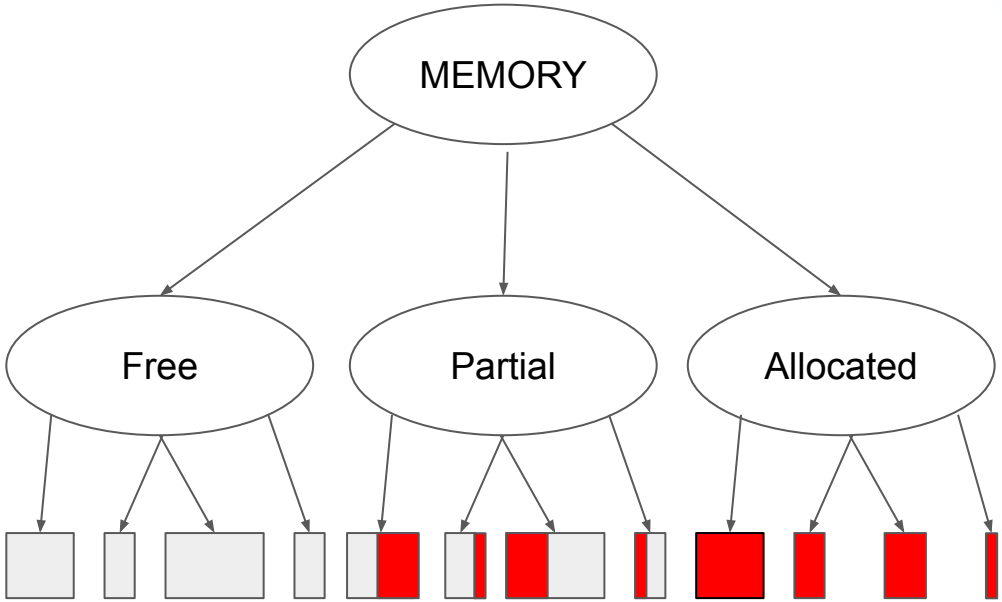
# Slab Allocation



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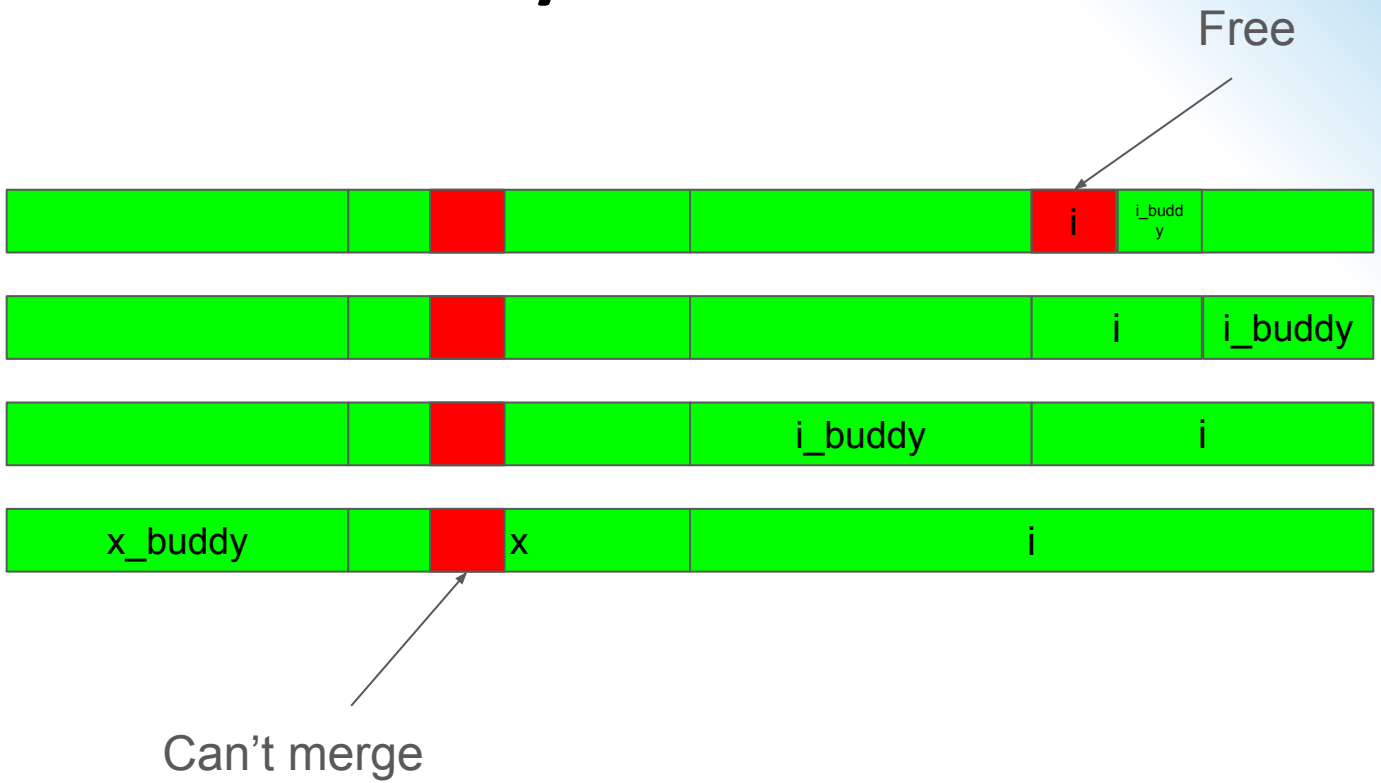
# Buddy Allocation



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03

# Architecture ideas

In this section, we will discuss Von Neumann and Harvard architecture.

