

OPERATING SYSTEMS

Memory Management

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Virtual Memory

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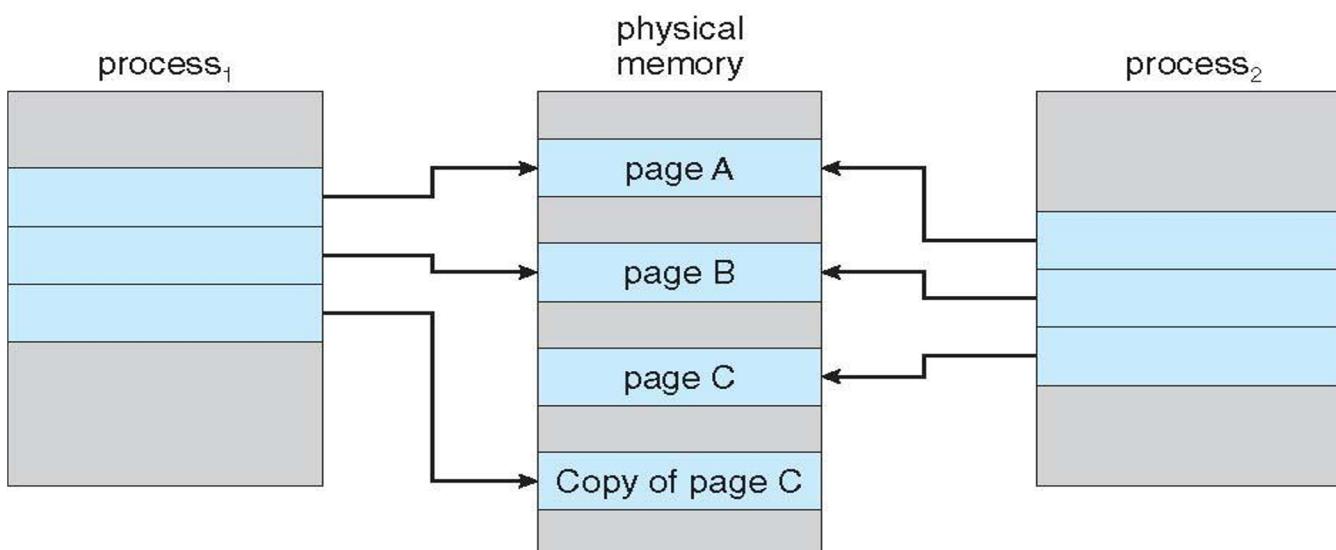
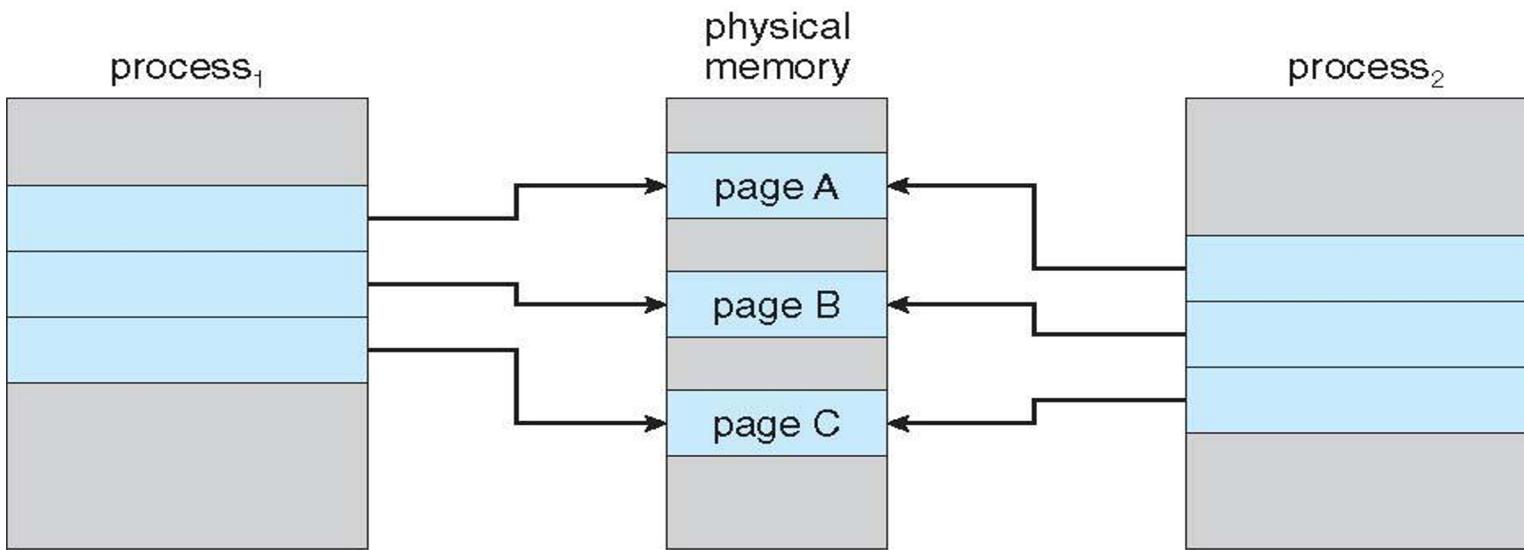
- The slides/diagrams in this course are an **adaptation, combination, and enhancement** of material from the following resources and persons:
1. Slides of Operating System Concepts, Abraham Silberschatz, Peter Baer Galvin, Greg Gagne - 9th edition 2013 and some slides from 10th edition 2018
 2. Some conceptual text and diagram from Operating Systems - Internals and Design Principles, William Stallings, 9th edition 2018
 3. Some presentation transcripts from A. Frank – P. Weisberg
 4. Some conceptual text from Operating Systems: Three Easy Pieces, Remzi Arpaci-Dusseau, Andrea Arpaci Dusseau

