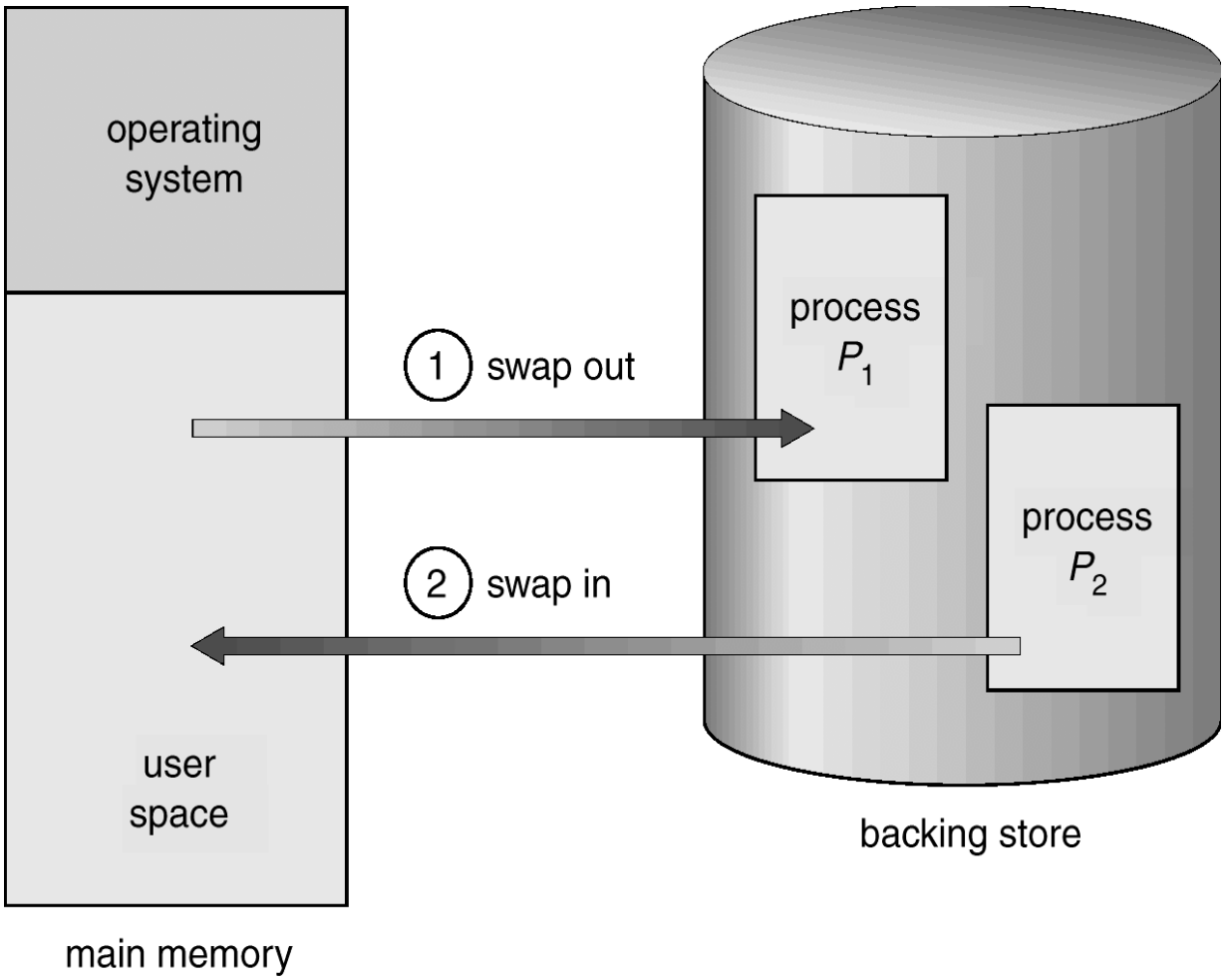
Memory Management

- Need to be able to keep several processes in memory for:
  - Better CPU utilization
  - Better response time
- Address Binding
  - Compile time
  - Load time
  - Execution time
- Logical vs. Physical Address space

