



Operating Systems

# Virtual Memory

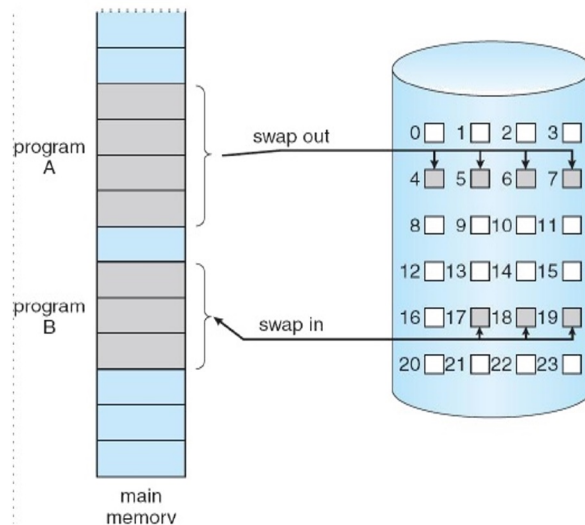


# Background

- ❑ The term “virtual memory” refers to something which appears to be present but actually it is not.
- ❑ The virtual memory technique allows users to use more memory for a program than the real memory of a computer.
- ❑ Virtual memory is a concept that we use when we have processes that exceed the main memory.
- ❑ When computer runs out of physical memory, it writes its requirement to the hard disc in a swap file as “virtual memory”.

# Demand Paging

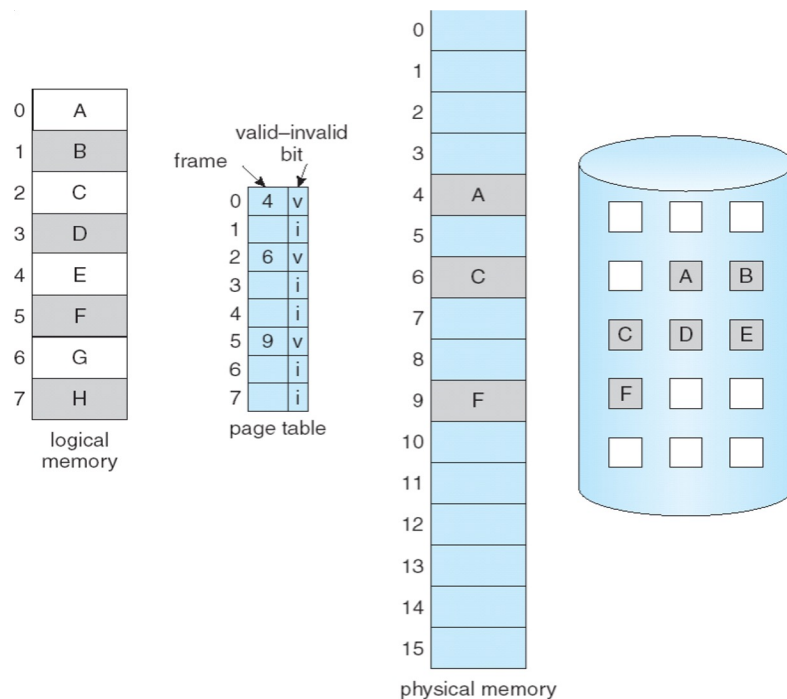
- ❑ Bring a page **into memory** only when it is needed
  - Less I/O needed
  - Less memory needed
  - **Faster** response
  - **More users**
- ❑ Disadvantage: **Page fault interrupt**
- ❑ Required hardware support:
  - Page Table with **valid-invalid bit**
  - Secondary memory