Copy-on-Write

- Copy-on-Write (COW) allows both parent and child processes to initially *share* the same pages in memory
 - If either process modifies a shared page, only then is the page copied
- COW allows more efficient process creation as only modified pages are copied
- In general, free pages are allocated from a pool of zero-fill-on-demand pages
 - Pool should always have free frames for fast demand page execution
 - 4 Don't want to have to free a frame as well as other processing on page fault
 - Why zero-out a page before allocating it?
- vfork() variation on fork() system call has parent suspend and child using copy-on-write address space of parent
 - Designed to have child call exec()
 - Very efficient

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Before and After Process 1 Modifies Page C

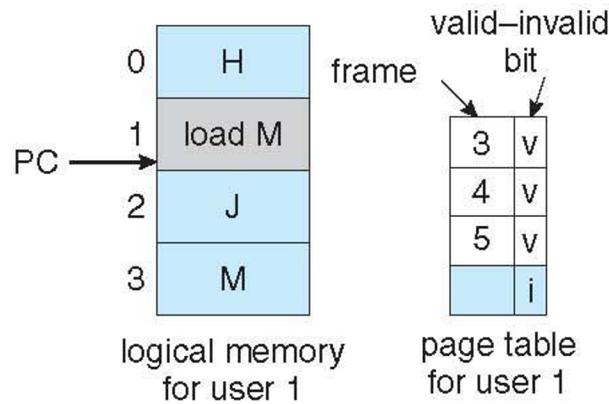


What Happens if There is no Free Frame?

