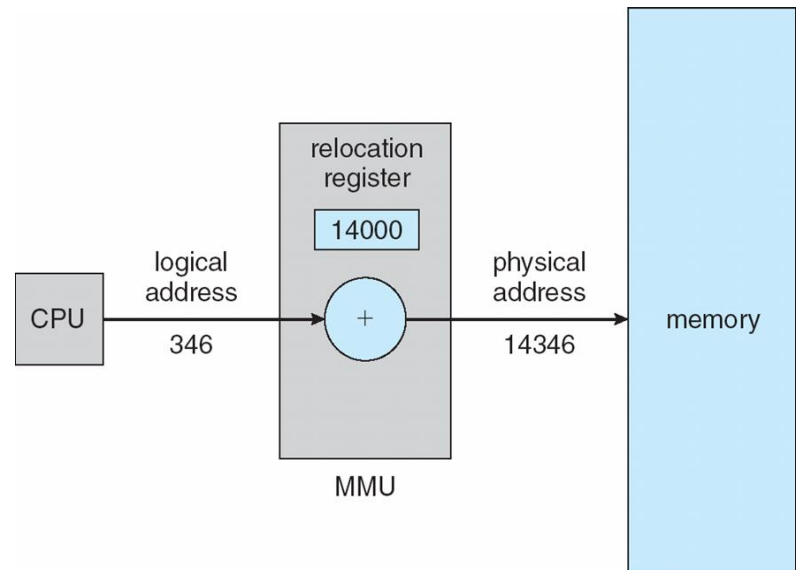




Dynamic relocation using a relocation register

- Routine is not loaded until it is called
- Better memory-space utilization; unused routine is never loaded
- All routines kept on disk in relocatable load format
- Useful when large amounts of code are needed to handle infrequently occurring cases
- No special support from the operating system is required
 - Implemented through program design
 - OS can help by providing libraries to implement dynamic loading





Dynamic Linking

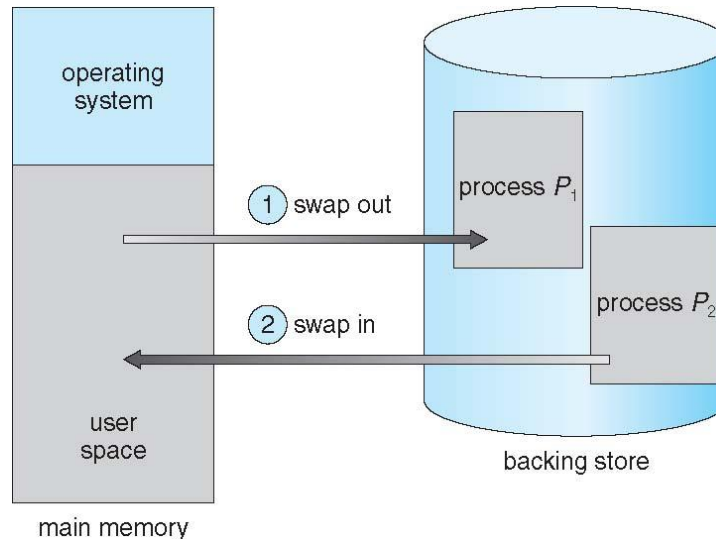
- **Static linking** – system libraries and program code combined by the loader into the binary program image
- Dynamic linking – linking postponed until execution time
- Small piece of code, **stub**, used to locate the appropriate memory-resident library routine
- Stub replaces itself with the address of the routine, and executes the routine
- Operating system checks if routine is in processes' memory address
 - If not in address space, add to address space
- Dynamic linking is particularly useful for libraries
- System also known as **shared libraries**





Swapping

- A process can be **swapped** temporarily out of memory to a backing store, and then brought back into memory for continued execution
 - Total physical memory space of processes can exceed physical memory
- Major part of swap time is transfer time; total transfer time is directly proportional to the amount of memory swapped
- System maintains a **ready queue** of ready-to-run processes which have memory images on disk





