



Operating Systems

Virtual Memory

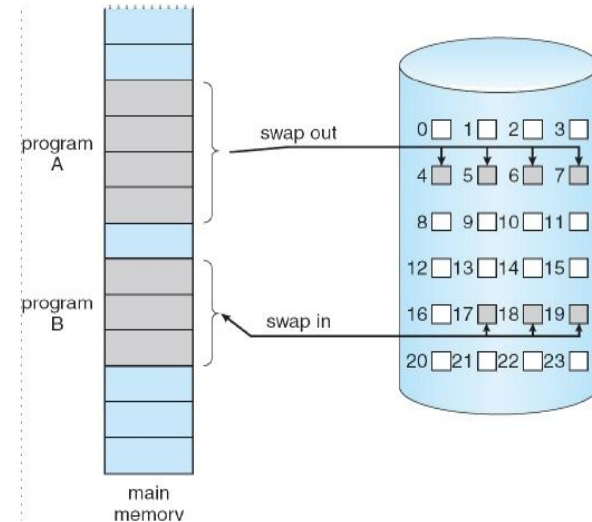


Background

- ❑ 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

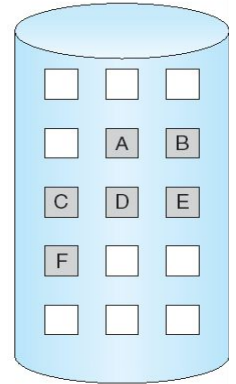
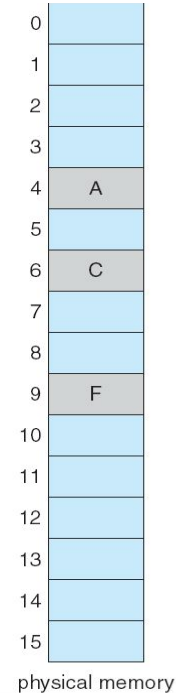
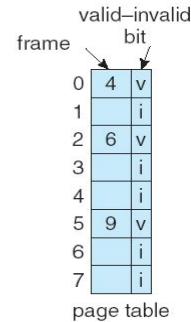
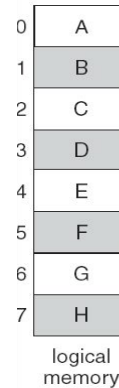
- ❑ Bring a page into memory only when it is needed
 - Less I/O needed
 - Less memory needed
 - Faster response
 - More users
- ❑ Disadvantage: Page fault interrupt
- ❑ Required hardware support:
 - Page Table with valid-invalid bit
 - Secondary memory



Demand Paging in OS

Valid-Invalid Bit

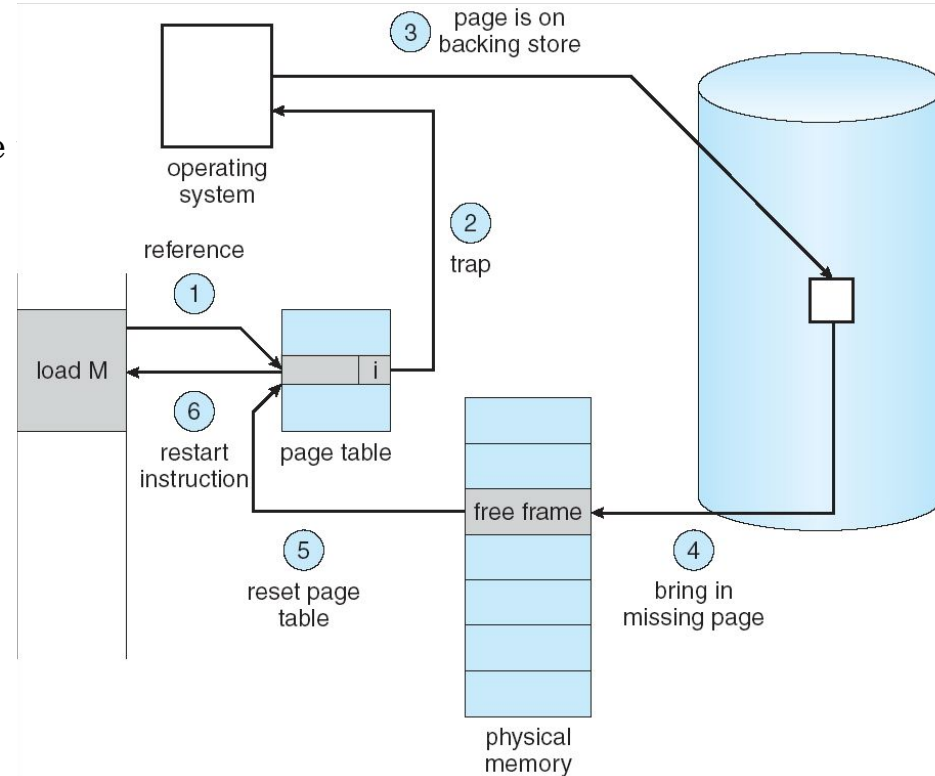
- ❑ An extra bit in the page table which indicates the existence of the page in the main memory.
- ❑ Attempt to access page
- ❑ If page is valid (in memory) then continue processing instruction as normal.
- ❑ If page is invalid then a page-fault trap / page-fault interrupt occurs.
- ❑ Page is needed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