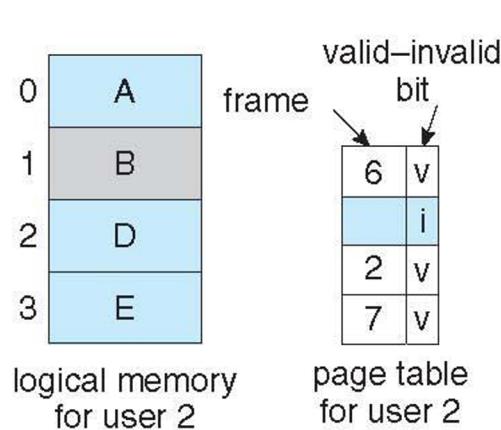
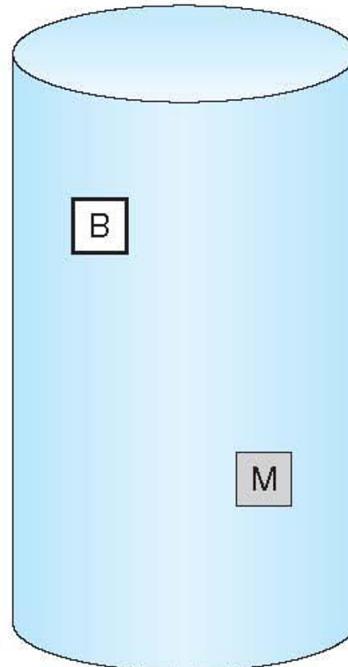
- Used up by process pages
- Also in demand from the kernel, I/O buffers, etc
- How much to allocate to each?
- Page replacement – find some page in memory, but not really in use, page it out
 - Algorithm – terminate? swap out? replace the page?
 - Performance – want an algorithm which will result in minimum number of page faults
- Same page may be brought into memory several times

- Prevent **over-allocation** of memory by modifying page-fault service routine to include page replacement (vs simply increasing degree of multiprogramming)
- Use **modify (dirty) bit** to reduce overhead of page transfers – only modified pages are written to disk
- Page replacement completes separation between logical memory and physical memory – large virtual memory can be provided on a smaller physical memory