Context Switch Time including Swapping

- If next processes to be put on CPU is not in memory, need to swap out a process and swap in target process
- Context switch time can then be very high
- 100MB process swapping to hard disk with transfer rate of 50MB/sec
 - Swap out time of 2000 ms
 - Plus swap in of same sized process
 - Total context switch swapping component time of 4000ms (4 seconds)





Swapping on Mobile Systems

- Not typically supported
 - Flash memory based
 - ▶ Small amount of space
 - ▶ Limited number of write cycles
 - ▶ Poor throughput between flash memory and CPU on mobile platform
- Instead use other methods to free memory if low
 - iOS **asks** apps to voluntarily relinquish allocated memory
 - ▶ Read-only data thrown out and reloaded from flash if needed
 - ▶ Failure to free can result in termination
 - Android terminates apps if low free memory, but first writes **application state** to flash for fast restart





Contiguous Allocation

- Main memory must support both OS and user processes
- Limited resource, must allocate efficiently
- Contiguous allocation is one early method
- Main memory usually into two **partitions**:
 - Resident operating system, usually held in low memory with interrupt vector
 - User processes then held in high memory
 - Each process contained in single contiguous section of memory

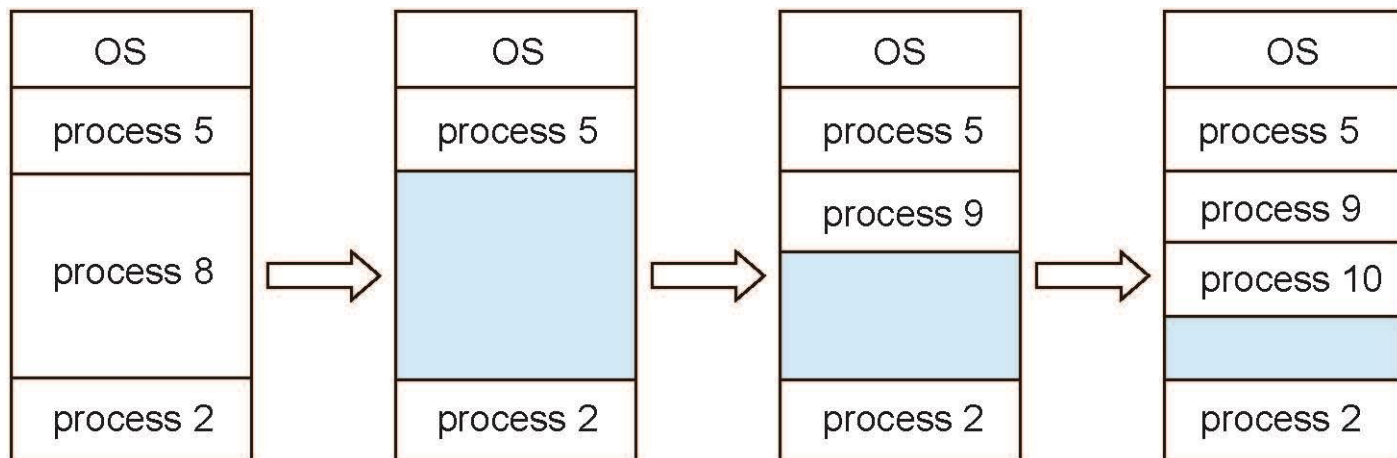




Multiple-partition allocation

■ Multiple-partition allocation

- Degree of multiprogramming limited by number of partitions
- **Variable-partition** sizes for efficiency (sized to a given process' needs)
- **Hole** – block of available memory; holes of various size are scattered throughout memory
- When a process arrives, it is allocated memory from a hole large enough to accommodate it
- Process exiting frees its partition, adjacent free partitions combined
- Operating system maintains information about:
a) allocated partitions b) free partitions (hole)





Dynamic Storage-Allocation Problem

How to satisfy a request of size n from a list of free holes?

