Information Technology Fundamentals

Memory – Part 1

School of Information Technology and Mathematical Sciences

Memory Process

Data and instructions are typically stored on a hard drive.

They are then copied to main memory (RAM).

Then transferred to cache.

Before being moved to registers in the CPU.

We distinguish between memory and storage.

Storage is long term, typically *non-volatile*.

Can be *mutable* or *immutable*.

Memory is short-term and *mutable*.

It can be *volatile* or *non-volatile*.

Memory is typically RAM – Random Access Memory.

RAM is memory on which any address can be accessed in an equal amount of time.

Types of Memory

Main Memory

Cache Memory

Registers

Fastest, smallest and most expensive

Memory	Registers	Located on the microprocessor Volatile
	Caches	Between main memory and the microprocessor Volatile
	Main	Between the microprocessor, its caches and storage Usually volatile
	Storage	Hard drive, etc Non-volatile

Slowest, largest and cheapest

Memory organised by speed.

Memory speed depends on *efficiency* and *distance*.

Distance has a surprising impact: assume that data is propagated through copper at 1/3 speed of light in free space.

Using a 1 Ghz clock, a signal can propagate
10 cm in one clock cycle

If a signal to a RAM has to travel 10 cm, it is going to take at least 2 clock cycles to get a response

Memory scale:

* 120 GB Hard drive
* 2 GB memory
* 2 MB cache
* 1 KB registers

Memory scale:

Hard drive:RAM	1:60
Hard drive:Cache	1:60,000
Hard drive:Registers	1:120,000,000

Megabytes	10^6 or 1000KB or 2^{20}	1,000,000 or 1,024,000 or 1,048,576
Gigabytes	10^9 or 2^{30}	1,000,000,000 or 1,073,741,824
Terabytes	10^{12} or 2^{40}	1,000,000,000,000 or 1,099,511,627,776
And so on, up to…		
Yottabytes	10^{24} or 2^{80}	… or 1,208,925,819,614,629,174,706,176

Memory Management

Every memory location is identified by a numeric address.

Managing this is memory management hardware and software.

There are two goals: make it easy to insert data into memory; make the most of the available memory

Hardware includes memory circuitry, MMUs (Memory Management Units), caches, disks and registers.

Most computers need more more memory than they physically have available.

Therefore they use software to make the best use of the memory that they have.

Goals are to:

* Allow as many processes as possible
* Respond to memory requirements
* Prevent unauthorised changes to memory
* Implement these tasks as quickly as possible

Memory partitioning divides memory into portions.

Two options: fixed and variable width partitions.

Variable width partitions use different algorithms: best-fit, first-fit and largest-fit.

Both approaches result in fragmentation (internal or external)

Most processes won’t fit in full into memory.

Therefore the OS needs to work out how best to manage them.

Locality of Reference is an approach to predicting what data will be needed.

Three approaches:

Temporal Locaility

Spatial Locality

Sequential Locality

Paged memory exploits locality of reference.

Large processes are broken into pages,
relying on *concurrency*.

Main memory is broken into *frames*.
Each frame can hold one page.

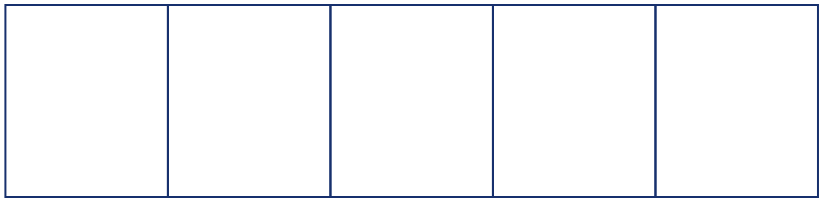
A page replacement algorithm is used to select each page.

The aim is to reduce *page faults.*

These, in turn, rely on locality of reference.

Longest Resident – evict the page
that has been in memory the longest

Frames (5)



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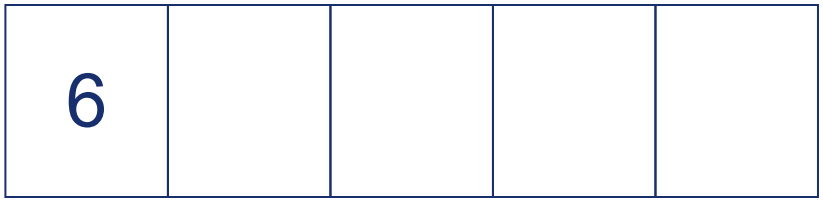

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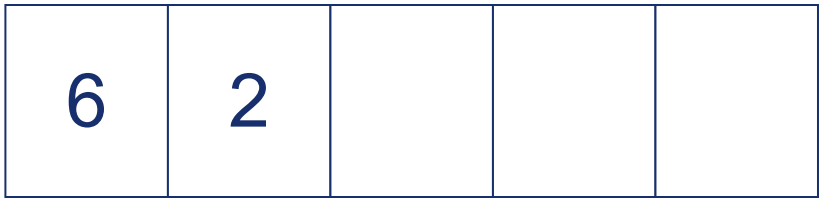

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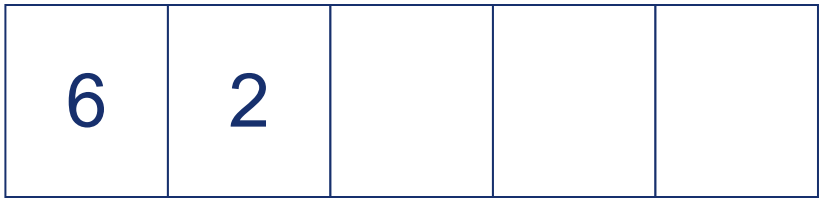