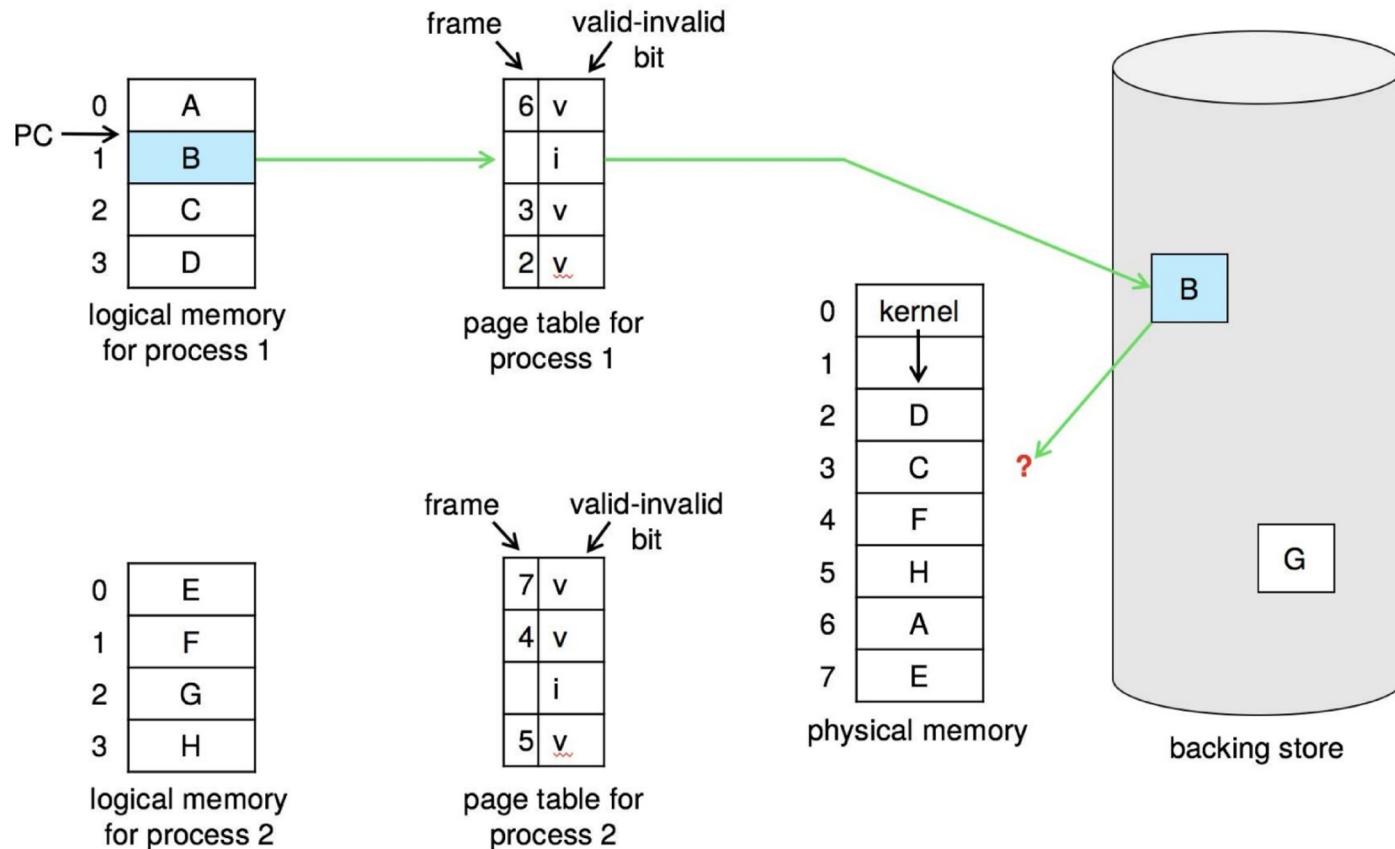
Need For Page Replacement – Example 1



0	monitor
1	
2	D
3	H
4	load M
5	J
6	A
7	E

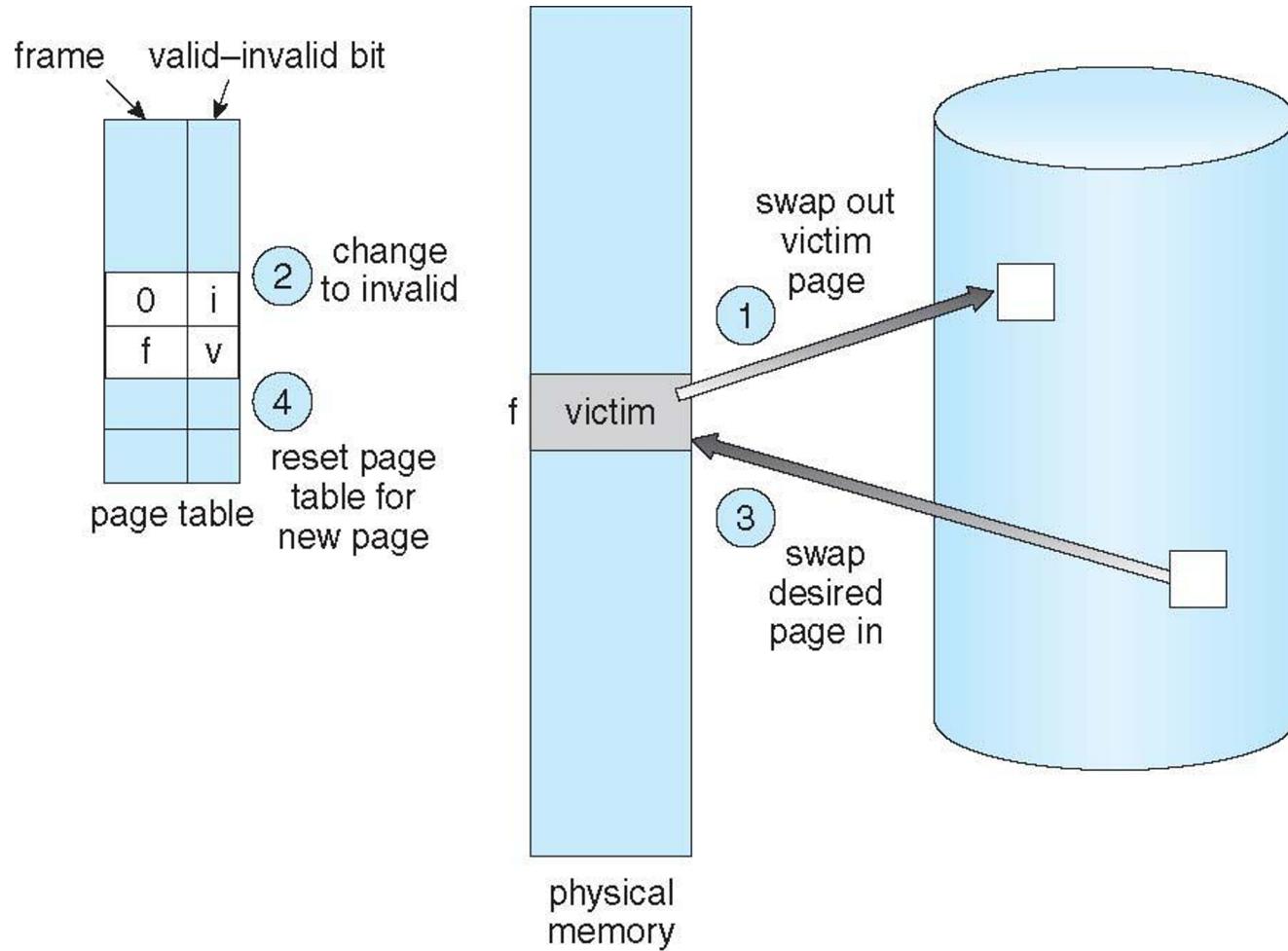


Need For Page Replacement –Example 2



1. Find the location of the desired page on disk
2. Find a free frame:
 - If there is a free frame, use it
 - If there is no free frame, use a page replacement algorithm to select a **victim frame**