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# Von Neumann architecture

1) Memory and processor separation
2) Principle of memory addressing
3) Principle of command control
4) Principle of binary encoding

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# Harvard architecture

1) Instructions memory
2) Data memory

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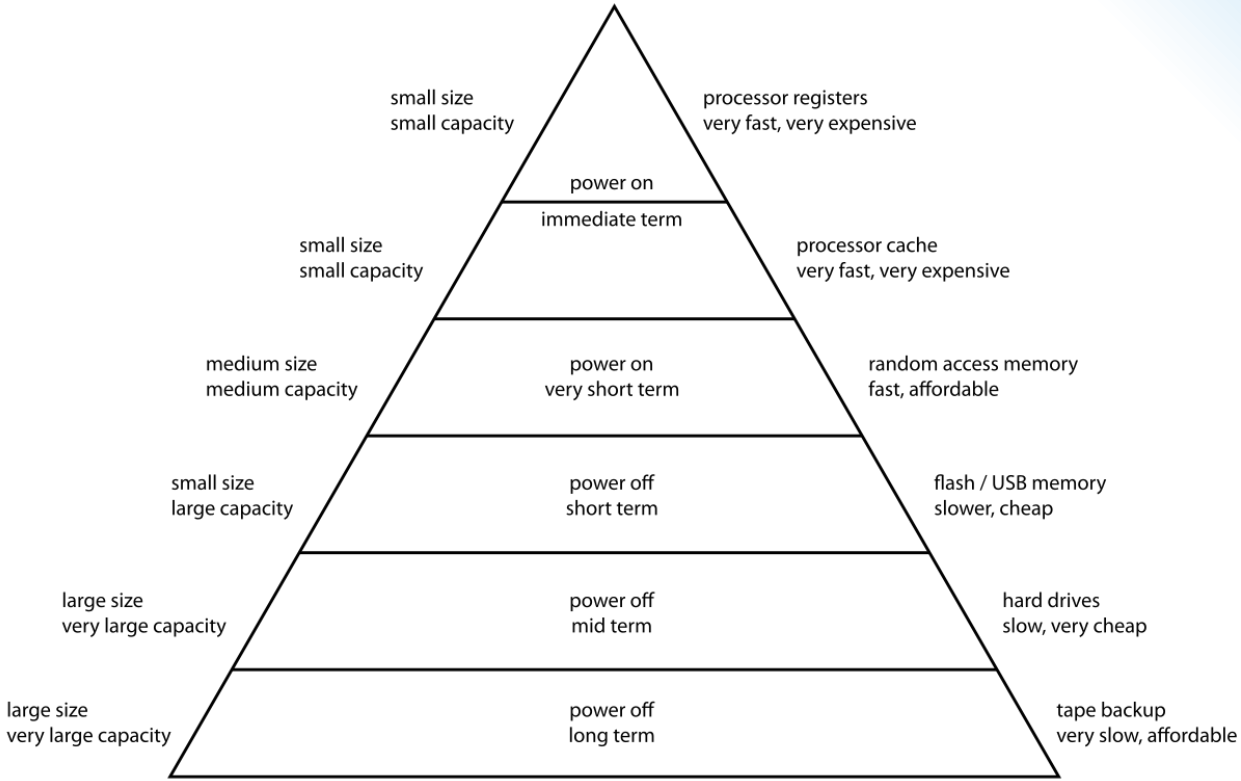
# Computer Memory Hierarchy



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# SRAM


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# DRAM


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# Comparison

| Static Random Access Memory | Dynamic Random Access Memory |
| --- | --- |
| SRAM is a type of RAM where each memory cell is made up of a set of transistors that store data in the form of charge. | Consists of a capacitor and a transistor that stores data in the form of charge on the capacitor. |
| It is more expensive and takes up more space on the chip than DRAM. | It is cheaper and has a higher packing density but requires constant refreshing of the charge to maintain data. |
| | DRAM is slower than SRAM. |

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# When to use?

| SRAM | DRAM |
| --- | --- |
| SRAM is used in cache memory and other places where fast access to data is required. | DRAM is used in the main computer memory and other devices where a large amount of memory is required at an affordable price. |

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04

# Registers

In this section, we will discuss registers.

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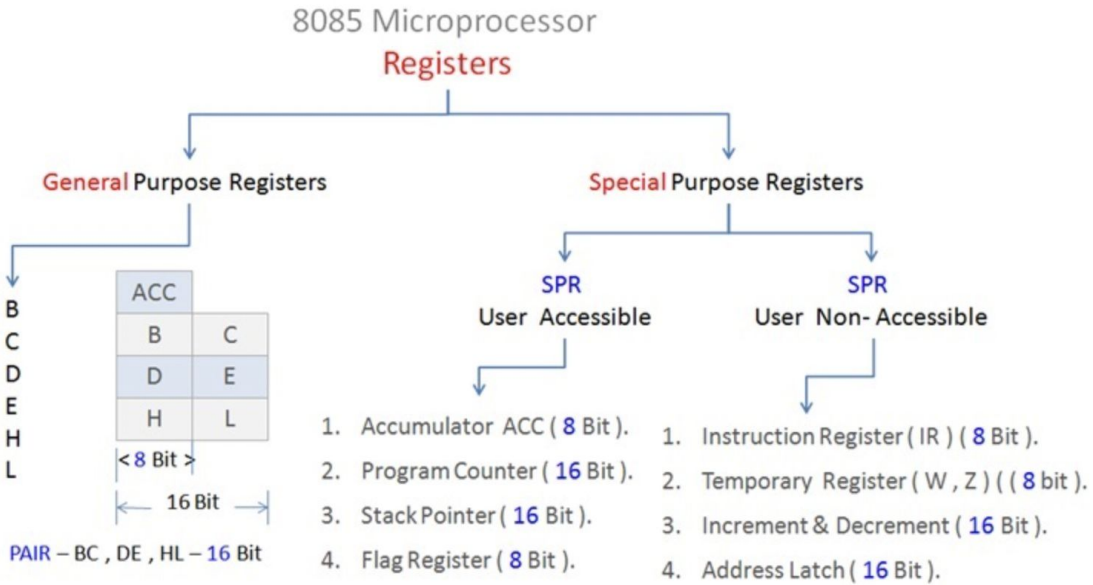
# Registers