**Demand Paging in OS**

# Valid-Invalid Bit

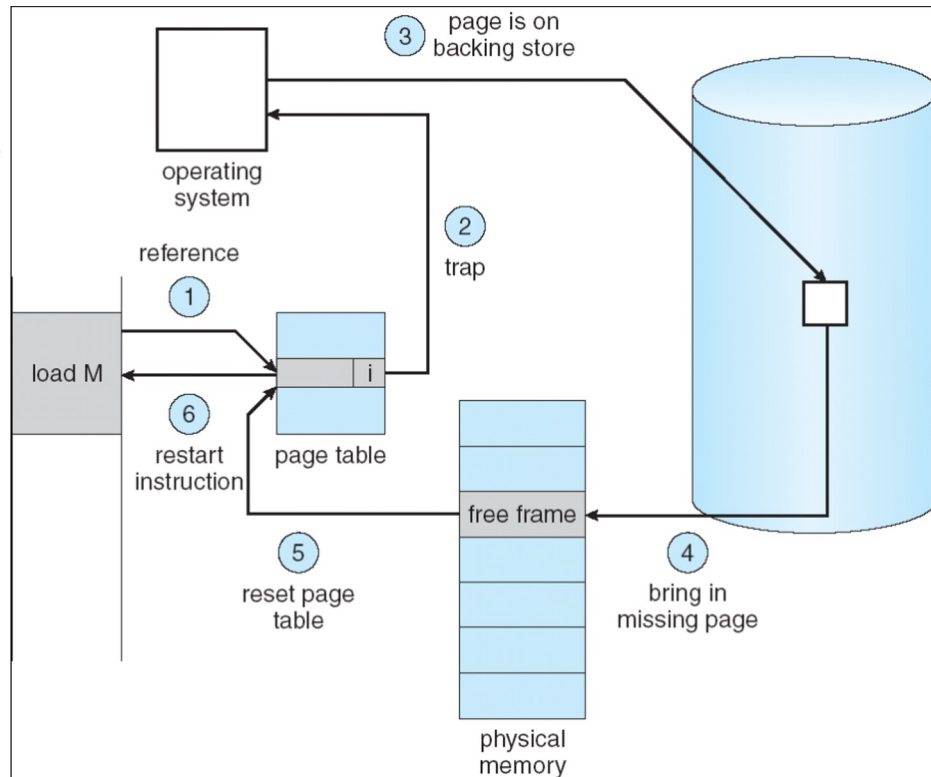
- ❑ An extra bit in the page table which indicates the existence of the page in the main memory.
- ❑ Attempt to access page
- ❑ If page is valid (in memory) then continue processing instruction as normal.
- ❑ If page is invalid then a page-fault trap / page-fault interrupt occurs.
- ❑ Page is needed  $\Rightarrow$  reference to it
  - Invalid reference  $\Rightarrow$  abort
  - Not-in-memory  $\Rightarrow$  bring to memory