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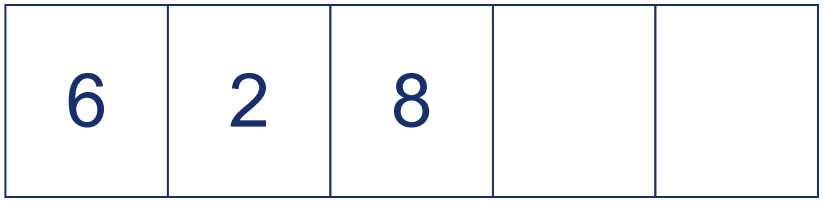

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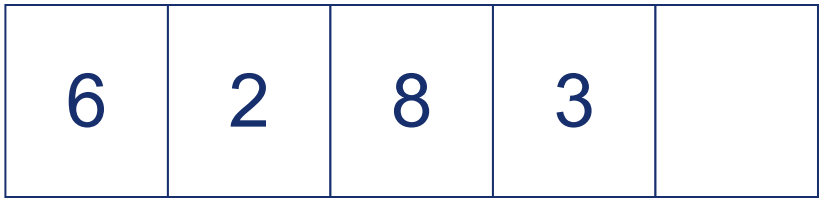

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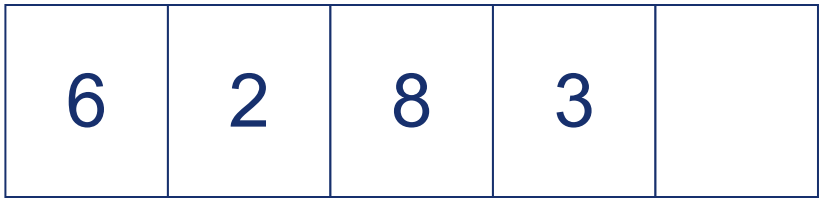

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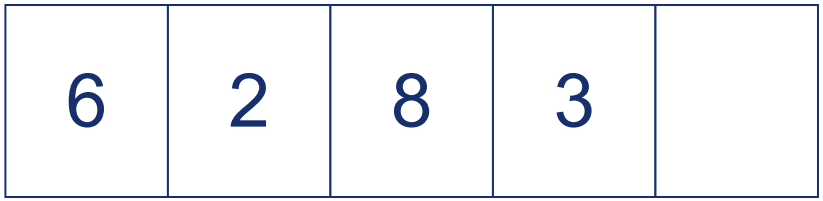

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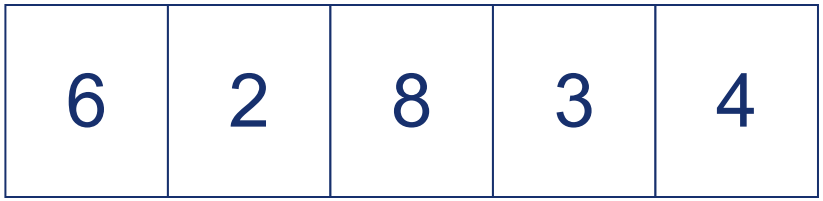

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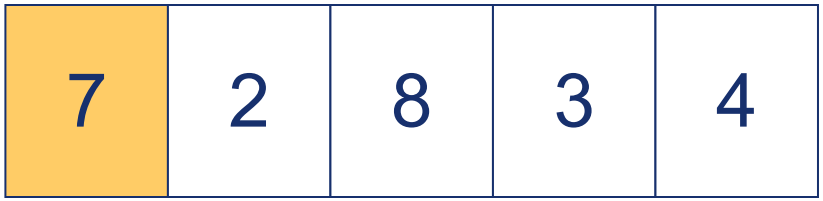

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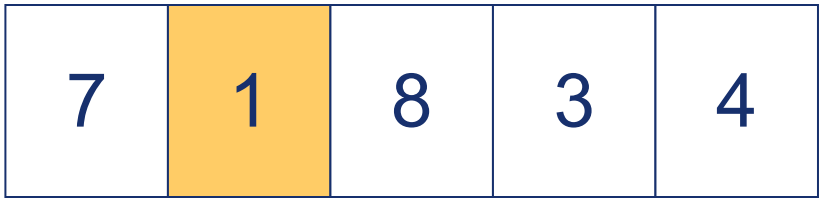

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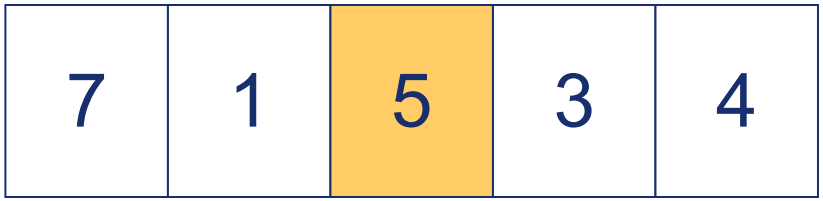

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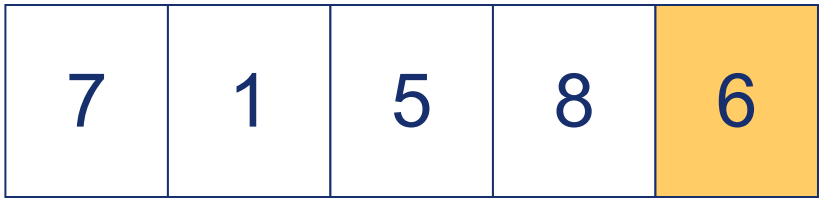