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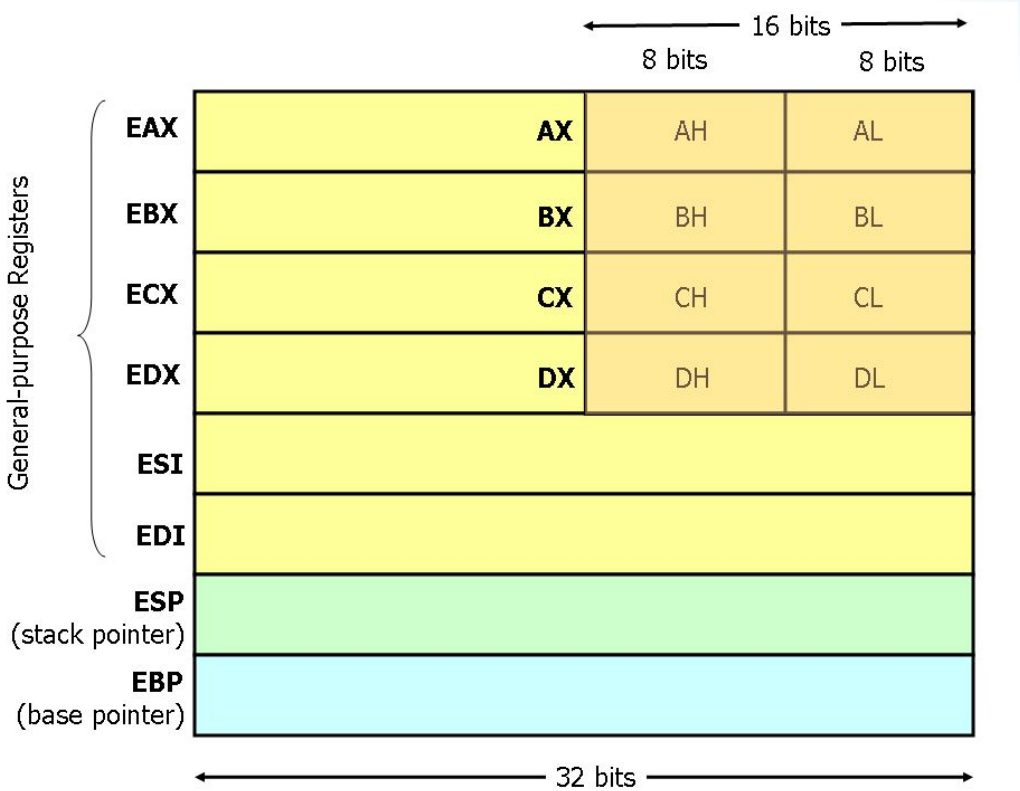
# Registers



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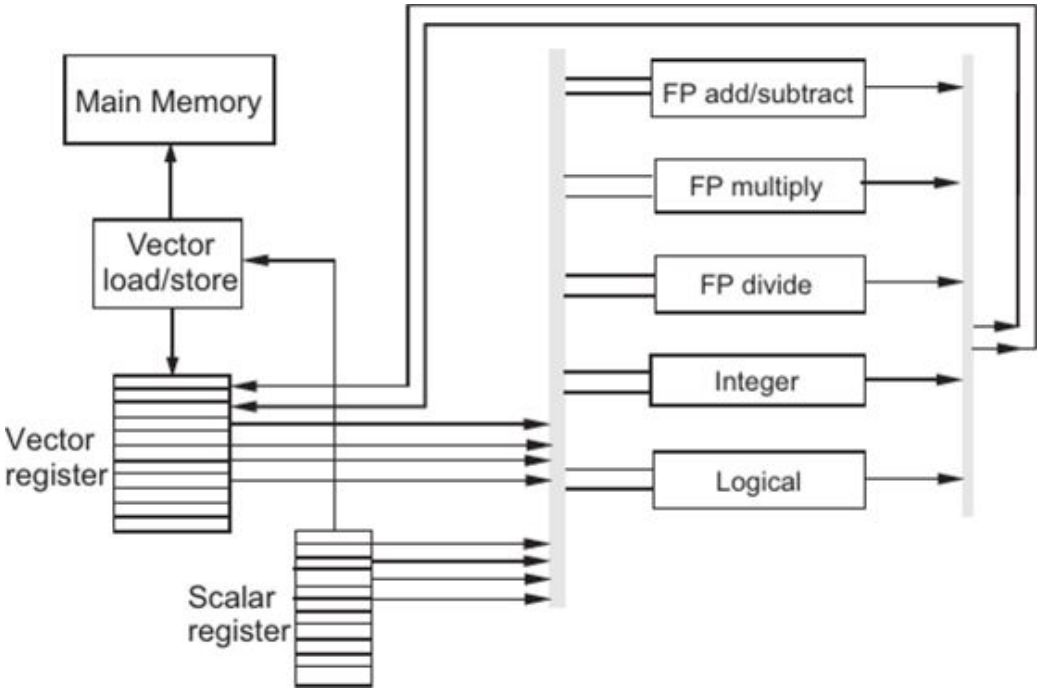
# AVX



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05

# Caches

In this section, we will discuss caches.