 - Write victim frame to disk if dirty
3. Bring the desired page into the (newly) free frame; update the page and frame tables
4. Continue the process by restarting the instruction that caused the trap

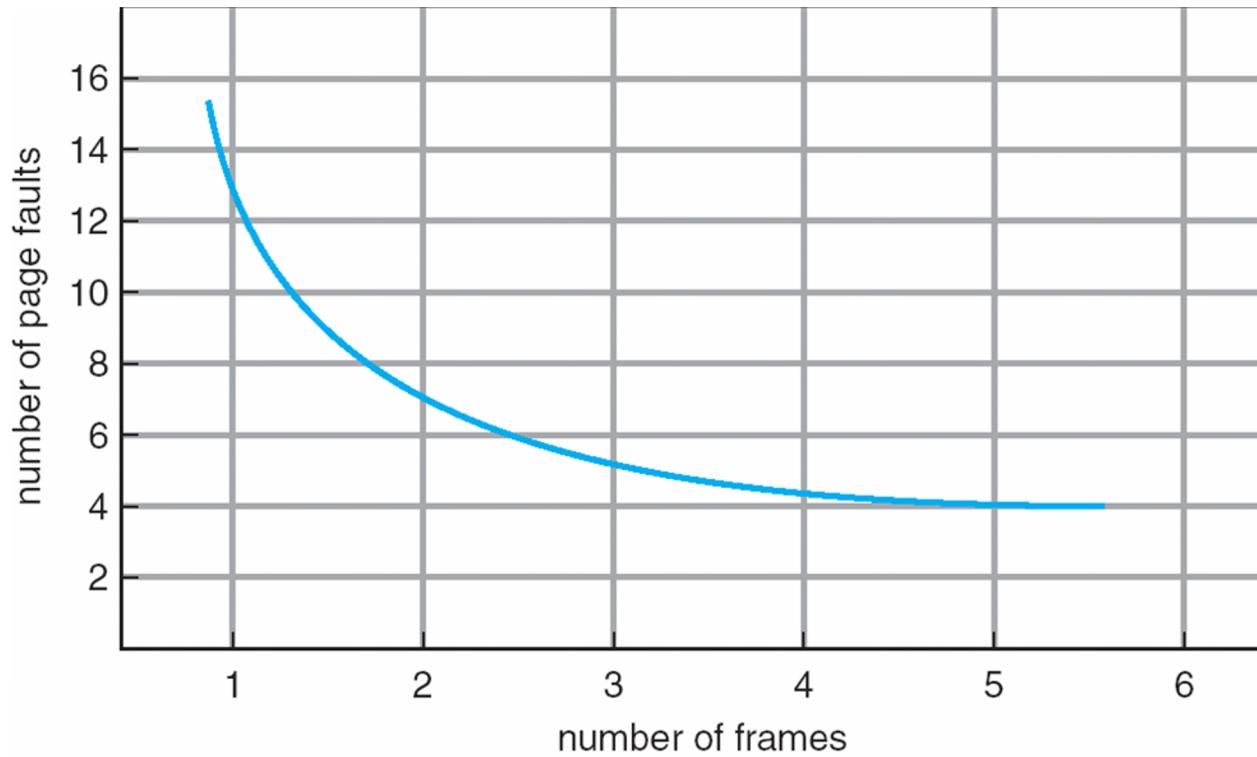
Note now potentially 2 page transfers for page fault – increasing EAT