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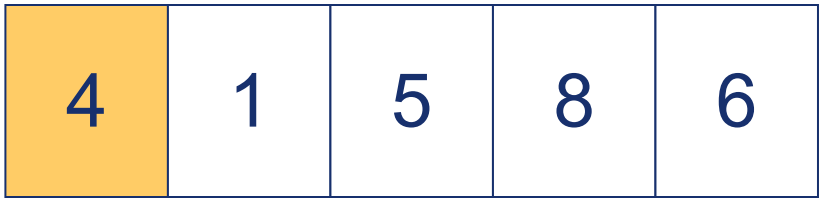

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Swaps

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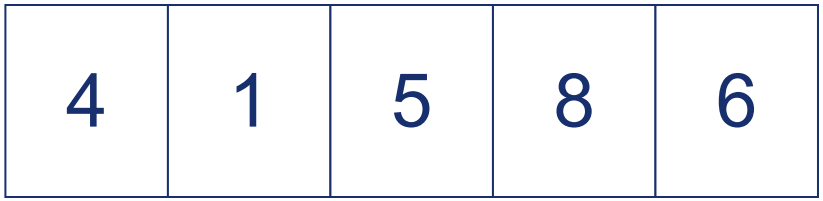

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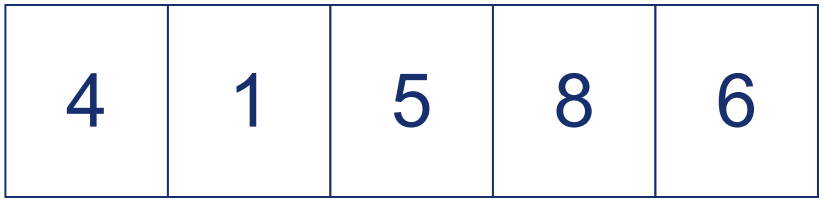

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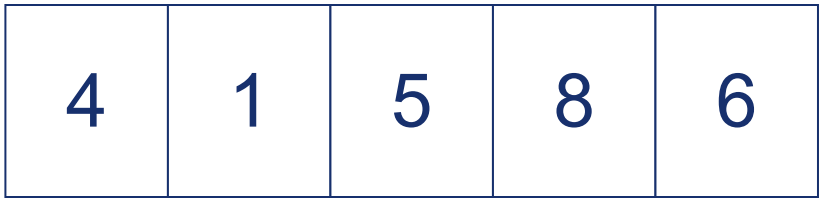

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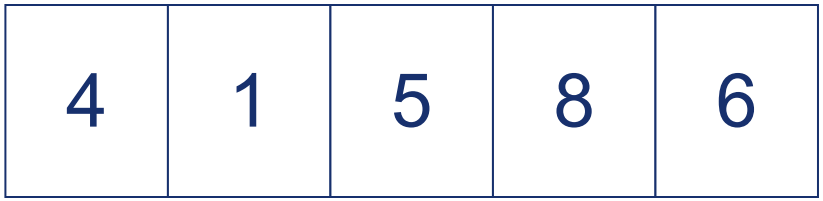

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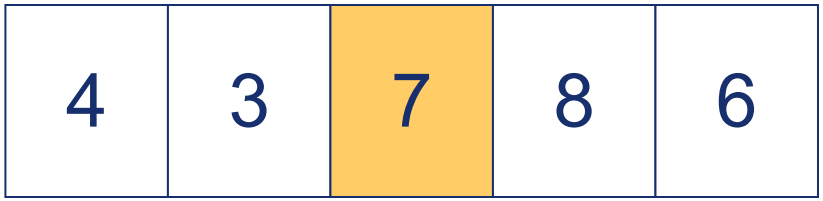

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Swaps

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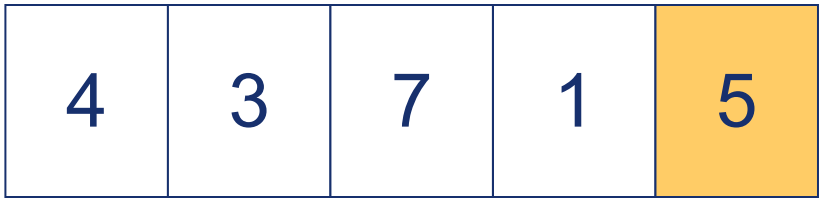

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Swaps

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Least Recently Used – evict the page
that has been there the longest without being used.

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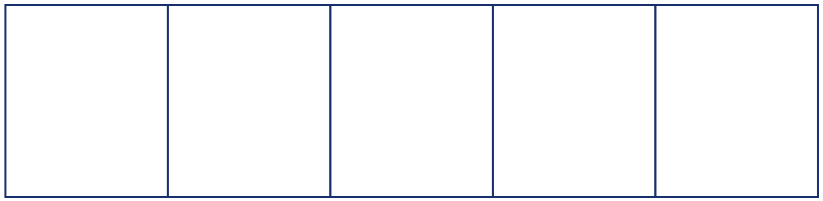

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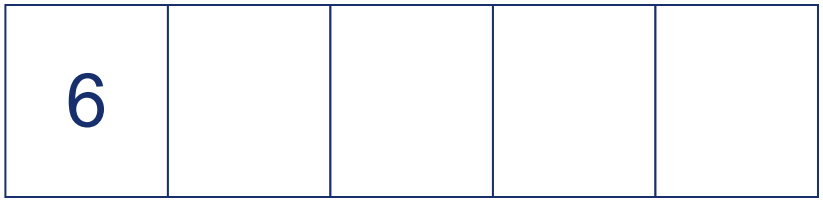