- **First-fit**: Allocate the *first* hole that is big enough
- **Best-fit**: Allocate the *smallest* hole that is big enough; must search entire list, unless ordered by size
 - Produces the smallest leftover hole
- **Worst-fit**: Allocate the *largest* hole; must also search entire list
 - Produces the largest leftover hole

First-fit and best-fit better than worst-fit in terms of speed and storage utilization





Fragmentation

- **External Fragmentation** – total memory space exists to satisfy a request, but it is not contiguous
- **Internal Fragmentation** – allocated memory may be slightly larger than requested memory; this size difference is memory internal to a partition, but not being used





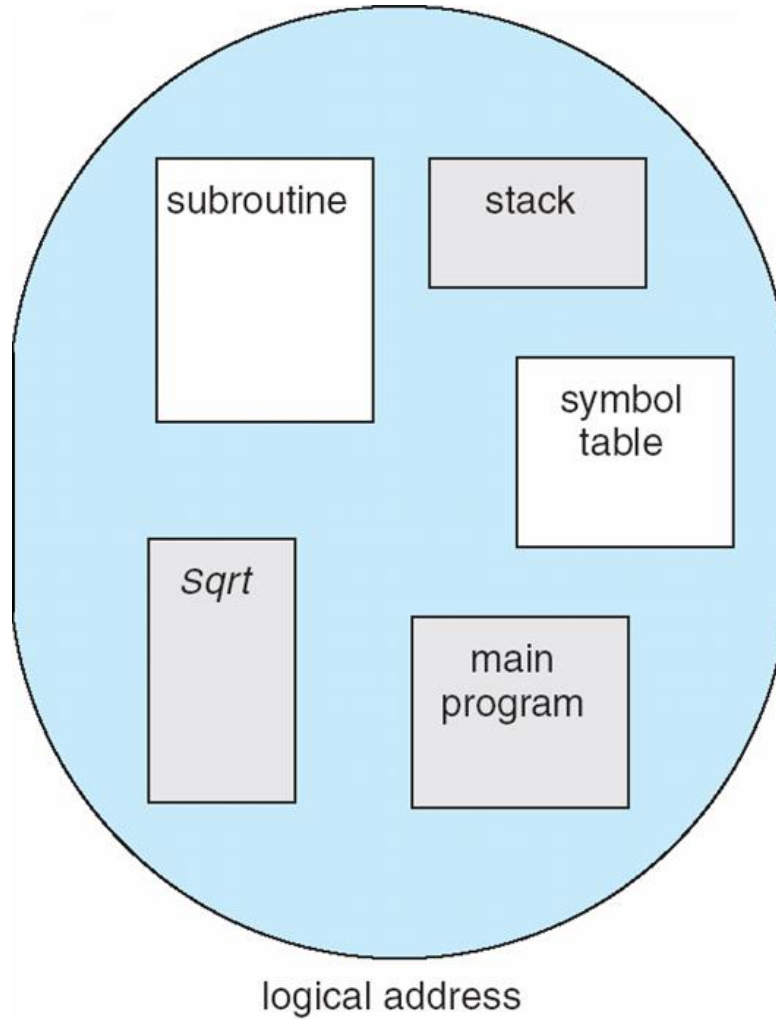
Segmentation

- Memory-management scheme that supports user view of memory
- A program is a collection of segments
 - A segment is a logical unit such as:
 - main program
 - procedure
 - function
 - method
 - object
 - local variables, global variables
 - common block
 - stack
 - symbol table
 - arrays