Swapping

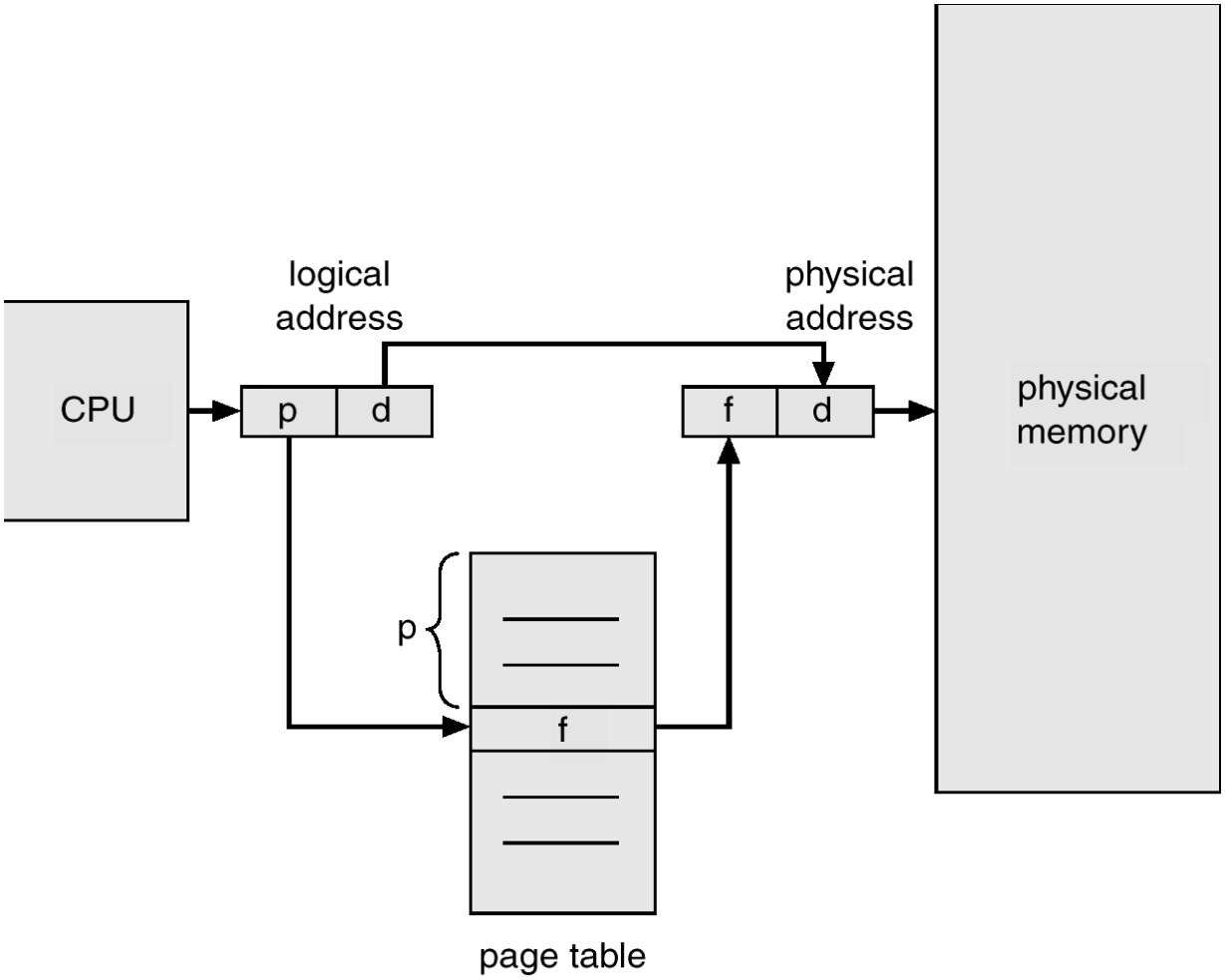

operating system
process P_1
1 swap out
process P_2
2 swap in
user space
backing store
main memory