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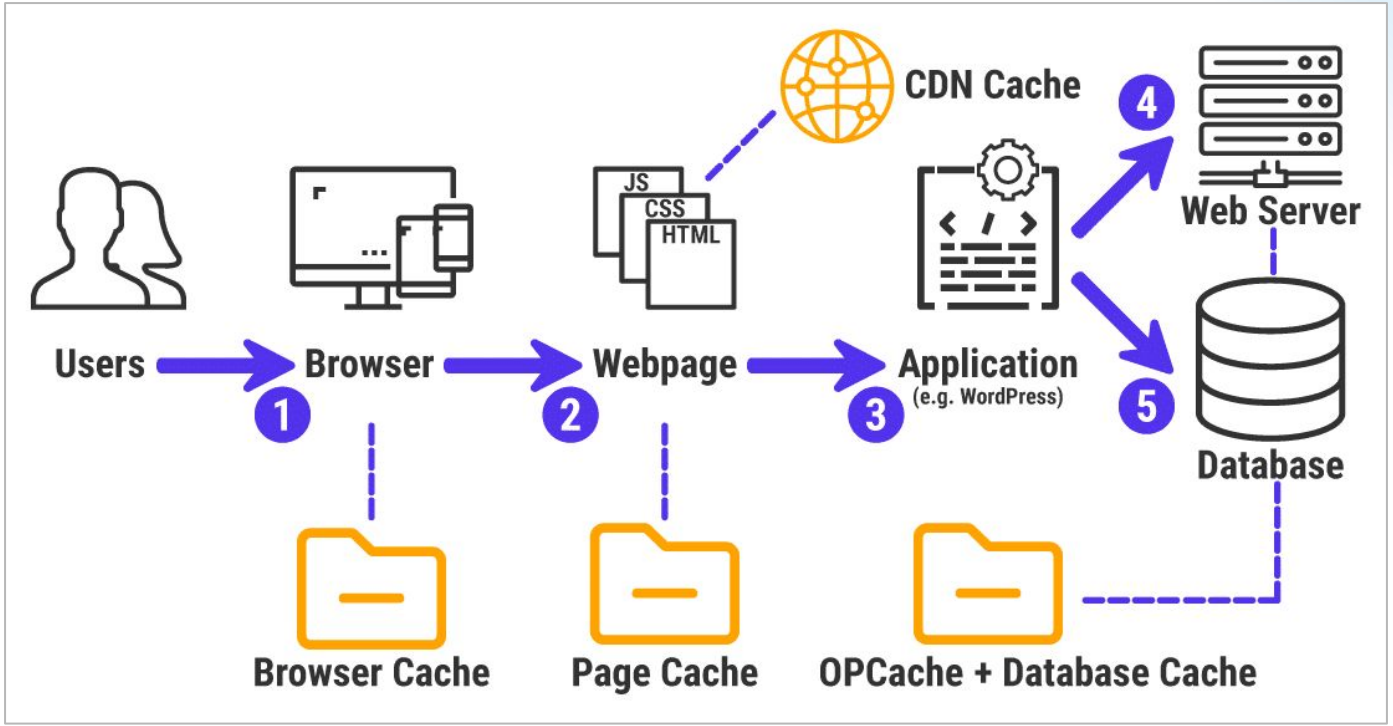
# Caches



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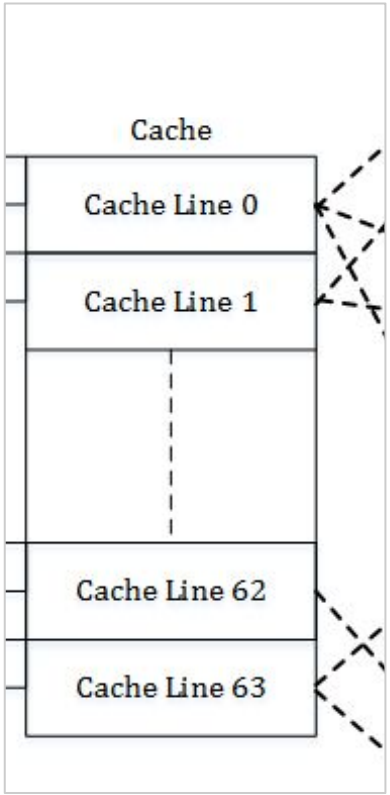
# Cache line

Usually like system



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# Why cache is working?

1) Time locality
2) Memory locality

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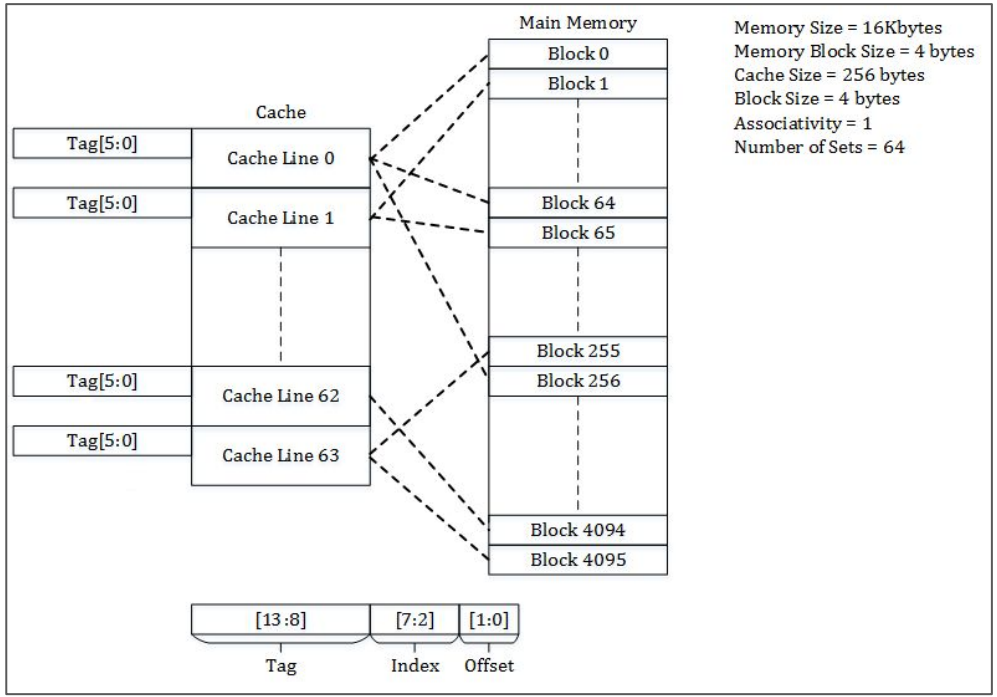
# How to cache?