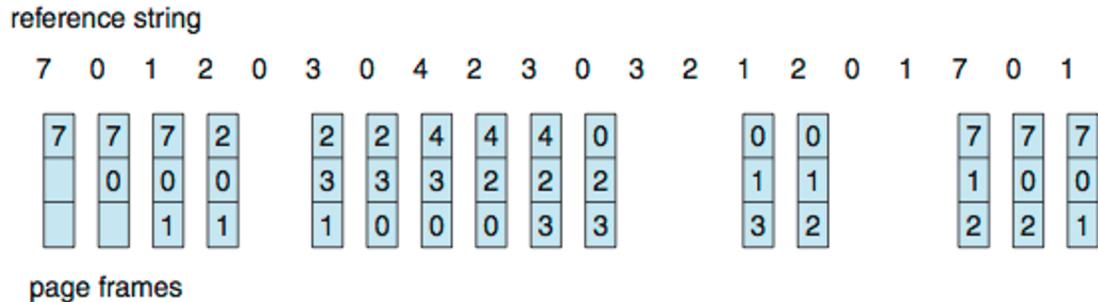
- **Frame-allocation algorithm** determines
 - How many frames to give each process
 - Which frames to replace
- **Page-replacement algorithm**
 - Want lowest page-fault rate on both first access and re-access
- Evaluate algorithm by running it on a particular string of memory references (reference string) and computing the number of page faults on that string
 - String is just page numbers, not full addresses
 - Repeated access to the same page does not cause a page fault
 - Results depend on number of frames available
- In all our examples, the **reference string** of referenced page numbers is