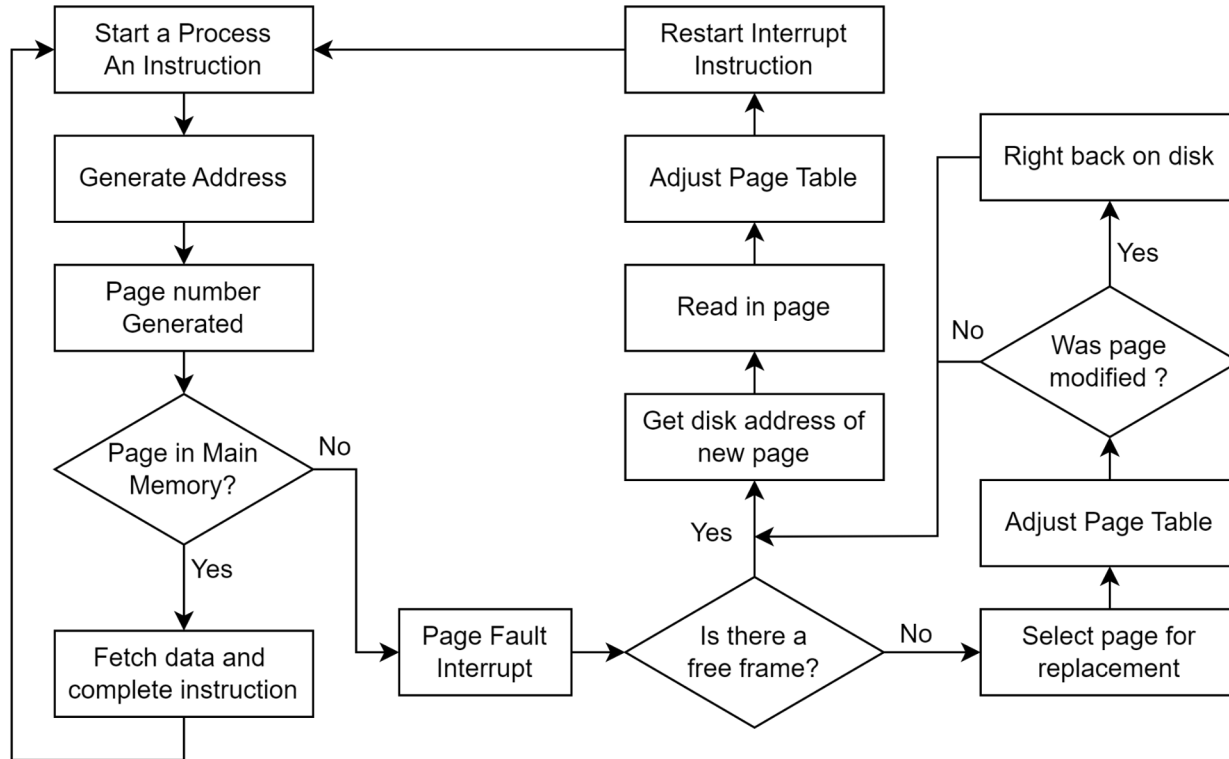
# Page Fault

If there is ever a reference to a page, first reference trap to OS ⇒ **page fault**

1. OS looks at another table to decide:
  - Invalid reference ⇒ **abort**.
  - Just **not in** memory.
2. Find empty/ free frame.
3. Load page **from disk** into frame.
4. Reset tables, **validation bit = 1**.
5. **Restart instruction** that caused **page fault**