1) Direct-mapped cache
2) Fully associative cache
3) Set-associative cache
4) Two-way skewed associative cache*
5) Pseudo-associative cache*

maybe some others

# Direct-mapped cache




search 300 block:

1) check cache line with id (300 mod 64) = 44
2) check tag of cache line with id 44
3) if tag = 4 then take element from cache

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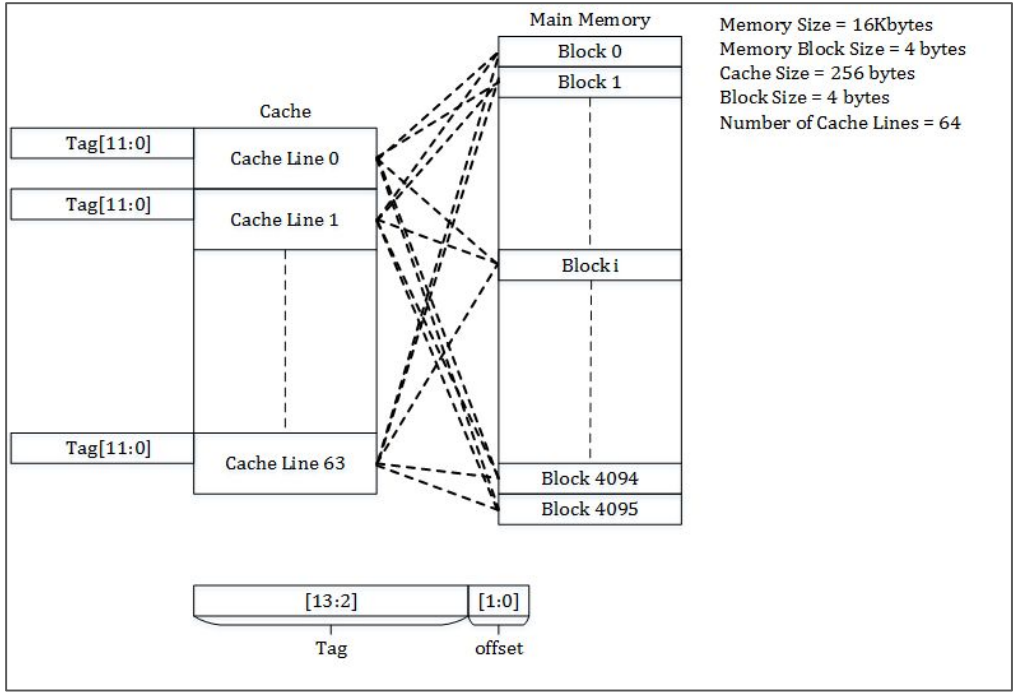
# Fully associative cache




search 300 block:

1) check all tags
2) if we have our block number return result

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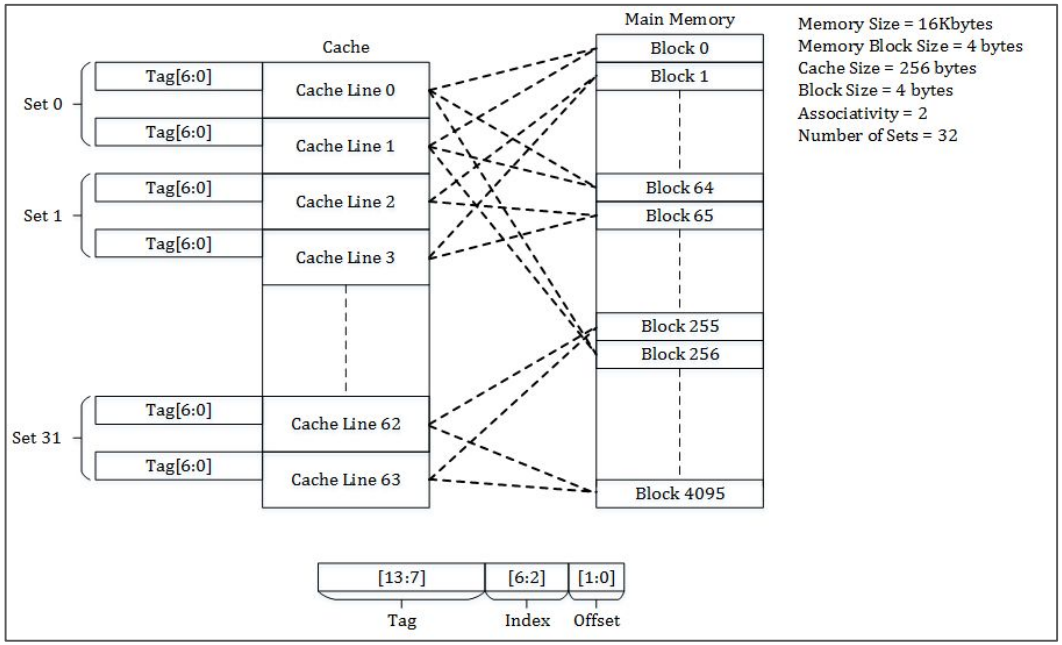
# Set-associative cache




search 300 block:

1) check set with id (300 mod 32) = 12
2) check both tags in it
3) if find one -> return