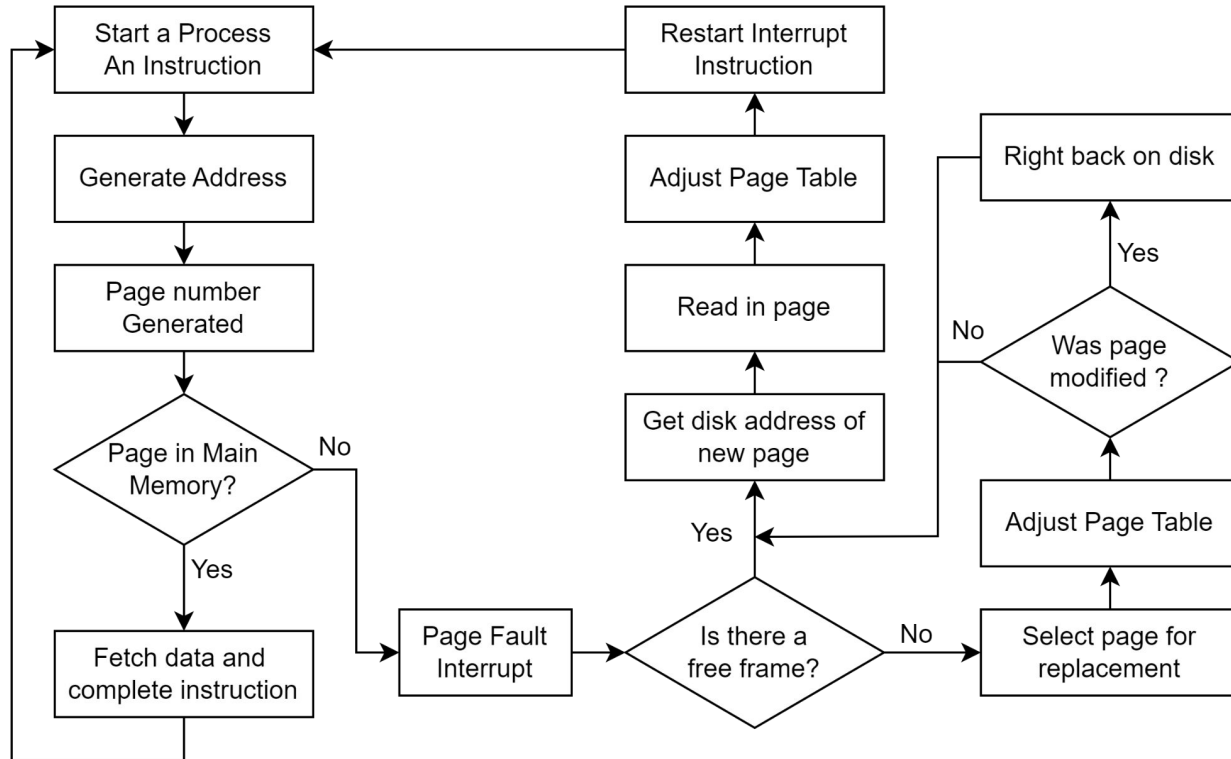
Page Fault

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

1. OS looks at another table to decide:
 - Invalid reference \Rightarrow 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