Paging

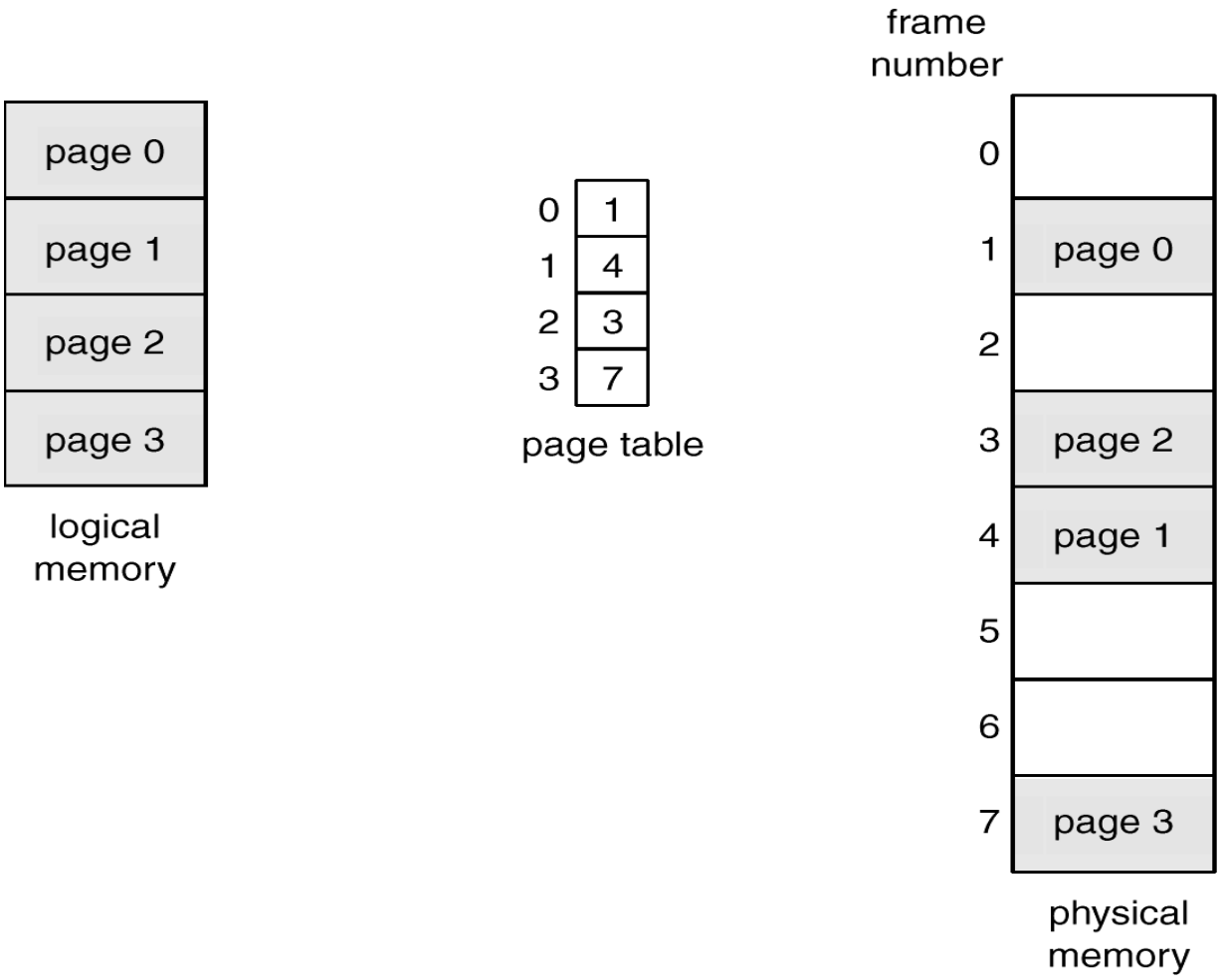
- Swapping
- Contiguous memory allocation
  - Problems: Fragmentation
  - Solution: Paging

- Paging
  - Page table
  - Frames
  - Pages

Paging Hardware



Paging Model



Paging Example

- Address Translation. Assume a frame size of 512 bytes, a physical memory size of 64 MB, and a page table of 16 entries. These entries are shown in figure:

index	entry
0x0	0x17
0x1	0x03
0x2	0x0A
0x3	0x1F
0x4	0x22
0x5	0x32
0x6	0x09
0x7	0x14
0x8	0x1B
0x9	0x0B
0xA	0x2C
0xB	0x1D
0xC	0x0D
0xD	0x3E
0xE	0x07
0xF	0x1A

- **How many frames of memory are there?**
  #frames = 2^{26} (64 MB memory) / 2^{9} (512_byte frame) = 2^{17}

- **How many pages can a process address?**
  #pages = 2^{4} = 16

- **How much memory can a process address?**
  #Virtual_memory = $2^{4} * 2^{9} = 2^{13}$

Paging Example (contd.)

What is the physical address that corresponds to virtual = address 0x057A?

0x057A = 0000 0101 0111 1010,

so the page index is

0x2(0 010),

and the entry is

0x0A(0001010),

so with the last 9 bits offset (1 0111 1010), the 16bit physical address is:

0001 0101 0111 1010 = 0x157A

index	entry
0x0	0x17
0x1	0x03
0x2	0x0A
0x3	0x1F
0x4	0x22
0x5	0x32
0x6	0x09
0x7	0x14
0x8	0x1B
0x9	0x0B
0xA	0x2C
0xB	0x1D
0xC	0x0D
0xD	0x3E
0xE	0x07
0xF	0x1A

Paging Example (contd.)

- **What is the physical address that corresponds to virtual address 0x1B8C?**

0x1B8C = 0001 1011 1000 1100,

so the page index is

0xD(1 101)

and the entry is

0x3E(0111110),

so with the last 9 bits offset

(1 1000 1100),

the 16bit physical address is:

0111 1101 1000 1100 = 0x7D8C

index	entry
0x0	0x17
0x1	0x03
0x2	0x0A
0x3	0x1F
0x4	0x22
0x5	0x32
0x6	0x09
0x7	0x14
0x8	0x1B
0x9	0x0B
0xA	0x2C
0xB	0x1D
0xC	0x0D
0xD	0x3E
0xE	0x07
0xF	0x1A

Paging Example (contd.)

What is the virtual address that corresponds to physical = address 0x7D38?

0x7D38 = 0111 1101 0011 1000,

so the entry (first 7 = bits) is

0111110 = 0x3E,

with the corresponding page index

0xD,

the 13bit = virtual address is:

1 1011 0011 1000 = 0x1B38

index	entry
0x0	0x17
0x1	0x03
0x2	0x0A
0x3	0x1F
0x4	0x22
0x5	0x32
0x6	0x09
0x7	0x14
0x8	0x1B
0x9	0x0B
0xA	0x2C
0xB	0x1D
0xC	0x0D
0xD	0x3E
0xE	0x07
0xF	0x1A