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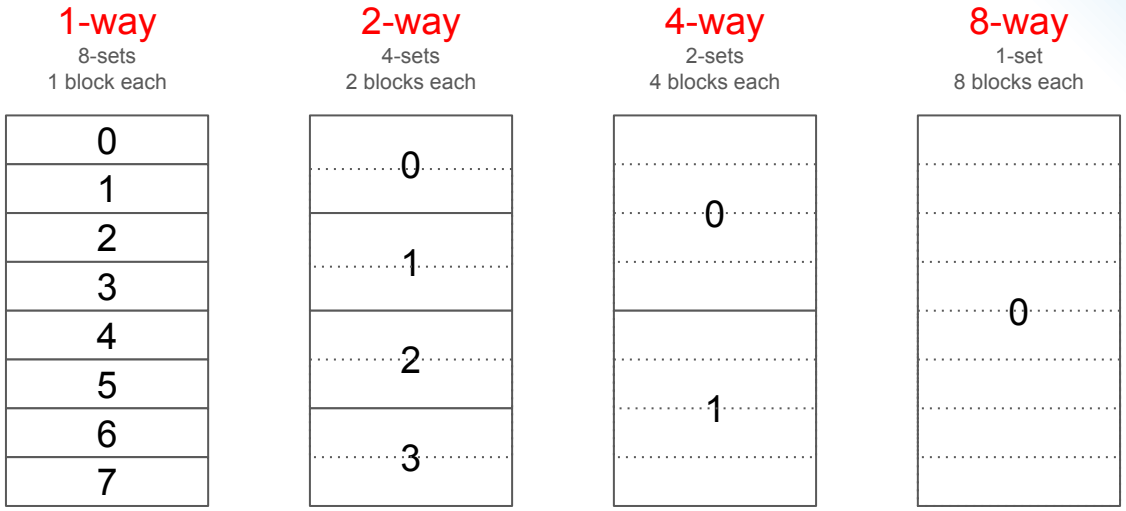
# n-way cache



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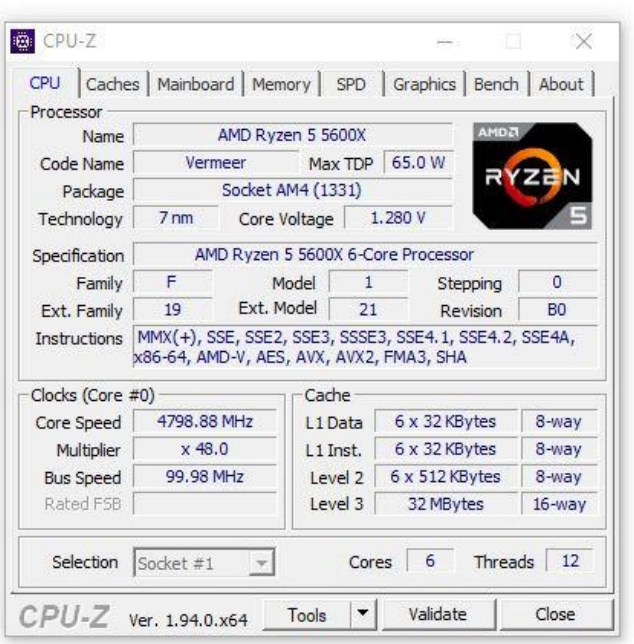
# Real Life

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# Explanation(L1)

line size = 4 kb
32-bit

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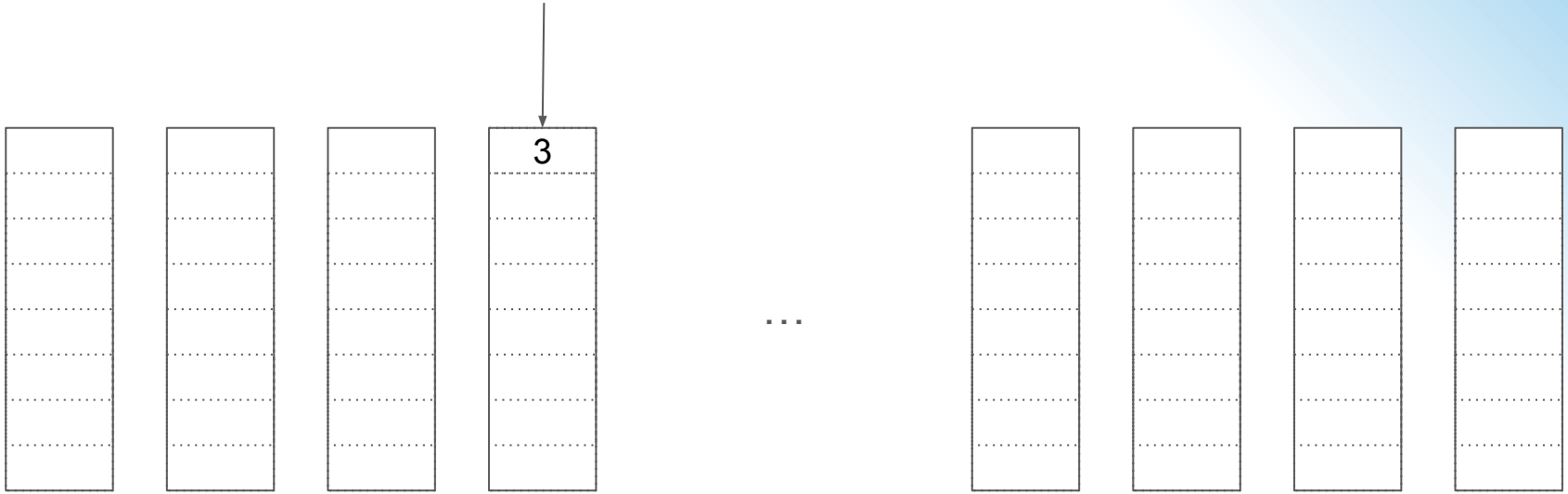
# Explanation(L1)