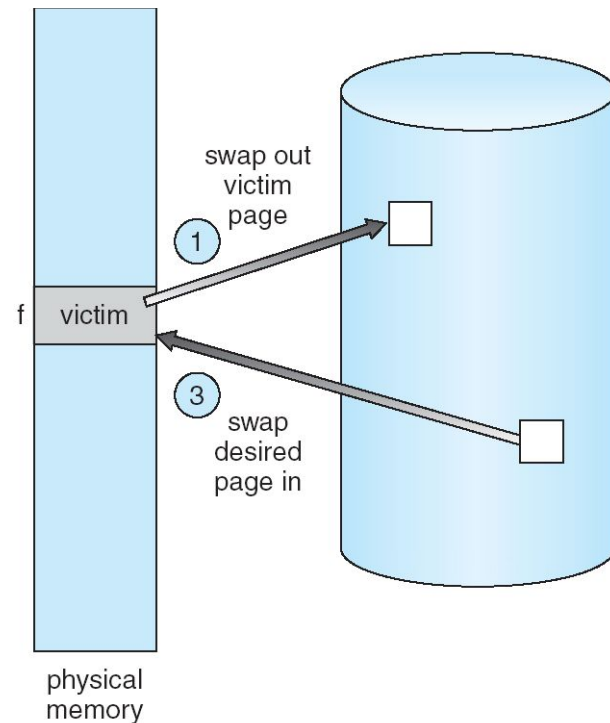
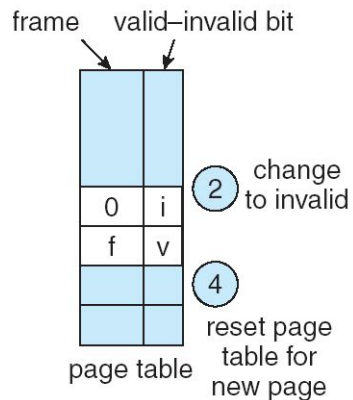
Demand Paging Flowchart



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
	<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>P5</div> <div>p3*</div> <div>p1</div> </div>	<div> <div>p5</div> <div>P2</div> <div>P1*</div> </div>	<div> <div>p5*</div> <div>P2</div> <div>p4</div> </div>	<div> <div>p5*</div> <div>P2</div> <div>p4</div> </div> <div>hit</div>	<div> <div>P3</div> <div>p2*</div> <div>p4</div> </div>	<div> <div>P3</div> <div>P2*</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>

LRU (Least Recently 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																																
	<table><tr><td>p2</td></tr><tr><td></td></tr><tr><td></td></tr></table>	p2			<table><tr><td>p2</td></tr><tr><td>p3</td></tr><tr><td></td></tr></table>	p2	p3		<table><tr><td>P2</td></tr><tr><td>p3</td></tr><tr><td></td></tr></table> hit	P2	p3		<table><tr><td>P2</td></tr><tr><td>p3</td></tr><tr><td>P1</td></tr></table>	P2	p3	P1	<table><tr><td>P2</td></tr><tr><td>P3</td></tr><tr><td>P5</td></tr></table> hit	P2	P3	P5	<table><tr><td>P2</td></tr><tr><td>P3</td></tr><tr><td>P5</td></tr></table>	P2	P3	P5	<table><tr><td>P4</td></tr><tr><td>P3</td></tr><tr><td>p5</td></tr></table> hit	P4	P3	p5	<table><tr><td>P4</td></tr><tr><td>P3</td></tr><tr><td>p5</td></tr></table> hit	P4	P3	p5	<table><tr><td>P2</td></tr><tr><td>P3</td></tr><tr><td>P5</td></tr></table>	P2	P3	P5	<table><tr><td>P2</td></tr><tr><td>P3</td></tr><tr><td>P5</td></tr></table> hit	P2	P3	P5	<table><tr><td>P2</td></tr><tr><td>P3</td></tr><tr><td>P5</td></tr></table> hit	P2	P3	P5
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