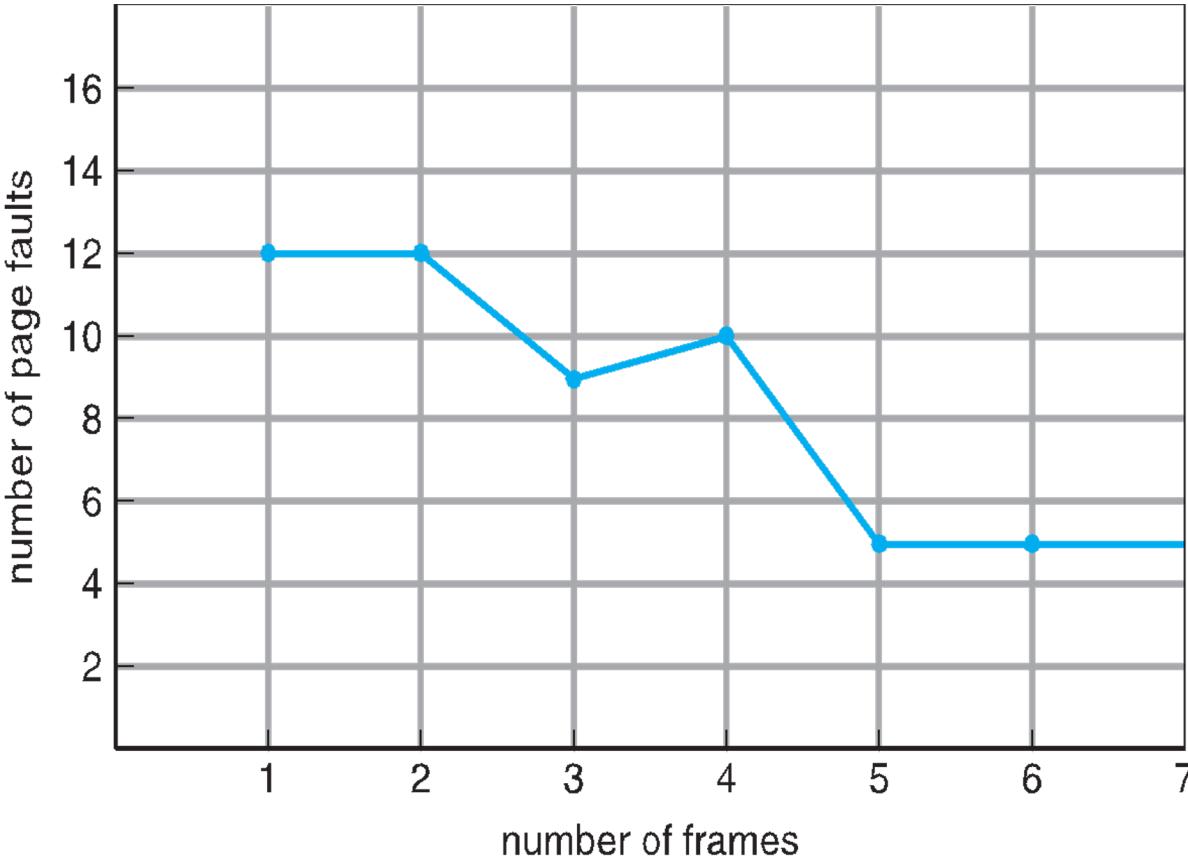
7,0,1,2,0,3,0,4,2,3,0,3,0,3,2,1,2,0,1,7,0,1

Graph of Page Faults Versus The Number of Frames

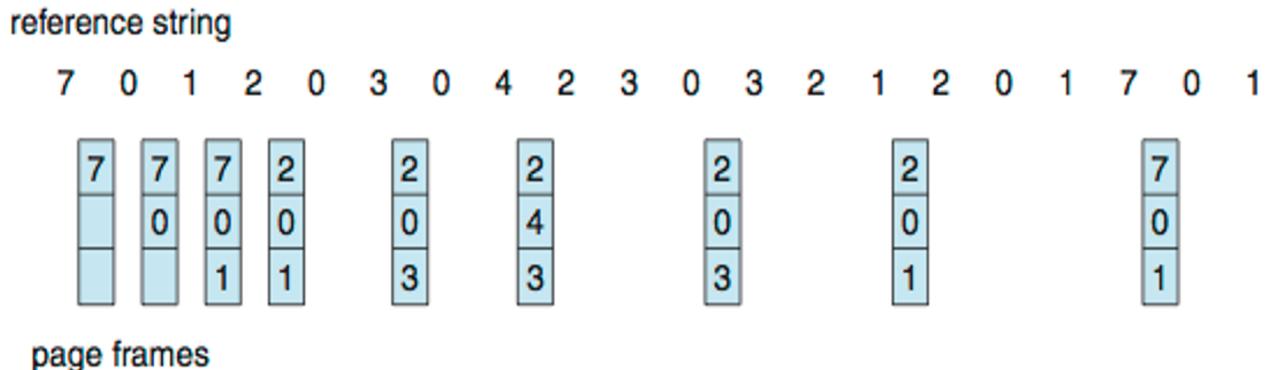


- Reference string: **7,0,1,2,0,3,0,4,2,3,0,3,0,3,2,1,2,0,1,7,0,1**
- 3 frames (3 pages can be in memory at a time per process)





- Replace page that will not be used for longest period of time
 - 9 is optimal for the example
- How do you know this?
 - Can't read the future
- Used for measuring how well your algorithm performs





THANK YOU

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