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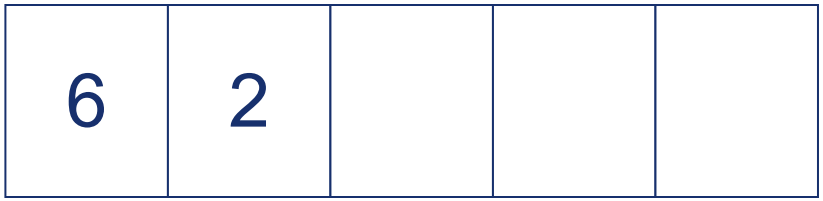

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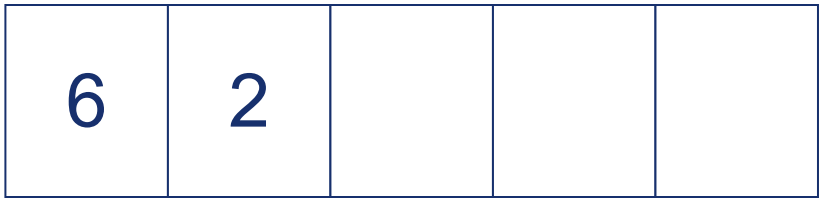

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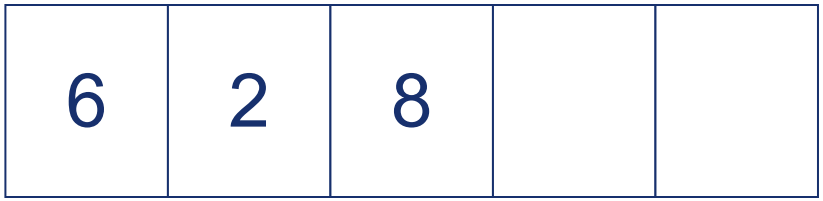

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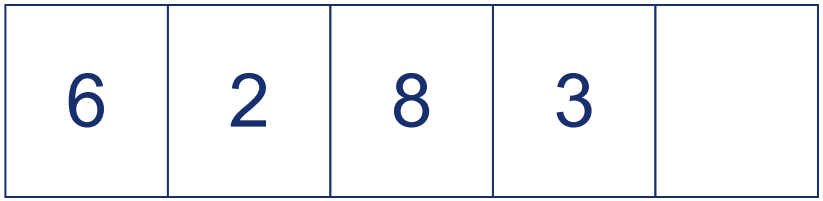

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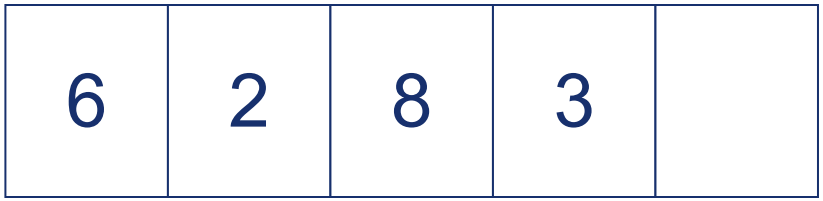

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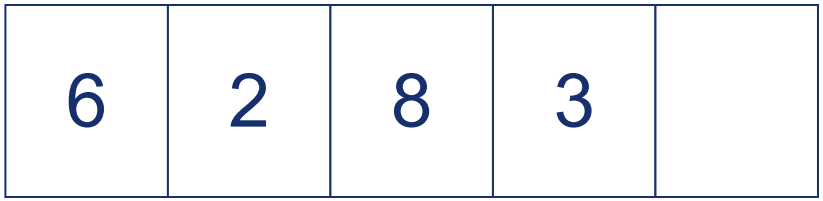

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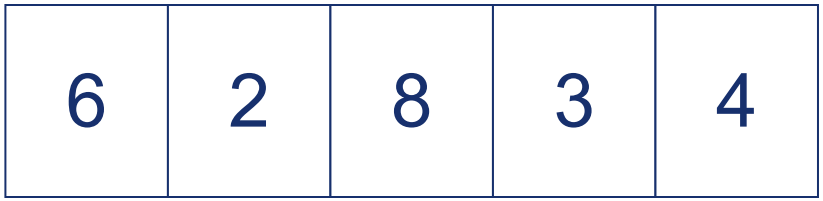

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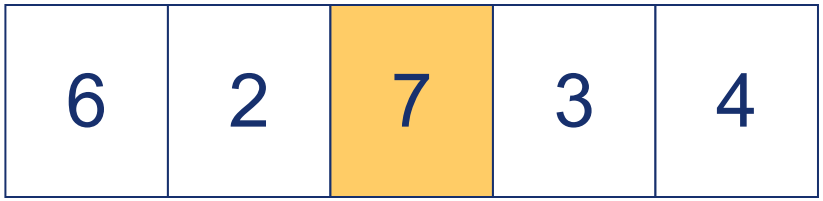

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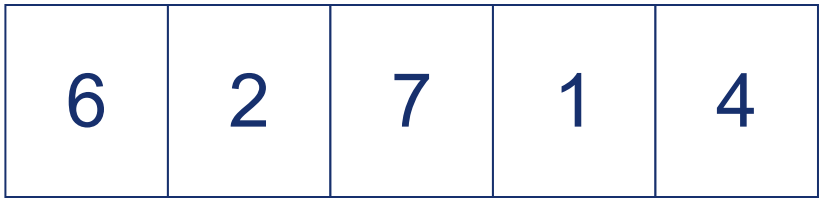

