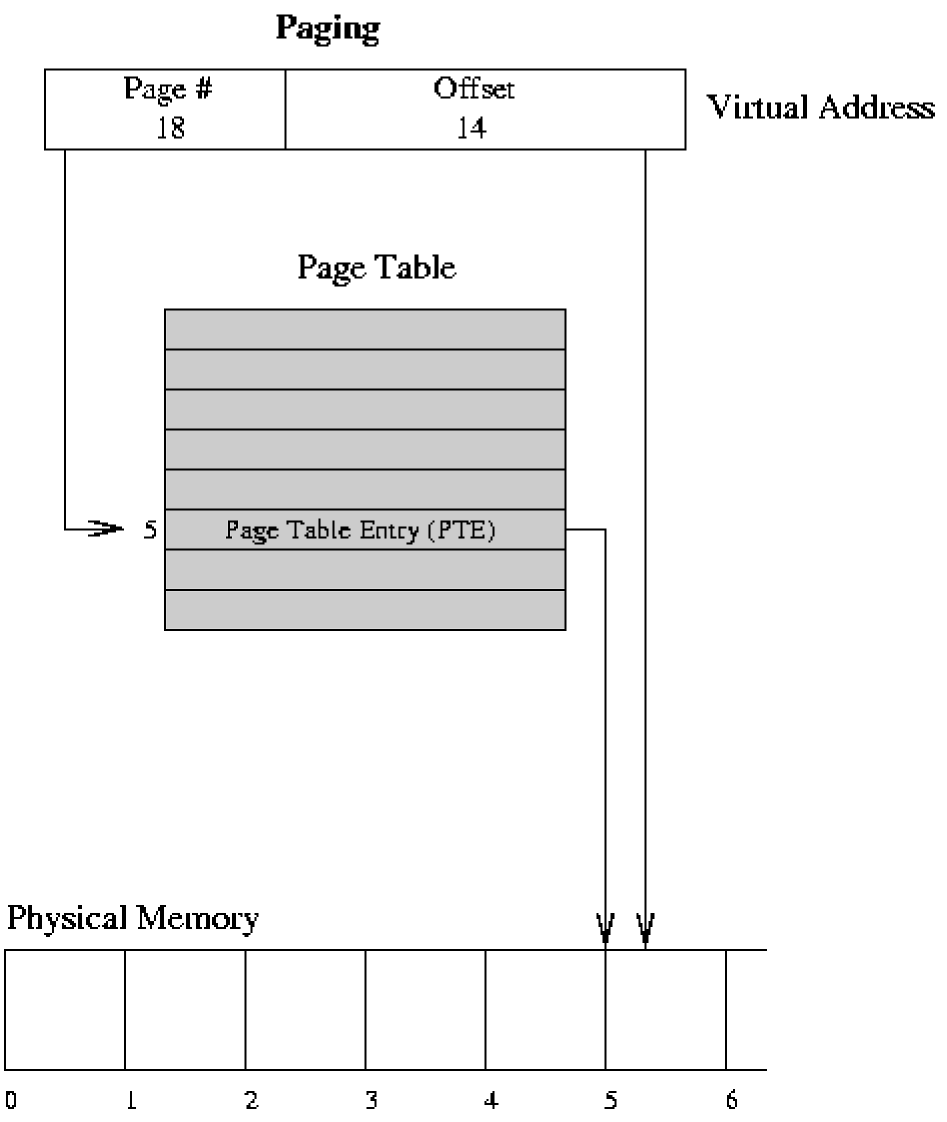
CS 537 Notes, Section #16: Paging

Paging:

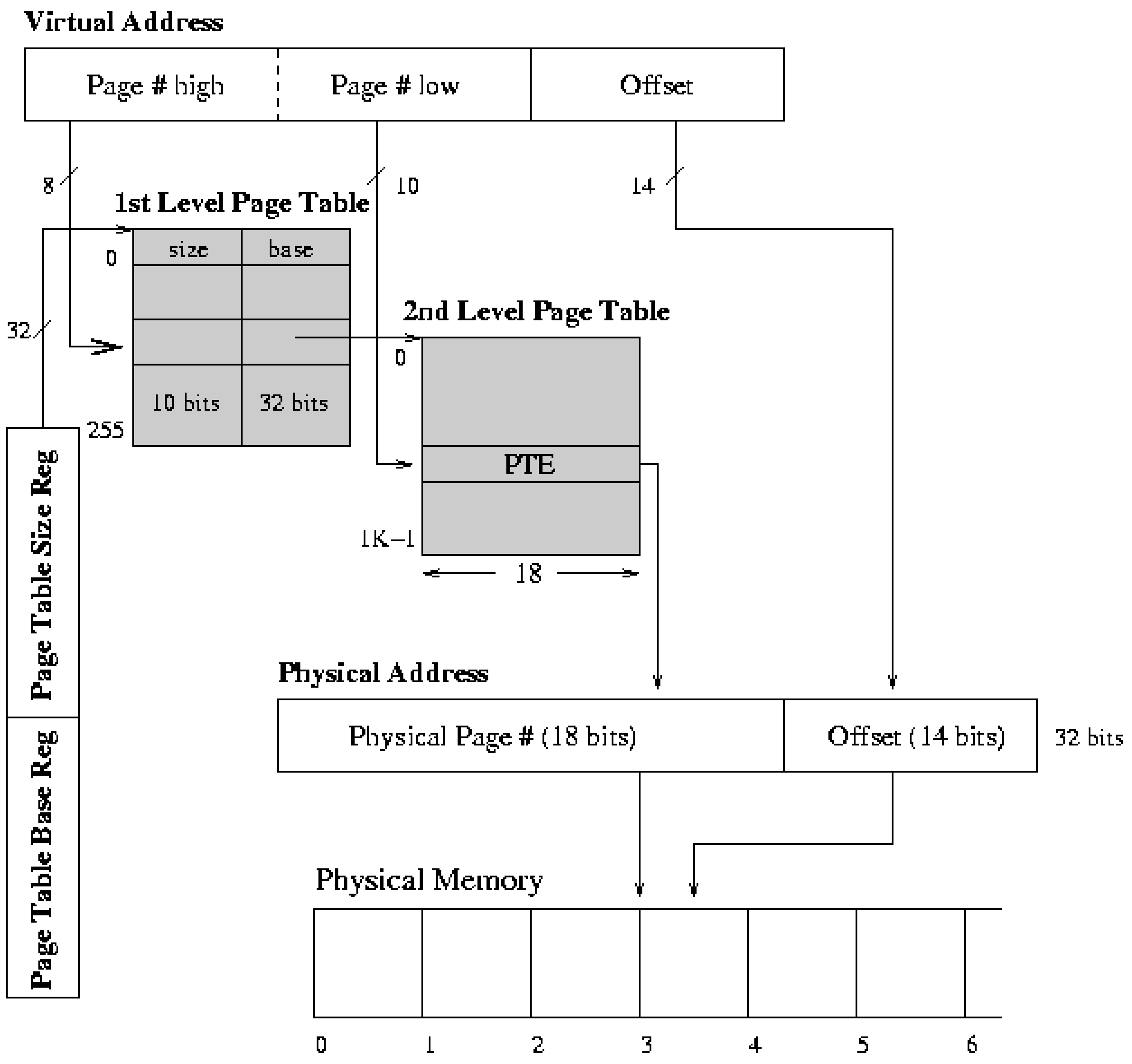
Goal is to make allocation and swapping easier, and to reduce memory fragmentation.

- Make all chunks of memory the same size, call them *pages*. Typical sizes range from 512-8k bytes.
- For each process, a *page table* defines the base address of each of that process' pages along with read/only and existence bits.
- Page number always comes directly from the address. Since page size is a power of two, no comparison or addition is necessary. Just do table lookup and bit substitution.
- Easy to allocate: keep a free list of available pages and grab the first one. Easy to swap since everything is the same size, which is usually the same size as disk blocks to and from which pages are swapped.
- Problems:
    - Internal fragmentation: page size does not match up with information size. The larger the page, the worse this is.
    - Table space: if pages are small, the table space could be substantial. In fact, this is a problem even for normal page sizes: consider a 32-bit address space with 1k pages. What if the whole table has to be present at once? Partial solution: keep base and bounds for page table, so only large processes have to have large tables.
    - Efficiency of access: it may take one overhead reference for every real memory reference (page table is so big it has to be kept in memory).



Two-Level (Multi-Level) Paging:

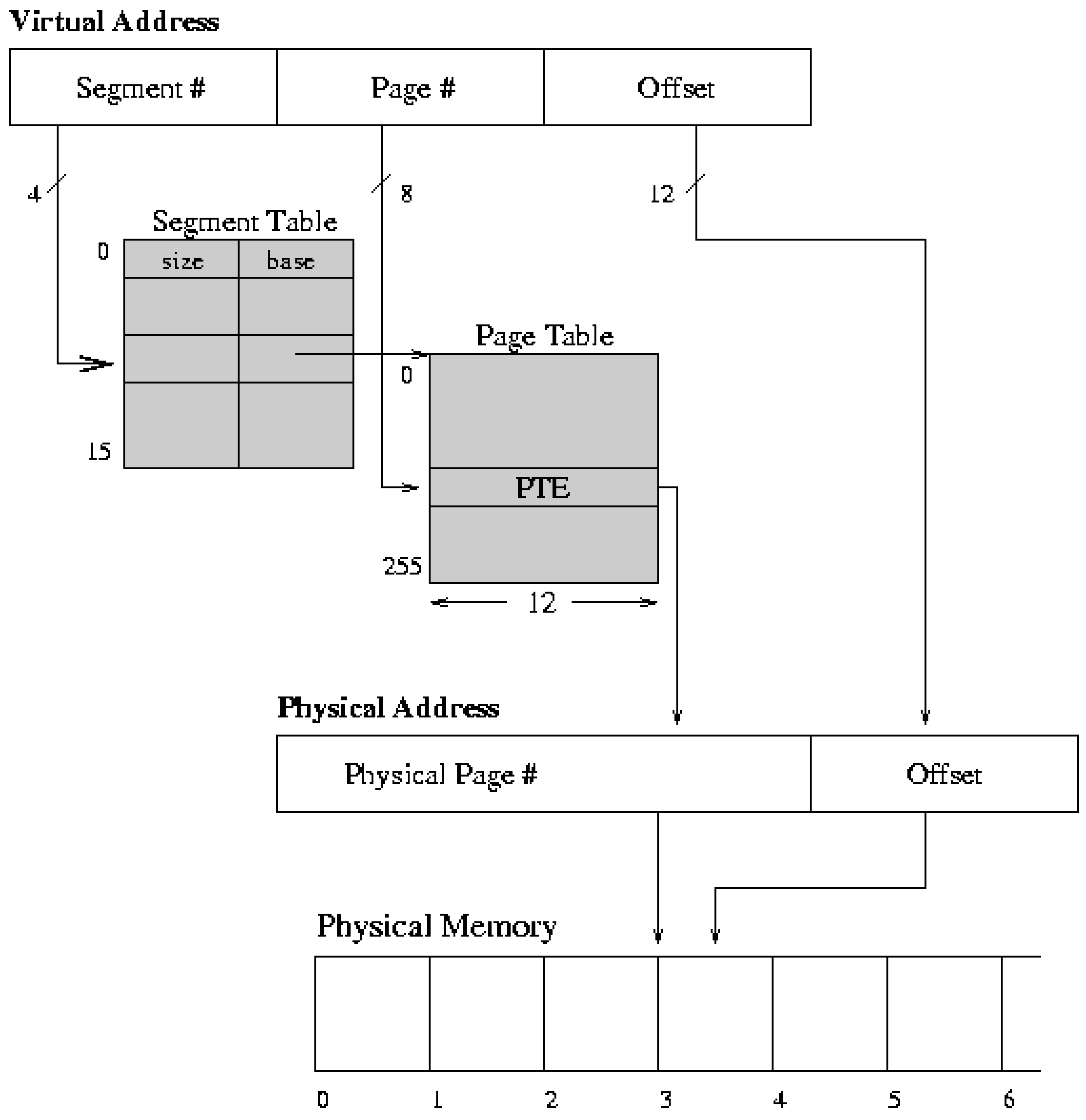
Use two levels of mapping to make tables manageable.



Segmentation and Paging:

Use two levels of mapping, with logical sizes for objects, to make tables manageable.

- Each segment contains one or more pages.
- Segment correspond to logical units: code, data, stack. Segments vary in size and are often large. Pages are for the use of the OS; they are fixed size to make it easy to manage memory.
- Going from paging to P+S is like going from single segment to multiple segments, except at a higher level. Instead of having a single page table, have many page tables with a base and bound for each. Call the stuff associated with each page table a segment.



System 370 example: 24-bit virtual address space, 4 bits of segment number, 8 bits of page number, and 12 bits of offset. Segment table contains real address of page table along with the length of the page table (a sort of bounds register for the segment). Page table entries are only 12 bits, real addresses are 24 bits.

- If a segment is not used, then there is no need to even have a page table for it.
- Can share at two levels: single page, or single segment (whole page table).

Pages eliminate external fragmentation, and make it possible for segments to grow without any reshuffling.

If page size is small compared to most segments, then internal fragmentation is not too bad.

The user is not given access to the paging tables.

If translation tables are kept in main memory, overheads could be very high: 1 or 2 overhead references for every real reference.

Another example: VAX.

- Address is 32 bits, top two select segment. Three base-bound pairs define page tables (system, P0, P1).
- Pages are 512 bytes long.
- Read-write protection information is contained in the page table entries, not in the segment table.
- One segment contains operating system stuff, two contain stuff of current user process.
- Potential problem: page tables can get big. Do not want to have to allocate them contiguously, especially for large user processes. Solution:
    - System base-bounds pairs are physical addresses, system tables must be contiguous.
    - User base-bounds pairs are virtual addresses in the system space. This allows the user page tables to be scattered in non-contiguous pages of physical memory.
    - The result is a two-level scheme.

In current systems, you will see three and even four-level schemes to handle 64-bit address spaces.