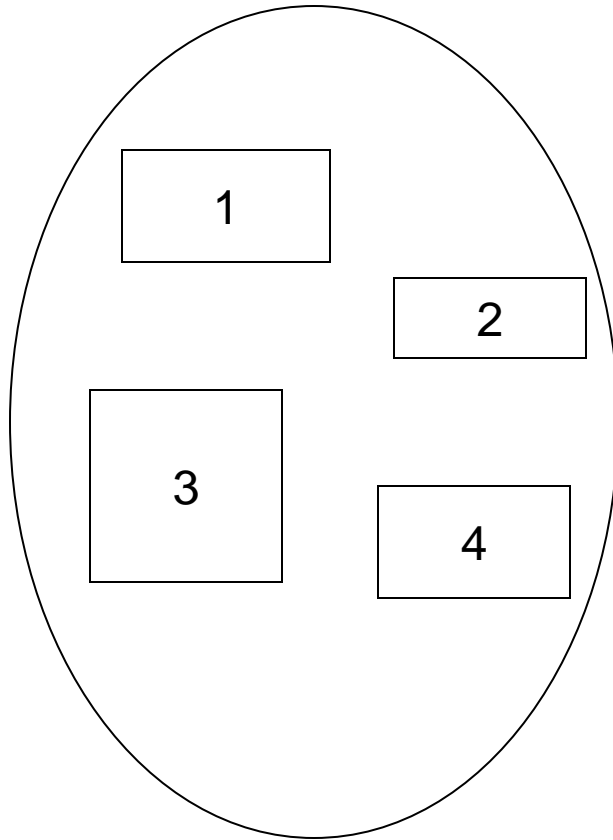


User's View of a Program

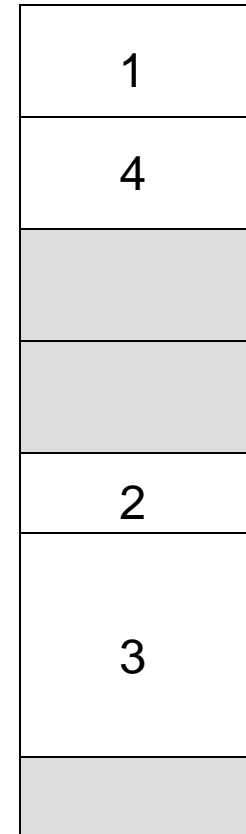




Logical View of Segmentation



user space



physical memory space





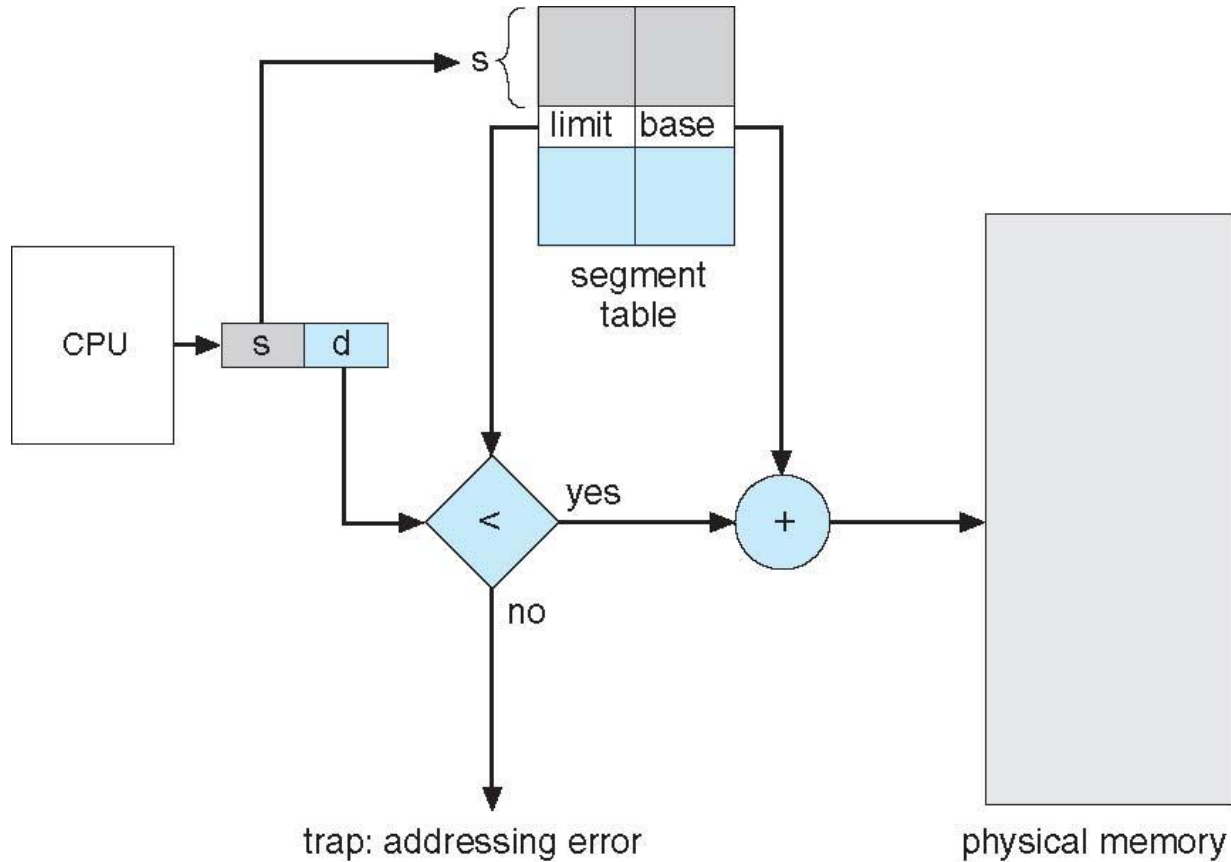
Segmentation Architecture

- Logical address consists of a two tuple:
 <segment-number, offset>,
- **Segment table** – maps two-dimensional physical addresses; each table entry has:
 - **base** – contains the starting physical address where the segments reside in memory
 - **limit** – specifies the length of the segment