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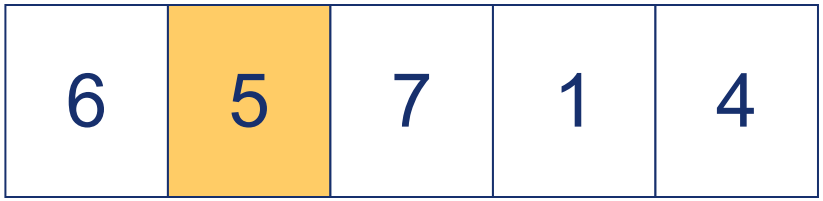

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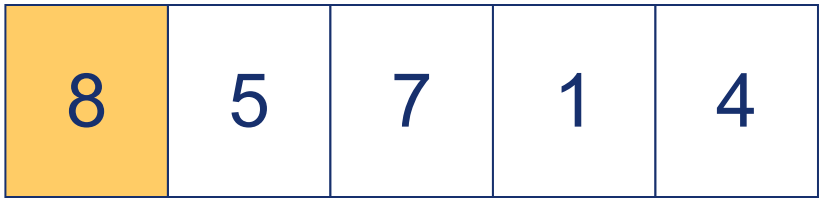

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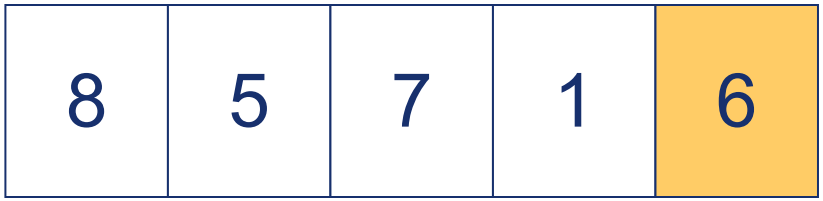

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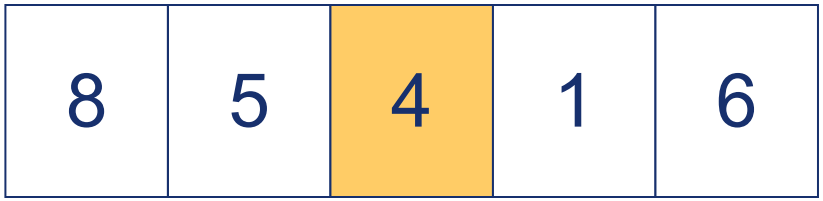

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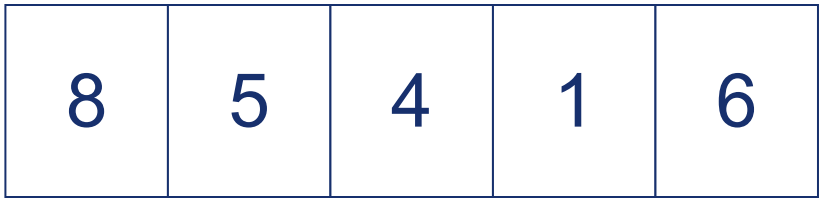

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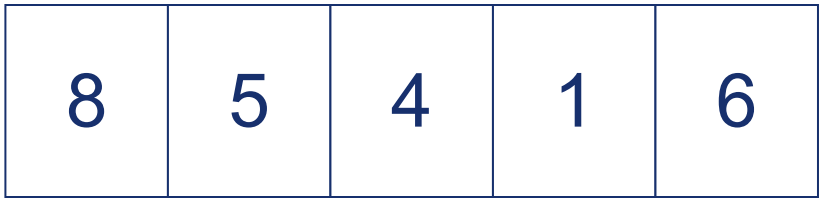

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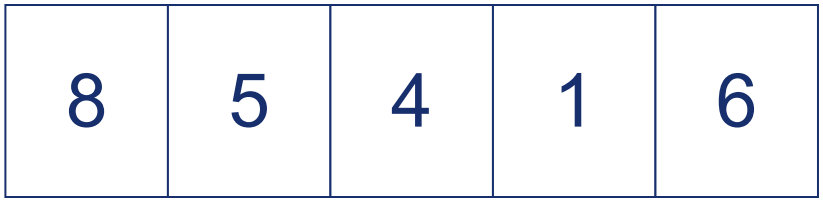

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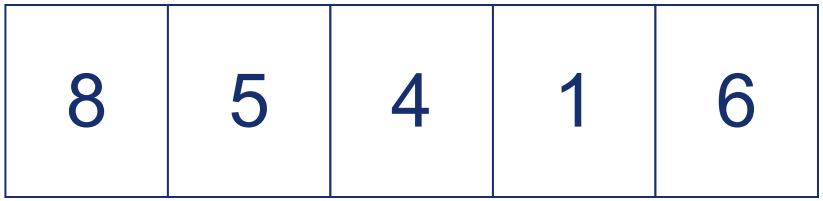

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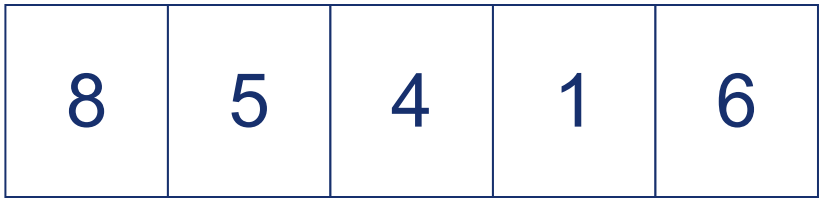