Insert 3
3 mod 16 = 3



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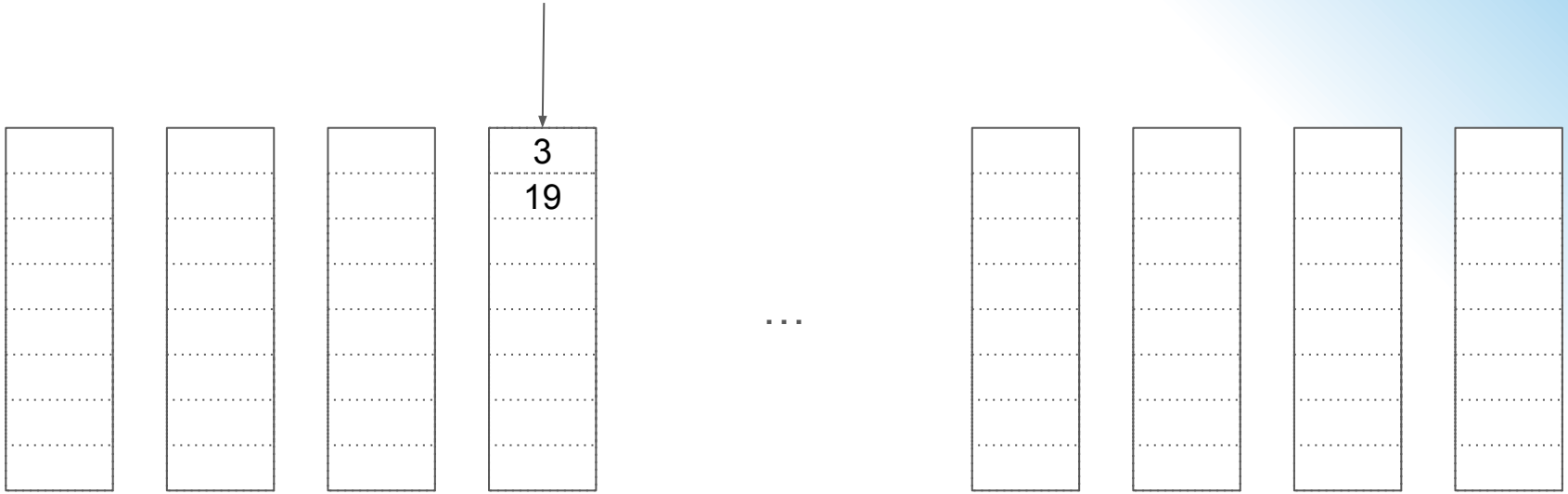
# Explanation(L1)

Insert 19
3 mod 16 = 3



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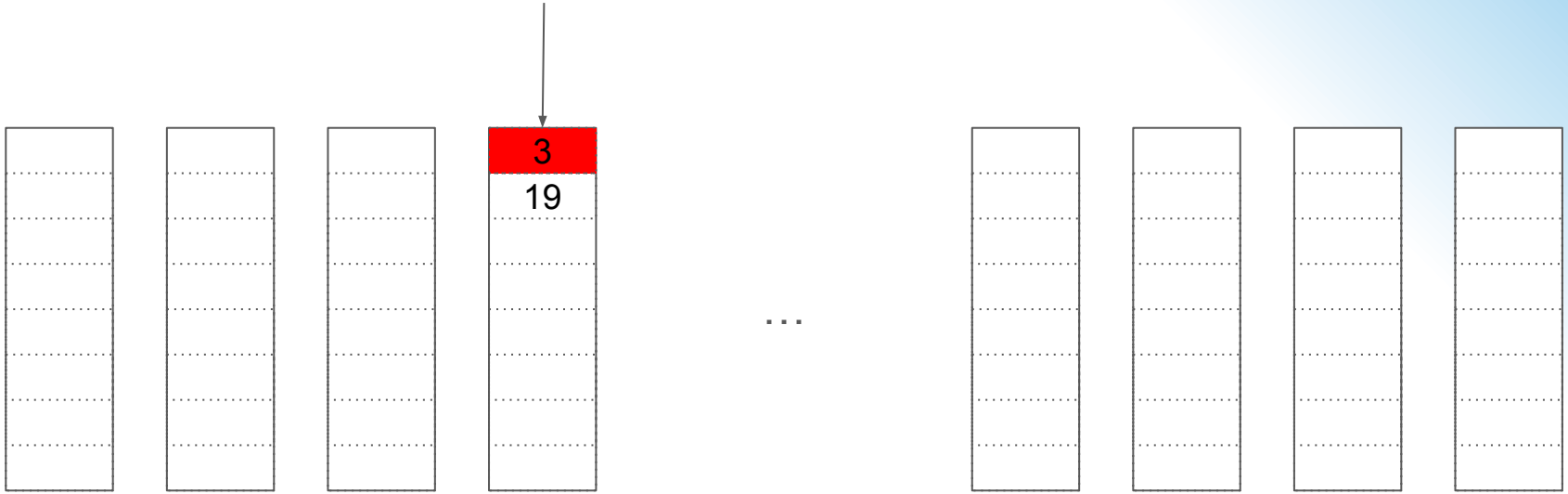
# Explanation(L1)