- **Segment-table base register (STBR)** points to the segment table's location in memory
- **Segment-table length register (STLR)** indicates number of segments used by a program;
 segment number **s** is legal if **s** < **STLR**



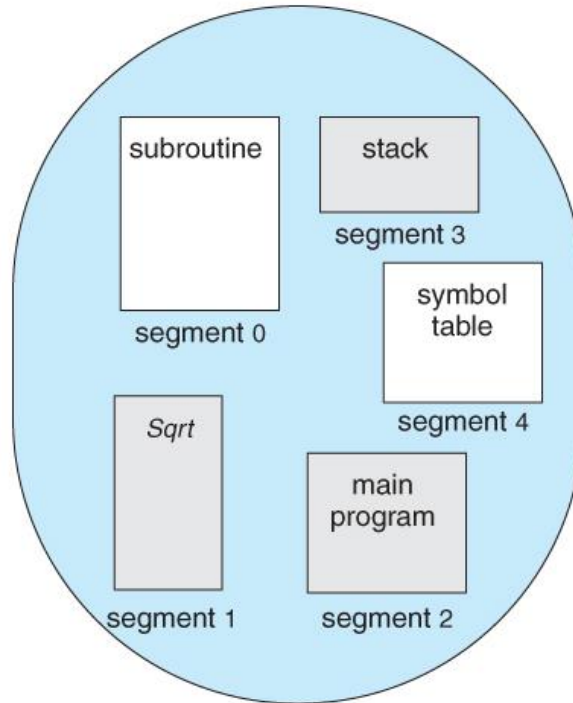


Segmentation Hardware





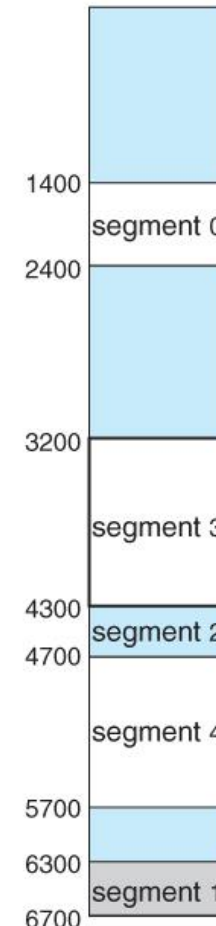
Segmentation Architecture (Cont.)



logical address space

	limit	base
0	1000	1400
1	400	6300
2	400	4300
3	1100	3200
4	1000	4700

segment table



physical memory