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Swaps

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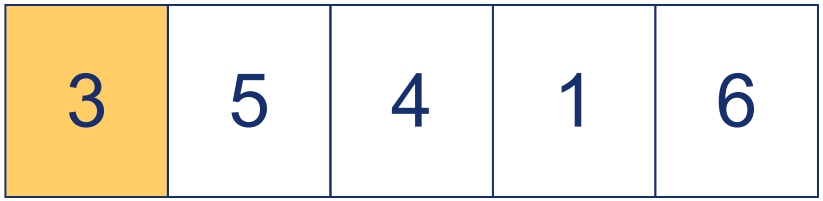
Frames (5)



Required Pages

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Swaps

7

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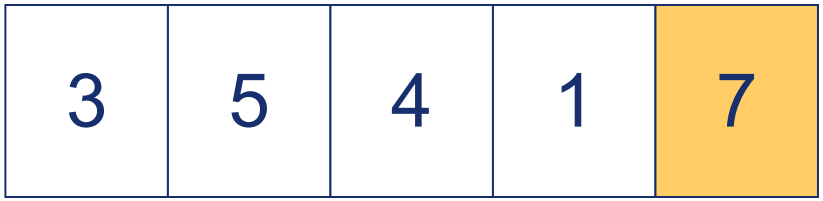

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Swaps

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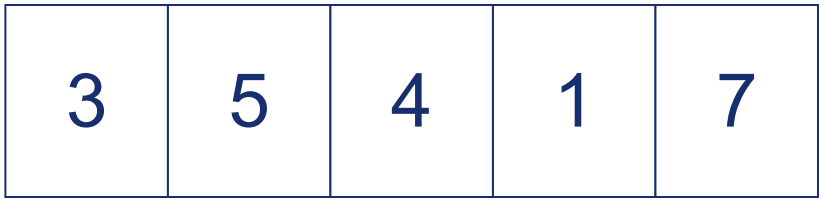

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Swaps

8

Frames (5)

3	5	4	1	7

Required Pages

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Swaps

8

Least Frequently Used – evict the page that has been used the least.

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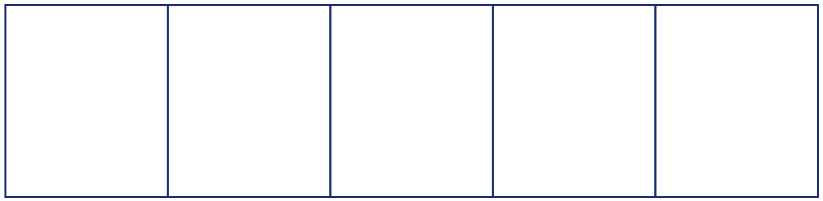

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Swaps

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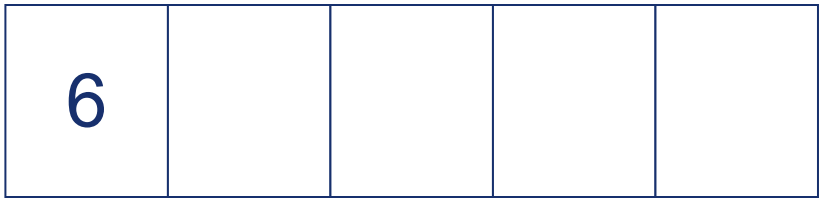

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Swaps

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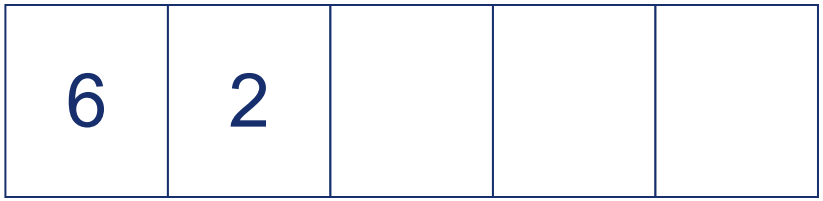

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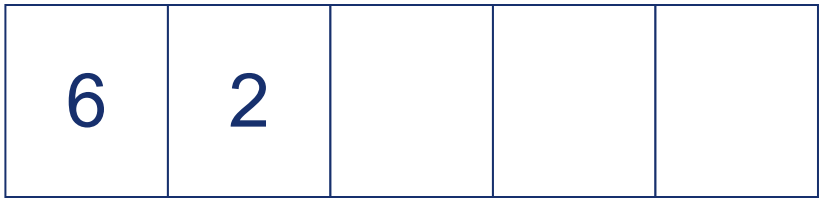

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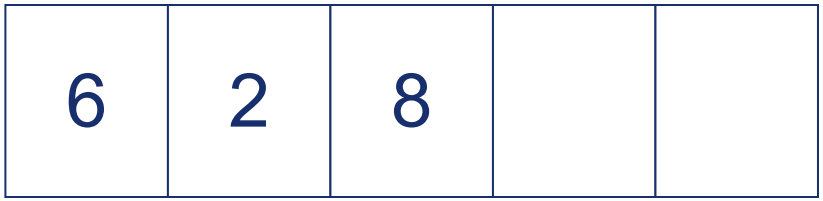

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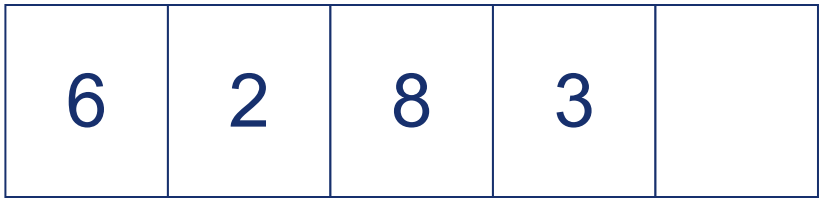