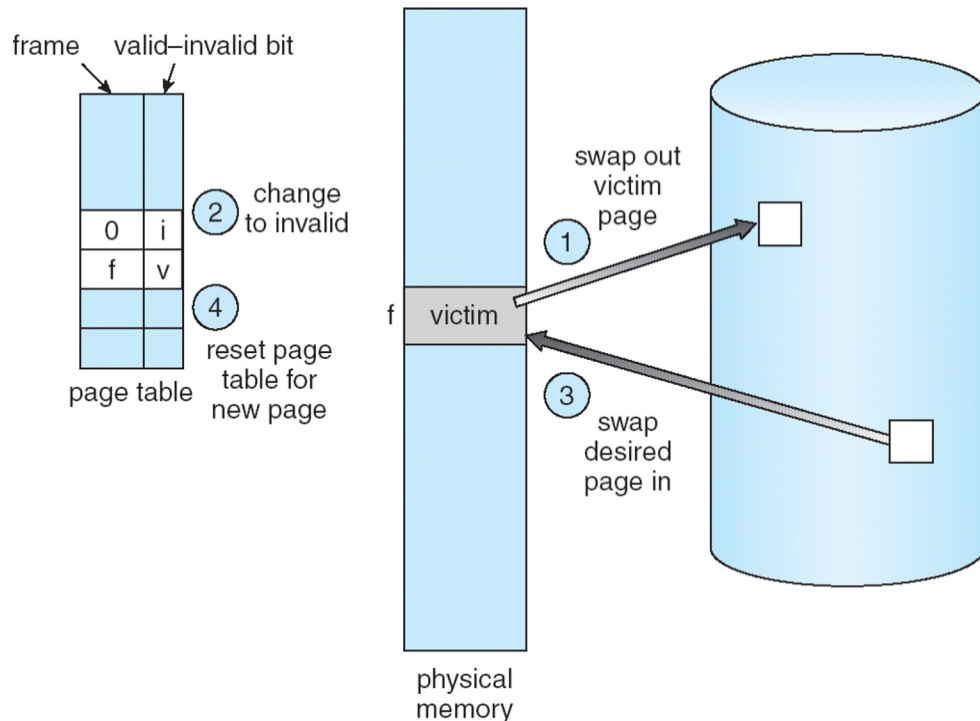
# Demand Paging Flowchart



# Page Replacement

## Page Replacement Algorithms:

- ❑ FIFO (First In First Out)
- ❑ LRU (Least Recently Used)
- ❑ OPT (Optimal)



# FIFO (First In First Out)

- ❑ Selects the page for replacement that has been in the memory for the longest amount of time

time	1	2	3	4	5	6	7	8	9	10	11	12
page	p2	p3	p2	p1	p5	p2	p4	p5	p3	p2	p5	p2
	p2*	p2*	p2*	p2*	p5	p5	p5*	p5*	p3	p3	p3	p3*
		p3	p3	p3	p3*	p2	p2	p2	p2*	p2*	p5	p5
			p1	p1	p1*	p4	p4	p4	p4	p4	p4*	p2
		hit				hit			hit			



# LRU (Least Recently Used)

Less Used

- ❑ Replace the least recently used page in the past
- ❑ Can be implemented by associating a counter with every page that is in main memory

time	1	2	3	4	5	6	7	8	9	10	11	12
page	p2	p3	p2	p1	p5	p2	p4	p5	p3	p2	p5	p2
	<div> <div>p2*</div> <div></div> <div></div> </div>	<div> <div>p2*</div> <div>p3</div> <div></div> </div>	<div> <div>P2</div> <div>p3*</div> <div></div> </div> <div>hit</div>	<div> <div>P2</div> <div>p3*</div> <div>P1</div> </div>	<div> <div>p2*</div> <div>P5</div> <div>P1</div> </div>	<div> <div>P2</div> <div>P5</div> <div>P1*</div> </div> <div>hit</div>	<div> <div>P2</div> <div>p5*</div> <div>p4</div> </div>	<div> <div>p2*</div> <div>P5</div> <div>P4</div> </div> <div>hit</div>	<div> <div>P3</div> <div>P5</div> <div>p4*</div> </div>	<div> <div>P3</div> <div>P5*</div> <div>P2</div> </div>	<div> <div>P3*</div> <div>P5</div> <div>P2</div> </div> <div>hit</div>	<div> <div>P3*</div> <div>P5</div> <div>p2</div> </div> <div>hit</div>

# Optimal

- Replace the page which is **not used in longest dimension** of time **in future**

time	1	2	3	4	5	6	7	8	9	10	11	12
page	p2	p3	p2	p1	p5	p2	p4	p5	p3	p2	p5	p2
	<div><div>p2</div><div></div><div></div></div>	<div><div>p2</div><div>p3</div><div></div></div>	<div><div>P2</div><div>p3</div><div></div></div>	<div><div>P2</div><div>p3</div><div>P1</div></div>	<div><div>P2</div><div>P3</div><div>P5</div></div>	<div><div>P2</div><div>P3</div><div>P5</div></div>	<div><div>P4</div><div>P3</div><div>p5</div></div>	<div><div>P4</div><div>P3</div><div>P5</div></div>	<div><div>P4</div><div>P3</div><div>p5</div></div>	<div><div>P2</div><div>P3</div><div>P5</div></div>	<div><div>P2</div><div>P3</div><div>P5</div></div>	<div><div>P2</div><div>P3</div><div>P5</div></div>
			hit		hit		hit	hit		hit	hit	

Here, this one is optimal as it has only 6 page replacement