Find 35
35 mod 16 = 3



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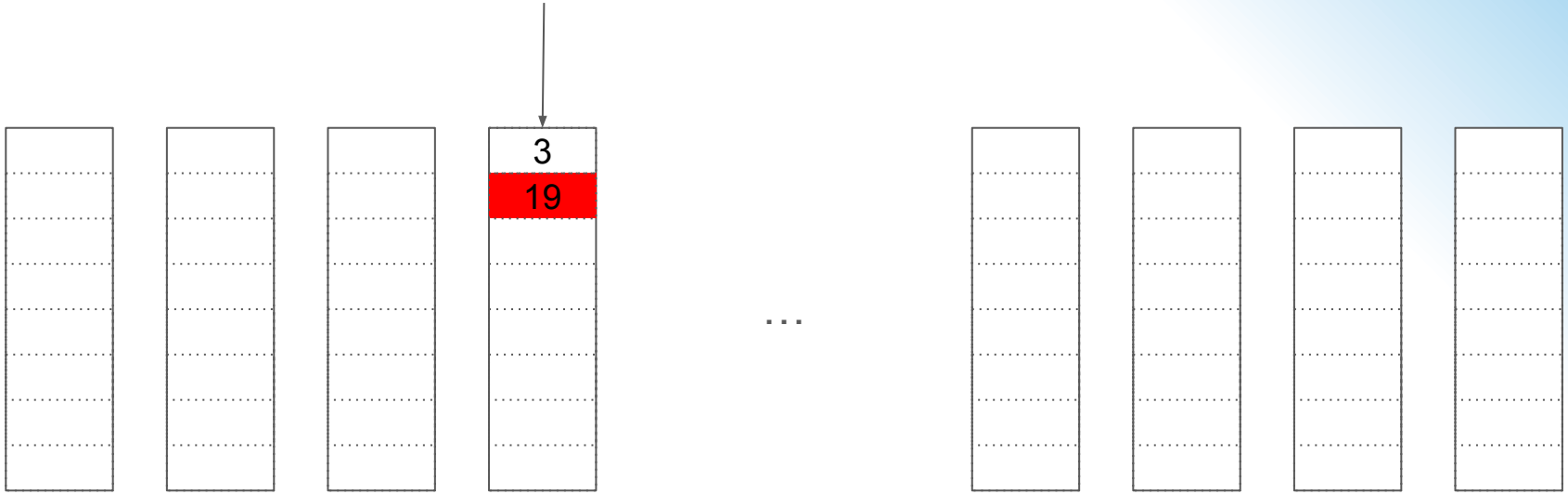
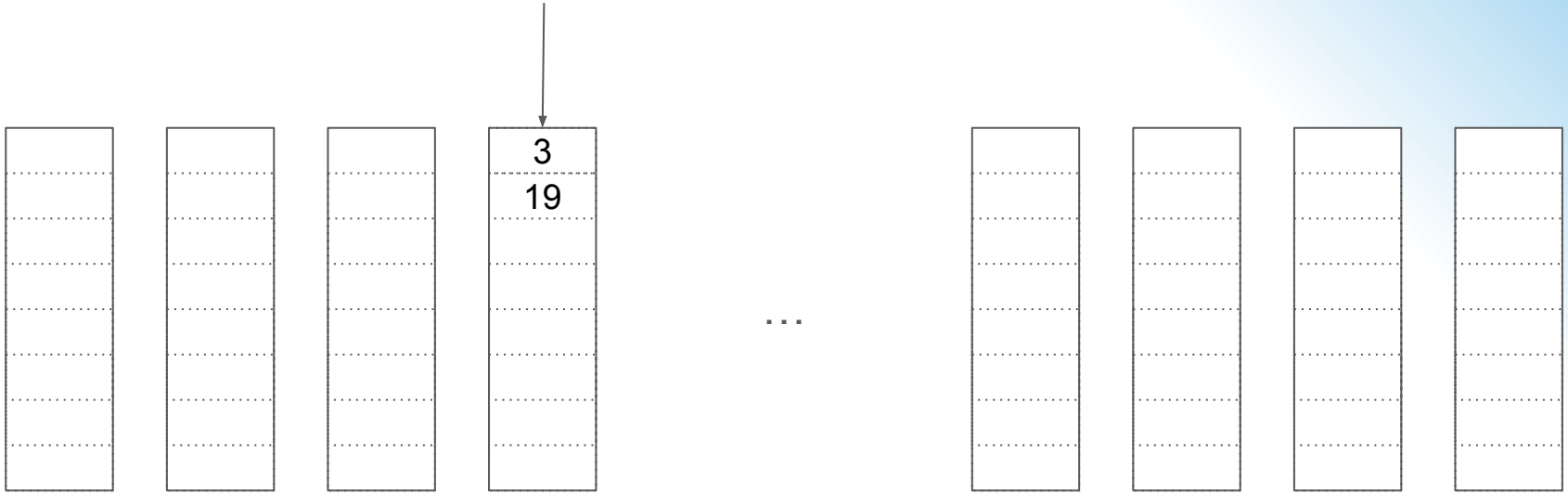
# Explanation(L1)

Find 35
35 mod 16 = 3



# Explanation(L1)





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# What to keep in cache?

1) LRU (Least Recently Used)
2) FIFO (First-In, First-Out)
3) LFU (Least Frequently Used)
4) MRU (Most Recently Used)
5) Random
6) LRU-k

maybe some others

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# LRU

| 1 | 2 | 3 | 4 | 5 | 1 | 3 | 1 | 6 | 3 | 2 | 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|

| 1 | 1 | 1 | 1 | 5 | 5 | 5 | 5 | 5 | 5 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| | | | 4 | 4 | 4 | 4 | 4 | 6 | 6 | 6 | 6 |
| M | M | M | M | M | M | H | H | M | H | M | H |

M = Miss
H = Hit

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# FIFO

Page reference stream:

| 1 | 2 | 3 | 2 | 1 | 5 | 2 | 1 | 6 | 2 | 5 | 6 | 3 | 1 | 3 | 6 | 1 | 2 | 4 | 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 5 | 1 | 6 | 6 | 2 | 5 | 5 | 3 | 3 | 1 | 6 | 2 |
| | 2 | 2 | 2 | 2 | 3 | 3 | 5 | 1 | 6 | 2 | 2 | 5 | 3 | 3 | 1 | 1 | 6 | 2 | 4 |
| | | 3 | 3 | 3 | 5 | 5 | 1 | 6 | 2 | 5 | 5 | 3 | 1 | 1 | 6 | 6 | 2 | 4 | 3 |
| * | * | * | | | * | | * | * | * | * | | * | * | | * | | * | * | * |

FIFO

Total 14 page faults

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# LFU

## Least Frequently Used (LFU)

| | x | | x | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 0 | 1 | 2 | 0 | 3 | 0 | 4 | 2 | 3 | 0 | 3 | 2 | 1 | 2 |
| 7 | 7 | 7 | 2 | 2 | 2 | | | | | | | | | |
| | 0 | 0 | 0 | 0 | 0 | | | | | | | | | |
| | | 1 | 1 | 1 | 3 | | | | | | | | | |
| F | F | F | F | | F | | | | | | | | | |

**Frequencies :**

7 = 0  0 = 2  1 = 0  2 = 1  3 = 1  4 = 0

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# LRU-k