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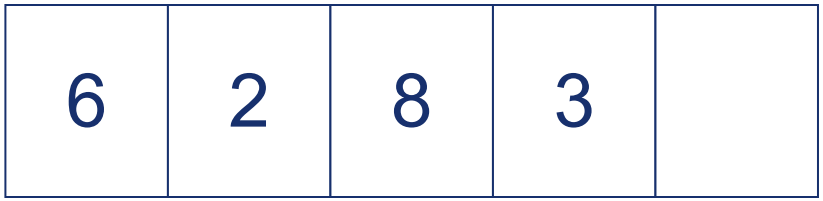

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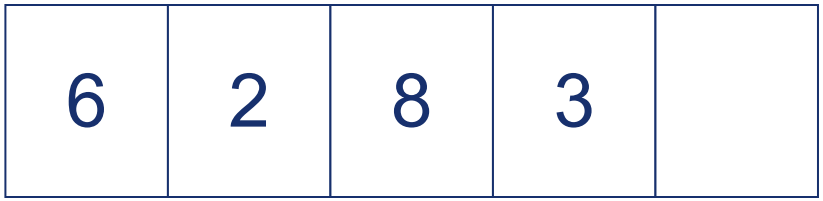

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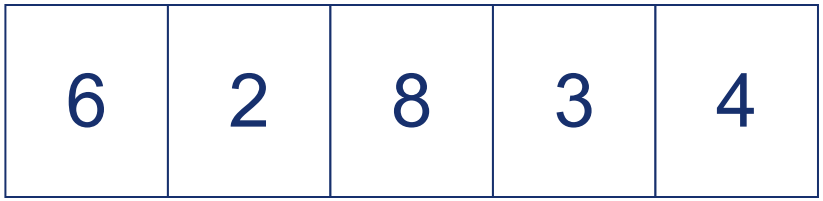

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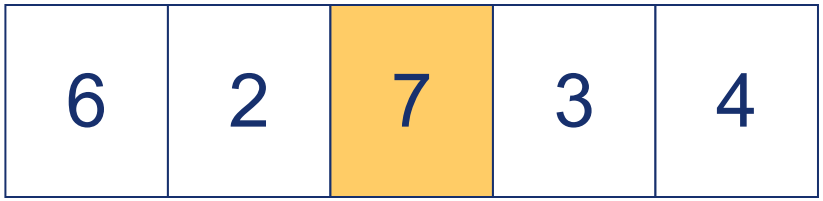

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Swaps

1

Least Frequently Used

Frames (5)

Required Pages

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Swaps

2

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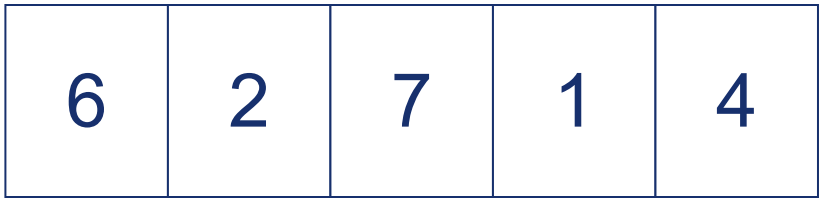

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Swaps

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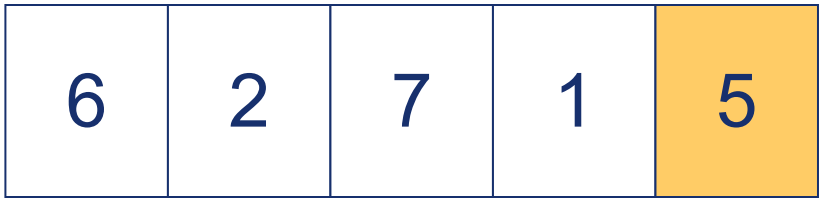

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Swaps

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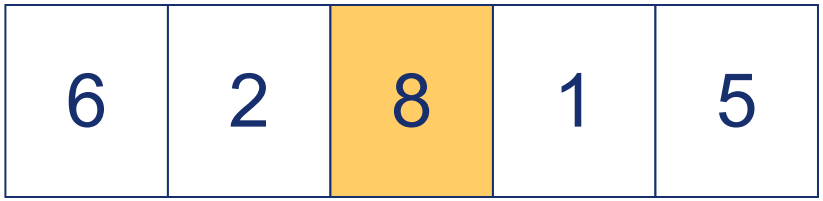

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Swaps

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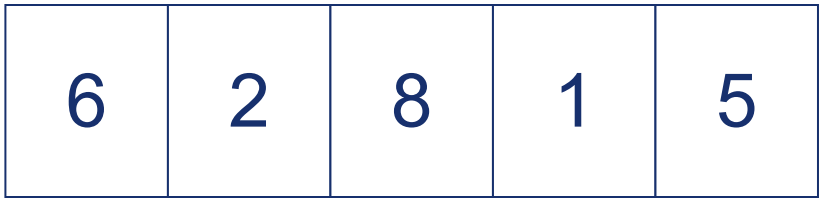

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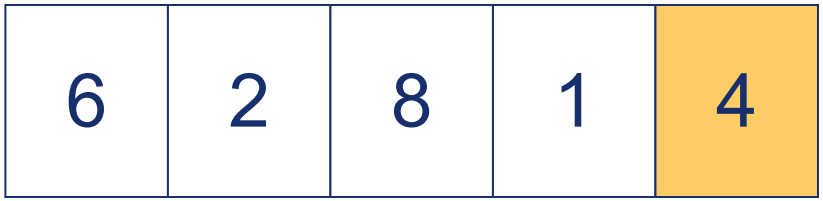

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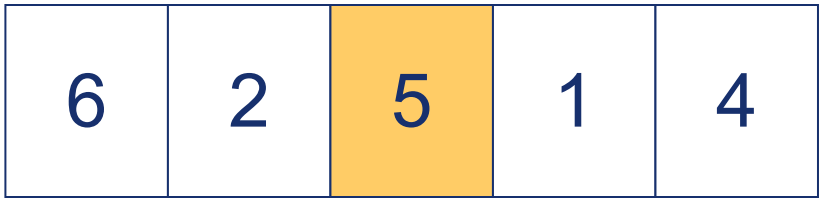

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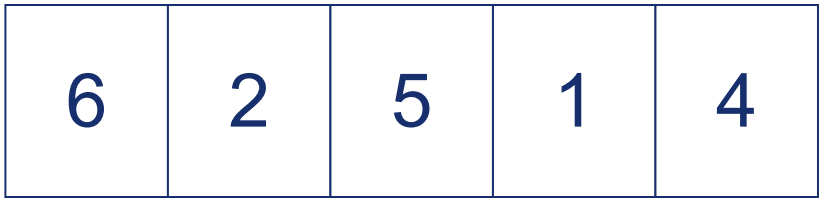

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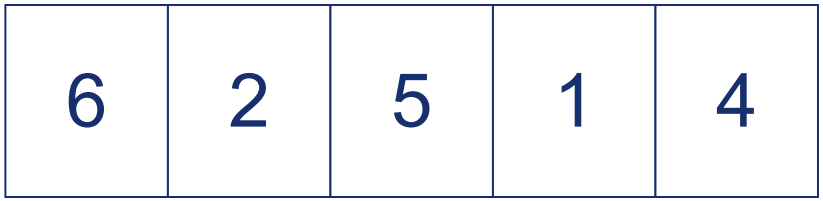

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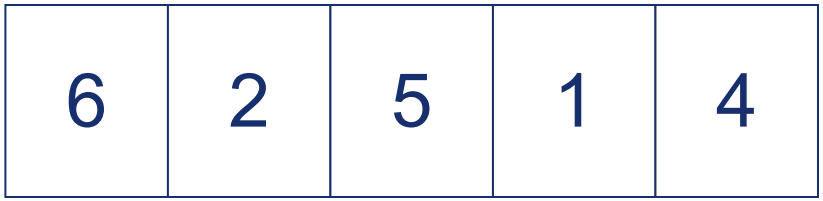

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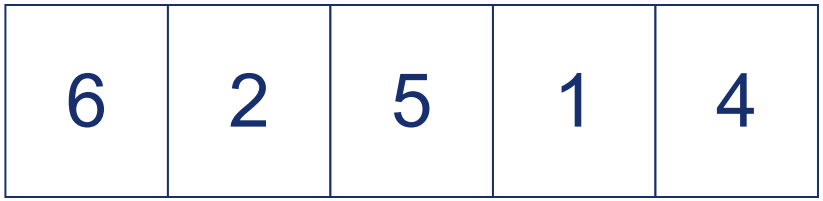

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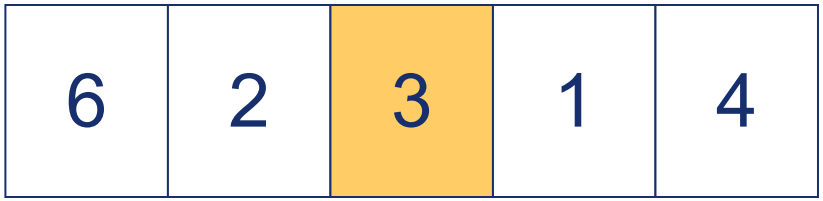

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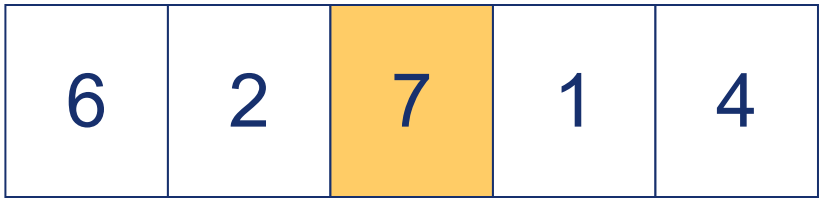

Required Pages

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Swaps

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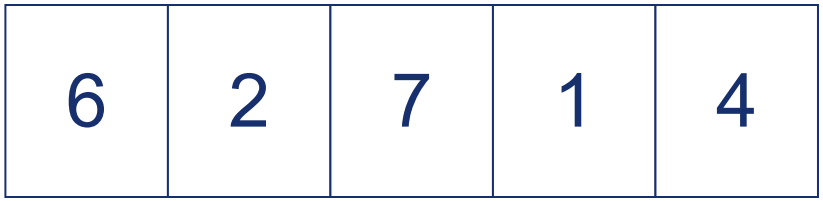

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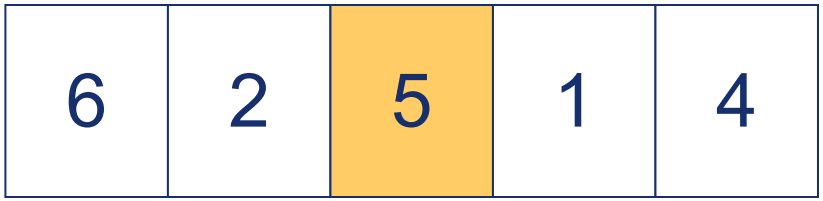

Required Pages

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Swaps

9